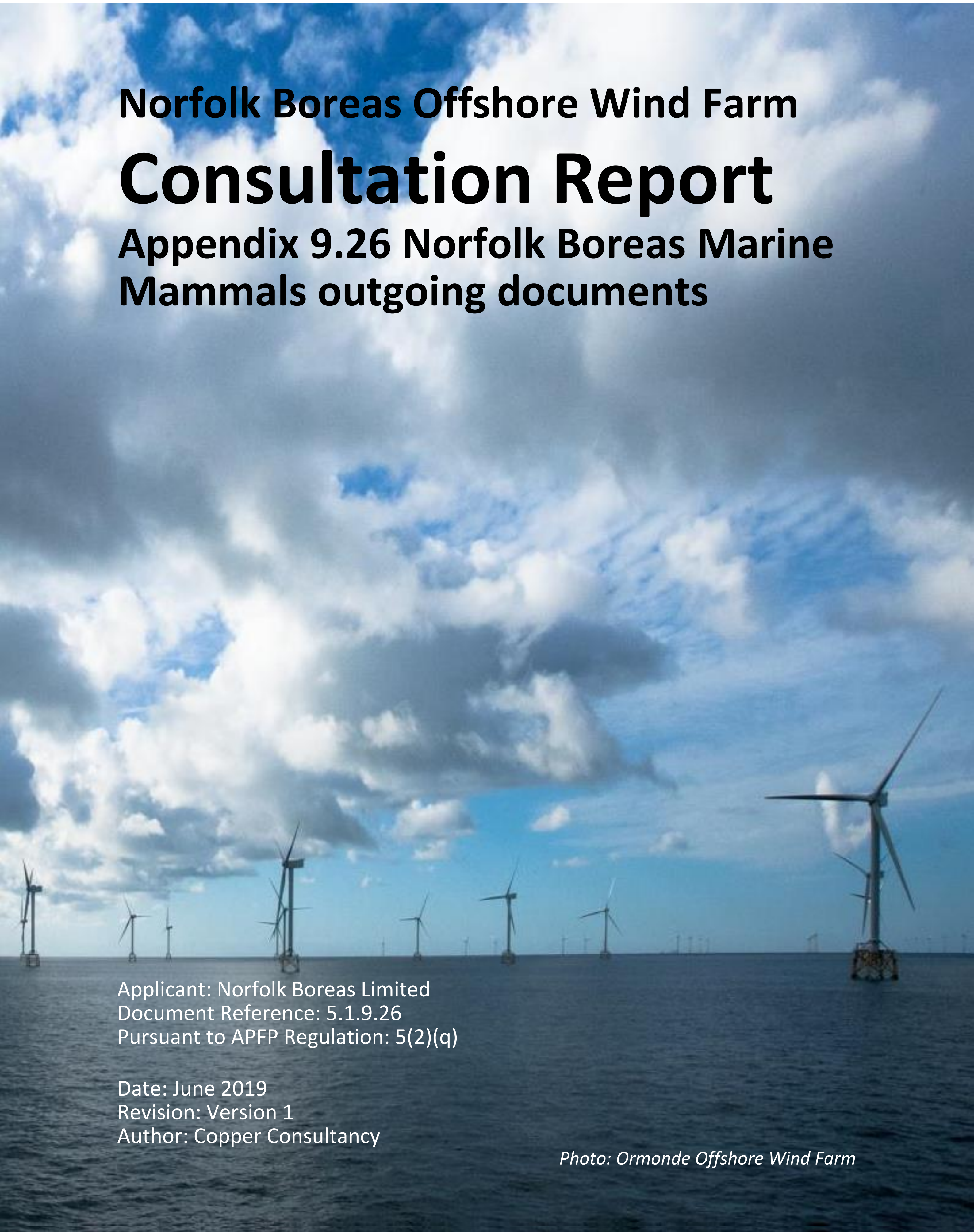

Norfolk Boreas Offshore Wind Farm

Consultation Report

Appendix 9.26 Norfolk Boreas Marine Mammals outgoing documents

Applicant: Norfolk Boreas Limited
Document Reference: 5.1.9.26
Pursuant to APFP Regulation: 5(2)(q)

Date: June 2019
Revision: Version 1
Author: Copper Consultancy

Photo: Ormonde Offshore Wind Farm

This page is intentionally blank.

Norfolk Boreas Offshore Wind Farm

Environmental Impact Assessment

Marine Mammal Method Statement

Document Reference: PB5640-004-014

Author: Royal HaskoningDHV
Applicant: Norfolk Boreas Ltd
Date: February 2018

Date	Issue No.	Remarks / Reason for Issue	Author	Checked	Approved
16/11/17	01D	Issue for internal review	GS/Jennifer Learmonth (JAL)	DT	AD
12/12/17	02D	Comments addressed following internal review	JL	DT	
16/01/18	02D	Issue for Vattenfall review	DT	Jesper Larsen (JkL)	Jake Laws (JLa)
29/01/19	03D	Updated following review by Vattenfall	JAL	DT	
05	01F	Issued to ETG	JAL	DT	JLa

This method statement has been prepared by Royal HaskoningDHV on behalf of Norfolk Boreas Limited in order to build upon the information provided within the Norfolk Boreas Environmental Impact Assessment (EIA) Scoping Report. It has been produced following a full review of the Scoping Opinion provided by the Planning Inspectorate. All content and material within this document is draft for stakeholder consultation purposes, within the Evidence Plan Process.

Many participants of the Norfolk **Boreas** Evidence Plan Process will also have participated in the Norfolk **Vanguard** Evidence Plan Process. This document is presented as a complete and standalone document, however in order to maximise resource and save duplication of effort, the main areas of deviation from what has already been presented through the Norfolk Vanguard Evidence Plan Process and PEIR or in the Norfolk Boreas Scoping Report are presented in orange text throughout this document.

Royal HaskoningDHV
Enhancing Society Together

VATTENFALL

Table of Contents

Glossary of Acronyms

CI	Confidence Interval
CIA	Cumulative Impact Assessment
CO	Conservation Objectives
cSAC	candidate Special Area of Conservation
CV	Coefficient of Variation
DCO	Development Consent Order
EIA	Environmental Impact Assessment
EMF	Electromagnetic Field
EPP	Evidence Plan Process
EPS	European Protected Species
ETG	Expert Topic Group
FCS	Favourable Conservation Status
GSD	Ground Sampling Distance
HRA	Habitats Regulation Assessment
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
IAMMWG	Inter-Agency Marine Mammal Working Group
JCP	Joint Cetacean Protocol
JNCC	Joint Nature Conservation Committee
km	Kilometre
km2	Kilometre squared
m	Metre
MCZ	Marine Conservation Zone
MMMP	Marine Mammal Mitigation Plan
MMO	Marine Management Organisation
MU	Management Unit
NE	Natural England
NOAA	National Oceanic and Atmospheric Administration
O&M	Operation & Maintenance
PEI	Preliminary Environmental Information
PEIR	PEI Report
PTS	Permanent Threshold Shift
SCANS	Small Cetaceans in European Atlantic waters and the North Sea
SCOS	Special Committee on Seals
SNCBs	Statutory Nature Conservation bodies
SNS	Southern North Sea
SoS	Secretary of State
TLP	Tension Leg Platform
TSEG	Trilateral Seal Expert Group
TTS	Temporary Threshold Shift
TWT	The Wildlife Trust
UXO	Unexploded Ordnance
VWPL	Vattenfall Wind Power Limited
WDC	Whale and Dolphin Conservation

1 INTRODUCTION

1. The purpose of this method statement is to build upon the information provided within the Norfolk Boreas Environmental Impact Assessment (EIA) Scoping Report and experience gained through the Norfolk Vanguard Evidence Plan Process (EPP), in outlining the proposed approach to be taken and considerations to be made in the assessment of the potential effects on marine mammals of the proposed development. Indicative project information is provided, to inform the method statement and consultation. These may be subject to change as the EIA progresses.

2. This method statement and the consultation around it form part of the Norfolk Boreas Evidence Plan Process (EPP). The aim is to gain agreement on this Method Statement from all members of the Marine Physical Processes Expert Topic Group (ETG).

1.1 Scoping Opinion Responses

3. This marine mammal method statement has been produced following a full review of the Scoping Opinion provided by the Planning Inspectorate. The Method Statement also takes account of what has been agreed through the Norfolk Vanguard EPP and the recent consultation on the Norfolk Vanguard PEIR (Royal Haskoning DHV, 2017a). The comments in the EIA Scoping Opinion relating to marine mammals are summarised in **Table 1.1**.

4. The approach outlined in this method statement also takes account of previous correspondence with Natural England, the Marine Management Organisation (MMO), The Wildlife Trust (TWT), the Whale and Dolphin Conservation (WDC) and Cefas, including:

- Introduction meeting between Vattenfall Wind Power Limited (VWPL) and the MMO 14th January 2016;
- Meeting with Natural England and the MMO to discuss aerial survey scope 21st March 2016;
- Natural England (NE) Review of Geophysical and Grab Sampling Impact Assessment on the Southern North Sea candidate Special Area of Conservation (cSAC) 20th April 2016.

5. It is recognised that Norfolk Vanguard ETG meetings are being held in January 2018 and that agreements will be made during those meetings in relation to Norfolk Vanguard which may be relevant to Norfolk Boreas, but cannot be reflected here, due to the timescales of the two projects.

Table 1.1: Scoping opinion responses

Consultee	Comment	Response
Secretary of State (SoS) Paragraph 3.72	The Applicant's attention is drawn to paragraph 2.6.92 of NPS EN-3 and the need to provide details of likely feeding areas; known birthing areas/haul out sites; nursery grounds; and known migration or commuting routes.	Information on marine mammals (including details of likely feeding areas; known birthing areas/haul out sites; nursery grounds; and known migration or commuting routes), has been provided in **Section 3** of this Method Statement and further information will also be included in the PEIR and ES.
SoS Paragraph 3.73	Where modelling is undertaken to determine the abundance of cetaceans, the Environmental Statement (ES) should explain the methodology used.	An outline of the proposed approach to underwater noise modelling and assessment of the potential impacts is provided in **Section 5.1** of this Method Statement and further details will be provided in the PEIR and ES.
SoS Paragraph 3.74	The Applicant's attention is drawn to the existence of the Defra Marine Noise Registry which could inform the baseline noise environment.	The Marine Noise Registry will be investigated as a potential source to inform the baseline noise environment. This will be included within the PEIR and ES, if suitable.
SoS Paragraph 3.75	The SoS agrees to the approach of scoping out disturbance to seal haul-out sites from construction activities due to their distance from the site, but to scope in disturbance from vessels during construction.	Disturbance from vessels is considered in section 5.1.4
SoS Paragraph 3.76	The SoS agrees that disturbance to seal haul-out sites during operation can be scoped out.	Disturbance to seal haul-out sites during operation is not considered within this Method Statement
SoS Paragraph 3.77	The SoS agrees that EMF can be scoped out.	EMF is not considered within this Method Statement
SoS Paragraph 3.78	The SoS welcomes consideration of construction noise impacts on marine mammals.	The potential construction noise impacts on marine mammals to be assessed in the ES are outlined in **Section 5.1** of this Method Statement and further details will be provided in the PEIR and ES.
SoS Paragraph 3.80	The ES should set out in full the potential risk to European Protected Species (EPS) and confirm if any EPS licences will be required for example, for harbour porpoises and grey seals.	The PEIR and ES will assess any potential risk to EPS and determine whether any EPS licences will be required.
SoS Paragraph 2.105	The ES should further consider (to the extent that it is possible): • quantification of the planned maintenance visits / vessel trips required for offshore infrastructure (including cabling); • the need for large-scale offshore components (e.g. turbine blades or substation transformers) to require maintenance or replacement during operation and the 'significant' periods which these activities may require (paragraph 244 of the Scoping Report); • frequency of periodic conditions surveys of cables and potential remedial maintenance	The PEIR and ES will consider and quantify (wherever possible): • the possible number of vessel / maintenance trips required; • the potential maintenance requirements during operation and the duration of these activities; and

Consultee	Comment	Response
	activities; and • based on experience from other wind farms, an indication of the frequency of 'occasional access' that would be required at joint bays / link boxes and the need for and type of unplanned works that may be required at the landfall location.	• any other activities associated with operation and maintenance that could have an impact on marine mammals.
Natural England (NE)	Our key concerns are as follows and we consider that these issues will need thorough consideration through the EIA and Habitats Regulation Assessment (HRA) and close discussion between the Applicant, Natural England and where possible the regulators and Marine Management Organisation (MMO): Potential effects on marine mammals from noise during construction – both at a project level and cumulatively.	As with Norfolk Vanguard, Norfolk Boreas also plans to follow a non-statutory Evidence Plan Process (EPP), which will include an Expert Topic Group (ETG) for marine mammals. The EPP will be used to consult with Natural England (NE), the Marine Management Organisation (MMO), The Wildlife Trust (TWT) and Whale and Dolphin Conservation (WDC), to agree the approach taken forward in many aspects of the impact assessment for marine mammals (see **Section 1.3.2**).
NE	Natural England's response to this chapter has been developed in consultation with JNCC. The comments below are reflective of both Natural England's and JNCC's views in respect to impacts to designated sites. *The Southern North Sea (SNS) cSAC* has been selected primarily on the basis of long-term, preferential use by harbour porpoise in contrast to other areas of the North Sea.	The potential for any adverse effects on the integrity of the SNS cSAC with regards to its Conservation Objectives will be assessed in the HRA for Norfolk Boreas.
NE	*Noise assessment* 514: Piling has been identified as a key concern in relation to the effects on marine mammals and the applicant states "impacts associated with underwater noise will be considered fully during the EIA, taking into account the most recent and robust research available". Previous best practice has been to use injury thresholds proposed by Southall et al. 2007 when considering potential impacts to marine mammals. However, in 2016, the National Oceanic and Atmospheric Administration (NOAA) published revised injury thresholds. The Statutory Nature Conservation bodies (SNCBs) are currently evaluating the implications of the NOAA thresholds and how these may be incorporated into noise risk assessments. We recommend the developer engage with the SNCBs with regard their noise assessment and how this will inform the EIA and HRA.	The noise thresholds to be used to assess the potential impact of piling on marine mammals are outlined in **Appendix 1** of this Method Statement and will be agreed as part of the EPP. The thresholds and criteria from NOAA (NMFS, 2016) will be used to determine potential impact ranges for PTS and TTS. The threshold and criteria from Lucke *et al*. (2009) will be used to assess the potential impacts of behavioural response in harbour porpoise. As agreed with NE for Norfolk Vanguard.
NE	*In-combination impacts* In-combination impacts are a key issue for the SNS cSAC given the scale and number of activities planned to occur within the site in the forthcoming years and how these could potentially result in an adverse effect on site integrity. We would welcome further discussions with the developer over which projects and industries may need to be considered in relation to in-combination and cumulative effects on the SNS site and marine mammal interests in general.	The assessment of potential in-combination impacts and effects will be agreed as part of the EPP.
NE	*European Protected Species and disturbance*	The PEIR and ES will assess any potential risk to EPS and

Consultee	Comment	Response
	The risk of a disturbance offence under The Offshore Marine Conservation Regulations 2007 (as amended), as a result of pile-driving during the installation of the wind farm should be assessed and if it cannot be mitigated and there are no satisfactory alternatives, we recommend the Applicant applies to the MMO for a disturbance licence.	determine whether any EPS licences will be required.
NE	*Marine mammal mitigation* 510: This paragraph states "With the application of soft-start piling protocol employed (whereby the energy of the hammer is slowly ramped up allowing marine mammals to flee the immediate area of piling) it is not anticipated that any marine mammals would be at risk of any physical injuries." This implies that only a soft-start is required to reduce the risk of injury. We highlight that current mitigation guidelines include additional measures which will need to be considered by the applicant and a marine mammal mitigation plan should be agreed prior to construction. Again, we welcome future discussions with the applicant regarding this.	The MMMP will be developed following the most relevant recent guidance in relation to marine mammal mitigation measures. Mitigation requirements will be discussed as part of the EPP.
NE	*Further marine mammal comments* 482: There appears to be a typo in the last-but-one bullet point. Presumably this is meant to include harbour seal. If the timeline allows, Small Cetaceans in European Atlantic waters and the North Sea (SCANS) III survey data should be incorporated. 486: This paragraph states that 12.5% of cetaceans sited were either identified as a porpoise or a dolphin, however, in the Norfolk Vanguard scoping report this figure in the same paragraph was 2.5%. Please could it be clarified which one is correct? 502: Figures 2.8 and 2.9 appear to show grey and harbour seal mean at-sea usage estimates to be 0 – 1.0 individuals per km^2 at the array and 0 – 5 individuals per km2 in the provisional offshore cable corridor for both species, not 0 – 0.2 individuals per km^2 as stated here. 518: Natural England is satisfied that given the distance to the nearest seal haul out at landfall is at least 10km, disturbance at seal haul outs may be scoped out of the assessment.	482: Harbour seal will be included in the seal usage maps. SCANS-III data will be included in both the PEIR and ES. 486: This should be 2.5% and will be corrected within the PEIR and EA reports. 502: This will be made clearer in the PEIR and ES and updated based on the latest SMRU seal-at-sea maps. 518: Acknowledged.

