Department for
Business, Energy
& Industrial Strategy

RECORD OF THE HABITATS REGULATIONS ASSESSMENT UNDERTAKEN UNDER REGULATION 65 OF THE CONSERVATION OF HABITATS AND SPECIES (2017), AND REGULATION 33 OF THE CONSERVATION OF OFFSHORE MARINE HABITATS AND SPECIES REGULATIONS (2017).

Review of Consented Offshore Wind Farms in the Southern North Sea Harbour Porpoise SCI.

October 2018

CONTENTS

FIGURES

TABLES

ACRONYMS

%	Percent
<	Less Than
>	More Than
µ	Micro
µPA^{2}s	Micro Pascal Squared per Second
0-p	Zero to Peak
2D	Two Dimensional
3D	Three Dimensional
ABPMer	ABP Marine Environmental Research
ADD	Acoustic Deterrent Devices
ASCOBANS	The Agreement on the Conservation of Small Cetaceans in the Baltic and North Seas
BEIS	The Department of Business Energy and Industrial Strategy
BOEM	Bureau of Ocean Energy Management
BOWind	Barrow Offshore Wind
BOWL	Beatrice Offshore Windfarm Ltd.
c.	Approximately
C.I.	Confidence Interval
CfD	Contract for Difference
CMS	Construction Method Statement
cSAC	Candidate Special Area of Conservation
Cu. in.	Cubic Inches
CV	Coefficient of Variation
dB	Decibel
dB re 1 µPA	Decibel Relative to one Micro Pascal
DCO	Development Consent Order
DECC	The Department of Energy and Climate Change
Defra	The Department for Environment, Food and Rural Affairs
DEPONS	The Distance Effects on the Harbour Porpoise Population in the North Sea
DfT	Department for Transport
dML	deemed Marine Licence
DONG	Danish Oil and Natural Gas
DOWF	Dudgeon Offshore Windfarm Ltd.
dSAC	Draft Special Area of Conservation
EAOWL	East Anglia Offshore Windfarm Ltd.
EC	European Commission
ED	European datum
EDR	Effective Deterrent Radius
EMF	Electromagnetic Field
EIA	Environmental Impact Assessment
ESAS	European Seabirds at Sea
EU	European Union
FCS	Favourable Conservation Status
FPSO	Floating, Production, Supply and Offloading
GGOWL	Greater Gabbard Offshore Wind Ltd.
GW	Gigawatt
GWFL	Galloper Windfarm Ltd.
ha	Hectares
hr^{-1}	Per hour
HRA	Habitats Regulations Assessment
hrs	Hours
HVAC	High Voltage Alternating Current
HVDC	High Voltage Direct Current
Hz	Hertz
IAMMWG	Inter-Agency Marine Mammal Working Group
ICES	The International Council for Exploration of the Sea
ind./km^2	Individuals per Square Kilometre
iPCoD	Interim Population Consequences of Disturbance
JCP	Joint Cetacean Protocol
JNCC	The Joint Nature Conservation Committee
kg	Kilograms

kHz	Kilohertz
kJ	Kilojoules
km	Kilometre
Km/h	Kilometre per Hour
km^2	Squared Kilometre
LCCC	Low Carbon Contracts Company
m	Metres
m/s	Metres per Second
m^2	Metres Squared
Max.	Maximum
Min.	Minimum
MMMP	Marine Mammal Mitigation Plan
MMMU	Marine Mammal Management Unit
MMO	Marine Management Organisation
MORL	Moray Offshore Renewables Limited
MU	Management Unit
MW	Megawatt
NBDL	Navitus Bay Development Ltd
NE	Natural England
NEQ	Net Equivalent Quantity
nm	Nautical Miles
NMFS	National Marine Fisheries Service
No.	Number
NOAA	National Oceanic Atmospheric Administration
OGP/IAGC	International Association of Oil and Gas Producers
OSPAR	Oslo and Paris Convention
Pa	Pascal
PAM	Passive Acoustic Monitoring
Para	Paragraph
PCB	Polychlorinated Biphenyls
PEIR	Preliminary Environmental Information Report
PINS	Planning Inspectorate
pSAC	possible Special Area of Conservation
PTS	Permanent Threshold Shift
Q1,2,3 or 4	Quarter (One, Two, Three, Four)
re	Relative
rms	Root Mean Square
SAC	Special Area of Conservation
SCANS	Small Cetacean Abundance in the North Sea
SCAR	Scientific Committee on Antarctic Research
SCI	Site of Community Importance
SEL	Sound Exposure Level
SIP	Site Integrity Plan
SNCB	Statutory Nature Conservation Body
SNS	Southern North Sea
SPA	Special Protection Area
SPL	Sound Pressure Level
TBC	To Be Confirmed
TCE	The Crown Estate
THV	Trinity House Vessel
TKOWFL	Triton Knoll Offshore Windfarm Ltd.
TTS	Temporary Threshold Shift
UK	United Kingdom
UKCS	United Kingdom Continental Shelf
UTM	Universal Transverse Mercator
UXO	Unexploded Ordinance
VSP	Vertical Seismic Profiles

EXECUTIVE SUMMARY

Background

In June 2015 the Joint Nature Conservation Committee (JNCC) submitted to Government a network of draft Special Area of Conservation (dSAC) sites for consideration as sites to be designated for harbour porpoise. One of the sites consulted on was the then Southern North Sea pSAC (JNCC 2017a). Following consultation, this site, along with four other sites being designated for harbour porpoise, was submitted to the European Commission and was formally adopted as a Site of Community Importance (SCI) on 12 December 2017. The Southern North Sea SCI lies in an area extending from the central North Sea, north of the Dogger Bank, to the Strait of Dover. The site covers an area of 36,951 km^2 (JNCC 2017a)

Where a new site is put forward, Regulations require certain existing consents to be reviewed, such that existing consents take into account the protections afforded to the new SAC/SCI (DECC 2016). Consequently, where a competent authority reviews a decision, consent, permission or other authorisation, the competent authority may affirm, modify or revoke the existing consent. The review is undertaken in the form of a Habitats Regulations Assessment (HRA).

This is a record of the Habitats Regulations Assessment (HRA), undertaken by the Secretary of State for the Department of Business Energy and Industrial Strategy (BEIS) alongside the Marine Management Organisation (MMO) in respect of offshore wind farms consented under the Planning Act 2008, Electricity Act 1989 and the Marine and Coastal Access Act 2009 that may cause a significant effect on the qualifying features of the Southern North Sea SCI.

The consented developments relevant to this assessment are not directly connected with, or necessary to, the management of the European site but they may affect it. The purpose of this Assessment is to determine whether consented offshore wind farm developments will adversely affect the integrity of the Southern North Sea SCI.

Approach to HRA

Prior to commencing this HRA, on 6 October 2017 BEIS published a Call for Information that included a Scoping Document that outlined the scope and approach to this assessment. Following receipt of the responses to the Call for Information, a Stakeholder Workshop was held on 5 December 2017. The Workshop provided an opportunity for stakeholders to discuss their responses to the Scoping document with the Department.

