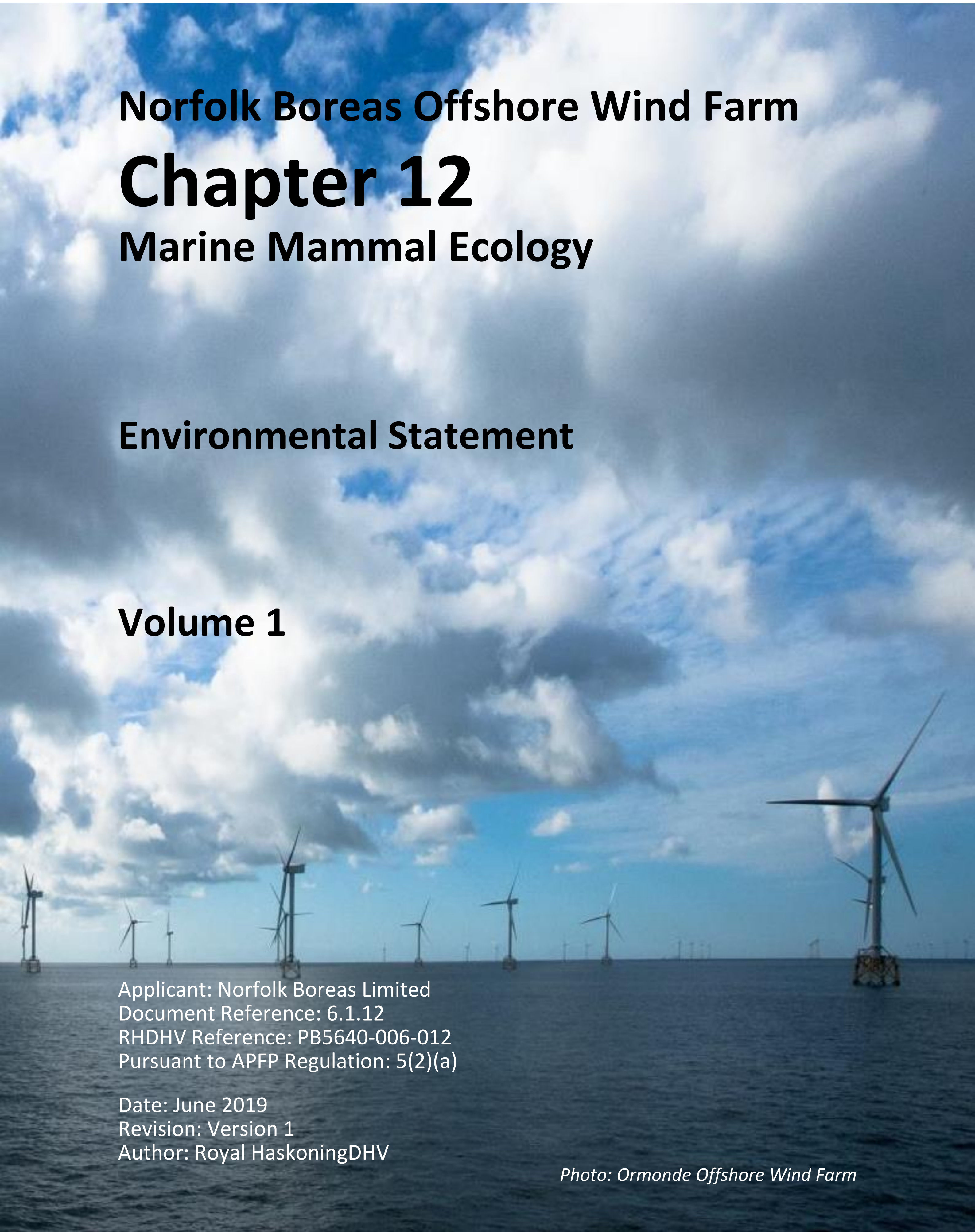

Norfolk Boreas Offshore Wind Farm

Chapter 12

Marine Mammal Ecology

Environmental Statement

Volume 1

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Glossary of Acronyms

µPa	Micro pascal
AA	Appropriate Assessment
ADD	Acoustic Deterrent Device
ASCOBANS	Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas
BEIS	Business Energy and Industrial Strategy
BSI	British Standards Institution
CBD	Convention on Biological Diversity
CCW	Countryside Council for Wales
CEDA	Central Dredging Association
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CI	Confidence Interval
CIA	Cumulative Impact Assessment
CIEEM	Chartered Institute of Ecology and Environmental Management
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CF	Correction Factor
CRoW	Countryside Rights of Way
cSAC	candidate Special Area of Conservation
cum	Cumulative
CV	Confidence Variation
dB	Decibels
DCO	Development Consent Order
DECC	Department of Energy and Climate Change
DEPONS	Disturbance Effects of Noise on the Harbour Porpoise Population in the North Sea
DOW	Dudgeon Offshore Windfarm
DWR	Deep Water Routes
EAOW	East Anglia Offshore Wind
EATL	East Anglia THREE Ltd
EC	European Commission
EDR	Effective Disturbance Radius
EIA	Environmental Impact Assessment
EMF	Electromagnetic Field
EMP	Environmental Management Plan
EOD	Explosive Ordnance Disposal
EPP	Evidence Plan Process
EPS	European Protected Species
ES	Environmental Statement
ETG	Expert Topic Group
EU	European Union
FCS	Favourable Conservation Status
FPSO	Floating Production Storage and Offloading
GBS	Gravity Base Structure
GC	Allied designation for German type LMB mine

GG	Allied designation for German type BM1000 mine
GNS	Greater North Sea
GS	Grey seal
GSD	Ground Sampling Distance
HE	High Explosive
HF	High Frequency Cetaceans
HP	Harbour porpoise
HRA	Habitats Regulation Assessment
HS	Harbour seal
Hz	Hertz
IAMMWG	Inter-Agency Marine Mammal Working Group
IEEM	Institute for Ecology and Environmental Management
iPCoD	interim Population Consequences of Disturbance
IWC	International Whaling Commission
JCP	Joint Cetacean Protocol
JNCC	Joint Nature and Conservation Committee
kg	Kilogram
kJ	Kilojoule
km	Kilometre
Km^2	Kilometre squared
lb	Pound
LAT	Lowest Astronomical Tide
LiDAR	Light Detection and Ranging
LSE	Likely Significant Effect
m	Metre
m/s	Metres per second
MCA	Maritime and Coastguard Agency
Met	Meteorological (Met mast)
mg/l	Milligrams per litre
MHWS	Mean High Water Spring
MLWS	Mean Low Water Spring
MMMP	Marine Mammal Mitigation Protocol
MMO	Marine Management Organisation
MMOs	Marine Mammal Observers
MPS	Marine Policy Statement
MSFD	Marine Strategy Framework Directive
MTD	Marine Technology Directorate
MU	Management Unit
MW	Megawatt
N/A	Not Applicable
NE	Natural England
NEQ	Net Explosive Quantities
nm	Nautical Miles
NMFS	National Marine Fisheries Services
NNR	National Nature Reserve
NOAA	National Oceanic and Atmospheric Administration

NPL	National Physical Laboratory
NPS	National Policy Statement
NS	North Sea
NSIP	Nationally Significant Infrastructure Projects
NV East	Norfolk Vanguard East
NV West	Norfolk Vanguard West
O&M	Operation and Maintenance
OMR	Offshore Marine Regulations
OSPAR	Oslo and Paris Convention for the Protection of the Marine Environment
OWF	Offshore Wind Farm
PAM	Passive Acoustic Monitoring
PDV	Phocine Distemper Virus
PEIR	Preliminary Environmental Information Report
PEMP	Project Environmental Management Plan
pSAC	proposed Special Area of Conservation
PTS	Permanent Threshold Shift
QA	Quality Assurance
RMS	Root Mean Square
RoC	Review of Consents
SAC	Special Area of Conservation
SCANS	Small Cetaceans in the European Atlantic and North Sea
SCI	Site of Community Importance
SCOS	Special Committee on Seals
SD	Standard Deviation
SE	South East
SEL	Sound Exposure Level
SIP	Site Integrity Plan
SMRU	Sea Mammal Research Unit
SNCB	Statutory Nature Conservation Body
SNS	Southern North Sea
SoS	Secretary of State
SPL	Sound Pressure Level
SST	Sea Surface Temperature
SW	South West
TNT	Trinitrotoluene
TSEG	Trilateral Seal Expert Group
TSHD	Trailing Suction Hopper Dredger
TTS	Temporary Threshold Shift
TWT	The Wildlife Trust
UK	United Kingdom
UWN	Underwater Noise
UXO	Unexploded Ordnance
VWPL	Vattenfall Wind Power Limited
WDC	Whale and Dolphin Conservation
ZEA	Zonal Environmental Appraisal

Glossary of Terminology

Array cables	Cables which link wind turbine to wind turbine, and wind turbine to offshore electrical platforms.
Evidence Plan Process	A voluntary consultation process with specialist stakeholders to agree the approach to the EIA and information to support HRA.
Interconnector cables	Offshore cables which link offshore electrical platforms within the Norfolk Boreas site
Landfall	Where the offshore cables come ashore at Happisburgh South.
Norfolk Boreas site	The Norfolk Boreas wind farm boundary. Located offshore, this will contain all the wind farm array.
Norfolk Vanguard	Norfolk Vanguard offshore wind farm, sister project of Norfolk Boreas.
Norfolk Vanguard OWF sites	Term used exclusively to refer to the two distinct offshore wind farm areas, Norfolk Vanguard East and Norfolk Vanguard West (also termed NV East and NV West) which will contain the Norfolk Vanguard arrays.
Offshore cable corridor	The corridor of seabed from the Norfolk Boreas site to the landfall site within which the offshore export cables will be located.
Offshore electrical platform	A fixed structure located within the Norfolk Boreas site, containing electrical equipment to aggregate the power from the wind turbines and convert it into a suitable form for export to shore.
Offshore export cables	The cables which transmit electricity from the offshore electrical platform to the landfall.
Offshore project area	The area including the Norfolk Boreas site, project interconnector search area and offshore cable corridor.
Offshore service platform	A platform to house workers offshore and/or provide helicopter refuelling facilities. An accommodation vessel may be used as an alternative for housing workers.
Project interconnector cable	Offshore cables which would link either turbines or an offshore electrical platform in the Norfolk Boreas site with an offshore electrical platform in one of the Norfolk Vanguard sites.
Project interconnector search area	The area within which project interconnector cables would be installed.
Safety zone	An area around a vessel which should be avoided during offshore construction.
Scour protection	Protective materials to avoid sediment being eroded away from the base of the foundations as a result of the flow of water.
The Applicant	Norfolk Boreas Limited.
The project	Norfolk Boreas Wind Farm including the onshore and offshore infrastructure.

12 MARINE MAMMAL ECOLOGY

12.1 Introduction

1. This chapter of the Environmental Statement (ES) describes the existing environment with regard to marine mammals which includes cetaceans (whales, dolphins and porpoises) and pinnipeds (seals) and assesses the potential impacts of the proposed Norfolk Boreas project (hereafter referred to as the project) during the construction, operation and maintenance (O&M), and decommissioning phases. Where appropriate, mitigation measures and residual impacts are presented.

2. This assessment also considers information from, and refers to, the following chapters within the ES:

- Chapter 3 Policy and Legislative Context;
- Chapter 5 Project Description;
- Chapter 6 Environmental Impact Assessment (EIA) Methodology;
- Chapter 9 Marine Water and Sediment Quality;
- Chapter 11 Fish and Shellfish Ecology; and
- Chapter 15 Shipping and Navigation.

3. This chapter is supported by the following Appendices

- Appendix 5.3 Ordtek Unexploded Ordnance (UXO) Review;
- Appendix 5.4: Underwater Noise Modelling Report;
- Appendix 5.5 Underwater Noise modelling from UXO;
- Appendix 12.1 Marine Mammal Consultation Responses;
- Appendix 12.2: Marine Mammal Information and Survey Data;
- Appendix 12.3: Marine Mammal Cumulative Impact Assessment (CIA) screening;
- Appendix 12.4: Additional Assessment in relation to the potential Southern North Sea Special Area of Conservation (SNS SAC);
- Appendix 12.5: Additional Underwater Noise Assessments; and
- Appendix 12.6: Additional Cumulative Impact Assessment (CIA) Scenarios.

4. This chapter is also supported by the following documents

- Consultation Report (document reference 5.1) and relevant appendices;
- Report to inform the Habitat Regulations Assessment (HRA) (document reference 5.3);
- Draft Marine Mammal Mitigation Protocol (MMMP) for piling (document reference 8.13) and
- In Principle Norfolk Boreas Southern North Sea SAC Site Integrity Plan (SIP) (document reference 8.17).

5. Vattenfall Wind Power Limited (VWPL) (the parent company of Norfolk Boreas Limited) is also developing Norfolk Vanguard, a 'sister project' to Norfolk Boreas. Norfolk Vanguard's development schedule is approximately one year ahead of Norfolk Boreas and as such the Development Consent Order (DCO) application was submitted in June 2018.

6. Norfolk Vanguard may undertake some enabling works for Norfolk Boreas, but these are only relevant to the assessment of impacts onshore. This assessment does however include interconnector cables between the Norfolk Boreas and Norfolk Vanguard projects (herein, 'the project interconnector'). If Norfolk Vanguard does not proceed then the project interconnector would not be required.

7. This chapter of the ES was written by Royal HaskoningDHV and incorporates survey data collected by APEM Ltd and density estimates analysed by MacArthur Green which have been further interpreted in Appendix 12.2.

12.2 Legislation, Guidance and Policy

12.2.1 Legislation

12.2.1.1 The Habitats Directive

8. The European Union Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (92/43/EEC) (hereafter called the *Habitats Directive*) gives regulation to the conservation and management of natural habitats, wild fauna (except birds) and flora in Europe. Its primary aim is to maintain or restore natural habitats and wild species at a favourable conservation status.

9. Annex II of the Habitats Directive lists as species for which member states are expected to establish a "consistent network of special areas of conservation". This list includes harbour porpoise *Phocoena phocoena*, bottlenose dolphin *Tursiops truncatus* along with the grey seal *Halichoerus grypus* and harbour seal *Phoca vitulina* all of which are relevant to Norfolk Boreas.

10. Although not legally binding, the European Commission's Guidance document on the strict protection of animal species of Community interest under the Habitats Directive (European Commission (EC), 2007) states that:

> *"In order to assess a disturbance, consideration must be given to its effect on the conservation status of the species at population level and biogeographic level in a Member State. For instance, any disturbing activity that affects the survival chances, the breeding success or the reproductive ability of a protected species or leads to a reduction in the occupied area should be regarded as a "disturbance" in terms of Article 12."*

11. The Habitats Directive protects all species of cetaceans under Annex IV as European Protected Species (EPS), being classed as endangered, vulnerable or rare, and grey and harbour seals are protected under Annex V which requires their exploitation or removal from the wild to be subject to management measures. Harbour porpoise, bottlenose dolphin and both seal species are additionally listed under Annex II, which requires member states to designate sites, identified as being key areas for their life and reproduction, as Special Areas of Conservation (SACs).

12. Article 12 of the Habitats Directive requires member states to establish stricter protection for species within their natural range; prohibiting all forms of deliberate capture or killing, deliberate disturbance (particularly during breeding and rearing periods, hibernations and migration) and the deterioration or destruction of breeding and resting sites.

12.2.1.2 The Habitats Regulations

13. The Conservation of Habitats and Species Regulations 2017 and the Conservation of Offshore Marine Habitats and Species Regulations 2017 (collectively referred to as '*the Habitats Regulations 2017*') transpose the Habitats Directive into national law. The Habitats Regulations place an obligation on 'competent authorities' to carry out an appropriate assessment (AA) of any proposal likely to have a significant effect on a Natura 2000 site, to seek advice from Statutory Nature Conservation Bodies (SNCBs) and to reject an application that would have an adverse effect on a Natura 2000 site except under very tightly constrained conditions. The competent authority in the case of the proposed project is the Secretary of State for Business Energy and Industrial Strategy (BEIS).

14. All cetacean species are listed under Schedule 2 and defined as EPS and all seals are listed under Schedule 4 (animals which may not be captured or killed in certain ways).

15. Under the Habitats Regulations a person is guilty of an offence if that person:

- Deliberately captures, injures or kills a wild animal belonging to a species with EPS status;
- Deliberately disturbs such animal; or
- Damages or destroys any resting or breeding place of such animal.

16. However, there is a provision to apply for an EPS licence where any of the above is expected to occur, provided there is no satisfactory alternative, and there will be no long-term detrimental effects. This is especially relevant to marine mammals and the likelihood of disturbance due to marine activities.

17. As in the Habitats Directive, there is a requirement to create SACs for species listed under Annex II (i.e. harbour porpoise, bottlenose dolphin, grey and harbour seals)

and to advise on what marine operations may adversely affect the integrity of the site.

18. There are a number of provisions within the regulations that protect marine species from harmful activities. EPS, as listed under Annex IV of the Habitats Directive, are protected from:

- The deliberate capture, injury, killing;
- Any disturbance that is likely to result in a significant impact to the ability of any species group to survive, breed, rear or nurture their young, to disrupt a species' hibernation or migrations, or to affect significantly the local distributions or abundance of the species; and
- Damage or destroy any breeding or resting site.

12.2.1.3 Summary of relevant legislation

19. Table 12.1 provides an overview of national and international legislation in relation to marine mammals.

Table 12.1 National and international legislation in relation to marine mammals

Legislation	Level of Protection	Species included	Details
Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS)	International	Odontocetes	Formulated in 1992, this agreement has been signed by 10 European countries bordering the Baltic and North Seas (including the English Channel) and includes the United Kingdom (UK). Under the Agreement, provision is made for the protection of specific areas, monitoring, research, information exchange, pollution control and increasing public awareness of small cetaceans.
The Berne Convention 1979	International	All cetaceans, grey seal and harbour seal	The Convention conveys special protection to those species that are vulnerable or endangered. Appendix II (strictly protected fauna): 19 species of cetacean. Appendix III (protected fauna): all remaining cetaceans, grey and harbour seal. Although an international convention, it is implemented within the UK through the Wildlife and Countryside Act 1981.
The Bonn Convention 1979	International	All cetaceans	Protects migratory wild animals across all, or part of their natural range, through international co-operation, and relates particularly to those species in danger of extinction. One of the measures identified is the adoption of legally binding agreements, including ASCOBANS.
Oslo and Paris Convention for the Protection of the Marine Environment 1992 (OSPAR)	International	Bowhead whale *Balaena mysticetus*, northern right whale *Eubalaena glacialis*, blue whale *Balaenoptera musculus*, and harbour porpoise	OSPAR has established a list of threatened and/or declining species in the North East Atlantic. These species have been targeted as part of further work on the conservation and protection of marine biodiversity under Annex V of the OSPAR Convention. The list seeks to complement, but not duplicate, the work under the EC Habitats and Birds directives and measures under the Berne Convention and the Bonn Convention.
International Convention for the Regulation of Whaling 1956	International	All cetacean species	This Convention established the International Whaling Commission (IWC) who regulates the direct exploitation and conservation of large whales (in particular, sperm whale *Physeter macrocephalus* and large baleen whales) as a resource and the impact of human activities on cetaceans. The regulation considered scientific matters related to small cetaceans, in particular the enforcing a moratorium on commercial whaling which came into force in 1986.
Convention on International Trade in Endangered Species of Wild Fauna and Flora	International	All cetacean species	Prohibits the international trade in species listed in Appendix 1 (including sperm whales, northern right whales, and baleen whales) and allows for the controlled trade of all other cetacean species.

Legislation	Level of Protection	Species included	Details
(CITES) 1975			
Convention on Biological Diversity (CBD) 1993	International	All marine mammal species	Requires signatories to identify processes and activities that are likely to have impacts on the conservation of and sustainable use of biological diversity, inducing the introduction of appropriate procedures requiring an EIA and mitigation procedures.
The Conservation of Habitats and Species Regulations 2017 and The Conservation of Offshore Marine Habitats and Species Regulations 2017	National	All cetaceans, grey and harbour seal	'The Habitats Regulations 2017'. Provisions of The Habitats Regulations are described further above. It should be noted that the Habitats Regulations apply onshore, within the territorial seas and to marine areas within UK jurisdiction, beyond 12 nautical miles (nm).
The Wildlife and Countryside Act 1981 (as amended)	National	All cetaceans	All cetaceans listed in Schedule 5 are fully protected within UK territorial waters. The Act protects them from killing or injury, sale, destruction of a particular habitat (which they use for protection or shelter) and disturbance. Short-beaked common dolphin *Delphinus delphis*, bottlenose dolphin and harbour porpoise are listed on Schedule 6 of the Act. Under the Act these species are prohibited from being used as a decoy to attract other animals. The Act also prohibits the use of vehicles in immediate pursuit to take, kill or drive them, it prevents nets, traps or electrical devices from being set in such a way that would injure them and prevents the use of nets or sounds to trap or snare them.
The Countryside and Rights of Way Act (CRoW) 2000	National	All cetaceans	Under the CRoW Act 2000, it is an offence to intentionally or recklessly disturb any wild animal included under Schedule 5 of the Wildlife and Countryside Act.

Legislation	Level of Protection	Species included	Details
Conservation of Seals Act 1970	England and Wales	Grey and harbour seal	Provides closed seasons, during which it is an offence to take or kill any seal, except under licence or in certain circumstances (grey seal: 1 September to 31 December; harbour seal: 1 June to 31 August). Following the halving of the harbour seal population as a result of the Phocine Distemper Virus (PDV) in 1988, an Order was issued under the Act which provided year-round protection of both grey and harbour seal on the east coast of England. The Order was last renewed in 1999.

12.2.2 Guidance and Policy

20. The assessment of potential impacts upon marine mammals has been made with specific reference to the relevant National Policy Statements (NPS). These are the principal decision-making documents for Nationally Significant Infrastructure Projects (NSIP).

21. The Overarching NPS for Energy (EN-1) sets out the Government's policy for delivery of major energy infrastructure, with generic considerations which are further considered in the technology-specific NPSs such as the NPS for Renewable Energy Infrastructure (EN-3). Table 12.2 sets out the specific assessment requirements for marine mammals.

22. Paragraphs 2.6.92 to 2.6.99 of EN-3 outline the main priorities and concerns for offshore wind farm development projects that should be considered in relation to marine mammals. EN-3 refers to the preferred methods of construction and noise mitigation practices, as well as the conservation status of marine EPS, and the need to take into account the views of the relevant statutory advisers. Additionally, within EN-3 it is noted that fixed structures (such as offshore wind turbines) are unlikely to pose a significant collision risk to marine mammals.

23. Paragraphs 2.6.97 to 2.6.99 of EN-3 state the specific requirements for marine mammal mitigation; such as monitoring of the area pre-piling and during piling events, and the use of soft-start procedures before any piling event. This section also highlights the preference for 24 hour working practices to reduce the overall construction program and the resultant impact to marine mammals.

Table 12.2 NPS assessment requirements

NPS requirement	NPS reference to text	Section reference
"There are specific considerations from piling noise which apply to offshore wind energy infrastructure proposals with regard to marine mammals, including cetaceans and seals, which have statutory protection. Offshore piling may reach noise levels which are high enough to cause injury, or even death, to marine mammals. If piling associated with an offshore wind farm is likely to lead to the commission of an offence (which would include deliberately disturbing, killing or capturing a European Protected Species), an application may have to be made for a wildlife licence to allow the activity to take place."	Paragraphs 2.6.90-2.6.91 of the NPS EN-3 (July 2011).	Section 12.7.2 provides an overview of the worst-case scenario for possible piling works. Section 12.7.3.2 provides an overview of the assessment of pile driving (including noise modelling results).
"Where necessary, assessment of the effects on marine mammals should include details of: • Likely feeding areas;	Paragraph 2.6.92 of the NPS EN-3 (July 2011).	Section 12.6 provides a description of the existing environment.

NPS requirement	NPS reference to text	Section reference
• Known birthing areas / haul out sites; • Nursery grounds; • Known migration or commuting routes; • Duration of the potentially disturbing activity including cumulative / in-combination effects with other plans or projects; • Baseline noise levels; • Predicted noise levels in relation to mortality, Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS). and • Soft-start noise levels according to proposed hammer and pile design; and operational noise."		Section 12.7.3 details the assessment of impacts during construction, including pile driving. Section 12.7.4 provides the assessment of operational noise.
"The applicant should discuss any proposed piling activities with the relevant body. Where assessment shows that noise from offshore piling may reach noise levels likely to lead to an offence [as described above], the applicant should look at possible alternatives or appropriate mitigation before applying for a licence."	Paragraph 2.6.93 of the NPS EN-3 (July 2011).	Section 12.7.3 details the assessment of impacts during construction, including pile driving, and mitigation measures. Norfolk Boreas has consulted with NE (Table 12.4) through the Evidence Plan Process (EPP).
"The IPC [*now the Planning Inspectorate and the Secretary of State (SoS)*] should be satisfied that the preferred methods of construction, in particular the construction method needed for the proposed foundations and the preferred foundation type, where known at the time of application, are designed so as to reasonably minimise significant disturbance effects on marine mammals. Unless suitable noise mitigation measures can be imposed by requirements to any development consent the IPC [*now SoS*] may refuse the application. The conservation status of marine European Protected Species and seals are of relevance to the IPC [*now SoS*]. IPC [*now SoS*] should take into account the views of the relevant statutory advisors. Fixed submerged structures such as foundations are likely to pose little collision risk for marine mammals and the IPC [*now SoS*] is not likely to have to refuse to grant consent for a development on the grounds that offshore wind farm foundations pose a collision risk to marine mammals."	Paragraphs 2.6.94 to 2.6.96 of the NPS EN-3 (July 2011).	Chapter 5 describes the foundation options under consideration for Norfolk Boreas. Section 12.7.2 describes the worst-case scenario for marine mammals.
"Monitoring of the surrounding area before and during the piling procedure can be undertaken. During construction, 24-hour working practices may be employed so that the overall construction	Paragraphs 2.6.97 to 2.6.99 of the NPS EN-3 (July 2011).	An outline Project Environmental Management Plan (PEMP) (document reference 8.14) and an In

NPS requirement	NPS reference to text	Section reference
programme and the potential for impacts to marine mammal communities are reduced in time. Soft start procedures during pile driving may be implemented. This enables marine mammals in the area disturbed by the sound levels to move away from the piling before significant adverse impacts are caused.”		Principle Monitoring Plan (IPMP) (document reference 8.12) have been submitted with the DCO application. These plans will be developed in consultation with the relevant SNCBs and the Marine Management Organisation (MMO) and will be finalised post consent. These documents will identify any monitoring requirements.

24. In addition to the NPS guidance, there are further planning guidance for strategically planning and consenting marine activities, including:

- The Marine Strategy Framework Directive (MFSD) 2008/56/EC (EC, 2008);
- The Marine Policy Statement (MPS) (HM Government, 2011); and
- The East Inshore and East Offshore Marine Plans (HM Government, 2014).

25. Annex I of the MSFD states that to ensure that good environmental status is met, the following must be considered:

- Biological diversity should be maintained;
- The quality and occurrence of habitats, as well as the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions;
- All elements of the marine food web, to the extent that they are known, occur at normal abundance and diversity levels capable of ensuring the long-term abundance of the species and the retention of their full reproductive capacity;
- Concentrations of contaminants are at levels not giving rise to pollution effects;
- Properties and quantities of marine litter do not cause harm to the coastal and marine environment; and
- Introduction of energy, including underwater noise, is at levels that do not adversely affect the marine environment.

26. The MPS (HM Government, 2011) provides a high-level approach to marine planning and the general principles for decision making. It sets out the framework for environmental, social and economic considerations that need to be taken into account in marine planning. The high level objective of ‘Living within environmental limits’ covers the points relevant to marine mammals, this requires that:

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

27. Within both the East Inshore and East Offshore Marine Plans (HM Government, 2014), a set of objectives have been set out to ensure biodiversity protections and are of relevance to marine mammals as they cover policies and commitments on the wider ecosystem, as set out within the MPS and the MSFD:

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

28. The principal guidance documents used to inform the assessment of potential impacts on marine mammals are as follows:

- The Protection of Marine EPS from Injury and Disturbance: Draft Guidance for the Marine Area in England and Wales and the UK Offshore Marine Area (JNCC et al. 2010);
- Guidelines for Ecological Impact Assessment in Britain and Ireland, Marine and Coastal (Institute for Ecology and Environmental Management (IEEM), 2010);
- Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater and Coastal (Chartered Institute of Ecology and Environmental Management (CIEEM), 2016)
- Environmental Impact Assessment for offshore renewable energy projects – guide (British Standards Institution (BSI), 2015);
- Approaches to Marine Mammal Monitoring at Marine Renewable Energy Developments Final Report (Sea Mammal Research Unit Ltd (SMRU Ltd) on behalf of The Crown Estate, 2010);
- Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects (Cefas, 2012); and
- Statutory Nature Conservation Agency Protocol for Minimising the Risk of Injury to Marine Mammals from Piling Noise (JNCC, 2010a).

12.2.2.1 EPS guidance

29. The JNCC, Natural England and the Countryside Council for Wales (CCW) (JNCC et al., 2010) have produced draft guidance concerning the Regulations on the deliberate

disturbance of marine EPS, provides an interpretation of the regulations in greater detail, including for pile driving operations (JNCC, 2010a), seismic surveys (JNCC, 2017a) and the use of explosives (JNCC, 2010b).

30. The draft guidance provides advice on activities at sea that could potentially cause deliberate injury or disturbance to marine mammals and summarises information and sensitivities of the species to which these regulations apply. The guidance refers to the European Commission's Guidance document (EC, 2007) stating that, there must be some ecological impact in order for significant disturbance to occur.

31. The draft guidance provides the following interpretations of deliberate injury and disturbance offences under both the Habitats Regulations and Offshore Regulations (now the Habitats Regulations 2017), as detailed in the paragraphs below:

> "*Deliberate actions are to be understood as actions by a person who knows, in light of the relevant legislation that applies to the species involved, and the general information delivered to the public, that his action will most likely lead to an offence against a species, but intends this offence or, if not, consciously accepts the foreseeable results of his action;*
>
> *Certain activities that produce loud sounds in areas where EPS could be present have the potential to result in an injury offence, unless appropriate mitigation measures are implemented to prevent the exposure of animals to sound levels capable of causing injury*."

32. For the purposes of marine users, the draft guidance states that a disturbance which can cause offence should be interpreted as:

> *"Disturbance which is significant in that it is likely to be detrimental to the animals of an EPS or significantly affect their local abundance or distribution."*

33. The draft guidelines further states that a disturbance offence is more likely where an activity causes persistent noise in an area for long periods of time, and a disturbance offence is more likely to occur when there is a risk of:

- Animals incurring sustained or chronic disruption of behaviour scoring five or more in the Southall et al. (2007) behavioural response severity scale; or
- Animals being displaced from the area, with redistribution significantly different from natural variation.

34. The draft guidance (JNCC et al., 2010) highlights that sporadic "trivial disturbance" should not be considered as a disturbance offence under Article 12.

35. In order to assess whether a disturbance could be considered non-trivial in relation to the objectives of the Directive, JNCC et al. (2010) suggest that consideration

should be given to the definition of the Favourable Conservation Status (FCS; see section 12.2.2.2) of a species given in Article 1(i) of the Habitats Directive. There are three parameters that determine when the conservation status of a species can be taken as favourable:

- Population dynamics data on the species concerned indicate that it is maintaining itself on a long-term basis as a viable element of its natural habitats.
- The natural range of the species is neither being reduced nor is likely to be reduced for the foreseeable future.
- There is, and will probably continue to be, a sufficiently large habitat to maintain its populations on a long-term basis.

36. Therefore, any action that could increase the risk of a long-term decline of the population, increase the risk of a reduction of the range of the species, and/or increase the risk of a reduction of the size of the habitat of the species can be regarded as a disturbance under the Regulations. For a disturbance to be considered non-trivial, the disturbance to marine EPS would need to be likely to at least increase the risk of a certain negative impact on the species at FCS.

37. JNCC et al. (2010) do not provide guidance as to what would constitute a 'significant group' or proportion of the population, but provide some discussion on how to assess whether the numbers potentially affected could be of concern for a population's FCS.

38. JNCC et al. (2010) state that:

> "*In any population with a positive rate of growth, or a population remaining stable at what is assumed to be the environmental carrying capacity, a certain number of animals can potentially be removed as a consequence of anthropogenic activities (e.g. through killing, injury or permanent loss of reproductive ability), in addition to natural mortality, without causing the population to decrease in numbers, or preventing recovery, if the population is depleted. Beyond a certain threshold however, there could be a detrimental effect on the population*".

39. Further discussion on the use of thresholds for significance and the permanent or temporary nature of any disturbance is considered by defining the magnitude of potential effect in this assessment (section 12.4.1.3). Consideration of any potential essential habitat or geographical structuring of EPS is provided in the Existing Environment section (section 12.6) of this chapter.

40. In order to assess the number of individuals from a species that could be removed from the regional population through injury or disturbance without compromising the FCS, the EIA considers:

- The numbers affected in relation to the best and most recent estimate of population size; and
- The threshold for potential impact on the FCS, which will depend on:
    - The species' / populations' life-history;
    - The species' FCS assessment in UK waters; and
    - Other pressures encountered by the population (cumulative effects).

41. One of the key parameters for consideration within this assessment is the population size. The EPS Guidance advises that the best available abundance estimates could be used as a baseline population size, taking account of any evidence of regional population structuring (JNCC et al*.,* 2010).

42. An EPS licence is required if the risk of injury or disturbance to cetacean species is assessed as likely under the Habitats Regulations 2017.

43. If a licence is required, an application must be submitted, the assessment of which comprises three tests, namely:

- Whether the activity falls within one of the purposes specified in Regulation 55 of the Habitats Regulations. Only the purpose of "*preserving public health or public safety or other imperative reasons of overriding public interest, including those of a social or economic nature and beneficial consequences of primary importance for the environment*" is of relevance to marine mammals in this context;
- That there are no satisfactory alternatives to the activity proposed (that would not incur the risk of offence); and
- That the licensing of the activity will not result in a negative impact on the species'/ population's FCS.

44. Under the definitions of 'deliberate disturbance' in the Habitats Regulations, chronic exposure and / or displacement of animals could be regarded as a disturbance offence. Therefore, if these risks cannot be avoided, then Norfolk Boreas Limited is likely to be required to apply for an EPS licence from the Marine Management Organisation (MMO) in order to be exempt from the offence.

45. If required, the EPS licence application will be submitted post-consent. At that point in time, the project design envelope will have been further refined through detailed design and procurement activities and further detail will be available on the techniques selected for the construction of the wind farm, as well as the mitigation measures that will be in place following the development of the Marine Mammal Mitigation Protocol (MMMP) for piling and unexploded ordnance (UXO) clearance. An outline MMMP has been submitted as part of the DCO application (document reference 8.13)

12.2.2.2 Favourable Conservation Status (FCS)

46. Member states report back to the European Union (EU) every six years on the Conservation Status of marine EPS. Based on the most recent 2007-2012 reporting by the Joint Nature and Conservation Committee (JNCC, 2013), seven species of the 11 cetacean species were assessed as having a ‘favourable’ Conservation Status (Table 12.3).

47. Four of 11 cetacean species were assessed as having an ‘unknown’ Conservation Status (JNCC, 2013). This is a result of a lack of recent population[1] estimates that encompassed their natural range in UK and adjacent waters and / or having no evidence to determine long-term trends in population abundance.

48. Another 17 species were considered to be uncommon, rare or very rare in occurrence, so it was not possible to ascertain their Conservation Status (JNCC, 2013).

Table 12.3 FCS assessment of cetacean species in Annex IV of the Habitats Directive occurring in UK and adjacent waters (JNCC, 2013)

Species	FCS assessment
Atlantic white-sided dolphin *Lagenorhynchus acutus*	Favourable
Bottlenose dolphin *Tursiops truncatus*	Favourable
Common dolphin *Delphinus delphis*	Favourable
Fin whale *Balaenoptera physalus*	Favourable
Harbour porpoise *Phocoena phocoena*	Favourable
Killer whale *Orcinus orca*	Unknown
Long-finned pilot whale *Globicephala melas*	Unknown
Minke whale *Balaenoptera acutorostrata*	Favourable
Risso’s dolphin *Grampus griseus*	Unknown
Sperm whale *Physeter macrocephalus*	Unknown
White-beaked dolphin *Lagenorhynchus albirostris*	Favourable

[1] ‘Population’ is defined in the EC guidance on the strict protection of animal species as a group of individuals of the same species living in a geographic area at the same time that are (potentially) interbreeding (i.e. sharing a common gene pool).

12.3 Consultation

49. Consultation is a key part of the DCO application process. As outlined in section 12.1, VWPL are also developing the Norfolk Vanguard project which is located adjacent to the Norfolk Boreas site, therefore much of the consultation undertaken by Norfolk Vanguard is relevant to Norfolk Boreas and as such consultation has often been conducted for both projects. Norfolk Boreas Limited has followed a non-statutory Evidence Plan Process (EPP), which has included an Expert Topic Group (ETG) for marine mammals. The EPP has been used to consult with Natural England, 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.

50. To date, consultation regarding marine mammals has been conducted through ETG meetings and through the consultation on the Scoping Report (Royal HaskoningDHV, 2017) and through the PEIR (Norfolk Boreas Limited 2018b). An overview of the project consultation process is presented within Chapter 7 Technical Consultation.

51. Pre-application consultation for Norfolk Boreas (some of which included consultation for Norfolk Vanguard) to date has included the following key stages:

- Norfolk Boreas EIA Scoping Report (Royal HaskoningDHV, 2017);
- Norfolk Boreas Scoping Opinion (the Planning Inspectorate, 2017);
- EIA Marine Mammal Method Statement (Appendix 9.26 of the consultation report (document reference 5.1));
- Norfolk Boreas PEIR Chapter 12 Marine Mammals (Royal HaskoningDHV, 2018)
- EPP marine mammal ETG meetings (12th March 2018 for Norfolk Boreas and 15th February 2017 and 6th July 2017 for Norfolk Vanguard;); and
- EPP marine mammal ETG conference calls (26th March 2018 and 8th December 2017 for Norfolk Vanguard).

52. Detailed minutes and agreement logs from EPP meetings are provided as Appendix 9.44 and 28.1 of the consultation report (document reference 5.1).

53. During the course of the Norfolk Boreas EIA new information and guidance has been incorporated. However, it was necessary to have a cut-off point prior to the DCO submission to allow the assessment to be completed, after which new guidance or information would not be considered. This cut-off point was taken to be the 20th March 2019.

54. As Norfolk Boreas and Norfolk Vanguard share an offshore cable corridor, the pre-application consultation undertaken as part of Norfolk Vanguard has been used to inform the approach to the Norfolk Boreas marine mammal ecology assessment. Furthermore, information submitted as part of the Norfolk Vanguard examination,

has also been incorporated. However, in order that the programmed submission of the Norfolk Boreas DCO has not been impacted it has been necessary to use the cut-off point of the 20th March 2019 here also. This coincided with Norfolk Vanguard Examination Deadline 5). After this date information provided at the Norfolk Vanguard examination as well as any wider information has not been included in this assessment unless it could be done without impacting the programme for submission.

55. Relevant consultation responses, from the Scoping Opinion, PEIR consultation, and the Marine Mammals ETG meetings for Norfolk Boreas and Norfolk Vanguard are presented in Appendix 12.1. The key responses that have had a direct effect on the development of this chapter from PEIR to ES are included in Table 12.4. Further details of the Evidence Plan Process are provided in the Consultation Report (document reference 5.1).

Table 12.4 Consultation Responses

Consultee	Date & Document	Comment	Response / where addressed in the ES
The Wildlife Trust	letter dated 7th December 2018 Comments on the Norfolk Boreas PEIR	TWT consider that fishing should be included in both cumulative and in-combination assessments. Fishing is a licensable activity that has the potential to have an adverse impact on the marine environment. This is supported in the leading case C-127/02 Waddenzee [2004] ECR I-7405, the CJEU held at para. 6. "The act that the activity has been carried on periodically for several years on the site concerned and that a licence has to be obtained for it every year, each new issuance of which requires an assessment both of the possibility of carrying on that activity and the site where it may be carried on, does not itself constitute an obstacle to considering it, at the time of each application, as a distinct plan or project within the meaning of the Habitats Directive". This case law demonstrates that fishing is considered a plan or a project and therefore not part of the baseline. Current Defra policy is to ensure that all existing and potential fishing operations are managed in line with Article 6 of the Habitats Directive. The current, risk-based, 'revised approach' to fisheries management in European Marine Sites is a compromise agreed by all to prevent the closure of fisheries during assessment. This approach further supports that fishing is considered a plan or a project and therefore must be included in the in-combination assessment in line with Article 6(3) of the Habitats Directive. A precedent was set for the inclusion of fishing in in-combination assessments when TWT began Judicial Review proceedings against the Department for Energy and Climate Change (DECC) in August 2015 against the approval of Dogger Bank Teesside A & B Offshore Wind Farm Order due to the exclusion of fishing from the in-combination assessment as part of the HRA. TWT withdrew the claim due to assurances given by the government regarding the management of fishing within Dogger Bank SAC. One of those	By-catch by commercial fisheries is recognised as a historic and continuing cause of harbour porpoise mortality in the Southern North Sea (SNS). This will therefore be a factor in shaping the size of the current North Sea (NS) MU population. The available prey resource for harbour porpoise has also been influenced by historic and continuing commercial fishing. As a result, the Norfolk Boreas CIA and in-combination assessment considers commercial fisheries to be part of the baseline environment for marine mammals, including harbour porpoise. Noise from vessels associated with other, non-wind farm, plans or projects such as oil and gas, aggregates and commercial fisheries, are also considered to be part of the baseline conditions. This approach is in accordance with the Planning Inspectorate Advice Note 17 Cumulative Effects Assessment. The draft Review of Consents (RoC) HRA suggests that by-catch has not hindered the population achieving FCS. Information from the BEIS (2018) draft RoC HRA have been included in section 12.4.2. See Appendix 12.1 for full response.

Consultee	Date & Document	Comment	Response / where addressed in the ES
		assurances was that steps would be put in place to ensure that this scenario would not happen again and that Defra and DECC would work together to ensure fishing would be included in future offshore wind farm impact assessments.	
The Wildlife Trust	letter dated 7th December 2018 Comments on the Norfolk Boreas PEIR	TWT does not agree with the SNCB advice on underwater noise management. The proposed thresholds are not based on strong science and are therefore not precautionary enough. TWT advocate the management approach used in Germany.	This is the current SNCB advice for assessments on the SNS SAC and is therefore used in the assessments. However, it should be noted that in addition to the area based approach, assessments were also conducted on the harbour porpoise North Sea Management Unit population, with additional assessments on the estimated number of harbour porpoise that the SNS SAC site could support.
The Wildlife Trust	letter dated 7th December 2018 Comments on the Norfolk Boreas PEIR	TWT is pleased that Norfolk Boreas has committed to a piling and UXO MMMP and a Site Integrity Plan (SIP) for the Southern North Sea SCI. However, as detailed plans are not available at the time of consent, TWT wish to be named as a consultee in the development of the MMMPs and SIP. TWT also wish to continue the good relationship we have developed with Norfolk Boreas into the post-consent stage. TWT expect the MMMPs and the SIP to detail the effectiveness of the potential mitigation to ensure no adverse effect beyond reasonable scientific doubt.	Acknowledged. TWT will be consulted on during the development of the final MMMP for piling and the SIP. A draft MMMP for piling and In Principle SIP has been included with the DCO application (document references 8.13 and 8.17).
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas PEIR	The results of the aerial surveys undertaken (Section 2.2.4 of Appendix 12.1 Marine Mammal Information and Survey Data), shows that for cetaceans identified as harbour porpoise that there is the highest peak in the summer months, but there are also smaller peaks in winter. Additionally, for unidentified small cetaceans, which are being assumed to be harbour porpoises for the purpose of the impact assessment, there was a peak in winter with a smaller peak in summer "indicating that higher than normal numbers are seen in these summer months, but the highest peaks are seen in winter". Whilst Norfolk Boreas area is within the summer area of the SNS SCI, there are harbour porpoise,	The potential for impacts on the winter area of the SNS SAC have been fully considered within the Information to Support Habitats Regulation Assessment Report submitted as part of the DCO application (document reference 5.3), due to the proximity of the winter area to the Norfolk Boreas site.

Consultee	Date & Document	Comment	Response / where addressed in the ES
		potentially at significant number, in the winter. Therefore, construction at any time of the year will require proven mitigation methods to ensure there is no adverse impact on the population of harbour porpoise at the site.	
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas PEIR	One of our main concerns is that the assessment on the harbour porpoise population in the SNS SCI is based against the North Sea Management Unit. WDC acknowledges that this is following guidance from the SNCB's, and within the SNS SCI Site Selection Document, it states "because this estimate is from a one-month survey in a single year it cannot be considered as a specific population number for the site. It is therefore not appropriate to use site population estimates in any assessments of effects of plans or projects (i.e. Habitats regulation Assessments), as these need to take into consideration population estimates at the MU level, to account for daily and seasonal movements of the animals" (JNCC, 2017). WDC strongly disagree with this advice. The European Commission guidance on managing Natura 2000 sites also states that the integrity of the site (habitat and species) must be maintained (European Commission and Office for Official Publications of the European Communities, 2000).	Assessments were conducted based on the current SNCB advice. As outlined in section 12.6.1.5, it is currently not advised to use the SNS SAC site population estimate in any assessments of effects of plans or projects, as these need to take into consideration population estimates at the MU level (JNCC, 2017b). However, an additional assessment has been completed, based on the estimate that the SNS SAC could support 29,384 harbour porpoise (SCANS-III data for 17.5% of the UK North Sea MU). This additional assessment which if for information only is provided in Appendix 12.4.
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas PEIR	The results of this assessment estimate that a significant area of the SNS SCI, and the harbour porpoise population supported by the site could be impacted by construction activities, particularly piling during construction when the data is extrapolated for 200 foundations required for Norfolk Boreas. As detailed below, pile driving during construction has been demonstrated to cause behavioural changes in harbour porpoises, and reduce abundance in the area during the entire construction window, and beyond (see section below on Potential Impacts).	The MMMP and SIP, will reduce the potential impacts of piling on harbour porpoise in the SNS SAC. A draft MMMP (document reference 8.13) and an In Principle SIP (document reference 8.17) are submitted as part of the DCO application.
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the	We agree with the approach for the cumulative impact assessment (CIA) in paragraph 51, as this is the only way to ensure the cumulative impacts on the SNS SCI are adequately assessed. We	The project and plans included in the CIA were determined in the CIA screening (Appendix 12.3), including marine aggregates etc. Seismic surveys from the oil and gas industry

Consultee	Date & Document	Comment	Response / where addressed in the ES
	Norfolk Boreas PEIR	agree with the other offshore wind farms that have been included in the CIA, however activities other than offshore wind farm construction within the SNS SCI, do not seem to be included e.g. oil and gas, marine aggregates etc.	have been included in the CIA.
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas PEIR	During piling activities, it is possible that there could be two vessels driving piles at any one time, and that pile-driving will start at one site, and then continue at another. We recommend that the CIA includes pile driving commencing at a second location, whilst the first is still being driven. The impact of the second pile driving location on the harbour porpoise population of the SNS SCI is highly dependent upon the location of the second pile-driving site which is likely to have a different potential area of impact to the first. This second pile-driving location will increase the noise levels generated and have a cumulative impact.	An assessment of the potential effects of concurrent piling has been undertaken for both Norfolk Boreas alone (see section 12.7.3.2.4) and for concurrent piling at Norfolk Boreas cumulatively with other offshore wind farms (see section 12.8.4.1).
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas PEIR	We recognise that the assessment has been undertaken with no mitigation measures applied, and we welcome the commitment to using mitigation methods to reduce the risk of piling activities on harbour porpoise and the SNS SCI. We also acknowledge that the full details of mitigation to be used are yet to be finalised in the MMMP, and the Site Integrity Plan (SIP) will set out the approach to deliver any project mitigation or management measures in relation to the SNS SCI. However, we have concerns over the embedded mitigation measures proposed and would like to see a commitment to using proven mitigation methods (see section below on Mitigation Methods). Until the details of the MMMP and SIP are finalised, it is impossible to conclude that there will be no Adverse Effect on Integrity (AEoI) on the SNS SCI.	Developing the MMMP and SIP in the pre-construction period will allow for a detailed review and assessment of the most effective and appropriate mitigation methods at that time, based on the latest scientific evidence to reduce underwater noise impacts, including embedded mitigation. A draft MMMP (document reference 8.13) and an In Principle SIP (document reference 8.17) are submitted as part of the DCO application.
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas	Our primary concern surrounds the intense noise pollution resulting from pile driving for all cetacean species and the harbour porpoise population supported by the SNS SCI. Reactions of harbour porpoises to the pile driving process have been recorded at distances many kilometres from the piling location (Brandt et	Acknowledged. An assessment of the potential for disturbance from pile driving is included in section 12.7.3.2.4. The assessments for the potential disturbance and possible behavioural response in harbour porpoise was based on the currently advised thresholds and criteria for underwater

Consultee	Date & Document	Comment	Response / where addressed in the ES
	PEIR	al., 2018, 2011; Carstensen et al., 2006; Dähne et al., 2013; Thomsen et al., 2006). In some cases pile driving is audible by harbour porpoises beyond 80 km from the source and could mask communication at 30 – 40 km (Thomsen et al., 2006). Bottlenose dolphins (*Tursiops truncatus*) could exhibit behavioural responses at distances of up to 40 km from pile driving locations (Bailey et al., 2010).	noise modelling, as well as the SNCB recommended 26km Effective Disturbance Radius (EDR). In addition, a review all relevant publications were conducted to put the assessment into context. There is no evidence that bottlenose dolphin would be present in the area of the Norfolk Boreas site, however, the MMMP and SIP (document reference 8.13 and 8.17) although aimed primarily at harbour porpoise would provide mitigation for other cetaceans / EPS.
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas PEIR	Research has shown that pile driving causes behavioural changes in harbour porpoises which leave the area during construction and in some instances did not later return to their usual numbers (Brandt et al., 2011; Carstensen et al., 2006; Teilmann and Carstensen, 2012). Some studies have shown harbour porpoise start to return in one area, yet years later have not returned to other areas (Snyder and Kaiser, 2009). The longest running study into the effects of windfarms on harbour porpoises shows that ten years later, the population has only recovered to 29% of the baseline level (Teilmann and Carstensen, 2012). Even where areas have been recolonised, it is not clear if these are the same animals returning or new animals moving into the area, or if the animals are using the area in the same way.	Acknowledged. An assessment of the potential for disturbance and behavioural response for harbour porpoise from pile driving is included in sections 12.7.3.2.4 and 12.7.3.2.5. VWPL has been heavily involved in the development of DEPONS (Disturbance Effects of Noise on the Harbour Porpoise Population in the North Sea), which used at a strategic level would allow consideration of the biological fitness consequences of disturbance from underwater noise, and the conclusions of a quantitative assessment to be put into a population level context.
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas PEIR	Either scenario is a significant period of time in a harbour porpoise life span (608 days for single phase, 243 days in each phase for the two phase approach, paragraph 405 Chapter 12 Marine Mammal Ecology), and with the potential for piling at more than one location at any one time, therefore the potential impact of pile-driving for Norfolk Boreas on the harbour porpoise population is high, covering the lifespan of a porpoise and with a high potential to affect breeding and feeding activity.	The assessment of disturbance to harbour porpoise as a result of pile driving, taking into account the total time that pile driving may be undertaken, is included in section 12.7.3.2.4.
Whale and Dolphin	letter dated 28th	Although it is likely that pile driving activity will not be constant, the installation of monopile foundations has been found to have a	Nabe-Nielsen et al. (2018) developed the DEPONS (Disturbance Effects of Noise on the Harbour Porpoise

Consultee	Date & Document	Comment	Response / where addressed in the ES
Conservation	November 2018 Comments on the Norfolk Boreas PEIR	profound negative effect on harbour porpoise acoustic activity up to 72 hours after pile driving activity (Brandt et al., 2011). It is unlikely that harbour porpoises will return to an area during these gaps, resulting in them most likely being excluded from the area for the entire duration of construction.	Population in the North Sea) model to stimulate individual animal's movements, energetics and survival for assessing population consequences of sub-lethal behavioural effects. The model was used to assess the impact of offshore windfarm construction noise on the North Sea harbour porpoise population, based on the acoustic monitoring of harbour porpoise during construction of the Dutch Gemini offshore windfarm. Local population densities around the Gemini windfarm recovered 2–6 hours after piling, similar recovery rates were obtained in the model. The model indicated that, assuming noise influenced porpoise movements as observed at the Gemini windfarm, the North Sea harbour porpoise population was not affected by construction of 65 wind farms, as required to meet the EU renewable energy target (Nabe-Nielsen et al., 2018).
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas PEIR	We are pleased that it is recognised in Chapter 12 Marine Mammal Ecology, section 12.7.3.2 that the impacts from piling include both physiological and behavioural impacts on marine mammals. We note that INSPIRE modelling has been used to predict underwater noise levels from the construction of Norfolk Boreas. Whilst we feel this is model will be helpful in the assessment, the model has been found to under predict noise levels (Spiga, 2015) which can potentially lead to underestimate the impact of piling on cetaceans. We are pleased that the National Marine Fisheries Service (NMFS) modelling (National Marine Fisheries Service (NMFS), 2016) is also used instead as agreed in the ETG.	Norfolk Boreas Limited are confident that the modelling used is appropriate for the purposes of this assessment. A precautionary approach has been used for the underwater noise modelling with the worst-case parameters used within the model, including piling hammer energies, soft-start and ramp-up scenarios, strike rate, duration of piling, receptor swim speeds and water depths. More information on the underwater noise modelling and INSPIRE model can be found in Appendix 5.4. During the development of the final MMMP for piling the underwater noise modelling will be reviewed, and updated, if required.
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas	WDC is concerned about the impacts of increased vessel activity particularly during construction. Increased vessel noise can interrupt harbour porpoise foraging behaviour and echolocation, which can lead to significantly fewer prey capture attempts (Wisniewska et al., 2018). There is an increased risk of collision and	An assessment of the increase of collision risk to harbour porpoise has been included in section 12.7.3.6, and an assessment of the potential disturbance due to increased vessel presence is included in section 12.7.3.4.