1.2 Background

6. A Scoping Report for the Norfolk Boreas EIA was submitted to the Planning Inspectorate on the 9th May 2017. Further background information on the project can be found in the Scoping Report which is available at:

https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010087/EN010087-000015-Scoping%20Report.pdf

7. The Scoping Opinion was received on the 16th June 2017 and can be found at:

https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010087/EN010087-000013-Scoping%20Opinion.pdf

1.3 Norfolk Boreas Programme

8. This section provides an overview of the planned key milestone dates for Norfolk Boreas.

1.3.1 Development Consent Order (DCO) Programme

- EIA Scoping Request submission - 09/05/17
- Preliminary Environmental Information (PEI) submission - Q4 2018
- Environmental Statement (ES) and DCO submission - Q2 2019

1.3.2 Evidence Plan Process Programme

9. The Evidence Plan Terms of Reference provides an overview of the Evidence Plan Process (EPP) and expected logistics, below is a summary of anticipated meetings:

- Agreement of Terms of Reference -Q3 2018
- Post-scoping Expert Topic Group (ETG) consultation
  - Discuss method statements and Project Design Statement -Q1 2018
- Expert Topic Group and Steering Group meetings as required - 2018
  - To be determined by the relevant groups based on issues raised
- PEI Report (PEIR) Expert Topic Group and Steering Group meetings - Q4 2018/ - Q1 2019
  - To discuss the findings of the PEI (before or after submission)
- Pre-submission Expert Topic Group and Steering Group meetings - Q1/Q2 2019
  - To discuss updates to the PEIR prior to submission of the ES

1.3.3 Consultation to Date

10. Norfolk Boreas is the sister project to Norfolk Vanguard. A programme of consultation has already been undertaken for Norfolk Vanguard which is of relevance to Norfolk Boreas and these Norfolk Vanguard consultations are listed below:

• EIA Scoping Request submission	03/10/16
• Receipt of Scoping Opinion	11/11/16
• Steering Group meeting	21/03/16
• Steering Group meeting	20/09/16
• Expert Topic Group meeting (Norfolk Vanguard Marine Mammal EPP) to discuss Method Statement and Project Design Statement	15/02/2017
• Expert Topic Group meeting (Norfolk Vanguard Marine Mammal EPP) to discuss approach to noise modelling and HRA Method Statement	06/07/2017
• Expert Topic Group meeting (Norfolk Vanguard Marine Mammal EPP) to discuss PEIR and draft HRA	08/12/2017

1.3.4 Survey Programme

11. Details of the proposed data collection for marine mammals are provided in Section 3.

1.3.4.1 Aerial survey

12. The following monthly aerial surveys are currently being conducted at the Norfolk Boreas to characterise the site for marine mammals (see section 3.2 for more information):

- APEM aerial survey data of Norfolk Boreas with 4km buffer from August 2016 to July 2018 (24 months of survey data).

2 PROJECT DESCRIPTION

2.1 Indicative Worst Case Scenarios

13. The following sections set out the indicative worst case scenarios for marine mammals. The PEIR/ES will provide a detailed Project Description describing the final project design (also known as Rochdale) envelope for the Norfolk Boreas DCO application. Each chapter of the PEIR/ES will define the worst case scenario arising from the construction, operation and decommissioning phases of the Norfolk Boreas project for the relevant receptors and impacts. Additionally, each chapter will consider separately the anticipated cumulative impacts of Norfolk Boreas with other relevant projects on the receptors under consideration.

14. The following sections provide an overview of the key elements of the proposed project that are of relevance to marine mammals. **Table 2.2** provides a summary of the indicative worst case scenario for marine mammals.

2.1.1 Wind Turbine Generators

2.1.1.1 Capacity

15. A range of 7MW to 20MW wind turbines is included in the Norfolk Boreas project design envelope in order to future proof the EIA and DCO to accommodate foreseeable advances in technology.

2.1.1.2 Number of Wind Turbines

16. In order to achieve the maximum 1,800MW installed capacity, there would be between 90 (20MW wind turbines) and 257 (7MW wind turbines). Turbines of 15MW and 20MW are estimated to have the same foundation parameters. As a result, if the worst-case scenario is associated with the largest turbines, 120 x 15MW will be the worst case scenario (rather than 90 x 20MW), due the greater number of devices making up the maximum site capacity of 1,800MW. The maximum number of turbines would be 257 x 7MW.

2.1.1.3 Foundation Types

17. A range of foundation options are being considered: jacket (pin-piles), gravity base, suction caisson, monopile and tension leg floating foundations with anchors and will be included in the project design envelope. The worst-case scenario for each impact is outline in **Table 2.2**.

18. Monopiles and pin piles will be driven, drilled or drilled-driven into the seabed. It is anticipated that piling will be possible at most locations. However it is estimated that

a maximum of 50% of the locations could need drilling if these foundation options are used.

19. **Table 2.1** outlines the indicative maximum hammer energies required for the largest and smallest pile size options. The underwater noise modelling will also consider the starting hammer energies for the soft-start.

Table 2.1: Indicative maximum piling hammer energies

Maximum hammer energy	7MW pin pile (3m diameter)	15-20MW pin pile (4m diameter)	7MW monopile (8.5m diameter)	15-20MW monopile (15m diameter)
Maximum hammer energy (kJ)	2,700	2,700	4,000	5,000
Starting energy (kJ)	270	270	400	500

2.1.1.4 Layout

20. The layout of wind turbines will be determined pre-construction based on post consent site investigation works and detailed design works. The minimum spacing will be four times the turbine diameter (616m based on the minimum diameter of 154m).

21. The maximum generating capacity of Norfolk Boreas will be 1,800MW. The wind farm layout can only be described in general terms at this stage of the project. It will have some form of regularity in plan, i.e. wind turbines will be set out in rows. However, the locations may not follow a rectangular grid system; it is more likely an offset packing arrangement will be adopted.

2.1.2 Offshore Cabling

22. Two electrical solutions are being considered for Norfolk Boreas, a High Voltage Alternating Current (HVAC) and a High Voltage Direct Current (HVDC) scheme. The HVAC option requires the greatest number of cables and offshore platforms, therefore this represents the worst-case scenario for marine mammals and this is the basis of the parameters shown in **Table 2.2**. The choice between HVAC and HVDC will have no impact on the number or type of wind turbines. The decision as to which option will be used for the project will be agreed post consent and will depend on availability, technical considerations and cost.

2.1.3 Ancillary Infrastructure

23. Up to three substations, two accommodation platforms, up to two meteorological masts, two LiDAR platforms, two wave buoys, plus offshore cables are considered as part of the worst-case scenario (**Table 2.2**).

2.1.4 Construction Vessels

24. Indicative vessel movement and numbers of vessels that may be on site at one time during construction are provided in **Table 2.2**.

2.1.5 Landfall

25. The landfall denotes the location where the export cables are brought ashore and jointed to the onshore cables within transition pits. Norfolk Boreas would share a landfall with Norfolk Vanguard at Happisburgh South.

2.1.6 Construction Programme

2.1.6.1 Phasing

26. Norfolk Boreas is currently considering several scenarios for constructing the project:

- A single phase of up to 1800MW, or
- Two phases, each consisting of up to 900MW per phase, or
- Three phases each consisting of up to 600MW per phase.

27. The infrastructure would be the same for each phasing scenario and therefore the total time for construction activities (e.g. active piling time) would be the same. Consideration is given to the impacts on marine mammals over the full construction window which is expected to be three to seven years for the full 1800MW capacity, regardless of the phasing scenario.

2.1.6.2 Foundation installation duration

28. It expected that installation of all foundations would take up to:

- approximately 15 months for the single phase;
- approximately 9 months per phase for the two phase option; or
- approximately 6 months per phase for the three phase option.

29. The options for foundations installation including single pile installation and concurrent piling is considered for the spatial and temporal worst-case scenarios.

30. The worst case scenario for piling duration is estimated to be up to 6 hours per foundation for a 7MW monopile or quadropod; up to 6 hours for a 15-20MW monopile or up to 12 hours for a 15-20MW quadropod (**Table 2.2**), allowing contingency for issues such as refusal.

2.1.6.3 Offshore cable laying

31. It expected that installation of array and inter-connector cable laying would take up to:

- approximately 14 months for single phase;
- approximately 8 months per phase for the two phase option; or
- approximately 5 months per phase for the three phase option.

32. For the export cable laying, installation is expected to take up to:

- approximately 14 months for single phase;
- approximately 8 months per phase for the two phase option; or
- approximately 5 months per phase for the three phase option.

2.1.6.4 Overall construction activity

33. In summary, it expected that overall the construction would take up to:

- approximately 23 months for single phase;
- approximately 13 months per phase for the two phase option; or
- approximately 8 months per phase for the three phase option.

2.1.7 Operation and Maintenance (O&M) Strategy

34. Once commissioned, the wind farm would operate for up to 25 years. All offshore infrastructure including wind turbines, foundations, cables and offshore substation platforms would be monitored and maintained during this period in order to maximise efficiency.

35. An estimate of the amount of potential maintenance work required, including annual vessel numbers and movements are provided in **Table 2.2**.

2.1.8 Decommissioning

36. The process for removal of foundations is generally the reverse of the installation process (without piling). Explosives will not be used, it is assumed piles cut off below seabed level and all wind turbine components above seabed level removed. Some or all of the array cables, interconnector cables, and offshore export cables would be removed. Scour and cable protection would likely be left *in situ*.

37. It is anticipated that a full EIA will be carried out ahead of any decommissioning works to be undertaken.

2.1.9 Summary

Table 2.2: Summary of Indicative Worst Case Parameters for Marine Mammals

Impact	Parameter	Maximum worst case	Rationale
Construction			
Underwater noise from pile driving (alternative foundation types are also considered but do not represent the worst case scenario for underwater noise)	Number of wind turbines	257 (7MW devices) 120 (15MW devices) 90 (20MW devices which are the same physical size as 15MW turbines and therefore not considered to be the worst case)	The maximum number of turbines would represent the temporal worst-case scenario however the maximum number of the largest piled foundations would represent the greatest spatial impact.
	Number of offshore platforms	3 x Electrical 2 x Met masts 2 x LiDAR 2 x Accommodation = 9	The maximum number of offshore platforms represents the worst case scenario in addition to turbine footprints.
	Platform foundation options	• Electrical – monopile, pin-pile or suction caisson • Met masts - GBS, monopile or pin-pile • Lidar - floating with anchors or monopile • Accommodation – monopile, pin-pile or suction caisson	Piled platforms represent the worst case scenario for underwater noise.
	Proportion of foundations that are piled	100%	The maximum proportion of piled foundations represents the worst case scenario for underwater noise.
	Number of piles per foundation	1 (monopile) 3 (tripod with pin-piles of the same diameter as the quadropod and therefore this will not be the worst-case scenario) 4 (quadropod with pin-piles or tension leg floating platform with up to	The maximum number of piles would represent the temporal worst-case scenario however the maximum number of the largest piles (monopiles) would represent the

Impact	Parameter	Maximum worst case	Rationale
		4 anchors)	greatest spatial impact.
	Number of piled foundations – wind turbines	257 x 1 (7MW monopile) = 257 **257 x 4 (7MW quadropod) = 1,028** 120 x 1 (15MW monopile) = 120 120 x 4 (15MW quadropod) = 480	The 7MW quadropod will represent the worst-case temporal impact due to having the greatest number of piles.
	Number of piled foundations - offshore platforms	3 x Electrical = 12 2 x Met masts = 8 2 x LiDAR = 8 2 x Accommodation = 8 = 36	Assumes a worst-case of 4 pin-piles/piled anchors per platform.
	Total number of piled foundations	1,064	The maximum number of piles would represent the temporal worst-case scenario.
	Hammer energies	Maximum hammer energy: • 2,700kJ (7MW-20MW pin-pile) • 5,000kJ (15MW-20MW monopile) Starting hammer energies of 10% will be used for 20minutes. Ramp up will then be undertaken for the next 40minutes up to the maximum hammer energy.	5,000kJ hammer energy represents the worst-case scenario for the noise impact at any one time. Consideration will also be given to the increased temporal impact associated with the 7MW quadropod foundations with pin-piles.
	Pile diameter	8.5m (7MW monopile) 3m (7MW quadropod) 15m (15MW monopile) 4m (15MW quadropod)	The largest pile (15-20MW monopile) requires the maximum hammer energy and will represent the worst-case spatial impact.

Impact	Parameter	Maximum worst case	Rationale
	Total piling time – per foundation (providing allowance for soft start and issues such as low blow rate, refusal)	6hr (7MW monopile) x 257 turbines = 1542 hours (4000kJ hammer) 6hr (7MW quadropod) x 257 turbines = 1542 hours (2700kJ hammer) 6hr (15-20MW monopile) x 120 turbines = 720 hours (5000kJ hammer) 12hr (15-20MW quadropod) x 120 turbines = 1440 hours (2700kJ hammer)	The maximum piling duration represents the temporal worst case scenario.
	Foundation installation period within construction period	1800MW phase – 15 months 900MW phase – 9 months x 2 600MW phase – 6 months x 3	This is an indicative period within which foundation installation, including piling is anticipated to occur.
	Number of concurrent piling events	Up to 2	The maximum number of concurrent piling events represents the worst case spatial impact.
	Min. spacing between piling vessels	616m based on the closest turbine spacing	
	Max. spacing between piling vessels	Limits of the Offshore Wind Farm (OWF) site boundary	The maximum spacing represents the worst case spatial impact.

Impact	Parameter	Maximum worst case	Rationale
Underwater noise from seabed preparation, rock dumping and cable installation	Cable installation methods	• Surface laid with cable protection; • Ploughing; • Jetting; • Dredging; • Mass flow excavation; and • Trenching.	
	Max no. of cable laying vessels on site	2	
	Duration of cable installation	1800MW phase = up to 14 months 900MW phase – 8 months x 2 = up to16 months 600MW phase – 5 months x 3 = up to 15 months	16 months represents the indicative maximum cable installation duration
Barrier Effects	Maximum impact ranges associated with underwater noise	The worst case scenario in relation to barrier effects as a result of underwater noise will be the maximum spatial (i.e. largest pile) and temporal (i.e. longest piling duration) scenarios outlined above.	
Vessels • Underwater noise from vessels • Collision risk • Disturbance to seal haul out sites	Maximum number of vessels on site at any one time during construction	Maximum = 57	These numbers are based on all activities occurring concurrently which is unlikely but provides a conservative worst case scenario.
	Indicative number of movements	1800MW phase – 1130 900MW phase – 565 x 2 phases = 1130 in total	

Impact	Parameter	Maximum worst case	Rationale
		600MW phase – 565 x 3 = 1695 in total	
	Vessel types	Vessel types that could be on site during construction include: • Seabed preparation vessels • Transition piece installation vessels • Scour Installation Vessels • Number of vessels engaged in foundations • Wind turbine installation vessels • Commissioning vessels • Accommodation vessels • Inter-array cable laying vessels • Export cable laying vessels • Landfall cable installation vessels • Substation / collector station installation vessels • Other vessels	
	Port locations	Will be determined post consent. Assessment will consider Great Yarmouth, Lowestoft and Hull.	A local port on the east coast of England is likely scenario. Vessel traffic to and from port would likely become integrated in existing shipping routes.
Changes to prey resource	Impacts upon prey species	See Fish and Shellfish Ecology Method Statement	
Changes to water quality	Impacts on water quality	See Marine Water and Sediment Quality Method Statement	
Operation and maintenance			
Underwater noise from operational	Number of turbines	257 (7MW devices) 120 (15MW devices)	

Impact	Parameter	Maximum worst case	Rationale
turbines	Wind turbine size	7-20MW	
Underwater noise from maintenance activities, such as any additional rock dumping and cable re-burial	Parameters for any cable lengths or areas requiring any additional rock dumping or cable re-burial are unknown, but the following estimates are assumed: • Reburial of all sections of array cable once every 5 years. • One interconnector repair per year • Up to 20km of export cable reburial or 10km of reburial with 10km of rock dumping.		Maximum potential for disturbance
Vessels • Underwater noise and disturbance from vessels • Collision risk • Disturbance at seal haul-out sites	Number of wind farm support vessel trips per year	480	Maximum potential for disturbance or collision risk
Entanglement – floating foundations	Mooring line diameter	7MW – 0.3m 15-20MW – 0.65m	
	Mooring line material	Steel	Indicative worst case scenario for entanglement
	Mooring line length	20m	

Impact	Parameter	Maximum worst case	Rationale
	Number of mooring lines per foundation	12 (up to 3 lines per anchor)	
Impacts upon prey species	Impacts upon prey species	See Fish and Shellfish Ecology Method Statement	
Changes to water quality	Impacts on water quality	See Marine Water and Sediment Quality Method Statement	
Decommissioning			
Underwater noise from foundation removal (e.g. cutting)	Assumed to be as per construction (with no pile driving). Explosives will not be used, assumed piles cut off below seabed level and all structures above seabed level removed.		
Barrier Effects	Maximum impact ranges associated with underwater noise.		
Vessels • Underwater noise from vessels • Collision risk • Disturbance to seal haul out sites	Assumed to be similar vessel types, numbers and movements to construction phase (or less).		
Changes to prey resource	See Fish and Shellfish Ecology Method Statement		
Changes to water quality	See Marine Water and Sediment Quality Method Statement		

3 BASELINE ENVIRONMENT

38. The Scoping Report (Royal HaskoningDHV, 2017b) provides an overview of the baseline environment based on available information. This section outlines the approach to further characterising the baseline environment for the PEIR and EIA.