Eleven offshore wind farms were identified as meeting the criteria required by the regulations for a review of their consents to be undertaken. The projects were:

- Dudgeon,
- Greater Gabbard,
- Galloper,
- Hornsea Project One,
- Hornsea Two,
- East Anglia One,
- Triton Knoll,
- Creyke Beck A and B,
- Teesside A and B.

Three of the above projects: Hornsea Project One, East Anglia One and Triton Knoll, have been subject to an HRA that included an assessment of the potential impacts on the qualifying features of the Southern North Sea SCI. One additional project, East Anglia Three, lies within the SCI and received consent following the designation of the site. As these four wind farms have already been subject to HRA decisions that considered potential likely significant and adverse effects on the SCI, no further assessment of their consents is required. However, their potential impacts on harbour porpoise are considered as part of the in-combination assessments undertaken for the project consents subject to this review.

Likely Significant Effect

The first stage of the HRA process is to identify the likely impacts of a project upon a European site and determine whether the impacts, either alone or in combination with other plans and projects, will cause a likely significant effect (IPC 2011).

The HRA assesses the potential for a likely significant effect alone and in-combination with other plans or projects and concludes that there is potential for a likely significant effect alone or in-combination on harbour porpoise from:

- Pile-driving (alone and in-combination),
- Sub-bottom profilers (alone and in-combination),
- UXO detonation (alone and in-combination),
- Physical impacts to the seabed (alone and in-combination),
- Seismic surveys (in-combination),
- Vessel activity (in-combination),
- Commercial fisheries (in-combination).

The above activities are considered further in the Appropriate Assessment to determine whether they have potential to cause an adverse effect on the integrity of the site.

Appropriate Assessment

The second stage of the HRA process considers whether there are adverse effects on the integrity of the European site, either alone or in combination with other plans and projects, with regard to the site's structure and function and its Conservation Objectives (IPC 2011).

The Appropriate Assessment considers potential impacts from a number of different activities associated with the consented projects based on the results from a variety of different approaches to assessment, including the results from noise modelling and the use of the proposed Statutory Nature Conservation Bodies' (SNCB) thresholds.

- In-combination impact assessments have been undertaken for:
- Pile-driving at more than one wind farm,
- Impacts on habitats from all offshore wind farms,
- Pile-driving and geophysical seismic surveys,
- Pile-driving and sub-bottom profilers,
- Wind farm vessel and commercial shipping,
- Wind farm pile driving and UXO detonation,
- UXO detonation and seismic surveys,
- Wind farm pile-driving and commercial fisheries.

The Appropriate Assessment concludes that the consents under review will not have adverse effects on the integrity of the Southern North Sea SCI either alone or in-combination with other plans or projects. The conclusions are supported by having agreed mitigation measures in place within each projects' Marine Mammal Mitigation Plan (MMMP). Further, a pre-construction Marine Licence condition requiring a Site Integrity Plan (SIP) will ensure that the parameters used in order to undertake this assessment will not be exceeded.

1 INTRODUCTION

1.1 This is a record of the Habitats Regulations Assessment (HRA), undertaken by the Secretary of State for the Department of Business Energy and Industrial Strategy (BEIS) alongside the Marine Management Organisation (MMO) in respect of offshore wind farms consented under the Planning Act 2008 and Electricity Act 1989 that may cause a significant effect on the qualifying features of the Southern North Sea SCI (Site of Community Importance).

1.2 The consented developments relevant to this assessment are not directly connected with, or necessary to, the management of the European site but they may affect it. The purpose of this HRA is to determine whether the consented offshore wind farm developments will adversely affect the integrity of the Southern North Sea SCI.

1.3 Council Directive 92/43/EC on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive) and Council Directive 2009/147/EC on the conservation of wild birds (the Birds Directive) aim to ensure the long-term survival of certain habitats and species by protecting them from the adverse effects of plans and projects.

1.4 The Habitats Directive provides for the designation of sites for the protection of habitats and species of European importance. These sites are called Special Areas of Conservation (SACs). SACs form part of a network of protected sites across Europe called Natura 2000.

1.5 Before SACs are designated, the Government will undertake a public consultation. Prior to consultation the site is considered to be a draft SAC (dSAC). At the public consultation stage, the site is referred to as a possible SAC (pSAC). When a pSAC is submitted to the European Commission it becomes a candidate SAC (cSAC) at which point it is legally afforded the same protection as a SAC. Following adoption by the European Community the site becomes a Site of Community Importance (SCI) until formal designation by the Government when the site becomes a SAC.

1.6 Any plan or project, which either alone or in-combination with other plans or projects would be likely to have a significant effect on a qualifying site must be subject to an Appropriate Assessment to determine the implications for a site’s integrity and conservation objectives. Such a plan or project may only be agreed after ascertaining that it will not adversely affect the integrity of a European Site unless there are imperative reasons of overriding public interest for carrying out the plan or project.

1.7 The Southern North Sea SCI overlays the geographical extent of two relevant Regulations that transpose the Habitats Directive into UK law:

- The Conservation of Habitats and Species Regulations 2017 (the ‘Habitats Regulations’).
- The Conservation of Offshore Marine Habitats and Species Regulations 2017.

1.8 Where a new SAC is put forward and is designated as a cSAC, both Regulations require certain existing consents to be reviewed, such that existing consents can take into account the protections afforded to the new cSAC (DECC 2016). Consequently, where a competent authority reviews a decision, consent, permission or other authorisation, the competent authority may affirm, modify or revoke the existing consent. The review is undertaken in the form of a Habitats Regulations Assessment.

1.9 Differences exist for projects consented under the Planning Act 2008 and the Electricity Act 1989 that lie within territorial waters, i.e. within 12nm. Under the Planning Act, Development Consent Orders (DCOs) for projects located inside of the outermost extent of the territorial sea, which are not completed before a site becomes a cSAC will need to be reviewed (regulation 85(1)(a) of The Conservation of Habitats and Species Regulations 2017). Works are to be treated as completed for this purpose when the marine works authorised by the development consent have been completed, by which it is meant fully built out.

1.10 Consents under section 36 of the Electricity Act for projects located inside of the outermost extent of the territorial sea which are not completed before a site becomes a cSAC will need to be reviewed (regulation 89(3) and (4) of the Conservation of Habitats and Species Regulations 2017). Works, are to be treated as completed for this purpose when a generating station is first operated under the consent (regulation 89(4) of the 2017 Regulations), i.e. the date it generates and exports electricity. Under regulation 91(3), any variation or revocation will not affect anything done under the consent or direction prior to the revocation or variation taking effect.

1.11 Subject to provisions, DCOs and section 36 consents for all projects beyond the territorial sea, will be reviewed after a site becomes a cSAC or Special Protection Area (SPA) (regulation 33(1) of the Conservation of Offshore Marine Habitats and Species Regulations 2017). However, nothing in the review can affect anything done in pursuance of the consent before the site became a cSAC.