Consultee	Date & Document	Comment	Response / where addressed in the ES
	PEIR	disturbance to cetaceans from increased vessel activity (Dyndo et al., 2015; James, 2013). This is of particular importance as there are expected to be a large increase in the number of vessels in the Norfolk Boreas area during construction.	
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas PEIR	WDC do not agree with the assumption in 12.7.3.6 Chapter 12 Marine Mammal Ecology that "Marine mammals in the Norfolk Boreas offshore project area would be habituated to the presence of vessels and would be able to detect and avoid vessels"; as there is no evidence to base these assumptions upon. We also disagree with paragraph 505 "In addition, based on the assumption that harbour porpoise would be disturbed from a 26km radius during piling, there should be no potential for increased collision risk with vessels at Norfolk Boreas during the construction period" as harbour porpoise may not move out of the area, especially if the area is important for feeding and breeding.	Assessments on the potential impacts of vessels have been based on the worst-case scenarios. All vessel operators will use good practice to reduce any risk of collisions with marine mammals.
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas PEIR	Section 12.7.1 of Chapter 12 Marine Mammal Ecology cover the embedded mitigation measures that have already been incorporated into the project design. As discussed at EWG meetings, WDC are pleased to see a commitment to mitigation measures however, we strongly disagree that these measures are appropriate mitigation methods.	Developing the MMMP and SIP in the pre-construction period will allow for a detailed review and assessment of the most effective and appropriate mitigation methods at that time, based on the latest scientific evidence to reduce underwater noise impacts, including embedded mitigation. A draft MMMP (document reference 8.13) and an In Principle SIP (document reference 8.17) are submitted as part of the DCO application.
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas PEIR	We understand that the JNCC guidance for minimising the risk of injury to marine mammals from piling noise (JNCC, 2010) has been followed, with a more precautionary approach. We recognise that currently these are the only guidelines available to developers to use to minimise the impacts of piling activity on marine mammals, however it is widely known that these guidelines are outdated, and do not use the latest scientific evidence.	Reference to the JNCC guidance (JNCC, 2010) has been provided for context. Developing the MMMP in the pre-construction period will allow for a detailed review and assessment of the most effective and appropriate mitigation methods at that time, including the latest scientific evidence and guidance.
Whale and Dolphin	letter dated 28th	In particular WDC have concerns over the guidance that soft-starts should be used and the use of Marine Mammal Observers	Developing the MMMP in the pre-construction period will allow for a detailed review and assessment of the most

Consultee	Date & Document	Comment	Response / where addressed in the ES
Conservation	November 2018 Comments on the Norfolk Boreas PEIR	(MMOs). WDC do not consider 'soft-start' to be an adequate mitigation measure as they are only a reduction in sound source at the initiation of a piling event. It cannot be assumed that cetaceans will leave an area during a soft- start as they may be remain the area due to prey availability or breeding despite the harmful noise levels (Faulkner et al., 2018). Whilst a common sense measure, soft-starts are not a proven mitigation technique and so cannot be relied upon to mitigate impacts, especially for developments within the SNS SCI.	effective and appropriate mitigation methods at that time, including the latest scientific evidence and guidance for 'soft-starts'.
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas PEIR	We are concerned that acoustic deterrent devices (ADDs) such as pingers may be used to move marine mammals out of the area. Not only will this add another source of noise into the environment (Faulkner et al., 2018), the use of ADDs has not been proven as a mitigation for pile driving and cannot be relied upon for the range of species likely to be encountered in the wind farm region. The range of displacement from ADDs has the potential to exceed the range of displacement from pile driving itself when using bubble curtains (Dähne et al., 2017).	The potential disturbance from the proposed use of ADDs has been assessed in section 12.7.3.2.4. If the use of ADDs is proposed as a mitigation method the potential disturbance will be assessed against the risk of any physical or permanent auditory injury (PTS) to marine mammals. Examples of ADD use were included, but as outlined above all effective and appropriate mitigation methods will be reviewed during the development of the MMMP. The use of ADDs has been used as mitigation during piling at several European and UK offshore wind farms.
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas PEIR	Due to Norfolk Boreas being located within the SNS SCI, WDC would like to see a commitment to using mitigation methods that have been proven in both test scale (Diederichs et al., 2013; Wilke et al., 2012) and full-scale sites, in particular bubble curtains (Brandt et al., 2018; Dähne et al., 2017; Nehls et al., 2016).	Norfolk Boreas Limited is committed to using effective, proven and appropriate mitigation methods based on the latest scientific evidence as necessary to comply with the Conservation Objectives of the SNS SAC.
Whale and Dolphin Conservation	letter dated 28th November 2018 Comments on the Norfolk Boreas PEIR	However, until the details of the MMP are decided it is impossible to conclude that the MMMP will ensure that impacts from piling activity will be sufficiently mitigated. We are concerned that the MMMP currently only includes mitigation methods from the JNCC guidelines and would like to see a commitment to ensure that only proven mitigation methods are included in the MMMP.	Developing the MMMP in the pre-construction period will allow for a detailed review and assessment of the most effective and appropriate mitigation methods at that time, including the latest scientific evidence.
Whale and	letter dated 28th	Due to the concerns over the embedded mitigation methods, and	The MMMP and SIP will set out the approach to deliver any

Consultee	Date & Document	Comment	Response / where addressed in the ES
Dolphin Conservation	November 2018 Comments on the Norfolk Boreas PEIR	until the mitigation methods that are to be used are known, it is inaccurate to conclude that the mitigation measures will ensure that impacts from piling on harbour porpoise and the harbour porpoise population supported by SNS SCI will be reduced. WDC strongly disagrees with the conclusions in the PEIR that either stand-alone or in-combination, that impacts on the harbour porpoise will be negligible with or without embedded mitigation.	project mitigation or management measures in relation to harbour porpoise and the SNS SAC. Developing the MMMP and SIP in the pre-construction period will allow for a detailed review and assessment of the most effective and appropriate mitigation methods at that time, based on the latest scientific evidence to reduce underwater noise impacts. It is acknowledged that WDC disagree with the conclusions of the assessment that either stand-alone or in-combination, that impacts on the harbour porpoise will be negligible with or without embedded mitigation. However, we stand by the findings of the assessment and as previously outlined, Norfolk Boreas Limited is committed to using effective, proven and appropriate mitigation methods based on the latest scientific evidence.
Natural England	letter dated 27th November 2018 Statutory Consultation under Section 42 of the Planning Act 2008 and Regulation 11 of the Infrastructure Planning (Environmental Impact Assessment) Regulations 2009	Ongoing issues for Vanguard Marine Mammals: The main issues are summarised as: • In combination underwater noise • Mitigation • Soft start as mitigation • Risk of injury from UXO • Review of Consents strategic approach to noise • 20% of SAC disturbance threshold Advise that there will be a requirement to provide 'a revised site integrity plan based on final project design including adoption of possible mitigation measures which confirms the proposed timeframes of both site preparation and construction activities	Norfolk Boreas Limited have had due regard to ongoing consultation between Natural England and Norfolk Vanguard, however due to the timescales of both projects it has only been possible to include all agreements or changes made until the 20th March 2019. It is acknowledged that Natural England's concern regarding the soft-start as mitigation has now been removed (Marine Mammal ETG, 21st February 2019).

Consultee	Date & Document	Comment	Response / where addressed in the ES
		which pose a disturbance risk to marine mammals' to the MMO 6 months prior to construction.	
Marine Management Organisation	letter dated 7th December 2018 RE: Norfolk Boreas Offshore Wind Farm – Section 42 consultation	1.3 Chapter 3 describes the potential scenarios for construction of the Norfolk Boreas OWF; in one single phase or 2 phases, both spanning 4 years. Chapter 3 includes provision for a multi-phase construction approach with the proposed Norfolk Vanguard OWF. In the event that the Norfolk Vanguard OWF development is consented, this would increase overall duration of the construction phase. Chapter 3 also acknowledges that if the proposed Norfolk Vanguard OWF is not progressed, the construction programme for the Norfolk Boreas OWF could be brought forward by up to one year. In all scenarios, further consideration is required to demonstrate how the likely impacts will differ for each construction scenario, i.e. for a build scenario lasting 3 years compared to a build scenario lasting 7-10 years. If a multi-phase construction approach is to be adopted, then the MMO considers that the in-combination impacts must be assessed accordingly.	Further work has been undertaken to define the construction periods for both projects under single and two phased construction approaches. The revised indicative Norfolk Boreas programme (Table 12.16 and Table 12.17) show a three year construction programme. The most likely scenario would be that Norfolk Boreas is constructed approximately 1 year behind Norfolk Vanguard and therefore the combined construction period would last for up to five years.
Marine Management Organisation	letter dated 7th December 2018 RE: Norfolk Boreas Offshore Wind Farm – Section 42 consultation	The underwater noise assessment should provide a plot showing the predicted received sound levels against range, for the single strike sound exposure level (SEL). This will facilitate and streamline the process of comparing predictions with any future construction noise monitoring data collected for compliance purposes.	The Underwater Noise report (Appendix 5.4) has been updated to include a plot showing the transects of the single strike SEL results, against range. See section 5.1.1 of Appendix 5.4.
Marine Management Organisation	letter dated 7th December 2018 RE: Norfolk Boreas Offshore Wind Farm – Section 42 consultation	2.3 Section 6 of Appendix 5.4 considers noise impacts (aside from pilling activity). The text refers to a simple modelling approach based on measured data scaled to relevant parameters for the site. The MMO requests further detail on the modelling used.	The Underwater Noise report (Appendix 5.4) has been updated to include information on the 'SPEAR' model used within this assessment.

Consultee	Date & Document	Comment	Response / where addressed in the ES
Marine Management Organisation	letter dated 7th December 2018 RE: Norfolk Boreas Offshore Wind Farm – Section 42 consultation	Table 6.2 summarises the estimated unweighted source levels for the different construction noise sources considered, which are based on various datasets. The MMO requests that the references be provided for these datasets.	The data sets used to estimate the unweighted source levels are not formally published, and so cannot be directly referenced. It should be noted that data from hundreds of datasets have been built into the model and it doesn't refer explicitly to any of them, they only identify trends. In addition, because of confidentiality it is not possible to specifically reference any other projects. The modelling has been used successfully at other offshore wind farms and shown to be accurate/conservative based on the measurements during construction.
Marine Management Organisation	letter dated 7th December 2018 RE: Norfolk Boreas Offshore Wind Farm – Section 42 consultation	2.6 Section 6.3 focuses on the assessment of operational noise. The MMO requests further detail is provided on why the linear fit is considered to give a worst-case estimate, as shown in Figure 6.1 (Appendix 5.4).	The Underwater Noise report (Appendix 5.4) has been updated to include the following information: "*This fit was applied to the data available for operational wind turbine noise as this was the extrapolation that would lead to the highest, and thus worst case, estimation of source noise level from the larger 15 MW turbine. This resulted in an estimated source level of 158.5 dB SPL_{rms}, 12 dB higher than the 6 MW turbine, the largest for which noise data existed. Alternatively, using a logarithmic fit (3 dB per doubling of power output) to data would lead to a source level of 149.8 dB SPL_{rms}. A more extreme and unlikely 6 dB increase per doubling of power output would lead to 154.5 dB SPL_{rms}. Thus, the linear estimate used is considerably higher than alternatives and is considered precautionary*."
Marine Management Organisation	letter dated 7th December 2018 RE: Norfolk Boreas Offshore Wind Farm – Section 42	2.7 In Table 6.5 of Appendix 5.4, it is not clear how the unweighted Root Mean Square source levels for operational wind farms have been derived. The MMO requests further clarification.	The Underwater Noise report (Appendix 5.4) has been updated to include the following information: "*The operational source levels (as SPLRMS) for the measured sites are given in Table 6.5 (Cheesman, 2016), with an estimated source level for Norfolk Boreas in the bottom two rows. These were derived from measurement campaigns at*

Consultee	Date & Document	Comment	Response / where addressed in the ES
	consultation		*each of the identified wind farm sites, based on data at multiple distances to predict a source level*."
Eastern Inshore Fisheries and Conservation Authority	letter dated 7th December 2018 Response to Norfolk Boreas PEIR	Whilst the East Marine Plans state that proposals that contribute to offshore wind energy generation within the Plan area should be supported, consideration needs to be given to the cumulative impacts that developments within the area and adjacent areas have on the ecosystem. The East Marine Plans support sustainably-developed offshore wind energy generation projects. There are many such projects in the southern North Sea, including Dudgeon, Sheringham Shoal, Scroby Sands, Race Bank, Triton Knoll, Lynn and Inner Dowsing, Lincs, East Anglia and Norfolk Vanguard offshore wind farms as well as other projects and plans. While Eastern IFCA appreciate that the cumulative impacts of Norfolk Boreas with Norfolk Vanguard, East Anglia THREE and aggregate extraction activities have been comprehensively assessed within this PEIR, Eastern IFCA do not agree with the cumulative impact approach taken, in particular the consideration that already operational offshore wind farms, active licenced activities and implemented measures form part of the existing environment. Eastern IFCA would encourage further assessment of the cumulative impacts of all Southern North Sea wind farm activity, licenced or otherwise, as well as other activities. The impacts of these projects on the marine environment and fisheries should be assessed in-combination, highlighting any potential cumulative effects associated with the licence application and guiding decision-making and plan implementation in a stepwise approach.	The project and plans included in the CIA were determined in the CIA screening (Appendix 12.3). The CIA for marine mammals has taken into account operational offshore wind farms (see section 12.8.5.1.2).
Marine Management Organisation	letter dated 27th February 2019 UWN assessment	In Section 6.2 of the assessment, 'Other Construction Activities' are all continuous sources and source levels have been provided as root mean square (RMS) levels (which is appropriate), as summarised in Table 6-2 and 6-5 of the report. However, the National Marine Fisheries Service (NMFS) (2018) noise exposure	The impulsive criteria are stricter than the non-pulse. All of the results for the continuous noise using the impulsive criteria are low, less than 500m. Any ranges calculated using the non-pulse criteria will therefore be much smaller than this. Therefore, new modelling using the non-pulse criteria

Consultee	Date & Document	Comment	Response / where addressed in the ES
		criteria relevant for impulsive sources (for PTS) have been used, instead of the non-impulsive criteria. This should be corrected.	would not add anything further to the assessment.
Marine Management Organisation	letter dated 27th February 2019 UWN assessment	Section 6.3 of the UWN assessment focuses on Permanent Threshold Shift (PTS) and there is no consideration of Temporary Threshold Shift (TTS) in marine mammals (see Table 6-3 and Table 6-6 in the report). The MMO acknowledges that to date it remains difficult for TTS to be quantified and to what extent TTS results in PTS for Cetaceans. The MMO recommends that the ES should reference TTS in a qualitative manor for context	TTS has not been modelled for other construction activities and operational turbines, but the ES provides an assessment of the possible behavioural response of harbour porpoise to underwater noise during other construction activities and from operational turbines based on the Lucke et al. (2009) Unweighted SEL 145 dB re 1 µPa criteria. Chapter 12 sections 12.7.3.3, 12.7.4.4 and 12.7.4.1 of the ES refers to TTS in a qualitative manor for context.

12.4 Assessment Methodology

12.4.1 Impact Assessment Methodology

56. The general EIA methodology is set out within Chapter 6. In principle, a matrix approach has been used to assess impacts following best practice, EIA guidance and the approach outlined in the Norfolk Boreas Scoping Report (Royal HaskoningDHV, 2017) and the Marine Mammal Method Statement (Appendix 9.26 of the Consultation Report (document reference 5.1)). The data sources summarised in section 12.5.2 were used to characterise the existing environment (see section 12.6 and Appendix 12.2). Each potential impact has been identified using expert judgement and through consultation with SNCBs via the Scoping Process, PEIR and EPP. An assessment of the significance is then made based on the sensitivity, value and magnitude of effect, the definitions of which were also agreed in consultation during the EPP.

12.4.1.1 Sensitivity

57. The sensitivity of a receptor is determined through its ability to accommodate change and on its ability to recover if it is negatively 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 and rarity (as reflected in the species conservation status and legislative importance, see section 12.4.1.2).

58. 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 12.5 defines the levels of sensitivity and what they mean for the receptor.

Table 12.5 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.

Sensitivity	Definition
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.

12.4.1.2 Value

59. In addition, the 'value' of the receptor forms an important element within the assessment, for instance, if the receptor is a protected species. It is important to understand that high value and high sensitivity are not necessarily linked. A receptor could be of high value (e.g. an Annex II species), 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.

60. In the case of marine mammals all cetaceans in UK waters are EPS and, therefore, are internationally important. Harbour porpoise, bottlenose dolphin, grey seal and harbour seals are also afforded international protection through the designation of Natura 2000 sites. As such, all species of marine mammal can be considered to be of high value.

61. The value will be considered, where relevant, as a modifier for the sensitivity assigned to the receptor, based on expert judgement. Table 12.6 provides definitions for the value afforded to a receptor based on its legislative importance.

Table 12.6 Definitions of 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

12.4.1.3 Magnitude

62. The significance of the potential impacts is also based on the intensity or degree of disturbance to the baseline conditions and is categorised into four levels of magnitude: high; medium; low; or negligible, as defined in Table 12.7.

63. The thresholds defining each level of magnitude of effect for each 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 magnitude of each effect is calculated or described in a quantitative or qualitative way within the assessment.

64. The number of animals that can be 'removed' from a population through injury or disturbance will vary between species, but is largely dependent on the growth rate of the population; populations with low growth rates can sustain the removal of a smaller proportion of the population. 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 FCS. The JNCC et al. (2010) draft guidance also provides limited consideration of temporary effects, with guidance reflecting consideration of permanent displacement. As such this guidance has been considered in defining the thresholds for magnitude of effects.

65. Temporary effects are considered to be of medium magnitude at greater than 5% of the reference population being affected within a year. 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 would be halted. In assigning 5% to a temporary impact in this assessment, consideration is given to uncertainty of the individual consequences of temporary disturbance.

66. Permanent effects to greater than 1% of the reference population being affected within a year are considered to be high magnitude in this assessment. The assignment of this level 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 12.7 Definitions of 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 lifetime of the project). Assessment indicates that >5% of the reference population are anticipated to be exposed to the effect. OR Temporary effect (limited to 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 >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 between >0.01% and <=1% 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

Magnitude	Definition
	project). Assessment indicates that >1% and <=5% of the reference population are anticipated to be exposed to the effect. OR Temporary effect (limited to 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 between >5% and <=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 between >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 lifetime 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 (limited to 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 between >1% and <=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 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.

12.4.1.4 Impact significance

67. Following the identification of receptor sensitivity and the magnitude of the effect, the impact significance is 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, a precautionary approach is taken to assign a higher level of probability to adverse effects.

68. The matrix (provided in Table 12.8) will be used as a framework to aid determination of the impact assessment. Definitions of impact significance are provided in Table 12.9.

69. For the purposes of this assessment and specifically the marine mammal assessment, major and moderate impacts are considered to be significant. However, whilst minor impacts would not be considered significant in their own right, they may contribute to significant impacts cumulatively or through inter-relationships.

Table 12.8 Impact significance matrix

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

Table 12.9 Impact significance definitions

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

70. Embedded mitigation will be referred to and included in the initial assessment of impact. If the resultant impact does not require mitigation (or none is possible) the residual impact will remain the same. If, however, mitigation is required, there is an assessment of the post-mitigation residual impact.

12.4.2 Cumulative Impact Assessment

71. The CIA identifies areas where the predicted impacts of the construction, operation, maintenance and decommissioning of the project could interact with impacts from different plans or projects within the same region and impact sensitive receptors.

72. As outlined in The Planning Inspectorate (2015) Advice Note 17:

The need to consider cumulative effects in planning and decision making is set out in planning policy[2], in particular the National Policy Statements (NPS)[3]. For example, the Overarching NPS for Energy (EN-1)[4] paragraph 4.2.5 states that "*When considering cumulative effects, the ES should provide information on how the effects of the applicant's proposal would combine and interact with the effects of other development*[5] *(including projects for which consent has been sought or granted, as well as those already in existence)*".

73. The 'other development' types that should be considered in the CIA, as set out in Advice Note 17 are:

1. *Under construction, including:*
   Permitted application(s) but not yet implemented; and
   Submitted application (s) but not yet determined.
2. *Projects on the Planning Inspectorate's Programme of Projects where a scoping report has been submitted.*
3. *Projects on the Planning Inspectorate's Programme of Projects where a scoping report has not been submitted.*
   Identified in the relevant Development Plan (and emerging Development Plans – with appropriate weight being given as they move closer to adoption) recognising that much information on any relevant proposals will be limited; and
   Identified other plans and programmes (as appropriate) which set the framework for future development consent/approvals, where such development is reasonably likely to come forward.

74. For this assessment, the stages of project development have been adopted as 'Tiers' of project development status within the cumulative impact assessment. These Tiers are based on guidance issued by JNCC and Natural England in September 2013, as follows:

- Tier 1: built and operational projects;
- Tier 2: projects under construction;
- Tier 3: projects that have been consented (but construction has not yet commenced);
- Tier 4: projects that have an application submitted to the appropriate regulatory body that have not yet been determined;

[2] For example: The relevant National Policy Statements (England and Wales) and National Planning Policy Framework (NPPF) (England);
[3] http://infrastructure.planninginspectorate.gov.uk/legislation-and-advice/national-policy-statements/
[4] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47854/1938-overarchingnps-
for-energy-en1.pdf
[5] 'other development' is taken to include plans and projects

- Tier 5: projects that the regulatory body are expecting to be submitted for determination (e.g. projects listed under the Planning Inspectorate programme of projects); and
- Tier 6: projects that have been identified in relevant strategic plans or programmes.

75. These Tiers are used as they are considered more appropriate to use compared to the Tiers in The Planning Inspectorate (2015) Advice Note 17 for the types of projects and plans considered in this assessment, in particular for the offshore wind farm stages.

76. The types of plans and projects to be taken into consideration are:

- Other offshore wind farms;
- Other renewables developments;
- Aggregate extraction and dredging;
- Licenced disposal sites;
- Shipping and navigation;
- Planned construction sub-sea cables and pipelines;
- Potential port/harbour development;
- Oil and gas development and operation, including seismic surveys; and
- UXO clearance.

77. Commercial fisheries within the North Sea and underwater noise associated with vessels from industries other than offshore wind farms, have the potential to cause a cumulative impact on marine mammals, including harbour porpoise, alongside the construction of the Norfolk Boreas project, through both the direct impact of by-catch and the indirect impact through the loss of marine mammal prey species (from commercial fisheries) and the disturbance from underwater noise (from vessel presence).

78. By-catch by commercial fisheries is recognised as a historic and continuing cause of harbour porpoise mortality in the southern North Sea and will therefore be a factor in shaping the size of the current North Sea (NS) Management Unit (MU) population. The available prey resource for harbour porpoise has also been influenced by historic and continuing commercial fishing. Noise from vessels associated with other (than offshore wind farm industries) plans or projects such as oil and gas, aggregates and commercial fisheries, are also considered to be part of the baseline conditions.

79. This approach is in accordance with the Planning Inspectorate Advice Note 17 Cumulative Effects Assessment, which states that:

"*Where other projects are expected to be completed before construction of the proposed NSIP and the effects of those projects are fully determined, effects arising from them should be considered as part of the baseline*".

80. The potential for cumulative impacts associated with commercial fisheries has been considered in the recent draft HRA for the Review of Consents (RoC) (which was consulted upon in November 2018; BEIS, 2018). With regard to effects to habitats, the draft RoC HRA states that (note that the site was designated as a SCI at the time of writing):

"*19.152 There have been no quantified assessments undertaken on the extent impacts from commercial fishing may have within the SCI and therefore information to inform this assessment is not available.*

19.154 Without knowing the extent of impact on the seabed arising from the fishing industry and aggregate extraction it is not possible to undertake an in-combination assessment that addresses all the potential impacts on the habitats within the SCI."

81. The conservation status of harbour porpoise has not declined in the years that commercial fishing has been undertaken in the North Sea and remains at a favourable level within North Sea and in UK waters as a whole; therefore, the historical and current levels of commercial fishing in the North Sea is not considered to have affected the conservation status of the species (BEIS, 2018).

82. With regard to direct effects on harbour porpoise, the draft RoC HRA (BEIS, 2018) also states that:

"*19.213 Commercial fishing has occurred within the SCI for many years and has had, and will continue to have, direct and indirect impacts on harbour porpoise, their habitat and prey within the SCI. As the conservation status of harbour porpoise in UK waters and the SCI is considered favourable (JNCC 2016, 2017a) current and historical levels of fishing in the SCI are not considered to have affected the conservation status of the species.*

19.214 There are no known plans to suggest that the level of fishing within the SCI will significantly increase over the period the consented wind farms are planned to be constructed, such that, it is predicted that the current level of impacts from fishing on harbour porpoise within the SCI will not increase."

83. It is also noted that Natural England's Deadline 4 Response to the Further Examiners' Questions and Requests for information for Hornsea Project 3 (15th January 2019) (page 46, Q 2.2.73) was that:

"*Where there is ongoing fishing activity in the site it, is important that the impacts of the activity are captured within the assessment in the context of the conservation* *objectives of the affected designated site(s). This assessment will likely take place as part of the baseline characterisation of the development area, however, as fishing activity is mobile, variable and subject to change, there may be instances whereby fishing impacts are not adequately captured in the baseline characterisation and therefore may need to be considered as part of the in-combination assessment. This could be due to a change in effort; change in management; or a change in legislation amongst other things, and fishery managers (i.e. MMO and IFCAs) would be best placed to advise on this.*

In relation to the assessment of impacts on the SNS SCI, Natural England……. are not currently aware of anything that would have significantly altered the levels of fishing activity within the site; any current plans for new fisheries, or changes to existing fisheries that have not been captured, but we would look to fisheries managers to advise more definitively on these points."

84. This, along with the draft RoC, suggests that by-catch has not affected a population considered to be in FCS, whilst Natural England acknowledge that there is no known change to the fishery which would alter this position.

85. Therefore, the potential impacts from commercial fishing (including by-catch and loss of prey species) and from the underwater noise associated with other, non-offshore wind farm industries (including oil and gas, aggregates and commercial fisheries) are considered to be a part of the environmental baseline for marine mammals of the North Sea, including for harbour porpoise, and are screened out of further assessment for Norfolk Boreas.

86. The CIA is a two-part process in which an initial list of potential projects is identified with the potential to interact with Norfolk Boreas based on the mechanism of interaction and spatial extent of the reference population for each marine mammal receptor. Following a tiered approach, the list of projects is then refined based on the level of information available for this list of projects to enable further assessment.

87. The plans and projects screened in to the CIA are:

(1) Located in the marine mammal MU population reference area (defined for individual species in the assessment sections);
(2) Offshore wind farm and other renewable developments, if there is the potential that the construction period could overlap with Norfolk Boreas. This has been based on the date of consent, following which the projects could be constructed (a highly precautionary approach); and
(3) Offshore wind farm and other renewable developments, if the construction and / or piling period could overlap with Norfolk Boreas, based on best available

information on when the developments are likely to be constructed and piling (a more realistic approach and indicative scenario).

88. 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.

89. The project Tiers considered in the CIA for marine mammals are outlined in Table 12.10 and the CIA screening is provided in Appendix 12.3.

Table 12.10 Tiers in relation to project category which have been screened into the CIA

Project category	UK	Other
Other offshore wind farms	Tier 1,2,3,4	Tier 1,2,3
Other renewable developments (tidal and wave)	Tier 1,2,3,4	Tier 1,2,3
Aggregate extraction and dredging	Tier 1,2,3	Screened out
Oil and Gas installations (including surveying)	Tier 1,2,3	Screened out
Navigation and shipping	Tier 1,2,3	Screened out
Planned construction of sub-sea cables and pipelines	Tier 1,2,3	Screened out
Licenced disposal sites	Tier 1,2,3	Screened out

12.4.3 Transboundary Impact Assessment

90. The potential for transboundary impacts has been addressed by considering the reference populations and potential linkages to non-UK sites as identified through telemetry studies.

91. The assessment of the effect on the integrity of the transboundary European sites as a result of impacts on the designated marine mammal populations will be undertaken and presented in the Report to inform the HRA (document reference 5.3), which will be submitted as part of the DCO application.

12.5 Scope

12.5.1 Study Area

92. Marine mammals are highly mobile and transitory in nature, therefore it is necessary to examine species occurrence not only within the Norfolk Boreas offshore project area, but also over the wider North Sea region. For each species of marine mammal, the following study areas have been 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:

- Harbour porpoise North Sea (NS) MU;
- White-beaked dolphin Celtic and Greater North Seas MU;
- Minke whale Celtic and Greater North Seas MU;
- Grey seal South-east England, North-east England and UK East Coast MUs, and the Wadden Sea region; and
- Harbour seal South-east England MU and the Wadden Sea region.

93. 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). The study areas, MUs and reference populations (see section 12.6.1 and Appendix 12.2) used in the assessment have been determined based on the most relevant information and scale at which potential impacts from Norfolk Boreas alone and in-combination with other plans and projects could occur.

94. The status and activity of marine mammals known to occur within or adjacent to Norfolk Boreas is 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 agreed reference population.

12.5.2 Data Sources

95. Information to support the EIA is based on 24 months (August 2016 to July 2018) of survey data for Norfolk Boreas, as agreed through the EPP (Marine Mammal ETG meeting, March 2018).

96. High resolution aerial digital still imagery was collected for marine mammals (combined with ornithology surveys) over the Norfolk Boreas site with a 4km buffer, covering an area of 1,223km^2 (see Appendix 12.2). Coverage of the site and 4km buffer was between approximately 8.7% and 9.5% per month. All images were analysed to enumerate marine mammals to species level, where possible (see Appendix 12.2 for further details).

97. The Norfolk Boreas project interconnector search area falls within the Norfolk Vanguard offshore project areas; half of the search area within Norfolk Vanguard West and half in Norfolk Vanguard East. In addition, the Norfolk Vanguard East surveys overlap with the Norfolk Boreas Offshore Project Area. Therefore, the surveys undertaken for Norfolk Vanguard are also used to further inform the baseline assessment and provide further information on the wider area. The surveys undertaken for Norfolk Vanguard were:

- Aerial survey data of the former East Anglia FOUR site (now NV East) with 4km buffer between March 2012 and February 2014;

- Aerial survey data of NV East with 4km buffer from September 2015 to April 2016; and
- Aerial survey data of NV West with 4km buffer from September 2015 to August 2017.

98. In addition, the surveys for other offshore wind farms in the former Zone, as outlined in Table 12.11 provide useful context (see Appendix 12.2).

99. During consultation, discussions were held as part of the EPP to agree the best available information to use in the ES. Table 12.11 summarises the agreed data sets and information sources.

Table 12.11 Data and information sources

Data	Year	Coverage	Confidence	Notes
Aerial survey of the Norfolk Boreas site	August 2016 to July 2018	Norfolk Boreas Offshore Project Area plus 4km buffer	High	Data available from August 2016 to July 2018.
Aerial survey of Norfolk Vanguard site	March 2012 to February 2014 September 2015 to April 2016 September 2015 to August 2017	Former East Anglia FOUR site (now NV East) with 4km buffer. NV East with 4km buffer NV West with 4km	High	The Norfolk Boreas Project Interconnector cable search areas are within the Norfolk Vanguard OWF sites.
Aerial survey of the Former East Anglia Zone	November 2009 to March 2010	The Former East Anglia Zone (including Norfolk Boreas)	High	The Crown Estate Enabling Action data (video aerial survey).
Aerial survey data of the former East Anglia Zone	April 2010 to April 2011	The Former East Anglia Zone (including Norfolk Boreas)	High	Provides information and context for wider area.
Aerial survey data of East Anglia ONE site	April 2010 to October 2011	East Anglia ONE site plus buffer	High	Provides information and context for wider area.
East Anglia ONE boat based	May 2010 to April	East Anglia ONE	High	Provides information and

Data	Year	Coverage	Confidence	Notes
surveys	2011	site		context for wider area.
Aerial surveys of East Anglia THREE site	September 2011 to August 2013	East Anglia THREE site plus 4km buffer	High	Provides information and context for wider area.
Aerial surveys of the East Anglia ONE North site	September 2016 to July 2018	East Anglia ONE North site plus 4km buffer	High	Provides information and context for wider area.
Aerial surveys of the East Anglia TWO site	November 2015 to April 2016, September 2016 to October 2016, and May 2018	East Anglia TWO site plus 4km buffer	High	Provides information and context for wider area.
Small Cetaceans in the European Atlantic and North Sea (SCANS-III) data (Hammond et al., 2017)	Summer 2016	North Sea and European Atlantic waters	High	Provides information including abundance and density estimates for the Norfolk Boreas area.
SCANS-II data (Hammond et al., 2013)	July 2005	North Sea and European Atlantic shelf waters	High	Provides information including abundance and density estimates for the Norfolk Boreas area.
Management Units (MUs) for cetaceans in UK waters (Inter-Agency Marine Mammal Working Group (IAMMWG), 2015)	2015	UK waters	High	Provides information on MU for the Norfolk Boreas area.
Offshore Energy Strategic Environmental Assessment (including relevant appendices and technical reports) (Department of Energy and Climate Change (DECC) (now BEIS, 2016)	2016	UK waters	High	Provides information for wider area.
The identification of discrete and persistent areas of relatively high harbour porpoise density in the wider UK marine area (Heinänen and Skov, 2015)	1994-2011	UK Exclusive Economic Zone (EEZ)	High	Data was used to determine harbour porpoise SAC sites. Provides information on harbour porpoise in southern North Sea area.
Revised Phase III data analysis of Joint Cetacean Protocol (JCP) data resources (Paxton et al.,	1994-2011	UK EEZ	High	Provides information for the Norfolk Bank development area, which includes the Norfolk

Data	Year	Coverage	Confidence	Notes
2016)				Boreas site.
Survey for small cetaceans over the Dogger Bank and adjacent areas in summer 2011 (Gilles et al., 2012)	Summer 2011	Dogger Bank and adjacent areas	High to Medium	Provides information for wider area.
Seasonal habitat-based density models for a marine top predator, the harbour porpoise, in a dynamic environment (Gilles et al., 2016)	2005-2013	UK (SCANS II, Dogger Bank), Belgium, the Netherlands, Germany, and Denmark	High to Medium	Provides information for central and southern North Sea area.
Distribution of Cetaceans, Seals, Turtles, Sharks and Ocean Sunfish recorded from Aerial Surveys 2001-2008 (The Wildfowl & Wetlands Trust (WWT), 2009)	2001-2008	UK areas of the North Sea	High to Medium	Provides information for on species sighted in southern North Sea area.
MARINElife surveys from ferries routes across the southern North Sea area (MARINElife, 2018)	2017-May 2018	Southern North Sea	Medium	Provides information on species sighted in southern North Sea area.
Sea Watch Foundation volunteer sightings off eastern England (Sea Watch Foundation, 2018)	2017-May 2018	East coast of England	Medium to Low	Provides information on species sighted along east coast of England.
UK seal at sea density estimates and usage maps (Russell et al., 2017)	1988-2012	North Sea	High	Provides information on abundance and density estimates for seal species.
Seal telemetry data (e.g. Sharples et al., 2008; Russel and McConnell, 2014; Russell, 2016)	1988-2010; 2015	North Sea	High	Provides information on movements and distribution of seal species.
Special Committee on Seals (SCOS) annual reporting of scientific advice on matters related to the management of seal populations (SCOS, 2017)	2017	North Sea	High	Provides information on seal species.
Seal count data at Horsey haul-out sites during breeding season (Friends of Horsey Seals, 2017/2018)	2017-2018	Norfolk coastline from Winterton to Waxham	Medium	Counts of grey seal at haul-out sites during breeding season.
Counts of grey seal in the Wadden Sea (Trilateral Seal Expert Group (TSEG), 2017a)	Spring 2017	Wadden Sea	Medium	Counts of grey seal during moult season.

Data	Year	Coverage	Confidence	Notes
Counts of harbour seal counts in the Wadden Sea (TSEG), 2017b)	June 2017	Wadden Sea	Medium	Counts of harbour seal during pupping season.

12.5.3 Assumptions and Limitations

100. Due to the large amount of data collected during the Zone Environmental Appraisal (ZEA) and site specific surveys for Norfolk Boreas, as well as other projects in the former Zone and other available data for marine mammals within the region, there is a good understanding of the existing environment. There are, however some limitations to marine mammal surveys, primarily due to the highly mobile nature of marine mammals and therefore the potential variability in usage of the site; each survey provides only a snapshot. However, the surveys in the study area over the last decade show relatively consistent results. There are also limitations in the detectability of marine mammals from aerial surveys. Appendix 12.2 seeks to address these limitations by estimating a correction factor in order to determine estimated absolute density estimates from the site specific aerial surveys.

101. Where possible, an overview of the confidence of the data and information underpinning the assessment will be presented. Confidence will be classed as High, Medium or Low depending on the type of data (quantitative, qualitative or lacking) as well as the source of information (e.g. peer reviewed publications, grey literature) and its applicability to the assessment.

12.6 Existing Environment

102. The available data (Table 12.11) indicate that harbour porpoise is the most abundant cetacean species present within this region, with occasional sightings of dolphin species (most likely white-beaked dolphin), with rare sightings of low numbers of other cetaceans.

103. As agreed with the Norfolk Boreas marine mammal ETG, consideration has been given to white-beaked dolphin and minke whale and baseline information has been included in Appendix 12.2, however, given the low numbers and infrequent sightings of these species in and around the Norfolk Boreas site, it has been concluded that there is a very low risk of any significant impacts and therefore these species have not been assessed further.

104. A review of the data and information sources outlined in Table 12.11, as well as other relevant information (Appendix 12.2), indicates that marine mammal species likely to be present in the Norfolk Boreas area and therefore taken forward for the impact assessment (as agreed with the marine mammal ETG, 12th March 2018) are:

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

105. Section 12.6.4 provides a summary of the relevant density estimates and reference populations that are used in the assessments.

12.6.1 Harbour porpoise

106. The information relevant to the assessment for harbour porpoise has been included in this section, with further information provided in Appendix 12.2.

12.6.1.1 Distribution

107. Data from the SCANS-III survey indicates that the occurrence of harbour porpoise is greater in the central and southern areas of the North Sea compared to the northern North Sea (Hammond et al., 2017), which is consistent with the SCANS-II survey (Hammond et al., 2013).

108. Within the southern North Sea, Heinänen and Skov (2015) identified one area of high harbour porpoise density; from the western slopes of Dogger Bank south along a 30m depth contour towards an area off the Norfolk coast. The Heinänen and Skov (2015) analysis was used in the identification of potential SACs for harbour porpoise in UK waters (see section 12.6.1.5.1).

109. The seasonal maps produced by Gilles et al. (2016) for harbour porpoise density across the central and south-eastern North Sea were consistent with previously described seasonal patterns of harbour porpoise distribution. With the spring seasonal density map indicating major hotspots in the southern and south-eastern part of the North Sea, mainly inshore close to the Belgian and Dutch coasts extending toward the German coast. Another potential hotspot in spring was at Dogger Bank and the area north-west of this large sandbank (Gilles et al., 2016). In summer, there was an apparent shift, compared to spring, toward offshore and western areas, with a large hotspot present off the German and Danish west coast that extended toward the Dogger Bank. The seasonal model for autumn indicated lower densities compared to spring and summer, the distribution was spatially heterogeneous and areas with higher densities were predicted north-west of the Dogger Bank and off the German and Danish west coasts (Gilles et al., 2016).

110. The JCP Phase-III report (Paxton et al., 2016) indicated a high use area for the Norfolk Bank development area (see Appendix 12.2).

12.6.1.2 Diet

111. The distribution and occurrence of harbour porpoise and other marine mammals is most likely to be related to the availability and distribution of their prey species. For

example, sandeels (Ammodytidae species), which are known prey for harbour porpoise, exhibit a strong association with particular surface sediments (Gilles et al., 2016; Clarke et al., 1998).

112. Harbour porpoises are generalists and their diet will therefore differ according upon their location. The diet varies geographically, seasonally and annually, reflecting changes in available food resources and differences in diet between sexes or age classes may also exist. The diet of the harbour porpoise consists of a wide variety of fish, including pelagic schooling fish, as well as demersal and benthic species, especially Gadoids, Clupeids and Ammodytes. Other prey species such as cephalopods, other molluscs, crustaceans and polychaetes have also been recorded (Berrow and Rogan, 1995; Kastelein et al., 1997; Börjesson et al., 2003; Santos and Pierce, 2003; Santos et al., 2004; Pierce et al., 2007).

113. Harbour porpoise tend to concentrate their movements in small focal regions (Johnston et al., 2005), which often approximate to particular topographic and oceanographic features and are associated with prey aggregations (Raum-Suryan and Harvey, 1998; Johnston et al., 2005; Keiper et al., 2005; Tynan et al., 2005). Consequently, habitat use is highly correlated with prey density rather than any particular habitat type.

114. Harbour porpoise have relatively high daily energy demands and need to consume between 4% and 9.5% of their body weight in food per day (Kastelein et al., 1997). If a harbour porpoise does not capture enough prey to meet its daily energy requirements it has been estimated that it can only rely on stored energy (primarily blubber) for three to five days, depending on body condition (Kastelein et al., 1997).

12.6.1.3 Abundance and density estimates

12.6.1.3.1 North Sea MU

115. The SCANS-III estimate of harbour porpoise abundance in the North Sea MU is 345,373 (CV = 0.18; 95% CI = 246,526-495,752) with a density estimate of 0.52/km^2 (CV = 0.18; Hammond et al., 2017). This is the reference population for harbour porpoise, as agreed with Natural England as part of the Norfolk Vanguard EPP (letter dated 03/01/2018; Table 12.4) and this approach was agreed for the Norfolk Boreas at the ETG meeting on 12th March 2018.

12.6.1.3.2 SCANS data

116. For the entire SCANS-III survey area, harbour porpoise abundance in the summer of 2016 was estimated to be 466,569 with an overall estimated density of 0.381/km^2 (CV = 0.154; 95% CI = 345,306-630,417; Hammond et al., 2017).

117. The Norfolk Boreas site is located in both SCANS-III survey blocks L and O (see Appendix 12.2):

- The estimated abundance of harbour porpoise in SCANS-III survey block L is 19,064 harbour porpoise (CV = 0.38; 95% CI = 6,933-35,703), with an estimated density of 0.607 harbour porpoise/km^2 (CV = 0.38; Hammond et al., 2017).
- The estimated abundance of harbour porpoise in SCANS-III survey block O is 53,485 harbour porpoise (CV = 0.21; 95% CI = 37,413-81,695), with an estimated density of 0.888 harbour porpoise/km^2 (CV = 0.21; Hammond et al., 2017).

12.6.1.3.3 Norfolk Vanguard site specific surveys

118. The Norfolk Vanguard site specific surveys included 32 months of data for Norfolk Vanguard East, and 24 months for Norfolk Vanguard West. The Norfolk Vanguard East survey data included a 4km buffer, with an overlap with the Norfolk Boreas Site. The project interconnector search area is located within both the Norfolk Vanguard East and West project boundaries (Figure 5.1)

119. The Norfolk Vanguard site specific surveys were undertaken using the same methodologies as that of the Norfolk Boreas site specific surveys.

120. The annual mean density estimate, when using the seasonal correction factor is 1.26/km^2 for NV East (without buffer). The annual mean density estimate, when using the seasonal correction factor is 0.79/km^2 for the NV West area (without buffer); see Appendix 12.2.

121. The NV East and NV West density estimates of 1.26/km^2 and 0.79/km^2, respectively, based on the mean annual density and using the seasonal correction factors (see Appendix 12.2), will be used to inform any assessment of impacts within the project interconnector search areas. Using the mean annual density allows for seasonal variation in the number of harbour porpoise that could be present.

12.6.1.3.4 Norfolk Boreas site specific surveys

122. As outlined in section 12.5.2, APEM collected high resolution aerial digital still imagery for marine mammals over the Norfolk Boreas site, with a 4km buffer area, covering a total of 1,223km^2. Plate 2.1 in Appendix 12.2 shows the survey area for the Norfolk Boreas site. Further information is provided on the analysis and interpretation of the survey results in Appendix 12.2.

123. The information included in this ES is based on 24 months of survey for the Norfolk Boreas site; August 2016 to July 2018.

124. Data from the site specific surveys were used to generate density estimates at the Norfolk Boreas site. Further information on the data analysis, including correction factors, is provided in Appendix 12.2.

125. The annual mean density estimate when using the seasonal correction factor is 1.06/km^2 for the Norfolk Boreas site.

126. The density estimate during summer (April to September) is 0.664/km^2 and during the winter (October to March) the estimated density is 1.458/km^2 using the corrected densities.

127. The Norfolk Boreas site density estimate of 1.06/km^2, based on the mean annual density and using the seasonal correction factors, has been used to inform the assessments of impact (Table 12.15). Using the mean annual density allows for seasonal variation in the number of harbour porpoise that could be present.

128. The harbour porpoise density estimate for the Norfolk Boreas site is comparable to other offshore wind farm sites in the former East Anglia Zone and SCANS-III survey:

- Norfolk Boreas = 1.06/km^2
- Norfolk Vanguard East = 1.26/km^2
- Norfolk Vanguard West = 0.79/km^2
- East Anglia THREE = 0.294/km^2
- East Anglia ONE = 0.19/km^2 (maximum = 1.4/km^2)
- East Anglia ONE North (PEIR) = 0.573/km^2
- East Anglia TWO (PEIR) = 0.71/km^2
- SCANS-III survey block O = 0.888/km^2

12.6.1.4 Reference population for assessment

129. The reference population used in the assessment for harbour porpoise is the latest SCANS-III estimate of harbour porpoise abundance in the North Sea MU of 345,373 (Coefficient of Variation (CV) = 0.18; 95% CI = 246,526-495,752; Hammond et al., 2017).

12.6.1.5 Designated sites and conservation importance of harbour porpoise

130. For harbour porpoise, connectivity was considered potentially possible between Norfolk Boreas and any designated site within the North Sea MU (IAMMWG, 2015). The extent of the North Sea MU has been agreed during consultation with the marine mammal ETG for Norfolk Vanguard (February 2017), as the most appropriate population which any harbour porpoise occurring within the Norfolk Vanguard or Norfolk Boreas site may be part of.

131. The HRA screening (Appendix 10.3) considers any designated site within the harbour porpoise North Sea MU, where the species is considered as a grade A, B or C feature.

Grade D indicates a non-significant population (JNCC, 2017c). All designated sites outwith the harbour porpoise North Sea MU area were screened out from further consideration.

132. The approach to HRA screening primarily focuses on the potential for connectivity between individual marine mammals from designated populations and Norfolk Boreas (i.e. demonstration of a clear source-pathway-receptor relationship). This was based on the distance of Norfolk Boreas from the designated site, the range of each effect and the potential for animals from a site to be within range of an effect.

133. Designated sites were screened on the basis of the following:

- The distance between the potential impact range of the proposed project and any sites with a marine mammal interest feature which are within the range for which there could be an interaction e.g. the pathway is not too long for significant noise propagation.
- The distance between the proposed project and resources on which the interest feature depends (i.e. an indirect effect acting though prey or access to habitat) and which is within the range for which there could be an interaction i.e. the pathway is not too long.
- The likelihood that a foraging area or a migratory route occurs within the zone of interaction of the proposed project (applies to mobile interest features when outside the SAC).

134. In total, 32 sites were initially considered in the screening process for harbour porpoise, and these sites were assessed for any potential effects from indirect impacts through effects on prey species; underwater noise; and vessel interactions.

135. Norfolk Boreas is located within the Southern North Sea (SNS) SAC area (Figure 12.1). Therefore, any harbour porpoise affected by Norfolk Boreas would be within or in close proximity to the SNS SAC.

136. As harbour porpoise are wide-ranging within the North Sea MU, no discrete population can be assigned to an individual designated site. It is, therefore, assumed that at any one time, harbour porpoise within or in the vicinity of the Norfolk Boreas offshore development area are associated with the SNS SAC (as they cannot simultaneously be part of the population of multiple designated sites, although all are part of the larger MU population). Therefore, with regard to the potential effects of Norfolk Boreas, connectivity of harbour porpoise from designated sites, other than the SNS SAC is screened out.

12.6.1.5.1 Southern North Sea SAC

137. The designation of the SNS candidate Special Area of Conservation (cSAC) was approved by the European Commission as a Site of Community Importance (SCI), and was further formally designated by the UK government in February 2019 as a SAC. The site is referred to throughout as the SNS SAC.

138. The SNS SAC has been recognised as an area with persistent high densities of harbour porpoise (JNCC, 2017b). The SNS SAC 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 (Figure 12.1; JNCC, 2017b).

139. The Norfolk Boreas site lies within the SNS SAC and is located within the summer area (Figure 12.1).

140. The SNS cSAC Site Selection Report (JNCC, 2017b) identified that the SNS cSAC site supported approximately 18,500 individuals (95% CI = 11,864 - 28,889) for at least part of the year (JNCC, 2017b). However, JNCC (2017b) states that because this estimate is from a one-month survey in a single year (the SCANS-II survey in July 2005) it cannot be considered as an estimated population for the site. It is therefore not appropriate to use site population estimates in any assessments of effects of plans or projects on the site (i.e. HRA), as they need to take into consideration population estimates at the MU level, to account for daily and seasonal movements of the animals (JNCC, 2017b).

141. However, it was agreed with the marine mammal ETG at the Norfolk Vanguard EPP meeting on 15th February 2017 that the estimate that the SNS SAC could support 17.5% of the UK North Sea reference population could be considered in the EIA. Therefore, for information purposes, Appendix 12.4 presents an assessment on the estimated number of harbour porpoise that the SNS SAC site could support of 29,384 harbour porpoise. This estimate is based on the UK North Sea MU area (322,897km^2), the overall harbour porpoise density estimate of 0.52/km^2 (CV = 0.18) for the North Sea MU area from the SCANS-III survey (Hammond et al., 2017) and the estimated UK North Sea MU population of 167,906 harbour porpoise, with 17.5% of the population within the UK part of the North Sea MU of approximately 29,384 harbour porpoise.

142. The SNCBs current advice (Natural England, June 2017) on the assessment of impacts on the SNS harbour porpoise SAC is that:

- A distance of 26km from an individual percussive piling location should be used to assess the area of SNS SAC habitat which harbour porpoise may be disturbed from during piling operations (noting previous references made during industry 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 SNS SAC at any one time and or on average exceed 10% of the seasonal component of the SNS SAC over the duration of that season.
- The effect of the project should be considered in the context of the seasonal components of the SNS SAC, rather than the SNS SAC as a whole.
- A buffer of 10km around seismic operations and 26km around UXO detonations should be used to assess the area of SAC habitat from which harbour porpoise may be disturbed.

143. This latest SNCB advice has been used in the assessments for the HRA and is used in the EIA to ensure consistency. Guidance on managing noise disturbance within the SNS SAC is currently under review and subject to change.