39. Site characterisation will be undertaken using site specific data for Norfolk Boreas, as well as existing data from other offshore wind farms in the area, the former East Anglia Zone and other available information for the region.

3.1 Study Area

40. Marine mammals are highly mobile and transitory in nature, therefore it is necessary to examine species occurrence not only within the Norfolk Boreas site, but also over the wider North Sea region. For each species of marine mammal, the study areas will be defined based on the relevant management units (MUs), current knowledge and understanding of the biology of each species; taking into account the feedback received during consultation for Norfolk Vanguard.

41. The status and activity of marine mammals known to occur within or adjacent to Norfolk Boreas will be considered in the context of regional population dynamics at the scale of the southern North Sea, or wider North Sea, depending on the data available for each species and the extent of the relevant reference population.

3.2 Data Sources

3.2.1 Project Specific Data Collection

3.2.1.1 Norfolk Boreas Aerial Surveys

42. APEM are currently collecting high resolution aerial digital still imagery for marine mammals (combined with ornithology surveys) over both the Norfolk Boreas site ($725km^2$) and a 4km buffer around the site covering a total survey area of $1,223km^2$.

43. The monthly aerial surveys have been undertaken since August 2016 and will be completed in July 2018, when 24 months of data has been collected for the Norfolk Boreas site.

44. The aerial survey method has been designed to optimise the data collection for all bird and marine mammal species using a grid-based survey design at 2cm resolution to achieve a minimum of 8% coverage using a twin-engine aircraft.

45. **Table 3.1** shows the numbers of marine mammals recorded during the aerial surveys at the Norfolk Boreas site and 4km buffer from August 2016 to July 2017. The results indicate that harbour porpoise and harbour porpoise / dolphin species are the main

species recorded, with just one individual identified as a dolphin species and three individuals as seals.

46. Early indications are that there is no particular area within the Norfolk Boreas site and 4km buffer with a consistently higher proportion of marine mammal presence and that individuals are recorded across the site.

Table 3.1: Number of marine mammals recorded during Norfolk Boreas aerial surveys

Date	Harbour porpoise	Dolphin / porpoise	Dolphin species	Seal species
August 2016	12	17		
September 2016	24	72		
October 2016	3	12		
November 2016	2	7		
December 2016	11	156	1	1
January 2017	3	66		
February 2017		67		
March 2017		34		
April 2017	3	14		
May 2017	7	3		2
June 2017	7	4		
July 2017	26	2		

47. The technology underlining aerial digital methods for surveying marine mammals has evolved considerably in the recent years and several independent studies have justified the growing confidence in the emerging use of digital survey methods (Voet *et al.*, 2017; Lowry, 1999; Koski *et al.*, 2013; Stewart *et al.*, 2013). The improvement of digital sensors and enhancement of imagery resolution now allows for the monitoring of large areas at a small ground sampling distance (Voet *et al.*, 2017). Additionally, perception or detection bias can be minimised and the production of permanent records allows species identification, group size and behaviour to be re-analysed. During aerial surveys, marine mammals can be seen not only when breaking the surface, but when below the surface as well. Under normal conditions, harbour porpoises are available for detection during aerial surveys when in the top

two metres of the water column (Teilmann *et al*., 2007, 2013). Therefore, with the use of correction factors to take into account the animals that are submerged it is possible to use aerial survey data to provide robust abundance and density estimates.

3.2.1.2 Norfolk Vanguard Aerial Surveys

48. Norfolk Vanguard East and West are located to the south and west of the Norfolk Boreas site. Data from the aerial surveys at these sites will also be used provide information on marine mammals in the area around the Norfolk Boreas site.

49. The following monthly aerial surveys have been undertaken of the Norfolk Vanguard sites to characterise the area for marine mammals:

- APEM aerial survey data of the former East Anglia FOUR site (now Norfolk Vanguard East) with 4km buffer between March 2012 and February 2014;
- APEM aerial survey data of Norfolk Vanguard East with 4km buffer from September 2015 to April 2016 (as agreed with Natural England); and
- APEM aerial survey data of Norfolk Vanguard West with 4km buffer from September 2015 to August 2017.

3.2.1.3 East Anglia OWF Surveys

50. Surveys for other offshore wind farms in the area also provide useful context, these include:

- East Anglia ONE (boat based surveys from May 2010 to April 2011 and APEM aerial surveys from April 2010 to October 2011); and
- East Anglia THREE (APEM aerial surveys from September 2011 to August 2013).

3.2.1.4 Former East Anglia Zone Surveys

51. Marine mammal data has also been collected during the extensive aerial surveys across the former East Anglia Zone, including:

- The Crown Estate Enabling Action data (video aerial survey) from November 2009 to March 2010, completed by HiDef Aerial Surveying Ltd; and
- APEM aerial survey data of the former East Anglia Zone from April 2010 to April 2011.

3.2.2 Desk Based Review

3.2.2.1 Available Data and Information

52. Further to the survey data outlined above, a range of information and further data is available and which will be incorporated into the PEIR and EIA, including, but not limited to:

- Small Cetaceans in the European Atlantic and North Sea (SCANS-III): Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys (Hammond *et al*., 2017);
- Small Cetaceans in the European Atlantic and North Sea (SCANS-II): Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management (Hammond *et al*., 2013);
- Management Units for cetaceans in UK waters (Inter-Agency Marine Mammal Working Group (IAMMWG), 2015));
- Offshore Energy Strategic Environmental Assessment (including relevant appendices and technical reports) (Department of Energy and Climate Change (DECC) (now Department for Business, Energy and Industrial Strategy (BEIS), 2016);
- The identification of discrete and persistent areas of relatively high harbour porpoise density in the wider UK marine area (Heinänen and Skov, 2015);
- Revised Phase III data analysis of Joint Cetacean Protocol (JCP) data resources (Paxton *et al*., 2016);
- Seasonal habitat-based density models for a marine top predator, the harbour porpoise, in a dynamic environment (Gilles *et al*., 2016);
- Survey for small cetaceans over the Dogger Bank and adjacent areas in summer 2011 (Gilles *et al*., 2012);
- Distributions of Cetaceans, Seals, Turtles, Sharks and Ocean Sunfish recorded from Aerial Surveys 2001-2008 (The Wildfowl and Wetlands Trust (WWT), 2009);
- MARINElife surveys from ferries routes across the southern North Sea area (MARINElife, 2017);
- Sea Watch Foundation volunteer sightings off eastern England (Sea Watch Foundation, 2017);
- Seal count data at Hornsey haul-out sites during breeding season (Friends of Hornsey Seals, 2017/2018);
- Norfolk bird and mammal reports (Norfolk and Norwich Naturalist Society, 2017);
- Aerial survey reports of harbour and grey seals counts in the Wadden Sea (Trilateral Seal Expert Group (TSEG), 2017);
- Seal telemetry data (e.g. Sharples *et al*., 2008; Russell and McConnell, 2014);
- UK seal at sea density estimates and usage maps (Russell *et al*., 2017); and

- Special Committee on Seals (SCOS) annual reporting of scientific advice on matters related to the management of seal populations (e.g. SCOS, 2017).

53. Consultation with key marine mammal stakeholders will be ongoing during the EIA through the EPP and will include discussion of the best available information and any updates to use in the PEIR and ES.

3.2.3 Summary of Main Data Sources

54. The main data sources that will be used to inform the baseline marine mammal information on the Norfolk Boreas PEIR and ES are summarised in **Table 3.2**.

Table 3.2: Key data sources

Data	Source	Date
Norfolk Boreas aerial survey data	**APEM Ltd**	**August 2016 – July 2018**
Norfolk Vanguard East (former East Anglia FOUR site) aerial survey data	APEM Ltd	March 2012 and February 2014
Norfolk Vanguard East aerial survey data	APEM Ltd	September 2015 to April 2016
Norfolk Vanguard East aerial survey data	APEM Ltd	September 2015 to August 2017
East Anglia THREE aerial survey data	APEM Ltd	September 2011 to August 2013
SCANS-III	Hammond *et al.* (2017)	Summer 2016
JCP data	Paxton *et al.* (2016)	Sightings from 1994 to 2010
UK grey and harbour seal at-sea usage maps	SMRU (Russell *et al.*, 2017)	Surveys between 1996 and 2013
SCOS reports	SCOS (2017)	2016-2017
Aerial survey counts of harbour and grey seals in the Wadden Sea	TSEG (2017)	2017
Haul-out seal counts during the breeding season	Friends of Horsey seals	2012-2017/2018

3.3 Marine Mammal Species

55. In UK waters, two groups of marine mammals occur: cetaceans (whales, dolphins and porpoises) and pinnipeds (seals). The data presented by Reid *et al*. (2003), SCANS-I (Hammond *et al*., 2002), SCANS-II (Hammond *et al*., 2013), SCANS-III (Hammond *et al*., 2017) and JNCC (2013) indicate the marine mammal species that occur regularly over large parts of the southern North Sea are harbour porpoise, grey seal, harbour seal, white-beaked dolphin and minke whale.

56. Marine mammal species, including Atlantic white-sided dolphin, bottlenose dolphin, killer whale, sperm whale, long-finned pilot whale, Risso's dolphin, striped dolphin and other seal species are occasional or rare visitors to the southern North Sea (e.g. Reid *et al*., 2003; Hammond *et al*., 2013, 2017; DECC, 2016; SCOS, 2017).

57. The available data from the Norfolk Boreas surveys (August 2016 to July 2017; **Table 3.1**), the Norfolk Vanguard site specific surveys, surveys within the former Zone, surveys for other offshore wind farms in the area and other data sources, including SCANS-III (Hammond *et al*., 2017) and SCANS-II (Hammond *et al*., 2013), indicate that harbour porpoise is the most abundant cetacean species present within this region, with only occasional sightings of dolphin species (most likely white-beaked dolphin), and rare sightings in very low numbers of other cetacean species.

58. It is proposed that the only cetacean species included in the more detailed assessment for Norfolk Boreas is harbour porpoise, as agreed as part of the EPP for Norfolk Vanguard.

59. Information on white-beaked dolphin and minke whale will be considered as part of the baseline information in the PEIR and ES. However, given the low numbers and infrequent sightings of these species in and around Norfolk Boreas and Norfolk Vanguard, there is a very low risk of any potential significant impact. It is therefore, currently proposed that these species will not be assessed further (i.e. not included in impact assessment) in the Norfolk Boreas PEIR and ES, as agreed as part of the EPP for Norfolk Vanguard. However, if any further data and information becomes available throughout the EIA process this will be reviewed for Norfolk Boreas and discussed as part of the EPP.

60. The marine mammal species to be included in the Norfolk Boreas PEIR and ES are:

- Harbour porpoise;
- Grey seal; and
- Harbour seal.

3.4 Density Estimates

3.4.1 Harbour Porpoise

3.4.1.1 Site Specific Survey Density Estimates

61. Data from the Norfolk Boreas site specific surveys will be used to generate abundance and density estimates for Norfolk Boreas site with 4km buffer (see **Section 3.2.1.1**).

62. The density estimates for harbour porpoise will be calculated from the raw data counts for (i) harbour porpoise; and (ii) the number of individuals recorded as “dolphin/porpoise” combined with the number of individual harbour porpoise.

63. To date, surveys within the Norfolk Boreas and Norfolk Vanguard sites indicate that harbour porpoise are the most abundant marine mammal species. It is therefore

assumed that a large number of unidentified small cetaceans are likely to be harbour porpoise. As a precautionary approach, the maximum possible density estimate for harbour porpoise will be obtained classing all small cetaceans as harbour porpoise (i.e. by adding the number of harbour porpoise recorded to the number of unidentified dolphin/porpoise).

64. Correction factors will then applied to the data to account for the presence of individuals below 2m water depth (the depth at which it is no longer possible to detect marine mammals from aerial imagery).

65. Voet *et al*. (2017) have determined seasonal correction factors for harbour porpoise that can be used to determine abundance and density estimates obtained from aerial digital surveys (**Table 3.3**).

66. These seasonal correction factors are based on published dive profile data from harbour porpoise tagged in the North Sea. The Teilmann *et al*. (2013) tagging study indicated significant differences in the percentage of time that each harbour porpoise spent between 0 and 2m water depth with the time of year. Spring and summer had a higher average time spent between 0 and 2m compared autumn and winter. Therefore, to take this into account, Teilmann *et al*. (2013) suggest that aerial survey data should be corrected for time submerged as well as for seasonal effects.

67. The seasonal correction factors in **Table 3.3** will be used to generate harbour porpoise site specific density estimates for the Norfolk Boreas site and 4km buffer.

Table 3.3: Harbour porpoise seasonal correction factors

Season	Correction Factor
Spring (Mar – May)	0.571
Summer (Jun – Aug)	0.547
Autumn (Sept – Nov)	0.455
Winter (Dec - Feb)	0.472

68. Site specific density estimates will be calculated for both summer and winter periods to account for the seasonal differences, particularly with respect to the Southern North Sea cSAC.

3.4.1.2 SCANS-III Density Estimates

69. In addition to the site specific density estimates for harbour porpoise, density estimates from the SCANS-III surveys (Hammond *et al*., 2017) will also be used to provide context for the wider area.

70. The Norfolk Boreas site crosses the boundaries of two SCANS-III survey blocks: block L and block O.

- SCANS-III Block O:
  - Abundance = 53,485 harbour porpoise (CV=0.21; 95% CI = 37,413-81,695)
  - Density = 0.888 harbour porpoise/km^2 (CV=0.21; 95% CI = 37,413-81,695)
- SCANS-III Block L:
  - Abundance = 19,064 harbour porpoise (CV=0.38; 95% CI = 6,933-35,703)
  - Density = 0.607 harbour porpoise/km^2 (CV=0.38; 95% CI = 6,933-35,703)

71. The average harbour porpoise density estimate from the two survey blocks will be used for the Norfolk Boreas site. Therefore the density estimate of 0.75 harbour porpoise/km^2 will be used within the impact assessment.

3.4.2 Grey and Harbour Seal

72. It is anticipated that grey and harbour seal sightings during the Norfolk Boreas site specific surveys will be too low to determine robust site specific density estimates, based on survey data to date within the Norfolk Boreas and Norfolk Vanguard sites. It is therefore proposed that the density estimates from the latest SMRU seals at-sea density data (Russell *et al.*, 2017) will be used.

73. The seal density maps (Russell *et al.*, 2017), were produced by Sea Mammal Research Unit (SMRU) by combining information about the movement patterns of electronically tagged seals with survey counts of seals at haul-out sites. The resulting maps show estimates of mean seal usage (seals per 5km x 5km grid cell).

74. Grey seal and harbour seal density estimates for Norfolk Boreas will be calculated from the 5km x 5km cells (Russell *et al.*, 2017) based on the area of overlap with (i) the Norfolk Boreas offshore wind farm area; and (ii) the Norfolk Boreas offshore cable route area.

3.5 Reference Populations

75. The suggested reference populations in the following sections will be used unless any new data sources become available during the assessment.

76. The reference populations will be used to assess impacts as part of the EIA process and may also be used within the HRA assessment.

3.5.1 Harbour Porpoise

3.5.1.1 North Sea Management Unit

77. Harbour porpoise within the eastern North Atlantic are generally considered to be part of a continuous biological population that extends from the French coastline of the Bay of Biscay to northern Norway and Iceland (Tolley and Rosel, 2006; Fontaine

et al., 2007, 2014; IAMMWG, 2015). However, for conservation and management purposes, it is necessary to consider this population as smaller Management Units (MUs). MUs provide an indication of the spatial scales at which effects of plans and projects alone, and in-combination, need to be assessed for the key cetacean species in UK waters, with consistency across the UK (IAMMWG, 2015).

78. The Inter-Agency Marine Mammal Working Group (IAMMWG) defined three MUs for harbour porpoise: North Sea (NS); West Scotland (WS); and the Celtic and Irish Sea (CIS). Norfolk Boreas is located in the North Sea MU.

79. The reference population for harbour porpoise to be used in the assessment is the North Sea MU, which, based on the latest SCANS-III survey has an estimated abundance of 345,373 harbour porpoise (Coefficient of Variation (CV) = 0.18; 95% Confidence Interval (CI) = 246,526-495,752; Hammond *et al*., 2017). This reference population has been agreed with Natural England (letter dated 3rd January 2018; Ref: 10430 Consultation 234941) for Norfolk Vanguard ES and HRA.

3.5.2 Grey Seal

80. In accordance with the approach agreed with Natural England for other offshore wind farms, including Norfolk Vanguard and East Anglia THREE, the reference population extent for grey seal will incorporate the south-east England MU, north-east England MU and east coast of Scotland MU (IAMMWG, 2013; SCOS, 2017) and the Waddenzee population (Trilateral Seal Expert Group (TSEG), 2017a).