1.12 Activities consented under the Marine and Coastal Access Act 2009, including deemed consents as part of the DCO process, are also subject to the requirements made under the Habitats Regulations.

2 DESIGNATED SITE

2.1 In June 2015 the Joint Nature Conservation Committee (JNCC) submitted to Government a network of draft SAC (dSAC) sites for consideration as sites to be designated for harbour porpoise. In January 2016 the Government started consultation on the dSACs in English and Welsh waters and the classification of the sites changed from dSAC to pSAC. One of the sites consulted on was the then Southern North Sea pSAC (JNCC 2017a). Consultation closed on 3 May 2016 and a recommendation to designate the site was submitted to Government on

28 September 2016. This site, along with four other sites being designated for harbour porpoise, was submitted to the European Commission on 30 January 2017 and became a cSAC. Subsequently, the site was adopted by the Commission on 12 December 2017 and became a Site of Community Importance (SCI) (JNCC 2018).

2.2 The Southern North Sea SCI lies in an area extending from the central North Sea, north of the Dogger Bank, to the Strait of Dover (Figure 1). The site covers an area of 36,951 km^2 (JNCC 2017a)[1]. The site recognises the seasonal variations in harbour porpoise distribution with identified 'summer' and 'winter' areas, within which relatively higher densities of harbour porpoise are predicted to occur during their respective season. The northern 'summer' area is 27,000 km^2 and covers the period from between April to September. The southern 'winter' area is 12,687 km^2 and covers the period between October and March (Heinänen & Skov 2015).

2.3 Based on data collected during the SCANS-II survey used to support the designation of the site, it is estimated that the site potentially supports approximately 18,500 harbour porpoise (95% Confidence Interval: 11,864 - 28,899) for at least part of the year as seasonal differences are likely to occur (JNCC 2017a).

2.4 At the time of site selection, the European Atlantic Shelf harbour porpoise population was estimated to be 375,358 (95% CI 256,304 - 549,713) individuals, of which 227,298 (95% CI 176,360 - 292,948) occurred in the North Sea Management Unit. In the UK sector of the North Sea Management Unit, the harbour porpoise population was estimated to be 110,433 (80,866 - 150,811) (IAMMWG 2015). Consequently, at the time of site selection the Southern North Sea SCI potentially supported 17.5% of the harbour porpoise population within the UK sector of the North Sea Management Unit[2] (JNCC 2017a).

2.5 Densities of harbour porpoise will vary across the site and across seasons. Although no mean densities for the site are provided, modelling used to identify the site boundaries indicate that densities of >3.0 harbour porpoise/km^2 occur across areas of the SCI (Heinänen and Skov 2015).

2.6 This HRA assesses the possible impacts from consented offshore wind farm projects alone and in-combination with other plans or projects on the qualifying features of Southern North Sea SCI.

[1] Note the site area used for this assessment is based on the published area of 36,951 km^2 (JNCC 2017a). Shapefiles provided by the JNCC for the purposes of this assessment indicate that the area of the cSAC is 36,928 km^2. As these figures have not been published they have not been used. However, the difference between the published and unpublished areas are very minor and do not affect any conclusions made in this assessment.

[2] Management Units - UK waters have been divided into three Management Units (MUs) identified by the Interagency Marine Mammal Working Group (IAMMWG). These MUs align with the UK parts of the Assessment Units proposed for the harbour porpoise by the International Council for the Exploration of the Sea (ICES) in their advice to OSPAR. The Management Units were selected to combine what is understood about the ecology of the species with the practicality of managing human activities. The North Sea Management Unit is of relevance to the harbour porpoise population considered in this assessment.

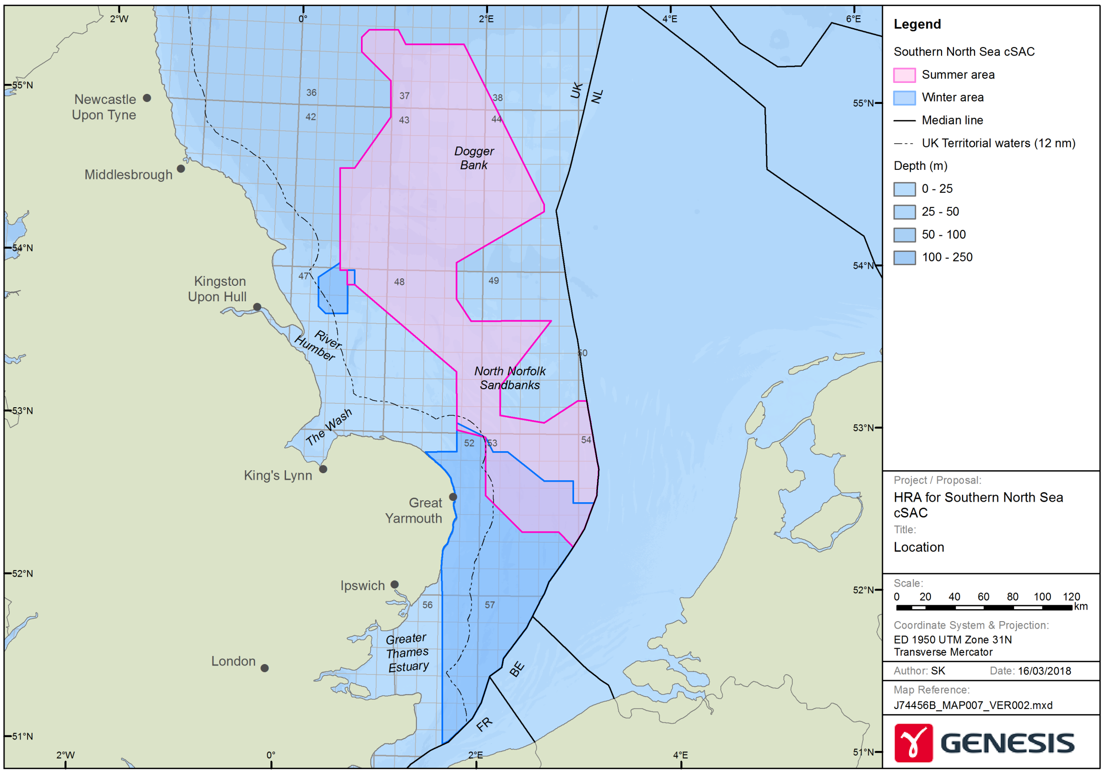


Figure 1: Southern North Sea SCI.