12.6.2 Grey seal

12.6.2.1 Distribution

144. SMRU, in collaboration with others, deployed 269 telemetry tags on grey seals around the UK between 1988 and 2010 (Russell and McConnell, 2014). The telemetry data for grey seal adults and indicate that very few tagged greys seals have been recorded in and around the Norfolk Boreas site, with the tracks of only one grey seal pup tagged at the Isle of May in 2002 and one adult grey seal in the vicinity of the Norfolk Boreas site (see Plate 6 in Appendix 12.2; Russell and McConnell, 2014).

145. Aerial surveys conducted for the former East Anglia Zone, the aerial and boat surveys at the East Anglia ONE site did not record any observations of seals (EAOW, 2012b,c) and during East Anglia THREE surveys only two seals were recorded (EATL, 2015). The results of the surveys support the tagging data and suggest that there is low usage of the former East Anglia Zone.

146. For the East Anglia THREE EIA (EATL, 2015), EATL commissioned SMRU Marine Ltd and IMARES to investigate the connectivity between tagged grey seal and the East Anglia THREE site plus a 20km buffer area (EATL, 2015). The data indicated the movement of grey seals between MUs on the east coast of England and Scotland and the movement of grey seal between the UK and Dutch sites (see Appendix 12.2).

147. The north Dutch coastline is an important foraging zone and migration route for grey seal (Brasseur et al., 2010). A study on the grey seal development in the Dutch part of the Wadden Sea shows that the growth of the breeding population is fuelled by the annual immigration of grey seals from the UK (Brasseur et al., 2015).

148. Tags deployed on grey seals at Donna Nook and Blakeney Point in May 2015, indicated the tagged seal travelled along the coast between haul-out sites on the east coast of England, as well as to the north of France and up to the Firth of Forth and across Fladden Ground and Dogger Bank (see Plate 1.7 in Appendix 12.2; Russell, 2016).

149. There is a considerable amount of movement of grey seals that occurs (as observed from telemetry data) among the different areas and regional subunits of the North Sea and no evidence to suggest that grey seals on the North Sea coasts of Denmark, Germany, the Netherlands or France are independent from those in the UK (SCOS, 2017).

12.6.2.2 Haul-out sites

150. Compared with other times of the year, grey seals in the UK spend longer hauled out during their annual moult (between December and April) and during their breeding season (SCOS, 2017).

151. In eastern England, pupping occurs mainly between early November and mid-December (SCOS, 2017). Pups are typically weaned 17 to 23 days after birth, when they moult their white natal coat, and then remain on the breeding colony for up to two or three weeks before going to sea. Mating occurs at the end of lactation and then adult females depart to sea and provide no further parental care (SCOS, 2017).

152. The Norfolk Boreas site is located approximately 73km offshore (at the closest point). Principal grey seal haul-out sites are at Scroby Sands (approximately 67km), Blakeney Point (approximately 121km), The Wash (approximately 168km) and at Donna Nook (approximately 180km) (Figure 12.4).

153. The landfall for the Norfolk Boreas offshore export cables will be at Happisburgh South, approximately 9km from the Horsey seal haul-out sites to the south and 44km from the Blakeney Point haul-out site to the north (Figure 12.4).

12.6.2.3 Diet and foraging

154. Grey seals are generalist feeders, feeding on a wide variety of prey species (SCOS, 2017; Hammond and Grellier, 2006). Diet varies seasonally and from region to region (SCOS, 2016).

155. Grey seals typically forage in the open sea and return regularly to haul out on land where they rest, moult and breed. They may range widely to forage and frequently travel. Foraging trips can last anywhere between one and 30 days (SCOS, 2017).

156. Individual grey seals based at a specific haul-out site often make repeated trips to the same region offshore, but will occasionally move to a new haul-out site and begin foraging in a new region (SCOS, 2017). Telemetry studies of grey seal in the UK

have identified a highly heterogeneous spatial distribution with a small number of offshore ‘hot spots’ continually utilised (Matthiopoulos et al., 2004; Russell et al., 2017).

12.6.2.4 Abundance and density estimates

157. Grey seal population trends are assessed from the counts of pups born during the autumn breeding season, when females congregate on land to give birth (SCOS, 2017). The pup production estimates are converted to estimates of total population size (1+ aged population) using a mathematical model and projected forward (SCOS, 2017).

158. The most recent surveys of the principal grey seal breeding sites Scotland, Wales, Northern Ireland and south-west England, resulted in an estimate of 60,500 pups (95% CI = 53,900-66,900; SCOS, 2017). When the pup production estimates are converted to estimates of total population size, there was an estimated 141,000 grey seals in 2016 (approximate 95% CI = 117,500-168,500; SCOS, 2017).

159. The estimated adult UK grey seal population size in regularly monitored colonies in 2016 was 128,200 (95% CI = 106,200-154,400), an increase of approximately 1% on the 2015 estimate (SCOS, 2017).

160. In the southern North Sea, the rates of increase in pup production from 2010 to 2014 (by an average 22% p.a.) suggests that there must be some immigration from colonies further north (SCOS, 2016).

161. The most recent counts of grey seal in the August surveys 2011-2016, estimated that the total count of grey seals in the UK was 40,662 (SCOS, 2017).

12.6.2.4.1 Management units

162. The most recent August counts (2016) of grey seal at haul-out sites in the south-east England MU provides an estimated abundance of 6,085 grey seal (SCOS, 2017). This includes 3,964 grey seals at Donna Nook, 431 grey seals at The Wash, 355 grey seals at Blakeney Point, 642 grey seals at Scroby Sands and 481 grey seals along the Essex and Kent coast (SCOS, 2017).

163. For the north-east MU there is an estimated 6,948 grey seal, based on the most recent counts in 2016 (SCOS, 2017). This includes 6,767 grey seals in Northumberland and 22 at The Tees (SCOS, 2017).

164. It should be noted, that, grey seal summer counts are known to be more variable than harbour seal summer counts. Therefore, SCOS (2017) suggests that caution is advised when interpreting these numbers.

165. The north Dutch coastline is an important foraging zone and migration route for grey seal. The coordinated aerial, boat and land surveys of the Dutch, German and Danish Wadden Sea grey seal areas including Helgoland (Germany) are aimed at estimating changes in numbers of grey seal in the Wadden Sea area. Annual surveys are conducted in the Wadden Sea, during the moult and breeding season by the Trilateral Seal Expert Group (TSEG). The most recent TSEG counts for adult grey seals were conducted by aerial surveys during the moulting period in the spring of 2017. Studies show that in moult period, the animals present are not necessarily animals breeding in the Wadden Sea and considerable exchange occurs with the much larger UK population (Brasseur et al., 2015). In total, the number of grey seal recorded in 2017 increased by 10% compared to 2016, to 5,445 in the Wadden Sea area (TSEG, 2016a, 2017a).

12.6.2.4.2 Seal density maps

166. The latest seal at sea maps (Russell et al., 2017), were produced by 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; Figure 12.2).

167. Table 12.12 shows the grey seal density estimates for Norfolk Boreas which have been calculated from the 5km x 5km cells (Russell et al., 2017) based on the area of overlap with the Norfolk Boreas offshore project area (Figure 12.2). The upper at-sea density estimates for these areas have been used in the assessment.

Table 12.12 Grey seal density estimates (based on Russell et al., 2017)

Density Estimate	Individuals per km^2 (Russell et al., 2017)				
	Offshore Cable Corridor	Norfolk Boreas site	Project Interconnector search area (in NV West)	Project Interconnector search area (in NV East)	Total for Norfolk Boreas offshore project area
Lower at-sea	0.00002	0.0002	0.0001	0.00005	0.0001
Mean at-sea	0.076	0.0006	0.0005	0.0001	0.015
Upper at-sea	**0.162**	**0.001**	**0.001**	**0.0001**	**0.032**

12.6.2.4.3 Norfolk Vanguard site specific surveys

168. The total number of seal species recorded during the aerial surveys for NV East, including the former East Anglia FOUR surveys, from March 2012 to April 2016 (32 months) for NV East and 4km buffer was five seals, these were not identified to species.

169. The total number of seal species recorded during the aerial surveys for NV West from September 2015 to February 2017 for NV West and 4km buffer was four seals, two of which were identified as grey seal.

12.6.2.4.4 Norfolk Boreas site specific surveys

170. A total of 27 individual seals were recorded during the aerial surveys for the Norfolk Boreas site, from August 2016 to July 2018 (24 months), these were not identified to species level (see Appendix 12.2).

171. As the sightings data was too low within the Norfolk Boreas and Vanguard sites to determine a robust site specific density estimate for grey seal, the SMRU seals at-sea density data (Table 12.12; Russell et al., 2017) has been used in the assessment, as agreed with the marine mammal ETG (meeting 15th February 2017).

12.6.2.5 Reference population for assessment

172. In accordance with the approach agreed with the marine mammals ETG, the reference population extent for grey seal incorporates the south-east England, north-east England and east coast of Scotland MUs (IAMMWG, 2013; SCOS, 2017) and the Wadden Sea region (TSEG, 2017a).

173. The telemetry studies outlined in Appendix 12.2 (Plate 6 and Plate 7) justify the inclusion of UK south-east England MU, north east England MU, east coast of Scotland MU and the Wadden Sea region in the reference population for this assessment. The area is also appropriate for assessing the potential impact of Norfolk Boreas alone and in-combination with other projects and plans.

174. It is acknowledged that the UK grey seal counts are based on surveys conducted in August and the Wadden Sea region is based on counts in winter / spring (and is not a population estimate). As outlined in Appendix 12.2, when the pup production estimates from autumn counts are converted to estimates of total population size, there was an estimated 141,000 grey seals in 2016 (approximate 95% CI = 117,500-168,500; SCOS, 2017). The most recent counts of grey seal in the August surveys 2008-2016, estimated that the total count of grey seals in the UK was 40,662 (SCOS, 2017). Therefore, using the August grey seal counts for the reference population is a precautionary approach and is likely to be an underestimate of the number of grey seals in the UK MUs.

175. It is also acknowledged that the counts for the Wadden Sea region are not corrected for seals in the water and are therefore an indication of the minimum estimates of the number of seals in the area and not actual population counts.

176. The reference population is therefore based on the most recent counts 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
- The Wadden Sea region = 5,445 grey seal (TSEG, 2017a).

177. The total reference population for the assessment is therefore 22,290 grey seal. In addition, the assessment of the potential impacts will also be assessed on the south-east England MU of 6,085 grey seal (Table 12.14).

12.6.3 Harbour seal

12.6.3.1 Distribution

178. SMRU, in collaboration with others, has deployed around 344 telemetry tags on harbour seals around the UK between 2001 and 2012 (Russell and McConnell, 2014). The tracks indicate that very few tagged harbour seals have been recorded in the immediate vicinity of the Norfolk Boreas offshore project area, with tracks moving along the coast between The Wash and the Thames estuaries (see Plate 1.8 in Appendix 12.2). This is reflected in the harbour seal density estimates for the Norfolk Boreas site compared to the offshore cable corridor (Table 12.13), although harbour seal numbers in the Norfolk Boreas site and the offshore cable corridor are very low.

179. Aerial surveys conducted for the East Anglia Zone and East Anglia ONE site, did not record any of seals (EAOW, 2012b,c). Boat based surveys at the East Anglia ONE site, recorded three harbour seal (EAOW, 2012b). As outlined for grey seal, only two unidentified seals were recorded during East Anglia THREE surveys (EATL, 2015). The results of the surveys support the tagging data and suggest that there is low usage of the former East Anglia Zone.

180. For the East Anglia THREE EIA (EATL, 2015), EATL commissioned SMRU Marine Ltd and IMARES to investigate the connectivity between tagged harbour seal and the East Anglia THREE site plus a 20km buffer area (EATL, 2015). The SMRU study indicated that none of the 43 tagged harbour seals aged one or above entered the East Anglia THREE site plus a 20km buffer area or surrounding area. The IMARES telemetry studies indicated the long ranging movements of harbour seal connectivity between Dutch haul out sites and those on the east coast of England (see Appendix 12.2).

181. The SMRU maps of harbour seal distribution in UK waters (Russell et al., 2017), based on the movement patterns of electronically tagged seals with survey counts of seals at haul-out sites, indicate that harbour seal usage is relatively low in and around the Norfolk Boreas offshore project area, and is higher along the coast and cable corridor (Figure 12.3; Russell et al., 2017).

12.6.3.2 Haul-out sites

182. Harbour seal come ashore in sheltered waters, typically on sandbanks and in estuaries, but also in rocky areas. Harbour seal regularly haul-out on land in a pattern that is often related to the tidal cycle (SCOS, 2017).

183. Harbour seal give birth to their pups in June and July and pups can swim almost immediately after birth (SCOS, 2017). Harbour seals moult in August and spend a higher proportion of their time on land during the moult than at other times (SCOS, 2017).

184. There are principal harbour seal haul-out sites at Scroby Sands (approximately 67km), at Blakeney Point (approximately 121km) and The Wash (approximately 168km) (Figure 12.4).

185. The Happisburgh South landfall location is approximately 9km from the Horsey seal haul-out site to the south and 44km from the Blakeney Point haul-out site to the north. These are the closest haul-out sites to the landfall location (Figure 12.4).

12.6.3.3 Diet and foraging

186. Harbour seal take a wide variety of prey including sandeels, gadoids, herring and sprat, flatfish and cephalopods. Diet varies seasonally and regionally, prey diversity and diet quality also showed some regional and seasonal variation (SCOS, 2017).

187. Harbour seal normally forage within 40-50 km around their haul out sites. Tracking studies have shown that harbour seal typically travel 50-100km offshore and can travel 200km between haul-out sites (Lowry et al., 2001; Sharples et al., 2012). Harbour seal exhibit relative short foraging trips from their haul out sites. The range of these trips does vary depending on the surrounding marine habitat (see Appendix 12.2).

12.6.3.4 Abundance and density estimates

188. Harbour seal are counted while they are on land during their August moult, giving a minimum estimate of population size (SCOS, 2017). Combining the most recent counts (2011-2015) gives a total of 31,300 counted in the UK. Scaling this by the estimated proportion hauled out (0.72 (95% CI = 0.54-0.88)) produces an estimated total population for the UK in 2015 of 43,500 harbour seal (approximate 95% CI = 35,600-58,000; SCOS, 2016).

189. Approximately 30% of European harbour seal are found in the UK; this proportion has declined from approximately 40% in 2002 (SCOS, 2017).

12.6.3.4.1 Management units

190. The most recent August counts (2016) of harbour seal at haul-out sites in the south-east England MU provides an estimated abundance of 5,061 harbour seal (SCOS,

2017). This includes 369 harbour seals at Donna Nook, 3,377 at The Wash, 424 at Blakeney Point, 198 at Scroby Sands and 694 along the Essex and Kent coast (SCOS, 2017).

191. Harbour seal are also routinely surveyed in the Wadden Sea, as part of the TSEG coordinated aerial surveys in Denmark, Germany and the Netherlands. The estimate for the total Wadden Sea harbour seal population, including seals in the water during the survey, in 2017 was estimated to be 38,100 (TSEG, 2017b).

12.6.3.4.2 Seal density maps

192. Table 12.13 shows the harbour seal density estimates for the Norfolk Boreas site which have been calculated from the 5km x 5km cells of the SMRU harbour seal at sea usage maps (Russell et al., 2017) based on the area of overlap with Norfolk Boreas (Figure 12.3). The upper at-sea density estimate for these areas have been used in the assessment.

Table 12.13 Harbour seal density estimates (based on Russell et al., 2017)

Density Estimate	Individuals per km^2 (Russell et al., 2017)				
	Offshore Cable Corridor	Norfolk Boreas site	Project Interconnector search area (in NV West)	Project Interconnector search area (in NV East)	Total for Norfolk Boreas offshore project area
Lower at-sea	0.003	0.00003	0.00005	0.00004	0.0006
Mean at-sea	0.051	0.00006	0.0001	0.00008	0.01
Upper at-sea	**0.098**	**0.0001**	**0.0001**	**0.0001**	**0.019**

12.6.3.4.3 Norfolk Vanguard site specific surveys

193. The total number of seal species recorded during the aerial surveys for NV East, including the EA4 surveys, from March 2012 to April 2016 (32 months) for NV East OWF and 4km buffer was five seals, these were not identified to species.

194. The total number of seal species recorded during the aerial surveys for NV West from September 2015 to February 2017 for NV West and 4km buffer was four seals, none were identified as harbour seal.

12.6.3.4.4 Norfolk Boreas site specific surveys

195. The total number of seal species recorded during the aerial surveys for the Norfolk Boreas site, from August 2016 to July 2018 (24 months) was 27 seals, these were not identified to species level (see Appendix 12.2).

196. As the sightings data was too low within the Norfolk Boreas and Vanguards sites to determine a robust site specific density estimate for harbour seal, the SMRU seals at-sea density data (Table 12.13; Russell et al., 2017) has been used in the assessment, as agreed with the marine mammal ETG (meeting 15th February 2017).

12.6.3.5 Reference population for assessment

197. In accordance with the approach agreed with the marine mammal ETG, the reference population for harbour seal will incorporate the south-east England MU and the Wadden Sea region.

198. The telemetry studies outlined in Appendix 12.2, justifies the inclusion of UK south-east England MU and the Wadden Sea region in the reference population for this assessment. The area is also appropriate for assessing the potential impact of Norfolk Boreas alone and in-combination with other projects and plans.

199. The UK harbour seal counts are based on surveys conducted in August during the moult period and the Wadden Sea count is based on harbour seal in June during the pupping season (TSEG, 2017b). Given that harbour seal in the UK also give birth to their pups in June and July (SCOS, 2017), there is unlikely to be double counting of seals during these surveys. Using these counts for the reference population is a precautionary approach and is likely to be an underestimate of the actual number of harbour seal.

200. The reference population is therefore based on the following most recent counts:

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

201. The total harbour seal reference population for the assessment is therefore 43,161. In addition, consideration is also given to the potential impacts on the south-east England MU of 5,061 harbour seal (Table 12.14).

12.6.3.6 Designated sites and conservation importance for pinnipeds

202. In England and Wales, seals are protected under the Conservation of Seals Act 1970. The Conservation of Seals Act prohibits taking seals during a close season (1st September to 31st December for grey seal and 1st June to 31st August for harbour seal) except under licence issued by the Marine Management Organisation. The Act also allows for specific Conservation Orders to extend the close season to protect vulnerable populations. Under this order, there is year-round protection to grey and harbour seals on the east coast of England (SCOS, 2017).

203. Both grey and harbour seals are listed in Annex II of the EU Habitats Directive, requiring specific SACs to be designated for their protection.

12.6.3.6.1 Grey seal

204. The HRA screening initially considered a total of 58 European designated sites where grey seal is a qualifying feature and which could have theoretical connectivity with the Norfolk Boreas offshore project area based upon distance from the site. This list was refined based upon field data to a list of sites with potential connectivity, which will then assessed in terms of the potential for Likely Significant Effect (LSE) of the project. Based upon this process the Humber Estuary SAC was screened in for further assessment in the HRA to take into account the movements of grey seal along the east coast of England.

205. Although grey seal are not currently a qualifying feature at the Wash and North Norfolk SAC (which includes Blakeney Point) or Winterton-Horsey Dunes SAC, it is recognised that these sites are important for the population, as breeding, moulting and haul-out sites. Therefore, in the assessments for the HRA, consideration will be given to grey seal as part of the Wash and North Norfolk SAC and Winterton-Horsey Dunes SAC, to determine if there is the potential for any disturbance of seals hauled out at these sites.

206. For grey seal, all designated sites within 100km, based on the typical foraging range of grey seal (SCOS, 2017), have also been considered further in the HRA for any potential effects on foraging grey seal. This includes Klaverbank (NL2008002) located 67km from the Norfolk Boreas site and Noordzeekustzone (NL9802001) located 94km from the Norfolk Boreas site.

12.6.3.6.2 Harbour seal

207. The HRA screening initially considered a total of 73 European designated sites where harbour seal is a qualifying feature and which could have theoretical connectivity with the Norfolk Boreas offshore project area based upon distance from the site. This list was refined based upon field data to a list of sites with potential connectivity which was then assessed in terms of the potential for LSE of the project. Based upon this process, the Wash and North Norfolk Coast SAC was screened in for further assessment in the HRA to take into account the movements of harbour seal along the east coast of England.

208. For harbour seal, all designated sites within 80km, based on the typical and average foraging range of 50-80km for harbour seal (SCOS, 2017), have also been considered further in the HRA for any potential effects on foraging harbour seal. This includes Klaverbank (NL2008002) located 67km from the Norfolk Boreas site.

12.6.4 Summary of Marine Mammal Receptors and Reference Populations

209. Table 12.14 and Table 12.15 provide a summary of the reference populations and the density estimates for the marine mammal species being taken forward for the impact assessment.

210. During the impact assessment, the magnitude of impacts will be put in context against these reference populations (see Table 12.7 for definitions of magnitude).

Table 12.14 Summary of marine mammal reference populations (in bold) used in the impact assessment

Species	Reference population extent	Year of estimate	Size	Data source
Harbour porpoise	North Sea MU	2016	**345,373** (CV = 0.18; 95% CI = 246,526-495,752)	SCANS-III (Hammond et al., 2017)
	Southern North Sea SAC	2016	Area = 36,715km^2; winter area = 12,697km^2; and summer area = 27,018km^2. [SNS SAC supports an estimated 29,384 harbour porpoise - additional assessment in Appendix 12.4]	JNCC (2017b) SCANS-III (Hammond et al., 2017)
Grey seal	South-east England MU; North-east England MU; East coast of Scotland MU; & Wadden Sea 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	**6,085**	SCOS (2017)
Harbour seal	South-east England MU; and Wadden Sea population	2016 2017	5,061 + 38,100 = **43,161**	SCOS (20176) and TSEG (2017b)
	South-east England MU	2016	**5,061**	SCOS (2017)

Table 12.15 Summary of marine mammal density estimates used in the impact assessment

Species	Density estimate Number of individuals per km^2	Data source
Harbour porpoise	1.06/km^2 for the Norfolk Boreas site* 1.26/km^2 for project interconnector cable in NV East* 0.79/km^2 for project interconnector cable in NV West*	Site specific surveys (*Appendix 12.2 & Appendix 12.2 of the Norfolk Vanguard ES*)
	0.888/km^2	SCANS-III survey block O** (Hammond et al., 2017)
Grey seal	0.001/km^2 for the Norfolk Boreas site 0.162/km^2 for the offshore cable corridor area 0.001/km^2 for the project interconnector cable search area (NV West) 0.0001/km^2 for the project interconnector cable search area (NV East) 0.032/km^2 for the total offshore project area	SMRU seal at-sea usage maps (Russell et al., 2017)
Harbour seal	0.0001/km^2 for the Norfolk Boreas site 0.098/km^2 for the offshore cable corridor area 0.0001/km^2 for the project interconnector cable search area (NV West) 0.0001/km^2 for the project interconnector cable search area (NV East) 0.019/km^2 for the total offshore project area	SMRU seal at-sea usage maps (Russell et al., 2017)

**based on mean annual density estimate of highest monthly counts and seasonal correction factors of harbour porpoise counts combined with in unidentified dolphin/porpoise*
***the Norfolk Boreas site is located in both SCANS-III survey block L and survey block O; therefore, the maximum density from survey block O has been used as the worst-case scenario.*

12.6.5 Anticipated Trends in Baseline Conditions

211. The existing baseline conditions for marine mammals within the study area (described in section 12.6 and Appendix 12.2) are considered to be relatively stable. The baseline environment of the southern North Sea has been influenced by the oil and gas industry since the 1960s, fishing by various methods for hundreds of years and the construction and operation of offshore wind farms for over ten years (Kentish Flats in 2005; Lynn and Inner Dowsing in 2009). The baseline will continue to evolve as a result of global trends which include the effects of climate change.

212. For harbour porpoise in the North Sea, the latest SCANS-III survey results show no evidence for trends in abundance since the mid-1990s (Hammond et al*.,* 2017). Despite no overall change in population size, large scale changes in the distribution of harbour porpoise were observed between SCANS-I in 1994 and SCANS-II in 2005, with the main concentration shifting from North eastern UK and Denmark to the southern North Sea. Such large-scale changes in the distribution of harbour porpoise are likely the result of changes to the availability of principal prey within the North Sea (SCANS-II, 2008).

213. The number of grey seal pups throughout Britain has grown steadily since the 1960s; when records began and there is clear evidence that the population growth is levelling off in all areas, except the central and southern North Sea where growth rates remain high (SCOS, 2017). Pup production at colonies in the North Sea increased rapidly up to 2014. The majority of the increase up to 2014 was due to the continued rapid expansion of newer colonies on the mainland coasts in Berwickshire, Lincolnshire, Norfolk and Suffolk (SCOS, 2017). The 2015 and 2016 counts suggest a much lower annual increase for the east coast of England mainland colonies, with the largest colony at Blakeney showing a slight decrease after 12 years of extremely rapid increase (SCOS, 2017). At the colonies on the mainland east coast of England and especially in the southern North Sea, the rates of increase in pup production from 2010 to 2015 have been extremely high, suggesting that there must have been some immigration from colonies further north (SCOS, 2017).

214. Overall, the UK population of harbour seal has increased since the late 2000s and is close to the 1990s level (SCOS, 2017). However, there are significant differences in the population dynamics between regions, for example there have been general declines in the counts of harbour seals in several regions around Scotland, but the declines are not universal, with some populations either stable or increasing. Counts for the East coast of England appear stable, although the 2016 count was approximately 10% higher than in 2015, driven mainly by a doubling of the count from Essex and Kent (SCOS, 2017). The harbour seal population along the east coast of England (mainly in The Wash) was reduced by 52% following the 1988 phocine distemper virus (PDV) epidemic. A second epidemic in 2002 resulted in a decline of 22% in The Wash, but had limited impact elsewhere in Britain. Counts in the Wash and eastern England did not demonstrate any immediate recovery from the 2002 epidemic and continued to decline until 2006. The counts increased rapidly from 2006 to 2012 but have remained relatively constant since (SCOS, 2017). In contrast, the adjacent European colonies in the Wadden Sea experienced continuous rapid growth after the epidemic, but again, the counts over the last five years suggest that the rate of increase has slowed dramatically (SCOS, 2017). The decline in the rate of increase in the Wadden Sea is considered to be due to the population reaching carrying capacity.

12.7 Potential Impacts

215. The impacts and the methodologies used for assessing these impacts during the construction, operation and decommissioning of Norfolk Boreas have been agreed in consultation with the marine mammal ETG.

216. The potential impacts during construction assessed for marine mammals (section 12.7.3) are:

- The risk of permanent auditory injury resulting from the underwater noise associated with clearance of UXO;
- Behavioural impacts resulting from the underwater noise associated with clearance of UXO;
- The risk of permanent auditory injury resulting from underwater noise during piling;
- Behavioural impacts resulting from underwater noise during piling;
- Behavioural impacts resulting from underwater noise during other construction activities, for example, seabed preparation, rock dumping and cable installation;
- Underwater noise and disturbance from vessels;
- Barrier effects as a result of underwater noise associated with activities above;
- Vessel interaction (collision risk);
- Disturbance at seal haul-out sites; and
- Changes to prey resource, including habitat loss.

217. The potential impacts during operation and maintenance assessed for marine mammals (section 12.7.4) are:

- Behavioural impacts resulting from the underwater noise associated with operational turbines;
- Behavioural impacts resulting from the underwater noise associated with maintenance activities, such as any additional rock dumping and cable re-burial;
- Underwater noise and disturbance from vessels;
- Vessel interaction (collision risk);
- Disturbance at seal haul-out sites; and
- Changes to prey resource, including habitat loss.

218. The potential impacts during decommissioning assessed for marine mammals (section 12.7.5) are:

- The risk of permanent auditory injury resulting from the noise associated with foundation removal (e.g. cutting);
- Behavioural impacts resulting from the noise associated with foundation removal (e.g. cutting);
- Underwater noise and disturbance from vessels;
- Barrier effects as a result of underwater noise associated with activities above;
- Vessel interaction (collision risk);
- Disturbance at seal haul-out sites; and
- Changes to prey resource.

219. Section 12.7.1 summarises the embedded mitigation relevant to marine mammals, with any further mitigation, if required, outlined in the relevant impact section.

Section 12.7.2 outlines the worst-case scenarios used in the assessment of the potential impacts on marine mammals.

12.7.1 Mitigation

12.7.1.1 Embedded mitigation

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

221. A range of different information sources has been considered as part of embedding mitigation into the design of the project (for further details see Chapter 5 Project Description, Chapter 4 Site Selection and Assessment of Alternatives) including engineering requirements, ongoing discussions with stakeholders and regulators, commercial considerations and environmental best practice.

222. A number of embedded mitigation measures have been incorporated into the design of the development to prevent or reduce any significant adverse effects where possible.

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

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

12.7.1.1.1 Reduction of turbine numbers

225. Following Scoping, Norfolk Boreas Limited has reduced the maximum number of turbines from 257 to 180, while maintaining the maximum export capacity of 1,800MW by committing to using 10MW to 20MW turbines.

226. This reduction in the maximum number of turbines reduces the number of foundations that could require piling, thereby reducing the overall potential underwater impacts on marine mammals. The reduction in the maximum number of turbines also reduces the potential maximum duration for construction, reduces the number of vessels required, and reduces the physical footprint and any potential habitat loss for prey species.

12.7.1.1.2 Underwater noise

227. Norfolk Boreas Limited has committed to the following embedded mitigation which has already been incorporated into the project design in order to reduce potential effects on marine mammals:

- The use of a soft-start and ramp-up protocol:
  - Each piling event would commence with a soft-start for a minimum of 10 minutes at 10% of the maximum hammer energy followed by a gradual ramp-up for at least 20 minutes to the maximum hammer energy (although maximum hammer energy is only likely to be required at a few of the piling installation locations).

228. This minimum 30 minute soft-start and ramp-up duration is more precautionary than the current JNCC (2010a) guidance, which recommends that the soft-start and ramp-up period duration should be a period of not less than 20 minutes.

229. During the 30 minutes for the soft-start and ramp-up it is estimated that animals would move over 2.7km away from the piling location, based upon an average marine mammal swimming speed of 1.5m/s (Otani et al., 2000). However, Kastelein et al. (2018) recorded harbour porpoise swimming speeds of 1.97m/s during playbacks of pile driving sounds.

- During the minimum 10 minute soft-start it is estimated that marine mammals would move at least 0.9km from the piling location.
- During the 20 minute ramp-up it is estimated that marine mammals would move at least 1.8km.

12.7.1.2 Further Mitigation

12.7.1.2.1 MMMP for piling

230. The MMMP for piling will be developed in the pre-construction period and based upon best available information, methodologies, industry best practice, latest scientific understanding, current guidance and detailed project design. The MMMP for piling will be developed in consultation with the relevant SNCBs and the MMO, detailing the proposed mitigation measures to reduce the risk of any physical or permanent auditory injury (PTS) to marine mammals during all piling operations. This will include details of the embedded mitigation, for the soft-start and ramp-up, as well as details of the mitigation zone and any additional mitigation measures required in order to minimise potential impacts of any physical or permanent auditory injury (PTS), for example, the activation of acoustic deterrent devices (ADDs) prior to the soft-start.

231. The MMMP for piling will determine a suitable mitigation zone around the piling location before piling commences. Appropriate mitigation measures considered adequate to exclude marine mammals from within the mitigation zone will be implemented prior to piling, to reduce the risk of any permanent auditory injury (PTS).

232. For example, the activation of ADDs for just 10 minutes prior to the soft-start would allow harbour porpoise, grey and harbour seal to move at least 0.9km from the piling location (based on a precautionary average swimming speed of 1.5m/s), which is beyond the maximum PTS predicted impact range for the starting hammer energy of up to 500kJ.

233. The methods for achieving the mitigation zone would be agreed with the MMO in consultation with the relevant SNCBs and secured as commitments within the MMMP for piling.

234. A draft MMMP for piling has been submitted with the DCO application (document reference 8.13).

12.7.1.2.2 MMMP for UXO clearance

235. A detailed MMMP will also be prepared for UXO clearance following the pre-construction UXO survey when there would be more detailed information on the UXO clearance which could be required. The MMMP for UXO clearance will ensure there are adequate mitigation measures to minimise the risk of any physical or permanent auditory injury to marine mammals as a result of UXO clearance. The MMMP for UXO clearance will take account of the most suitable mitigation measures at that time and will be based upon best available information and methodologies at that time. The MMMP for UXO clearance will be developed in the pre-construction period, when there is more detailed information on the UXO clearance which could be required and the most suitable mitigation measures, based upon best available information and methodologies at that time, in consultation with the relevant SNCBs and the MMO.

236. The MMMP for UXO clearance will involve the establishment of a suitable mitigation zone around the UXO location before any detonation. Norfolk Boreas Limited will implement mitigation measures to reduce the risk of physical or permanent auditory injury (PTS) to marine mammals within the mitigation zone prior to any UXO detonation.

237. The MMMP for UXO clearance will include details of all the required mitigation measures to minimise the potential risk of physical and auditory injury (PTS) as a result of underwater noise during UXO clearance, for example, this would consider

the options, suitability and effectiveness of mitigation measures such as, but not limited to:

- All detonations taking place in daylight and, when possible, in favourable conditions with good visibility.
- The controlled explosions of the UXO, undertaken by specialist contractors, using the minimum amount of explosives required in order to achieve safe disposal of the device.
- Monitoring of the mitigation zone by marine mammal observers (MMOs) during daylight hours and when conditions allow suitable visibility, pre- and post-detonation.
- Deployment of passive acoustic monitoring (PAM) devices, if required, for example during poor visibility and if the equipment can be safely deployed and retrieved.
- The activation of acoustic deterrent devices (ADDs).
- If required and where possible and safe to do so, a soft-start procedure using scare charges.
- The sequencing of detonations, if there are multiple UXO in close proximity to be disposed of near simultaneously, where practicable, will start with the smallest detonation and end with the larger detonations.
- Noise reduction mitigation measures.

238. It should be noted that the MMMP for UXO clearance will not be part of the final DCO submission and Norfolk Boreas Limited will not be applying for consent for UXO clearance at this stage. A separate application (post DCO submission) will be submitted once there is further information on what UXO clearance could be required and the MMMP for UXO clearance has been prepared. The MMMP for UXO clearance will be secured when removal of UXO is licensed. Information on UXO clearance has been included in the EIA to provide a robust assessment of all the potential impacts and effects.

239. The final MMMP for UXO clearance will detail what is required for all agreed mitigation measures to ensure that they are successfully undertaken, including if marine mammals are observed in the mitigation zone.

12.7.1.2.3 In Principle Site Integrity Plan

240. In addition to the MMMPs for piling and UXO clearance, a Norfolk Boreas SNS SAC Site Integrity Plan (SIP) will be developed. The SIP will set out the approach to deliver any project mitigation or management measures in relation to the SNS SAC.

241. The SIP will be an adaptive management tool, which can be used to ensure that the most adequate, effective and appropriate measures, if required, are put in place to reduce the significant disturbance of harbour porpoise in the Southern North SAC.

242. An In Principle SIP has been submitted with the DCO application (document reference 8.17).

12.7.1.3 Project Environmental Management Plan

243. Norfolk Boreas Limited have committed to the production of a Project Environmental Management Plan (PEMP) and a Monitoring Plan (section 12.7.1.4) which will be mechanisms for securing the commitments made above. The PEMP will identify stakeholder requirements, ensure compliance with current legislation, minimises any potential adverse environmental effects during construction and translate committed mitigation into committed site procedure. An outline PEMP has been submitted as part of the DCO application (document reference 8.14).

12.7.1.4 In Principle Monitoring Plan

244. The In Principle Monitoring Plan will identify relevant offshore monitoring as required by the deemed marine licence conditions, establish the objectives of such monitoring and set out the guiding principles for delivering any monitoring measures as required. An outline of the In Principle Monitoring Plan has been submitted as part of the DCO application (document reference 8.12).

12.7.2 Worst Case

245. The offshore project area consists of:

- The offshore wind turbines and their associated foundations;
- Scour protection around foundations as required;
- Offshore electrical platforms supporting required electrical equipment, possibly also incorporating offshore facilities;
- An offshore service platform may be installed;
- Subsea cables consisting of;
    - Array cables: connecting wind turbines with each other and with the offshore electrical platforms;
    - Interconnector cables: interconnectors between the offshore electrical platforms within the Norfolk Boreas site; or
    - Project interconnector cables: interconnectors between an offshore electrical platform in the Norfolk Boreas site and an offshore electrical platform within one of the Norfolk Vanguard OWF sites;
    - Offshore export cables: cables joining the offshore electrical platforms with the landfall area;
    - Cable protections on subsea cables as required; and

   - Communications cables which would be buried along with some or all of the electrical cables.

- Meteorological masts (met masts) and their associated foundations for monitoring wind speeds during the operational phase (additional to existing met masts within the former East Anglia Zone);
- Monitoring equipment including Light Detection and Ranging (LiDAR) and wave buoys; and
- A number of navigational buoys around the Norfolk Boreas site which will be determined in consultation with the Maritime and Coastguard Agency (MCA) and Trinity House (TLS).

246. The realistic worst-case scenario for each category of potential impact has been determined. For this assessment, the realistic worst-case scenario involves consideration of both the timing of impacts, as well as the physical parameters that define the project design envelope for Norfolk Boreas.

247. Norfolk Boreas Limited is currently considering constructing the project in either a single phase or two phases (up to a maximum of 1,800MW). Offshore construction of the project under either approach would be expected to commence at the end of 2025 with piling starting in 2026.

248. 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.

249. However, if a two-phase construction approach was undertaken, the overall duration of the construction works could be longer. See Table 12.16 and Table 12.17 for the indicative construction programmes for both the single and two-phase approaches respectively.

250. Consideration is given to the impacts on marine mammals over the full construction window, which is expected to be up to approximately three years for the full 1800MW capacity, regardless of the phasing scenario (Table 12.16 and Table 12.17).

251. If Norfolk Vanguard has not progressed, the programmes presented in Table 12.16 and Table 12.17 could be brought forward by approximately one year. Under this scenario a project interconnector would not be installed.

252. Within Norfolk Boreas, several different sizes of wind turbine are being considered in the range of 10MW to 20MW. In order to achieve the maximum 1,800MW export capacity, there would be between 90 and 180 turbines.

253. The worst-case scenario for each effect is outlined in Table 12.18.

254. A range of foundation options is currently being considered, these include:

- For wind turbines:
    - monopiles (either piled or with suction caisson);
    - quadropod or tripod jackets (either pin-piles or suction caissons);
    - gravity base structure (GBS); and
    - TetraBase (with piled or suction caissons).
- For offshore electrical platforms these are GBS, six legged jacket (either piled or with suction caisson) and four legged jacket (either piled or with suction caisson);
- For the offshore service platforms, these are GBS, six legged jacket (either piled or with suction caisson) and four legged jacket (either piled or with suction caisson);
- For the met masts the options are GBS, monopile (either piled or with suction caisson) and quadropod or tripod jackets (either piled or with suction caisson); and
- For LiDAR platforms the foundations could be floating with anchors or monopile.

255. The worst-case scenario for each parameter that could have a potential impact on marine mammals is outline in Table 12.18.

256. Full details of the range of development options being considered are provided within Chapter 5 Project Description. Only those design parameters with the potential to influence the level of impact on marine mammals are included in Table 12.18.

257. The realistic worst-case scenarios identified here also apply to the Cumulative Impact Assessment (CIA). When the worst-case scenarios for the project in isolation do not result in the worst-case for cumulative impacts, this is addressed within the cumulative section of this chapter (see section 12.8).

Table 12.16 Indicative Norfolk Boreas construction programme – single phase

Indicative Programme	Approximate duration	2024				2025				2026				2027				2028			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Pre-construction survey	12 months				■	■	■														
UXO survey and licensing	12 months				■	■	■														
UXO clearance following licencing	9 months							■	■	■											
Foundation seabed preparation	3 months									■											
Foundation installation	18 months										■	■	■	■	■	■					
Scour protection installation	12 months									■	■	■	■								
Offshore electrical platform Installation Works	12 months										■	■	■	■							
Array & interconnector cable seabed preparation	6 months									■	■										
Array & interconnector cable installation	18 months										■	■	■	■	■	■					
Export cable installation seabed preparation	6 months								■	■											
Export cable installation	18 months									■	■	■	■	■	■						
Cable protection installation	18 months										■	■	■	■	■	■					
Wind turbine installation	18 months														■	■	■	■	■	■	
Total construction works	36 months								■	■	■	■	■	■	■	■	■	■	■	■	

Table 12.17 Indicative Norfolk Boreas construction programme – two phases

		2024				2025				2026				2027				2028			
Indicative Programme	**Approximate duration**	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Pre-construction survey	12 months																				
UXO survey and licensing	12 months																				
UXO clearance following licencing	9 months																				
Foundation seabed preparation	3 months																				
Foundation installation	2 x 9 months																				
Scour protection installation	2 x 6 months																				
Offshore electrical platform Installation Works	2 x 6 months																				
Array & interconnector cable seabed preparation	2 x 3 months																				
Array & interconnector cable installation	2 x 9 months																				
Export cable installation seabed preparation	2 x 3 months																				
Export cable installation	2 x 9 months																				
Cable protection installation	2 x 9 months																				
Wind turbine installation	2 x 9 months																				
Total construction works	39 months																				

Table 12.18 Worst-case parameters for marine mammal receptors

Impact	Parameter	Maximum worst-case	Notes
Construction			
Underwater noise from UXO clearance	Possible number of UXO	up to 30 in the Norfolk Boreas site 28 in offshore cable corridor Up to 22 in the project interconnector search area Total = up to 80	Indicative only, based on initial geophysical data (Fugro, 2016; 2017), but numbers will be determined by a pre-construction UXO survey.
	Possible type and size of UXO	German LMB (GC) Ground Mine (up to 700kg NEQ)) British A Mk6 Ground Mine (up to 430 kg NEQ) German E series buoyant mine (up to 150kg NEQ)) British MK14 Buoyant mine (up to 227kg NEQ) 250lb HE Bomb (up to 55kg NEQ)) 500lb HE Bomb (up to 120kg NEQ)) 1000lb HE Bomb (up to 250kg NEQ))	Indicative only, based on initial risk assessment (Ordtek, 2018, Appendix 5.4). A detailed UXO survey would be completed prior to construction. The exact type, size (net explosive quantities (NEQ)) and number of possible detonations and duration of UXO clearance operations is therefore not known at this stage.
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	180 (10MW turbines) or 90 (20MW turbines)	
	Number of other offshore platforms	2 x offshore electrical platforms 2 x Met masts 2 x LiDAR 1 x offshore service platform Total = 7	
	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 4 legged jacket pin-piles)	

Impact	Parameter	Maximum worst-case	Notes
	Maximum number of piles - Wind turbines	180 x 4 pin-piles (10MW quadropod) Total = 720	The 10MW quadropod will represent the worst-case temporal impact for wind turbines due to having the greatest number of piles. 10MW = 180 monopiles or 720 pin-piles 20MW = 90 monopiles or 360 pin-piles
	Maximum number of piles - Other offshore platforms	2 x offshore electrical platforms with 18 pin-piles = 36 pin-piles 2 x Met masts quadropod = 8 pin-piles 2 x LiDAR monopile = 2 monopiles 1 x offshore service platform with 6 piles = 6 piles Total = 52	Assumes a worst-case of 6 pin-piles/piled anchors for the offshore service platform and 18 pin-piles per electrical platforms.
	Total number of piled foundations	772	Maximum number of pin-piles = 720 (10MW) + 42 (platforms) + 8 (Met masts) plus 2 LiDAR monopiles = 772 Or Maximum number of monopiles = 180 (10MW) + 2 LiDAR monopiles plus 50 platform and Met mast pin-piles = 232
	Hammer energies	Maximum hammer energy: • 2,700kJ (for piled tripod or quadropod foundations) • 5,000kJ (largest monopile) Starting hammer energies of 10% will be used followed by ramp-up over one hour to the maximum hammer energy.	
	Pile diameter	• 10m (10MW monopile) • 3m (10MW pin pile) • 15m (20MW monopile) • 5m (20MW pin pile)	

Impact	Parameter	Maximum worst-case	Notes
	Total piling time – per turbine foundation (providing allowance for soft-start, ramp-up and issues such as low blow rate, refusal)	• 6hrs per pile (10MW monopile) x 180 piles = 1,080 hours (4,000kJ hammer); or • 1.5hrs per pin-pile (10MW quadropod) x 720 piles = 1,080 hours (2,700kJ hammer); or • 6hrs per pile (20MW monopile) x 90 piles = 540 hours (5,000kJ hammer); or • 3hrs per pin-pile (20MW) x 360 piles = 1,080 hours (2,700kJ hammer)	The maximum piling duration of 1,080 hours (including soft-start and ramp-up) associated with 10 MW monopile or 10MW or 20MW quadropod with pin-piles represents the temporal worst-case scenario for turbine foundations.
	Total piling time – per platform foundation (providing allowance for soft-start, ramp-up and issues such as low blow rate, refusal)	• 1.5hrs per pile (18 pin-piles for offshore electrical platforms) x 36 piles = 54 hours • 1.5hrs (six pin-piles for offshore service platform) x 6 piles = 9 hours • 1.5hrs per pile (Met masts quadropod) x 8 = 12 hours • 6hrs per pile (LiDAR monopiles) x 2 = 12 hours Total = 87 hours	Assumes a worst-case of 18 pin-piles per offshore electrical platforms and 6 pin-piles per offshore service platform.
	Maximum total active piling time for wind turbines and platforms	1,167 hours (48.6 days)	Based on the worst-case scenario of maximum number of pin-piles for wind turbines (up to 45 days) and platforms (up to 3.6 days).
	Activation of Acoustic Deterrent Devices (ADDs)	10 minutes per pile Up to 128.7 hours for 772 piled foundations	Maximum of 128.7 hours for 720 pin-piles (10MW) + 42 pin-piles (platforms) + 8 pin-piles (Met mast) plus 2 LiDAR monopiles Or Maximum of 38.7 hours for 180 monopiles (10MW) + 2 LiDAR monopiles plus 50 platforms and Met mast pin-piles
	Foundation installation period within construction period	Single phase = 18 months Two phase = 2 x 9 months	This is an indicative period within which foundation installation, including piling is anticipated to occur.

Impact	Parameter	Maximum worst-case	Notes
	Number of concurrent piling events	2	Maximum number of pile installation vessels on site at any one time.
	Min. spacing between piling vessels	720m	Based on the closest turbine spacing.
	Max. spacing between piling vessels	Approximately 46km	Based on the limits of the Norfolk Boreas site boundaries.
Underwater noise from seabed preparation, rock dumping and cable installation	Cable installation methods	• Ploughing; • Jetting; and • Trenching or cutting.	
	Array cable length	600km	
	Max no. of array cable laying vessels on site	5	
	Max no. of export cable laying vessels on site	5	
	Indicative duration of cable installation	Single phase = 18 months Two phase = 2 x 9 months = 18 months	18 months represents the indicative maximum cable installation duration.
	Project Interconnection cable length	90km (a pair of HVDC cables in one trench and a single AC cable in a second trench; therefore, 60km of trench, within the Norfolk Boreas site)*. 100km (a pair of DC cables in one trench and 9 AC cables in individual trenches resulting in 92km worth of trench within the project interconnector search areas)*.	
	Total export cable length	500km (100km in Norfolk Boreas site and 400km in export cable corridor) based on four cables laid as pairs with a total of 2 trenches, up to 250km trench length.	
Vessels	Maximum number of	Maximum = 57	

Impact	Parameter	Maximum worst-case	Notes
• Underwater noise and disturbance from vessels • Collision risk • Disturbance at seal haul-out sites	vessels on site at any one time during construction		
	Indicative number of movements	1,296 single phase	Approximately 36 vessels per month during the 36 month construction period for single phase development or approximately 33 vessels per month during 39 month construction period for two phase development.
	Vessel types	Vessel types that could be on site during construction include: Seabed preparation vessels, including dredging vessels Tugs and barges Jack-up vessels Dynamic Position Heavy Lift Vessel Scour vessels Substation / collector station installation vessels Array cable laying vessels Export cable laying vessels Landfall cable installation vessels Pre-trenching / backfilling vessel Cable jetting and survey vessel Filter layer vessel Commissioning vessels Crew transfer vessels Support and service vessels Accommodation vessels WTG installation vessels Other vessels	
	Port locations	Will be determined post consent. Assessment will consider Great Yarmouth, Lowestoft and Hull, with	A local port on the east coast of England is likely scenario. Vessel traffic to and from port would likely become integrated

Impact	Parameter	Maximum worst-case	Notes
		Great Yarmouth considered to be the most likely.	in existing shipping routes.
Changes in prey availability	Temporary loss of sea bed habitat; increased suspended sediments and sediment re-deposition; and underwater noise	Maximum area of physical disturbance and temporary loss of sea bed habitat = 23.31km^2 Maximum volume of increased suspended sediments and sediment re-deposition = 0.054km^3 Underwater noise during UXO clearance = parameters as outlined above. Underwater noise during piling = parameters as outlined above. Underwater noise from construction activities = parameters as outlined above.	Temporary habitat loss/disturbance in the Norfolk Boreas site = 15.4km^2; in the offshore cable corridor = 6.07km^2; and in the project interconnector search area = 1.84km^2. Temporary increases in suspended sediment concentrations and associated sediment deposition in the Norfolk Boreas site = 47,885,774m^3; in the offshore cable corridor = 3,750,000m^3; and in the project interconnector search area = 2,760,000m^3.
Operation and maintenance			
Underwater noise from turbines	Number of wind turbines	180 (10MW); or 90 (20MW)	
	Wind turbine size	10-20MW	
Underwater noise from maintenance activities, such as any additional rock dumping and cable re-burial	Unplanned repairs and reburial of cables may be required during O&M: • One export cable repair and two array cable repairs per year. • Up to 20km of export cable reburial at five year intervals. • Reburial of 25% of array cable once every five years. • One interconnector and one project interconnect cable repair per year. Rock dumping may be required should reburial not be possible.		
Vessels • Underwater noise and disturbance from vessels • Collision risk • Disturbance at seal	Number of wind farm support vessel trips per year.	445	

Impact	Parameter	Maximum worst-case	Notes
haul-out sites			
Permanent loss of seabed habitat – changes in prey availability	Permanent footprint of offshore infrastructure.	Worst-case for all infrastructure within the Norfolk Boreas sire (including foundations for turbines, platforms and other infrastructure as well as cable protection) footprint = $6.18km^2$ Worst-case cable protection within the offshore cable corridor = $0.17km^2$ Worst-case cable protection within the project interconnector search area = $0.061km^2$ Total WCS footprint = $6.4 km^2$	
	Temporary seabed disturbances from maintenance operations	Cable repairs/reburial, turbine maintenance and maintenance vessel footprints in the Boreas site = $1.07km^2$ Cable repairs and reburial in the offshore cable corridor = $0.12km^2$ Cable repairs and reburial in the project interconnector area = $0.07km^2$ Total worst-case = $1.25km^2$	
	EMF from installed array, interconnector, project connector and export cables	Worst case scenario total length of cable that is not buried = 119.76km	
Decommissioning			
Underwater noise from	Assumed to be as construction (with no pile driving).		

Impact	Parameter	Maximum worst-case	Notes
foundation removal (e.g. cutting)	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, project interconnector cables and offshore export cables would be removed. Scour and cable protection would likely be left *in situ*.		
Vessels • Underwater noise and disturbance from vessels • Collision risk • Disturbance at seal haul-out sites	Assumed to be similar vessel types, numbers and movements to construction phase (or less).		
Changes to prey resources	Assumed to be no greater than during construction phase.		

* Either "Interconnector cables" would be installed or "project interconnector cables" would be installed. Under no scenario would both be required.

12.7.3 Potential Impacts during Construction

258. The construction scenarios which this assessment has been based on are presented within Chapter 5 Project Description. The realistic worst-case scenario on which the assessment is based for marine mammal receptors is outlined in Table 12.18.

259. Depending on the receptor, the construction of the wind farm (including wind turbines, array cables, interconnector cables and platforms) may have very different impacts in terms of type and magnitude than those impacts resulting from the construction activities in the offshore cable corridor. The impacts of the entire project are assessed as a whole, although where relevant the impacts have been assessed separately for the Norfolk Boreas offshore wind farm, the project interconnector search areas and the offshore cable corridor. Therefore, for impacts that span across the Norfolk Boreas site, the project interconnector search area and the offshore cable corridor, magnitude may be discussed separately (under the same impact), however consideration is given to the combined magnitude in order to define the significance of that impact for the project overall. It should be noted that not all the assessed impacts within this ES could occur, as either the interconnector cables or the project interconnector cables would be installed, dependent on whether Norfolk Vanguard is built or not. Under no circumstance would both the interconnector cables and the project interconnector cables be installed. Further information relating to this is provided within each relevant impact assessment.