81. The reference population will be based on the most recent counts for the south-east England MU, the north-east England MU and the east coast of Scotland MU (e.g. currently SCOS, 2017) and the most recent estimate for the Waddenzee population (e.g. currently TSEG, 2017a).

82. The reference population for grey seal is therefore currently based on the following most recent estimates for the:

- South-east England MU = 6,085 grey seal (SCOS, 2017);
- North-east England MU = 6,948 grey seal (SCOS, 2017);
- East Coast Scotland MU = 3,812 grey seal (SCOS 2017); and
- Waddenzee population = 5,445 grey seal (TSEG, 2017a).

83. The total reference population for the assessment is currently 22,290 grey seal.

84. In addition, consideration will also be given to the potential impacts on the south-east England MU, the most recent count is currently 6,085 grey seal (SCOS, 2017).

3.5.3 Harbour Seal

85. In accordance with the approach agreed with Natural England for other offshore wind farms, including Norfolk Vanguard and East Anglia THREE, the reference population for harbour seal will incorporate the south-east England MU (IAMMWG, 2013; SCOS, 2017) and the Waddenzee population (TSEG, 2017b).

86. The reference population is therefore based on the following most recent estimates:

- South-east England MU = 5,061 harbour seal (SCOS, 2017); and
- The Waddenzee region = 38,100 harbour seal (TSEG, 2017b).

87. The total harbour seal reference population is therefore currently 43,161 individuals.

88. In addition, consideration will also be given to the potential impacts on the south-east England MU, the most recent count is currently 5,061 harbour seal (SCOS, 2017).

3.6 Summary of Marine Mammal Density Estimates and Reference Populations

89. **Table 3.4** and **Table 3.5** provide a summary of the reference populations and the density estimates for the marine mammal species to be used in impact assessment for Norfolk Boreas.

90. During the impact assessment, the magnitude of impacts will be put in context against these reference populations (see **Table 4.3** for definitions of magnitude).

Table 3.4: Summary of marine mammal reference populations used in the impact assessment

Species	Reference population			
	Extent	Year of estimate	Size	Data source
Harbour porpoise	North Sea MU	2016	**345,373** (95% CI = 246,526-495,752)	Hammond *et al.* (2017)
Grey seal	South-east England MU; North-east England MU; East coast of Scotland MU; & Waddenzee population	2016 2016 2016 2017	6,085 + 6,948 + 3,812 + 5,445 = **22,290**	SCOS (2017) and TSEG (2017a)
	South-east England MU	2016	5,637	SCOS (2017)
Harbour seal	South-east England MU; and Waddenzee population	2016 2017	5,061 + 38,100 = **43,161**	SCOS (2017) and TSEG (2017b)
	South-east England MU	2016	5,061	SCOS (2017)

Table 3.5: Summary of marine mammal density estimates used in the impact assessment

Species	Density estimate Number of individuals per km^2	Data source
Harbour porpoise	To be estimated based on mean annual density estimate of highest monthly counts and seasonal APEM correction factors of harbour porpoise counts combined with in unidentified	Site specific surveys

	dolphin/porpoise	
	0.75/km^2	SCANS-III survey* (Hammond *et al.*, 2017)
Grey seal	To be estimated for offshore wind farm sites To be estimated for offshore cable corridor area	SMRU seal at-sea usage maps (Russell *et al.*, 2017)
Harbour seal	To be estimated for offshore wind farm sites To be estimated for offshore cable corridor area	SMRU seal at-sea usage maps (Russell *et al.*, 2017)

*Norfolk Boreas is located in both SCANS-III survey block L and survey block O; therefore the average density from two survey blocks will be used.

4 IMPACT ASSESSMENT METHODOLOGY

4.1 Defining Impact Significance

91. A matrix approach will be used to guide the assessment of impacts following best practice, EIA guidance and the approach previously agreed with stakeholders for other recent offshore wind farms (including Norfolk Vanguard and East Anglia THREE).

92. In order to enable and facilitate a consistency of approach a matrix of definitions will be employed to structure the expertise and evidence led assessment of impacts. Receptor sensitivity for an individual from each marine mammal species will be defined within the PEIR and ES, following the definitions set out in **Table 4.1**. The potential magnitude of effect will be described for permanent and temporary outcomes, as detailed in **Table 4.3**. The assessment of the significance of impacts will be structured and guided by using the matrix presented in **Table 4.4**.

4.1.1 Sensitivity

93. The sensitivity of a receptor is determined through its ability to accommodate change and on its ability to recover if it is affected. The sensitivity level of marine mammals to each type of impact is justified within the impact assessment and is dependent on the following factors:

- **Adaptability** – The degree to which a receptor can avoid or adapt to an effect;
- **Tolerance** – The ability of a receptor to accommodate temporary or permanent change without a significant adverse effect;
- **Recoverability** – The temporal scale over and extent to which a receptor will recover following an effect; and
- **Value** – A measure of the receptors importance, rarity and worth (see below).

94. The sensitivity of marine mammals to impacts from pile driving noise is currently the impact of most concern across the offshore wind sector. The sensitivity to potential impacts of lethality, physical injury, auditory injury or hearing impairment, as well as behavioural disturbance or auditory masking will be considered for each species, using available evidence including published data sources. **Table 4.1** defines the levels of sensitivity and what they mean for each receptor.

Table 4.1: Definitions of sensitivity levels for marine mammals

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

4.1.2 Value

95. The 'value' of the receptor forms an important element within the assessment, for instance, if the receptor is a protected species or habitat or has an economic value. It is important to understand that high value and high sensitivity are not necessarily linked within a particular impact. A receptor could be of high value but have a low or negligible physical/ecological sensitivity to an effect. Similarly, low value does not equate to low sensitivity and is judged on a receptor by receptor basis.

96. In the case of marine mammals, most species are protected by a number of international commitments as well as European and UK law and policy. All cetaceans in UK waters are EPS and, therefore, are internationally important. Areas of importance for harbour porpoise, bottlenose dolphin, grey seal and harbour seals are afforded international protection through the designation of Natura 2000 sites, which have seals as a primary reason for site selection.

97. **Table 4.2** provides definitions for the value afforded to a receptor based on its legislative importance. The value will be considered, where relevant, as a modifier for the sensitivity assigned to the receptor, based on expert judgement.

Table 4.2: Definitions of the value levels for marine mammals

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

4.1.3 Magnitude

98. The thresholds for defining the potential magnitude of effect that could occur from a particular impact have been determined using expert judgement, current scientific

understanding of marine mammal population biology, and JNCC *et al*. (2010) draft guidance on disturbance to EPS species. The JNCC *et al*. (2010) EPS draft guidance suggests definitions for a 'significant group' of individuals or proportion of the population for EPS species. As such this guidance has been considered in defining the thresholds for magnitude of effects (**Table 4.3**).

99. The JNCC *et al*. (2010) draft guidance provides some indication on how many animals may be removed from a population without causing detrimental effects to the population at Favourable Conservation Status (FCS). The JNCC *et al*. (2010) draft guidance also provides limited consideration of temporary effects, with guidance reflecting consideration of permanent displacement.

100. Temporary effects are considered to be of medium magnitude at greater than 5% of the reference population. JNCC *et al*. (2010) draft guidance considered 4% as the maximum potential growth rate in harbour porpoise, and the 'default' rate for cetaceans. Therefore, beyond natural mortality, up to 4% of the population could theoretically be permanently removed before population growth could be halted. In assigning 5% to a temporary impact in this assessment, consideration is given to uncertainty of the individual consequences of temporary disturbance.

101. For permanent effects, greater than 1% of the reference population being affected within a year is considered to be high magnitude in this assessment. The assignment of these levels is informed by the JNCC *et al*. (2010) draft guidance (suggesting 4% as the 'default maximum growth rate for cetaceans) but also reflects the large amount of uncertainty in the potential individual and population level consequences of permanent effects.

Table 4.3: Definitions of the magnitude levels for marine mammals

Magnitude	Definition
High	Permanent irreversible change to exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that >1% of the reference population are anticipated to be exposed to the effect. OR Long-term effect for 10 years or more, but not permanent (e.g. limited to operational phase of the project). Assessment indicates that >5% of the reference population are anticipated to be exposed to the effect. OR Temporary effect (e.g. limited to the construction phase of development) to the exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that >10% of the reference population are anticipated to be exposed to the effect.
Medium	Permanent irreversible change to exposed receptors or feature(s) of the habitat of particular importance to the receptor. Assessment indicates that >0.01% or <=1% of the reference population anticipated to

Magnitude	Definition
	be exposed to effect. OR Long-term effect for 10 years or more, but not permanent (e.g. limited to operational phase of the project). Assessment indicates that >1% and <=5% of the reference population are anticipated to be exposed to the effect. OR Temporary effect (e.g. limited to the construction phase of development) to the exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that >5% or <=10% of the reference population anticipated to be exposed to effect.
Low	Permanent irreversible change to exposed receptors or feature(s) of the habitat of particular importance to the receptor. Assessment indicates that >0.001 and <=0.01% of the reference population anticipated to be exposed to effect. OR Long-term effect for 10 years or more, but not permanent (e.g. limited to operational phase of the project). Assessment indicates that >0.01% and <=1% of the reference population are anticipated to be exposed to the effect. OR Intermittent and temporary effect (e.g. limited to the construction phase of development) to the exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that >1% or <=5% of the reference population anticipated to be exposed to effect.
Negligible	Permanent irreversible change to exposed receptors or feature(s) of the habitat of particular importance to the receptor. Assessment indicates that <=0.001% of the reference population anticipated to be exposed to effect. OR Long-term effect for 10 years or more (but not permanent, e.g. limited to lifetime of the project). Assessment indicates that <=0.01% of the reference population are anticipated to be exposed to the effect. OR Intermittent and temporary effect (limited to the construction phase of development or Project timeframe) to the exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that <=1% of the reference population anticipated to be exposed to effect.

4.1.4 Impact Significance

102. Following the identification of receptor sensitivity and the magnitude of the effect, the impact significance will be determined using expert judgement. The probability of the impact occurring is also considered in the assessment process. If doubt exists concerning the likelihood of occurrence or the prediction of an impact, the

precautionary approach is taken to assign a higher level of probability to adverse effects.

103. The matrix (provided in **Table 4.4**) will be used as a framework to aid determination of the impact assessment. Definitions of impact significance are provided in **Table 4.5**. For the purposes of this EIA and specifically the marine mammal assessment, 'major' and 'moderate' impacts are deemed to be significant. However, whilst 'minor' impacts would not be deemed significant in their own right, they may contribute to significant impacts cumulatively or through inter-relationships.

Table 4.4: Impact Significance Matrix

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

Table 4.5: Impact Significance Definitions

Impact Significance	Definition
Major	Very large or large change in receptor, either adverse or beneficial, which are important at a population (national or international) level because they contribute to achieving national or regional objectives, or, expected to result in exceedance of statutory objectives and / or breaches of legislation.
Moderate	Intermediate or large change in receptor, which may to be important considerations at national or regional population level. Potential to result in exceedance of statutory objectives and / or breaches of legislation.
Minor	Small change in receptor, which may be raised as local issues but are unlikely to be important at a regional population level.
Negligible	No discernible change in receptor.

5 POTENTIAL IMPACTS

104. The impacts and the assessment methodologies during the construction, operation and decommissioning of the proposed Norfolk Boreas project are provided below for agreement during the consultation on this method statement.

105. The potential impacts during construction that will be assessed for marine mammals are:

- Physical injury, auditory injury and behavioural impacts resulting from the underwater noise associated with clearance of unexploded ordnance (UXO) – see **Section 5.1.1**;
- Auditory injury and behavioural impacts resulting from underwater noise during piling – see **Section 5.1.2**;
- Behavioural impacts resulting from underwater noise during other construction activities, for example, seabed preparation, rock dumping and cable installation – see **Section 5.1.3**;
- Barrier effects as a result of underwater noise – see **Section 5.1.5**;
- Impacts resulting from the deployment of construction vessels:
  - Underwater noise and disturbance from vessels – see **Section 5.1.4**;
  - Vessel interaction (collision risk) – see **Section 5.1.6**;
  - Disturbance at seal haul-out sites – see **Section 5.1.7**;
- Changes to prey resource – see **Section 5.1.8**; and
- Changes to water quality – see **Section 5.1.9**.

106. The potential impacts during operation and maintenance (O & M) that will be assessed for marine mammals are:

- Behavioural impacts resulting from the underwater noise associated with operational turbines – see **Section 5.2.1**;
- Behavioural impacts resulting from the underwater noise associated with maintenance activities, such as any additional rock dumping and cable re-burial – see **Section 5.2.2**;
- Impacts resulting from the deployment of maintenance vessels:
  - Underwater noise and disturbance from vessels – see **Section 5.2.3**;
  - Vessel interaction (collision risk) – see **Section 5.2.4**;
  - Disturbance at seal haul-out sites – see **Section 5.2.5**;
- Entanglement in floating foundations – see **Section 5.2.6**; and
- Changes to prey resource – see **Section 5.2.7;**
- Changes to water quality – see **Section 5.2.8**.

107. The potential impacts during decommissioning that will be assessed for marine mammals are:

- Physical injury, auditory injury and behavioural impacts resulting from the noise associated with foundation removal (e.g. cutting) – see **Section 5.3**;
- Barrier effects as a result of underwater noise – see **Section 5.3**;
- Impacts resulting from the deployment of vessels:
  - Underwater noise and disturbance from vessels – see **Section 5.3**;
  - Vessel interaction (collision risk) – see **Section 5.3**;
  - Disturbance at seal haul-out sites – see **Section 5.3**;
- Changes to prey resource – see **Section 5.3**; and
- Changes to water quality – see **Section 5.3**.

5.1 Potential Impacts during Construction

108. The construction scenarios which will be assessed for marine mammal receptors will be based on the realistic worst-case scenario outlined in **Section 2.1** and summarised in **Table 2.2**.

109. Depending on the receptor, the construction of the offshore wind farm (including wind turbines, array cables, interconnector cables and platforms) may have different impacts in terms of type and magnitude than those of the offshore cable corridor. The impacts of the entire project will be assessed as a whole, although where relevant the impacts will be assessed separately for the offshore wind farm site and the offshore cable corridor. Therefore, for impacts that span both the offshore wind farm site and the offshore cable corridor, magnitude may be discussed separately (under the same impact), however consideration will be given to the combined magnitude in order to define the significance of that impact for the project overall.

5.1.1 Impact 1: Underwater UXO Clearance

110. Prior to construction, there is the potential for UXO clearance to be required. While any identified UXO will either be avoided or removed and disposed of onshore in a designated place, there is the potential that underwater detonation could be required where it is necessary and unsafe to remove the UXO.

111. The potential effects of underwater explosions on marine mammals include: (1) physical injury from direct or indirect blast wave effect of the high amplitude shock waves and sound wave produced by underwater detonation, which could result in immediate or eventual mortality; (2) auditory impairment (from exposure to the acoustic wave), resulting in a temporary or permanent hearing loss such as temporary threshold shift (TTS) and permanent threshold shift (PTS); or (3)

behavioural change, such as disturbance to feeding, mating, breeding, and resting (Richardson *et al*., 1995; Ketten, 2004; von Benda-Beckmann *et al*., 2015).

5.1.1.1 Approach to Assessment

112. A detailed UXO survey will be completed prior to construction. Therefore, the number of possible detonations and duration of UXO clearance operations that could be required will not be known for the PEIR or ES.

113. For the assessment a conservative estimate will be made, if possible, based on the best available information from other offshore wind farm UXO clearance operations and other published information.

114. A desk based assessment using current scientific knowledge will be undertaken to assess the potential injury zones for marine mammals.

115. The maximum predicted impacts areas, based on the worst-case scenario, will be used to estimate the potential number of individuals that could be impacted, based on the species density estimates (see **Section 3.4** and **Table 3.5**).

116. The number of individuals of each species that could be impacted will be considered as a proportion of the reference population (see **Section 3.5** and **Table 3.4**).

117. Magnitudes and sensitivities will be based on the best available evidence and defined as outlined in **Section 4.1**.

118. Assessments will be made on the basis of embedded mitigation and proposed mitigation (see **Section 5.4**).

5.1.2 Impact 2: Underwater Noise during Piling

119. Underwater noise can cause both physiological (e.g. lethal, physical injury and auditory injury) and behavioural (e.g. disturbance, behavioural response and masking of communication) impacts on marine mammals (e.g. Bailey *et al*., 2010; Madsen *et al*., 2006; Thomsen *et al*., 2006).

120. As outlined in **Section 2.1.1.3**, a range of foundation options are being considered for the wind turbines at Norfolk Boreas, including monopile, jacket (tripod or quadropod), gravity base, suction caisson and floating platforms. Of these, monopiles, jackets and floating foundations may require piling.

121. Impact piling has been proposed to drive the foundation piles of the wind turbines into the seabed. Impact piling has been established as a source of high level underwater noise (Würsig *et al*., 2000; Caltrans, 2001; Nedwell *et al*., 2003 and 2007; Parvin *et al*., 2006; Thomsen *et al*., 2006).

122. The potential impacts of underwater noise are dependent on the noise source characteristics, the receptor species, distance from the sound source and noise attenuation within the environment.