3 SCOPE OF THE ASSESSMENT

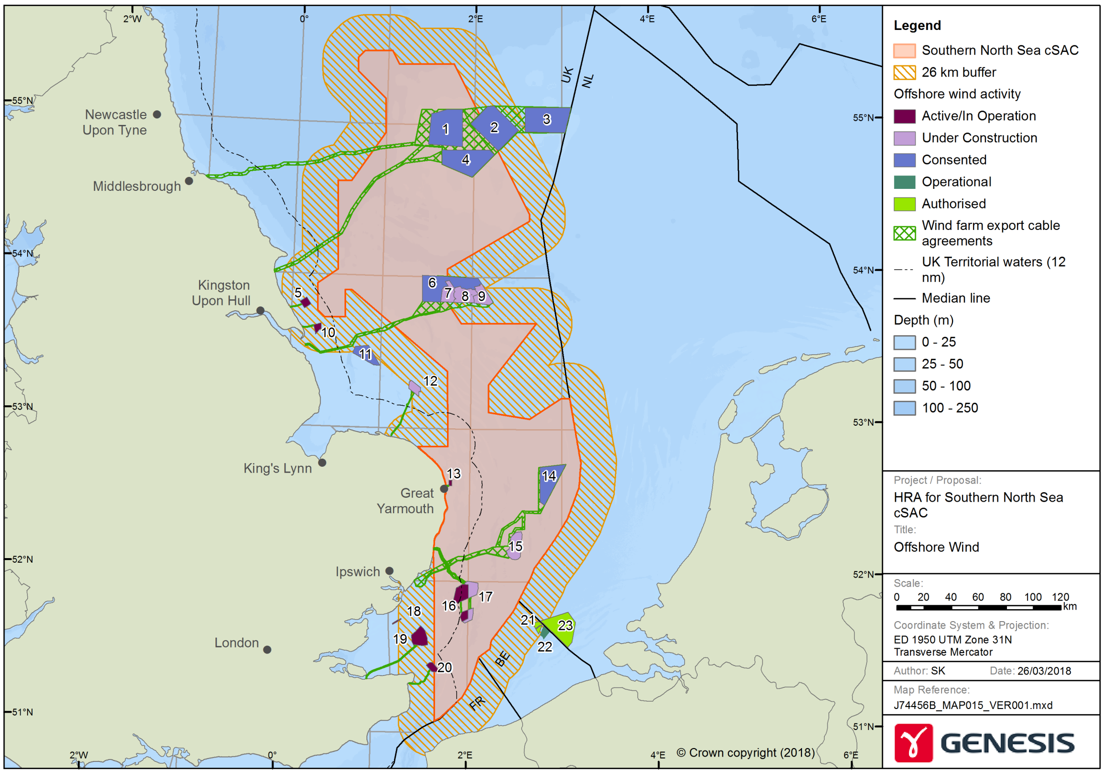
3.1 This HRA addresses the requirements to undertake a review of all relevant plans consented under section 36 of the Electricity Act 1998, the Planning Act 2008 and Chapter 1 of Part 4 of the Marine and Coastal Access Act 2009.

3.2 Prior to commencing this HRA, on 6 October 2017 BEIS published a Call for Information that included a Scoping Document that outlined the scope and approach to this assessment. Following receipt of the responses to the Call for Information, a Stakeholder Workshop was held on 5 December 2017. The Workshop provided an opportunity for stakeholders to discuss their responses to the Scoping document with the Department. Information relating to the Call for Information and Stakeholder Workshop were published on the Department's iPortal (BEIS 2018a).

3.3 There are eleven consented offshore wind farms that lie either wholly within or overlap the SCI: three are operating, two are under construction and six have been consented but are not currently under construction (Table 1). There are a further ten wind farms that lie within 26 km of the SCI, which is identified by the JNCC as an area that harbour porpoises may be displaced by noise arising from pile-driving activities (JNCC 2017b). Of these, three are in non-UK waters: THV Mermaid, Belwind I and Borssele II. Two of the wind farms: Triton Knoll and Teesside A, are within 26 km of the SCI boundary, have been consented but are not yet operational (Figure 2).

Table 1: Consented offshore wind farms located within the Southern North Sea SCI.

Wind farm	Development status	Requirement to review the consent?	Reasoning
Round 1			
Scroby Sands	Operating	No	Within 12 nm, operating prior to site designation as a SCI.
Round 2/2.5			
Greater Gabbard	Operating	Yes	In-part beyond 12 nm.
Galloper	Construction completed	Yes	Beyond 12 nm.
Thanet	Operating	No	Within 12 nm, operating prior to site designation as a SCI.
Round 3			
Creyke Beck A	Consented	Yes	Beyond 12 nm.
Creyke Beck B	Consented	Yes	Beyond 12 nm.
Teesside B	Consented	Yes	Beyond 12 nm.
Hornsea Project One	Under Construction	No	Has been subject to HRA decisions that considered potential Likely Significant and Adverse effects on the SCI.
Hornsea Two	Consented	Yes	Beyond 12 nm.
East Anglia One	Under Construction	No	Has been subject to HRA decisions that considered potential Likely Significant and Adverse effects on the SCI.
East Anglia Three	Consented	No	Consented following site designation.



1. Creyke Beck B
2. Teesside B
3. Teesside A
4. Creyke Beck A
5. Westermost Rough
6. Hornsea Two
7. Hornsea Project One - Heron West
8. Hornsea Project One - Njord
9. Hornsea Project One - Heron East
10. Humber Gateway
11. Triton Knoll
12. Dudgeon
13. Scroby Sands
14. East Anglia Three
15. East Anglia One
16. Greater Gabbard
17. Galloper
18. Gunfleet Sands II
19. London Array 1
20. Thanet
21. THV Mermaid
22. Belwind I
23. Borssele II

Figure 2: Offshore wind farms located within the Southern North Sea SCI and 26 km of the site boundary.

Table 2: Offshore wind farms located within 26 km of the Southern North Sea SCI that are consented or for which applications have been made.

Wind farm	Development status	Requirement to review the consent?	Reasoning
Round 2/2.5			
Triton Knoll	Consented	No	Has been subject to HRA decisions that considered potential Likely Significant and Adverse effects on the SCI.
Westermost Rough	Operating	No	Within 12 nm, operating prior to site designation as a cSAC.
Humber Gateway	Operating	No	Within 12 nm, operating prior to site designation as a cSAC.
Dudgeon	Construction completed	Yes	Beyond 12 nm.
Gunfleet Sands II	Operating	No	Within 12 nm, operating prior to site designation as a cSAC.
London Array Phase 1	Operating	No	Within 12 nm, operating prior to site designation as a cSAC.
Round 3			
Teesside A	Consented	Yes	Beyond 12 nm, consented but not yet operating.
Hornsea Project Three	Application submitted	No	Application made following designation of the cSAC. No consent decision.
Norfolk Vanguard	Application submitted	No	Application made following designation of the cSAC. No consent decision.
Thanet Extension	Application submitted	No	Application made following designation of the cSAC. No consent decision.
Belgium			
Mermaid	Consented	No	Non-UK.
Belwind	Operational	No	Non-UK.
Netherlands			
Borselle II	Consented	No	Non-UK.