12.7.3.1 Impact 1: Underwater UXO clearance

260. There is the potential requirement for underwater unexploded ordnance (UXO) clearance prior to construction. Whilst any underwater UXO that are identified would preferentially be avoided or if possible, removed from the seabed and disposed of onshore in a designated area, however, it is necessary to consider the potential for underwater UXO detonation where retrieval is considered to be unsafe.

261. A detailed UXO survey would be completed prior to construction. The exact number of possible detonations and duration of UXO clearance operations is therefore not known at this stage. It has been estimated (Fugro, 2016; 2017) that up to 30 UXO detonations may be required within the Norfolk Boreas site, 28 in the offshore cable corridor and 22 within the project interconnector search area. It is not currently known the size or type of the UXO that could be located within the offshore project area and therefore a strategic UXO risk management assessment has been conducted to determine the potential seabed effects during Explosive Ordnance Disposal (EOD). This technical note is presented in Appendix 5.3.

262. This technical note, based on practical offshore industry experience, open-source studies and principles applied by military EOD specialists:

- Assessed typical UXO items, likely to be recommended for high order disposal.
- Assumed that all items found are live and the maximum explosive content is present.
- Assumed that approximately 5kg donor charge will be used during the EOD phase.

263. The assessment indicates that the principal UXO to consider are German and British sea mines; with German High Explosive (HE) bombs, torpedoes and depth charges regarded as a lower residual background threat. In addition, there are munitions related wrecks within the area and therefore naval projectiles are also a consideration. From experience of UK North Sea developments, the presence of Allied HE bombs are considered to also be a principal UXO hazard.

264. Other items of UXO may be encountered, however the wide range of net explosive quantities (NEQ) of the items above provide a good baseline for predicting and measuring the effects of any other items that could be encountered. Table 12.19 illustrates the NEQ of the potential types of UXO that may be encountered within the Norfolk Boreas offshore project area.

Table 12.19 Potential UXO that could be located at Norfolk Boreas

UXO item	Nominal NEQ (kg)	TNT Equivalent (kg)
German LMB (GC) Ground Mine (Hexanite)	700	770
British A Mk6 Ground Mine	430	525
German E series buoyant mine (Wet Gun Cotton / TNT - worst case)	150	150
British MK14 Buoyant mine	227	261
250lb HE Bomb (Amatol / TNT)	55	55
500lb HE Bomb (Amatol / TNT)	120	120
1000lb HE Bomb (Amatol / TNT)	250	250

265. When an item of UXO detonates on the seabed underwater, several effects are generated, most of which are localised at the point of detonation, such as crater formation and movement of sediment and dispersal of nutrients and contaminants. After detonation, there is the rapid expansion of gaseous products known as the “bubble pulse”. Once it reaches the surface, the energy of the bubble is dissipated in a plume of water and the detonation shock front rapidly attenuates at the water/air boundary. Fragmentation (that is shrapnel from the weapon casing and surrounding seabed materials) is also ejected but does not pose a significant beyond approximately 10m from source, see Appendix 5.3.

266. The high amplitude shock waves and the attendant sound wave produced by underwater detonations have the potential to cause injury or death to marine mammals (e.g. Richardson et al., 1995; von Benda-Beckmann et al., 2015). The main potential effects of underwater explosions on an individual animal are (1) trauma (from direct or indirect blast wave effect injury) such as crushing, fracturing, haemorrhages, and rupture of body tissues caused by the blast wave, resulting 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. Studies of blast effects on cetaceans indicate that smaller species are at greatest risk for shock wave or blast injuries (Ketten, 2004; von Benda-Beckmann et al., 2015).

267. The severity of the consequences of UXO detonation will depend on many variables, but principally, on the charge weight and its proximity to the receptor. In simple terms, the larger the UXO charge weight and the closer it is to any given receptor, the more damage it may cause, as explained in Appendix 5.3. After detonation, the shock wave will expand spherically outwards and will travel in a straight line (i.e. line of sight), unless the wave is reflected, channelled or meets an intervening obstruction.

268. The shock wave from a detonation consists of an almost instantaneous rise in pressure to a peak pressure, followed by an exponential decay in pressure to the hydrostatic pressure. Initially, the velocity of the shock wave is proportional to the peak pressure but rapidly settles down to the speed of sound in water, around 1,525m/s.

269. The pressure from a shock wave, and thus the potential for impact on marine mammals depends largely on the NEQ and specific detonation velocity. Radiation and attenuation of the pressure wave depends on water depth, sediment, sea state, stratification of the water column, temperature, salinity and other variables. It is difficult to determine the precise distance at which physical injury and possible death could occur to marine mammals. However, research suggests that the shock effect on marine mammals, as air-breathers and with similar respiratory lung function, is akin to that of humans, as presented in Appendix 5.3. The current advice to Royal Navy EOD operators is to use the Diver/Swimmer minimum danger range, as outlined in Table 12.20.

Table 12.20 Royal Navy Minimum Safe Distance for Swimmers (Source: Ministry of Defence, 1988)

Charge Weight of TNT (kg)	Distance (m)
Up to 250	1,200
250-500	1,500
500-1,000	2,000
1,000-2,000	2,500

270. The source levels from explosive detonations are some of the largest sounds generated by anthropogenic activities and can produce source levels of 272-287 dB re1µPa@1m (0-peak), or greater (Genesis, 2011). Explosions generate low frequencies of 2-1,000Hz, with the main energy being between 6-21Hz, and have very short durations <1ms-10ms (Richardson et al., 1995; NRC, 2005; Genesis, 2011). The low frequency energy has the potential to travel considerable distances (Parvin et al., 2007).

271. As outlined above, the high amplitude shock waves and attendant sound wave produced by underwater detonations associated with the detonation of UXO, have the potential to cause injury or death to marine mammals, including immediate or eventual fatality due to injury caused by the blast, auditory injury, such as PTS and TTS, and behavioural changes such as disturbance to foraging and breeding areas (Richardson et al., 1995; Ketten, 2004; von Benda-Beckmann et al., 2015).

272. There are limited acoustic measurements for underwater explosions, and there can be large differences in the noise levels, depending on the charge size, as well as water depth, bathymetry and seabed sediments at the site, which can also influence noise propagation. The water depth in which the explosion occurs has a significant influence on the effect range for a given charge mass (von Benda-Beckmann et al., 2015).

273. Von Benda-Beckmann et al. (2015) undertook an assessment of UXO clearance in the southern North Sea. In this study, charge masses ranged from 10 to 1,000kg, with most at 125 to 250kg and most detonations occurring in water depths between 20m and 30m. In the measured explosions, large differences in received levels were noticeable, with Sound Exposure Levels (SELs) on average lower near the surface than near the bottom or in the middle of the water column. In this study, the largest distance at which the peak overpressure corresponded to risk of observed ear trauma was at approximately 500m based on measured peak overpressure for a charge mass of 263kg in water depth of 26m. Beyond 1,800m the peak overpressures fell below the limit at which no ear trauma occurred for a charge mass of 263kg in water depth of 26m. The minimum SEL measured within 2km was 191dB re 1 µPa^{2}s, which exceeded by 1 dB the SEL-based risk threshold above which PTS was considered very likely in harbour porpoise (190dB re 1 µPa^{2}s), and exceeded by 12dB, the lower limit of PTS onset in harbour porpoise (179dB re 1 µPa^{2}s). Model predictions of effect distances as a function of SEL thresholds indicated that the effect distances for the lower limit of PTS in harbour porpoise varied between hundreds of metres and 15km for the charge masses ranging from 10 to 1,000kg (von Benda-Beckmann et al., 2015).

12.7.3.1.1 Sensitivity

274. In this assessment, all species of marine mammal are considered to have high sensitivity to UXO detonations if they are within the potential impact ranges for

physical injury or auditory injury (PTS). Marine mammals within the potential impact area are considered to have very limited capacity to avoid such effects, and unable to recover from physical injury or auditory injury (Table 12.5).

275. The sensitivity of marine mammals to disturbance as a result of underwater UXO detonations is considered to be medium in this assessment as a precautionary approach. Marine mammals within the potential disturbance area are considered to have limited capacity to avoid such effects (Table 12.5), although any disturbance to marine mammals would be temporary and they would be expected to return to the area once the disturbance had ceased.

276. The sensitivity of each receptor to TTS onset and flee response / likely avoidance is considered the same as the sensitivity to disturbance.

12.7.3.1.2 Underwater noise modelling

277. Predictive underwater noise modelling was undertaken for Norfolk Boreas (Appendix 5.5). This underwater noise modelling has been used to estimate the potential impact ranges for marine mammals that could arise during UXO clearance for Norfolk Boreas (Table 12.19).

278. As outlined above, a number of UXOs with a range of charge weights could be located within the boundary of the Norfolk Boreas site. There is expected be a variety of explosive types, which will have been subject to degradation and burying over time. Two otherwise identical explosive devices are therefore likely to produce different blasts where one has spent an extended period on the seabed.

279. A selection of explosive sizes has been considered in the estimation of the underwater noise levels produced by detonation of UXO, based on the UXO Hazard and Risk Assessment with Risk Mitigation Strategy undertaken for Norfolk Boreas (presented in Appendix 5.3). The potential impact has been compared to up to date impact criteria in respect of marine mammals that could be present in the area. This assessment assumes the maximum explosive charge is present.

280. The noise produced by the detonation of explosives is affected by a number of different elements, only one of which, the charge weight, can easily be factored into a calculation. In this case, the charge weight is based on the equivalent weight of Trinitrotoluene (TNT). Many other elements relating to its situation (e.g. its design, composition, age, position, orientation, whether it is covered by sediment) are unknown and cannot be directly considered in an assessment. This leads to a high degree of uncertainty in the estimation of the source noise level (i.e. the noise level at the position of the UXO). A worst-case estimation has therefore been used for calculations, assuming that the UXO to be detonated is not buried, degraded or subject to any other significant attenuation.

281. The consequence of this is that the noise levels produced, particularly by the larger explosives under consideration, are likely to be over-estimated as they are likely to be covered by sediment and degraded.

282. The NEQ of explosive material in the device is corrected, depending on the type of explosive material, to an equivalent quantity of TNT for the purpose of calculations (Table 12.19).

283. Estimation of the source noise level for each charge weight was carried out in accordance with the methodology of Soloway and Dahl (2014), which follows Arons (1954) and MTD (1996). These cannot take into account the range of variables noted above and thus will only provide an indication of the noise output from each detonation, assuming a freely suspended charge.

284. The attenuation of the noise as it propagates from the source location is accounted for in calculations using geometric spreading and a sound absorption coefficient, using the methodologies cited in Soloway and Dahl (2014). This calculation is used to give an indication of the range of effect, but does not take into account variable bathymetry or seabed type. However, an attenuation correction has been made for the absorption over long ranges (i.e. of the order of thousands of metres), based on measurements of high intensity noise propagation taken in the North and Irish Seas in similar depths to that present at Norfolk Boreas.

285. The calculation also does not take into account the variation in the noise level at different depths. Where animals are swimming near the surface, the acoustics at the surface cause the noise level, and hence the exposure, to be lower at this position (MTD, 1996). The risk to animals near the surface may therefore be lower than indicated by the range estimate and therefore this can be considered conservative in respect of impact at different depths.

286. The impact criteria use thresholds and weightings based on the National Oceanic and Atmospheric Administration (NOAA) (National Marine Fisheries Services (NMFS), 2018) criteria (Table 12.27). The thresholds indicate the onset of PTS, or the point at which there is an increase in risk of permanent hearing damage (although not all individuals within the maximum PTS range will have permanent hearing damage, this is assumed as a worst-case scenario). These indicators do not take into account the spreading of underwater sound over long distances, and thus there is a greater likelihood of accuracy where the ranges are small.

287. The thresholds group marine mammal species based on their hearing capabilities, for example, species that are particular sensitivity to high frequency sound, such as harbour porpoise, are classed as high-frequency cetaceans. The thresholds are weighted, which adjusts the sound present at the receiver based on the sensitivity of

the receiver. Blast noise is fairly broadband, comprising a wide range of low to high frequency sound, although the majority is at low frequency.

288. It should be noted that longer range Sound Pressure Level peak (SPL_{peak}) values are difficult to predict accurately in a shallow water (less than 50m) environment (von Benda Beckmann, 2015) and would tend to be significantly over-estimated above ranges of the order of 3km compared to real data. Note that the offshore project area is located in water depths less than 50m in depth, and so would be considered a shallow water environment in this circumstance.

289. With increased distance from the source, impulsive noise, such as UXO detonation, becomes more of a non-impulsive noise, unfortunately it is currently difficult to determine the distance at which an impulsive noise becomes more like a non-impulsive noise. Therefore, modelling was conducted using both the impulsive and non-impulsive criteria for PTS weighted Sound Exposure Levels (SEL) to give an indication of the difference between maximum potential impact ranges.

290. NMFS (2018) suggest 3km as an estimate of a distance at which transition away from this impulse to a more non-pulse type of noise could occur, although the sound will not go through a 'step change' and this distance will change depending on the type of sound and situation. It is suggested that, for any injury ranges calculated using the impulsive criteria in excess of 5km, the non-pulse criteria should be considered more appropriate, however, this is still under review. Subacoustech, therefore suggest that 5km is likely to be the limit of risk of PTS onset (see Appendix 5.4 for more information).

291. The use of NOAA (NMFS, 2018) weighted Sound Exposure Level (SEL) is considered more suitable, especially over long ranges. However, as a precautionary approach and based on the current Natural England advice (20180209 NE position on NOAA UXOs and EPS) the assessment has been based on the worst-case scenarios for the unweighted SPL_{peak} predicted PTS impact ranges. Weighted SEL predicted impact ranges have been used for TTS, to take into account the species hearing capabilities.

12.7.3.1.3 Permanent auditory injury (PTS)

292. The number of harbour porpoise, grey seal and harbour seal that could potentially be impacted was estimated for Norfolk Boreas, based on the maximum potential PTS impact ranges with no mitigation for UXO clearance (Table 12.21). The resulting magnitude is shown to be medium for harbour porpoise in the offshore project area; medium for grey seal in the cable corridor; low for harbour seal in the cable corridor, and negligible for grey and harbour seal in the Norfolk Boreas wind farm site and project interconnector cable search areas.

293. As outlined above, caution should also be raised over the longer range SPL_{peak} values. Therefore, the use of NMFS weighted SEL is considered preferential at long range (see Appendix 5.4). However, as a precautionary approach and based on the current Natural England advice (20180209 NE position on NOAA UXOs and EPS) the assessment has been based on the worst-case scenarios for the unweighted SPL_{peak} predicted PTS impact ranges (Table 12.21). However, it is considered that the maximum potential impact range for PTS is likely to be 5km.

294. The range of equivalent charge weights of the potential UXO devices that could be present within the Norfolk Boreas site boundaries have been estimated as being from 25kg to 770kg. Estimation of the source noise level for each charge weight was carried out in accordance with the methodology of Soloway and Dahl (2014), which follows Arons (1954) and MTD (1996). These charge weights cannot take into account the range of variables noted above and thus will only provide an indication of the noise output from each detonation. They also assume a worst-case freely suspended charge.

295. A MMMP for UXO clearance will detail the proposed mitigation measures to reduce the risk of any permanent auditory (PTS) injury to marine mammals during any underwater detonations and will be completed pre-construction. See section 12.7.3.1.6.

Table 12.21 Potential impact of permanent auditory injury (PTS) on marine mammals during UXO clearance without mitigation

Species	Potential Impact	TNT Equivalent / Charge weights	25kg	60kg	145kg	151kg	312kg	340kg	770kg	Magnitude[2]
		Source Level, SPL_{peak}	284.9 dB	287.7 dB	290.6 dB	290.7 dB	293.1 dB	293.4 dB	296.1 dB	
Harbour porpoise (high-frequency cetacean)	PTS SPL_{peak} Unweighted (NMFS, 2018)	202 dB re 1 µPa	4.6km	6.1km	8.3km	8.4km	10.7km	11.0km	14.4km	**Medium** Permanent (between 0.01% and 1% of the reference population)
	PTS SEL Weighted (NMFS, 2018)	155 dB re 1 μPa^2s	0.56km	0.76km	1.0km	1.0km	1.2km	1.2km	1.5km	
	Number of harbour porpoise and % of reference population[1] based on predicted impact range (14.4km) for PTS unweighted SPL_{peak} (NMFS, 2018)	Predicted impact area* based on unweighted SPL_{peak} = 651.44km[2] 578 harbour porpoise (0.17% of NS MU) based on SCANS-III survey density (0.888/km[2]). 691 harbour porpoise (0.2% of NS MU) based on the site specific survey density at the Norfolk Boreas site (1.06/km[2]).								
	Number of harbour porpoise and % of reference population[1] based on maximum impact range (5km) for PTS	Maximum impact area* based on 5km range = 78.5km[2] 70 harbour porpoise (0.02% of NS MU) based on SCANS-III survey density (0.888/km[2]). 83 harbour porpoise (0.02% of NS MU) based on the site specific survey density at the Norfolk Boreas site (1.06/km[2]).								
Grey seal and harbour seal (pinnipeds in water)	PTS SPL_{peak} Unweighted (NMFS, 2018)	218 dB re 1 µPa	0.9km	1.2km	1.6km	1.6km	2.1km	2.1km	2.8km	**Medium** for grey seal in cable corridor Permanent (between 0.01% and 0.1% of the ref pop) **Low** for harbour seal in cable corridor
	PTS SEL Weighted (NMFS, 2018)	185 dB re 1 μPa^2s	0.38km	0.59km	0.91km	0.93km	1.3km	1.3km	2.0km	
Grey Seal	Number of grey seal and % of reference population[1] based on	Maximum impact area* based on unweighted SPL_{peak} = 24.63km[2] 0.025 grey seal (0.0001% ref pop; 0.0004% SE England MU) based on the Norfolk Boreas								

Species	Potential Impact	TNT Equivalent / Charge weights	25kg	60kg	145kg	151kg	312kg	340kg	770kg	Magnitude[2]
		SOURCE LEVEL, SPL_{PEAK}	284.9 dB	287.7 dB	290.6 dB	290.7 dB	293.1 dB	293.4 dB	296.1 dB	
	maximum impact range (2.8km) for PTS unweighted SPL_{peak} (NMFS, 2018)		site and project interconnector search area (NV West) densities (0.001/km^2). 4 grey seal (0.02% ref pop; 0.07% SE England MU) based on offshore cable corridor area density (0.162/km^2). 0.0025 grey seal (0.00001% ref pop; 0.00004% SE England MU) based on the project interconnector search area (NV East) density (0.0001/km^2).							Permanent (between 0.001% and 0.01% of the ref pop) **Negligible** for grey and harbour seal in Norfolk Boreas site and project interconnector cable search areas (less than 0.001% of ref pop).
Harbour seal	Number of harbour seal and % of reference population[1] based on maximum impact range (2.8km) for PTS unweighted SPL_{peak} (NMFS, 2018)		Maximum impact area* based on unweighted SPL_{peak} = 24.63km^2 0.0025 harbour seal (0.000005% ref pop; 0.00005% SE England MU) based on the Norfolk Boreas site and project interconnector search area densities (0.0001/km^2). 2.4 harbour seal (0.005% ref pop; 0.04% SE England MU) based on offshore cable corridor area density (0.098/km^2).							

*Maximum area based on area of circle with maximum impact range for radius.
[1]Based on density estimates and reference populations (see Table 12.14 and Table 12.15); [2] See Table 12.7 for definitions.

12.7.3.1.4 Temporary auditory injury and fleeing response

296. TTS ranges have been modelled and are presented for information. TTS ranges also indicate the potential fleeing response. However, it should be noted that the assessment of magnitude of effect or overall effect significance is likely to overestimate the potential for any significant effect. The TTS onset thresholds used in the NOAA (NMFS, 2018) criteria, are determined as a basis to predict when PTS might occur (rather than conducting experiments to induce permanent auditory injury (PTS) in marine mammals).

297. The number of harbour porpoise, grey seal and harbour seal that could potentially by impacted at Norfolk Boreas is estimated based on the maximum potential TTS impact ranges with no mitigation for UXO clearance (Table 12.22). The resulting effect is shown to be of negligible magnitude for harbour porpoise, grey seal and harbour seal.

298. The implementation of the agreed mitigation measures within the UXO MMMP for PTS will also reduce the number of animals that could be exposed to noise levels that could result in TTS.

Table 12.22 Potential maximum impact of temporary auditory injury (TTS) and fleeing response on marine mammals during UXO clearance

Species	Potential Impact	TNT Equivalent / Charge weights	25kg	60kg	145kg	151kg	312kg	340kg	770kg	Magnitude[2]
		SOURCE LEVEL, SPL_{PEAK}	284.9 dB	287.7 dB	290.6 dB	290.7 dB	293.1 dB	293.4 dB	296.1 dB	
Harbour porpoise (high-frequency cetacean)	TTS SPL_{peak} Unweighted (NMFS, 2018)	196 dB re 1 µPa	8.5km	11.3km	15.2km	15.4km	19.6km	20.2km	26.5km	**Negligible** Temporary (less than 1% of the reference population)
	TTS SEL Weighted (NMFS, 2018)	140 dB re 1 μPa^2s	2.4km	2.8km	3.3km	3.3km	3.7km	3.7km	4.2km	
	Number of harbour porpoise and % of reference population[1] based on maximum impact range (26.5km) for TTS SPL_{peak} unweighted (NMFS, 2018)		Maximum impact area* based on weighted TTS SEL = 2,206.2km^2 1,959 harbour porpoise (0.6% of NS MU) based on SCANS-III survey density (0.888/km^2). 2,339 harbour porpoise (0.7% of NS MU) based on the site specific survey density at the Norfolk Boreas site (1.06/km^2).							
Grey seal and harbour seal (pinnipeds in water)	TTS SPL_{peak} Unweighted (NMFS, 2018)	212 dB re 1 µPa	1.6km	2.2km	3.0km	3.0km	3.8km	3.9km	5.2km	**Negligible** Temporary (less than 1% of the reference population)
	TTS SEL Weighted (NMFS, 2018)	170 dB re 1 μPa^2s	5.2km	7.7km	11.5km	11.7km	15.9km	16.5km	23.0km	
Grey Seal	Number of grey seal and % of reference population[1] based on maximum impact range (23.0km) for TTS SEL Weighted (NMFS, 2018)		Maximum impact area* based weighted TTS SEL = 1,661.9km^2 1.7 grey seal (0.008% ref pop; 0.03% SE England MU) based on the Norfolk Boreas site and project interconnector cable search area (in NV West) densities (0.001/km^2). 269 grey seal (1.2% ref pop; 4.4% SE England MU) based on offshore cable corridor area density (0.162/km^2).							

Species	Potential Impact	TNT Equivalent / Charge weights	25kg	60kg	145kg	151kg	312kg	340kg	770kg	Magnitude[2]
		Source Level, SPL_{PEAK}	284.9 dB	287.7 dB	290.6 dB	290.7 dB	293.1 dB	293.4 dB	296.1 dB	
		0.2 grey seal (0.0009% ref pop; 0.003% SE England MU) based on project interconnector cable search area (in NV East) density (0.0001/km^2).								
Harbour seal	Number of harbour seal and % of reference population[1] based on maximum impact range (23.0km) for TTS SEL Weighted (NMFS, 2018)	Maximum impact area* based on weighted TTS SEL = 1,661.9km^2 0.2 harbour seal (0.0005% ref pop; 0.004% SE England MU) based on the Norfolk Boreas site and project interconnector cable search area densities (0.0001/km^2). 163 harbour seal (0.4% ref pop; 3.2% SE England MU) based on offshore cable corridor area density (0.098/km^2).								

*Maximum area based on area of circle with maximum impact range for radius.
[1]Based on density estimates and reference populations (see Table 12.14 and Table 12.15); [2] See Table 12.7 for definitions.

12.7.3.1.5 Disturbance

299. For harbour porpoise, grey seal and harbour seal, a fleeing response is assumed to occur at the same noise levels as TTS. As outlined in Southall et al. (2007) the onset of behavioural disturbance is proposed to occur at the lowest level of noise exposure that has a measurable transient effect on hearing (i.e. TTS-onset). Although, as Southall et al. (2007) recognise that this is not a behavioural effect per se, exposures to lower noise levels from a single pulse are not expected to cause disturbance, however any compromise, even temporarily, to hearing functions could have the potential to affect behaviour.

300. Although mitigation in the MMMP for UXO clearance will increase the distance of marine mammals from any UXO detonations, it cannot mitigate the potential disturbance to marine mammals.

301. The SNCBs currently recommend that a potential disturbance range of 26km (approximate area of 2,124km^2) around UXO detonations is used to assess harbour porpoise disturbance in the SNS SAC. The Norfolk Boreas site is located mostly within the SNS SAC therefore this approach has been used for the EIA and applied to all species.

302. The estimated number of harbour porpoise, grey seal and harbour seal that could potentially be disturbed during underwater UXO clearance, based on a 26km radius, is presented in Table 12.23. The resulting impact is shown to be of negligible magnitude for harbour porpoise, harbour seal and grey seal, with the exception of a magnitude of low for grey seal within the cable corridor, without mitigation.

303. Disturbance from any UXO detonations would be instantaneous and occur for a very short-duration (i.e. the detonation). For the estimated worst-case (Table 12.18) it is predicted that there could be up to 30 clearance operations in the Norfolk Boreas site, 22 in the project interconnector search area and 28 in the offshore cable corridor based on initial geophysical data (Fugro, 2016; 2017), but final numbers will be determined by a pre-construction UXO survey. As a precautionary worst-case scenario, the maximum number of days of UXO clearance could be up to 80 days, based on one detonation per day.

Table 12.23 Estimated number of harbour porpoise, grey seal and harbour seal that could potentially be disturbed during UXO clearance and magnitude of effect

Potential Impact	Receptor	Estimated number in impact area[1]	% of reference population[1]	Magnitude[2]
Area of disturbance (2,124km^2) during underwater	Harbour porpoise	1,886 harbour porpoise based on SCANS-III survey block O density (0.888/km^2).	0.55% of NS MU based on SCANS-III density.	Temporary effect with **negligible** magnitude (i.e. less than 1% of the reference population
		2,251 harbour porpoise	0.65% of NS MU based	

Potential Impact	Receptor	Estimated number in impact area[1]	% of reference population[1]	Magnitude[2]
UXO clearance		based on site specific survey density ($1.06/km^2$) at the Norfolk Boreas site.	on the site specific survey density.	anticipated to be exposed to effect).
	Grey seal	2.1 grey seal based on the Norfolk Boreas site and project interconnector cable search area (in NV West) densities ($0.001/km^2$).	0.01% ref pop (0.04% SE England MU) for Norfolk Boreas site and project interconnector cable search area (in NV West).	Temporary effect with **negligible** magnitude for Norfolk Boreas site and project interconnector cable search areas (less than 1% of the reference population).
		0.2 grey seal based on project interconnector cable search area (in NV East) densities ($0.0001/km^2$).	0.0009% ref pop (0.003% SE England MU) project interconnector cable search area (in NV East).	
		344 grey seal based on offshore cable corridor area density ($0.162/km^2$).	1.5% ref pop (5.7% SE England MU) for cable corridor.	Temporary effect with **low** magnitude for cable corridor (between 1% of 5% of the reference population).
	Harbour seal	0.2 harbour seal based on the Norfolk Boreas site and project interconnector cable search area densities ($0.0001/km^2$).	0.0005% ref pop (0.004% SE England MU) for Norfolk Boreas site and project interconnector cable search area densities.	Temporary effect with **negligible** magnitude for Norfolk Boreas site and cable corridor (less than 1% of the reference population).
		208 harbour seal based on offshore cable corridor area density ($0.098/km^2$).	0.48% ref pop (4.1% SE England MU) for cable corridor.	

[1]Based on density estimates and reference populations (see Table 12.14 and Table 12.15);
[2] See Table 12.7 for definitions.

304. The spatial assessment of the potential effects of disturbance during UXO clearance on the SNS SAC will form part of the assessment for the Report to inform the HRA.

12.7.3.1.6 Impact significance

305. Taking into account the receptor sensitivity and the potential magnitude of the impact (e.g. number of individuals as a percentage of the reference population) and if the impact is permanent (e.g. PTS) or temporary (e.g. TTS and disturbance), the impact significance for any physical injury, permanent auditory injury, temporary auditory injury / fleeing response and disturbance in harbour porpoise, grey seal and harbour seal has been assessed as **major adverse** without mitigation for PTS in

harbour porpoise, **major to minor adverse** without mitigation for PTS in grey seal, and **moderate to minor adverse** in harbour seal (Table 12.24).

306. It should be noted that the conclusion of major adverse without mitigation for PTS in harbour porpoise and grey seal is very precautionary, as the assessment is based on the worst-case scenario for the largest UXO device that may (or may not) be present with the Norfolk Boreas offshore project area.

307. The risk of TTS in harbour porpoise, grey seal and harbour seal has been assessed as **minor adverse** (not significant) for UXO clearance, with no mitigation (Table 12.24).

308. The potential disturbance has been assessed as **minor adverse** (not significant) for harbour porpoise and harbour seal, and **moderate** to **minor adverse** for grey seal during UXO clearance, with no mitigation (Table 12.24).

Mitigation

309. As outlined in section 12.7.1.2.2, a MMMP for UXO clearance will be produced post-consent in consultation with the MMO and relevant SNCBs and will be based on the latest scientific understanding and guidance, pre-construction UXO surveys at the Norfolk Boreas offshore project area and detailed project design.

310. The MMMP for UXO clearance has not been included with the ES, as it will be developed post-consent and will be agreed with the relevant SNCBs prior to any UXO works progressing.

311. In addition to the MMMPs for UXO clearance, an In Principle Norfolk Boreas SNS SAC SIP has been developed and included with the DCO Application (document reference 8.17). The SIP sets out the approach to deliver any project mitigation or management measures in relation to the SNS SAC, in particular the significant disturbance of harbour porpoise. Any measures put in place to reduce the effects on harbour porpoise would also reduce any impacts on grey and harbour seal.

312. An EPS licence application, if required, will be submitted post-consent. At this time, pre-construction UXO surveys will have been conducted, as well as full consideration of the mitigation measures that will be in place following the development of the MMMP for UXO clearance.

Residual impact

313. The residual impact of the potential risk of physical injury and permanent auditory injury to marine mammals as a result of any underwater UXO clearance is reduced to a negligible magnitude taking into account the proposed mitigation to reduce the potential effects. Therefore, with high sensitivity the potential overall impact significance for any physical injury or permanent auditory injury, is likely to reduce to **minor adverse** (not significant) (Table 12.24).

Table 12.24 Assessment of impact significance for UXO clearance on marine mammals

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Permanent auditory injury (PTS) during underwater UXO clearance	Harbour porpoise	High	Medium based on worst-case scenario (Table 12.21)	Major	MMMP for UXO clearance.	**Minor adverse** (high sensitivity and negligible magnitude)
	Grey seal	High	Medium to Negligible based on worst-case scenario (Table 12.21)	Major to Minor		
	Harbour seal	High	Low to negligible based on worst-case scenario (Table 12.21)	Moderate to Minor		
Temporary auditory injury (TTS) and fleeing response during underwater UXO clearance	Harbour porpoise	Medium	Negligible	Minor	MMMP for UXO clearance.	**Minor adverse** (high sensitivity and negligible magnitude)
	Grey and harbour seal	Medium	Negligible	Minor		
Disturbance during UXO clearance	Harbour porpoise	Medium	Negligible	Minor	MMMP for UXO clearance and SIP for SNS SAC.	**Minor adverse** (high sensitivity and negligible magnitude)
	Grey seal	Medium	Low to negligible	Minor		
	Harbour seal	Medium	Negligible	Minor		

12.7.3.2 Impact 2: Underwater noise during piling

314. A range of foundation options are being considered for Norfolk Boreas, including monopile, jacket (tripod or quadropod), gravity base, suction caisson and TetraBase. Of these, monopiles, jackets and TetraBase foundations may require piling.

315. Impact piling has been proposed to drive the foundation piles 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). During piling, noise is created in air by the hammer as a direct result of the impact of the hammer with the pile; some of this airborne noise is transmitted into the water. Of more significance to the underwater noise is the

direct radiation of noise from the pile into the water because of the compressional, flexural or other complex structural waves that travel down the pile following the impact of the hammer on its head. Structural pressure waves in the submerged section of the pile transmit sound efficiently into the surrounding water. These waterborne pressure waves will radiate outwards, usually providing the greatest contribution to the underwater noise.

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

317. Should a marine mammal be very close to the source, the high peak pressure sound levels have the potential to cause death or physical injury, with any severe injury potentially leading to death, if no adequate mitigation is in place. High exposure levels from underwater noise sources can cause auditory injury or hearing impairment taking the form of a permanent loss of hearing sensitivity (PTS) or a temporary loss in hearing sensitivity (TTS). The potential for auditory injury is not just related to the level of the underwater sound and its frequency relative to the hearing bandwidth of the animal, but is also influenced by the duration of exposure. The level of impact on an individual is a function of the SEL that an individual receives as a result of underwater noise.

318. Marine mammals may exhibit varying intensities of behavioural response at different noise levels. These include orientation or attraction to a noise source, increased alertness, modification of characteristics of their own sounds, cessation of feeding or social interaction, alteration of movement / diving behaviour, temporary or permanent habitat abandonment, and in severe cases, panic, flight stampede or stranding, sometimes resulting in injury or death. The response can vary due to exposure level, the hearing sensitivity of the individual, context, previous exposure history or habituation, motivation and ambient noise levels (e.g. Southall et al., 2007).

319. The potential impact of underwater noise 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 (dependent upon species);
- Propagation range, which is dependent on:
    - Sediment/sea floor composition;
    - Water depth;
- Duration of exposure;

- Distance of the animal to the source; and
- Ambient noise levels.

12.7.3.2.1 Underwater noise modelling

320. Underwater noise modelling was carried out by Subacoustech to estimate the noise levels likely to arise during construction of Norfolk Boreas and determine the potential impacts on marine mammals using the INSPIRE subsea noise propagation model (Appendix 5.4). The INSPIRE model is a semi-empirical noise propagation model based on the use of a combination of numerical modelling and actual measured underwater noise data. It was designed to calculate the propagation of noise in shallow, mixed water, typical of both conditions around the UK and therefore the Norfolk Boreas site.

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

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

Piling locations

322. Modelling was undertaken at two representative locations. One at the closest point to land (in the South West (SW) of the site) which is also one of the deepest locations (38m water depth) and the furthest position from this location (North East (NE)) which is in 28m water depth (Appendix 5.4).

323. The SW location represents the worst-case scenario for underwater noise propagation. Therefore, the worst-case impact ranges modelled for this location were used to inform the assessment of the potential impacts on receptor groups, in order to provide a very conservative assessment.

Hammer energy, soft-start and ramp-up

324. The underwater noise modelling is based on the following worst-case scenarios for monopiles and pin-piles (jacket):

- 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, maximum hammer energy of 2,700kJ and maximum starting hammer energy of 270kJ.

325. For the SEL_{cum}, the soft-start and ramp up takes place over the first 30 minutes of piling, with the soft-start for a minimum of 10 minutes at 10% of maximum hammer energy, then a minimum of 20 minutes for the ramp-up, during which there will be a gradual increase in hammer energy and strike rate until reaching the maximum hammer energy where it is assumed to remain for the duration of the pile installation (however, maximum hammer energy is only likely to be required at a few of the piling installation locations and for shorter periods of time). The soft-start, ramp-up and piling duration used to assess SEL_{cum} for monopiles and pin-piles are summarised in Table 12.25.

326. The monopile scenario contains 10,350 pile strikes over 360 minutes (6 hours, including soft-start and ramp-up).

327. The pin-pile scenario includes four individual piles installed consecutively, with a total of 9,000 strikes over 6 hours, with an installation time of 1 hour 30 minutes for each pin-pile. For the purposes of noise modelling, it is assumed that there is no pause between each individual pin-pile, as it is assumed that the marine mammal will continue swimming away from the source.

328. The noise modelling in Appendix 5.4, also included a scenario based on 3 hours to install each pin-pile, however, 1 hour 30 minutes for each pin-pile was determined to be the most realistic worst-case scenario and has therefore been used in the assessment.

Table 12.25 Hammer energies, ramp-up and duration used for calculating cumulative SELs

	Starting hammer energy (10%)	Ramp-up	Maximum hammer energy (100%)
Monopile			
Monopile hammer energy	500kJ	Gradual increase	5,000kJ
Number of strikes	150 strikes	300 strikes	9,990 strikes
Duration	10 minutes	20 minutes	330 minutes
Pin-pile			
Pin-pile hammer energy	270kJ	Gradual increase	2,700kJ
Number of strikes per pile (6 hours total duration for quadropod)	150 strikes	300 strikes	1,800 strikes
Duration per pile (6 hours total duration for quadropod)	10 minutes	20 minutes	60 minutes

329. The offshore electrical platforms may require the use of a six-legged jacket foundation with three pin-piles per leg (tripod legs), therefore, this is less than the modelled scenario of four pin-piles being installed consecutively with no breaks, as

each leg of the jacket would be installed separately. It is assumed that up to a maximum of four pin-piles could be installed, before a break and a further four pin-piles being installed. However, it is more likely that there would be a break in piling between each pin-pile being installed to allow for the next pin-pile to be placed in the correct location.

330. The size of the pile being installed is used for estimating the frequency content of the noise. Generally, increasing pile diameter would be expected to move the dominant frequency of the sound produced by impact piling, further below the frequencies of greatest hearing sensitivity of marine mammals, and thus the sound would appear slightly quieter to a receptor with higher sensitivities to higher frequencies, such as harbour porpoise. For this modelling, frequency data has been sourced from Subacoustech's noise measurement database and an average taken to obtain representative third-octave levels, i.e. frequency levels for installing monopiles and pin piles (for further details see Appendix 5.4).

Environmental conditions

331. The semi-empirical nature of the INSPIRE mode considers the seabed type and speed of sound in water the mixed conditions around the Norfolk Boreas site. Mean tidal depth has been used for the bathymetry as the tidal state will fluctuate throughout installation of the foundations (see Appendix 5.4).

Baseline ambient noise

332. In principle, when noise is introduced by anthropogenic sources, and propagates far enough from the source, it will reduce to the level of ambient noise levels, at which point it is considered negligible. As the underwater noise thresholds used within the modelling are all considerably above the level of background noise, the noise baseline is not featured in the assessment (Appendix 5.4).

Noise source levels

333. Underwater noise modelling requires knowledge of the source level, which is the theoretical noise level at 1m from the noise source. The INSPIRE noise propagation model assumes that the noise acts as a single point source, which is adjusted to take into account water depth at the source location to allow for the length of pile in contact with the water, which affects the amount of noise that is transmitted from the pile into surroundings (Appendix 5.4).

334. The unweighted SPL_{peak} source levels estimated for this assessment are provided in Table 12.26.

Table 12.26 Unweighted SPL_{peak} and SEL_{ss} source levels used in underwater noise modelling for maximum and starting hammer energy

Location	Source Level	Monopile source level (5,000kJ)	Pin-pile source level (2,700kJ)	Monopile source level (500kJ)	Pin-pile source level (270kJ)
South-West (SW) location	SPL_{peak}	242.6 dB re 1 µPa @ 1 m	240.3 dB re 1 µPa @ 1 m	231.2 dB re 1 µPa @ 1 m	226.9 dB re 1 µPa @ 1 m
	SPL_{ss}	223.6 dB re 1 µPa @ 1 m	221.3 dB re 1 µPa @ 1 m	212.2 dB re 1 µPa @ 1 m	207.9 dB re 1 µPa @ 1 m

Thresholds and criteria

335. Sound measurements underwater are usually expressed using the decibel (dB) scale, which is a logarithmic measure of sound.

336. The sound pressure level (SPL) is normally used to characterise noise and vibration of a continuous nature. The variation in sound pressure can be measured over a specific time period to determine the root mean square (RMS) level of the time varying acoustic pressure, therefore SPL (i.e. SPLRMS) can be considered as a measure of the average unweighted level of the sound over the measurement period.

337. Peak SPLs (SPL_{peak}) are often used to characterise sound transients from impulsive sources, such as percussive impact piling. A peak SPL is calculated using the maximum variation of the pressure from positive to zero within the wave. This represents the maximum change in positive pressure (differential pressure from positive to zero) as the transient pressure wave propagates.

338. The sound exposure level (SEL) sums the acoustic energy over a measurement period, and effectively takes account of both the SPL of the sound source and the duration the sound is present in the acoustic environment (further details are provided in Appendix 5.4).

339. SEL_{ss} is the potential sound exposure level from a single strike of the hammer, e.g. one hammer strike at the starting hammer energy or maximum hammer energy.

340. SEL_{cum} is the cumulative sound exposure level during the duration of piling including the soft-start, ramp-up and time required to complete the installation of the pile (Table 12.25). To determine SEL_{cum} ranges, a fleeing animal model has been used. This assumes that the animal exposed to high noise levels will swim away from the noise source. For this a fleeing speed of 1.5 m/s has been used, which is based on the average swimming speed for a harbour porpoise (Otani et al., 2000). This is considered a 'worst-case' scenario as marine mammals are expected to be able to swim faster. For example, the swimming speed of a harbour porpoise during playbacks of pile driving sounds (SPL of 154 dB re 1 µPa) was 1.97 m/s (7.1km/h) and

during quiet baseline periods the mean swimming speed was 1.2 m/s (4.3km/h; Kastelein et al., 2018).

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

342. The assessment in the ES considers the metrics and criteria from NOAA (NMFS, 2018) and Lucke et al. (2009) to assess the potential effects of impact piling noise on marine mammals. This was agreed with the marine mammal ETG as part of the EPP. In addition, Appendix 12.5 presents the potential effects using the criteria proposed by Southall et al. (2007). This was agreed with the marine mammal ETG as part of the EPP to allow comparison with previous projects.

343. NMFS (2018) presents 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.

344. The NOAA (NMFS, 2018) metrics and criteria used in the underwater noise modelling are summarised in Table 12.27.

345. NOAA (NMFS, 2018) groups marine mammals into functional hearing groups and applies filters to the unweighted noise to approximate the hearing sensitivity of the receptor.

Table 12.27 NOAA (NMFS, 2018) metrics and criteria used in the underwater noise modelling

Species or species group	Impact	NOAA (NMFS, 2018)	
		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
	TTS and fleeing response (Temporary Threshold Shift)	196	140
Grey seal and harbour seal Pinnipeds in water	Auditory Injury - PTS (Permanent Threshold Shift)	218	185
	TTS and fleeing response (Temporary Threshold Shift)	212	170

346. The criteria from Lucke et al. (2009) are derived from testing harbour porpoise hearing thresholds before and after being exposed to seismic airgun stimuli (a pulsed noise like impact piling). The Lucke et al. (2009) criteria for possible behavioural

response in harbour porpoise used in the assessment are unweighted single strike SELs (Table 12.28).

Table 12.28 Lucke et al. (2009) metrics and criteria used in the underwater noise modelling

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

Assumptions and considerations

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

- The maximum hammer energy and maximum piling duration is assumed for all piling locations, however it is unlikely that maximum hammer energy and duration will be required at the majority of piling locations.
- The maximum predicted impact ranges are based on the location with the greatest potential noise propagation range and this was assumed as the worst-case for each piling location.
- Impact ranges for a single strike are from the piling location and do not take into account (i) mitigation measures, such as soft-start or the use of ADDs to move marine mammals out of the area where there could be a risk of physical or auditory injury; or (ii) the potential disturbance and movement of marine mammals away from the site as a result of the vessels and set-up prior to mitigation.
- The assumption that fleeing animals (harbour porpoise, grey seal and harbour seal) are swimming at a speed of 1.5 m/s (based on harbour porpoise mother calf pairs; Otani et al., 2000), however, marine mammals are expected to swim much faster. For example, harbour porpoise have been recorded swimming at speeds of up to 4.3m/s (Otani et al., 2000) and, as outlined above, Kastelein et al. (2018) reported swimming speed of a harbour porpoise during playbacks of pile driving sounds of 1.97m/s.
- The assumption that animals are submerged 100% of the time which does not account for any time that a receptor may spend at the surface or the reduced SELs near the surface where the animal would not be exposed to such high levels or for seals having their head out of the water.
- Underwater noise modelling assumes that marine mammals will travel in the mid-water column where sound pressure levels are greatest. However, in reality animals would not be subjected to these high sound pressure levels at all times since they are likely to move up and down through the water column, and surface to breathe, where the sound pressure would drop to zero. A study by

Teilmann et al. (2007) on diving behaviour of harbour porpoise in Danish waters suggests that animals spent 55% of their time in the upper 2m of the water column from April to August and over the whole year they spent 68% of their time in less than 5m depth. However, it should be noted that this study was conducted for “undisturbed” animals, which could show a different behaviour.

348. The swimming patterns of harbour porpoise undertaking direct travel are typically characterised by short submergence periods, compared to feeding animals (Watson and Gaskin, 1983). These short duration dives with horizontal travel suggest that travelling animals, such as harbour porpoise moving away from pile driving noise, would swim in the upper part of the water column. It would be anticipated, that during a fleeing response, from a loud underwater noise, such as piling, that their swimming behaviour may change with a reduction in deep dives. For example, during pile driving playback sounds to examine TTS, harbour porpoise showed behaviour response during the exposure periods, which included increased swimming speeds and jumping out of the water more (Kastelein et al., 2016). This behavioural response would allow the animal to move to a greater distance from the adverse noise source in a shorter period of time and result in exposure to lower noise propagation close to the sea surface, compared to mid-water at a comparable distance (Nabe-Nielsen Pers. Comm).

349. Noise impact assessments assume that all animals within the noise contour may be affected to the same degree for the maximum worst-case scenario. For example, that all animals exposed to noise levels that induce behavioural avoidance will be displaced or all animals exposed to noise levels that are predicted as inducing PTS or TTS will suffer permanent or temporary auditory injury respectively. However, a study looking at the proportion of trials at different SELs that result in TTS in exposed bottlenose dolphins suggests that to induce TTS in 50% of animals it would be necessary to extrapolate well beyond the range of measured SEL levels (Finneran et al., 2005). This suggests that for a given species, the potential effects follow a dose-response curve such that the probability of inducing TTS will decrease moving further away from the SEL threshold required to induce TTS. Further work by Thompson et al. (2013b) has adopted this dose-response curve to produce a theoretical dose-response for PTS in harbour seal by scaling up Finneran et al. (2005) dose response curve for changes in levels of TTS at different SEL, where the probability of seals experiencing PTS increases from an SEL of 186 up to 240 dB re 1 μPa^2 s; the point at which all animals are predicted to have PTS.

12.7.3.2.2 Permanent auditory injury

Permanent auditory injury sensitivity

350. All species of cetaceans rely on sonar for navigation, finding prey and communication; they are therefore highly sensitive to permanent hearing damage

(Southall et al., 2007). However, when considering the impact that any auditory injury has on an individual, the frequency range over which the auditory injury occurs must be considered. PTS would normally only be expected in the critical hearing bands in and around the critical band of the fatiguing sound (e.g. Kastelein et al., 2012). Auditory injury resulting from sound sources like piling (where most of the energy occurs at lower frequencies) is unlikely to negatively affect the ability of high-frequency cetaceans to communicate or echo-locate. As such, sensitivity to PTS from pile driving noise is assessed as high for harbour porpoise (Table 12.29).

351. Pinnipeds use sound both in air and water for social and reproductive interactions (Southall et al., 2007), but not for finding prey. Therefore, Thompson et al. (2012) suggest damage to hearing in pinnipeds may not be as important as it could be in cetaceans. Pinnipeds also have the ability to hold their heads out of the water during exposure to loud noise, and potentially avoid PTS during piling. As such, sensitivity to PTS in harbour and grey seal is probably lower than harbour porpoise, with the individual showing some tolerance to avoid, adapt to or accommodate or recover from the impact (for example, Russell et al., 2016), but as a precautionary approach they are considered as having high sensitivity in this assessment (Table 12.29).

352. Marine mammals within the potential impact area are considered to have very limited capacity to avoid such effects, and unable to recover from the effects.

Table 12.29 Summary of marine mammal sensitivity to noise impacts from pile driving

Species	Lethal effect or physical injury	Auditory injury (PTS)	Onset of TTS / fleeing response	Disturbance	Possible behavioural response
Harbour porpoise	High	High	Medium	Medium	Low
Grey and harbour seal	High	High	Medium	Medium	N/A

Permanent auditory injury magnitude

353. The underwater noise modelling results for the maximum predicted ranges (and areas) for permanent auditory injury (PTS) in harbour porpoise, grey seal and harbour seal are presented in Table 12.30 for the following:

- Single strike SPL_{peak} for maximum starting hammer energy of 500kJ for monopile;
- Single strike SPL_{peak} for maximum starting hammer energy of 270kJ for pin-piles;
- Single strike SPL_{peak} for monopile with maximum hammer energy of 5,000kJ;
- Single strike SPL_{peak} for pin-pile with a maximum hammer energy of 2,700kJ; and

- Cumulative SEL taking into account soft-start and ramp-up plus duration to install pile at maximum hammer energy. For the pin-piles the SEL_{cum}, is based on the duration to install four pin-piles for each foundation (not per individual pin-pile).

354. The underwater noise modelling results for the maximum predicted ranges (and areas) for permanent auditory injury (PTS) in harbour porpoise, grey seal and harbour seal are based on:

- NOAA (NMFS, 2018) criteria for unweighted SPL_{peak} and PTS from cumulative exposure (SEL_{cum}) for harbour porpoise and seals.

Table 12.30 Maximum predicted impact ranges (and areas) for permanent auditory injury (PTS) from a single strike and from cumulative exposure based on NOAA (NMFS, 2018) criteria

Potential Impact	Receptor	Criteria and threshold	Maximum predicted impact range (km) and area* (km^2)			
			Monopile		Pin-pile	
			Starting hammer energy (500kJ)	Maximum hammer energy (5,000kJ)	Starting hammer energy (270kJ)	Maximum hammer energy (2,700kJ)
PTS without mitigation – single strike	Harbour porpoise	NMFS (2018) unweighted SPL_{peak} 202 dB re 1 µPa	0.07km (0.014km^2)	0.34km (0.373km^2)	<0.05km (0.004km^2)	0.25km (0.204km^2)
PTS without mitigation – single strike	Grey seal and harbour seal	NMFS (2018) unweighted SPL_{peak} 218 dB re 1 µPa	<0.05km (0.0002km^2)	<0.05km (0.006km^2)	<0.05km (0.00009km^2)	<0.05km (0.0001km^2)
PTS from cumulative SEL (including soft-start and ramp-up)	Harbour porpoise	NMFS (2018) SEL_{cum} Weighted 155 dB re 1 µPa^{2}s	N/A	<0.1km (0.031km^2)	N/A	0.3km (0.203km^2)
PTS from cumulative SEL (including soft-start and ramp-up)	Grey seal and harbour seal	NMFS (2018) SEL_{cum} Weighted 185 dB re 1 µPa^{2}s	N/A	<0.1km (0.031km^2)	N/A	<0.1km (0.391km^2)

*areas for maximum hammer energies for monopile and pin-pile based on modelled contour area

Harbour porpoise PTS from first strike of soft-start

355. The estimated maximum area within which PTS could occur in harbour porpoise (Figure 12.5) is 0.014km^2 for the maximum starting hammer energy (500kJ) (Table 12.30).

356. The estimated maximum number of harbour porpoise that could potentially be at risk of PTS as a result of a single strike of 500kJ is 0.015 individuals (0.000004% of the North Sea MU reference population; Table 12.31). The magnitude of the potential impact is assessed as negligible with less than 0.001% of the reference population anticipated to be exposed to effect without mitigation.

357. Mitigation, as outlined in section 12.7.1.2.1, would ensure no harbour porpoise were in the potential impact range for PTS from the first strike of the soft-start and therefore reduce the risk of PTS.

Pinniped PTS from first strike of soft-start

358. The estimated maximum area within which PTS could occur in grey and harbour seal is up to 0.002km^2 for the maximum starting hammer energy (500kJ) (Table 12.30).

359. The magnitude of the potential effect on grey seal without any mitigation is assessed as negligible, with less than 0.001% of the reference populations anticipated to be exposed to the effect (Table 12.31).

360. The magnitude of the potential effect on harbour seal without any mitigation is assessed as negligible, with less than 0.001% of the reference populations anticipated to be exposed to the effect (Table 12.31).

361. Mitigation, as outlined in section 12.7.1.2.1, would ensure no grey or harbour seal were in the potential impact range for PTS from the first strike of the soft-start and therefore reduce the risk of PTS.