123. The potential impact will depend on a number of factors which include, but are not limited to:

- The source levels of noise;
- Frequency relative to the hearing bandwidth of the animal;
- Duration of exposure;
- Distance of the animal to the source; and
- Ambient noise levels.

124. The spatial footprint of the impact as a feature of noise propagation conditions which will depend on several factors, including, but not limited to:

- Sediment/sea floor composition;
- Water depth; and
- The sensitivity of marine mammal species present in the area.

5.1.2.1 Approach to Assessment

125. Underwater noise modelling will be undertaken to determine the potential impacts on marine mammals during piling at Norfolk Boreas for:

- Auditory injury (Permanent Threshold Shift (PTS)); and
- Disturbance and Possible behavioural response.

126. **Appendix 1** provides an overview of the proposed approach to the underwater noise modelling. The proposed approach, including the thresholds and criteria, for each species to be assessed will be discussed and agreed through the EPP.

127. In the assessment it is proposed that the potential impact ranges for PTS in harbour porpoise, grey seal and harbour seal will be based on the NOAA (NMFS, 2016) metrics and criteria.

128. The SNCBs current advice is that a potential disturbance range of 26km (approximate area of 2,124km^2) around piling and UXO locations is used to assess the area that harbour porpoise may be disturbed in the Southern North Sea (SNS) cSAC. Norfolk Boreas is located within the SNS cSAC therefore it is proposed to use this approach in the EIA as well as the HRA.

129. TTS onset can be used to determine the onset of disturbance (Southall *et al*., 2007). It is proposed that the potential onset of disturbance in grey seal and harbour seal will be based on the NOAA (NMFS, 2016) metrics and criteria for TTS.

130. The threshold and criteria from Lucke *et al*. (2009) will be used to assess the potential impacts of behavioural response in harbour porpoise, based on a dose-response function.

131. The Popper *et al*. (2014) thresholds and criteria will be used to assess the potential impacts of underwater noise on fish.

132. The Marine Noise Registry, where possible, will be used to inform the baseline noise environment.

133. The underwater noise modelling for piling will provide the range and area of the potential impacts for each species group. The maximum predicted impacts areas, based on the worst-case scenario, will be used to estimate the potential number of individuals that could be impacted, based on the species density estimates (see **Section 3.4** and **Table 3.5**).

134. The number of individuals of each species that could be impacted will be considered as a proportion of appropriate the reference population (see **Section 3.5** and **Table 3.4).**

135. The duration of piling will be based on the worst-case scenario for the maximum time required to install an individual pile and the maximum number of piles that could be installed, taking into account the possible phasing options and scenarios (see **Table 2.2**).

136. Magnitudes and sensitivities will be based on the best available evidence and defined as outlined in **Section 4.1**.

137. Assessments will be made on the basis of embedded mitigation and proposed mitigation (see **Section 5.4**).

5.1.3 Impact 3: Underwater Noise during other Construction Activities

138. Other sources of underwater noise associated with offshore wind farm construction include seabed preparation, rock dumping and cable installation.

139. The construction activity likely to have the greatest potential noise impacts, other than piling, is cable installation and has therefore this will be assessed as a worst-case scenario.

140. As outlined in **Section 2.1.2**, the possible cable installation techniques that are currently being considered include:

- Ploughing;
- Jetting;

- Dredging;
- Mass flow excavation[1]; and
- Trenching.

141. There are no clear indications that underwater noise caused by the installation of sub-sea cables poses a high risk of harming marine fauna (OSPAR, 2009). However, behavioural responses of marine mammals to dredging, an activity emitting comparatively higher underwater noise levels, are predicted to be similar to those during cable installation (OSPAR, 2009).

142. Based on reviews of published sources of underwater noise during dredging activity (e.g. Thomsen *et al*., 2006; CEDA, 2011; Theobald *et al*., 2011; WODA, 2013; Todd *et al*., 2014), sound levels that marine mammals may be exposed to during dredging activities are usually below auditory injury thresholds or PTS exposure criteria (as defined in Southall *et al*., 2007); TTS cannot be ruled out if marine mammals are exposed to noise for prolonged periods (Todd *et al*., 2014), however, marine mammals remaining in close proximity to such activities for long periods of time is unlikely. Therefore the potential risk of PTS or TTS in marine mammals as a result of cable installation activity is highly unlikely.

143. Underwater noise as a result of dredging activity also has the potential to disturb marine mammals (Pirotta *et al*., 2013). Therefore there is the potential for short, perhaps medium-term behavioural reactions and disturbance to marine mammals in the area during dredging / cable installation activity.

144. The potential for any disturbance from underwater noise during cable installation or other activities associated with offshore wind farm construction will be assessed in the Norfolk Boreas PEIR and ES.

5.1.3.1 Approach to Assessment

145. The number of harbour porpoise, grey seal and harbour seal that could be potentially disturbed as a result of underwater noise during construction from activities, other than piling and vessel movements, will also be assessed, based on the type of activity and potential area of disturbance.

146. As outlined in **Section 5.1.2**, the Marine Noise Registry, where possible, will be used to inform the baseline noise environment.

147. The maximum potential number of individuals that could be impacted will be based on the species density estimates (see **Section 3.4**and **Table 3.5**).

[1] An example of a mass flow excavator is available at http://www.rotech.co.uk/subsea/

148. The number of individuals of each species that could be impacted will be considered as a proportion of the reference population (see **Section 3.5** and **Table 3.4).**

149. The duration of the construction activities will be based on the worst-case scenario, taking into account the possible phasing options and scenarios.

150. Magnitudes and sensitivities will be based on the best available evidence and defined as outlined in **Section 4.1**.

151. Assessments will be made on the basis of embedded mitigation and proposed mitigation (see **Section 5.4**).

5.1.4 Impact 4: Underwater Noise and Disturbance from Vessels

152. During the construction phase there will be an increase in the number of vessels associated with installation of the turbine foundations and associated sub-structures and also with the installation of the inter-array and export cables. Vessel movements to and from any port will be incorporated within existing vessel routes and therefore any increase in disturbance as a result of underwater noise from vessels during construction will be within the wind farm site and cable route.

153. As outlined in **Section 2.1.4**, it is anticipated that the types of vessels that could be on site during construction include:

- Seabed preparation vessels;
- Foundation installation vessels;
- Wind turbine installation vessels;
- OSP/OCP installation vessels;
- Cable installation vessels;
- Commissioning vessels; and
- Other vessels.

154. Noise levels reported by Malme *et al*. (1989) and Richardson *et al*. (1995) for large vessels, typically those being used during construction, indicates that any physical or auditory damage to marine mammals is unlikely. However, the levels could be sufficient to cause local disturbance of sensitive marine fauna in the immediate vicinity of the vessel, depending on ambient noise levels.

155. Underwater noise and disturbance from vessels during construction are likely to be localised in comparison to existing shipping noise. The disturbance of marine mammals from the presence and underwater noise of vessels would be temporary as the vessels move in and out of the site and move between different locations

within the site, marine mammals would be expected to return to the area once the disturbance had ceased or they had become habituated to the sound.

5.1.4.1 Approach to Assessment

156. A determination of the type and number of vessels to be used during the construction period will be taken into account and the likely noise emissions from those vessels will be given consideration to determine the potential impact of vessel noise on marine mammals. In addition, consideration will also be given to existing vessel activity in and around the Norfolk Boreas site, based on site specific data collected during winter and summer shipping surveys and detailed within the Navigational Risk Assessment.

157. The increase in vessel movements during construction will be put into the context of current vessel movements in and around the Norfolk Boreas site.

158. The number of harbour porpoise, grey seal and harbour seal that could potentially be disturbed will be determined, based on the types of vessels and taking into account current levels of vessel activity in the area.

159. As outlined in **Section 5.1.2**, the Marine Noise Registry, where possible, will be used to inform the baseline noise environment.

160. The maximum potential number of individuals that could be impacted will be based on the species density estimates (see **Section 3.4**and **Table 3.5**).

161. The number of individuals of each species that could be impacted will be considered as a proportion of the reference population (see **Section 3.5** and **Table 3.4**).

162. The duration of the construction vessels on site will be based on the worst-case scenario, taking into account the possible phasing options and scenarios (**Table 2.2**).

163. Magnitudes and sensitivities will be based on the best available evidence and defined as outlined in **Section 4.1**.

164. Assessments will be made on the basis of embedded mitigation and proposed mitigation (see **Section 5.4**).

5.1.5 Impact 5: Barrier Effect

165. Underwater noise during construction, including piling, other construction activities and vessels, could have the potential to create a barrier effect, preventing movement or migration of marine mammals between important feeding and / or breeding areas, or potentially increasing swimming distances if marine mammals avoid the site and go round it.

166. Norfolk Boreas is not located on any known migration routes for marine mammals. Telemetry studies for seals (e.g. Sharples *et al*., 2008; Russel and McConnell, 2014) and low seal at sea usage (Jones *et al*., 2016) in and around the Norfolk Boreas do not currently indicate any regular seal foraging routes through the site.

5.1.5.1 Approach to Assessment

167. The assessment of barrier effects will take account of the maximum potential area of potential noise impacts, in particular the predicted extent towards the coastline. The maximum duration of underwater noise impacts will also be considered.

168. The worst-case scenario in relation to barrier effects as a result of underwater noise will be based on the maximum spatial and temporal (i.e. longest duration) scenarios (**Table 2.2**).

169. The maximum potential number of individuals that could be impacted will be based on the species density estimates (see **Section 3.4**and **Table 3.5**).

170. The number of individuals of each species that could be impacted will be considered as a proportion of the reference population (see **Section 3.5** and **Table 3.4**).

171. Magnitudes and sensitivities will be based on the best available evidence and defined as outlined in **Section 4.1**.

172. Assessments will be made on the basis of embedded mitigation and proposed mitigation (see **Section 5.4**).

5.1.6 Impact 6: Vessel Collision Risk

173. The additional vessel movements associated with the construction of Norfolk Boreas could have the potential to increase the collision risk with marine mammals. Despite the potential for marine mammals to detect and avoid vessels, strikes are known to occur possibly due to distraction whilst foraging and socially interacting, or due to the mammals' inquisitive nature (Wilson *et al*., 2007).

174. Heinänen and Skov (2015) indicated a negative relationship between the number of ships and the distribution of harbour porpoises in the North Sea suggesting potential avoidance behaviour. However, approximately 4% of all harbour porpoise post mortem examinations from the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS area) are thought to have evidence of interaction with vessels (Evans *et al*., 2011).

5.1.6.1 Approach to Assessment

175. The assessment of the potential impact of vessel interaction will take into account the type and number of vessels to be used during the construction period and the potential collision risk associated with those vessels. This will be considered in the context of the existing vessel activity in and around the Norfolk Boreas site, based on site specific data collected during winter and summer shipping surveys and detailed within the Navigational Risk Assessment.

176. The increase in vessel movements during construction will be put into the context of current vessel movements in and around the Norfolk Boreas site.

177. The maximum potential number of individuals that could be impacted will be based on the species density estimates (see **Section 3.4**and **Table 3.5**).

178. The number of individuals of each species that could be impacted will be considered as a proportion of the reference population (see **Section 3.5** and **Table 3.4**).

179. The duration of the construction vessels on site will be based on the worst-case scenario, taking into account the possible phasing options and scenarios.

180. Magnitudes and sensitivities will be based on the best available evidence and defined as outlined in **Section 4.1**.

181. Assessments will be made on the basis of embedded mitigation and proposed mitigation (see **Section 5.4**).

5.1.7 Impact 7: Disturbance at Seal Haul-Out Sites

182. Increased activity near seal haul-out sites as a result of transiting vessels could have the potential to disturb seals.

183. There no potential for any direct disturbance as a result of construction activities within the Norfolk Boreas offshore wind farm site due to the distance between the site and the closest point onshore.

184. The landfall at Happisburgh South is approximately 11km from the Horsey seal haul-out site to the south of the landfall search area and 43km from the Blakeney Point haul-out site to the north. Given the distances between the Norfolk Boreas cable landfall area and the nearest known seal haul-out sites; there is very little potential for any direct disturbance as a result of construction activities associated with offshore cable route.

185. The construction port to be used for Norfolk Boreas is not yet known and could be located on the south east coast of England. Vessel movements to and from any port

will be incorporated within existing vessel routes. Taking into account the proximity of shipping channels to and from existing ports, it is likely that seals hauled-out along these routes and in the area of the ports would be habituated to the noise, movements and presence of vessels.

5.1.7.1.1 Approach to assessment

186. The likelihood of increased vessels near to the locations of nearby seal haul-out sites will be used to determine the level of potential disruption and behavioural impact caused to the seals. An expert judgement will be made using current scientific knowledge.

187. The duration of the construction vessels movement to and from the site will be based on the worst-case scenario, taking into account the possible phasing options and scenarios (**Table 2.2**).

188. The increase in vessel movements during construction will be put into the context of current vessel movements in and around the Norfolk Boreas site.

189. Magnitudes and sensitivities will be based on the best available evidence and defined as outlined in **Section 4.1**.

190. Assessments will be made on the basis of embedded mitigation and proposed mitigation (see **Section 5.4**).

5.1.8 Impact 8: Changes to Prey Resources

191. The potential to injure or to displace prey species during construction can result from physical disturbance and temporary loss of seabed habitat; increased suspended sediment concentrations and sediment re-deposition; changes in water quality and underwater noise (that could lead to mortality, physical injury, auditory injury or behavioural responses). Potential impacts on fish could affect prey availability for marine mammals.

5.1.8.1 Approach to Assessment

192. The Fish and Shellfish Ecology Method Statement outlines the proposed approach to the assessment of impacts associated with Norfolk Boreas. The fish species present at Norfolk Boreas that could potentially be affected during construction will determined by site specific surveys and a number of existing data sources. The potential impacts on known prey species for each marine mammal receptor will be assessed based on the results of the Fish and Shellfish Ecology impact assessment, including underwater noise modelling (see Appendix 1, based on the appropriate realistic worst-case scenarios for these receptors. The assessment will consider the

known dependence of each marine mammal species to those prey species and the potential impact on energy demands should prey species be displaced. An expert judgement will be made regarding the potential impact.

193. The underwater noise modelling for piling will provide the maximum range and area of the potential impacts for each prey species group. The maximum predicted impacts areas for fish, based on the worst-case scenario, will be used to estimate the potential number of marine mammals that could be present in the fish impact areas, based on the marine mammal species density estimates (see **Section 3.4** and **Table 3.5**).

194. The number of individuals of each marine mammal species that could be impacted will be considered as a proportion of the reference population (see **Section 3.5** and **Table 3.4**).

195. The duration of piling will be based on the worst-case scenario for the maximum time required to install an individual pile and the maximum number of piles that could be installed, taking into account the possible phasing options and scenarios.

196. Magnitudes and sensitivities will be based on the best available evidence and defined as outlined in **Section 4.1**.

197. Assessments will be made on the basis of embedded mitigation and proposed mitigation (see **Section 5.4**).

5.1.9 Impact 9: Changes to Water Quality

198. Accidental release of contaminants, increased suspended sediment, or mobilisation of sediment contaminants if contained in those sediments could have potential to impact on marine mammals directly or indirectly through effects on prey. Therefore this impact was scoped into the EIA in the Scoping Report (Royal HaskoningDHV, 2017b).

199. The risk of accidental release of contaminants (e.g. through spillage) will be mitigated through appropriate contingency planning and remediation measures for the control of pollution.

200. Disturbance of seabed sediments during construction has the potential to release any sediment-bound contaminants, such as heavy metals and hydrocarbons that may be present within them into the water column.

201. Since the Scoping Report (Royal HaskoningDHV, 2017b was published data collected from the site specific surveys has shown that levels of contaminants within the Norfolk Boreas site and offshore cable corridor are low. Sediment sampling at the

Norfolk Boreas site (see the Marine Sediment and Water Quality Method Statement) and the offshore cable corridor (Norfolk Vanguard site specific surveys in 2016) found that out of 17 samples taken across the site and cable corridor arsenic was found to exceed Cefas Action Level 1 but was below Action level 2 at three locations. This was attributed to natural causes. No other contaminants were found at levels that exceeded Action level 1. Therefore, it is proposed the assessment impacts on marine mammals through changes in water quality be scoped out of the EIA.

5.2 Potential Impacts during Operation and Maintenance

202. Once commissioned, the wind farm would operate for up to 25 years. All offshore infrastructure including wind turbines, foundations, cables and offshore substations would be monitored and maintained during this period in order to maximise efficiency.

5.2.1 Impact 1: Underwater Noise from Operational Turbines

203. Noise levels generated by operational wind turbines are much lower than those generated during construction activities. Operational turbine noise mainly originates from the gearbox and the generator and has tonal characteristics (Madsen *et al.* 2006; Tougaard *et al.* 2009b). The main contribution to the underwater noise emitted from the wind turbines is expected to be from acoustic transfer of the vibrations of the substructure into the water rather than from transmission of in-air noise from the wind turbines into the water column (Lidell, 2003).

204. Lidell (2003) concluded that noise levels of the operating wind farm would be too low to cause injury to marine mammals. Touggard *et al*. (2009b) indicated that sound masking from operational noise is unlikely to impact harbour porpoise and seal acoustic communication, due to the low frequencies and low levels produced.