3.4 As required under the Regulations, projects within 12 nm that were completed prior to the site becoming a cSAC are excluded from any consent review. Consequently, the consents of the following wind farms are not subject to review but are considered as part of the in-combination assessment:

- Westermost Rough,
- Humber Gateway,
- Scroby Sands,
- Gunfleet Sands II,
- London array,
- Thanet.

3.5 Consents for projects that lie within 12 nm of the coast but were not operational at the time the site became a cSAC on 30 January 2017 and consents for projects that lie beyond 12 nm of the coast and are within the cSAC/SCI or the 26 km area of effective deterrent radius (see Section 11 for reasoning) are subject to review. When the Call for Information was published on 6 October 2017 eleven projects were identified as meeting the criteria required by the regulations for a review of their consents to be undertaken. The projects were:

- Dudgeon,
- Greater Gabbard,
- Galloper,
- Hornsea Project One,
- Hornsea Two,
- East Anglia One,
- Triton Knoll,
- Creyke Beck A and B,
- Teesside A and B.

3.6 Hornsea Project One and East Anglia One offshore wind farms are both under construction. Since the publication of the Call for Information both wind farms have been subject to an HRA that included an assessment of the potential impacts on the qualifying features of the Southern North Sea SCI.

3.7 The assessment undertaken by the MMO for Hornsea Project One concluded that '*With having regarded the best available evidence and through consultation with the MMO's advisors, the MMO conclude that, considering the above mitigation measures are secured through condition, there is no significant risk of the plan or project causing an adverse effect on site integrity for Southern North Sea cSAC*' (MMO 2017a).

3.8 The assessment undertaken by BEIS for East Anglia One concluded that '*After having had regard to the best available evidence, the Secretary of State concludes that, considering the* *above mitigation measures and the commitments which are secured through the MMMP to be implemented under Requirement 36 of the DCO, there is no real risk of the plan or project causing an adverse effect on site integrity for the Southern North Sea cSAC*.' (BEIS 2018b).

3.9 Triton Knoll Offshore Wind Farm has been consented but is not yet under construction. Since the publication of the Call for Information this wind farm has been subject to an HRA for a non-material change that considered a reduction in the number of turbines to be installed. The HRA considered the potential impacts on the SCI and concluded that '*the Project will not have an adverse effect on integrity on any European Site, either alone or in-combination with other plans or projects*.' (BEIS 2018c).

3.10 One project, East Anglia Three, lies within the SCI and received consent following the designation of the site as a cSAC. The potential impacts arising from the project on the qualifying features of the SCI were subject to an HRA prior to the consent decision being made (BEIS 2017a). The HRA concluded that '*The Secretary of State has undertaken a robust assessment using all of the information available to him, not least the advice from the SNCBs, the recommendations of the ExA and the views of Interested Parties including the Applicant. Having considered all of the information available to him and the mitigation measures secured through the DCO and dMLs, the Secretary of State has concluded that the Project will not have an adverse effect on integrity on any European Site, either alone or in-combination with other plans or projects*' (BEIS 2017a).

3.11 As these four wind farms have been subject to HRA decisions that considered potential likely significant and adverse effects on the SCI, no further assessment of their consents is required. However, their potential impacts on the qualifying features of the site are considered as part of the in-combination assessments undertaken for projects, the consents of which are subject to this review.

3.12 There are three consented projects that lie outwith the UK but are within 26 km of the SCI boundary. The review of their consents is beyond the remit of this review, but it is recognised that they have potential to cause in-combination impacts. The projects are:

- Mermaid (Belgium),
- Belwind (Belgium),
- Borselle II (Netherlands).

3.13 BEIS recognises that there is potential for future applications for offshore wind farms that could affect the qualifying features of the Southern North Sea SCI. All future offshore wind farm projects will require a consent and be subject to the requirements of the Habitats Regulations, including an HRA to be undertaken by the competent authority. Potential impacts arising from future projects, both alone and in-combination, will be assessed during the determination of the application.

3.14 Following a scoping exercise undertaken by BEIS to inform this HRA it is considered that the most likely impacts from offshore wind farms that could affect the integrity of the site will be from sound caused during the construction, operation and decommissioning of offshore wind farms (BEIS 2017b). This HRA assesses the potential effects from sound on harbour porpoise and their prey, i.e. fish species, from offshore wind farm related sources that could cause a likely significant or adverse effect. Sources of sound from offshore wind farm activities that have been considered within the HRA include:

- Pile-driving,
- Geophysical surveys, e.g. sub-bottom profilers,
- Vessels,
- Cable laying,
- Rock dumping,
- Cutting equipment,
- Unexploded Ordnance (UXO) clearance (detonation),
- Operating noise.

3.15 The use of Acoustic Deterrent Devices (ADDs) may be potentially used as a form of mitigation to minimise the risk of injury to marine mammals from piling activities. It is unknown if they will be used and if so, which type of ADD may be used. Consequently, it is not intended to consider the potential impacts of ADDs on harbour porpoise on their own but their use may be considered, if appropriate, as part of possible mitigation.

3.16 Drilling activities may occur during the construction of offshore wind farms within the area. However, this is considered to be a contingency option for all developments and therefore is not expected to occur. Drilling noise arising specifically from offshore wind farm developments within or adjacent to the SCI has not been considered as part of this review of renewable consents. However, there is potential for in-combination impacts from drilling noise arising from the offshore oil and gas industry where drilling is a routine activity. Consequently, the potential for an impact from drilling noise on harbour porpoise is considered in this assessment.

3.17 In addition to impacts from noise, there is potential for impacts to the supporting habitats that are relevant to harbour porpoises and their prey within the SCI. The main activities from the consented wind farm developments identified as causing impacts to habitats are the installation of wind turbines and associated infrastructure and the trenching and burying of cables including the placement of cable protection.

3.18 Physical impacts from vessels on harbour porpoise could occur and is considered within this assessment.

3.19 No other sound sources or other impacts from offshore wind farms either alone or in-combination with other activities have been identified as likely to cause a significant effect on harbour porpoise or their prey species.

Information Sources

3.20 The HRA draws on a number of information sources relating to the consented wind farms and the site designation which should be read in conjunction with this report.

- The Triton Knoll Offshore Wind Farm Order 2013. SI No. 1734. UK201307113 07/2013 19585. http://www.legislation.gov.uk/uksi/2013/1734/contents/made. Infrastructure Planning (2013a).
- The Galloper Wind Farm Order 2013. SI No. 1203. https://www.legislation.gov.uk/uksi/2013/1203/contents/made. Infrastructure Planning (2013).
- *The Hornsea One Offshore Wind Farm Order 2014*. SI No. 3331. UK2014121025 12/2014 19585. http://www.legislation.gov.uk/uksi/2014/3331/contents/made. Infrastructure Planning (2014a).
- *The East Anglia ONE Offshore Wind Farm Order 2014*. SI No. 1599. UK2014062012 06/2014 19585. https://www.legislation.gov.uk/uksi/2014/1599/contents/made. Infrastructure Planning (2014b).
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3.21 References to technical papers and other documents are given in the text as necessary.