Harbour porpoise PTS from single strike at maximum hammer energy

362. The estimated maximum areas (without mitigation) within which PTS could occur in harbour porpoise (Figure 12.5) is estimated to be 0.373km^2 and 0.204km^2 for the maximum hammer energy of the monopile (5,000kJ) and pin-pile (2,700kJ), respectively (Table 12.30).

363. The magnitude of the potential impact without any mitigation is assessed as negligible, with 0.001% or less of the North Sea MU reference population anticipated to be exposed to the effect without mitigation (Table 12.31).

364. Mitigation, as outlined in section 12.7.1.1.2 and 12.7.1.2.1, would reduce the risk of PTS from a single strike of the maximum hammer energy.

Pinniped PTS from single strike at maximum hammer energy

365. The estimated maximum areas (without mitigation) within which PTS could occur in grey and harbour seal is up to 0.006km^2 for the maximum hammer energy of the monopile (5,000kJ) and up to 0.0001km^2 the pin-pile (2,700kJ) (Table 12.30).

366. Without any mitigation, for grey seal the magnitude of the potential effect without any mitigation is assessed as negligible, with less than 0.001% of the reference population anticipated to be exposed to the effect (Table 12.31).

367. Without any mitigation, for harbour seal the magnitude of the potential impact without any mitigation is assessed as negligible, with less than 0.001% of the reference population anticipated to be exposed to the effect (Table 12.31).

368. Mitigation, as outlined in section 12.7.1.1.2 and 12.7.1.2.1, would reduce the risk of PTS from a single strike of the maximum hammer energy.

Table 12.31 Maximum number of individuals (and % of reference population) that could be at risk of permanent auditory injury (PTS) from a single strike

			Monopile with maximum hammer energy of 5,000kJ		Pin-pile with maximum hammer energy of 2,700kJ		Starting hammer energy of 500kJ	
Potential Impact	Receptor	Criteria and threshold	Maximum number of individuals (% of reference population)[1] (no mitigation)	Magnitude[2]	Maximum number of individuals (% of reference population)[1] (no mitigation)	Magnitude[2]	Maximum number of individuals (% of reference population)[1]	Magnitude[2]
PTS without mitigation – single strike	Harbour porpoise	NMFS (2018) unweighted SPL_{peak} 202 dB re 1 µPa	0.33 harbour porpoise (0.0001% NS MU) based on SCANS-III survey block O density (0.888/km^2). 0.4 harbour porpoise (0.0001% NS MU) based on site specific survey density (1.06/km^2).	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population anticipated to be exposed to effect without mitigation).	0.18 harbour porpoise (0.00005% NS MU) based on SCANS-III survey block O density (0.888/km^2). 0.22 harbour porpoise (0.00006% NS MU) based on site specific survey density (1.06/km^2).	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population anticipated to be exposed to effect without mitigation).	0.012 harbour porpoise (0.000004% NS MU) based on SCANS-III survey block O density (0.888/km^2). 0.015 harbour porpoise (0.000004% NS MU) based on site specific survey density (1.06/km^2).	Permanent effect with **negligible** magnitude (less than 0.001% of reference population).
PTS without mitigation – single strike	Grey seal	NMFS (2018) unweighted SPL_{peak} 218 dB re 1 µPa	0.000006 grey seal (<0.0000001% ref pop; 0.0000001% SE England MU) based on the Norfolk Boreas site area density (0.001/km^2).	Permanent effect with **negligible** magnitude (less than 0.001% of reference population).	0.0000001 grey seal (<0.0000001% ref pop; 0.00000002% SE England MU) based on the Norfolk Boreas site density (0.001/km^2).	Permanent effect with **negligible** magnitude (less than 0.001% of reference population).	0.0000002 grey seal (<0.0000001% of ref pop & SE England MU) based on the Norfolk Boreas site density (0.001/km^2).	Permanent effect with '**negligible**' magnitude (less than 0.001% of reference population).
PTS without mitigation –	Harbour seal	NMFS (2018) unweighted	0.0000006 harbour seal (<0.0000001% ref pop & SE	Permanent effect with **negligible**	0.00000001 harbour seal (<0.0000001% ref	Permanent effect with **negligible** magnitude (less	0.00000002 harbour seal (<0.0000001% of	Permanent effect with **negligible** magnitude (less

			Monopile with maximum hammer energy of 5,000kJ		Pin-pile with maximum hammer energy of 2,700kJ		Starting hammer energy of 500kJ	
Potential Impact	**Receptor**	**Criteria and threshold**	**Maximum number of individuals (% of reference population)[1]** **(no mitigation)**	**Magnitude[2]**	**Maximum number of individuals (% of reference population)[1]** **(no mitigation)**	**Magnitude[2]**	**Maximum number of individuals (% of reference population)[1]**	**Magnitude[2]**
single strike		SPL_{peak} 218 dB re 1 µPa	England MU) based on the Norfolk Boreas site density (0.0001/km^2).	magnitude (less than 0.001% of reference population).	pop & SE England MU) based on the Norfolk Boreas site density (0.0001/km^2).	than 0.001% of reference population).	ref pop & SE England MU) based on the Norfolk Boreas site density (0.0001/km^2).	than 0.001% of reference population).

[1]Based on density estimate and reference population (see Table 12.14 and Table 12.15); [2]See Table 12.7 for definitions

Harbour porpoise PTS from cumulative exposure

369. This section of the impact assessment considers the risk of PTS from the repeated percussive strikes required to install a single monopile or four pin-piles. The ranges at which an individual could experience PTS are assessed as a result of cumulative exposure during the entire piling duration including the soft-start and ramp-up, based on the animals fleeing at a precautionary average speed of 1.5m/s.

370. The SEL_{cum} results for harbour porpoise using the NMFS (2018) criteria indicates that the larger hammer hitting a monopile results in lower impact ranges than a smaller hammer hitting a pin-pile. This reflects the hearing sensitivity of harbour porpoise and the sound frequencies produced by the different piles. The noise from pin-piles contains more high frequency components than the noise from monopiles. The overall unweighted noise level is higher for the monopile due to the low frequency components of piling noise (i.e. most of the pile strike energy is in the lower frequencies). The high-frequency cetacean filters, used for harbour porpoise, to determine the weighting used in the criteria, removes the low frequency components of the noise, as these marine mammals are much less sensitive to noise at these frequencies. This leaves the higher frequency noise, which, in the case of the pin-piles, is higher than that for the monopiles (for further details see Appendix 5.4).

371. As a result of the maximum pin-pile hammer energy of 2,700kJ, the estimated maximum number of harbour porpoise that could potentially be at risk of PTS from cumulative SEL is up to 0.2 harbour porpoise (0.00006% of the reference population) during the six hours to install four pin-piles (Table 12.32). The magnitude of the potential impact is assessed as negligible, with less than 0.001% of the reference population anticipated to be exposed to the effect. This assessment is without any further mitigation, as the embedded mitigation of the soft-start and ramp-up has been included in the modelling for PTS from cumulative exposure.

372. Mitigation, as outlined in section 12.7.1.1.2 and 12.7.1.2.1, would reduce the risk of cumulative PTS.

Pinniped PTS from cumulative exposure

373. For grey and harbour seals, the maximum potential impact areas for PTS from cumulative SEL is 0.031km^2 for the maximum hammer energy of 5,000kJ for monopiles and 0.391km^2 for the maximum hammer energy of 2,700kJ for installation pin-piles. This is based on the total piling duration for a single monopile (including the soft-start and ramp-up) and total duration to install four pin-piles (including the soft-start and ramp-up) and the animals fleeing at a precautionary average speed of 1.5m/s (Table 12.30).

374. The magnitude of the potential effect on grey seal is assessed as negligible with less than 0.001% of the reference population anticipated to be exposed to effect (Table 12.32).

375. The magnitude of the potential effect on harbour seal is assessed as negligible, with less than 0.001% of the reference population anticipated to be exposed to the effect (Table 12.32).

Considerations of the risk of PTS from cumulative SEL

376. The risk of PTS from cumulative SEL ranges indicates the distance that an individual animal would need to be from the noise source, at the onset of the piling sequence, to prevent a cumulative noise exposure which could lead to PTS. It should be noted that this assessment is highly precautionary for the following reasons:

- The maximum impact ranges provided in Appendix 5.4, based on the worst-case exposure levels an animal may receive at different depths in the water column, have been used in the assessment, this is highly conservative as it is unlikely a marine mammal would remain at this depth level;
- The assessment does not take account of periods where exposure will be reduced when they are at the surface or heads are out of the water; and
- The cumulative noise dose received by the marine mammal will be largely dependent on the swimming speed, and whether the animal moves away from the noise source rapidly as a flee response. For the SEL_{cum} noise modelling the swim speed of 1.5m/s used is highly conservative and therefore this is likely to overestimate the received noise levels, especially for seals, as they are likely to have their heads out of the water most of the time.

Table 12.32 Indicative maximum number of individuals (and % of reference population) that could be at risk of PTS from cumulative exposure

Potential Impact	Receptor	Criteria and threshold	Maximum number of individuals (% of reference population)[1]			
			Monopile with maximum hammer energy of 5,000kJ	Magnitude[2]	Four pin-piles with maximum hammer energy of 2,700kJ	Magnitude[2]
PTS – cumulative exposure (including soft-start and ramp-up)	Harbour porpoise	NMFS (2018) SEL$_{cum}$ Weighted 155 dB re 1 μPa^{2}s	0.028 harbour porpoise (0.000008% of NS MU) based on SCANS-III survey block O density (0.888/km^2). 0.033 harbour porpoise (0.00001% of NS MU) based on site specific survey density (1.06/km^2).	Permanent effect with **negligible** magnitude (less than 0.001% of reference population).	0.18 harbour porpoise (0.00005% of NS MU) based on SCANS-III survey block O density (0.888/km^2). 0.2 harbour porpoise (0.00006% of NS MU) based on site specific survey density (1.06/km^2).	Permanent effect with **negligible** magnitude (less than 0.001% of reference population).
PTS – cumulative exposure (including soft-start and ramp-up)	Grey seal	NMFS (2018) SEL$_{cum}$ Weighted 185 dB re 1 μPa^{2}s	0.00003 grey seal (0.0000001% ref pop; 0.0000005% SE England MU) based on the Norfolk Boreas site density (0.001/km^2).	Permanent effect with **negligible** magnitude (less than 0.001% of reference population).	0.0004 grey seal (0.000002% ref pop; 0.000007% SE England MU) based on the Norfolk Boreas site density (0.001/km^2).	Permanent effect with **negligible** magnitude (less than 0.001% of reference population).
PTS – cumulative exposure (including soft-start and ramp-up)	Harbour seal	NMFS (2018) SEL$_{cum}$ Weighted 185 dB re 1 μPa^{2}s	0.000003 harbour seal (<0.0000001% ref pop and SE England MU) based the Norfolk Boreas site density (0.0001/km^2).	Permanent effect with **negligible** magnitude (less than 0.001% of reference population).	0.00004 harbour seal (<0.0000001% ref pop; 0.0000008% SE England MU) based on the Norfolk Boreas site density (0.0001/km^2).	Permanent effect with **negligible** magnitude (less than 0.001% of reference population).

[1]Based on density estimate and reference population (see Table 12.14 and Table 12.15); [2]See Table 12.7 for definitions

Permanent auditory injury impact significance

377. Taking into account the receptor sensitivity and the potential magnitude of the effect (i.e. number of individuals as a percentage of the reference population) and the embedded mitigation, the impact significance for any permanent auditory injury in harbour porpoise, grey seal and harbour seal has been assessed as **minor adverse** (not significant) (Table 12.33).

<u>Mitigation</u>

378. As outlined in section 12.7.1, the MMMP for piling will be developed post-consent in consultation with SNCBs and will be based on the latest information, scientific understanding and guidance and detailed project design. The final MMMP for piling will be based on the draft MMMP submitted with the DCO application (document reference 8.13).

379. The mitigation, as outlined in section 12.7.1.1.2 and 12.7.1.2.1 would reduce the risk of PTS from the first strike of the soft-start, single strike of the maximum hammer energy and cumulative PTS.

<u>Residual impact</u>

380. The residual impact of the potential risk of permanent auditory injury (PTS) to marine mammals as a result of underwater noise during piling will be reduced to a negligible magnitude taking into account the mitigation in the MMMP for piling to reduce the risk of PTS. Therefore, with high sensitivity the potential impact significance for any permanent auditory injury will be **minor adverse** (not significant) (Table 12.33).

Table 12.33 Assessment of impact significance for any permanent auditory injury (PTS) in marine mammals from underwater noise during piling

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Permanent auditory injury (PTS) injury as a result of underwater noise from single strike of starting hammer energy	Harbour porpoise, grey seal and harbour seal	High	Negligible	Minor adverse	MMMP	**Minor adverse**
Permanent auditory injury (PTS) injury as a result of underwater noise from single strike of maximum hammer energy	Harbour porpoise	High	Negligible (without embedded mitigation)	Minor adverse	MMMP including embedded mitigation	**Minor adverse**
	Grey seal and harbour seal	High	Negligible (without embedded mitigation)	Minor adverse		
Permanent auditory injury (PTS) injury as a result of underwater noise during piling from cumulative exposure	Harbour porpoise	High	Negligible (without mitigation)	Minor adverse	MMMP including embedded mitigation	**Minor adverse**
	Grey seal and harbour seal	High	Negligible (without mitigation)	Minor adverse		

12.7.3.2.3 Temporary auditory injury and fleeing response

381. As outlined above, precaution should be used in the significance of the potential TTS ranges that have been modelled and presented for information. The TTS onset thresholds used in the NOAA (NMFS, 2018) criteria, are determined as a basis to predict when PTS might occur (rather than conducting experiments to induce permanent auditory injury (PTS) in marine mammals).

Temporary auditory injury sensitivity

382. Harbour porpoise, grey seal and harbour seal are assessed as having medium sensitivity to TTS onset (Table 12.29).

Temporary auditory injury and fleeing response magnitude

383. The underwater noise modelling results for the maximum predicted ranges (and areas) for temporary auditory injury (TTS) and fleeing response in harbour porpoise, grey seal and harbour seal are presented in (Table 12.34) for:

- Monopile with maximum hammer energy of 5,000kJ; and
- Pin-pile with maximum hammer energy of 2,700kJ.

384. Based on:

- The NOAA (NMFS, 2018) criteria for unweighted SPL_{peak} and TTS from cumulative SEL (SEL_{cum}).

385. For harbour porpoise, grey seal and harbour seal a fleeing response is assumed to occur at the same noise levels as TTS. The response of individuals to a noise stimulus will vary and not all individuals will respond, however, for the purpose of this assessment, it is assumed that 100% of the individuals in the TTS range will respond and flee the area.

Table 12.34 Maximum predicted impact ranges (and areas) for TTS / fleeing response from a single strike and for TTS from cumulative exposure

Potential Impact	Receptor	Criteria and threshold	Maximum predicted impact range (km) and area (km^2)	
			Monopile with maximum hammer energy of 5,000kJ	Pin-pile with maximum hammer energy of 2,700kJ
TTS and fleeing response without mitigation – single strike	Harbour porpoise	NMFS (2018) unweighted SPL_{peak} 196 dB re 1 µPa	0.79km (1.98km^2)	0.57km (1.04km^2)
	Grey seal and harbour seal	NMFS (2018) unweighted SPL_{peak} 212 dB re 1 µPa	0.08km (0.028km^2)	0.06km (0.018km^2)
TTS from cumulative SEL	Harbour porpoise	NMFS (2018) SEL_{cum} Weighted 140 dB re 1 µPa^{2}s	7.4km (152.8km^2)	15.0km (576.5km^2)
	Grey seal and harbour seal	NMFS (2018) SEL_{cum} Weighted 170 dB re 1 µPa^{2}s	5.0km (69.4km^2)	2.7km (20.5km^2)

Harbour porpoise TTS / fleeing response from single strike at maximum hammer energy

386. The risk of TTS / fleeing response from a single strike of maximum hammer energy is significantly reduced through embedded mitigation as the maximum hammer energy strike would always be preceded by the soft-start and ramp-up and other mitigation measures (for example, the activation of ADDs).

387. The estimated maximum ranges for TTS / fleeing response in harbour porpoise, is estimated to be 0.79km and 0.57km for the maximum hammer energy of the monopile (5,000kJ) and pin-pile (2,700kJ), respectively (Figure 12.6; Table 12.34).

388. The magnitude of the potential impact is assessed as negligible, with less than 1% of the reference population anticipated to be exposed to the temporary effect (Table 12.35).

Pinniped TTS / fleeing response from single strike at maximum hammer energy

389. The estimated maximum ranges within which TTS / fleeing response could occur in grey and harbour seal is up to 0.08km for the maximum hammer energy of the monopile (5,000kJ) and up to 0.06km for the maximum hammer energy of the pin-pile (2,7000kJ) (Figure 12.7; Table 12.34).

390. The magnitude of the potential effect on grey seal is assessed as negligible, with less than 1% of the reference population anticipated to be exposed to the temporary effect (Table 12.35).

391. The magnitude of the potential effect on harbour seal is assessed as negligible, with less than 1% of the reference population anticipated to be exposed to the temporary effect (Table 12.35).

Table 12.35 Maximum number of individuals (and % of reference population) that could be at risk of temporary auditory injury (TTS) / fleeing response from a single strike

Potential Impact	Receptor	Criteria and threshold	Maximum number of individuals (% of reference population)[1]			
			Monopile with maximum hammer energy of 5,000kJ	Magnitude[2]	Pin-pile with maximum hammer energy of 2,700kJ	Magnitude[2]
TTS / fleeing response – single strike	Harbour porpoise	NMFS (2018) unweighted SPL_{peak} 196 dB re 1 µPa	1.8 harbour porpoise (0.0005% NS MU) based on SCANS-III survey block O density (0.888/km^2). 2.1 harbour porpoise (0.0006% NS MU) based on the Norfolk Boreas site specific survey density (1.06/km^2).	Temporary effect with **negligible** magnitude (less than 1% of reference population).	0.9 harbour porpoise (0.0003% NS MU) based on SCANS-III survey block O density (0.888/km^2). 1.1 harbour porpoise (0.0003% NS MU) based on the Norfolk Boreas site specific survey density (1.06/km^2).	Temporary effect with **negligible** magnitude (less than 1% of reference population).
TTS / fleeing response – single strike	Grey seal	NMFS (2018) unweighted SPL_{peak} 212 dB re 1 µPa	0.00003 grey seal (0.0000001% ref pop; 0.0000005% SE England MU) based on the Norfolk Boreas site density (0.001/km^2).	Temporary effect with **negligible** magnitude (less than 1% of reference population).	0.00002 grey seal (0.0000001% ref pop; 0.0000003% of SE England MU) based on the Norfolk Boreas site density (0.001/km^2).	Temporary effect with **negligible** magnitude (less than 1% of reference population).
TTS / fleeing response – single strike	Harbour seal	NMFS (2018) unweighted SPL_{peak} 212 dB re 1 µPa	0.000003 harbour seal (<0.0000001 ref pop and SE England MU) based on the Norfolk Boreas site density (0.0001/km^2).	Temporary effect with **negligible** magnitude (less than 1% of reference population).	0.000002 harbour seal (<0.0000001% ref pop and SE England MU) based on the Norfolk Boreas site density (0.0001/km^2).	Temporary effect with **negligible** magnitude (less than 1% of reference population).

[1]Based on density estimate and reference population (see Table 12.14 and Table 12.15); [2]See Table 12.7 for definitions

Harbour porpoise TTS from cumulative exposure

392. The ranges at which an individual could experience TTS as a result of cumulative exposure during the total piling duration, including the soft-start and ramp-up, based on the SEL_{cum} noise modelling using animals fleeing at a speed of 1.5m/s, but not taking into account any preceding mitigation, such as ADD activation, is estimated to be 7.4km and 15km for harbour porpoise for the maximum hammer energies of 5,000kJ for monopiles and 2,700kJ for the installation of four pin-piles, respectively, based on the NOAA (NMFS, 2018) criteria (Table 12.34).

393. The indicative maximum number of harbour porpoise that could potentially be at risk of TTS from cumulative SEL as a result of the maximum monopile hammer energy of 5,000kJ is up to 162 individuals (0.05% of the North Sea MU reference population), based on the site specific density for the Norfolk Boreas site (1.06 harbour porpoise per km^2) (Table 12.36). The magnitude of the potential impact is assessed as negligible, with less than 1% of the reference population anticipated to be exposed to the temporary effect.

394. For pin-piles with maximum hammer energy of 2,700kJ and based on the duration to install four pin-piles for each foundation, including soft-start and ramp-up, the indicative maximum number of harbour porpoise that could potentially be at risk of TTS from cumulative SEL is up to 611 harbour porpoise (0.18% of the North Sea MU reference population) based on site specific survey density (1.06/km^2) at the Norfolk Boreas site (Table 12.36). The magnitude of the potential impact is assessed as negligible, with less than 1% of the reference population anticipated to be exposed to the temporary effect.

Pinniped TTS from cumulative exposure

395. For grey and harbour seals, the maximum potential impact ranges for TTS from cumulative SEL is 5km for the maximum hammer energy of 5,000kJ for monopiles and 2.7km for the maximum hammer energy of 2,700kJ for the installation of four pin-piles (Table 12.34).

396. The magnitude of the potential effect on grey seal is assessed as negligible**,** with less than 1% of the reference population anticipated to be exposed to the temporary effect (Table 12.36).

397. The magnitude of the potential effect on harbour seal is assessed as negligible, with less than 1% of the reference population anticipated to be exposed to the temporary effect (Table 12.36).

Considerations of the risk of TTS from cumulative exposure

398. As outlined for PTS from cumulative exposure, the ranges indicate the distance that an individual needs to be from the noise source at the onset of the piling sequence

to prevent a cumulative noise exposure which could lead to TTS. However, this type of assessment is completed for information purposes only, as discussed in section 12.7.3.2.2 this is highly conservative because the assessment assumes the worst-case exposure levels for an animal in the water column, and does not take account of periods where exposure will be reduced in seals when their heads are out of the water; or that the cumulative noise dose received by the marine mammal will be largely dependent on the swimming speed, and whether the animal moves away from the noise source rapidly as a flee response. The cumulative SEL dose does not take account of this and therefore is likely to overestimate the received noise levels.

Table 12.36 Indicative maximum number of individuals (and % of reference population) that could be at risk of TTS from cumulative exposure

Potential Impact	Receptor	Criteria and threshold	Maximum number of individuals (% of reference population)[1]			
			Monopile with maximum hammer energy of 5,000kJ	Magnitude[2]	Four pin-piles with maximum hammer energy of 2,700kJ	Magnitude[2]
TTS without mitigation – cumulative exposure	Harbour porpoise	NMFS (2018) SEL_{cum} Weighted 140 dB re 1 µPa^{2}s	136 harbour porpoise (0.04% NS MU) based on SCANS-III survey block O density (0.888/km^2). 162 harbour porpoise (0.05% NS MU) based on the Norfolk Boreas site specific survey density (1.06/km^2).	Temporary effect with **negligible** magnitude (less than 1% of reference population).	512 harbour porpoise (0.15% NS MU) based on SCANS-III survey block O density (0.888/km^2). 611 harbour porpoise (0.18% NS MU) based on the Norfolk Boreas site specific survey density (1.06/km^2).	Temporary effect with **negligible** magnitude (less than 1% of reference population).
	Grey seal	NMFS (2018) SEL_{cum} Weighted 170 dB re 1 µPa^{2}s	0.07 grey seal (0.0003% ref pop; 0.001% SE England MU) based on the Norfolk Boreas site density (0.001/km^2).	Temporary effect with **negligible** magnitude (less than 1% of reference population).	0.02 grey seal (0.00009% ref pop; 0.0003% SE England MU) based on the Norfolk Boreas site density (0.001/km^2).	Temporary effect with **negligible** magnitude (less than 1% of reference population).
	Harbour seal	NMFS (2018) SEL_{cum} Weighted 170 dB re 1 µPa^{2}s	0.007 harbour seal (0.00002% ref pop; 0.0001% SE England MU) based on the Norfolk Boreas site density (0.0001/km^2).	Temporary effect with **negligible** magnitude (less than 1% of reference population).	0.002 harbour seal (0.000005% ref pop; 0.00004% of SE England MU) based on the Norfolk Boreas site density (0.0001/km^2).	Temporary effect with **negligible** magnitude (less than 1% of reference population).

[1]Based on density estimate and reference population (see Table 12.14 and Table 12.15); [2]See Table 12.7 for definitions

Temporary auditory injury and fleeing response impact significance

399. Taking into account the receptor sensitivity and the potential magnitude of the temporary impact (e.g. number of individuals as a percentage of the reference population), the impact significance for any temporary auditory injury (TTS) and fleeing response in harbour porpoise, grey seal and harbour seal has been assessed as **minor adverse** (not significant) (Table 12.37).

Mitigation

400. The mitigation to reduce the risk of PTS will move animals away from the piling location and will therefore also reduce the number of animals in the predicted impact area for TTS.

Residual impact

401. The residual impact of the potential risk of temporary auditory injury (TTS) to marine mammals as a result of underwater noise during piling will be reduced to a negligible magnitude taking into account the MMMP for piling, including embedded mitigation, therefore with medium sensitivity the potential impact significance for any temporary auditory injury, it is expected that the overall impact significance will be **minor adverse** (not significant) (Table 12.37).

Table 12.37 Assessment of impact significance for underwater noise during piling on marine mammals

<table>
<tr><th>Potential Impact</th><th>Receptor</th><th>Sensitivity</th><th>Magnitude</th><th>Significance</th><th>Mitigation</th><th>Residual Impact</th></tr>
<tr><td>Temporary auditory injury (TTS) and fleeing response as a result of underwater noise from single strike of maximum hammer energy</td><td>Harbour porpoise, grey seal and harbour seal</td><td>Medium</td><td>Negligible</td><td>Minor adverse</td><td rowspan="2">MMMP including embedded mitigation</td><td rowspan="2">Minor adverse</td></tr>
<tr><td>Temporary auditory injury (TTS) as a result of underwater noise during piling from cumulative exposure</td><td>Harbour porpoise, grey seal and harbour seal</td><td>Medium</td><td>Negligible</td><td>Minor adverse</td></tr>
</table>

12.7.3.2.4 Disturbance

Disturbance sensitivity

402. Harbour porpoise have relatively high daily energy demands and need to consume between 4% and 9.5% of their body weight in food per day (Kastelein et al., 1997). If a harbour porpoise does not capture enough prey to meet its daily energy requirements it can rely on stored energy (primarily blubber) for an estimated three to five days, depending on body condition (Kastelein et al., 1997). Should harbour porpoise be excluded from an area of key prey resource it will likely seek an alternative food resource and this could have an effect on the individual's fitness. For example, they may have to travel further or take less than optimum prey species. The effects on an individual's fitness are partly caused by the exclusion of animals from high-quality foraging areas and partly by the net energy losses associated with fleeing from disturbances (Nabe-Nielsen et al., 2014). Therefore, impacts in lower quality habitat are likely to have a lower potential impact on an animal's fitness.

403. Harbour porpoise are assessed as having medium sensitivity to disturbance (Table 12.29).

404. Harbour seal and grey seal exhibit alternate periods of foraging and resting at haul out sites (during which limited or no feeding occurs). Prolonged fasting also occurs in these species during annual breeding and moult, when there are marked seasonal changes in body condition (Rosen and Renouf, 1997; Bäcklin et al., 2011). Although adult seals may be relatively robust to short term (weeks rather than days compared to harbour porpoise) changes in prey availability, young and small individuals have a more sensitive energy balance. This is exhibited through effects of mass dependant survival (Harding et al., 2005). Although disturbance to harbour or grey seal may lead to a severe or sustained avoidance of an area, these species can be considered less sensitive to such an impact than harbour porpoise. Tagged harbour seals in the Wash indicated that seals were not excluded from the vicinity of the wind farm during the overall construction phase but that there was clear evidence of avoidance during pile driving, with significantly reduced levels of seal activity at ranges up to 25km from piling sites (Russell et al., 2016). However, within two hours of cessation seal distribution returned to pre-piling levels (Russell et al., 2016). However, as a precautionary approach, harbour and grey seal are also assessed as having medium sensitivity to disturbance (Table 12.29).

405. The sensitivity of marine mammals to disturbance is considered to be medium in this assessment as a precautionary approach. Marine mammals within the potential disturbance area are considered to have limited capacity to avoid such effects, although any disturbance to marine mammals would be temporary and they would be expected to return to the area once the disturbance had ceased.

Disturbance magnitude

406. For harbour porpoise, grey seal and harbour seal, a fleeing response is assumed to occur at the same noise levels as TTS. Therefore, the potential range and areas for fleeing response in harbour porpoise, grey seal and harbour seal are presented in Table 12.34, with the estimated number and percentage of reference populations in Table 12.35. The response of individuals to a noise stimulus will vary and not all individuals will respond; however, for the purpose of this assessment, it is assumed that at the 'disturbance' range, as outlined below, 100% of the individuals exposed to the noise stimulus will respond and be displaced from the area. However, as outlined in section 12.7.3.2.5, it is unlikely that all individuals would be displaced from the potential disturbance area, therefore this a very precautionary approach.

<u>Disturbance during possible mitigation</u>

407. During the implementation of the possible mitigation, for example the activation of ADDs for 10 minutes and the minimum 30 minutes for the soft-start and ramp-up, it is estimated that animals would move at least 3.6km (2.7km for 30 minute soft-start and ramp-up plus 0.9km during ADD activation for 10 minutes) from the piling location (based on a precautionary marine mammal swimming speed of 1.5m/s), resulting in an area of 41km^2.

408. The number of harbour porpoise that could potentially be disturbed as a result of the possible mitigation would be 43.5 individuals (0.01% of the North Sea MU reference population), based on the site specific density for the Norfolk Boreas site (1.06 harbour porpoise per km^2) as a worst-case scenario. Therefore, the magnitude of the potential temporary impact is assessed as negligible. Less than 1% of the reference population would be temporarily exposed to the effect.

409. The number of grey seal that could potentially be disturbed as a result of the possible mitigation would be 0.04 individuals (0.0002% of the reference population or 0.0007% of the South-east England MU). Therefore, the magnitude of the potential temporary impact is assessed as negligible.

410. The number of harbour seal that could potentially be disturbed as a result of the possible mitigation would be 0.004 individuals (0.00001% of the reference population or 0.00008% of the South-east England MU). Therefore, the magnitude of the potential temporary impact is assessed as negligible.

411. For two concurrent piling installations, if both were starting piling at the same time, the potential area of disturbance as a result of the possible mitigation would be 82km^2. The number of harbour porpoise that could potentially be disturbed as a result of the possible mitigation for two concurrent piling locations would be 87 individuals (0.03% of the North Sea MU reference population), based on the site specific density for the Norfolk Boreas site (1.06 harbour porpoise per km^2).

Therefore, the magnitude of the potential temporary impact is assessed as negligible, with less than 1% of the reference population anticipated to be exposed to the effect.

412. For two concurrent piling installations, the number of grey seal that could potentially be disturbed as a result of the possible mitigation would be 0.08 grey seal (0.0004% of the reference population or 0.001% of the South-east England MU) and the number of harbour seal is 0.008 (0.00002% of the reference population or 0.0002% of the South-east England MU). Therefore, the magnitude of the potential temporary impact is assessed as negligible**,** with less than 1% of the reference population anticipated to be exposed to the effect.

413. It should be noted that the disturbance as a result of the possible mitigation prior to piling would be part of the 26km disturbance range for piling and is therefore not an additive effect to the overall area of potential disturbance. However, the duration of the possible mitigation prior to piling has been taken into account, as a worst-case scenario, in the assessment of the duration of potential disturbance.

Disturbance during single pile installation

414. The current advice from the SNCBs is that a potential disturbance range of 26km (approximate area of 2,124km^2) around piling locations is used to assess the area that harbour porpoise may be disturbed in the SNS SAC. Norfolk Boreas is located within the SNS SAC therefore this approach has been used for the EIA as well as the assessments for the HRA. The estimated number of harbour porpoise that could be disturbed as a result of underwater noise during piling is presented in Table 12.38.

415. Tagged harbour seals in the Wash indicate that seals were not excluded from the vicinity of the wind farm during the overall construction phase but that there was clear evidence of avoidance during pile driving, with significantly reduced levels of seal activity at ranges up to 25km from piling sites (Russell et al., 2016; SCOS, 2016, 2017). Therefore, the 26km disturbance range has also been used for grey and harbour seals to be consistent with harbour porpoise range (Figure 12.7; Table 12.38). It is acknowledged that this is not Natural England's advice; however, this approach was agreed by the ETG as part of the EPP.

416. The estimated maximum number of harbour porpoise that could potentially be disturbed as a result of underwater noise from piling is 2,251 individuals (0.65% of the North Sea MU reference population), based on all porpoises in 2,124km^2 area being disturbed and the site specific density for the Norfolk Boreas site (1.06 harbour porpoise per km^2) (Table 12.38). The magnitude of the potential effect is assessed as negligible, with less than 1% of the reference population anticipated to be exposed to the temporary effect.

417. The estimated maximum number of grey seals that could potentially be disturbed as a result of underwater noise from piling is 2 grey seals (0.009% of the reference population or 0.03% of the South-east England MU; Table 12.38). The magnitude of the potential effect is assessed as negligible, with less than 1% of the reference population anticipated to be exposed to the temporary effect.

418. The estimated maximum number of harbour seals that could potentially be disturbed as a result of underwater noise from piling is 0.2 individuals (0.0005% of the reference population or 0.004% of the South-east England MU; Table 12.38). The magnitude of the potential effect is assessed as negligible, with less than 1% of the reference population anticipated to be exposed to the temporary effect.

419. The maximum total piling duration for the installation would be up to 1,080 hours for 180 10MW turbines (Table 12.18) plus an estimated maximum of 120 hours for 10 minute ADD activation per pile, based on worst-case scenario of up to 720 pin-piles, resulting in approximately 1,200 hours of disturbance for wind turbine foundation installation. In addition, piling for the offshore platforms would be up to 87 hours (Table 12.18) plus an estimated 8 hours and 40 minutes for 10 minute ADD activation per pile for the 52 piles. Therefore, the maximum piling duration (including ADD activation) for Norfolk Boreas would be up to 1,295 hours and 40 minutes (equivalent of up to 54 days).

420. Indicative installation worst-case scenarios (Table 12.18) for the different phasing options include:

- Single phase – up to 180 wind turbine foundations (either 180 monopiles or 720 pin-piles for 10MW turbines) and seven offshore platforms (up to 52 piles) in the 18 month foundation installation period of the 36 months for overall construction; or
- Two phase – up to 90 wind turbine foundations (either 90 monopiles or 360 pin-piles for 10MW turbines) as well as up to four offshore platforms (up to 44 piles) in each of the two 9 month foundation installation periods and 39 months for overall construction.

421. For the single phase approach, the total piling time (of up to 54 days) would be approximately 10% of the 18 month (547 days) foundation installation period. For the two phase approach this would be approximately 10% of each of the two nine month (274 days in each phase) foundation installation periods.

422. Phases could either be constructed consecutively, condensing the overall construction programme (similar to that of a single phased installation) or could require gaps between each phase, up to an overall construction programme of approximately four years. Under the latter scenario marine mammals would be

expected to return in between construction phases (see estimated return times of harbour porpoise after piling events, outlined below).

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

424. The duration of piling is based on a worst-case scenario and a very precautionary approach, and as has been shown at other offshore wind farms, the duration used in the impact assessment can be overestimated. For example, for the installation of monopile foundations at the Dudgeon Offshore Wind Farm (DOW) the impact assessment was based on an estimated piling period of 93 days, time to install each monopile was estimated to be up to 4.5 hours and the estimated duration of active piling was 301.5 hours (approximately 13 days). However, the actual total duration of active piling to install the 67 monopiles was 65 hours (approximately 3 days) with the average time for installation per monopile of 71 minutes (DOWL, 2016). Therefore, the actual piling duration was approximately 21% of the predicated maximum piling duration. The piling duration to install the individual monopiles at DOW varied considerably for each location and the worst-case scenario of up to 4.5 hours to install a pile was an accurate assessment of the actual maximum duration (4.35 hours), however the majority of piles were installed in much shorter duration. At DOW the time intervals between the installations of individual monopiles, not including the intervals between groups of monopiles was on average approximately 23 hours. Monopiles were installed in groups of up to three, due to the capacity of the piling vessel, which meant that it could only carry three monopiles and three transition pieces before returning to port to collect the next three monopiles. The intervals between groups of monopiles being installed ranged from approximately 2.5 days to 11 days with an average of approximately four days between the 22 groups of three monopiles (DOWL, 2016).

425. It is possible that a behavioural disturbance from a single pile driving event could be sufficient to exclude harbour porpoise from the area in close proximity to the noise source for six hours to three days (Thomsen et al., 2006; Brandt et al., 2009; 2011; Thompson et al., 2010b). The Borkum West II project in Germany deployed a large bubble curtain during monopile installation. Studies showed that on average (median) a significant displacement effect was recorded until 9 to 12 hours after pile driving activity. However, detection rates were lowest for four hours after pile driving and then increased gradually (Diederichs et al., 2014).

426. The duration of the exclusion could last up to three days following a single piling event if the animal is close to the source. Data presented by Brandt et al. (2009,

2011) indicated that harbour porpoise would completely leave the area (indicated by the duration of waiting time between porpoise detections after first piling) for a median time of 16.6 hours and a maximum of 74.2 hours within 0.5-6km of the noise source. Waiting times did not return to 'normal' until 22.7 hours after piling. At distances of greater than approximately 9km from the noise source there was a much shorter duration of effect; with waiting times returning to 'normal' between one and 2.6 hours after piling ceased. However, at 18-25km there was still a marked effect. Porpoise activity (measured by the number of minutes per hour in which porpoise were detected) was significantly lower within approximately 3km of the noise source up to 40 hours after piling.

427. A study on the effects of offshore wind farm construction on harbour porpoise within the German North Sea between 2009 and 2013 (Brandt et al., 2016), indicated that the duration of effect after piling was about 20-31 hours within close vicinity of the construction site (up to 2km) and decreased with increasing distance. The study also observed significant decreases in porpoise detections prior to piling at distances of up to 10km, which is thought to relate to increased shipping activity during preparation works. The study concluded that although there were adverse short-term effects (1-2 days in duration) of construction on acoustic porpoise detections, there is currently no indication that harbour porpoises within the German Bight were negatively affected by wind farm construction at the population level (Brandt et al., 2016). It is acknowledged that some of the project included in this study used noise mitigation techniques.

428. The duration of any potential displacement effect will differ depending on the distance of the individual from the piling activity and the noise level the animal is exposed to. Furthermore, for those individuals that are distant from the activity that do not respond, and therefore are not affected, will continue with their normal behaviour that may involve approaching the wind farm area.

Table 12.38 Estimated number of harbour porpoise, grey seal and harbour seal potentially disturbed during piling based on 26km range from piling location

Potential Impact	Receptor	Estimated number in impact area[1]	% of reference population[1]	Magnitude[2]
Area of disturbance (2,124km^2) from underwater noise during piling	Harbour porpoise	1,886 harbour porpoise based on SCANS-III survey block O density (0.888/km^2). 2,251 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km^2).	0.55% of NS MU based on SCANS-III density. 0.65% of NS MU b based on the Norfolk Boreas site specific survey density (1.06/km^2).	Temporary effect with **negligible** magnitude (less than 1% of reference population).
	Grey seal	2 grey seal based on the Norfolk Boreas site	0.009% ref pop (0.03% SE England	Temporary effect with

Potential Impact	Receptor	Estimated number in impact area[1]	% of reference population[1]	Magnitude[2]
		density (0.001/km^2).	MU)	**negligible** magnitude.
	Harbour seal	0.2 harbour seal based on the Norfolk Boreas site density (0.0001/km^2).	0.0005% ref pop (0.004% SE England MU)	Temporary effect with **negligible** magnitude.

[1]Based on density estimate and reference population (see Table 12.14 and Table 12.15); [2]See Table 12.7 for definitions

Disturbance during concurrent piling

429. The maximum potential area of disturbance, based on 26km range (area of 2,124km^2 around each piling location), has been estimated for the worst-case concurrent piling scenarios (e.g. maximum distance between piling vessels and least amount of overlap in potential impact areas, see Figure 12.8) for:

- Two concurrent piling events in Norfolk Boreas (4,147km^2).

430. The spatial worst-case is the maximum area (4,174km^2) over which displacement could occur at any one time based on two concurrent foundations being installed at the Norfolk Boreas site. The maximum impact area is less than double the single impact area due to the overlap in potential impact areas (Figure 12.8).

431. The estimated maximum number of harbour porpoise that could potentially be temporarily disturbed as a result of underwater noise from concurrent piling is 1.3% of the North Sea MU reference population (Table 12.39), based on the worst-case scenario. The magnitude of the potential effect is assessed as low, with between 1% and 5% of the reference population anticipated to be exposed to the temporary effect.

432. The estimated maximum number of grey seal that could potentially be disturbed as a result of underwater noise from concurrent piling is 0.02% of the reference population or 0.07% of the South-east England MU; Table 12.39). The magnitude of the potential effect is assessed as negligible, with less than 1% of the reference population anticipated to be exposed to the temporary effect.

433. The estimated maximum number of harbour seal that could potentially be disturbed as a result of underwater noise from concurrent piling is 0.001% of the reference population or 0.008% of the South-east England MU; Table 12.39). The magnitude of the potential effect is assessed as negligible, with less than 1% of the reference population anticipated to be exposed to the temporary effect.

434. The duration of concurrent piling, assuming two concurrent operations would be approximately half the total duration for single pile installation, as well as reducing

the overall construction window. The maximum concurrent piling duration (including ADD activation) for Norfolk Boreas would be up to 647.8 hours (equivalent of up to approximately 27 days).

435. For the single phase approach this would be approximately 5% of the 18 month (547 days) foundation installation period. For the two phase approach this would be approximately 5% of each of the two nine month (274 days in each phase) foundation installation periods.

Table 12.39 Estimated number of harbour porpoise, grey seal and harbour seal potentially disturbed during concurrent piling based on 26km range

Potential Impact	Receptor	Estimated number in impact area[1]	% of reference population[1]	Magnitude[2]
Two concurrent piling events in Norfolk Boreas (4,147km^2)	Harbour porpoise	3,682.5 harbour porpoise based on SCANS-III survey block O density (0.888/km^2). 4,396 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km^2).	1.1% NS MU based on SCANS-III density. 1.3% of NS MU based on the Norfolk Boreas site specific survey density.	Temporary effect with **low** magnitude (between 1% and 5% of the reference population anticipated to be exposed to effect).
	Grey seal	4 grey seal based on the Norfolk Boreas site density (0.001/km^2).	0.02% of ref pop (0.07% of SE England MU)	Temporary effect with **negligible** magnitude (less than 1% of reference population).
	Harbour seal	0.4 harbour seal based on the Norfolk Boreas site density (0.0001/km^2).	0.001% of ref pop (0.008% of SE England MU)	Temporary effect with **negligible** magnitude.

[1]Based on density estimate and reference populations (see Table 12.14 and Table 12.15); [2]See Table 12.7 for definitions

Disturbance impact significance

436. Taking into account the receptor sensitivity and the potential magnitude of the temporary impact (e.g. number of individuals as a percentage of the reference population), the impact significance for any disturbance in harbour porpoise, grey seal and harbour seal has been assessed as **minor adverse** (not significant) (Table 12.40).

Table 12.40 Assessment of impact significance for disturbance of marine mammals as a result of underwater noise during piling

Potential Impact	Receptor	Sensitivity	Magnitude	Significance
Disturbance as a result of underwater noise during piling for single installation (2,124km^2)	Harbour porpoise	Medium	Negligible	**Minor adverse**
	Grey seal	Medium	Negligible	**Minor adverse**
	Harbour seal	Medium	Negligible	**Minor adverse**
Disturbance as a result of underwater noise during concurrent piling (4,147km^2)	Harbour porpoise	Medium	Low	**Minor adverse**
	Grey seal	Medium	Negligible	**Minor adverse**
	Harbour seal	Medium	Negligible	**Minor adverse**

12.7.3.2.5 Possible behavioural response in harbour porpoise

Possible behavioural response sensitivity

437. The possible behavioural response severity scaling for multiple pulses is used as an indicator of ranges where behavioural changes and some level of reduction in animal abundance may be expected (possible avoidance) in cetaceans. While no data are reported in Southall et al. (2007) for high-frequency cetaceans (this category includes the harbour porpoise), in this assessment possible avoidance thresholds are considered to approximate to the severity scoring of 5-6 (Southall et al., 2007). This type of behavioural response has the ability to affect foraging, reproduction or survival, should an individual respond. Not all individuals that are exposed to this level or noise will respond.

438. The sensitivity of harbour porpoise to this type of effect is considered to be low (Table 12.29).

Possible behavioural response magnitude

439. The range of possible behavioural reactions that may occur as a result of exposure to noise include orientation or attraction to a noise source, increased alertness, modification of characteristics of their own sounds, cessation of feeding or social interaction, alteration of movement / diving behaviour, temporary or permanent habitat abandonment and, in severe cases, panic, or stranding, sometimes resulting in injury or death (Southall et al., 2007).

440. Based on the unweighted Lucke et al. (2009) criteria (unweighted SEL of 145 dB re 1 μPa^2s), the estimated maximum range which could result in a possible behavioural response by harbour porpoise is estimated to be up to 24km and 20km for the maximum hammer energy of the monopile (5,000kJ) and pin-pile (2,700kJ), respectively.

441. The response of individuals to a noise stimulus will vary and not all animals within the range of potential behavioural response will respond. The study of harbour porpoise at Horns Rev (Brandt et al., 2011), showed that at closer distances (2.5 to 4.8km) there was 100% avoidance, however, this proportion decreased significantly moving away from the pile driving activity, such that at distances of 10.1 to 17.8km, avoidance occurred in 32 to 49% of the population and at 21.2km, the abundance reduced by just 2%. This suggests that an assumption of behavioural displacement of all individuals is unrealistic and that in reality not all individuals would move out of the area. To take this into account, the proportion of harbour porpoise that may show a behavioural response has been calculated by assuming 50% could respond. This approach is consistent with the response at distances of 10.1 to 17.8km indicated by the Brandt et al. (2011) study, at which approximately 50% could respond at the maximum predicted level as suggested by the dose-response curve in Thompson et al. (2013).

442. It should be noted that a behavioural response does not mean that the individuals will avoid the area. In addition, the maximum predicted ranges for behavioural response are based on the maximum hammer energy at the worst case location for noise propagation. In reality the duration of any piling at maximum energy would be short (if this energy is reached at all) and noise propagation would vary considerably with location (i.e. be less than the worst case).

443. The estimated number of harbour porpoise that could potentially exhibit a possible behavioural response as a result of a single strike of the maximum monopile hammer energy of 5,000kJ is up to 818 individuals (0.2% of the reference population) based on the Lucke et al. (2007) unweighted criteria and 50% of the harbour porpoise in the maximum predicted area responding (Table 12.41). The magnitude of the potential effect is assessed as negligible with between 1% and 5% of the reference population anticipated to respond.

444. As outlined above, the maximum duration for the installation of a single monopile is up to six hours, including the soft-start and ramp-up, however the average piling duration is expected to be three hours, plus an estimated ADD activation time of 10 minutes prior to the soft-start.

445. As outlined in section 12.7.3.2.4, it is important to note that piling and therefore any possible behavioural response would not be constant during the construction periods and phases of development. As also outlined in section 12.7.3.2.4, if there are long gaps between construction phases, animals would be expected to return to the area after piling had ceased.

Table 12.41 Estimated number of harbour porpoise that could exhibit a possible behavioural response to underwater noise during piling based on unweighted Lucke et al. (2009) threshold of 145 dB re 1 µPa²s

Potential Impact	Estimated number based on 100% of individuals in area responding[1]	% of reference population[1]	Estimated number based on 75% of individuals in area responding[1]	% of reference population[1]	Estimated number based on 50% of individuals in area responding[1]	% of reference population[1]	Magnitude[2]
Possible behavioural response to underwater noise during piling – maximum hammer energy for monopile (1,543km²)	1,370 harbour porpoise based on SCANS-III survey block O density (0.888/km²).	0.4% of NS MU based on SCANS-III density.	1,028 harbour porpoise based on SCANS-III survey block O density (0.888/km²).	0.3% of NS MU based on SCANS-III density.	685 harbour porpoise based on SCANS-III survey block O density (0.888/km²).	0.2% of NS MU based on SCANS-III density.	Temporary effect with **negligible** magnitude (less than 1% of the reference population anticipated to respond).
	1,636 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km²).	0.47% of NS MU based on site specific survey density at the Norfolk Boreas site.	1,227 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km²).	0.36% of NS MU based on site specific survey density at the Norfolk Boreas site.	818 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km²).	0.24% of NS MU based on site specific survey density at the Norfolk Boreas site.	
Possible behavioural response to underwater noise during piling – maximum hammer energy for pin-pile (1,144km²)	1,016 harbour porpoise based on SCANS-III survey block O density (0.888/km²).	0.3% of NS MU based on SCANS-III density.	762 harbour porpoise based on SCANS-III survey block O density (0.888/km²).	0.22% of NS MU based on SCANS-III density.	508 harbour porpoise based on SCANS-III survey block O density (0.888/km²).	0.15% of NS MU based on SCANS-III density.	Temporary effect with **negligible** magnitude (less than 1% of the reference population anticipated to respond).
	1,213 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km²).	0.35% of NS MU based on site specific survey density at the Norfolk Boreas site.	910 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km²).	0.26% of NS MU based on site specific survey density at the Norfolk Boreas site.	607 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km²).	0.18% of NS MU based on site specific survey density at the Norfolk Boreas site.	

[1]Based on density estimate and reference population (see Table 12.14 and Table 12.15); [2]See Table 12.7 for definitions

Possible behavioural response impact assessment

446. Taking into account the receptor sensitivity and the potential magnitude of the temporary impact (e.g. number of individuals as a percentage of the reference population), the impact significance for any possible behavioural response in harbour porpoise has been assessed as **negligible** (not significant) (Table 12.42).

447. In addition to the MMMP, an In Principle Norfolk Boreas SNS SAC Site Integrity Plan (SIP) has been developed and provided with the DCO Application (document reference 8.17) (section 12.7.1.2.3). The SIP sets out the approach to deliver any project mitigation or management measures in relation to the SNS SAC.

Table 12.42 Assessment of impact significance for possible behavioural response of harbour porpoise as a result of underwater noise during piling at Norfolk Boreas

Potential Impact	Receptor	Sensitivity	Magnitude	Significance
Possible behavioural response as a result of underwater noise during piling	Harbour porpoise	Low	Negligible	**Negligible**

12.7.3.2.6 Summary of underwater noise during piling impact significance assessment

448. The impact magnitudes described in sections 12.7.3.2.1 to 12.7.3.2.5 represent a conservative worst-case for the overall project by using the maximum density estimates and the maximum noise propagation. This conservative approach is considered to be appropriate due to the mobile nature of marine mammals.

449. Taking into account the receptor sensitivity and the potential magnitude of the impact (e.g. number of individuals as a percentage of the reference population), if the impact is permanent (e.g. PTS) or temporary (e.g. TTS and disturbance) and the proposed mitigation, the impact significance for any physical injury, permanent auditory injury, temporary auditory injury / fleeing response and disturbance in harbour porpoise, grey seal and harbour seal has been assessed as **minor adverse** (not significant) (Table 12.43).