205. The MMO (2014) review found that available data on the operational turbine noise, from the UK and abroad, in general showed that noise levels radiated from operational wind turbines are low and the spatial extent of the potential impact of the operational wind turbine noise on marine receptors is generally estimated to be small, with behavioural response only likely at ranges close to the turbine.

206. The low-level noise generated during operation is likely to be detected by marine mammals only at short distances over background noise levels and below levels which would elicit a response (Madsen et al., 2006; Thomsen *et al*., 2006). The overall effect of the operational noise and the ability of marine mammals to perceive this noise will be largely dependent on ambient noise levels and wind speed.

207. There is no indication of any disturbance or exclusion of small cetaceans or seals around wind farm sites during operation (Tougaard *et al*., 2005; Scheidat *et al*.,

2011). Data collected suggests that behavioural responses for harbour porpoise and seal may only occur up to a few hundred metres away (Touggard *et al*., 2009a; McConnell *et al*., 2012). Tagged harbour seals have been recorded within operational wind farm sites and the movements of several of the seals suggest foraging behaviour around wind turbine structures (Russell *et al*., 2014).

208. Therefore, it is proposed that disturbance from the underwater noise of operational turbines at Norfolk Boreas will be based on the latest evidence and guidance, and agreed as part of the EPP.

5.2.2 Impact 2: Underwater Noise from Maintenance Activities

209. The requirements for any potential maintenance work, such as additional rock dumping or cable re-burial, are currently unknown, however the work required and associated impacts would be less than those during construction.

210. As outlined in **Section 5.1.3**, the potential for TTS is only likely in very close proximity to activities such as cable laying, and noise generated would not be sufficient to cause PTS or other injury to marine mammals. Disturbance is the only potential noise impact from maintenance activities.

211. The impacts from additional cable laying and protection would be temporary in nature, and would be limited to relatively short-periods during the operational and maintenance phase. Disturbance responses are likely to occur at significantly shorter ranges than construction noise. Any disturbance is likely to be limited to the area in and around where the actual activity is actually taking place.

5.2.2.1 Approach to Assessment

212. As a precautionary approach, the same assessment methodology as outlined in **Section 5.1.3.1** will be undertaken.

5.2.3 Impact 3: Underwater Noise and Disturbance from Vessels

213. The requirements for any potential maintenance work are currently unknown (indicative numbers are presented in **Section 2.1.7**), however the work required and impacts associated with underwater noise and disturbance from vessels during operation and maintenance would be less than those during construction.

214. As outlined in **Section 5.1.4**, the potential for TTS is only likely in very close proximity to vessels, and noise generated should not be sufficient to cause PTS or other injury to marine mammals. Disturbance is the only potential noise impact from vessels.

215. The potential impacts as a result of underwater noise and disturbance from additional vessels during operation and maintenance from vessels would be short-

term and temporary in nature. Disturbance responses are likely to be limited to the area in the immediate vicinity of the vessel. Marine mammals would be expected to return to the area once the disturbance had ceased or they had become habituated to the sound.

5.2.3.1 Approach to Assessment

216. As a precautionary approach, the same assessment methodology as outlined in **Section 5.1.4.1** will be undertaken.

5.2.4 Impact 4: Vessel Collision Risk

217. The operation and maintenance ports to be used for Norfolk Boreas are not yet known and could be located on the south east coast of England. Vessel movements to and from any port will be incorporated within existing vessel routes and therefore the increased risk for any vessel interaction is within the wind farm site and cable route. Indicative operational and maintenance vessel movements are provided in **Section 2.1.7**. The number of vessels required during operation and maintenance would be less than those during construction

5.2.4.1 Approach to Assessment

218. As a precautionary approach, the same assessment methodology as outlined in **Section 5.1.6.1** will be undertaken.

5.2.5 Impact 5: Disturbance at Seal Haul-Out Sites

219. Increased activity near seal haul-out sites as a result of transiting vessels could have the potential to disturb seals.

220. As outlined in **Section 5.1.7**, there no potential for any direct disturbance as a result of activities within the Norfolk Boreas offshore wind farm site or cable corridor route, due to the distance to the nearest known seal haul-out sites.

221. The operation and maintenance ports to be used for Norfolk Boreas are not yet known and could be located on the south east coast of England. Vessel movements to and from any port will be incorporated within existing vessel routes. Taking into account the proximity of shipping channels to and from existing ports, it is likely that seals hauled-out along these routes and in the area of the ports would be habituated to the noise, movements and presence of vessels.

5.2.5.1 Approach to Assessment

222. The same assessment methodology as outlined in **Section 5.1.7.1.1** will be undertaken.

5.2.6 Impact 6: Entanglement in Floating Foundations

223. To date, there have been no recorded instances of marine mammal entanglement from mooring systems of renewable devices (Sparling *et al*., 2013; Isaacman and Daborn, 2011), or for anchored floating production, storage and offloading (FPSO) vessels in the oil and gas industry (Bejamins *et al*., 2014) with similar mooring lines as proposed for floating turbine structures.

224. The proposed floating turbines for Norfolk Boreas, if used, would to be Tension Leg Floating Platforms.

5.2.6.1 Approach to Assessment

225. The assessment will take into account the risk to each marine mammal species and the worst-case parameters for the types of mooring lines that could be used.

226. An expert judgement will be made regarding the potential impact and the risks discussed as part of the EPP.

5.2.7 Impact 7: Changes to Prey Resources

227. Potential impacts on fish species during operation and maintenance can result from permanent loss of habitat; introduction of hard substrate; operational noise; and electromagnetic fields (EMF).

228. Potential impacts on marine mammal prey species will be assessed in the Fish and Shellfish Ecology Chapter using the appropriate realistic worst case scenario for these receptors. The Fish and Shellfish Ecology Method Statement outlines the proposed approach to the assessment of impacts associated with the operation and maintenance of Norfolk Boreas.

5.2.7.1.1 Approach to Assessment

229. The proposed approach for the assessment of changes to prey resources during operation and maintenance will be the same as for construction (as outlined in **Section 5.1.8**).

5.2.8 Impact 8: Changes to Water Quality

230. Potential changes in marine physical processes in the area caused by the deployment of the wind farm may alter suspended sediment concentrations and deposition. In addition, small volumes of sediment could be re-suspended during maintenance activities as a result of the physical disturbance.

5.2.8.1.1 Approach to assessment

231. An expert judgement will be made using the findings of the Marine Water and Sediment Quality impact assessment to determine if there is the potential to impact marine mammals directly or indirectly via effects on prey. The Marine Water and Sediment Quality Method Statement outlines the proposed approach to the assessment of impacts associated with Norfolk Boreas during O&M.

5.3 Potential Impacts during Decommissioning

232. Potential impacts on marine mammals associated with the decommissioning stage(s) will be assessed, based on the potential impacts associated with construction; however a further assessment will be carried out ahead of any decommissioning works to be undertaken taking account of known information at that time, including all relevant guidelines and requirements.

233. The potential impacts during decommissioning of Norfolk Boreas that will be assessed for marine mammals are:

- Physical injury, auditory injury and behavioural impacts resulting from the noise associated with foundation removal (e.g. cutting);
- Barrier effects as a result of underwater noise;
- Impacts resulting from the deployment of vessels:
    - Underwater noise and disturbance from vessels;
    - Vessel interaction (collision risk);
    - Disturbance at seal haul-out sites;
- Changes to prey resource; and
- Changes to water quality.

5.3.1 Approach to Assessment

234. The proposed approach for the assessment of potential impacts during decommissioning will follow the same proposed methodology outlined for similar activities during construction (as outlined in **Section 5.1**).

5.4 Mitigation

5.4.1 Embedded Mitigation

235. Embedded mitigation (i.e. those measures that will be incorporated into the design of the development to prevent or reduce any significant adverse effects) will include, but may not be limited to:

- Soft start and ramp up of piling activity to minimise potential risks of physical and auditory injury.

- Mitigation zone to ensure marine mammals are outside the range of PTS.
- A Vessel Management Plan (VMP) and Construction Environmental Management Plan (CEMP) will also be produced outlining mitigation measures in relation to collision risk and water quality impacts.

236. In addition to embedded mitigation, if further mitigation is required and possible, (i.e. those measures to prevent or reduce any remaining significant adverse effects) these will be reviewed in the relevant impact sections of the PEIR and ES.

5.4.2 Marine Mammal Mitigation Plan

237. A detailed Marine Mammal Mitigation Plan (MMMP) will be prepared for any UXO clearance. The MMMP for UXO clearance works will ensure there are embedded mitigation measures, as well as any additional mitigation, if required, to prevent the risk of any physical or permanent auditory injury to marine mammals. The MMMP for UXO clearance will be developed in the pre-construction period, when there is more detailed information on what UXO clearance could be required and what the most suitable mitigation measures are, based upon best available information and methodologies at that time, in consultation with the relevant authorities.

238. A detailed MMMP will also be prepared for piling. The MMMP will detail the proposed mitigation measures to reduce the risk of any physical or permanent auditory injury to marine mammals during all piling operations. This will include details of the embedded mitigation, for the soft-start, ramp-up and mitigation zone, as well as details of any additional mitigation that could be required. The MMMP for piling will be developed in the pre-construction period and will be based upon best available information and methodologies at that time.

239. The MMMPs will be produced in consultation as part of the Norfolk Boreas EPP.

5.5 Potential Cumulative Impacts

240. The potential for projects to act cumulatively on marine mammals will be considered in the context of the likely spatial and temporal extent of impacts. Each potential impact described for the construction and O&M phases of Norfolk Boreas will be considered in the Cumulative Impact Assessment (CIA).

241. In addition to Norfolk Boreas, Vattenfall is also developing the Norfolk Vanguard offshore wind farm to the south and west of the Norfolk Boreas site, with the EIA approximately a year ahead of the Norfolk Boreas EIA. The full implications of the Norfolk Boreas and Norfolk Vanguard cumulative impact scenarios, as well as cumulative impacts with respect to other existing and planned projects, will be considered as part of the EIA process.

242. The CIA will include any projects with any potential impacts occurring from the end of the project baseline, as detailed in the ES chapter, until the end of the project. The types of plans or projects to be taken into consideration include:

- Other wind farms;
- Aggregate extraction and dredging;
- Licensed disposal sites;
- Navigation and shipping;
- Planned construction sub-sea cables and pipelines;
- Potential port/harbour development; and
- Oil and gas operations.

5.5.1 Approach to Assessment

243. The CIA will review the impact assessments for other projects where this is publicly available and will make assumptions regarding Norfolk Boreas based on VWPL's plans for this project to determine the magnitude of the cumulative impact along with Norfolk Vanguard. Where quantitative assessments are available, the total number of marine mammals potentially affected will be considered in the context of the reference populations.

244. Each potential impact described for the construction and O&M phases of Norfolk Boreas will be considered in the CIA.

245. There will be an inherent level of uncertainty associated with assessments of cumulative impacts on this basis. It is important that stakeholders understand that significant cumulative impacts may be the result of an overly precautionary worst case (precaution built on precaution) and that this will be highlighted within documents and discussions. Taking the worst-case for all aspects can result in an unrealistic scenario being assessed. Therefore, the assessment will be based on the most realistic worst-case scenario. To help reduce any uncertainty and unrealistic worst-case scenarios, carefully consideration and discussion with the stakeholders will be undertaken to agree the best options for the cumulative impact assessments that are or may become available in time for the ES application. The aim would be to strive for a more evidence based and realistic assessment of the cumulative population impacts, in particular for the disturbance of harbour porpoise caused by piling noise.

246. Screening of specific plans and projects will be follow a stepwise process defined below as:

a) Definition of a study area based on receptor ecology and/or footprint of impact (temporal and spatial).

i. Spatial boundaries will take account both of the relevant spatial scales for individual receptors (foraging distances, migratory routes) and the spatial extent of environmental changes introduced by developments. These spatial boundaries will be analogous to the extent of the reference populations considered in the impact assessment.

ii. Temporal boundaries will take account of the project life cycle and the receptor life cycles and recovery times.

b) Establish a source-pathway-receptor rationale. Projects will be screened out where no pathway exists, with clear justification will be provided. This screening process will be species specific.

247. These steps will lead to an initial list of potential projects which could have a cumulative impact with Norfolk Boreas. The next stage of screening considers the plans or projects where sufficient information exists to undertake an assessment.

248. The CIA will consider projects, plans and activities which have sufficient information available in order to undertake the assessment. Insufficient information will preclude a meaningful quantitative assessment, and it is not appropriate to make assumptions about the detail of future projects in such circumstances. The focus of the assessment will therefore be on those projects or activities where sufficient relevant information exists. Whilst other projects may be acknowledged within the assessment, in the case of inadequate information it is up to the regulator to judge how to take these into account. The screening process will follow a tiered approach analogous to that outlined by Joint Nature Conservation Committee (JNCC) and Natural England (undated) in the document 'Suggested Tiers for Cumulative Impact Assessment', as outlined in **Table 5.1**.

Table 5.1: Suggested tiers for undertaking a staged cumulative impact assessment (JNCC and Natural England)

Tier Description	Consenting or Construction Phase	Data Availability
Tier 1	Built and operational projects should be included within the cumulative assessment where they have not been included within the environmental characterisation survey, i.e. they were not operational when baseline surveys were undertaken, and/or any residual impact may not have yet fed through to and been captured in estimates of "baseline" conditions e.g. "background" distribution or mortality rate for birds.	Pre-construction (and possibly post-construction) survey data from the built project(s) and environmental characterisation survey data from proposed project (including data analysis and interpretation within the ES for the project).
Tier 2	Tier 1 + projects under construction.	As Tier 1 but not including post-construction survey data.

Tier Description	Consenting or Construction Phase	Data Availability
Tier 3	Tier 2 + projects that have been consented (but construction has not yet commenced).	Environmental characterisation survey data from proposed project (including data analysis and interpretation within the ES for the project) and possibly pre-construction.
Tier 4	Tier 3 + projects that have an application submitted to the appropriate regulatory body that have not yet been determined.	Environmental characterisation survey data from proposed project (including data analysis and interpretation within the ES for the project).
Tier 5	Tier 4 + projects that the regulatory body are expecting an application to be submitted for determination (e.g. projects listed under the Planning Inspectorate programme of projects).	Possibly environmental characterisation survey data (but strong likelihood that this data will not be publicly available at this stage).
Tier 6	Tier 5 + projects that have been identified in relevant strategic plans or programmes (e.g. projects identified in Round 3 wind farm zone appraisal and planning (ZAP) documents).	Historic survey data collected for other purposes/by other projects or industries or at a strategic level.

249. Each plan or project will be assigned a tier level. The CIA will include all projects classed as tier 1, 2, 3 and 4 in the assessment as a realistic scenario. Consideration will be given to a further assessment including tier 5 and projects, where there is more uncertainty. CIA screening will be undertaken in consultation, as part of the EPP.

250. Following submission of the PEIR, reviews will be undertaken to ensure that any new information is incorporated into the CIA. Once issues, plans or projects have been scoped out and agreed there must be a strong justification for scoping them back in again, and this will be agreed as part of the EPP.

251. Given the fast moving nature of offshore development, it is likely that new projects relevant to the assessment will arise throughout the pre-application period. In order to finalise an assessment, it will be necessary to have a cut-off period after which no more projects will be included. A reasonable cut-off point would be the date of receipt of comments upon the PEIR.

5.6 Potential Transboundary Impacts

252. The highly mobile nature of marine mammal species means that there are potential transboundary impacts.

253. For harbour porpoise the extent of the reference population (**Section 3.5**) includes UK, Dutch, German, French, Belgian, Danish and Swedish waters. For harbour seal

the extent of the reference population includes UK, Dutch, German, Belgian and French waters. For grey seal the extent of the reference population includes UK, Dutch, German, Belgian, Danish and French waters. As a result the potential transboundary impacts are embedded within the assessment of impacts on the reference populations.

6 INFORMATION FOR HABITATS REGULATION ASSESSMENT

254. The Habitats Regulation Assessment (HRA) screening will determine the sites for which there are potential effect pathways from Norfolk Boreas. The HRA will then consider the effects covered by the EIA in terms of designated sites.

6.1 HRA Screening

255. HRA Screening will be undertaken on the basis of the connectivity between Norfolk Boreas and Natura 2000 sites which have harbour porpoise, grey seal or harbour seal as a designated conservation feature compared with the predicted effect ranges of the proposed development.

256. An initial list of designated sites will be considered during the Screening and the outputs will be discussed with stakeholders through the EPP to determine which sites require further assessment.

257. The entire Norfolk Boreas site is located within the Southern North Sea cSAC, therefore this designated site will be screened in and information to support HRA for this designated site provided with the DCO application.

258. The key information that will be identified within the Information to Support HRA report in relation to the cSAC is outlined below. The Information to Support HRA will also consider other sites as appropriate, once more information is known about the potential effect ranges of Norfolk Boreas to allow the HRA screening to be completed.

6.1.1 Harbour Porpoise Southern North Sea cSAC

259. The Southern North Sea (SNS) candidate Special Area of Conservation (cSAC) has been recognised as an area with persistent high densities of harbour porpoise (JNCC, 2017a). The SNS cSAC has a surface area of 36,951km^2 and covers both winter and summer habitats of importance to harbour porpoise, with approximately 66% of the candidate site being important in the summer and the remaining 33% of the site being important in the winter period (JNCC, 2017a).