4 WIND FARM CONSENTS

4.1 The following section provides a summary of the relevant information relating to each of the wind farms, the consents of which are subject to this review. The information is based on that presented in the Development Consent Orders (DCOs), Section 36 Consents and Marine Licences along with any subsequent variations. Information from documents submitted to the Planning Inspectorate, BEIS or the MMO as part of the relevant applications has also been used.

Dudgeon Offshore Wind Farm

4.2 The Dudgeon offshore wind farm is a Round 2 project and was consented on 6 July 2012. The wind farm is located approximately 32 km off the coast of Norfolk and covers an area of 35 km^2. The project lies outwith the SCI (Figure 3) (DOWF 2018).

4.3 The consented project was for a maximum capacity of 560 MW, comprising up to 168 turbines and three offshore substations. Variations to the consent reduced the maximum capacity to 414 MW and the number of turbines to 77 (DECC 2012).

4.4 The constructed project comprises 67 turbines with monopile foundations, a total of 95 km of inter array cables and two export cables each 42 km in length. The installation of the foundations started in March 2016 and was completed in August 2016.

4.5 First electricity to the grid occurred in February 2017 and the project was fully commissioned in October 2017.

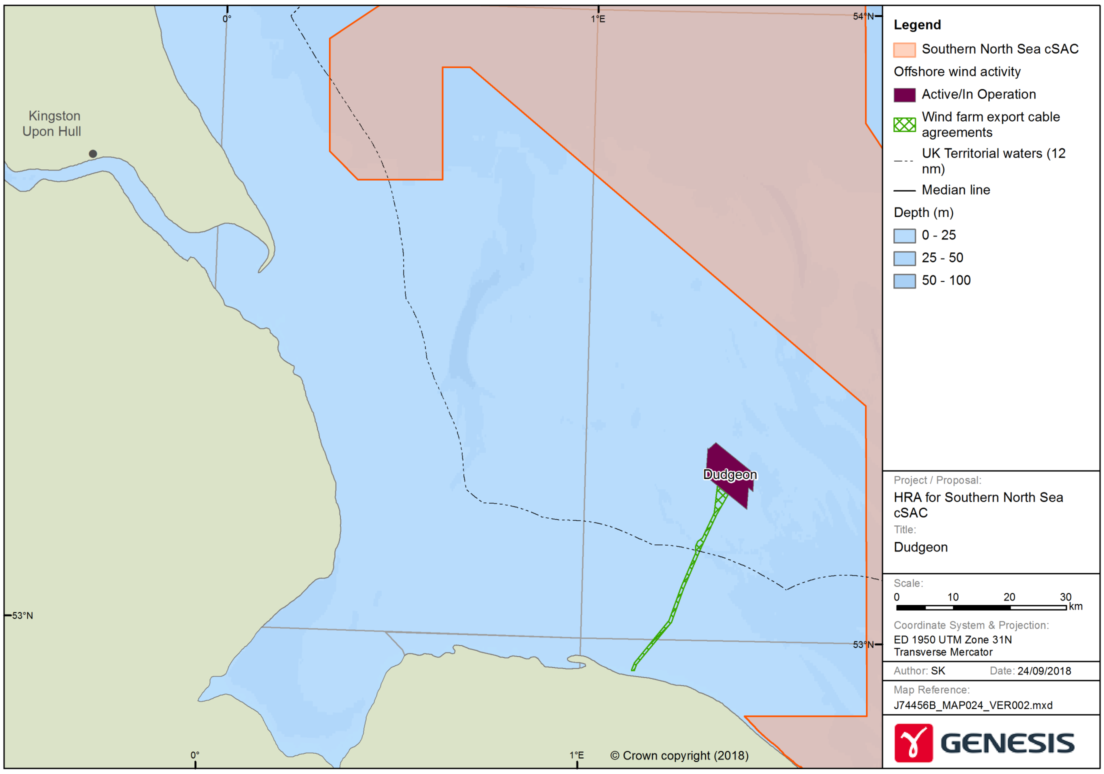


Figure 3: Location of Dudgeon offshore wind farm and the Southern North Sea SCI.

Greater Gabbard Offshore Wind Farm

4.6 The Greater Gabbard offshore wind farm is a Round 2 project and was consented on 19 February 2007. The wind farm is located approximately 25 km off the Suffolk coast and covers an area of 146 km^2 (Figure 4).

4.7 The consented project was for a maximum capacity of 500 MW comprising 140 turbines, four electricity substations and six meteorology masts (DTI 2007). The constructed project comprises 140 turbines with monopile foundations and two offshore substations, a total of 173 km of inter array cables and three export cables each approximately 42 km in length (GGOWL 2005).

4.8 The installation of the foundations commenced in May 2010 and completed in August 2010. The wind farm was fully commissioned in August 2013.

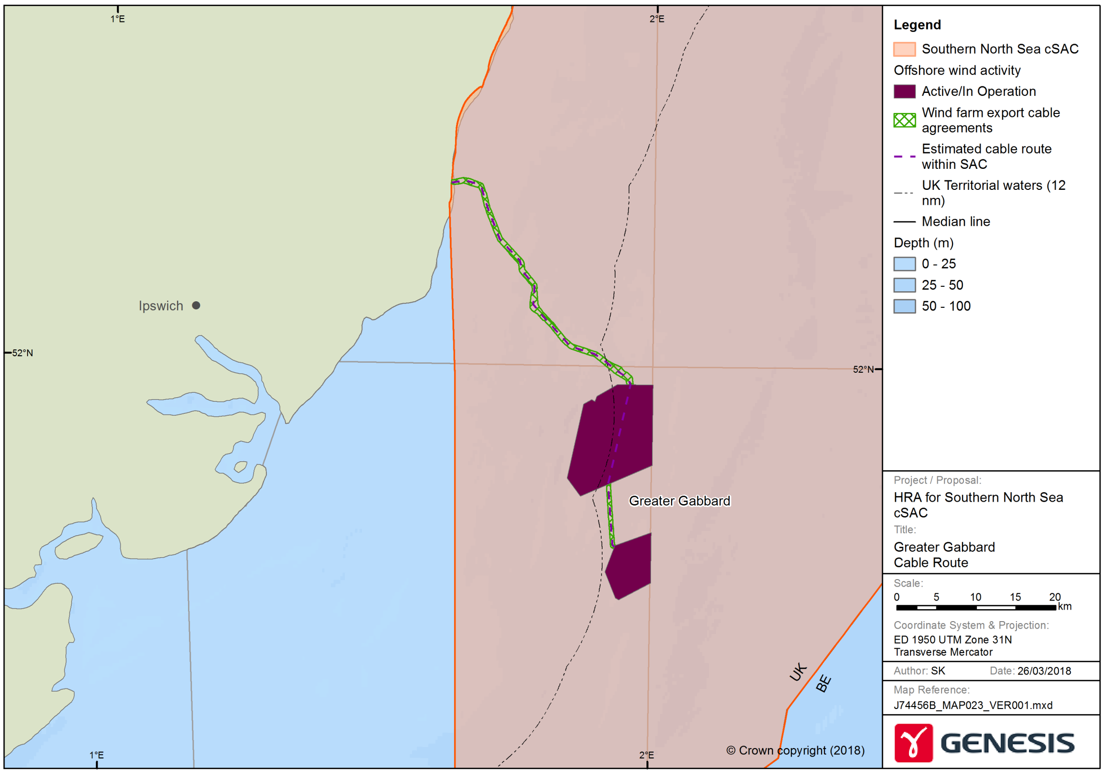


Figure 4: Location of Greater Gabbard offshore wind farm and the Southern North Sea SCI.