450. The confidence in the data used in this assessment is medium and the level of precaution is high.

Table 12.43 Overall assessment of impact significance of underwater noise during piling on marine mammals

Potential Impact	Receptor	Sensitivity	Magnitude	Significance
Permanent auditory injury (PTS) injury as a result of underwater	Harbour porpoise	High	Negligible	**Minor adverse**

Potential Impact	Receptor	Sensitivity	Magnitude	Significance
noise from single strike of starting hammer energy	Grey seal	High	Negligible	**Minor adverse**
	Harbour seal	High	Negligible	**Minor adverse**
Permanent auditory injury (PTS) injury as a result of underwater noise from single strike of maximum hammer energy	Harbour porpoise	High	Negligible with or without embedded mitigation	**Minor adverse**
	Grey seal	High	Negligible with or without embedded mitigation	**Minor adverse**
	Harbour seal	High	Negligible with or without embedded mitigation	**Minor adverse**
Permanent auditory injury (PTS) injury as a result of underwater noise during piling from cumulative exposure	Harbour porpoise	High	Negligible with or without embedded mitigation	**Minor adverse**
	Grey seal	High	Negligible with or without embedded mitigation	**Minor adverse**
	Harbour seal	High	Negligible with or without embedded mitigation	**Minor adverse**
Temporary auditory injury (TTS) and fleeing response as a result of underwater noise from single strike of maximum hammer energy	Harbour porpoise	Medium	Negligible with or without embedded mitigation	**Minor adverse**
	Grey seal	Medium	Negligible with or without embedded mitigation	**Minor adverse**
	Harbour seal	Medium	Negligible with or without embedded mitigation	**Minor adverse**
Temporary auditory injury (TTS) and fleeing response as a result of underwater noise during piling from cumulative exposure	Harbour porpoise	Medium	Negligible with or without embedded mitigation	**Minor adverse**
	Grey seal	Medium	Negligible with or without embedded mitigation	**Minor adverse**
	Harbour seal	Medium	Negligible with or without embedded mitigation	**Minor adverse**
Disturbance as a result of underwater noise during piling for	Harbour porpoise	Medium	Negligible	**Minor adverse**

Potential Impact	Receptor	Sensitivity	Magnitude	Significance
single installation (2,124km^2)	Grey seal	Medium	Negligible	**Minor adverse**
	Harbour seal	Medium	Negligible	**Minor adverse**
Disturbance as a result of underwater noise during concurrent piling (4,147km^2)	Harbour porpoise	Medium	Low	**Minor adverse**
	Grey seal	Medium	Negligible	**Minor adverse**
	Harbour seal	Medium	Negligible	**Minor adverse**
Possible behavioural response as a result of underwater noise during piling	Harbour porpoise	Low	Negligible	**Negligible**

12.7.3.3 Impact 3: Underwater noise during other construction activities

451. This section assesses the potential impacts that could be associated with underwater noise during construction activities, other than pile driving (section 12.7.3.2). Noise associated with vessels is assessed in section 12.7.3.4. Potential sources of underwater noise during construction activities, other than piling, include seabed preparation, dredging, rock dumping, drilling (if piling is refused at any location), vessel noise trenching, and cable installation.

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

- Ploughing;
- Trenching or cutting;
- Jetting;
- Surface laid with cable protection where burial is not possible; and
- Rock dumping for protection of the cables.

453. 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).

454. Dredging produces continuous, broadband sound. Sound pressure levels (SPLs) can vary widely, for example, with dredger type, operational stage, or environmental conditions (e.g. sediment type, water depth, salinity and seasonal phenomena such as thermoclines; Jones and Marten, 2016). These factors will also affect the propagation of sound from dredging/cable installation activities and along with

ambient sound already present, will influence the distance at which sounds can be detected.

455. Sound sources for trailing suction hopper dredger (TSHD) include the draghead on the seabed, material going through the underwater pipe, as well as sound sources from the vessel, such as inboard pump, thrusters, propeller and engine noise (CEDA, 2011, WODA, 2013). Noise measurements indicate that the most intense sound emissions from TSHD dredgers are typically low frequencies, up to and including 1kHz (Robinson et al., 2011). Underwater noise from a TSHD is comparable to those for a cargo ship travelling at modest speed (between 8 and 16 knots) (Theobald et al., 2011).

456. 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; however, TTS cannot be ruled out if marine mammals are exposed to noise for prolonged periods (Todd et al., 2014), although marine mammals remaining in close proximity to such activities for long periods of time is unlikely. Therefore, the potential risk of any auditory injury (permanent or temporary) in marine mammals as a result of dredging / cable installation activity is highly unlikely.

457. Underwater noise as a result of dredging activity/cable installation, 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. Marine mammals may exhibit varying behavioural reactions intensities as a result of exposure to noise (Southall et al., 2007).

458. The noise levels produced by dredging activity/cable installation, could overlap with the hearing sensitives and communication frequencies used by marine mammals (Todd et al., 2014), and therefore have the potential to impact marine mammals present in the area. However, species such as harbour porpoise, have a relatively poor sensitivity below 1kHz are less likely to be affected by masking, although for seals there could be the potential of masking communication, especially during the breeding season (Todd et al., 2014).

12.7.3.3.1 Sensitivity

459. The sensitivity of marine mammals to disturbance as a result of underwater noise during construction activities, other than piling, is considered to be medium in this assessment as a precautionary approach. Marine mammals within the potential disturbance area are considered to have limited capacity to avoid such effects (see

Table 12.5), although any disturbance to marine mammals would be temporary and they would be expected to return to the area once the disturbance had ceased or they had become habituated to the sound.

12.7.3.3.2 Magnitude

460. Underwater noise modelling was undertaken to assess the impact ranges of construction activities, other than piling, on marine mammals, and this has been used to determine the potential impact on marine mammal species. The underwater noise propagation modelling was undertaken using a simple modelling approach for a number of offshore construction activities; using measured sound source data scaled to relevant parameters for the Norfolk Boreas site (see Appendix 5.4 for further information). The activities that were assessed include:

- Dredging (estimated sound source of 186dB re 1µPs @1m): a TSHD may be required for the export cable, array cable and interconnector cable installation;
- Drilling (estimated sound source of 179dB re 1µPs @1m): drilling of the foundations may need to be undertaken in the case of impact piling refusal;
- Cable laying (estimated sound source of 171dB re 1µPs @1m);
- Rock placement (estimated sound source of 172dB re 1µPs @1m): this is potentially required during offshore cable installation and scour protection; and
- Trenching (estimated sound source of 172dB re 1µPs @1m): plough trenching may be required during the export cable installation.

461. The results of the underwater noise modelling show that at the source levels predicted for the listed activities, any marine mammal would have to remain close (i.e. less than 500m for some activities, and less than 50m for most) to the sound source for 24 hours to be exposed to levels of sound that are sufficient to induce PTS as per the NMFS (2018) threshold criteria (Table 12.44) shows the modelled results and areas of impact).

462. The number of harbour porpoise, grey seal and harbour seal that could be impacted as a result of underwater noise during construction from activities other than piling has been assessed based on the number of animals that could be present in each of the modelled impact ranges for the other construction activities as listed in Table 12.45.

Table 12.44 Maximum predicted impact ranges (and areas) for auditory injury (PTS) and for possible behavioural response from construction activities, other than piling, based on underwater noise modelling

	Receptor	Criteria and threshold	The modelled impact ranges (km) (and areas* (km^{2*}) for each offshore construction activity				
			Dredging	Drilling	Cable Laying	Rock Placement	Trenching
Auditory injury (PTS) from cumulative SEL during other construction activities	Harbour porpoise	NMFS (2018) 155 dB re 1 µPa HF SEL_{cum}	0.15km (0.07km^2)	<0.1km (0.03km^2)	<0.1km (0.03km^2)	0.46km (0.66km^2)	<0.1km (0.03km^2)
	Grey and Harbour seal	NMFS (2018) 185 dB re 1 µPa PW SEL_{cum}	<0.1km (0.03km^2)	<0.1km (0.03km^2)	<0.1km (0.03km^2)	<0.1km (0.03km^2)	<0.1km (0.03km^2)
Possible behavioural response to underwater noise during other construction activities	Harbour porpoise	Lucke et al. (2009) Unweighted SEL 145 dB re 1 µPa	0.15km (0.07km^2)	0.13km (0.05km^2)	0.11km (0.04km^2)	0.18km (0.10km^2)	0.12km (0.045km^2)

**Area based on area of circle not modelled impact area*

Table 12.45 Maximum number of individuals (and % of reference population) that could be impacted as a result of underwater noise associated with construction activities, other than piling, based on underwater noise modelling

Potential Impact (area km²)	Receptor	Criteria and Threshold	Estimated number in impact area[1]	% of reference population[1]	Magnitude[2]
Dredging (0.07km²)	Harbour porpoise	NMFS (2018) 155 dB re 1 µPa PTS from cumulative SEL	0.06 harbour porpoise based on SCANS-III survey block O density (0.888/km²). 0.07 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km²).	0.00002% of NS MU based on SCANS-III density. 0.00002% of NS MU based on site specific survey density.	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).
		Lucke et al. (2009) Unweighted SEL 145 dB re 1 µPa Possible behavioural response	0.06 harbour porpoise based on SCANS-III survey block O density (0.888/km²). 0.07 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km²).	0.00002% of NS MU based on SCANS-III density. 0.00002% of NS MU based on site specific survey density.	Temporary effect with **negligible** magnitude (less than 1% of the reference population).
Dredging (0.03km²)	Grey seal	NMFS (2018) 185 dB re 1 µPa PTS from cumulative SEL	0.001 grey seal based on Norfolk Boreas offshore project area density (0.032/km²).	0.0000045% of ref pop (0.00002% of SE England MU).	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).
	Harbour seal		0.0006 harbour seal based on Norfolk Boreas offshore project area density (0.019/km²).	0.000001% of ref pop (0.00001% of SE England MU).	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).
Drilling (0.03km²)	Harbour porpoise	NMFS (2018) 155 dB re 1 µPa PTS from cumulative SEL	0.03 harbour porpoise based on SCANS-III survey block O density (0.888/km²). 0.03 harbour porpoise based on the Norfolk Boreas site specific survey	0.000009% of NS MU based on SCANS-III density. 0.000009% of NS MU based on site specific survey density.	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).

Potential Impact (area km²)	Receptor	Criteria and Threshold	Estimated number in impact area[1]	% of reference population[1]	Magnitude[2]
			density (1.06/km²).		
Drilling (0.05km²)		Lucke et al. (2009) Unweighted SEL 145 dB re 1 µPa Possible behavioural response	0.04 harbour porpoise based on SCANS-III survey block O density (0.888/km²). 0.05 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km²).	0.00001% of NS MU based on SCANS-III density. 0.000015% of NS MU based on site specific survey density.	Temporary effect with **negligible** magnitude (less than 1% of the reference population).
Drilling (0.03km²)	Grey seal	NMFS (2018) 185 dB re 1 µPa PTS from cumulative SEL	0.001 grey seal based on Norfolk Boreas offshore project area density (0.032/km²).	0.0000045% of ref pop (0.00002% of SE England MU).	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).
	Harbour seal		0.0006 harbour seal based on Norfolk Boreas offshore project area density (0.019/km²).	0.000001% of ref pop (0.00001% of SE England MU).	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).
Cable laying (0.03km²)	Harbour porpoise	NMFS (2018) 155 dB re 1 µPa PTS from cumulative SEL	0.03 harbour porpoise based on SCANS-III survey block O density (0.888/km²). 0.03 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km²).	0.000009% of NS MU based on SCANS-III density. 0.000009% of NS MU based on site specific survey density.	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).
Cable laying (0.04km²)		Lucke et al. (2009) Unweighted SEL 145 dB re 1 µPa Possible behavioural response	0.04 harbour porpoise based on SCANS-III survey block O density (0.888/km²). 0.04 harbour porpoise based on the Norfolk Boreas site specific survey	0.00001% of NS MU based on SCANS-III density. 0.00001% of NS MU based on site specific survey density.	Temporary effect with **negligible** magnitude (less than 1% of the reference population).

Potential Impact (area km²)	Receptor	Criteria and Threshold	Estimated number in impact area[1]	% of reference population[1]	Magnitude[2]
			density (1.06/km²).		
Cable laying (0.03km²)	Grey seal	NMFS (2018) 185 dB re 1 µPa PTS from cumulative SEL	0.001 grey seal based on Norfolk Boreas offshore project area density (0.032/km²).	0.0000045% of ref pop (0.00002% of SE England MU).	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).
	Harbour seal		0.0006 harbour seal based on Norfolk Boreas offshore project area density (0.019/km²).	0.000001% of ref pop (0.00001% of SE England MU).	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).
Rock placement (0.66km²)	Harbour porpoise	NMFS (2018) 155 dB re 1 µPa PTS from cumulative SEL	0.6 harbour porpoise based on SCANS-III survey block O density. 0.7 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km²).	0.0002% of NS MU based on SCANS-III density. 0.0002% of NS MU based on site specific survey density.	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).
Rock placement (0.1km²)	Harbour porpoise	Lucke et al. (2009) Unweighted SEL 145 dB re 1 µPa Possible behavioural response	0.09 harbour porpoise based on SCANS-III survey block O density. 0.1 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km²).	0.00003% of NS MU based on SCANS-III density. 0.00003% of NS MU based on site specific survey density.	Temporary effect with **negligible** magnitude (less than 1% of the reference population).
Rock placement (0.03km²)	Grey seal	NMFS (2018) 185 dB re 1 µPa PTS from cumulative SEL	0.001 grey seal based on Norfolk Boreas offshore project area density (0.032/km²).	0.0000045% of ref pop (0.00002% of SE England MU).	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).
	Harbour seal		0.0006 harbour seal based on Norfolk Boreas offshore project area density (0.019/km²).	0.000001% of ref pop (0.00001% of SE England MU).	Permanent effect with **negligible** magnitude (less than 0.001% of the reference

Potential Impact (area km²)	Receptor	Criteria and Threshold	Estimated number in impact area[1]	% of reference population[1]	Magnitude[2]
					population).
Trenching (0.03km²)	Harbour porpoise	NMFS (2018) 155 dB re 1 µPa PTS from cumulative SEL	0.03 harbour porpoise based on SCANS-III survey block O density (0.888/km²). 0.03 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km²).	0.000009% of NS MU based on SCANS-III density. 0.000009% of NS MU based on site specific survey density.	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).
Trenching (0.04km²)	Harbour porpoise	Lucke et al. (2009) Unweighted SEL 145 dB re 1 µPa Possible behavioural response	0.04 harbour porpoise based on SCANS-III survey block O density (0.888/km²). 0.04 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km²).	0.00001% of NS MU based on SCANS-III density. 0.00001% of NS MU based on site specific survey density.	Temporary effect with **negligible** magnitude (less than 1% of the reference population).
Trenching (0.03km²)	Grey seal	NMFS (2018) 185 dB re 1 µPa PTS from cumulative SEL	0.001 grey seal based on Norfolk Boreas offshore project area density (0.032/km²).	0.0000045% of ref pop (0.00002% of SE England MU).	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).
	Harbour seal		0.0006 harbour seal based on Norfolk Boreas offshore project area density (0.019/km²).	0.000001% of ref pop (0.00001% of SE England MU).	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).

[1]Based on density estimate and reference population (see Table 12.14 and Table 12.15); [2]See Table 12.7 for definitions

463. The magnitude of the potential impact of auditory injury (PTS) as a result of construction noise, other than piling, is negligible for harbour porpoise, grey seal and harbour seal, with 0.0002% or less of the reference population likely to be affected. Based on the possible behavioural response threshold, 0.00003% or less of the North Sea MU could be temporary disturbed (Table 12.45).

464. TTS has not been modelled for construction noise (other than piling), however, based on the potential PTS impact ranges and possible behavioural response of harbour porpoise, the TTS ranges are also expected to be very small and highly unlikely to result in any temporary significant impacts.

465. The indicative duration of the cable installation is estimated to be:

- 21 months for single phase option; or
- 12 months per phase for two phase option.

466. The indicative duration of the overall construction activity is estimated to be:

- 36 months for single phase option (Table 12.16); or
- 39 months for two phase option (Table 12.17).

467. The indicative total programme for construction of the full 1800MW capacity is estimated to be four years depending on the time between commencements of the phases.

468. The potential effects that could result from underwater noise during construction from activities other than piling would be temporary in nature, not consistent throughout these periods and would be limited to only part of the overall construction period and area.

12.7.3.3.3 Impact significance

469. Taking into account the receptor sensitivity and the potential magnitude of the effect, the impact significance as a result of underwater noise during construction from activities other than piling on harbour porpoise, grey seal and harbour seal has been assessed as **minor adverse** (not significant) (Table 12.46); therefore no further mitigation measures are proposed beyond those embedded measures presented in section 12.7.1.

470. It should be noted that construction activities, other than piling, underway at the same time as piling, are not cumulative impacts, as the maximum potential impact area for those activities are less than those assessed for piling and will therefore be included in the predicted impact area assessed for piling.

471. The confidence in the data used in this assessment is medium and the level of precaution is high.

Table 12.46 Assessment of impact significance for underwater noise from construction activities other than piling on marine mammals

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual impact
Auditory injury (PTS) from cumulative SEL during other construction activities	Harbour porpoise	Medium	Negligible	Minor	No mitigation required	**Minor adverse**
	Grey seal	Medium	Negligible	Minor		**Minor adverse**
	Harbour seal	Medium	Negligible	Minor		**Minor adverse**
Possible behavioural response to underwater noise during other construction activities	Harbour porpoise	Medium	Negligible	Minor	No mitigation required	**Minor adverse**

12.7.3.4 Impact 4: Vessel underwater noise and disturbance

472. 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 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 Norfolk Boreas site and offshore cable corridor and project interconnector search area.

473. It is anticipated that the types of vessels that could be on site during construction include:

- Seabed preparation vessels, including dredging vessels;
- Jack-up vessels;
- Dynamic Positioning Heavy Lift vessels;
- Scour Installation Vessels;
- Commissioning vessels;
- Accommodation vessels;
- Array cable laying vessels;
- Export cable laying vessels;
- Landfall cable installation vessels;
- Pre-trenching/backfilling vessels;

- Cable jetting and survey vessels;
- Filter layer vessels;
- Substation / collector station installation vessels;
- WTG installation vessels; and
- Other vessels, including tugs and barges, service and support vessels.

474. The vessels within the site will be slow moving (or stationary) and most noise emitted is likely to be of a lower frequency. Noise levels reported by Malme et al. (1989) and Richardson et al. (1995) for large surface vessels indicate that physiological damage to auditory sensitive marine mammals is unlikely. However, the levels could be sufficient to cause local disturbance to sensitive marine mammals in the immediate vicinity of the vessel, depending on ambient noise levels.

475. Modelling by Heinänen and Skov (2015) indicates that the number of ships represents a relatively important factor determining the density of harbour porpoise in the North Sea MU during both seasons, with markedly lower densities with increasing levels of traffic. A threshold level in terms of impact seems to be approximately 20,000 ships per year (approximately 80 vessels per day within a 5km^2 area).

476. Chapter 15 Shipping and Navigation provides a description of the baseline conditions and anticipated additional ship movements arising from the construction and operation of the proposed project.

477. A number of busy shipping lanes pass in close proximity to the Norfolk Boreas site, with a large number of vessels recorded using two Deep Water Routes (DWRs), one passing approximately 1nm (1.9km) to the west of the Norfolk Boreas site and the other passing approximately 3.4nm (6.3km) at its closest point to the east of the Norfolk Boreas site (Chapter 15 Shipping and Navigation, and Figure 15.2).

478. Baseline surveys for shipping and navigation indicate that throughout the summer period, there was on average 79, 106 and 24 unique vessels per day recorded within the Norfolk Boreas site study area, the offshore cable corridor study area and project interconnector search area, respectively. Throughout the winter period of the, there was on average 36, 84 and 15 unique vessels per day recorded within the Norfolk Boreas site study area, offshore cable corridor study area and project interconnector search area, respectively. The majority of vessels recorded were cargo vessels and tankers, with most of these vessels utilising the IMO Routeing Measures in the area; however other main routes were identified out with the DWRs, including routes which intersected the Norfolk Boreas site. Fishing activity was also notable in the area. These baseline figures indicate relatively high shipping activity in and around Norfolk Boreas.

479. There would be some re-routeing of existing vessels around the Norfolk Boreas site, with a minimum passing distance of 500m from areas where construction is underway. This is likely to re-route existing large and fast moving vessels (predominantly cargo ships).

480. During the construction phase, there will be an increase in vessels within the site associated with installation of the foundations, the wind turbines, array and export cables, despite the potential displacement of existing vessel traffic. Table 12.18 provides details of the worst-case scenario for vessels during construction.

481. The maximum number of vessels on site at any one time during construction is estimated to be 57 vessels. This could therefore represent up to a 27% increase in the number of vessels during the summer period and 42% increase in the number of vessels during the winter periods, compared to current baseline vessel numbers.

482. The maximum number of 57 vessels at any one time in the offshore project area (1,178km^2) during construction would be significantly less (approximately 0.05 vessels per km^2) than the Heinänen and Skov (2015) threshold of 80 vessels per day within an area of 5km^2 (approximately 16 vessels per km^2). Based on the precautionary worst-case scenario, including existing vessel movements in around the offshore project area, but taking into account that other vessels would be restricted from entering the immediate construction site (with a 500m safety zone around construction vessels and partially installed foundations), the number of vessels would be unlikely to exceed the Heinänen and Skov (2015) threshold level of 80 vessels per day in a 5km^2 area. Therefore, there is unlikely to be the potential for significant disturbance to harbour porpoise as a result of the increased number of vessels during construction.

12.7.3.4.1 Sensitivity

483. Thomsen et al. (2006) reviewed the effects of ship noise on harbour porpoise and seal species. As both species use lower frequency sound for communicating (with acute hearing capabilities at 2kHz) there is the potential for detection, avoidance and masking in both species. Thomsen et al. (2006) considered the detection thresholds for harbour porpoises (Hearing threshold = 115dB rms re 1 µPa at 0.25 kHz; Ambient noise = 91dB rms re 1 µPa at 2kHz) and conclude that ship noise around 0.25kHz could be detected by the species at distances of 1km; and ship noise around 2kHz could be detected at around 3km[6].

484. Wisniewska et al. (2018) studied the change in foraging rates of harbour porpoise in response to vessel noise. Wideband sound and movement recording tags were

[6] These calculations are valid for ambient noise levels typical for the German Bight / North Sea at wind-speeds between 3 and 8m/s.

deployed on seven harbour porpoise to determine foraging rates as a function of the vessel noise present at that time. Tagged individuals were exposed to vessel noise between 17 and 89% of the time, with results showing that foraging was interrupted in the presence of high noise levels. Results show that a harbour porpoise stopped producing foraging echolocation clicks immediately when vessel noise became audible in the recording, seven minutes prior to the closest approach of the vessel which was 140m. This was estimated to be 7km from the individual based on known vessel speeds. Regular foraging activity resumed 8 minutes after the closest approach of the vessel, 15 minutes after initial exposure. Significantly fewer foraging echolocation clicks were made in minutes with vessel noise of above 96 dB re 1 µPa for three of the individuals and at 102 dB re 1 µPa for one individual. In addition, high vessel noise was incidentally associated with vigorous fluking, bottom diving and the cessation of echolocation completely. Therefore, if the exposure to vessel noise at over 96 dB re 1µPa is prolonged, there is the potential for reduced foraging activity (Wisniewska et al., 2018).

485. Given the range of predicted response, and observations of harbour porpoise swimming away from vessels (e.g. Polacheck and Thorpe 1990; Evans et al., 1993), harbour porpoise are considered to have low sensitivity to vessel noise.

486. Thomsen et al. (2006) also consider that ship noise around 2kHz will be detected at a distance of approximately 3km for harbour seals (ambient noise = 94 and 91dB rms re 1µPa at 0.25 and 2 kHz, respectively); and the zone of audibility will be approximately 20km. However, there is no evidence to suggest that vessel noise adversely affects seals, suggesting they may have a lower sensitivity than cetacean species. As such, both harbour and grey seal are considered to have a low sensitivity to vessel noise.

12.7.3.4.2 Magnitude

487. Underwater noise modelling was undertaken to assess the potential impact ranges of vessels on marine mammals (Appendix 5.4), and this is used to determine the impact on harbour porpoise, grey seal and harbour seal.

488. As outlined in section 12.7.3.3, the underwater noise propagation modelling was undertaken using a simple modelling approach for underwater noise associated with both medium and large sized vessels, using measured sound source data scaled to relevant parameters for the Norfolk Boreas site (see Appendix 5.4 for further information). The sound sources for vessels modelled were 171dB re 1µPs @1m for large vessels and 164dB re 1µPs @1m for medium vessels.

489. The results of the underwater noise modelling show that at the source levels predicted for the listed activities, any marine mammal would have to remain in close

proximity (i.e. less than 150m) of the vessel for 24 hours to be exposed to levels of sound that are sufficient to induce PTS as per the NMFS (2018) threshold criteria (Table 12.47).

Table 12.47 Maximum predicted impact ranges (and areas) for auditory injury (PTS) and possible behavioural response from vessels

Potential Impact	The modelled impact ranges (km) (and areas (km^{2*}) for vessel noise			
	Receptor	Threshold and criteria	Vessels (Large)	Vessels (Medium)
Auditory injury (PTS) from cumulative SEL from each vessel during construction, based on 24 hour exposure	Harbour porpoise	NMFS (2018) 155 dB re 1 µPa	<0.1km ($0.03km^2$)	<0.1km ($0.03km^2$)
	Grey and Harbour seal	NMFS (2018) 185 dB re 1 µPa	<0.1km ($0.03km^2$)	<0.1km ($0.03km^2$)
Possible behavioural response to underwater noise from each vessel during construction	Harbour porpoise	Lucke et al. (2009) Unweighted SEL 145 dB re 1 µPa	0.15km ($0.07km^2$)	<0.05km ($0.008km^2$)

**Area based on area of circle not modelled impact area*

490. The number of harbour porpoise, grey seal and harbour seal that could be impacted as a result of underwater noise from construction vessel movements has been assessed based on the number of animals that could be present in the modelled impact ranges for vessels (Table 12.48).

Table 12.48 Maximum number of individuals (and % of reference population) that could be impacted by underwater noise associated with vessels

Potential Impact (area km^2)	Criteria and Threshold	Receptor	Estimated number in impact area[1]	% of reference population[1]	Magnitude[2]
Large vessels (57 x 0.03km^2 = 1.71km^2)	NMFS (2018) 155 dB re 1 µPa PTS from cumulative SEL	Harbour porpoise	1.5 harbour porpoise based on SCANS-III survey block O density (0.888/km^2). 1.8 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km^2).	0.0004% of NS MU based on SCANS-III density. 0.0005% of NS MU based on site specific survey density.	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).
Large vessels (57 x 0.07km^2= 4km^2)	Lucke et al. (2009) Unweighted SEL 145 dB re 1 µPa Possible behavioural response		3.6 harbour porpoise based on SCANS-III survey block O density (0.888/km^2). 4 harbour porpoise based on the Norfolk Boreas site specific survey density (1.06/km^2).	0.001% of NS MU based on SCANS-III density. 0.001% of NS MU based on site specific survey density.	Temporary effect with **negligible** magnitude (less than 0.1% of the reference population).
Large vessels (57 x 0.03km^2 = 1.71km^2)	NMFS (2018) 185 dB re 1 µPa PTS from cumulative SEL	Grey seal	0.06 grey seal based on Norfolk Boreas offshore project area density (0.032/km^2).	0.0003% of ref pop (0.001% of SE England MU).	Permanent effect with **negligible** magnitude (0.001% or less of the reference population).
		Harbour seal	0.03 harbour seal based on Norfolk Boreas offshore project area density (0.019/km^2).	0.00007% of ref pop (0.0006% of SE England MU).	Permanent effect with **negligible** magnitude (less than 0.001% of the reference population).

[1]Based on density estimate and reference population (see Table 12.14 and Table 12.15); [2]See Table 12.7 for definitions

491. The magnitude of the potential impact of auditory injury (PTS) as a result of construction vessel noise is negligible for harbour porpoise, grey seal and harbour seal, with 0.0005% or less of the reference population likely to be impacted. Based on the possible behavioural response of harbour porpoise, 0.001% or less of the North Sea MU could be temporary disturbed (Table 12.48).

492. TTS has not been modelled, however, based on the potential PTS impact ranges and possible behavioural response of harbour porpoise, the TTS ranges are also expected to be very small and highly unlikely to result in any temporary significant impacts.

12.7.3.4.3 Impact significance

493. Taking into account the receptor sensitivity and the potential magnitude of the impact, the impact significance as a result of underwater noise from vessels for harbour porpoise, grey seal and harbour seal has been assessed as **negligible** (Table 12.49); therefore no further mitigation measure are proposed beyond those embedded measures presented in section 12.7.1. It should be noted that any impacts from vessels will not be cumulative with piling or any other construction activity impacts as any impact areas will be overlapped by the piling impact areas.

494. The confidence in the data used in this assessment is medium to high.

Table 12.49 Assessment of impact significance for underwater noise and disturbance of marine mammals from vessels during construction

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual impact
Auditory injury (PTS) from cumulative SEL from vessels during construction, based on 24 hour exposure	Harbour porpoise	Low	Negligible	Negligible	No mitigation required	**Negligible**
	Grey seal	Low	Negligible	Negligible		**Negligible**
	Harbour seal	Low	Negligible	Negligible		**Negligible**
Possible behavioural response to underwater noise from vessels during construction	Harbour porpoise	Low	Negligible	Negligible	No mitigation required	**Negligible**

12.7.3.5 Impact 5: Barrier effects from underwater noise

12.7.3.5.1 Sensitivity

495. Harbour porpoise, grey seal and harbour seal are assessed as having medium sensitivity to a barrier effect as a result of disturbance (Table 12.32).

12.7.3.5.2 Magnitude

496. Underwater noise during construction 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 around it. However, the Norfolk Boreas offshore project area is not located on any known migration routes for marine mammals. Telemetry studies (see Appendix 12.2) and the relatively low seal at sea usage observed (Russell et al*.,* 2017; Figure 12.2 and 12.3) in and around the Norfolk Boreas offshore project area (section 12.6) do not indicate any regular seal foraging routes through the site.

497. The worst-case scenario in relation to barrier effects as a result of underwater noise is based on the maximum spatial and temporal (i.e. longest duration) scenarios.

Maximum spatial impact for any barrier effects

498. The spatial worst-case is the maximum area (4,147km^2) over which potential disturbance could occur at any one time based on two concurrent foundations being installed (Table 12.39). However, this would only be for a relatively small duration of the potential construction period.

499. As outlined in section 12.7.3.2.4, the estimated maximum number of harbour porpoise that could potentially be temporarily disturbed as a result of underwater noise from concurrent piling is 1.3% of the reference population (Table 12.39), based on the worst-case scenario. The magnitude of the potential impact is assessed as low, with between 1% and 5% of the reference population anticipated to be exposed to the temporary effect.

500. As outlined in section 12.7.3.2.4, the estimated maximum number of grey seal that could potentially be disturbed as a result of underwater noise from concurrent piling is 0.02% of the reference population (0.07% of the South-east England MU). The magnitude of the potential impact is assessed as negligible, with less than 1% of the reference population anticipated to be exposed to the temporary effect (Table 12.39).

501. As outlined in section 12.7.3.2.4, the estimated maximum number of harbour seal that could potentially be disturbed as a result of underwater noise from concurrent piling is 0.001% of the reference population (0.008% of the South-east England MU).

The magnitude of the potential impact is assessed as negligible, with less than 1% of the reference population anticipated to be exposed to the temporary effect.

Maximum temporal impact for any barrier effects

502. The duration of concurrent piling, for two concurrent locations would be approximately half the total maximum duration for single pile installation, as well as reducing the overall construction window. The maximum concurrent piling duration (including potential ADD activation) for Norfolk Boreas would be approximately 27 days.

503. For the single phase approach, this would be approximately 5% of the 18 month (547 days) foundation installation period and 2.5% of the 36 month (1,096 day) overall construction period.

504. For the two phase approach, this would be approximately 14 days per phase and therefore 5% of each of the two nine month (274 day) foundation installation periods and 1.2% of the total 39 month (1,188 day) overall construction period.

505. As outlined above, it is important to note that piling and therefore any potential barrier effects would not be constant during the construction periods and phases of development. It is therefore important to take into account that when piling is not taking place, there are periods where marine mammals could return to the area, rather than assuming that they will be disturbed / move away for the entire construction period.

506. The magnitude for any potential barrier as a result of underwater noise has been based on the maximum potential disturbance area and on the basis that any associated barrier effects would be temporary and intermittent.

12.7.3.5.3 Impact significance

507. As outlined above, piling activity would only be for a very small proportion of the construction period, therefore any potential barrier effects from piling activity would only be temporary. Underwater noise from other activities and vessels (section 12.7.3.3 and section 12.7.3.4) would have a limited area of potential disturbance and negligible magnitude of effect, and would therefore not result in any potential barrier effects.

508. Therefore, taking into account the receptor sensitivity and the potential magnitude of the temporary impact, the impact significance for any potential barrier as a result of underwater noise during construction has been assessed as **minor adverse** (not significant) for harbour porpoise, grey seal and harbour seal (Table 12.50).

509. The confidence in the data used in this assessment is medium with a precautionary approach, based on maximum potential piling durations for each pile.

Table 12.50 Assessment of impact significance for any barrier effects from underwater noise

Potential Impact	Receptor	Sensitivity	Magnitude for temporary effect	Significance for temporary effect	Mitigation	Residual impact
Potential barrier effects from underwater noise during construction	Harbour porpoise	Medium	Low	Minor adverse	MMMP to reduce impacts from piling noise And SIP	**Minor adverse**
	Grey seal	Medium	Negligible	Minor adverse		**Minor adverse**
	Harbour seal	Medium	Negligible	Minor adverse		**Minor adverse**

12.7.3.6 Impact 6: Vessel collision risk

12.7.3.6.1 Sensitivity

510. Marine mammals in the Norfolk Boreas offshore project area would be habituated to the presence of vessels and would be able to detect and avoid vessels. Therefore, harbour porpoise, grey seal and harbour seal are considered to have a low sensitivity to the risk of a vessel strike.

12.7.3.6.2 Magnitude

511. During the construction of Norfolk Boreas there will be an increase in vessel traffic. Vessels will follow established shipping routes utilising the shipping lane to the west of Norfolk Boreas and routes to the relevant ports in order to minimise vessel traffic in the wider area.

512. For Norfolk Boreas, the overall worst-case scenarios for vessel movements during construction would be:

- Up to 1,296 two-way vessel movements based on a single phase approach; or
- Up to 1,296 (648 x2) two-way vessel movements for a two phased approach.

513. The construction port to be used for Norfolk Boreas is not yet known. Indicative daily vessel movements (return trips to a local port) during construction of Norfolk Boreas are estimated to be an average of two per day. The maximum number of vessels on site at any one time would be 57.

514. As outlined in section 12.7.3.4, Chapter 15 Shipping and Navigation provides a description of the baseline conditions and anticipated additional ship movements arising from the construction and operation of the proposed project. The baseline conditions indicate an already relatively high level of shipping activity in and around the Norfolk Boreas.

515. Based on the worst-case scenario of an average of two vessel movements per day, the increase in vessels movement per day at the Norfolk Boreas site during construction is going to be relatively small compared to existing vessel traffic. Although there could be a maximum of 57 vessels on site at any one time, most vessels once on site would remain within the site area.

516. The additional vessel movements associated with the construction of Norfolk Boreas could have the potential to increase the collision risk with marine mammals.

517. Marine mammals are able to detect and avoid vessels. However, vessel strikes are known to occur, possibly due to distraction of animals whilst foraging and socially interacting, or due to the marine mammals' inquisitive nature (Wilson et al., 2007). Therefore, increased vessel movements, especially those outwith recognised vessel routes, can pose an increased risk of vessel collision to harbour porpoise, grey seal and harbour seal.

518. Marine mammals are relatively robust with a thick sub-dermal layer of blubber that provides some protection for their vital organs in the event of a vessel strike (Wilson et al., 2007). However, non-fatal collisions can leave the animal vulnerable to secondary infection, other complications or predation (Wilson et al., 2007).

519. Studies have shown that larger vessels are more likely to cause the most severe or lethal injuries, with vessels over 80m in length causing the most damage to marine mammals (Laist et al., 2001). Vessels travelling at high speeds are considered to be more likely to collide with marine mammals, and those travelling at speeds below 10 knots would rarely cause any serious injury (Laist et al., 2001). It is not possible to fully quantify strike rates between marine mammals and vessels because it is believed that a number go unnoticed (Evans et al., 2011).

520. Harbour porpoises are small and highly mobile, and given their responses to vessel noise (e.g. Thomsen et al., 2006; Evans et al., 1993; Polacheck and Thorpe, 1990), are expected to largely avoid vessel collisions. 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.

521. Of the 273 reported harbour porpoise stranding's in 2015 (latest UK Cetacean Stranding's Investigation Programme Report currently available), 53 were investigated at post mortem (27 were conducted in England, 13 in Scotland and 13 in Wales). A cause of death was established in 51 examined individuals (approximately 96% of examined cases). Of these, four (8%) had died from physical trauma of unknown cause, which could have been vessel strikes (CSIP, 2015). 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).

522. There is limited information on which to quantity the collision risk of marine mammals, especially harbour porpoise, grey seal and harbour seal from the large vessels typically used for offshore wind farm construction. Therefore, although the risk of collision is likely to be low, a precautionary 5-10% increased collision risk has been used in the assessment (e.g. 5-10% of the individuals present in the area could be at increased collision risk).

523. This is very precautionary, especially taking into account the increase in number of vessel movements compared to existing vessel movements in the area. In addition, it should be noted that the total area of offshore construction works would be less than as assessed below, as either the interconnector cables or the project interconnector cables (and therefore project areas), would be constructed, dependant on whether Norfolk Vanguard is built. Under no circumstance would construction take place for both the interconnector cable and the project interconnector cable.

524. Vessel movements, where possible, will be incorporated into recognised vessel routes and hence to areas where marine mammals are accustomed to vessels, in order to reduce any increased collision risk. All vessel movements will be kept to the minimum number that is required to reduce any potential collision risk. Additionally, vessel operators will use good practice to reduce any risk of collisions with marine mammals.

525. In addition, based on the assumption that harbour porpoise would be disturbed by noisy activities (and therefore displaced from large part of the Norfolk Boreas offshore project area), there should be no potential for increased collision risk during those construction activities.

Table 12.51 Estimated number of harbour porpoise, grey seal and harbour seal that could be at potential increased vessel collision risk during construction based on 5-10% of individuals present in the Norfolk Boreas offshore area (wind farm site, project interconnector cable search areas and export cable corridor)

Potential Impact Area	Receptor	Estimated number at potential increased collision risk	% of reference population[1]	Magnitude[2] for permanent impact
Total offshore project area (1,178km^2)	Harbour porpoise	52-105 harbour porpoise based on SCANS-III survey block O density (0.888/km^2). 62-125 harbour porpoise based on site specific survey density (1.06/km^2).	0.015-0.03% of NS MU based on SCANS-III density. 0.018-0.04% of NS MU based on site specific survey density.	Permanent effect with **medium** magnitude (between 0.01% and 1% of the reference population anticipated to be exposed to effect).
	Grey seal	2-4 grey seal based on number on Norfolk Boreas offshore project area density (0.032/km^2).	0.009-0.02% of ref pop (0.03-0.06% of SE England MU).	Permanent effect with **low to medium** magnitude (between 0.001% and 1% of the reference population anticipated to be exposed to effect).
	Harbour seal	1-2 harbour seal based on number on Norfolk Boreas offshore project area density (0.019/km^2).	0.002-0.005% of ref pop (0.02-0.04% of SE England MU).	Permanent impact with **low** magnitude (between 0.001% and 0.01% of the reference population anticipated to be exposed to effect).

[1]Based on density estimates and reference populations (see Table 12.14 and Table 12.15); [2]See Table 12.7 for definitions

12.7.3.6.3 Impact significance

526. Taking into account the receptor sensitivity and the potential magnitude of the impact, the impact significance for any potential increase in collision risk with vessels during construction has been assessed as **minor adverse** (not significant) for harbour porpoise, grey seal and harbour seal (Table 12.52). However, this assessment has been based on a very precautionary 5-10% increased collision risk. No further mitigation measures are proposed beyond those embedded measures presented in section 12.7.1.

527. The confidence in the data used in this assessment is low.

Table 12.52 Assessment of impact significance for increased collision risk from vessels during construction

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual impact
Increased collision risk from vessels during construction for total offshore project area	Harbour porpoise	Low	Medium	Minor	No further mitigation proposed other than good practice.	**Minor adverse**
	Grey seal	Low	Low / Medium	Minor		**Minor adverse**
	Harbour seal	Low	Low	Minor		**Minor adverse**

12.7.3.7 Impact 7: Disturbance at seal haul-out sites

12.7.3.7.1 Sensitivity

528. 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. Therefore, the sensitivity of grey and harbour seals at haul-out sites to disturbance from vessels during construction is likely to be negligible. As a very precautionary approach, it is proposed that sensitivity during the breeding season and annual moult could be slightly higher and has therefore been considered as low in this assessment. However, at Donna Nook in Lincolnshire, it seems that seals have become habituated to human disturbance as over 70,000 people visit this colony during the breeding season with no apparent impact on the breeding seals (SCOS, 2017).

12.7.3.7.2 Magnitude

529. The response of seals to disturbance at haul-out sites can range from increased alertness to moving into the water (Wilson, 2014). The potential impact on pupping groups can include temporary or permanent pup separation, disruption of suckling, energetic costs and energetic deficit to pups, physiological stress and sometimes

enforced move to distant or suboptimal habitat. Potential impacts on moulting groups can include energy loss and stress, while impacts on other haul-out groups can cause loss of resting and digestion time and stress (Wilson, 2014). The potential impacts will be determined by the response of the seals, the duration and proximity of the disturbance to the seals.

530. Studies on the distance of disturbance, on land or in the water, from hauled-out harbour seals have found that the closer the disturbance, the more likely seals are to move into the water. The estimated distance between a disturbance and haul out site, at which most seal movements into the water occur, varies for different locations and type of disturbance, but has been estimated at typically less than 100m (Wilson, 2014). For the grey seal, mothers responded by moving into the water more due to boat speed than as a result of the distance, although movement into the water was generally observed to occur at distances of between 20 and 70m, with no detectable disturbance at 150m (Wilson, 2014; Strong and Morris, 2010). However, grey and harbour seals have also been reported to move into the water when vessels are at a distance of approximately 200m to 300m (Wilson, 2014).

531. The Norfolk Boreas site is located approximately 73km offshore (at the closest point). Principal grey seal and harbour seal haul-out sites are at:

- Horsey, located 76km from the Norfolk Boreas site;
- Scroby Sands, approximately 67km from the Norfolk Boreas site;
- Blakeney Point, approximately 121km from the Norfolk Boreas site;
- Donna Nook, approximately 180km from the Norfolk Boreas site; and
- The Wash, approximately 168km from the Norfolk Boreas site.

532. The main breeding site for harbour seal on the east coast of England is in The Wash (SCOS, 2017). The main breeding site for grey seal on the east coast of England is at Blakeney Point (SCOS, 2017).

533. There is therefore no potential for any direct disturbance as a result of construction activities within the offshore wind farm site due to the distances between the Norfolk Boreas site and the nearest seal haul-out sites.

534. The landfall at Happisburgh South, which is approximately:

- 9km from the Horsey seal haul-out site to the south; and
- 44km from the Blakeney Point haul-out site to the north.

535. Given the distances between the Norfolk Boreas cable landfall area and the nearest known seal haul-out sites; there is no potential for any direct disturbance as a result of construction activities within the cable corridor and landfall site.

536. The construction port to be used for Norfolk Boreas is not yet known. Vessel movements to and from any port, where possible, will be incorporated within existing vessel routes. Vessel movements to the offshore project area would use direct routes and are unlikely to be close to the shore (i.e. within a few hundred metres) except when near the port to avoid the risk of collision and grounding. However, taking into account the proximity of shipping channels to and from existing ports, it is likely that any seals hauled-out along these routes and in the area of the ports would be habituated to the noise, movements and presence of vessels. There is therefore no potential for any direct disturbance at seal haul-out sites as a result of vessels moving to and from the wind farm sites and cable corridor, as vessels would not be moving at distances of 500m or less off the coast.

537. The potential for any increase in disturbance to seal haul-out sites as a result of construction activities at the offshore wind farm sites, activities along the cable route and at landfall site, or from vessels movements during construction will be negligible.

12.7.3.7.3 Impact significance

538. Taking into account the receptor sensitivity and the potential magnitude of the impact and the temporary nature of the disturbance, the impact significance for any disturbance at seal haul-out sites during construction has been assessed as **negligible** (not significant) (Table 12.53); therefore no further mitigation measure are proposed beyond those embedded measures presented in section 12.7.1.

539. The confidence in the data used in this assessment is medium to high.

Table 12.53 Assessment of impact significance for disturbance at seal haul-out sites during construction

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual impact
Disturbance at seal haul-out sites during construction	Grey seal	Low	Negligible	Negligible	No mitigation required or proposed	**Negligible**
	Harbour seal	Low	Negligible	Negligible		**Negligible**

12.7.3.8 Impact 8: Changes to prey resource

12.7.3.8.1 Sensitivity

540. Grey and harbour seal feed on a variety of prey species, both are considered to be opportunistic feeders, they are able to forage in other areas and have relatively large foraging ranges (see section 12.6 and Appendix 12.2). Grey seal and harbour seal are therefore considered to have low sensitivity to changes in prey resources.

541. The diet of the harbour porpoise consists of a wide variety of prey species and varies geographically and seasonally, reflecting changes in available food resources. As outlined in section 12.6.1.2, harbour porpoise have relatively high daily energy demands and need to capture enough prey to meet its daily energy requirements. It has been estimated that, depending on the conditions, harbour porpoise can rely on stored energy (primarily blubber) for three to five days, depending on body condition (Kastelein et al., 1997). Harbour porpoise are therefore considered to have low to medium sensitivity to changes in prey resources.

12.7.3.8.2 Magnitude

542. Potential impacts on marine mammal prey species have been assessed in Chapter 11 Fish and Shellfish Ecology using the appropriate realistic worst-case scenarios for these receptors. The existing environment for the assessment has been informed by site specific surveys and a number of existing data sources.

543. Potential impacts on fish species during construction can result from physical disturbance and temporary loss of seabed habitat; increased suspended sediment concentrations and sediment re-deposition; and underwater noise (that could lead to mortality, physical injury, auditory injury or behavioural responses). None of the potential impacts are assessed as being significant (**minor adverse** at worst; Chapter 11 Fish and Shellfish Ecology).

544. As outlined in Chapter 11 Fish and Shellfish Ecology, the maximum (worst-case scenario) potential area of physical disturbance and/or temporary loss of habitat to fish during construction is likely to be a very small proportion of the offshore project area (equating to a maximum of 2.0%). The assessment determined that with the low magnitude of impact, the impact on fish species, including sandeel and herring, would be of **minor adverse** significance (not significant; Chapter 11 Fish and Shellfish Ecology).

545. Similarly, the magnitude of impact on prey from any increased suspended sediment concentrations and sediment re-deposition would be low, with only a small proportion of fine sand and mud staying in suspension long enough to form a passive plume. As outlined in section 12.7.3.8.1, this plume (tens of mg/l) would only exist for half a tidal cycle (i.e. approximately 6 hours), the sediment would then settle to the seabed within approximately 1km along the axis of tidal flow from the location at which it was released and these deposits would be very thin (millimetres). For the offshore cable installation, it is predicted that in water depths greater than 20m LAT (which are seen across the majority of the offshore cable corridor), peak suspended sediment concentrations would be typically less than 100mg/l, except in the immediate vicinity (a few tens of metres) of the release location. In shallow water nearer to shore (less than 5m LAT), the potential for dispersion is more limited and

therefore the concentrations are likely to be greater, approaching 400mg/l at their peak. However, these plumes would be localised to within less than 1km of the location of installation and would persist for no longer than a few hours. Following cessation of installation activities any plume would have been fully dispersed as a result of advection and diffusion. Therefore, the assessment determined that with the low magnitude of impact, the impact on fish species, including sandeel and herring, would be **minor adverse** significance (not significant; Chapter 11 Fish and Shellfish Ecology).

546. Potential sources of underwater noise and vibration during construction include piling, increased vessel traffic, seabed preparation, rock dumping and cable installation. Of these, piling is considered to produce the highest levels of underwater noise and therefore has the greatest potential to result in adverse impacts on fish. Underwater noise modelling (Appendix 5.4), assessed the following fish groups (based on Popper et al., 2014):

- No swim bladder (e.g. sole, plaice, lemon sole, mackerel and sandeels);
- Swim bladder not involved in hearing (e.g. sea bass, salmon and sea trout); and
- Swim bladder which is involved in hearing (e.g. cod, whiting, sprat and herring).

547. The underwater noise modelling results (Appendix 5.4) indicates that fish species in which the swim bladder is involved in hearing are the most sensitive to the impact of piling noise, with impact ranges of up to 0.17km for mortality and potential mortal injury for SPL_{peak} (for monopile with full hammer energy of 5,000kJ) and up to 6.5km for recoverable injury, based on maximum potential ranges for cumulative exposure (SEL_{cum} for monopile with full hammer energy, based on a fleeing animal approach).

548. Additional underwater noise modelling was undertaken to assess the effects using a stationary animal approach on cumulative exposure (Appendix 5.4 Annex 1). This is considered to be a highly precautionary approach, as it is unlikely that an individual would remain within the vicinity of the high noise levels of piling activity. For stationary fish species, exposed to piling noise over 12 hours, a maximum impact range of 18km was determined for the onset of TTS in all fish species.

549. Taking into account their wide distribution ranges, including areas used as spawning grounds, in the context of the potential ranges where TTS and behavioural impacts could occur, the assessment in Chapter 11 Fish and Shellfish Ecology, determined the potential impact to be of **minor adverse** significance.

550. As a precautionary worse-case scenario, the number of harbour porpoise, grey seal and harbour seal that could be impacted as a result of changes to prey resources during construction has been assessed based on the number of animals that could be present in the entire Norfolk Boreas offshore project area (1,178km^2). This is very

precautionary, as it is highly unlikely that any changes in prey resources could occur over the entire offshore project area during construction. It is more likely that effects would be restricted to an area around the working sites.

551. In addition, there would be no additional displacement of marine mammals as a result of any changes in prey resources during construction, as they would already be potentially disturbed from the wind farm sites or cable corridor as a result of underwater noise during piling, other construction activities or vessels, as the potential area of effect would be less or the same as those assessed for piling, other construction activities or vessels.

552. Based on the very precautionary approach that any changes in prey resource could occur across the entire offshore project area (1,178km^2), approximately 1,249 harbour porpoise (0.4% of the North Sea MU reference population), 38 grey seal (0.2% of reference population; 0.6% of the grey seal South-east England MU) and up to 22 harbour seal (0.05% of reference population; 0.4% of the harbour seal South-east MU) could be temporarily displaced.

553. The magnitude of effect is negligible for harbour porpoise, grey seal and harbour seal, for 100% displacement from the entire offshore project area, with less than 1% of the reference population being potentially temporarily affected by any changes to prey resources.

12.7.3.8.3 Impact significance

554. Taking into account the receptor sensitivity and the potential magnitude of the impact and the temporary nature of the disturbance, the impact significance for any changes in prey resource has been assessed as **negligible** (not significant) for grey seal and harbour seal and **negligible** to **minor adverse** (not significant) for harbour porpoise (Table 12.54); therefore no further mitigation measure are proposed beyond those embedded measures presented in section 12.7.1.

555. The confidence in the data used in this assessment is medium.

Table 12.54 Assessment of impact significance for any changes in prey resources on marine mammals

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual impact
Temporary changes to prey resources	Harbour porpoise	Low to Medium	Negligible	Negligible to Minor	No further mitigation currently required, beyond embedded mitigation to reduce piling noise impacts.	**Negligible to Minor adverse**
	Grey seal	Low	Negligible	Negligible		**Negligible**
	Harbour seal	Low	Negligible	Negligible		**Negligible**

12.7.4 Potential Impacts during Operation

556. All offshore infrastructure including wind turbines, foundations, cables and offshore electrical platforms would be monitored and maintained during the operational period in order to maximise efficiency.

12.7.4.1 Impact 9: Underwater noise from operational turbines

12.7.4.1.1 Sensitivity

557. Currently available data indicates that there is no, if any, marked exclusion of harbour porpoise or seals from wind farm sites during operation (Diederichs et al., 2008; Lindeboom et al., 2011; Marine Scotland, 2012; McConnell et al., 2012; Russell et al., 2014; Scheidat et al., 2011; Teilmann et al., 2006; Tougaard et al., 2005, 2009a, 2009b). Data collected suggests that any behavioural responses may only occur very close to or up to a few hundred metres away from turbines for harbour porpoise and seals, respectively (Tougaard et al., 2009b; McConnell et al., 2012).

558. With the exception of a single study (Nysted in the Baltic; Teilmann and Carstensen, 2012), harbour porpoise abundance has not been found to be reduced within wind farms in the operational phase, one study even suggesting an increase (Scheidat et al., 2011). Teilmann and Carstensen (2012) found a reduction in harbour porpoise abundance at the Nysted wind farm in the Baltic Sea from pre- to post-construction, which they attributed to the wind farm. However, other factors may have played a role as suggested by the fact that another study in the same wind farm didn’t find an effect (Diederichs et al., 2008). In addition, a similar study in a later neighbouring wind farm (Rødsand) also found no reduction in harbour porpoise abundance during operation (Teilmann et al., 2012). Monitoring was carried out at the Horns Rev and Nysted wind farms in Denmark during the operational phase between 1999 and 2006 (Diederichs et al., 2008). Numbers of harbour porpoise within Nysted were slightly reduced compared to the wider area during the first two years of operation,

however, it was not possible to conclude that the wind farm was solely responsible for this change in abundance (Tougaard et al., 2009b). Further studies (Diederichs et al., 2008) recorded no noticeable effect on the abundances of harbour porpoise at both of the offshore wind farms studied, following the first two years of operation. Some studies have indicated that over eight years harbour porpoise may become habituated to the presence of the turbines (Teilmann et al., 2012).