260. The total Southern North Sea cSAC area is 36,951km^2 (JNCC, 2017a). The northern 'summer' area is approximately 27,088km^2 and covers the period from April to September (183 days). The southern 'winter' area is approximately 13,366km^2 and covers the period from October to March (182 days) (Heinänen and Skov, 2015).

261. Norfolk Boreas is located within the summer area of the SNS cSAC. The potential effects of Norfolk Boreas will therefore be assessed in relation to the summer area of the SNS cSAC.

6.1.1.1 Conservation Objectives

262. The HRA will consider the draft Conservation Objectives of the Southern North Sea cSAC subject to any revisions which will be discussed through the marine mammal expert topic group and EPP for Norfolk Boreas.

263. The draft Conservation Objectives for the SNS cSAC are designed to ensure that the obligations of the Habitats Directive can be met. Article 6(2) of the Directive requires that there should be no deterioration or significant disturbance of the qualifying species or to the habitats upon which they rely.

264. The draft Conservation Objectives for the site are (JNCC and NE, 2016):

To avoid deterioration of the habitats of the harbour porpoise or significant disturbance to the harbour porpoise, thus ensuring that the integrity of the site is maintained and the site makes an appropriate contribution to maintaining FCS for the UK harbour porpoise.

To ensure for harbour porpoise that, subject to natural change, the following attributes are maintained or restored in the long term:

1. *The species is a viable component of the site;*
2. *There is no significant disturbance of the species; and*
3. *The supporting habitats and processes relevant to harbour porpoises and their prey are maintained.*

265. These draft Conservation Objectives 'are based on considerations of the ecological requirements of the species within the site, yet their interpretation is contextualised in their contribution to maintaining FCS at a wider scale. With regard the SNS site, harbour porpoise need to be maintained rather than restored' (JNCC and NE, 2016).

6.1.1.2 Potential Effects

266. **Table 6.1** outlines the potential effects associated with Norfolk Boreas in relation to the current draft Conservation Objectives of the SNS cSAC for harbour porpoise

Table 6.1: Potential effects in relation to the draft Conservation Objectives for the Southern North Sea cSAC

Draft Conservation Objective	Potential effect
The species is a viable component of the site	Lethal effects and auditory injury from underwater noise during installation and operation
	Disturbance and displacement as a result of increased underwater noise levels during construction
	Increased collision risk with vessels during installation and operation

Draft Conservation Objective	Potential effect
There is no significant disturbance of the species	Disturbance and displacement as a result of increased underwater noise levels during construction
The supporting habitats and processes relevant to harbour porpoises and their prey are maintained	Changes in prey availability
	Re-suspension of sediment during installation
	Accidental release of contaminants

6.1.1.3 Approach to Assessment

267. The approach to the HRA will be discussed through ongoing meetings of the Norfolk Boreas marine mammal expert topic group as part of the EPP, as well as wider industry workshops. Given the ongoing development of the cSAC, it is likely that new information and guidance will become available during the course of the Norfolk Boreas EIA.

268. The SNCB's current advice on the assessment of effects on the SNS harbour porpoise cSAC (NE advice to Norfolk Vanguard dated June 2017) is that:

- A distance of 26km from an individual percussive piling location should be used to assess the area of cSAC habitat harbour porpoise may be disturbed from during piling operations (noting previous references during workshops to the potential for a reduction in this measure, where project specifics allow).
- Displacement of harbour porpoise should not exceed 20% of the seasonal component of the cSAC at any one time and or on average exceed 10% of the seasonal component of the cSAC over the duration of that season.
- The effect of the project should be considered in the context of the seasonal components of the cSAC, rather than the cSAC as a whole.
- A buffer of 10km around seismic operations and 26km around UXO detonations should be used to assess the area of cSAC habitat harbour porpoise may be disturbed.

269. Natural England also advised that the planned approach to in-combination assessment for Norfolk Vanguard should consider the following:

- Inclusion of seismic surveys within 10km of the cSAC;
- Inclusion of projects undertaking percussive piling within 26km from the cSAC boundary (or relevant seasonal component); and
- Inclusion of UXO detonation within 26km of the cSAC.

270. It is proposed that this latest advice from Natural England to Norfolk Vanguard is also used for the Norfolk Boreas assessments in the PEIR/ES and incorporated in the HRA. However, guidance on managing noise disturbance within the cSAC is currently under review and subject to change. Therefore, if any further data and information becomes available throughout the EIA process this will be discussed as part of the Norfolk Boreas EPP.

271. In order to finalise the information to include within the DCO application, it will be necessary to have a cut-off period after any further developments will be considered during the examination phase. A reasonable cut-off point would be the date of receipt of comments upon the PEIR.

North Sea MU reference population

272. The potential effects on the cSAC associated with Norfolk Boreas, as well as in-combination effects with other projects, will be assessed on the basis of the North Sea MU reference population for harbour porpoise (see **Section 3.5.1** and **Table 3.4**). This is in line with JNCC and Natural England (2016) draft Conservation Objectives and Advice on Activities, which states that the key concern with regards to the cSAC is how the potential effects within the site translate into effects on the harbour porpoise population, especially with regard to underwater noise.

6.1.2 Grey Seal Designated Sites

273. The Humber is the second-largest coastal plain estuary in the UK, and the largest coastal plain estuary on the east coast of Britain. Grey seal (Annex II species) are present as a qualifying feature, but not a primary reason for site selection (JNCC, 2017b). The Humber Estuary SAC is located 112km from the Norfolk Boreas offshore cable corridor (at closest point).

274. Grey seal are not currently a qualifying feature at the North Norfolk SAC (which includes Blakeney Point) or Winterton-Horsey Dunes SAC, however, it is recognised that these sites are important for the population, as breeding, moulting and haul-out sites.

275. The landfall for the Norfolk Boreas offshore export cables will be at Happisburgh South, approximately 11km from the Horsey seal haul-out site to the south and 43km from the Blakeney Point haul-out site to the north.

276. Therefore, as agreed for Norfolk Vanguard, consideration will be given to grey seal as part of the North Norfolk SAC or Horsey-Winterton SAC in the HRA, to determine if there is the potential for any disturbance of seals from these sites.

277. The Humber Estuary SAC, the Wash and North Norfolk SAC and Winterton-Horsey Dunes SAC are all located in the South-East England MU. It is assumed that grey seal from these sites are part of this MU. The latest grey seal counts from the south-east England MU in August 2015 was 5,637 (SCOS, 2016).

6.1.3 Harbour Seal Designated Sites

278. The Wash, on the east coast of England, is the largest embayment in the UK. The extensive intertidal flats here and on the North Norfolk Coast provide ideal conditions for harbour seal breeding and hauling-out. Harbour seal (Annex II species) are a primary reason for selection of this site (JNCC, 2017c).

279. The Wash and North Norfolk Coast SAC is located approximately 33km from the Norfolk Boreas offshore cable corridor.

280. Consideration will be given to harbour seal as part of the North Norfolk SAC in the HRA, to determine if there is the potential for any disturbance of seals from this site.

281. The reference population for harbour seal that encompasses the Wash and North Norfolk Coast SAC is the south-east England MU. The harbour seal count based on surveys from 2008 to 2015 for this area was 4,740 (SCOS, 2016).

7 REFERENCES

Bailey, H., Senior, B., Simmons, D., Rusin, J., Picken, G. and Thompson, P.M. (2010). Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. Marine Pollution Bulletin 60 (2010) 888–897.

Benjamins, S., Harnois, V., Smith, H.C.M., Johanning, L., Greenhill, L., Carter, C. and Wilson, B. (2014). Understanding the potential for marine megafauna entanglement risk from renewable marine energy developments. Scottish Natural Heritage Commissioned Report No. 791.

Caltrans (2001). Pile installation demonstration project, San Francisco – Oakland Bridge, East Span Safety Project. PIPD EA 01281, Caltrans contract 04A0148, August 2001.

CEDA (Central Dredging Association) (2011). Underwater sound in relation to dredging. Position Paper - 7 November 2011. Available URL: http://www.dredging.org/documents/ceda/downloads/2011-11_ceda_positionpaper_underwatersound.pdf

DECC (now Department for Business, Energy and Industrial Strategy) (2016), UK Offshore Energy Strategic Environmental Assessment 3 (OESEA3)

EC (2007). Guidance document on the strict protection of animal species of community interest under the Habitats Directive 92/43/EEC.

Evans, P. G., Baines, M.E., and Anderwald. P. (2011). Risk Assessment of Potential Conflicts between Shipping and Cetaceans in the ASCOBANS Region. 18th ASCOBANS Advisory Committee Meeting AC18/Doc.6-04 (S) rev.1 UN Campus, Bonn, Germany, 4-6 May 2011 Dist. 2 May 2011.

Fontaine, M.C., Baird, S.J.E., Piry, S., Ray, N. *et al*. (2007). Rise of oceanographic barriers in continuous populations of a cetacean: the genetic structure of harbour porpoises in Old World waters. BMC Biology 5: 30

Fontaine, M.C., Roland, K., Calves, I., Austerlitz, F., Palstra, F.P., Tolley, K.A., Ryan, S., Ferreira, M., Jauniaux, T., Llavona, A. and Öztürk, B. (2014). Postglacial climate changes and rise of three ecotypes of harbour porpoises, *Phocoena phocoena*, in western Palearctic waters. Molecular ecology, 23(13), pp.3306-3321.

Gilles, A., Peschko, V., Scheidat, M. and Siebert, U. (2012). Survey for small cetaceans over the Dogger Bank and adjacent areas in summer 2011. Document submitted by Germany to 19th ASCOBANS Advisory Committee Meeting in Galway, Ireland, 20-22 March 2012. AC19/Doc.5-08(P). 16pp.

Gilles, A., Viquerat, S., Becker, E. A., Forney, K. A., Geelhoed, S. C. V., Haelters, J., Nabe-Nielsen, J., Scheidat, M., Siebert, U., Sveegaard, S., van Beest, F. M., van Bemmelen, R.and Aarts, G. (2016). Seasonal habitat-based density models for a marine top predator, the harbor porpoise, in a dynamic environment. Ecosphere 7(6):e01367. 10.1002/ecs2.1367

Hammond, P. S., Benke, H., Borchers, D.L., Buckand, S.T., Collet, A., Heide-Jørgensen, M-P., Heimlich-Boran, S., Hiby, A.R., Leopold, M. F., and Øien, N. (2002). Distribution and abundance of the harbour porpoise and other small cetaceans in the North Sea and

Adjacent Waters. Journal of Applied Ecology, 39(2); 361-376.

Hammond, P.S., Macleod, K., Berggren, P., Borchers, D.L., Burt, L., Cañadas, A., Desportes, G., Donovan, G.P., Gilles, A., Gillespie, D., Gordon, J., Hiby, L., Kuklik, I., Leaper, R., Lehnert, K, Leopold, M., Lovell, P., Øien, N., Paxton, C.G.M., Ridoux, V., Rogan, E., Samarra, F., Scheidatg, M., Sequeirap, M., Siebertg, U., Skovq, H., Swift, R., Tasker, M.L., Teilmann, J., Canneyt, O.V. and Vázquez, J.A. (2013). Cetacean abundance and distribution in European Atlantic shelf waters to inform conservation and management. Biological Conservation 164, 107-122.

Hammond, P.S., Lacey, C., Gilles, A., Viquerat, S., Boerjesson, P., Herr, H., Macleod, K., Ridoux, V., Santos, M., Scheidat, M. and Teilmann, J. (2017). Estimates of cetacean abundance in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys. Wageningen Marine Research.

Heinänen, S. and Skov, H. (2015). The identification of discrete and persistent areas of relatively high harbour porpoise density in the wider UK marine area, JNCC Report No.544 JNCC, Peterborough.

IAMMWG (2013). Management Units for marine mammals in UK waters (June 2013).

IAMMWG (2015). Management Units for cetaceans in UK waters (January 2015). JNCC Report No. 547, JNCC Peterborough.

Isaacman, L. and Daborn, G. (2011). Pathways of Effects for Offshore Renewable Energy in Canada. Report to Fisheries and Oceans Canada. Acadia Centre for Estuarine Research (ACER) Publication No. 102, Acadia University, Wolfville, NS, Canada. 70 pp.

Jensen, F.B., Kuperman, W.A., Porter, M.B. and Schmidt, H. (2011). Computational Ocean Acoustics. Modern Acoustics and Signal Processing. Springer-Verlag, New York. ISBN: 978-1-4419-8678-8.

JNCC (2013). Individual Species Reports – 3rd UK Habitats Directive Reporting 2013. Available at: <http://jncc.defra.gov.uk/page-6391>

JNCC (2017a) SAC Selection Assessment: Southern North Sea. January, 2017. Joint Nature Conservation Committee, UK. Available from: http://jncc.defra.gov.uk/page-7243

JNCC (2017b) JNCC website: http://jncc.defra.gov.uk/ProtectedSites/SACselection/sac.asp?EUcode=UK0030170

JNCC (2017c) JNCC website: http://jncc.defra.gov.uk/ProtectedSites/SACselection/sac.asp?EUcode=UK0017075

JNCC and Natural England (2016). Harbour Porpoise (*Phocoena phocoena*) possible Special Area of Conservation: Southern North Sea Draft Conservation Objectives and Advice on Activities. Advice under Regulation 18 of The Offshore Marine Conservation (Natural Habitats, etc.) Regulations 2007 (as amended), and Regulation 35(3) of The Conservation of Habitats.

JNCC and Natural England (undated). JNCC and Natural England Suggested Tiers for Cumulative Impact Assessment, East Anglia THREE Document Reference – Deadline 5/ Second Written Questions/ JNCC and NE suggested tiers for CIA/ HRA12. Available at: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010056/EN010056-001638-EA3%20-%20JNCC%20and%20NE%20suggested%20tiers%20for%20CIA.pdf

JNCC, Natural England and CCW (2010). Draft EPS Guidance - The protection of marine European Protected Species from injury and disturbance. Guidance for the marine area in England and Wales and the UK offshore marine area. Joint Nature Conservation Committee, Natural England and Countryside Council for Wales. October 2010.

Jones, E.L., Morris, C.D., Smout, S. and McConnell, B.J. (2016). Population scaling in 5 km x 5 km grey and harbour seal usage maps. Note commissioned by Marine Scotland under contract MMSS/002/15.

Koski, W.R., Thomas, T.A., Funk, D.W. and Macrander, A.M. (2013). Marine mammals sightings by analysts of digital imagery versus aerial surveyors: a preliminary comparison. Journal of Unmanned Vehicle Systems 1: 25-40.

Lidell, H. (2003). Utgrunden off-shore wind farm: Measurements of underwater noise. Technical report prepared for Airicole, GE Wind Energy and SEAS/Energi/E2 by Ingemansson Technology AB, Goteborg, Sweden.

Lowry, M.S. (1999). Counts of California sea lion (*Zalophus californianus*) pups from aerial color photographs and from the ground: a comparison of two methods. Marine Mammal Science 15(1): 143–158.

Lowry, L.F., Frost, K.J., Hoep, J.M. and Delong, R.A. (2001). Movements of satellite-tagged subadult and adult harbor seals in Prince William Sound, Alaska. Marine Mammal Science 17(4): 835−861.

Lucke, K., Siebert, U., Lepper, P. A. and Blanchet, M. A. (2009). Temporary shift in masked hearing thresholds in a harbor porpoise (*Phocoena phocoena*) after exposure to seismic airgun stimuli, J. Acoust. Soc. Am., 125 (6), pp. 4060-4070.

Madsen, P. T., Wahlberg, M., Tougaard, J., Lucke, K. and Tyack, P. (2006). Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. Mar Ecol Prog Ser, 309; 279-295.

Malme, C.I., Miles, P.R., Miller, G.W., Richardson, W.J., Roseneau, D.G., Thomson, D.H. and Greene, C.R. (1989). Analysis and ranking of the acoustic disturbance potential of petroleum industry activities and other sources of noise in the environment of marine mammals in Alaska. Final Report No. 6945 to the US Minerals Management Service, Anchorage, AK. BBN Systems and Technologies Corp. Available at: <http://www.mms.gov>.

MARINElife (2017). Marine mammal sightings from southern North Sea ferry routes: http://www.marine-life.org.uk/sightings

Marine Management Organisation (MMO) (2014). Review of post-consent offshore wind farm monitoring data associated with licence conditions. A report produced for the Marine Management Organisation, pp 194. MMO Project No: 1031. ISBN: 978-1-909452-24-4.

McConnell, B., Lonergan, M. and Dietz, R. (2012). Interactions between seals and offshore wind farms. The Crown Estate. ISBN: 978-1-906410-34-5.

Nedwell, J.R., Turnpenny, A.W.H., Lovell, J., Langworthy, J.W., Howell, D. M. and Edwards, B. (2003). The effects of underwater noise from coastal piling on salmon (*Salmo salar*) and brown trout (*Salmo trutta*). Subacoustech report to the Environment Agency, report ref: 576R0113, December 2003.