Galloper Offshore Wind Farm

4.9 The Galloper offshore wind farm was consented on 24 May 2013 (Infrastructure Planning 2013b).

4.10 The Galloper offshore wind farm is a Round 2.5 offshore wind farm. At its closest point the Project site lies approximately 27 km off the coast of Suffolk and covers an area of 183 km^2

(Figure 5). The project comprises 56 turbines and one offshore substation. Two export cables have been installed each 45 km long.

4.11 The project commenced construction in 2014 and started the installation of turbine foundations in December 2016. The monopile turbine foundations were installed using maximum hammer energies of between 2,000 and 3,021 kJ and each pile took between 75 and 141 minutes, depending on the location of the turbine. All foundations had been installed by March 2017. The project was fully commissioned in April 2018 (GWFL 2018).

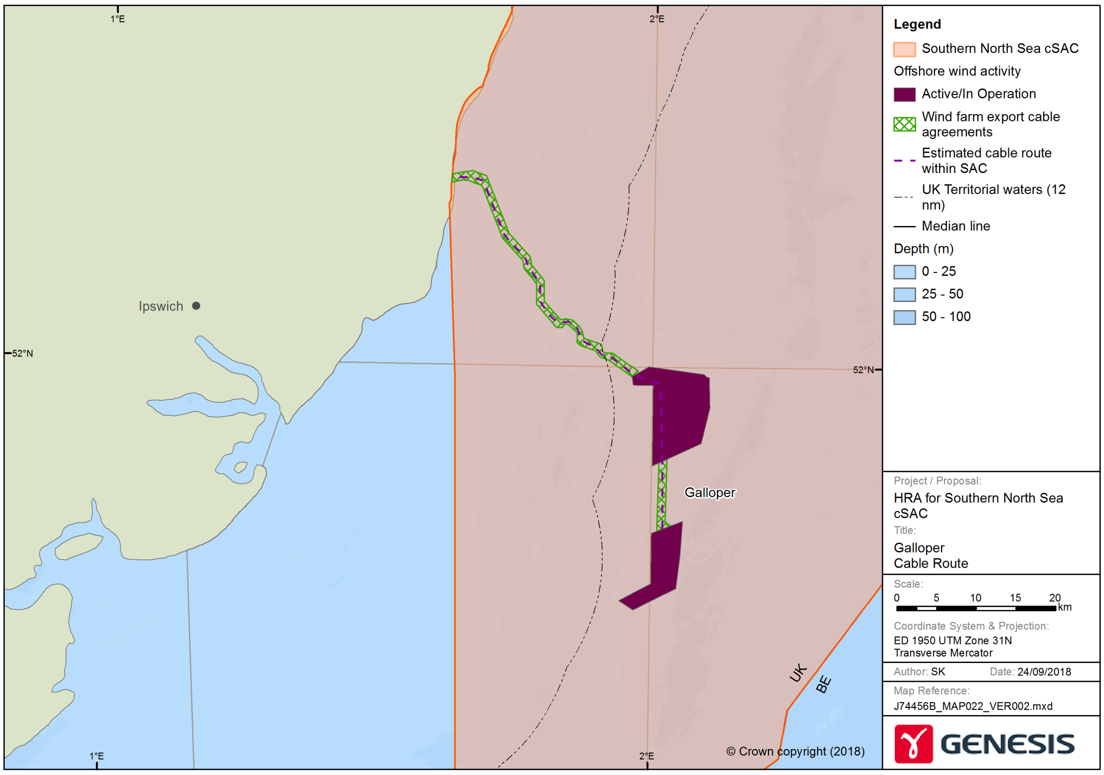


Figure 5: Location of Galloper offshore wind farm and the Southern North Sea SCI.

Hornsea Two Offshore Wind Farm

4.12 The Hornsea Two offshore wind farm is located within Subzone 2 of the Round 3 Offshore Wind Farm Zone; Zone 4: Hornsea. At its closest point Hornsea Two lies 89 km from shore and covers an area of 462 km^2. An area of 298 km^2 of the wind farm site lies within the SCI (Figure 6).

4.13 The Hornsea Two offshore wind farm was consented on 16 August 2016 and work on the project must start no later than 6 September 2021 (Infrastructure Planning 2016a).

4.14 The consented project comprises up to two wind farms with a combined maximum total of 300 turbines, six offshore High Voltage Alternating Current (HVAC) collector platforms, two compensation platform or two High Voltage Direct Current (HVDC) offshore converter platforms and two accommodation platforms. The wind turbine foundations will be either monopile, jacket or gravity based. In the event that export cables are HVAC there will be no requirement for the two converter platforms. A non-material change was approved in May 2018 reducing the permitted number of offshore HVAC collector substations from six to three (Infrastructure Planning 2018).

4.15 The consented gross electrical output capacity for Hornsea Two is up to 1.8 GW (Infrastructure Planning 2016a). However, the project was awarded a Contract for Difference (CfD) in September 2017 for a maximum generating capacity of 1.386 GW (LCCC 2017). This limits the maximum number of 6 MW turbines that could be installed to 231. The turbines planned to be installed are 8.5 MW and the number of turbines to be installed is 177. Subsequently, Ørsted has signed contracts for 165 turbines (Ørsted 2018) and therefore the final number of turbines that will be installed will be less than the 300 for which the project was consented, the 231 x 6 MW turbines that could theoretically be installed and the 177 turbines upon which this assessment is based.