559. Monitoring studies at Nysted and Rødsand have also indicated that operational activities have had no impact on regional seal populations (Teilmann et al., 2006; McConnell et al., 2012). Tagged harbour seals have been recorded within two operational wind farm sites (Alpha Ventus in Germany and Sheringham Shoal in UK) with the movement of several of the seals suggesting foraging behaviour around wind turbine structures (Russell et al., 2014).

560. Both harbour porpoise and seals have been shown to forage within operational wind farm sites (e.g. Lindeboom et al., 2011; Russell et al., 2014), indicating no restriction to movements in operational offshore wind farm sites. Therefore, harbour porpoise, grey seal and harbour seal are considered to have low sensitivity to disturbance from underwater noise as a result of operational turbines.

12.7.4.1.2 Magnitude

561. Underwater noise modelling was undertaken to assess the potential impact ranges of operational turbines on marine mammals. The underwater noise propagation modelling was undertaken using a simple modelling approach for underwater noise associated with operational turbines, using measured sound source data scaled to relevant parameters for the Norfolk Boreas site (see Appendix 5.4 for further information).

562. To predict the operational noise levels at Norfolk Boreas, the noise levels of existing operational turbines were taken and used to predict the noise levels for the Norfolk Boreas turbines based on the size of the turbines (see Appendix 5.4 for more information). The sound source for operational turbines modelled was 165.4dB re 1µP (RMS) @1m for 20MW turbines.

563. The results of the underwater noise modelling indicate that at the source levels predicted for underwater noise of operational turbines, any marine mammal would have to remain in close proximity (i.e. less than 100m (an area of 0.03km^2)) of the turbine for 24 hours to be exposed to levels of sound that are sufficient to induce PTS as per the NMFS (2018) threshold criteria, or within 110m (an area of 0.04km^2) to be exposed to sound levels that has the potential to cause a behavioural response under the Lucke et al. (2009) threshold.

564. Based on the Norfolk Boreas site specific density (of 1.06/km^2 as a worst-case), up to three harbour porpoise (or 0.0008% of the NS MU reference population) could be at risk of the onset of PTS if within 100m of one of the 20MW turbines for a period of 24 hours (i.e. this is the total number of harbour porpoise that could be at risk across the entire Norfolk Boreas site, taking into account 90 20MW turbines). A total of four harbour porpoise (or 0.001% of the NS MU reference population) could have a possible behavioural response if within 110m of one of the 90 20MW turbines.

565. Based on the Norfolk Boreas site density of 0.001/km^2, a total of 0.003 grey seal (or 0.00001% of the reference population; 0.0001% of the SE England MU) could be at risk of the onset of PTS onset if within 100m of one of the 90 20MW turbines, and a total of 0.0003 harbour seal (based on the Norfolk Boreas site density of 0.0001/km^2), or 0.0000006% of the reference population or 0.000006% of the SE England MU, could be at risk of PTS onset if within 100m of one of the 90 20MW turbines.

566. The resultant magnitude of the potential impact of any cumulative auditory injury (PTS) as a result of operational turbine noise is negligible for harbour porpoise, grey seal and harbour seal, if they were within 0.1km of the turbines for 24 hours.

567. The possible behavioural response of harbour porpoise is negligible, based on long-term temporary disturbance.

12.7.4.1.3 Impact significance

568. Taking into account the potential effects, the impact significance for any cumulative PTS as a result of operational turbines has been assessed as **negligible** (not significant) for harbour porpoise, grey seal and harbour seal, as it is highly unlikely that animals would remain within 0.1km of the turbines for 24 hours and therefore be at risk of any cumulative PTS.

569. TTS has not been modelled, however, based on the potential PTS impact ranges and possible behavioural response of harbour porpoise, the TTS ranges are also expected to be very small and highly unlikely to result in any temporary significant impacts.

570. The potential disturbance of harbour porpoise has also been assessed as **negligible** significance.

571. The confidence in the data used in this assessment is medium.

12.7.4.2 Impact 10: Underwater noise from maintenance activities

12.7.4.2.1 Sensitivity

572. As outlined in section 12.7.3.3, the sensitivity of marine mammals to disturbance as a result of underwater noise during maintenance activities, such as cable installation, is considered to be medium in this assessment as a precautionary approach.

12.7.4.2.2 Magnitude

573. 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. The following estimates are assumed (Table 12.18):

- One export cable repair and two array cable repairs per year.
- Up to 20km of export cable reburial at five year intervals (rock dumping may be required should reburial not be possible).
- Reburial of 25% of array cable once every five years.
- One interconnector or one project interconnect cable repair per year.

574. As outlined in section 12.7.3.3, the potential for PTS is only likely in very close proximity to cable laying or rock dumping activities and if within close proximity for 24 hours. There is also the potential for noise from maintenance activities to cause disturbance.

575. The impacts from additional cable laying and protection are temporary in nature, and will 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.

576. Therefore, the underwater noise from maintenance activities are considered to be the same as for underwater noise from for other construction activities (including rock dumping, trenching and cable laying) (section 12.7.3.3) and therefore the impact of maintenance activities will be the same as for other construction activities (Table 12.45 and Table 12.45).

577. The magnitude of effect in all species is assessed to be negligible based on the total within the modelled impact ranges for other construction activities (Table 12.45).

12.7.4.2.3 Impact significance

578. Taking into account the receptor sensitivity and the potential magnitude of the temporary impact, the impact significance for any disturbance of harbour porpoise, grey seal and harbour seal has been assessed as **minor adverse** (not significant);

therefore, no further mitigation measure are proposed beyond those embedded measures presented in section 12.7.1.

579. The confidence in the data used in this assessment is medium to high.

Table 12.55 Assessment of impact significance for underwater noise during maintenance activities

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual impact
Underwater noise during maintenance activities	Harbour porpoise	Medium	Negligible	Minor adverse	No mitigation required	**Minor adverse**
	Grey seal	Medium	Negligible	Minor adverse		**Minor adverse**
	Harbour seal	Medium	Negligible	Minor adverse		**Minor adverse**

12.7.4.3 Impact 11: Vessel underwater noise and disturbance during operation and maintenance

12.7.4.3.1 Sensitivity

580. As outlined in section 12.7.3.4, the sensitivity of harbour porpoise, grey seal and harbour seal is low to vessel noise.

12.7.4.3.2 Magnitude

581. The requirements for any potential maintenance work are currently unknown, 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. It estimated that there could be up to 445 support vessel round trips per year during operation and maintenance.

582. As outlined in section 12.7.3.4, the potential for PTS is only likely in very close proximity to vessels (less than 150m) if the individual remains in close proximity for 24 hours. There is also the potential for disturbance impacts from vessel noise.

583. Taking into account the existing vessel movements in and around the offshore project area (see section 12.7.3.4) and the potential 1-2 vessel movement per day during operation and maintenance (Table 12.56) the number of vessels would not exceed the Heinänen and Skov (2015) threshold level of approximately 80 vessels per day within an area of 5km^2 (approximately 16 vessels per km^2). Therefore, there is no increase in the potential for disturbance to harbour porpoise as a result of the increased number of vessels during operation and maintenance at Norfolk Boreas.

Table 12.56 Indicative operational and maintenance vessel movements

Parameter	Number of movements
Indicative total number of vessel movements per year	445
Average number of movements per day	1-2

584. 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.

585. The magnitude of effect in all species is assessed to be negligible (Table 12.48) for vessels during operation and maintenance the magnitude of effect would be less than underwater noise from vessels during construction (section 12.7.3.4).

12.7.4.3.3 Impact significance

586. Taking into account the receptor sensitivity and the potential temporary magnitude of the impact, the impact significance for any disturbance as a result of underwater noise from vessels during operation and maintenance on harbour porpoise, grey seal and harbour seal has been assessed as **negligible** (Table 12.57); therefore no further mitigation measure are proposed beyond those embedded measures presented in section 12.7.1.

587. The confidence in the data used in this assessment is medium to high.

Table 12.57 Assessment of impact significance for underwater noise from vessels during operation and maintenance activities

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual impact
Underwater noise from vessels during operation and maintenance activities	Harbour porpoise	Low	Negligible	Negligible	No mitigation required or proposed	**Negligible**
	Grey seal	Low	Negligible	Negligible		**Negligible**
	Harbour seal	Low	Negligible	Negligible		**Negligible**

12.7.4.4 Impact 12: Vessel collision risk

12.7.4.4.1 Sensitivity

588. As outlined in section 12.7.3.6, marine mammals in the Norfolk Boreas offshore project area would be habituated to the presence of vessels and would be able to

detect and avoid vessels. Therefore, harbour porpoise, grey seal and harbour seal are considered to have a low sensitivity to the risk of a vessel strike.

12.7.4.4.2 Magnitude

589. The operation and maintenance ports to be used for Norfolk Boreas are not yet known but they are likely to 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 Table 12.56.

590. As outlined in section 12.7.3.6, Chapter 15 Shipping and Navigation, indicates relatively high shipping activity in and around Norfolk Boreas. Therefore, based on the worst-case scenario of an average of two vessel movements per day (Table 12.56), the increase in vessels movement per day at the Norfolk Boreas site (up to approximately 445 round trips per year) during operation and maintenance is relatively small compared to existing vessel traffic.

591. It estimated that there could be up to 2 vessel trips per day during operation and maintenance, therefore the potential increased collision risk as a result of vessels during operation and maintenance is considered to be negligible.

12.7.4.4.3 Impact significance

592. The impact significance for any potential increase in collision risk with vessels during operation and maintenance has been assessed as **negligible** for harbour porpoise, grey seal and harbour seal (Table 12.58). No further mitigation measures are proposed.

593. The confidence in the data used in this assessment is medium.

Table 12.58 Assessment of impact significance for increased collision risk from vessels during maintenance and operation

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual impact
Increased collision risk from vessels during construction for total offshore project area	Harbour porpoise	Low	Negligible	Negligible	No further mitigation proposed other than good practice.	**Negligible**
	Grey seal	Low	Negligible	Negligible		**Negligible**
	Harbour seal	Low	Negligible	Negligible		**Negligible**

12.7.4.5 Impact 13: Disturbance at seal haul-out sites

594. As outlined in section 12.7.3.7, taking into account the receptor sensitivity (low) and the potential magnitude of the impact (negligible) and the temporary nature of the disturbance, the impact significance for any disturbance at seal haul-out sites during operation and maintenance has been assessed as negligible (not significant) (Table 12.59); therefore no further mitigation measure are proposed.

Table 12.59 Assessment of impact significance for disturbance at seal haul-out sites during operation and maintenance

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual impact
Disturbance at seal haul-out sites during operation and maintenance	Grey seal	Low	Negligible	Negligible	No mitigation proposed or required	**Negligible**
	Harbour seal	Low	Negligible	Negligible		**Negligible**

12.7.4.6 Impact 14: Changes to prey resource during operation and maintenance

12.7.4.6.1 Sensitivity

595. As outlined in section 12.7.3.8.1, grey seal and harbour seal are considered to have low sensitivity to changes in prey resources and, as a precautionary approach, harbour porpoise are considered to have low to medium sensitivity to changes in prey resources.

12.7.4.6.2 Magnitude

596. Potential impacts on marine mammal prey species have been assessed in Chapter 11 Fish and Shellfish Ecology using the appropriate realistic worst-case scenarios for these receptors during operation and maintenance.

597. Potential impacts on fish species during operation and maintenance could result from permanent loss of habitat; introduction of hard substrate; operational noise; and electromagnetic fields (EMF). None of the potential impacts are assessed as being significant (**minor adverse** at worst; Chapter 11 Fish and Shellfish Ecology).

598. As outlined in Chapter 11 Fish and Shellfish Ecology, the worst-case total area of habitat loss has been estimated to be 6.4km^2 (this would account for a very small proportion (approximately 0.5%) of the total Norfolk Boreas site (approximately 1,178km^2)). Therefore, with the low magnitude of effect, the impact of permanent loss of habitat was considered to be of **minor adverse** significance for fish species, including sandeels and herring (Chapter 11 Fish and Shellfish Ecology).

599. The introduction of hard substrate, such as turbines, foundations and associated scour protection and cable protection associated with Norfolk Boreas would increase

habitat heterogeneity through the introduction of hard structures in an area predominantly characterised by soft substrate habitat. However, any hard substrate would occupy discrete areas and given the relatively small areas of the infrastructure will result in a low magnitude of the effect; therefore, the impact is considered to be of **minor adverse** significance.

600. Operational noise would include wind turbine vibration, the contact of waves with offshore structures and noise associated with increased vessel movement, which could result in an increase in underwater noise in respect of the existing baseline (i.e. pre-construction). However, based on studies at other offshore wind farms, any increase above background noise levels during operation is expected to be small and localised, therefore the magnitude of the impact on fish species would be low, resulting in a potential impact of **minor adverse** significance.

601. As outlined in Chapter 11 Fish and Shellfish Ecology, the areas potentially affected by EMFs generated by the worst-case scenario offshore cables are expected to be small, limited to the offshore project area and restricted to the immediate vicinity of the cables (i.e. within metres). In addition, EMFs are expected to attenuate rapidly in both horizontal and vertical plains with distance from the source. The magnitude of the effect on fish species is therefore considered to be low and the impact of EMFs of **minor adverse** significance (Chapter 11 Fish and Shellfish Ecology).

602. Based on the worst-case scenario for the total footprint (presence of wind turbine and platform foundations, scour protection, array cables, inter-connector cables, and cable protection; 6.4km^2), approximately 7 harbour porpoise (0.002% of the North Sea MU reference population), 0.2 grey seal (0.0009% of reference population; 0.003% of the grey seal South-east England MU) and 0.1 harbour seal (0.0003% of reference population; 0.002% of the harbour seal South-east MU) could be affected by any changes to prey resource.

603. The magnitude of effect in all species is negligible for harbour porpoise, grey seal and harbour seal, with less than 0.01% of the reference population being likely to be long-term temporarily affected by any changes to prey resources.

12.7.4.6.3 Impact significance

604. Taking into account the receptor sensitivity and the potential temporary magnitude of the impact, the impact significance for any changes in prey resource has been assessed as **negligible** (not significant) for grey seal and harbour seal and **negligible** to **minor adverse** (not significant) for harbour porpoise (Table 12.60); therefore, no further mitigation measures are proposed.

605. The confidence in the data used in this assessment is medium.

Table 12.60 Assessment of impact significance of changes in prey resources on marine mammals

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual impact
Changes to prey resources	Harbour porpoise	Low to Medium	Negligible	Negligible to Minor	No mitigation required or proposed	**Negligible to Minor adverse**
	Grey seal	Low	Negligible	Negligible		**Negligible**
	Harbour seal	Low	Negligible	Negligible		**Negligible**

12.7.5 Potential Impacts during Decommissioning

606. Possible effects on marine mammals associated with the decommissioning have not been assessed in detail, as a further assessment will be carried out ahead of any decommissioning works to be undertaken taking account of known information at that time, including relevant guidelines and requirements. A detailed decommissioning plan will be provided to the regulator prior to decommissioning that will give details of the techniques to be employed and any relevant mitigation measures required.

12.7.5.1 Impact 15: Underwater noise from foundation removal

607. Decommissioning would most likely involve the removal of the accessible installed components comprising: all of the wind turbine components; part of the foundations (those above seabed level); and the sections of the array cables close to the offshore structures, as well as sections of the export cables. The process for removal of foundations is generally the reverse of the installation process. There would be no piling, and foundations may be cut to an appropriate level.

608. It is not possible to provide details of the methods that will be used during decommissioning at this time. However, is it expected that the activity levels will be comparable to construction (with the exception of pile driving noise which would not occur).

609. For this assessment it is assumed that the potential impacts from underwater noise during decommissioning would be less than those assessed for piling (section12.7.3.2) and comparable to those assessed for other construction activities (section 12.7.3.3).

12.7.5.2 Impact 16: Barrier effects from underwater noise

610. For this assessment, it is assumed that the potential impacts from any barrier effects during decommissioning would be less than those assessed for construction (section 12.7.3.5).

12.7.5.3 Impact 17: Vessel underwater noise and disturbance from vessels

611. For this assessment, it is assumed that the potential impacts would be the same as for construction (see section 12.7.3.4).

12.7.5.4 Impact 18: Vessel collision risk

612. For this assessment, it is assumed that the potential impacts would be the same as for construction (see section 12.7.3.6).

12.7.5.5 Impact 19: Disturbance at seal haul-out sites

613. For this assessment, it is assumed that the potential impacts would be the same as for construction (see section 12.7.3.7).

12.7.5.6 Impact 20: Changes to prey resource

614. For this assessment, it is assumed that the potential impacts would be the same as for construction (see section 12.7.3.8).

12.8 Cumulative Impacts

615. As outlined in section 12.4.2, the CIA considers plans or projects where the predicted impacts have the potential to interact with impacts from the proposed construction, operation and maintenance or decommissioning of Norfolk Boreas.

616. The plans and projects screened in to the CIA (Appendix 12.3) are located in the relevant marine mammal reference population areas for harbour porpoise, grey seal and harbour seal (as defined in Table 12.14).

12.8.1 Project Tiers

617. The types of plans and projects included in the CIA, and the approach to screening, are based on the current stage of the plan or project within the planning and development process. This approach allows for the different levels of ‘uncertainty’ to be taken into account in the CIA, as well as the quality of the data available. This approach and definitions of the Tiers used (as outlined in section 12.4.2) was agreed at the EPP meeting in February 2017 (Table 12.4).

12.8.1.1 Tier 1 and Tier 2 projects

618. Tier 1 projects are relevant operational projects and therefore there is no potential for any overlap in the construction and piling of these projects with the construction and piling at Norfolk Boreas.

619. The CIA screening identified 23 UK and 36 European Tier 1 offshore wind farms that could have possible cumulative operational, maintenance and decommissioning impacts (Appendix 12.3).

620. Nine Tier 1 wave and tidal projects (four wave and five tidal) were identified, which could have possible cumulative operational, maintenance and decommissioning impacts (Appendix 12.3).

621. Tier 2 projects are marine infrastructure projects currently under construction and which are due to be commissioned prior to the construction of Norfolk Boreas, therefore there is no potential for any overlap in the construction and piling of these projects with the construction and piling at Norfolk Boreas.

622. The CIA screening identified four UK and nine European Tier 2 offshore wind farms that could have possible cumulative operational, maintenance and decommissioning impacts (Appendix 12.2). One Tier 2 tidal project was identified (Appendix 12.3) and Sixteen Tier 2 subsea cables and pipelines projects were identified which could have cumulative impacts (Appendix 12.3).

12.8.1.2 Tier 3 projects

623. Tier 3 projects are relevant marine infrastructure projects which have been consented, but construction has not yet commenced. Therefore, there is more certainty that these projects will be constructed compared to projects for which an application has not yet been determined. For Tier 3 offshore wind farm projects there is also more information on when construction is likely to be undertaken and an assessment of the potential impacts during piling have been provided in the project ESs, which allows quantified assessment of the potential impacts of these projects in the CIA.

624. However, there is still significant uncertainty associated with these projects, for example, in terms of the scale of the final development which will be constructed, precise construction dates and the likely final impacts. In particular, offshore wind farm projects aim to get consent for a maximum design scenario, based on the worst-case parameters, and then these parameters are generally refined and reduced post consent.

625. The CIA screening identified 14 UK Tier 3 offshore wind farms, of which nine projects could have possible cumulative impacts during construction and all 14 could have possible cumulative operational, maintenance and decommissioning impacts (Appendix 12.3).

626. The CIA screening identified 22 European Tier 3 offshore wind farms, of which 13 projects could have possible cumulative impacts during construction and all 22 could have possible cumulative operational, maintenance and decommissioning impacts (Appendix 12.3).

627. Four tidal projects and two wave projects were identified in Tier 3 which could have possible operational, maintenance and decommissioning impacts (Appendix 12.2)

and Two Tier 3 subsea cables and pipelines projects were identified which could have cumulative impacts (Appendix 12.3).

12.8.1.3 Tier 4 projects

628. Tier 4 projects are relevant marine infrastructure projects which have an application submitted to the appropriate regulatory body but that have not yet been determined or are consented but currently on hold due to judicial challenge or appeal process. There is increased uncertainty about these projects, especially where the projects are currently on-hold, as to when or if they could be constructed and what changes could be made to the scale of the developments.

629. The CIA screening identified four UK Tier 4 offshore wind farms which could have possible cumulative impacts during construction, operational, maintenance and decommissioning impacts (Appendix 12.3).

630. Six Tier 4 subsea cables and pipelines projects were identified which could have cumulative impacts during their installation (Appendix 12.3).

12.8.1.4 Tier 5 projects

631. Tier 5 projects are relevant marine infrastructure projects that the regulatory body are expecting to be submitted for determination (e.g. projects listed under the Planning Inspectorate programme of projects).

632. As outlined in Table 12.10, Tier 5 projects were screened out of the CIA, as there is too much uncertainty and not enough information to allow a robust assessment. However, as a very precautionary approach, the Tier 5 UK offshore wind farm projects that we are currently aware of have been listed and included in the 'worst-case' scenario for cumulative impacts during offshore wind farm piling.

633. The CIA screening identified three UK Tier 5 offshore wind farms which could have possible cumulative impacts during construction, operation, maintenance and decommissioning (Appendix 12.3).

12.8.2 Types of Cumulative Impacts and Approach to Assessment

634. Types of impact considered in the CIA are summarised in Table 12.61. The CIA considers the three types of impact (underwater noise, indirect impacts and direct interaction) from all stages of any plan or project where there is the potential to temporarily overlap with Norfolk Boreas. Each type of potential cumulative impact has been assessed, where relevant, for harbour porpoise, grey seal and harbour seal.

12.8.2.1 Underwater noise

635. The potential sources of underwater noise during each stage of a plan or project are summarised in Table 12.61.

636. Auditory injury (PTS) could occur as a result of pile driving during offshore wind farm installation, pile driving during oil and gas platform installation, underwater explosives (used occasionally during the removal of underwater structures and UXO clearance) and seismic surveys (JNCC, 2010a, 2010b, 2017a). However, if there is the potential for any auditory injury (PTS), suitable mitigation would be put in place to reduce any risk to marine mammals. Other activities such as dredging, drilling, rock dumping and disposal, vessel activity, operational wind farms, oil and gas installations or wave and tidal sites will emit broadband noise in lower frequencies and auditory injury (PTS) from these activities is very unlikely. Therefore, as agreed with the Norfolk Vanguard Marine Mammal ETG, the potential risk of any auditory injury (PTS) in marine mammals is not included in the CIA.

637. The CIA assessment determines the potential for disturbance to marine mammals from underwater noise sources during the offshore construction, operation, maintenance and decommissioning of Norfolk Boreas.

638. The approach to the assessment for cumulative disturbance from underwater noise has been based on the approach in section 12.7.3.2.4 and follows the current advice from the SNCBs on the assessment of impacts on the SNS harbour porpoise SAC. This approach has been agreed and used for the Norfolk Vanguard EIA, including the CIA.

639. Following the current advice from the SNCBs, the CIA has been based on the following parameters:

- A distance of 26km from an individual percussive piling location has been used to assess the area that harbour porpoise, grey seal and harbour seal could potentially be disturbed during piling, for both single and concurrent piling operations.
- A distance of 10km around seismic operations has been used to assess the area that harbour porpoise, grey seal and harbour seal could potentially be disturbed.
- A distance of 26km around UXO clearance has been used to assess the area that harbour porpoise, grey seal and harbour seal could potentially be disturbed.

640. The potential disturbance from underwater noise has been assessed for the relevant plans and projects screened in to the CIA, based on these standard disturbance areas.

641. The potential disturbance from offshore wind farms during construction activities, other than piling, including vessels, seabed preparation, rock dumping and cable installation, has been based on the area of the offshore wind farm sites, this is a precautionary approach, as it is highly unlikely that construction activities, other than piling, would result in disturbance from the entire wind farm area. Any

disturbance is likely to be limited to the area in and around where the actual activity is actually taking place.

642. The potential disturbance from operational offshore wind farms and maintenance activities, including vessels, any rock dumping or cable re-burial, has also been based on the area of the offshore wind farm sites, this is again a precautionary approach, as it is highly unlikely that operational offshore wind farms and maintenance activities, including vessels, would result in disturbance from the entire wind farm area. Any disturbance is likely to be limited to the area in and around where the actual activity is actually taking place.

643. Where a quantitative assessment has been possible, the potential magnitude of disturbance in the CIA has been based on the number of harbour porpoise in the potential impact area using the site specific SCANS-III density estimates for each project (Hammond et al., 2017). The number of grey and harbour seal in the potential impact area has been estimated based on the latest seal at sea usage maps (Russell et al., 2017) for the area of the projects.

644. It is intended that this approach to assessing the potential cumulative impacts of disturbance from underwater noise will reduce some of the uncertainties and complications in using the different assessments from ESs, based on different noise models, thresholds and criteria, as well as different approaches to density estimates.

12.8.2.2 Changes in prey availability

645. The cumulative assessment on potential changes to prey availability has assumed that any potential impacts on marine mammal prey species from underwater noise, including piling, would be the same or less than those for marine mammals. Therefore, there would be no additional cumulative impacts other than those assessed for marine mammals, i.e. if prey are disturbed from an area as a result of underwater noise, marine mammals will be disturbed from the same or greater area, therefore any changes to prey availability would not affect marine mammals as they would already be disturbed from the same area.

646. Any impacts on prey species are likely to be intermittent, temporary and highly localised, with potential for recovery following cessation of the disturbance activity. Any permanent loss or changes of prey habitat will typically represent a small percentage of the potential habitat in the surrounding area.

647. Given that there will be no cumulative noise impacts and habitat losses are small, indirect impacts upon prey species are not considered further in this assessment.

12.8.2.3 Increased collision risk

648. As outlined in section 12.7.3.6, it is difficult to quantify the increased collision risk to marine mammals.

649. The potential increased collision risk with vessels during the construction and decommissioning of offshore wind farms has used a similar precautionary approach as outlined in section 12.7.3.6 and section 12.7.4.4. 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. Therefore, the number of harbour porpoise, grey seal and harbour seal that could be at increased collision risk with vessels has been assessed based on 5% of animals that could be present in the wind farm areas could be at increased collision risk. This is very precautionary, as it is highly unlikely that marine mammals present in the wind farm areas would be at increased collision risk with vessels.

650. Where a quantitative assessment has been possible, the number of harbour porpoise in the potential impact area has been determined using the latest SCANS-III density estimates (Hammond et al., 2017) for the area of the projects. The number of grey and harbour seal in the potential impact area has been estimated based on the latest seal at sea usage maps (Russell et al., 2017) for the area of the projects.

12.8.3 Considerations for CIA

651. It should be noted that a large amount of uncertainty is inherent in the completion of a CIA. At the project level, uncertainty in the assessment process has been expressed as a level of the confidence in the data used in the assessment. This relates to confidence in both the understanding of the consequences of the impacts in marine mammals, but also the information used to inform the predicted magnitude and significance of project impacts on marine mammals.

652. In the CIA, the potential for impacts over wider spatial and temporal scales means that the uncertainty arising from the consideration of a large number of plans or projects can lead to a lower confidence in the information used in the assessment, but also the conclusions of the assessment itself. To take this uncertainty into account, where possible, a precautionary approach has been taken at multiple stages of the assessment process.

653. The approach to dealing with uncertainty has led to a highly precautionary assessment of the cumulative impacts, especially for pile driving as the CIA is based on the worst-case scenarios for all projects being required. However, it should be noted that building precaution on precaution can lead to unrealistic worst-case scenarios within the assessment.

654. Therefore, the assessment is based on the most realistic worst-case scenario, to help reduce any uncertainty or present highly unrealistic worst-case scenarios while still providing a conservative assessment. Careful consideration has been undertaken to determine this likely worst-case scenario for the cumulative impact assessment. It

was agreed with the Norfolk Vanguard ETG on 8th December 2017, that the likely worst-case scenario was appropriate for the assessment for the that project (Table 12.4), and further advice has been to apply the same methods to Norfolk Boreas.

655. The aim of the CIA is to achieve a more evidence based and realistic assessment of the potential cumulative population effects as a result of the disturbance to harbour porpoise from piling noise.

656. The level of uncertainty in completing a CIA further supports the need for a more strategic level assessment rather than developer led assessment. Population models, such as Disturbance Effects of Noise on the Harbour Porpoise Population in the North Sea (DEPONS) and the interim Population Consequences of Disturbance (iPCoD) used at a strategic level would allow consideration of the biological fitness consequences of disturbance from underwater noise, and the conclusions of a quantitative assessment to be put into a population level context (e.g. Nabe-Nielsen et al., 2018). Norfolk Boreas Limited is supportive of these strategic initiatives, and will continue to work alongside other developers, Regulators and SNCBs in order to further understand the potential for significant cumulative impacts, and work to reduce potential impacts where appropriate.

Table 12.61 Impacts considered within the CIA

Impact	Sources of impact and stages of projects	Potential cumulative effects
Underwater Noise - disturbance	Pile driving noise: • Construction	Cumulative increase in underwater noise from piling during construction at offshore developments has the potential to cause disturbance to marine mammals. Included in the CIA: • Projects with overlapping construction phases with Norfolk Boreas, resulting in maximum potential for underwater piling noise to interact cumulatively in the regional marine mammal reference population boundaries. Worst case temporal adverse scenario considers the longest duration of the piling phase for each of the projects. This may include projects whose construction phases do not overlap with Norfolk Boreas but which occur immediately prior to or after and therefore increase the overall duration of sequential piling within the marine mammal reference population boundaries. Maximum spatial adverse scenario considers the maximum area of which marine mammal could be disturbed as a result of offshore piling.
	Vessel noise: • Construction; • Operation and maintenance; and • Decommissioning	Cumulative increase in vessel traffic arising from construction, operation and maintenance and decommissioning of offshore developments may result in increased noise disturbance to marine mammals. Included in the CIA: • Projects with overlapping construction phases with Norfolk Boreas, resulting in maximum increase in number of vessel movements. • Projects that could contribute to increased vessel traffic due to operational and maintenance or decommissioning activities.
	Other noise sources: seabed preparation / rock dumping; cable or pipe laying; surveying, including seismic surveys; drilling; disposal noise; dredging noise; wind turbine or other mechanical operational noise; foundation / cable removal; UXO clearance and explosives; • Construction; • Operation and maintenance; and • Decommissioning	Cumulative increase in noise for activities other than piling and vessels arising from construction, operation and maintenance and decommissioning of offshore developments may result in increased noise disturbance to marine mammals. Included in the CIA: • Projects with overlapping construction phases with Norfolk Boreas, resulting in maximum potential impacts on marine mammals. • Projects that could have the potential to disturb marine mammals due to operational and maintenance or decommissioning activities.

Impact	Sources of impact and stages of projects	Potential cumulative effects
Direct interaction – increased collision risk	Vessels: • Construction; • Operation and maintenance; and • Decommissioning Wave and tidal devices: • Operation	Cumulative increase in vessel traffic arising from construction, operation and maintenance, and decommissioning of offshore developments may result in increased collision risk to marine mammals. Included in the CIA: • Projects with overlapping construction phases with Norfolk Boreas, resulting in maximum increase in number of vessel movements. • Projects that could contribute to increased vessel traffic due to operational and maintenance or decommissioning activities.

12.8.4 Impact 1: Underwater noise impacts during construction from offshore wind farm piling

657. The greatest noise source is likely to result from pile driving during the construction of offshore wind farms. This stage of the cumulative assessment of underwater noise considers the potential disturbance of marine mammals during piling at Norfolk Boreas and piling at other offshore wind farm projects screened into the CIA that could potentially be piling at the same time.

658. Two scenarios for assessing the potential cumulative impacts of disturbance due to underwater noise from piling during offshore wind farm construction have been assessed.

659. The assessment has been undertaken based on the 'likely worst-case' scenario of the offshore wind farm developments that could be piling at the same time as Norfolk Boreas. This scenario is based on a precautionary approach using the maximum duration of piling periods.

660. In addition, a 'theoretical worst-case', scenario based on consent periods which allows for any delays and changes in project development has been assessed in Appendix 12.6.

661. The UK Tier 3, 4 and 5 offshore wind farm projects and European Tier 3 offshore wind farm projects are included in the likely worst-case scenario to assess the potential for cumulative disturbance of marine mammals during offshore wind farm piling, based on the periods of piling outlined in Table 12.62.

662. The likely worst-case scenario takes into account the most likely and most efficient build scenarios, based on certain assumptions e.g. developers of multiple sites are unlikely to develop more than one site at a time, as it is more efficient and cost effective to develop one site and have it operational prior to constructing the next site. It has therefore been assumed that there will be no overlap in the piling of Norfolk Boreas and Norfolk Vanguard, or between the East Anglia THREE, ONE North and TWO projects, and that two of the four Dogger Bank projects could be constructed at the same time.

663. The CIA has been based on single or concurrent piling in Norfolk Boreas, with single or concurrent piling in the other offshore wind farm projects identified to have an overlap with the Norfolk Boreas construction window.

664. For the CIA, the potential construction period of Norfolk Boreas has been based on the widest likely range of construction dates of between 2025 and 2028, based on a maximum four year construction period. Construction piling however is likely to

commence in 2026 and be completed in 2028 therefore being undertaken over a maximum three year period (Table 12.16 and Table 12.17).

665. As a precautionary worst-case, it has been assumed that piling could occur at any time during the potential construction period, although would not be continuous for the duration of the construction period. As outlined in section 12.7.3.2.4, active piling and ADD activation would only be for a relatively short period, up to 57 days, approximately 4% of the four year construction period.

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

Table 12.62 Offshore wind farms included in CIA for the potential disturbance of harbour porpoise, grey seal and harbour seal where there is the potential of piling occurring at the same time as construction at Norfolk Boreas. All details presented are based on the most up to date information for each project at the time of writing.

Name and country of project	Distance from Norfolk Boreas (km)	Size (MW)	Maximum number of turbines	Month/year consent authorised/ expected (7yr construction window)	Dates of offshore construction / piling[1]	Likely worst-case scenario of piling occurring at the same time as Norfolk Boreas piling[2]
Norfolk Boreas	**0**	**1,800**	**90-180**	**2020 (2020-2027)**	**Construction piling: 2026 – 2028**	**Yes**
Tier 3: consented						
Blyth Demonstration site (3A & 4)	351	58.4	10	2013 (2013-2020)	Unknown	No
Creyke Beck A, UK	173	1,200	200	Feb-15 (2015-2022)	2021-2027	**Yes**
Creyke Beck B, UK	196	1,200	200	Feb-15 (2015-2022)	2021-2028	No[3]
Teesside A, UK	191	1,200	200	Aug-15 (2015-2022)	2021-2028	**Yes**
Sophia (formerly Teesside B), UK	185	1,400	200	Aug-15 (2015-2022)	2020-2028	No[3]
East Anglia THREE, UK	13	1,200	172	Aug-17 (2017-2024)	Piling: 2020 – 2022	No
Hornsea Project Two, UK	101	1,386	165	Aug-16 (2016-2023)	2018-2021 Piling: 2018-2020	No
Triton Knoll phase 1-3, UK	288	860	90	Jul-13 (2013-2020)	2018-2021	No
Moray Firth East, UK	657	950	100	2014 (2014-2021)	2019-2022	No
Mermaid, Belgium	125	235	28	2015 (2015-2022)	2017-2019	No

Name and country of project	Distance from Norfolk Boreas (km)	Size (MW)	Maximum number of turbines	Month/year consent authorised/ expected (7yr construction window)	Dates of offshore construction / piling[1]	Likely worst-case scenario of piling occurring at the same time as Norfolk Boreas piling[2]
Norfolk Boreas	**0**	**1,800**	**90-180**	**2020 (2020-2027)**	**Construction piling: 2026 – 2028**	**Yes**
Northwester 2, Belgium	130	219	22	2015 (2015-2022)	Unknown	No
SeaStar, Belgium	134	252	30	2014 (2014-2021)	Unknown	No
Borssele I and II, Netherlands	133	752	94	May-16 (2016-2023)	2019	No
Borssele III and IV, Netherlands	123	731.5	77	May-16 (2016-2023)	2020	No
Borssele Site V - Leeghwater - Innovation Plot, Netherlands	108	20	2	May-16 (2016-2023)	2020	No
Eoliennes du Calvados, France	441	450	75	2016 (2016-2023)	Unknown	No
Parc éolien en mer de Fécamp, France	363	498	83	2016 (2016-2023)	Unknown	No
Borkum Riffgrund West II, Germany	237	240	16-18	2017 (2017-2024)	Unknown	No
Gode Wind 03, Germany	280	110	8	2016 (2016-2023)	From 2020	No
Kaskasi, Germany	334	325	34	2018 (2018-2025)	Completed by 2022	No
Hollandse Kust Zuid Holland I and II, Netherlands	73	700	126	2018 (2018-2025)	2023	No

Name and country of project	Distance from Norfolk Boreas (km)	Size (MW)	Maximum number of turbines	Month/year consent authorised/ expected (7yr construction window)	Dates of offshore construction / piling[1]	Likely worst-case scenario of piling occurring at the same time as Norfolk Boreas piling[2]
Norfolk Boreas	**0**	**1,800**	**90-180**	**2020 (2020-2027)**	**Construction piling: 2026 – 2028**	**Yes**
Windpark Fryslan, Netherlands	136	382.7	89	2018 (2018-2025)	2019-2021	No
Kvitsøy Wind Turbine Demonstration Area, Norway	662	10	2	2010 (2010-2017)	Unknown	No
Rennesøy Wind Turbine Demonstration Area, Norway	663	10	2	2010 (2010-2017)	Unknown	No
Tier 4: application submitted or project on-hold						
Norfolk Vanguard, UK	30	1,800	90-200	2019 (2019-2026)	Construction and piling: 2024 – 2028	No[4]
Thanet Extension, UK	175	340	34	2019 (2019-2026)	2024-2028	No[4]
Hornsea Project Three, UK	53	2,400	160-300	2019 (2019-2026)	Construction: 2022-2029 Piling: 2022-2023 and 2027-2028	**Yes**
Firth of Forth Phase 1 Seagreen Alpha and Bravo, UK	500	1,500	120	Oct-14 (2014-2021)	Unknown – on-hold	No
Inch Cape, UK	490	784	75	Oct-14 (2014-2021)	Unknown – on-hold	No
Neart na Gaoithe, UK	468	448	54	Oct-14 (2014-2021)	Unknown – on-hold	No
Moray Firth Western Development Area, UK	629	750	85	2014 (2014-2021)	Unknown – on-hold	No
Dounreay Tri, UK	766	10	2	2017 (2017-2024)	Unknown – project postponed	No

Name and country of project	Distance from Norfolk Boreas (km)	Size (MW)	Maximum number of turbines	Month/year consent authorised/ expected (7yr construction window)	Dates of offshore construction / piling[1]	Likely worst-case scenario of piling occurring at the same time as Norfolk Boreas piling[2]
Norfolk Boreas	**0**	**1,800**	**90-180**	**2020 (2020-2027)**	**Construction piling: 2026 – 2028**	**Yes**
Tier 5: application in preparation						
East Anglia ONE North, UK	51	Up to 800	Up to 67	2021 (2021-2028)	2026 - 2029	**Yes[5]**
East Anglia TWO, UK	73	Up to 900	Up to 75	2020 (2020-2027)	2024 - 2026	No[5]
Hornsea Project Four, UK	119	1,000	180	2021 (2021-2028)	Unknown	No[6]

[1]Piling and offshore construction dates are based on the latest dates and information available.
[2] Likely worst-case scenarios: projects for which consent has been granted (Tier 3 projects) and proposed piling is likely to overlap with the proposed piling of Norfolk Boreas.
[3]It is highly unlikely that all four Dogger Bank projects would be piling at the same time; therefore, two projects that could be constructed at the same have been included in the likely worst-case scenario. It has been assumed that one of the Creyke Beck projects and Sofia would be developed first and these were included in the CIA for Norfolk Vanguard, it is therefore assumed that the construction of the other Creyke Beck project and Teesside A could overlap with the construction of Norfolk Boreas.
[4] Based on the most efficient and most likely build scenario, VWPL would conduct piling at only one site at a time, with no concurrent piling between Thanet Extension, Norfolk Vanguard and Norfolk Boreas.
[5] Based on the most efficient and most likely build scenario, SPR would construct only one site at a time, with EA1N following EA2.
[6]There is currently not enough information on the Hornsea Project Four construction timelines in order to inform an assessment, however, as a precautionary approach, the potential for the overlap in offshore construction with Norfolk Boreas is included for activities other than piling.

12.8.4.1 Potential disturbance during offshore wind farm piling

667. The commitment to the mitigation measures agreed through the MMMP for piling (section 12.7.1.2.1) would result in no potential effects for lethal injury, physical injury and permanent auditory injury (PTS). As such, Norfolk Boreas would not contribute to any cumulative impacts for physical injury or permanent auditory injury (PTS), therefore the CIA only considers potential disturbance effects.

12.8.4.1.1 Sensitivity to disturbance

668. As outlined in section 12.7.3.2.4, harbour porpoise are assessed as having medium sensitivity to disturbance from underwater noise sources (Table 12.29).

669. As outlined in section 12.7.3.2.4, grey and harbour seal are assessed as having medium sensitivity to disturbance from underwater noise sources (Table 12.29).

12.8.4.1.2 Magnitude of cumulative impacts

670. The magnitude of the potential disturbance of harbour porpoise, grey seal and harbour seal has been estimated for each individual project based on:

- The potential impact area during single pile installation, based on a radius of 26km from each piling location (2,124km^2 per project); and
- The potential impact area during concurrent pile installation, based on a radius of 26km from two piling locations per project with no overlap in impact areas (4,248km^2 per project).

671. It should be noted that the potential areas of disturbance have not taken into account the potential overlap in the areas of disturbance between different projects and are therefore highly conservative.

672. For each project, the number of harbour porpoise in the potential impact areas, for single and concurrent piling, has been estimated using the latest SCANS-III density estimates (Hammond et al., 2017) for the relevant survey block that the project is located within.

673. The number of grey and harbour seal in the potential impact areas, for single and concurrent piling, has been estimated using the latest seal at sea usage maps to estimate densities (Russell et al., 2017) for the relevant area that the project is located.

674. Tagged harbour seals in the Wash indicated that seals were not excluded from the vicinity of the wind farm during the overall construction phase but that there was clear evidence of avoidance during pile driving, with significantly reduced levels of seal activity at ranges up to 25km from piling sites (Russell et al., 2016). Therefore,

26km was considered an appropriate and precautionary potential disturbance range for both seal species.

675. The likely worst-case scenario for offshore wind farms that could be piling at the same time as Norfolk Boreas in the harbour porpoise North Sea MU, grey and harbour seal reference population areas (Table 12.14) includes four other UK offshore wind farms (Table 12.62):

- Creyke Beck A
- Teesside A
- Hornsea Project 3
- East Anglia ONE North

676. In this likely worst-case scenario, for concurrent piling the estimated maximum area of potential disturbance is 21,240km^2, without any overlap in the potential areas of disturbance at each wind farm or between wind farms.

677. The maximum number of harbour porpoise that could potentially be temporarily disturbed is 17,451 individuals, which represents approximately 5.1% of the North Sea MU reference population (Table 12.63). Therefore, the magnitude would be a precautionary medium for harbour porpoise (with between 5% and 10% of the reference population anticipated to be exposed to the effect). However, this is very precautionary, as it is unlikely that five projects could be concurrently piling at exactly the same time.

678. The maximum number of grey seal that could potentially be disturbed is 942 (4% of the reference population) and 43 harbour seal (0.1% of the reference population) (Table 12.64). The potential magnitude for the cumulative impacts of concurrent piling is assessed as low for grey seal with less than 5% of the reference population that could be temporarily disturbed and negligible for harbour seal, with less than 1% of the reference population likely to be exposed to the effect.

679. Based on a single pile installation at each of the five offshore wind farms, the estimated maximum area of potential disturbance is 10,620km^2, without any overlap in the potential areas of disturbance at each wind farm or between wind farms.

680. The maximum number of harbour porpoise that could potentially be temporarily disturbed is 8,725 individuals which represent approximately 2.5% of the North Sea MU reference population (Table 12.63). Therefore, the potential magnitude of the temporary effect is assessed as low**,** with between 1% and 5% of the reference population likely to be exposed to the effect.

681. The maximum number of grey seal that could potentially be disturbed is 471 (2% of the reference population) and 22 harbour seal (0.05% of the reference population)

(Table 12.64). The potential magnitude for the cumulative impacts of single piling is assessed as low for grey seal with less than 5% of the reference population that could be temporarily disturbed and negligible for harbour seal, with less than 1% of the reference population likely to be exposed to the effect.

682. The approach to the CIA, based on the five UK offshore wind farms single piling, would allow for some of these sites not to be piling at the same time while others, including Norfolk Boreas, could be concurrent piling.

683. As outlined above, although the potential piling duration for Norfolk Boreas has been assessed based on a precautionary maximum duration for construction, the actual piling time and ADD activation, which could disturb harbour porpoise, grey seal and harbour seal is only a very small proportion of this time, of up to approximately 60 days, approximately 4% of the estimated four year construction period, based on the estimated maximum duration to install individual piles.

684. The potential temporary effects would be less than those assessed in this assessment as there is likely to be a great deal of variation in timing, duration, and hammer energy used throughout the various offshore wind farm project construction periods. In addition, not all harbour porpoise would be displaced over the entire 26km potential disturbance range. For example, the study of harbour porpoise at Horns Rev (Brandt et al., 2011), indicated that at closer distances (2.5 to 4.8km) there was 100% avoidance, however, this proportion decreased significantly moving away from the pile driving activity, falling to 49% at 18km and 2% at 21km.

Table 12.63 Quantified CIA for the potential disturbance of harbour porpoise during single and concurrent piling of offshore wind farms for the likely worst-case scenario based on the offshore wind farm projects which could be piling at the same time as Norfolk Boreas.

Name of Project	Tier	Distance to Norfolk Boreas (km)	SCANS-III Survey Block	SCANS-III density estimate (No/km²)	Potential number of harbour porpoise disturbed during single piling (2,124km²)	Potential number of harbour porpoise disturbed during concurrent piling with no overlap (4,248km²)
Norfolk Boreas	5	0	O[1]	0.888	1,886	3,772
Creyke Beck A	3	173	O	0.888	1,886	3,772
Teesside A	3	191	N	0.837	1,778	3,556
Hornsea Project THREE	4	53	O	0.888	1,886	3,772
East Anglia ONE North	5	73	L	0.607	1,289	2,579
Total					**8,725**	**17,451**
% of North Sea MU reference population (345,373 harbour porpoise)					**2.5%**	**5.1%**

[1]Norfolk Boreas is located in both SCANS-III survey block L and survey block O; therefore, higher density estimate from survey block O is used.

Table 12.64 Quantified CIA for the potential disturbance of grey and harbour seal during single and concurrent piling of offshore wind farms for the likely worst-case scenario based on the offshore wind farm projects which could be piling at the same time as Norfolk Boreas.

Name of Project	Tier	Distance to Norfolk Boreas (km)	Grey seal density estimate (No/km^2)[1]	Harbour seal density estimate (No/km^2)[1]	Potential number of grey seal disturbed		Potential number of harbour seal disturbed	
					single piling	concurrent piling	single piling	concurrent piling
Norfolk Boreas	5	0	0.001	0.0001	2	4	0.2	0.4
Creyke Beck A	3	173	0.05	0.0004	106	212	1	2
Teesside A	3	193	0.09	0.001	191	382	2	4
Hornsea Project THREE	4	80	0.08	0.008	170	340	17	34
East Anglia ONE North	5	45	0.0009	0.0006	1.91	3.82	1.27	2.55
Total					471	942	22	43
% of reference population (22,290 grey seal; 43,161 harbour seal)					**2%**	**4%**	**0.05%**	**0.1%**

[1]The densities included are based on a 26km buffer around the offshore wind farm site (or grouped offshore wind farms in the case of the Dogger Bank and East Anglia projects), using the 5x5km grid squares of the seals-at-sea total usage data that intersect with the projects and 26km buffer; based on Russell et al. (2017).

12.8.4.1.3 Cumulative impact significance

685. If all four offshore wind farms were concurrent piling at the same time as Norfolk Boreas is concurrently piling, there is the potential for a moderate impact for harbour porpoise, however, as outlined above, it is highly unlikely that all five offshore wind farms could be concurrently piling at exactly the same time or that 100% of animals would avoid the area of disturbance. In addition, with the implementation of the SIP for the SNS SAC, the potential impacts could be managed to a non-significant level, with a potential minor impact (Table 12.65).

686. Therefore, taking into account the medium receptor sensitivity and the low potential magnitude of the cumulative impact for harbour porpoise, the overall assessment of **minor adverse** (not significant impact) is considered to be a conservative assessment based on the likely worst-case scenario for four offshore wind farms single piling at the same time as Norfolk Boreas (Table 12.65).

687. Taking into account the medium receptor sensitivity and the low potential magnitude for grey seal and **negligible** potential magnitude for harbour seal of the cumulative impacts, the overall assessment is of **minor adverse** (not significant impact) for grey seal and harbour seal for single and concurrent piling (Table 12.65).

688. The confidence that this impact assessment is precautionary enough to comfortably encompass the likely uncertainty and variability is high. Throughout the assessment it has been made clear where multiple and compounding precautionary assumptions have been taken. Additionally, where possible the uncertainty in the data typically used to inform CIAs and the quantification of impacts when based on published ESs has been removed by using a standard impact range for disturbance and the SCANS-III density estimates for all offshore wind farm sites.

Table 12.65 Cumulative impact significance for disturbance to harbour porpoise, grey seal and harbour seal from offshore wind farm piling during piling at Norfolk Boreas

Potential Impact	Scenario	Species	Sensitivity	Magnitude	Significance	Mitigation	Residual impact
Cumulative impact of disturbance during single piling at offshore wind farms at the same time as Norfolk Boreas	Five UK and European Offshore wind farm projects (including Norfolk Boreas)	Harbour porpoise	Medium	Low	Minor	SIP for SNS SAC	**Minor adverse**
		Grey seal	Medium	Low	Minor		**Minor adverse**
		Harbour seal	Medium	Negligible	Minor		**Minor adverse**
Cumulative impact of disturbance	Five UK and European	Harbour porpoise	Medium	Medium	Moderate	SIP for SNS SAC	**Minor adverse**
		Grey seal	Medium	Low	Minor		**Minor**

Potential Impact	Scenario	Species	Sensitivity	Magnitude	Significance	Mitigation	Residual impact
during concurrent piling at offshore wind farms at the same time as Norfolk Boreas	offshore wind farm projects (including Norfolk Boreas)						**adverse**
		Harbour seal	Medium	Negligible	Minor		**Minor adverse**

12.8.5 Impact 2: Underwater noise impacts from all other noise sources

689. During the construction period at Norfolk Boreas, there are other potential noise sources in addition to offshore wind farm piling that could also disturb harbour porpoise, grey seal and harbour seal including:

- UXO clearance;
- Seismic surveys;
- Offshore wind farm construction (excluding piling – see section 12.8.4);
- Offshore wind farm operation and maintenance; and
- Subsea cables and pipelines.

690. The CIA screening (Appendix 12.3) determined that it was highly unlikely that the following activities could contribute significantly to the cumulative effects of the disturbance of harbour porpoise from underwater noise:

- Tidal and wave developments (construction, operation and maintenance);
- Aggregate extraction and dredging;
- Offshore mining;
- Oil and gas projects, other than potential seismic surveys;
- Licenced disposal sites;
- Navigation and shipping operations; and
- Carbon capture projects.

12.8.5.1 Potential disturbance from all other noise sources

12.8.5.1.1 Sensitivity to disturbance

691. As outlined in section 12.7.3.2.4, harbour porpoise are assessed as having medium sensitivity to disturbance from underwater noise sources (Table 12.29).

692. As outlined in section 12.7.3.2.4, grey and harbour seal are assessed as having medium sensitivity to disturbance from underwater noise sources (Table 12.29).

12.8.5.1.2 Magnitude of cumulative impacts

UXO clearance

693. The commitment to the mitigation measures agreed through the MMMP for UXO clearance would result in no potential effects for lethal injury, physical injury and permanent auditory injury (PTS). As such, Norfolk Boreas would not contribute to any cumulative impacts for lethal injury, physical injury and permanent auditory injury (PTS), therefore the CIA only considers potential disturbance effects.