Nedwell, J.R, Parvin, S.J., Edwards, B., Workman, R., Brooker, A.G and Kynoch J.E. (2007). Measurement and interpretation of underwater noise during construction and operation of offshore windfarms in UK waters. Report for COWRIE by Subacoustech.

NMFS (National Marine Fisheries Service) (2016). Technical guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing: Underwater Acoustic Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-55, 178 p.

Norfolk and Norwich Naturalist Society (2017). Norfolk bird and mammal reports.

OSPAR (2009). Overview of the impacts of anthropogenic underwater sound in the marine environment. London: OSPAR Commission Biodiversity Series. Publication no. 441/2009. 133 pp.

Parvin, S.J., Nedwell, J.R. and Workman, R. (2006). Underwater noise impact modelling in support of the London Array, Greater Gabbard and Thanet offshore wind farm developments. Report to CORE Ltd by Subacoustech, report ref: 710R0517.

Paxton, C.G.M., Scott-Hayward, L., Mackenzie, M., Rexstad, E. and Thomas, L. (2016). Revised Phase III Data Analysis of Joint Cetacean Protocol Data Resources with Advisory Note, JNCC Report 517, ISSN 0963-8091: http://jncc.defra.gov.uk/page-7201.

Pirotta, E., Laesser, B. E., Hardaker, A., Riddoch, N., Marcoux, M., and Lusseau, D. (2013). Dredging displaces bottlenose dolphins from an urbanised foraging patch. Marine Pollution Bulletin, 74: 396–402.

Reid, J.B, Evans, P.G.H. and Northridge, S.P. (2003). Atlas of cetacean Distribution in North west European waters. JNCC, Peterborough.

Richardson, J., Greene, C.R., Malme, C.I. and Thomson, D.H. (1995). Marine Mammals and Noise. San Diego California: Academic Press.

Robinson, S.P., Lepper, P.A. and Hazelwood, R.A. (2014). Good practice guide for underwater noise measurement. National Measurement Office, Marine Scotland, The Crown Estate. NPL Good Practice Guide No. 133, ISSN: 1368-6550.

Rothney, E. (2016). Grey Seal breeding colony report winter season 2015-16. Friends of Horsey Seals.

Rothney, E. (2017). Horsey Grey Seal breeding colony report 2016-17. Friends of Horsey Seals.

Royal HaskoningDHV. (2017a). Norfolk Vanguard Offshore Wind Farm Preliminary Environmental Information Report.

Royal HaskoningDHV (2017b). Norfolk Boreas Offshore Wind Farm Environmental Impact Assessment Scoping Report. May 2017. Document Reference: PB5640-102-101.

Russell, D.J.F. and McConnell, B.J. (2014). Seal at-sea distribution, movements and behaviour. Report to DECC. URN: 14D/085. March 2014 (final revision).

Russell, D.J.F, Jones, E.L. and Morris, C.D. (2017) Updated Seal Usage Maps: The Estimated at-sea Distribution of Grey and Harbour Seals. Scottish Marine and Freshwater Science Vol 8 No 25, 25pp. DOI: 10.7489/2027-1

Scheidat, M., Tougaard, J., Brasseur, S., Carstensen, J., van Polanen Petel, T., Teilmann, J., and Reijnders, P. (2011). Harbour porpoise (*Phocoena phocoena*) and wind farms: a case study in the Dutch North Sea. Environ. Res. Lett. 6 (April-June 2011) 025102.

SCOS (2017). SCOS Report. Scientific Advice on Matters Related to the Management of Seal Populations: 2017. http://www.smru.st-andrews.ac.uk/files/2018/01/SCOS-2017.pdf

Sea Watch Foundation (2017). Reports of cetacean sightings eastern England: http://www.seawatchfoundation.org.uk/recentsightings/

Sharples R.J., Matthiopoulos, J. and Hammond, P.S. (2008). Distribution and movements of harbour seals around the coast of Britain: Outer Hebrides, Shetland, Orkney, the Moray Firth, St Andrews Bay, The Wash and the Thames Report to DTI July 2008.

Sharples, R.J., Moss, S.E., Patterson, T.A. and Hammond, P.S. (2012). Spatial Variation in Foraging Behaviour of a Marine Top Predator (*Phoca vitulina*) Determined by a Large-Scale Satellite Tagging Program. PLoS ONE 7(5): e37216.

Southall, B.L., Bowles, A.E., Ellison, W.T., Finneran, J.J., Gentry, R.L., Greene Jr., C.R., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A., and Tyack, P.L. (2007). Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. Aquatic Mammals, 33 (4), pp. 411-509.

Sparling, C.E., Coram, A.J., McConnell, B., Thompson, D., Hawkins, K.R. and Northridge S.P. (2013). Paper Three: Mammals. Wave & Tidal Consenting Position Paper Series.

Stewart, R.E.A., Born, E.W., Dunn, J.B., Koski, W.R. and Ryan, A.K. (2013). Use of multiple methods to estimate walrus (*Odobenus rosmarus rosmarus*) abundance in the Penny Strait-Lancaster Sound and West Jones Sound stocks, Canada. NAMMCO Sci. Publ. 9: Online Early, doi: 10.7557/3.2608.

Teilmann, J., Larsen, F. and Desportes, G. (2007). Time allocation and diving behaviour of harbour porpoises (*Phocoena phocoena*) in Danish and adjacent waters. Journal of Cetacean Research and Management 9(3): 201-210.

Teilmann, J., Christiansen, C.T., Kjellerup, S., Dietz, R. and Nachman, G. (2013). Geographic, seasonal and diurnal surface behaviour of harbour porpoise. Marine Mammal Science 29(2): E60-E76.

Theobald, P.D., Robinson, S.P., Lepper, P.A., Hayman, G., Humphrey, V.F., Wang, L. and Mumford, S.E. (2011). The measurement of underwater noise radiated by dredging vessels during aggregate extraction operations. 4th International Conference and Exhibition on Underwater Acoustic Measurements: Technologies & Results.

Thomsen, F., Lüdemann, K., Kafemann, R. and Piper, W. (2006). Effects of offshore windfarm noise on marine mammals and fish, on behalf of COWRIE Ltd.

Todd,V.L.G., Todd, I.B., Gardiner, J.C., Morrin, E.C.N., MacPherson, N.A., DiMarzio, N.A. and Thomsen, F. (2014). A review of impacts of marine dredging activities on marine mammals. – ICES Journal of Marine Science, doi: 10.1093/icesjms/fsu187.

Tolley, K.A. and Rosel, P.E. (2006). Population structure and historical demography of eastern North Atlantic harbour porpoises inferred through mtDNA sequences. Marine Ecology Progress Series, 327, pp.297-308.

Tougaard, J., Carstensen, J., Wisch, M.S., Teilmann, J., Bech, N., Skov, H. and Henriksen, O.D. (2005). Harbour porpoises on Horns reef—effects of the Horns Reef Wind farm. Annual Status Report 2004 to Elsam. NERI, Roskilde (Also available at: www.hornsrev.dk).

Tougaard, J., Carstensen, J. and Teilmann, J. (2009a). Pile driving zone of responsiveness extends beyond 20km for harbour porpoises (*Phocoena phocoena* (L.)) (L). J. Acoust. Soc. Am., 126, pp. 11-14.

Tougaard, J., Henriksen, O.D. and Miller. L.A. (2009b). Underwater noise from three types of offshore wind turbines: estimation of impact zones for harbour porpoise and harbour seals. Journal of the Acoustic Society of America 125(6): 3766.

TSEG (2017a). TSEG Grey Seal surveys in the Wadden Sea and Helgoland in 2016-2017.

TSEG (2017b). Aerial surveys of harbour seals in the Wadden Sea in 2017.

Voet H., Rehfisch M., McGovern S. and Sweeney S. (2017). Marine Mammal Correction Factor for Availability Bias in Aerial Digital Still surveys. Case Study: Harbour porpoise (Phocoena phocoena) in the Southern North Sea. APEM Ltd.

Wilson, B. Batty, R. S., Daunt, F. and Carter, C. (2007). Collision risks between marine renewable energy devices and mammals, fish and diving birds. Report to the Scottish Executive. Scottish Association for Marine Science, Oban, Scotland, PA37 1QA.

WODA (2013). Technical Guidance on: Underwater Sound in Relation to Dredging. World Organisation of Dredging Associations.

Würsig, B., Greene, C.R. and Jefferson, T.A. (2000). Development of an air bubble curtain to reduce underwater noise of percussive piling. Mar. Environ. Res. 49 pp. 79-93.

WWT (2009). Distributions of Cetaceans, Seals, Turtles, Sharks and Ocean Sunfish recorded from Aerial Surveys 2001-2008. The Wildfowl and Wetlands Trust.

APPENDIX 1 UNDERWATER NOISE MODELLING METHOD

282. Underwater noise propagation modelling will be undertaken as part of the EIA for Norfolk Boreas. The proposed approach and methodology for the underwater noise modelling will be based on the best available current research and guidelines and will be agreed as part of the marine mammal EPP for Norfolk Boreas.

Modelling Method

283. The methods used will meet the requirements set by the NPL Good Practice Guide 133 for underwater noise measurement (Robinson *et al*., 2014).

284. The modelling will consider a wide array of input parameters, including bathymetry, sediment data, sound speed and source frequency content to ensure as detailed results as possible. It should also be noted that the results presented in the assessment will be precautionary as the worst-case parameters will be selected for:

- Piling hammer energies;
- Ramp-up profiles;
- Receptor swim speeds; and
- Position of the receptor in the water column.

285. The modelling will take into account of the environmental parameters within the Norfolk Boreas site and the characteristics of the noise source.

Piling Locations

286. Underwater noise modelling will be undertaken at two worst-case locations within the Norfolk Boreas site. The location with the worst-case scenario for underwater noise propagation (i.e. greatest potential impact range) will then be used to assess the potential impacts on receptor groups. In order to provide a conservative assessment, the worst-case scenario impact range will be applied to any location within the Norfolk Boreas site.

287. Consideration will be given to seabed bathymetry and conditions when selecting the worst-case scenario piling locations.

Environmental Conditions

288. Accurate modelling of underwater noise propagation requires knowledge of the sea and seabed conditions. Data from the Marine Environment Mapping Programme (MAREMAP) and the British Geological Survey (BGS) will be used to determine the seabed type used for the modelling, which is expected to be made up predominantly

of sand. Norfolk Boreas site specific benthic survey undertaken in 2016. The geoacoustic properties for the sediment types will be taken from Jensen *et al*. (2011).

289. The speed of sound in water at Norfolk Boreas will be calculated using mean temperature and salinity data for the North Sea over the whole year. It is anticipated that the levels used in the model will vary from 1,489.1m/s at the surface to 1,490.7m/s in the deepest waters.

290. Mean tidal depth will be used throughout for the bathymetry, as the tidal state will fluctuate throughout installation of foundations. Using the mean depth is a reasonable assumption to cover the differences in the tide variation.

Noise Source Levels

291. Underwater noise modelling requires knowledge of the source level, which is the theoretical noise level at 1m from the noise source.

292. Noise source levels to use in the modelling will be determined based on factors such as the hammer energy and water depth of a piling operation, which have been shown to be the primary factors when comparing piling operations and the subsequent subsea noise levels produced.

293. As the model assumes that the noise source acts as a single point, the water depth at the noise source will be used to adjust the source level to allow for the length of pile in contact with the water.

294. The unweighted SPL_{peak} source levels used for the assessment will be provided in the PEIR and ES.

Hammer Energy, Soft-Start and ramp-up

295. The underwater noise modelling will be based on the following worst-case scenarios (as outlined in **Table A.0.1**) for monopiles and pin-piles:

- Monopile with maximum diameter of 15m, maximum hammer energy of 5,000kJ and maximum starting energy of 500kJ.
- Pin-pile with minimum diameter of 3m and maximum hammer energy of 2,700kJ and maximum starting hammer energy of 270kJ.

296. For cumulative SELs (SEL_{cum}), the soft-start and ramp-up of hammer energy along with total duration and strike rate of the piling will also be considered. It is anticipated that the ramp up takes place over the first hour of piling, starting at ten percent of maximum hammer energy, gradually increasing in hammer energy and

strike rate until reaching the maximum hammer energy where is stays for the maximum remaining five hours. As a worst-case scenario it has been assumed that the maximum piling operation would last for a total of six hours, allowing for issues such as pile refusal. The average piling duration is expected to be 3 hours.

Table A.0.1: Hammer energies, ramp-up and duration to be used for calculating cumulative SELs

	Starting hammer energy (10%)	Ramp-up	Maximum hammer energy (100%)
Monopile hammer energy	500kJ	Gradual increase	5,000kJ
Pin-pile hammer energy	270kJ	Gradual increase	2,700kJ
Strike rate	1 strike every 4 seconds	1 strike every 4 seconds	1 strike every 2 seconds
Duration	20 minutes	40 minutes	5 hours

297. The size of the pile being installed is used for estimating the frequency content of the noise. For this modelling, an average based on frequency data will be used to obtain representative third-octave levels for installing monopiles and pin piles. It is worth noting that the monopiles contain more low frequency content and the pin-piles contain more high frequency content, due to the dimensions and acoustics of the pile.

Thresholds and Criteria

298. The metrics and criteria that will be used to assess the potential impact of underwater noise on marine mammals will be based on, at the time of writing, the most up to date publications and recommended guidance.

PTS Thresholds and Criteria

299. In the assessment it is proposed that the potential impact ranges for PTS in harbour porpoise, grey seal and harbour seal will be based on the NOAA (NMFS, 2016) metrics and criteria.

Disturbance and Possible Behavioural Response Thresholds and Criteria

300. Southall *et al.* (2007) and NOAA (NMFS, 2016) do not provide thresholds and criteria to determine potential impact ranges for disturbance.

301. The SNCBs current advice is that a potential disturbance range of 26km (approximate area of 2,124km^2) around piling and UXO locations is used to assess the area that harbour porpoise may be disturbed in the Southern North Sea (SNS) cSAC. Norfolk Boreas is located within the SNS cSAC therefore it is proposed to use this approach in the EIA as well as the HRA.

302. TTS onset can be used to determine the onset of disturbance (Southall *et al*., 2007). It is proposed that the potential onset of disturbance in grey seal and harbour seal will be based on the NOAA (NMFS, 2016) metrics and criteria for TTS.

303. The threshold and criteria from Lucke *et al*. (2009) will be used to assess the potential impacts of behavioural response in harbour porpoise, based on a dose-response function.

304. The assessment will consider the following criteria to assess the potential effects of underwater noise on marine mammals:

NOAA (NMFS, 2016) Thresholds and Criteria

305. NOAA (NMFS, 2016) produced recent technical guidance for assessing the effects of underwater anthropogenic sound on the hearing of marine mammal species. This guidance identifies the received levels, or acoustic thresholds, at which individual marine mammals are predicted to experience changes in their hearing sensitivity (either temporary or permanent) for acute, incidental exposure to underwater anthropogenic sound sources.

306. NMFS (2016) present single strike, unweighted peak criteria (SPL_{peak}) and cumulative (i.e. more than a single sound impulse), weighted sound exposure criteria (SEL_{cum}) for both PTS where unrecoverable hearing damage may occur and TTS where a temporary reduction in hearing sensitivity may occur in individual receptors.

307. The NOAA (NMFS, 2016) metrics and criteria to be used in the underwater noise modelling are summarised in **Table A.0.2**.

Table A.0.2: NOAA (NMFS, 2016) metrics and criteria to be used in the underwater noise modelling

Species or species group	Impact	NOAA (NMFS, 2016)	
		SPL_{peak} Unweighted (dB re 1 µPa)	SEL_{cum} Weighted (dB re 1 µPa^{2}s)
Harbour porpoise High Frequency Cetaceans (HF)	Auditory Injury -PTS (Permanent Threshold Shift)	202	155
Grey seal and harbour seal Pinnipeds in water	Auditory Injury - PTS (Permanent Threshold Shift)	218	185
	TTS (Temporary Threshold Shift) - to determine onset of distrubance	212	181

Lucke *et al*. (2009) Thresholds and Criteria

308. The Lucke *et al*. (2009) metrics and criteria to be used in the underwater noise modelling to determine the potential behavioural response in harbour porpoise is present in **Table A.0.3**. This will be assessed based on a dose-response function.

Table A.0.3: Lucke *et al*. (2009) metrics and criteria to be used in the underwater noise modelling

Species or species group	Impact	Lucke *et al*. (2007) SEL_{ss} Unweighted (dB re 1 µPa^{2}s)
Harbour porpoise	Possible Behavioural Response	145

SS = single strike

Fish Threshold and Criteria

309. The Popper *et al*. (2014) thresholds and criteria will be used to assess the potential impacts of underwater noise on fish, as outlined in **Table A.5**.

Table A.4: Popper ***et al***. (2014) thresholds and criteria to be used in the underwater noise modelling for fish

Effect on fish	Popper *et al.* (2014)	
	SPL_{peak} Unweighted (dB re 1 µPa)	SEL_{cum} Unweighted (dB re 1 µPa^{2}s)
Fish injury	207	203
TTS	None	186
Startle response / C-turn reaction	Qualitative	Qualitative
General behavioural response	Qualitative	Qualitative