694. It is currently not possible to estimate the number of potential UXO clearance operations that could be undertaken during the construction and potential piling activity at Norfolk Boreas.

695. It is therefore assumed as a worst-case scenario that there could potentially be:

- Up to one UXO clearance operation in the UK northern North Sea area;
- Up to one UXO clearance operation in the UK southern North Sea area;
- Up to one UXO clearance operation in the Netherlands / Belgium area of the North Sea; and
- Up to one UXO clearance operation in the German / Denmark area of the North Sea.

696. Based on a distance of 26km disturbance from UXO clearance, for the maximum of up to four UXO clearance events being undertaken at the same time, the potential disturbance area would be 8,496km^2.

697. The SCANS-III harbour porpoise density estimate for the North Sea MU is 0.52/km^2 (Hammond et al., 2017). As the actual location for any UXO clearance is not yet known, this has been used to estimate the potential number of harbour porpoise that could potentially be disturbed (Table 12.66).

698. Also due to the uncertainty about the location of UXO clearance, the mean density estimates are based on the average seal at sea density estimates for the areas of the UK and EU offshore wind farms. This is 0.1 grey seal per km^2 and 0.02 harbour seal per km^2. This is based on the seal-at-sea maps (Russell et al., 2017) and an average density based on a 50km buffer around all offshore wind farms (UK and EU) included within the CIA.

699. The maximum number of harbour porpoise that could potentially be disturbed during up to four UXO clearance operations would be up to 4,420 harbour porpoise, which represents up to 1% of the NS MU reference population (Table 12.66). The potential magnitude of the temporary effect is assessed as low, with between 1% and 5% of the reference population likely to be exposed to the effect.

700. However, it is highly unlikely that up to four UXO clearance operations would actually be undertaken at the same time, therefore a more likely worst-case scenario would be for two UXO operations (4,248km^2) in the southern North Sea, which could potentially disturb up to 2,210 harbour porpoise (approximately 0.6% of the North Sea MU reference population) (Table 12.66). Therefore, the magnitude would be negligible, with less than 1% of reference population likely to be disturbed, based on the more realistic worst-case scenario of up to two UXO operations being undertaken at the same time.

701. Two UXO operations (4,248km^2), could potentially disturb up to 425 grey seal (2% of the reference population) (Table 12.66). Therefore, the magnitude would be low, with between 1% and 5% of reference population likely to be disturbed. The maximum number of harbour seal that could potentially be disturbed would be 85 (0.2% of the reference population) (Table 12.66). The potential magnitude of the temporary effect is assessed as negligible, with less than 1% of the reference population likely to be exposed to the effect.

Table 12.66 Quantified CIA for the potential disturbance of harbour porpoise, grey seal and harbour seal during UXO clearance operations in the North Sea during construction at Norfolk Boreas (the results of the most likely scenario of two UXO operations at any one time are shown in bold).

UXO clearance	Area of potential disturbance	SCANS-III density estimate (No/km^2)	Grey seal density estimate (No/km^2)	Harbour seal density estimate (No/km^2)	Potential number of harbour porpoise impacted	Potential number of grey seal impacted	Potential number of harbour seal impacted
Up to one UXO clearance operation in the North Sea	2,124km^2	0.52	0.1	0.02	1,105	212	42
Up to two UXO clearance operations in the North Sea	**4,248km^2**	**0.52**	**0.1**	**0.02**	**2,209**	**425**	**85**
Up to four UXO clearance operations in the North Sea	8,496km^2	0.52	0.1	0.02	4,418	850	170

Seismic surveys

702. It is currently not possible to estimate the number of potential seismic surveys that could be undertaken during the construction and potential piling activity at Norfolk Boreas.

703. It is therefore assumed as a worst-case scenario that there could potentially be:

- Up to one seismic survey in the UK northern North Sea area;
- Up to one seismic survey in the UK southern North Sea area;
- Up to one seismic survey in the Netherlands / Belgium area of the North Sea; and
- Up to one seismic survey in the German / Denmark area of the North Sea.

704. Following the current SNCB advice, the CIA has been based on the following parameter:

- A distance of 10km around seismic surveys has been used to assess the area that harbour porpoise could potentially be disturbed (314km^2).

705. This approach has also been used for the potential disturbance of grey and harbour seal.

706. It should be noted that this assessment is based on the potential impacts for seismic surveys required by the oil and gas industry. Geophysical surveys conducted for offshore wind farms generally use multi-beam surveys in shallow waters. The higher frequencies typically used for surveys for offshore wind farms fall outside the hearing frequencies of cetaceans and the sounds produced are likely to attenuate more quickly than the lower frequencies used in deeper waters (JNCC, 2017e). JNCC (2071e) do not, therefore, advise mitigation is required for multi-beam surveys in shallow waters as there is no risk to EPS in relation to deliberate injury or disturbance offences.

707. In addition, the recent BEIS (2018) draft RoC HRA for the SNS SAC undertook underwater noise modelling to determine the potential for geophysical surveys and offshore wind farm piling, at the same time, to create a cumulative impact on harbour porpoise. Results of this modelling indicate that the use of geophysical survey equipment (namely sub-bottom profilers as the only equipment likely to impact harbour porpoise) would not significantly increase the area of disturbance from offshore wind farm piling on its own and would cause the potential disturbance to very few harbour porpoise over and above those that would be disturbed from offshore wind farm piling alone. The draft RoC HRA for the SNS SCI (as it was designated at the time of writing) therefore concluded that '*based on the results from the noise modelling and the temporary nature of any impacts, potential in-*

combination impacts between offshore wind farm pile-driving and the use of sub-bottom profilers will not have an adverse effect on the integrity of the Southern North Sea SCI.'

708. As per the UXO clearance impact assessment the SCANS-III harbour porpoise density estimate for the North Sea MU is 0.52/km^2 (Hammond et al., 2017) is used in this assessment (Table 12.67). The same rationale is used for the mean density estimates for seals, therefore densities of 0.1 grey seal per km^2 and 0.02 harbour seal per km^2 are used in this assessment.

709. The number of harbour porpoise potentially disturbed during one seismic survey would be up to 163 harbour porpoise (0.05% of the NS MU reference population). The number of grey seal that could potentially be disturbed during one seismic survey would be up to 31 individuals (0.1% of the reference population). The number of harbour seal that could potentially be disturbed during one seismic survey would be up to 6 individuals (0.01% of the reference population).

710. The maximum number of harbour porpoise that could potentially be disturbed during up to four seismic surveys would be up to 652 harbour porpoise, which represents up to 0.2% of the NS MU reference population (Table 12.67). The potential magnitude of the temporary effect is assessed as negligible**,** with less than 1% of the reference population likely to be exposed to the effect.

711. However, it is highly unlikely that up to four seismic surveys would be undertaken at the same time; therefore, a more likely worst-case scenario would be for two seismic surveys (628km^2) in the southern North Sea, which could potentially disturb up to 326 harbour porpoise (approximately 0.09% of the North Sea MU reference population) (Table 12.67). Therefore, the magnitude would be negligible, with less than 1% of reference population likely to be disturbed.

712. Two seismic surveys could potentially disturb up to 63 grey seal (0.3% of the reference population) (Table 12.67). Therefore, the magnitude would be negligible, with less than 1% of the reference population likely to be disturbed. The maximum number of harbour seal that could potentially be disturbed would be 13 (0.03% of the reference population) (Table 12.67). The potential magnitude of the temporary effect is assessed as negligible, with less than 1% of the reference population likely to be exposed to the effect.

Table 12.67 Quantified CIA for the potential disturbance of harbour porpoise, grey and harbour seal during seismic surveys in the North Sea during construction at Norfolk Boreas (the results of the most likely scenario of two seismic surveys at any one time are shown in bold).

Seismic survey	Area of potential disturbance	SCANS-III density estimate (No/km²)	Grey seal density estimate (No/km²)	Harbour seal density estimate (No/km²)	Potential number of harbour porpoise impacted	Potential number of grey seal impacted	Potential number of harbour seal impacted
Up to one seismic survey in the North Sea	314km²	0.52	0.1	0.02	163	31	6
Up to two seismic surveys in the North Sea	**628km²**	**0.52**	**0.1**	**0.02**	**327**	**63**	**13**
Up to four seismic surveys in the North Sea	1,256m²	0.52	0.1	0.02	653	126	25

Offshore wind farm construction, other than piling

713. During the construction of Norfolk Boreas, there is the potential to overlap with impacts from the construction activities, other than piling, at other offshore wind farms. Noise sources which could cause potential disturbance impacts during offshore wind farm construction activities, other than pile driving, can include vessels, seabed preparation, ploughing / jetting / pre-trenching or cutting for installation of cables and rock dumping for protection of the cable.

714. There would be no additional cumulative impacts of underwater noise from other construction activities for those projects which also have overlapping piling with Norfolk Boreas as the ranges for piling would be significantly greater than those from other construction noise sources.

715. The potential impact ranges of these noise sources during offshore wind farm construction will be localised and significantly less than the ranges predicted for piling. There could be potential cumulative impacts from construction of offshore wind farms in and around the area of Norfolk Boreas.

716. The CIA determined the UK and European offshore wind farms in the southern North Sea which could potentially have construction activities, other than piling, during the Norfolk Boreas construction period. This precautionary likely worst-case scenario, includes six UK offshore wind farms that could have construction activities, other than piling, during the Norfolk Boreas construction period:

- Creyke Beck B;
- Sofia;
- East Anglia TWO;
- Thanet Extension;
- Norfolk Vanguard; and
- Hornsea Project Four.

717. The potential temporary disturbance during offshore wind farm construction activities, other than pile driving noise sources, has been based on the area of the offshore wind farm sites. This is a precautionary approach, as it is highly unlikely that construction activities, other than piling activity, would result in disturbance from the entire wind farm area. Any disturbance is likely to be limited to the area in and around where the activity is actually taking place.

718. In addition, it is likely, as outlined for the cumulative impact assessment for piling, that developers of more than one site will develop one site at a time, as it is more efficient and cost effective to develop one site and have it operational prior to constructing the next site.

719. Based on this highly conservative approach, an assessment has been undertaken for the six UK offshore wind farms that could potentially have construction activities, other than piling, during the Norfolk Boreas construction period.

720. The assessment indicates that if all six of these offshore wind farms in the southern North Sea were conducting construction activities, other than piling, at the same time, the estimated maximum cumulative area of disturbance is 2,958km^2 (based on disturbance from the entire offshore wind farm areas) and the maximum number of harbour porpoise that could potentially be disturbed is 2,535 individuals, which represents approximately 0.7% of the North Sea MU reference population (Table 12.68). Therefore, the potential magnitude of the temporary effect is assessed as negligible, with less than 1% of the reference population likely to be exposed to the effect.

721. The maximum number of grey seal that could potentially be disturbed is 230 individuals, which represents approximately 1.0% of the reference population (Table 12.69). The potential magnitude of the temporary effect is assessed as low, with between 1% and 5% of the reference population likely to be exposed to the effect.

722. The maximum number of harbour seal that could potentially be disturbed is 40 individuals, which represents approximately 0.01% of the reference population (Table 12.69). The potential magnitude of the temporary effect is assessed as negligible, with less than 1% of the reference population likely to be exposed to the effect.

Table 12.68 Quantified CIA for the potential disturbance of harbour porpoise during construction activities (other than piling) at offshore wind farms during construction at Norfolk Boreas.

Name of Project	Distance to Norfolk Boreas (km)	SCANS-III Survey Block	SCANS-III density estimate (No/km^2)	Area of offshore wind farm site (km^2)*	Potential number of harbour porpoise disturbed from entire offshore wind farm area
Creyke Beck B	196	O	0.888	599km^2	532
Sofia[2]	185	O	0.888	593km^2	527
Norfolk Vanguard[1]	30	O	0.888	592km^2	526
Thanet Extension	175	L	0.607	73km^2	44
East Anglia TWO	73	L	0.607	255km^2	155
Hornsea Project Four	119	O	0.888	846km^2	751
Total				**2,958km^2**	**2,535**
% of North Sea MU reference population (345,373 harbour porpoise)					**0.8%**

*Source: http://www.4coffshore.com/
[1]Norfolk Vanguard East is within SCANS Survey Block O, Norfolk Vanguard West is within both Survey Blocks O and L; therefore, higher density estimate from survey block O is used.
[2]Sofia overlaps SCANS-III survey block O & N, but majority of site is in block O.

Table 12.69 Quantified CIA for the potential disturbance of grey and harbour seal during construction activities (other than piling) at offshore wind farms during construction at Norfolk Boreas.

Name of Project	Distance to Norfolk Boreas (km)	Grey seal density estimate (No/km^2)	Harbour seal density estimate (No/km^2)	Area of offshore wind farm site (km^2)*	Potential number of grey seal disturbed from entire offshore wind farm area	Potential number of harbour seal disturbed from entire offshore wind farm area
Creyke Beck B	196	0.09	0.001	599	54	0.6
Sofia	185	0.09	0.001	593	53	0.6
Thanet Extension	175	0.02	0.06	73	1	4.4
East Anglia TWO	73	0.01	0.002	255	3	0.5
Norfolk Vanguard	30	0.002	0.0001	592	1	0.1
Hornsea Project Four	119	0.14	0.04	846	118	34
Total				**2,112 km^2**	**230**	**40**
% of reference population (22,290 grey seal; 43,161 harbour seal)					**1.0%**	**0.01%**

*Source: http://www.4coffshore.com/

Offshore wind farm operation and maintenance

723. There is the potential for disturbance from other offshore wind farms as a result of any operational and maintenance activities, including vessels, during the Norfolk Boreas construction period. The potential disturbance from operational offshore wind farms and maintenance activities could include the operational turbines, vessels, any rock dumping or cable re-burial.

724. Operational offshore wind farms were considered part of the baseline if they were operational at the time of the start of the Norfolk Boreas site specific surveys (August 2016). Therefore, offshore wind farms were screened into the CIA as having the potential to be newly operational by the Norfolk Boreas construction period, in that they are currently under construction or will be constructed and operational by 2026.

725. As outlined in sections 12.7.4.1, 12.7.4.2 and 12.7.4.3, any potential disturbance as a result of underwater noise from these activities will be temporary and limited to the area of the offshore wind farm sites only, although this is a precautionary approach, as it is highly unlikely that operational offshore wind farms and maintenance activities, including vessels, would result in disturbance from the entire wind farm area. Any disturbance is likely to be limited to the area in and around where the actual activity is actually taking place. There is currently no evidence of any significant disturbance of harbour porpoise, grey seal or harbour seal from operational wind farm sites.

726. The maximum number of harbour porpoise that could be temporarily disturbed would be up to 2,783 individuals which represents approximately 0.8% of the North Sea MU reference population (Table 12.70). Therefore, the potential magnitude of the temporary effect is assessed as negligible, with less than 1% of the reference population likely to be exposed to the effect.

727. The maximum number of grey seal that could potentially be disturbed is 275 individuals, which represents approximately 1.2% of the reference population (Table 12.71). The potential magnitude of the temporary effect is assessed as low, with between 1% and 5% of the reference population likely to be exposed to the effect.

728. The maximum number of harbour seal that could potentially be disturbed is 97 individuals, which represents approximately 0.2% of the reference population (Table 12.71). The potential magnitude of the temporary effect is assessed as negligible, with less than 1% of the reference population likely to be exposed to the effect.

Table 12.70 Quantified CIA for the potential disturbance of harbour porpoise during operation and maintenance activities at offshore wind farms during construction at Norfolk Boreas for projects within the North Sea MU

Name of Project	Distance to Norfolk Boreas (km)	SCANS-III Survey Block	SCANS-III density estimate (No/km^2)	Area of offshore wind farm site (km^2)*	Potential number of harbour porpoise disturbed from entire offshore wind farm area
Beatrice	665	S	0.152	131	20
Blyth Offshore Wind Demo 2[1]	353	R	0.599	<1	1
Blyth Offshore Wind Demo 3A & 4[2]	351	R	0.599	4	2
Borkum Riffgrund II[2]	237	N	0.837	36	30
Borkum Riffgrund West I[2]	225	N	0.837	30	25
Borkum Riffgrund West II[2]	218	N[3]	0.837	16	13
Borssele I and II	121	N	0.837	129	108
Borssele III and IV	128	N	0.837	174	146
Borssele Site V	126	N	0.837	3	3
Deutsche Bucht (DeBu)	213	N	0.837	18	15
Deutsche Bucht Pilot Park	213	N	0.837	1	1
Dounreay Tri	766	S	0.152	25	4
Dudgeon[1]	90	O	0.888	55	49
East Anglia ONE	62	L	0.607	205	124
East Anglia THREE	13	L	0.607	301	183
EnBW He Dreiht	236	M	0.277	62	17
EnBW Hohe See (Hochsee Windpark 'Nordsee')	250	M	0.277	40	11
Eoliennes du Calvados	441	C	0.213	78	17
European Offshore Wind	530	R	0.599	20	12

Name of Project	Distance to Norfolk Boreas (km)	SCANS-III Survey Block	SCANS-III density estimate (No/km^2)	Area of offshore wind farm site (km^2)*	Potential number of harbour porpoise disturbed from entire offshore wind farm area
Deployment Centre EOWDC (Aberdeen Demonstration)					
Galloper[1]	108	L	0.607	113	69
Gemini[1]	214	N	0.837	70	59
Gode Wind 1 and 2[1]	271	M	0.277	70	19
Gode Wind 03[2]	276	M	0.277	4	1
Gode Wind 04[2]	277	M	0.277	29	8
Hollandse Kust Zuid Holland I & II	83	N	0.837	103	86
Horns Rev 3[2]	397	M	0.277	144	40
Hornsea Project One	86	O	0.888	407	361
Hornsea Project Two	101	O	0.888	462	410
Hywind Pilot Park[1]	546	R	0.599	15	9
Inch Cape	490	R	0.599	150	90
Kaskasi[2]	333	M	0.277	17	5
Kincardine	574	R	0.599	110	66
KvitsØy Wind Turbine Demonstration Area[2]	657	V	0.137	<1	0
Merkur[2]	243	M	0.277	39	11
Mermaid	126	N	0.837	16	13
Moray Firth East	657	S	0.152	295	45
Moray Firth West	659	S	0.152	226	34

Name of Project	Distance to Norfolk Boreas (km)	SCANS-III Survey Block	SCANS-III density estimate (No/km^2)	Area of offshore wind farm site (km^2)*	Potential number of harbour porpoise disturbed from entire offshore wind farm area
Neart na Gaoithe	468	R	0.599	105	63
Nissum Bredning Vind[1]	504	P	0.823	5	4
Nobelwind[1]	129	N	0.837	22	18
Nordsee One	257	M	0.277	31	9
Nordergrunde[1]	338	M	0.277	3	1
Norther[2]	132	L	0.607	38	23
Northwester 2[2]	130	L	0.607	12	7
OWP Albatros	249	M	0.277	11	3
OWP West[2]	220	N	0.837	14	12
Parc éolien en mer de Fécamp	363	C	0.213	88	19
Race Bank[1]	124	O	0.888	62	55
Rampion Wind Farm	318	C	0.213	79	17
RennesØy Wind Turbine Demonstration Area[2]	663	V	0.137	1	0
RENTEL[2]	140	L	0.607	23	14
Sandbank[1]	325	M	0.277	47	13
Seagreen Alpha and Bravo	500	R	0.599	391	234
SeaStar[2]	134	L	0.607	18	11
TetraSpar Demo (Metcentre)[2]	668	V	0.137	<1	0
Trianel Windpark Borkum Phase 2 (Borkum West II phase 2)[2]	240	M	0.277	23	6

Name of Project	Distance to Norfolk Boreas (km)	SCANS-III Survey Block	SCANS-III density estimate (No/km^2)	Area of offshore wind farm site (km^2)*	Potential number of harbour porpoise disturbed from entire offshore wind farm area
Triton Knoll phase 1-3	124	O	0.888	146	123
Veja Mate[1]	216	N	0.837	8	7
Vesterhav Nord/Syd[2]	519	P	0.823	10	8
Windpark Fryslan	136	N	0.837	35	29
Total				**4,770km^2**	**2,783**
% of North Sea MU reference population (345,373 harbour porpoise)					**0.8%**

*Source: http://www.4coffshore.com/
[1]Operational after the onset of the Norfolk Boreas site specific surveys, but before the submission of the PEIR
[2]Unknown date of project operation, but assumed to be before the foundation instillation for Norfolk Boreas in 2026
[3]Site is within both SCANS-III survey blocks N and M, the worst-case density estimate for Block N is used.

Table 12.71 Quantified CIA for the potential disturbance of grey and harbour seal during operation and maintenance activities at offshore wind farms during construction at Norfolk Boreas for projects within the grey and harbour seal reference population MUs (Table 12.14).

Name of Project	Distance to Norfolk Boreas (km)	Grey seal density estimate (No/km^2)	Harbour seal density estimate (No/km^2)	Area of offshore wind farm site (km^2)*	Potential number of grey seal disturbed from entire offshore wind farm area	Potential number of harbour seal disturbed from entire offshore wind farm area
Blyth Offshore Wind Demo 2	353	0.03	-	<1	0	0
Blyth Offshore Wind Demo 3A & 4	351	0.040	-	4	0	0
Dudgeon	90	0.11	0.19	55	6	10
East Anglia ONE	62	0.001	0.0003	205	0	0
East Anglia THREE	13	0.00009	0.00009	301	0	0
Galloper	108	0.01	0.001	113	1	0
Hornsea Project One	86	0.39	0.05	407	159	20
Hornsea Project Two	101	0.08	0.008	462	37	4
Nordergrunde[1]	338	0.000002	0.00004	3	0	0
Norther[2]	132	0.0003	0.0001	38	0	0
Northwester 2[2]	130	0.0004	0.0002	12	0	0
Race Bank	124	0.07	0.26	62	4	16
RENTEL[2]	140	0.0004	0.0002	23	0	0
Triton Knoll Phase 1-3	124	0.465	0.322	146	68	47
Total				**1,832km^2**	**275**	**97**
% of reference population (22,290 grey seal; 43,161 harbour seal)					**1.2%**	**0.2%**

*Source: http://www.4coffshore.com/

Subsea cables and pipelines

729. The underwater noise that could be generated during the seabed preparation, ploughing / jetting / pre-trenching or cutting for installation of cables / pipelines, rock dumping for protection of the cable / pipelines, and installation vessels, would be restricted to the area of installation and temporary (as outlined in section 12.7.3.3). Therefore, taking this into account along with the distances from the Norfolk Boreas site, potential for any cumulative impacts is negligible and has not been included in the CIA.

Overall magnitude of cumulative impacts from noise sources (other than piling)

730. The maximum number of harbour porpoise that could potentially be temporarily disturbed as a result of underwater noise from all other potential noise sources and activities, other than offshore wind farm piling, during construction at Norfolk Boreas is 7,854 individuals, which represents approximately 2.3% of the North Sea MU reference population (Table 12.72). The potential magnitude of the temporary effect is assessed as low**,** with between 1% and 5% of the reference population likely to be exposed to the effect.

731. The potential magnitude of the temporary effect is assessed as low for grey seal, with less than 5% of the reference population likely to be exposed to the effect and negligible for harbour seal, with less than 1% of the reference population likely to be exposed to the effect (Table 12.72).

Table 12.72 Quantified CIA for the potential disturbance of harbour porpoise, grey seal and harbour seal from all possible noise sources (other than offshore wind farm piling) during construction at the Norfolk Boreas site

Potential noise sources	Area of potential disturbance	Potential number of harbour porpoise disturbed	Potential number of grey seal impacted	Potential number of harbour seal impacted
UXO clearance (up to 2 operations)	4,248km^2	2,210	425	85
Seismic surveys (up to 2 surveys)	628km^2	326	63	13
UK and European offshore wind farm construction activities in the southern North Sea (i.e. offshore wind farms that are not piling but potential construction activities)	2,958km^2	2,535	230	34
Operation and maintenance of UK and European offshore wind farms in southern North Sea	4,770km^2 (for harbour porpoise) 1,832km^2 (for grey and harbour seal)	2,783	275	97
Total for other noise sources (excluding piling)	**12,604km^2** (for harbour porpoise) **9,666km^2** (for grey and harbour seal)	**7,854**	**993**	**229**

Potential noise sources	Area of potential disturbance	Potential number of harbour porpoise disturbed	Potential number of grey seal impacted	Potential number of harbour seal impacted
% of reference population (345,373 harbour porpoise; 22,290 grey seal; 43,161 harbour seal)		**2.3%**	**4.5%**	**0.5%**

12.8.5.1.3 Cumulative impact significance

732. Table 12.73 summarises the potential cumulative impact significance for disturbance to harbour porpoise, grey seal and harbour seal from other noise sources during Norfolk Boreas construction and piling.

733. Based on medium sensitivity and low magnitude of effect resulting from cumulative noise sources, the impact significance would be **minor adverse** (not significant) for harbour porpoise.

734. Based on medium sensitivity and low magnitude of effect resulting from cumulative noise sources excluding piling, the impact significance is assessed as **minor adverse** (not significant) for grey seal. The overall magnitude for harbour seal is negligible, resulting in a **minor** significance.

Table 12.73 Cumulative impact significance for disturbance from other noise sources during construction and piling Norfolk Boreas

Potential Impact	Species	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
All possible noise sources excluding piling	Harbour porpoise	Medium	Low	Minor	None proposed	**Minor adverse**
	Grey seal	Medium	Low	Minor		**Minor adverse**
	Harbour seal	Medium	Negligible	Minor		**Minor adverse**

12.8.6 Summary of the cumulative underwater noise impacts (Impacts 1 and 2)

12.8.6.1 Magnitude of cumulative impacts

735. This section considers the overall cumulative impact of underwater noise associated with piling (impact 1) and other noise sources (impact 2). There would be no additional cumulative impacts of noise from other construction activities for those projects which also have overlapping piling with Norfolk Boreas as the impact ranges for piling would be significantly greater than those impacts from other construction noise sources.

736. The potential cumulative impacts from all noise sources at Norfolk Boreas and other offshore wind farms that could be occurring at the same time as Norfolk Boreas construction are summarised in Table 12.74.

737. The potential magnitude of the temporary effect is assessed as low for harbour porpoise, with less than 5% of the reference population estimated to be disturbed, medium for grey seal, with between 5% and 10% of the reference population potentially exposed to the effect and negligible for harbour seal, with less than 1% of the reference population likely to be exposed to the effect.

738. This assessment is based on highly conservative assumptions (e.g. displacement of all marine mammals from the boundary of each offshore wind farm and the assumption that there is no overlap from the disturbance impacts listed).

Table 12.74 Quantified CIA for the potential disturbance of marine mammals from all possible noise sources during construction and piling at Norfolk Boreas

Potential noise sources during Norfolk Boreas piling	Area of potential disturbance	Potential number of harbour porpoise impacted	Potential number of grey seal impacted	Potential number of harbour seal impacted
UK and European offshore wind farm projects, including Norfolk Boreas, with the potential of single piling at the same time (see Impact 1)	10,620km^2	8,725	471	22
UXO clearance (up to 2 operations)	4,248km^2	2,210	425	85
Seismic surveys (up to 2 surveys)	628km^2	326	63	13
UK and European offshore wind farm construction activities (i.e. offshore wind farms that are not piling but potential construction activities)	2,958km^2	2,535	230	34
Operation and maintenance of UK and European offshore wind farms	4,770km^2 (for harbour porpoise) 1,832km^2 (for grey and harbour seal)	2,783	275	97
Total		**16,579**	**1,464**	**251**
% of reference population (345,373 harbour porpoise; 22,290 grey seal; 43,161 harbour seal)		**4.8%**	**6.6%**	**0.6%**

12.8.6.2 Cumulative impact significance

739. Based on medium sensitivity and low magnitude of effect resulting from cumulative noise sources, the impact significance is assessed as **minor adverse** for harbour porpoise. Based on medium sensitivity and medium magnitude of effect resulting from cumulative noise sources, the impact significance is assessed as **moderate adverse** for grey seal. The overall magnitude for harbour seal is negligible, resulting in a **minor adverse** significance.

Mitigation

740. The Norfolk Boreas contribution to the overall cumulative impact from underwater noise, during single pile installation (Table 12.38), would potentially be the disturbance of up to 2,251 harbour porpoise, approximately 13.6% of the total 16,579 harbour porpoise that could be disturbed; the disturbance of up to two grey seal, approximately 0.1% of the total of 1,464 grey seal that could be disturbed; and the disturbance of 0.2 harbour seal, approximately 0.1% of the 251 harbour seal that could be disturbed.

741. The Site Integrity Plan, to reduce the potential disturbance at the project level and in particular in relation to the SNS SAC, would be agreed with the relevant SNCBs post-consent. In order to address the overall cumulative impact, a possible strategic approach to mitigation could be required which Norfolk Boreas Limited is open to discussing with Natural England and the Marine Management Organisation. An outline Site Integrity Plan is submitted with the Norfolk Boreas DCO application.

Residual impact

742. It is anticipated that by working with the relevant SNCBs and the Marine Management Organisation to develop mitigation measures and a possible strategic approach as part of the SIP, the potential cumulative impacts of construction noise, including piling, would also ensure a **minor adverse** (not significant) impact on grey seal.

Table 12.75 Cumulative impact significance for disturbance to harbour porpoise, grey seal and harbour seal from all potential noise sources during construction and piling at Norfolk Boreas

Potential Impact	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
All possible noise sources including piling	Medium	Low for harbour porpoise Medium for grey seal Negligible for harbour seal	Minor for harbour porpoise Moderate for grey seal Minor for harbour seals	Possible strategic approach to reduce the magnitude of the cumulative impacts, if required.	**Minor adverse**

12.8.7 Impact 3: Direct interaction - collision risk

743. During the construction of offshore wind farms, 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 only. Marine mammals in the area would be habituated to the presence of vessels and therefore be expected to be able to detect and avoid construction vessels (see section 12.7.3.6).

744. As a precautionary approach, the number of harbour porpoise, grey seal and harbour seal that could be at increased collision risk with vessels has been assessed based on 5% of the number of animals that could be present in the wind farm areas having an increased collision risk. This is very precautionary, as it is highly unlikely that marine mammals present in the wind farm areas would be at increased collision risk with vessels.

745. The CIA has determined that the number of harbour porpoise that could have a potential increased collision risk with vessels in offshore wind farm sites during construction would be 243 individuals, which represents 0.07% of the NS MU reference population (Table 12.76). The potential magnitude of the effect is assessed as medium, based on a permanent effect with between 0.01% and 1% of the reference population likely to be exposed to the effect.

746. The CIA has determined that the number of grey seal that could have a potential increased collision risk with vessels in offshore wind farm sites during construction would be 16 individuals, which represents 0.07% of the reference population (Table 12.77). The potential magnitude of the effect is assessed as medium, based on a permanent effect with between 0.01% and 1% of the reference population could be at increased risk.

747. The CIA has determined that the number of harbour seal that could have a potential increased collision risk with vessels in offshore wind farm sites during construction would be 2, which represents 0.005% of the reference population (Table 12.77). The potential magnitude of the effect is assessed as low, based on a permanent effect between 0.001% and 0.01% of the reference population likely to be exposed to the effect.

748. Any increase in vessel movements during the operation and maintenance of offshore wind farms would be relatively small in relation to current ship movements in the area. Therefore, there is unlikely to be a significant increase in collision risk during the operation and maintenance of offshore wind farms and as a result this has not been included in the CIA.

749. Wave and tidal arrays can pose a potential collision risk for marine mammals. The likelihood for collision may depend on many variables such as species, underwater

visibility, detectability of the devices, the size and type of devices, the location, water depth and the rotation speed of the rotor blades. However, if there is the potential for significant collision risk for marine mammals then the wave or tidal development would be required to implement suitable mitigation to reduce the risk and any potential significant effects at the population level. Therefore, there should be no potential for any significant cumulative impacts and as a result this has not been included in the CIA.

750. All projects screened into the CIA (Appendix 12.3) have the potential to increase the amount of vessel activity over the range of each species, although there are already large numbers of vessel movements across the area. Therefore, for most of these projects any increase in vessel movements is likely to be relatively small in relation to current ship movements in the area.

751. Taking into account the location of the tidal and wave developments screened into the CIA (Appendix 12.3) and the mitigation that would be put in place at these developments to reduce the risk of collision for marine mammals, the magnitude for all marine mammal species is also considered to be negligible and not included in the CIA.

752. The cumulative effects of all projects and activities other than offshore wind farms have the potential to increase the collision risk for harbour porpoise, grey seal and harbour seal, therefore, as a precautionary approach, the magnitude for all marine mammal species is considered to be low.

Table 12.76 Quantified CIA for the potential increased collision risk with vessels for harbour porpoise during offshore wind farm construction

Name of Project	Tier	Distance to Norfolk Boreas (km)	SCANS-III Survey Block	SCANS-III density estimate (No/km^2)	Area of offshore wind farm site*	Potential number of harbour porpoise impacted
Norfolk Boreas	5	0	O[1]	0.888	725	32
Creyke Beck A	3	173	O	0.888	515	23
Creyke Beck B	3	196	O	0.888	599	27
Teesside A	3	191	N	0.837	562	24
Sofia	3	185	O[2]	0.888	593	26
Norfolk Vanguard	4	30	O[3]	0.888	592	26
Hornsea Project Three	4	53	O	0.888	695	31
Thanet Extension	4	175	L	0.607	73	2
East Anglia ONE North	5	51	L	0.607	206	6
East Anglia TWO	5	73	L	0.607	255	8
Hornsea Project Four	5	119	O	0.888	846	38
Total					**5,661km^2**	**243**
% of NS MU reference population (345,373 harbour porpoise)						**0.07%**

[1]Norfolk Boreas overlaps SCANS-III survey block O & L; therefore, higher density estimate from survey block O is used.
[2]Sofia overlaps SCANS-III survey block O & N, but majority of site is in block O.
[3] NV East is located in SCANS-III survey block L, NV West is located in both SCANS-III survey block L and survey block O; therefore, higher density estimate from survey block O is used.
*Source: http://www.4coffshore.com/

Table 12.77 Quantified CIA for the potential increased collision risk with vessels for grey seal and harbour seal during offshore wind farm construction

Name of Project	Country	Distance to Norfolk Boreas (km)	Grey seal density estimate (No/km^2)	Harbour seal density estimate (No/km^2)	Area of offshore wind farm site (km^2) *	Potential number of grey seal impacted	Potential number of harbour seal impacted
Norfolk Boreas	UK	0	0.001	0.0001	725	0.04	0.004
Creyke Beck A	UK	173	0.05	0.0004	515	1.29	0.004
Creyke Beck B	UK	196	0.09	0.001	599	2.70	0.01
Teesside A	UK	191	0.01	0.00004	562	0.28	0.0004
Sofia	UK	185	0.09	0.001	593	2.67	0.01
Norfolk Vanguard	UK	30	0.002	0.0001	592	0.06	0.003
Hornsea Project Three	UK	53	0.08	0.008	695	2.78	0.11
Thanet Extension	UK	175	0.02	0.06	73	0.07	0.09
East Anglia ONE North	UK	51	0.0009	0.0006	206	0.01	0.002
East Anglia TWO	UK	73	0.01	0.002	255	0.13	0.01
Hornsea Project Four	UK	119	0.14	0.04	846	6	1.7
Total					**4,815km^2**	**16**	**2**
% of reference population (22,290 grey seal; 43,161 harbour seal)						**0.07%**	**0.005%**

*Source: 4coffshore.com

12.8.7.1 Cumulative impact significance

753. Marine mammals would be habituated to the presence of vessels and would be able to detect and avoid vessels. Therefore, harbour porpoise, grey seal and harbour seal are considered to have a low sensitivity to the risk of a vessel strike (see section 12.7.3.6.1).

754. Based on the sensitivity of harbour porpoise, grey seal and harbour seal, and the potential magnitude of effect, the cumulative impact is assessed as having the potential to be **minor adverse** for the three species (Table 12.78).

Table 12.78 Cumulative assessment of impact significance of increased collision risk from vessels during offshore wind farm construction

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual impact
Increased collision risk from vessels during offshore wind farm construction	Harbour porpoise	Low	Medium	Minor adverse	No mitigation required or proposed.	**Minor adverse**
	Grey seal	Low	Medium	Minor adverse		**Minor adverse**
	Harbour seal	Low	Low	Minor adverse		**Minor adverse**

12.9 Transboundary Impacts

755. The highly mobile nature of marine mammal species considered in this assessment means that there are potential transboundary impacts for each receptor. These transboundary impacts are already considered in the assessment, as the impacts for all species have been based on the relevant Management Units and reference populations.

756. For harbour porpoise the extent of the reference population 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.

12.10 Inter-Relationships

757. Table 12.79 serves as sign-posting for inter-relationships.

Table 12.79 Marine mammal inter-relationships

Topic and description	Related Chapter	Where addressed in this Chapter	Rationale
Prey species	Chapter 11 Fish and Shellfish Ecology	Section 12.7.3.8 Section 12.7.4.6 Section 12.7.5.6	Potential impacts on fish and shellfish could affect the prey resource for marine mammals
Vessel collision risk and disturbance from vessels	Chapter 15 Shipping and Navigation	Section 12.7.3.4 Section 12.7.3.6 Section 12.7.4.3 Section 12.7.4.4 Section 12.7.5.3 Section 12.7.5.4 Section 12.8.7	Increased vessel traffic associated with the project could affect the level of collision risk for marine mammals and the disturbance of marine mammals.

12.11 Interactions

758. The impacts identified and assessed in this chapter have the potential to interact with each other, which could give rise to synergistic impacts as a result of that interaction. The worst-case impacts assessed within the chapter take these interactions into account and for the impact assessments are considered conservative and robust. For clarity the areas of interaction between impacts are presented in Table 12.80, Table 12.81 and Table 12.82, along with an indication as to whether the interaction may give rise to synergistic impacts.

759. Synergistic impacts of potential disturbance from underwater noise during construction from all noise sources at Norfolk Boreas have been assessed as potential barrier effects (Table 12.80).

12.12 Summary

760. The construction, operation and decommissioning phases of Norfolk Boreas would cause a range of effects on marine mammals which are summarised in Table 12.83.

Table 12.80 Interaction between impacts during construction

Potential interaction between impacts Construction	1 Physical and auditory injury resulting from the underwater noise associated with UXO clearance	2 Behavioural impacts resulting from the underwater noise associated with UXO clearance	3 Physical and auditory injury resulting from underwater noise during piling	4 Behavioural impacts resulting from underwater noise during piling	5 Behavioural impacts resulting from underwater noise during construction activities, other than piling	6 Behavioural impacts resulting from underwater noise and presence of vessels	7 Barrier effects as a result of behavioural impacts resulting from underwater noise associated with UXO clearance, piling, construction activities and vessels	8 Vessel interaction (collision risk)	9 Disturbance at seal haul-out sites	10 Changes to prey resource	11 Changes to water quality
1 Physical and auditory injury resulting from the underwater noise associated with UXO clearance	-	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No
2 Behavioural impacts resulting from the underwater noise associated with UXO clearance	Yes	-	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No
3 Physical and auditory injury resulting from underwater noise during piling	Yes	Yes	-	Yes	Yes	Yes	Yes	No	No	Yes	No
4 Behavioural impacts resulting from underwater noise during piling	Yes	Yes	Ye	-	Yes	Yes	Yes	No	No	Yes	No
5 Behavioural impacts resulting from underwater noise during construction activities, other than piling	Yes	Yes	Yes	Yes	-	Yes	Yes	No	Yes	Yes	No

Potential interaction between impacts											
Construction											
	1 Physical and auditory injury resulting from the underwater noise associated with UXO clearance	2 Behavioural impacts resulting from the underwater noise associated with UXO clearance	3 Physical and auditory injury resulting from underwater noise during piling	4 Behavioural impacts resulting from underwater noise during piling	5 Behavioural impacts resulting from underwater noise during construction activities, other than piling	6 Behavioural impacts resulting from underwater noise and presence of vessels	7 Barrier effects as a result of behavioural impacts resulting from underwater noise associated with UXO clearance, piling, construction activities and vessels	8 Vessel interaction (collision risk)	9 Disturbance at seal haul-out sites	10 Changes to prey resource	11 Changes to water quality
6 Behavioural impacts resulting from underwater noise and presence of vessels	Yes	Yes	Yes	Yes	Yes	-	Yes	No	Yes	Yes	No
7 Barrier effects as a result of behavioural impacts resulting from underwater noise associated with UXO clearance, piling, construction activities and vessels	Yes	Yes	Yes	Yes	Yes	Yes	-	No	Yes	Yes	No
8 Vessel interaction (collision risk)	No	No	No	No	No	No	No	-	No	No	No
9 Disturbance at seal haul-out sites	No	No	No	No	Yes	Yes	Yes	No	-	No	No
10 Changes to prey resource	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	-	Yes
11 Changes to water quality	No	No	No	No	No	No	No	No	No	Yes	-

Table 12.81 Interaction between impacts during operation and maintenance

Operation	1 Behavioural impacts resulting from the underwater noise associated with operational turbines	2 Behavioural impacts resulting from the underwater noise associated with maintenance activities	3 Behavioural impacts resulting from underwater noise and presence of vessels	4 Vessel interaction (collision risk)	5 Disturbance at seal haul-out sites	6 Entanglement in floating foundations	7 Changes to prey resource
1 Behavioural impacts resulting from the underwater noise associated with operational turbines	-	Yes	Yes	No	No	No	Yes
2 Behavioural impacts resulting from the underwater noise associated with maintenance activities	Yes	-	Yes	No	Ye	No	Yes
3 Behavioural impacts resulting from underwater noise and presence of vessels	Yes	Yes	-	No	Yes	No	Yes
4 Vessel interaction (collision risk)	No	No	No	-	No	No	No
5 Disturbance at seal haul-out sites	No	Yes	Yes	No	-	No	No
6 Entanglement in floating foundations	No	No	No	No	No	-	No
7 Changes to prey resource	Yes	Yes	Yes	No	No	No	-

Table 12.82 Interaction between impacts during decommissioning

Decommissioning
It is anticipated that the decommissioning impacts will be similar in nature to those of construction.

Table 12.83 Summary of potential impacts for marine mammals

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Construction						
Impact 1: Underwater UXO Clearance						
Permanent auditory injury	Harbour porpoise	High	Medium	**Major**	MMMP for UXO clearance.	**Minor adverse**
	Grey seal	High	Medium to Negligible	**Major to Minor**		**Minor adverse**
	Harbour seal	High	Low to Negligible	**Moderate to Minor**		**Minor adverse**
TTS and fleeing response	Harbour porpoise, grey seal & harbour seal	Medium	Negligible	**Minor**	MMMP for UXO clearance.	**Minor adverse**
Disturbance	Harbour porpoise	Medium	Negligible	**Minor**	MMMP for UXO clearance and SIP for SNS SAC	**Minor adverse**
	Grey seal	Medium	Low to Negligible	**Minor**		**Minor adverse**
	Harbour seal	Medium	Negligible	**Minor**		**Minor adverse**
Impact 2: Underwater Noise during Piling						
PTS from single strike of starting hammer energy	Harbour porpoise, grey seal & harbour seal	High	Negligible	**Minor**	MMMP for piling	**Minor adverse**
PTS from single strike of maximum hammer energy	Harbour porpoise, grey seal & harbour seal	High	Negligible	**Minor**	MMMP for piling including embedded mitigation	**Minor adverse**
PTS from Cumulative SEL	Harbour porpoise	High	Negligible	**Minor**	MMMP for piling including embedded mitigation	**Minor adverse**
	Grey seal & harbour seal	High	Negligible	**Minor**		**Minor adverse**
TTS and fleeing response	Harbour porpoise, grey seal & harbour seal	Medium	Negligible	**Minor**	MMMP for piling including embedded mitigation	**Minor adverse**

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Disturbance during piling for single installation	Harbour porpoise, grey seal & harbour seal	Medium	Negligible	**Minor**	SIP for SNS SAC	**Minor adverse**
Disturbance during concurrent piling	Harbour porpoise	Medium	Low	**Minor**		**Minor adverse**
	Grey seal & harbour seal	Medium	Negligible	**Minor**		**Minor adverse**
Possible behavioural	Harbour porpoise	Low	Negligible	**Negligible**		**Negligible**
Impact 3: Underwater Noise during Other Construction Activities						
PTS from Cumulative SEL	Harbour porpoise, grey seal & harbour seal	Medium	Negligible	**Minor**	No mitigation required	**Minor adverse**
Possible behavioural response	Harbour porpoise	Medium	Negligible	**Minor**		**Minor adverse**
Impact 4: Vessel Underwater Noise and Disturbance						
PTS from Cumulative SEL	Harbour porpoise, grey seal & harbour seal	Low	Negligible	**Negligible**	No mitigation required	**Negligible**
Possible behavioural response	Harbour porpoise	Low	Negligible	**Negligible**		**Negligible**
Impact 5: Barrier Effects from Underwater Noise						
Disturbance	Harbour porpoise	Medium	Low	**Minor**	MMMP for piling including embedded mitigation and SIP for SNS SAC	**Minor adverse**
	Grey seal & harbour seal	Medium	Negligible	**Minor**		**Minor adverse**
Impact 6: Vessel Collision Risk						
Increased collision risk	Harbour porpoise	Low	Medium	**Minor**	No further mitigation proposed other than	**Minor adverse**
	Grey seal	Low	Low to Medium	**Minor**		**Minor adverse**

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
	Harbour seal	Low	Low	**Minor**	good practice	**Minor adverse**
Impact 7: Disturbance at Seal Haul-Out Sites						
Disturbance	Grey seal & harbour seal	Low	Negligible	**Negligible**	No mitigation required	**Negligible**
Impact 8: Changes to Prey Resource						
Displacement	Harbour porpoise	Low to Medium	Negligible	**Negligible to Minor**	No further mitigation currently required, beyond embedded mitigation to reduce piling noise impacts	**Negligible to Minor adverse**
	Grey seal & harbour seal	Low	Negligible	**Negligible**		**Negligible**
Operation						
Impact 9: Underwater Noise from Operational Turbines						
Disturbance	Harbour porpoise, grey seal & harbour seal	Low	Negligible	**Negligible**	No mitigation required	**Negligible**
Impact 10: Underwater Noise from Maintenance Activities						
Disturbance	Harbour porpoise, grey seal & harbour seal	Medium	Negligible	**Minor**	No mitigation required	**Minor adverse**
Impact 11: Vessel Underwater Noise and Disturbance during Operation and Maintenance						
Disturbance	Harbour porpoise, grey seal & harbour seal	Low	Negligible	**Negligible**	No mitigation required	**Negligible**
Impact 12: Vessel Collision Risk						
Increased collision risk	Harbour porpoise	Low	Negligible	**Negligible**	No further mitigation	**Negligible**

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
	Grey seal	Low	Negligible	**Negligible**	proposed other than good practice	**Negligible**
	Harbour seal	Low	Negligible	**Negligible**		**Negligible**
Impact 13: Disturbance at Seal Haul-Out Sites						
Disturbance	Grey seal & harbour seal	Low	Negligible	**Negligible**	No mitigation required	**Negligible**
Impact 14: Changes to Prey Resource during Operation and Maintenance						
Displacement	Harbour porpoise	Low to Medium	Negligible	**Negligible to Minor**	No mitigation required	**Negligible to Minor adverse**
	Grey seal & harbour seal	Low	Negligible	**Negligible**		**Negligible**
Decommissioning						
Impact 15: Underwater Noise						
Disturbance	Harbour porpoise, grey seal & harbour seal	Medium	Negligible	**Minor**	No further mitigation required	**Minor adverse**
Impact 16: Barrier Effects from Underwater Noise						
Disturbance	Harbour porpoise	Medium	Low	**Minor**	No mitigation required	**Minor adverse**
	Grey seal & harbour seal	Medium	Negligible	**Minor adverse**		**Minor adverse**
Impact 17: Vessel Underwater Noise and Disturbance						
PTS from Cumulative SEL	Harbour porpoise, grey seal & harbour seal	Low	Negligible	**Minor**	No mitigation required	**Minor adverse**
Possible behavioural response	Harbour porpoise	Low	Negligible	**Minor**		**Minor adverse**

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
Impact 18: Vessel Collision Risk						
Increased collision risk	Harbour porpoise	Low	Medium	**Minor**	No further mitigation proposed other than good practice	**Minor adverse**
	Grey seal	Low	Low to Medium	**Minor**		**Minor adverse**
	Harbour seal	Low	Low	**Minor**		**Minor adverse**
Impact 19: Disturbance at Seal Haul-Out Sites						
Disturbance	Grey seal & harbour seal	Low	Negligible	**Negligible**	No mitigation required	**Negligible**
Impact 20: Changes to Prey Resource						
Displacement	Harbour porpoise	Low to Medium	Negligible	**Negligible to Minor**	No mitigation required	**Negligible to Minor adverse**
	Grey seal	Low	Negligible	**Negligible**		**Negligible**
Cumulative						
Impact 1: Underwater noise during piling						
Disturbance	Harbour porpoise	Medium	Low for single piling and Medium for concurrent piling	**Minor** for single piling and Moderate for concurrent piling	Project level mitigation, including MMMP and SIP, plus any strategic mitigation, if required	**Minor adverse**
	Grey seal	Medium	Low for single piling and concurrent piling	**Minor** for single piling and concurrent piling		**Minor adverse**
	Harbour seal	Medium	Negligible for single piling and concurrent piling	**Minor** for single piling and concurrent piling		**Minor adverse**
Impact 2: Underwater noise for all other noise sources						
Disturbance	Harbour porpoise	Medium	Low	**Minor**	No further mitigation currently proposed	**Minor adverse**
	Grey seal	Medium	Low	**Minor**		**Minor adverse**

Potential Impact	Receptor	Sensitivity	Magnitude	Significance	Mitigation	Residual Impact
	Harbour seal	Medium	Negligible	**Minor**		**Minor adverse**
Summary of impact 1 and 2 combined: Underwater noise for all other noise sources including piling at Norfolk Boreas						
Disturbance	Harbour porpoise	Medium	Low	**Minor**	Project level mitigation, including MMMP and SIP, plus any strategic mitigation, if required	**Minor adverse**
	Grey seal	Medium	Medium	**Moderate**		**Minor adverse**
	Harbour seal	Medium	Negligible	**Minor**		**Minor adverse**
Impact 3: Changes to prey availability						
Displacement	Harbour porpoise, grey seal and harbour seal	No additional cumulative impacts to those assessed for disturbance from underwater noise.				
Impact 4: Collision risk – vessels and tidal devices						
Increased collision risk	Harbour porpoise	Low	Medium	**Minor**	No further mitigation proposed other than good practice	**Minor adverse**
	Grey seal	Low	Medium	**Minor**		**Minor adverse**
	Harbour seal	Low	Low	**Minor**		**Minor adverse**

12.12.1 Summary of mitigation

12.12.1.1 Embedded mitigation

761. Embedded mitigation would include soft-start and ramp-up of piling activity in order to minimise potential impacts on physical and auditory injury.

762. The PEMP and In Principle Monitoring Plan will outline the embedded mitigation measures in relation to Marine Mammal impacts. These will be developed in consultation with the relevant statutory stakeholders.

12.12.1.2 Further mitigation

12.12.1.2.1 MMMP for piling

763. 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, in consultation with the relevant SNCBs and MMO. The MMMP for piling will include details of the embedded mitigation, for the soft-start and ramp-up, as well as detailing the mitigation zone and the mitigation measures to reduce the risk of any physical or permanent auditory injury (PTS) to marine mammals during all piling operations. Appropriate mitigation measures considered adequate to exclude marine mammals from within the mitigation zone will be implemented prior to piling, to reduce the risk of any PTS. (see section 12.7.1.1.2). A draft MMMP for piling has been included in the DCO application for Norfolk Boreas (document reference 8.13).

12.12.1.2.2 MMMP for UXO clearance

764. A detailed MMMP will be prepared for UXO clearance. The MMMP for UXO clearance will ensure there are adequate mitigation measures to reduce the risk of any physical or permanent auditory injury (PTS) to marine mammals. The MMMP for UXO clearance will be developed in the pre-construction period in line with the licence application made at that time, 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 SNCBs and MMO.

12.12.1.2.3 In Principle Site Integrity Plan

765. In addition to the MMMP for piling and MMMP for UXO clearance, a Norfolk Boreas SNS SAC Site Integrity Plan (SIP) will be developed, and an In Principle SIP has been provided with the DCO submission for Norfolk Boreas (document reference 8.17). The SIP will set out the approach to deliver any project mitigation or management measures in relation to the SNS SAC.

766. The SIP will be developed in the pre-construction period and will be based upon best available information and methodologies at that time, in consultation with the relevant SNCBs and MMO.

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