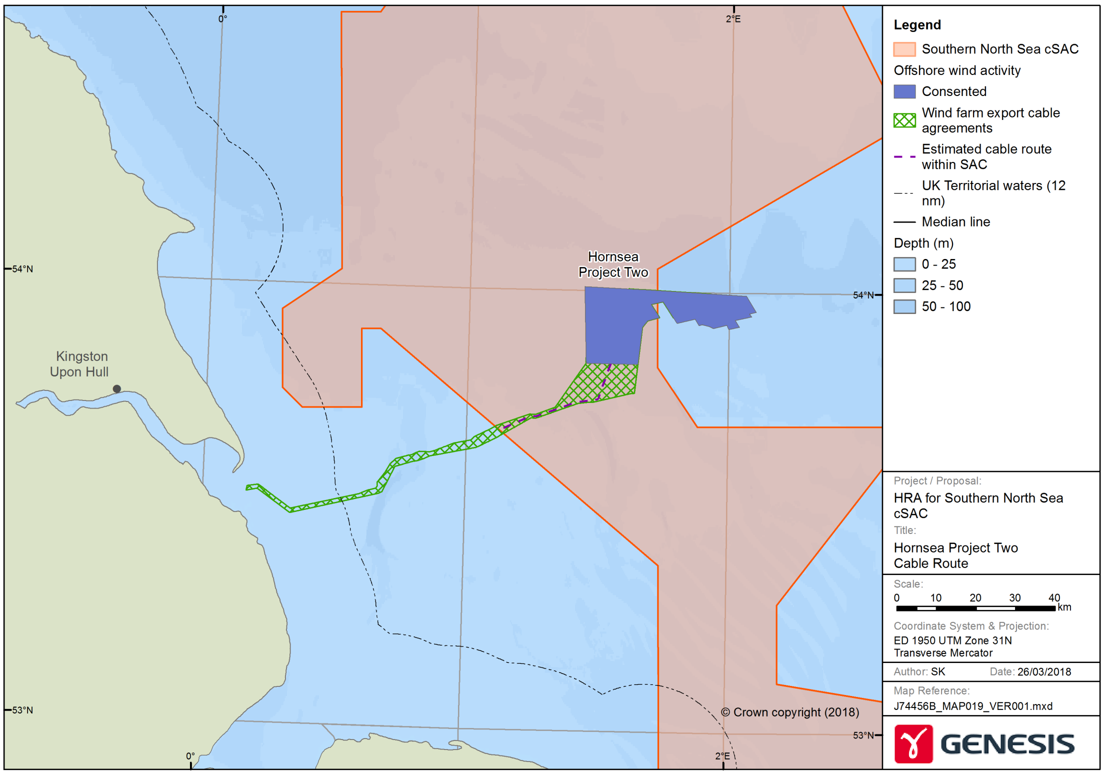


Figure 6: Location of Hornsea Two offshore wind farm and the Southern North Sea SCI.

4.16 The maximum area of seabed permitted to be impacted by the wind turbine foundations, including any scour protection ranges from between 0.5889 km^2 and 3.7788 km^2 depending on the foundation type. For the associated platforms and substations a total area of seabed permitted to be impacted is between 0.023556 km^2 and 0.22902 km^2, depending on foundation type (Infrastructure Planning 2016a).

4.17 In the event monopiled foundations are used the maximum pile diameter is 10 m and will be installed using a maximum hammer energy of 3,000 kJ. The consented and planned pile-driving parameters are presented in Table 3.

4.18 The export cable route will be approximately 115 km long and make landfall at Horseshoe Point in Lincolnshire and connect to the national grid substation at Killingholme in North Lincolnshire (SMart Wind 2015a).

4.19 A total of 675 km of HVAC inter array cabling will connect the wind turbines to the offshore collector platforms. A further 300 km of HVAC inter-platform cables will connect the collector platforms to the converter platform. If export is via HVDC cables, then up to four cable trenches may be required and an estimated 600 km of export cable will connect the converter platform(s) to the onshore landfall. If export is via HVAC cables, then up to eight cable trenches will be required and an estimated 1,200 km of cable will be required. Cables will be trenched and buried at depths of between 1 m and 3 m. Cable protection, typically using rock, gravel or concrete mattresses, may be required along 10% of the inter array and platform cables and 20% of the export cable route. (SMart Wind 2015a).

4.20 The planned development comprises a total of 165 wind turbines. If the selected turbine foundations are monopile, they may have a maximum pile diameter of 8.5 m. (Ørsted 2018). The maximum hammer energy for pile-driving the wind turbine foundations will be 3,000 kJ and the maximum hammer energy to be used to install the ancillary platforms will be 2,300 kJ (Ørsted 2017b).

Table 3: Consented and planned pile-driving parameters for wind turbines at Hornsea Two (Source: SMart Wind 2015a, Ørsted 2017b)

Parameter	Monopile wind turbine	Other infrastructure	Monopilew Wind turbine	Other infrastructure
	Consented		Planned	
Maximum pile diameter (m)	10	3.5	8.5	3.5
Maximum number of driven piles per foundation	1	8	1	4
Maximum hammer energy (kJ)	3,000	2,300	3,000	2,300
Maximum blows per minute (at full energy)	32	32	32	32
Indicative soft start duration (mins)	30	30	20	20
Indicative pile-driving time (excluding soft start) (mins)	540	220	220	220
Estimated total blows per pile (full energy)	12,960	-	-	-

Dogger Bank Creyke Beck A and B Offshore Wind Farms

4.21 The Dogger Bank Creyke Beck A and B offshore wind farms (hereafter Creyke Beck A and Creyke Beck B) were consented under a single DCO on 17 February 2015 (Infrastructure Planning 2015a). Both wind farms are located in Round 3 Offshore Wind Farm Zone; Zone 3: Dogger Bank. The Zone is located between 125 km and 290 km off the coast of Yorkshire (Figure 7).

4.22 The offshore construction start dates for either development are not currently known. However, construction of the wind farms is to start no later than March 2020, with the offshore construction lasting from between three and six years. It is possible that both projects could be constructed concurrently or sequentially (Forewind 2013a, Infrastructure Planning 2015a). Both wind farms lie within the boundaries of the SCI.

4.23 The Creyke Beck A offshore wind farm is located, at its closest point, 131 km from shore and covers an area of 515 km^2. The consented development comprises up to 200 wind turbines, four offshore HVAC collector platforms, one HVDC offshore converter platform and two accommodation platforms. Up to five meteorological masts may be installed. The gross electrical output capacity for Creyke Beck A is up to 1.2 GW (Infrastructure Planning 2015a, Forewind 2013a).

4.24 The Creyke Beck B offshore wind farm is located, at its closest point, 131 km from shore and covers an area of 599 km^2. The consented development comprises up to 200 wind turbines, four offshore HVAC collector platforms, one HVDC offshore converter platform and two accommodation platforms. Up to five meteorological masts may also be installed. The gross electrical output capacity for Creyke Beck B is up to 1.2 GW (Infrastructure Planning 2015a, Forewind 2013a).

4.25 The wind turbines to be installed at Creyke Beck A and B have not been finalised but range in generating capacity from between 6 MW or 10 MW machines; although larger capacity turbines could be installed. A range of turbine foundations are being considered and cover an array of monopole, multi-leg and gravity based options. Within the range of monopole foundations there are monopiles that will be driven and/or drilled into the seabed. The foundation options for the associated offshore platforms include multi-leg, jack-up and gravity based (Forewind 2013a).

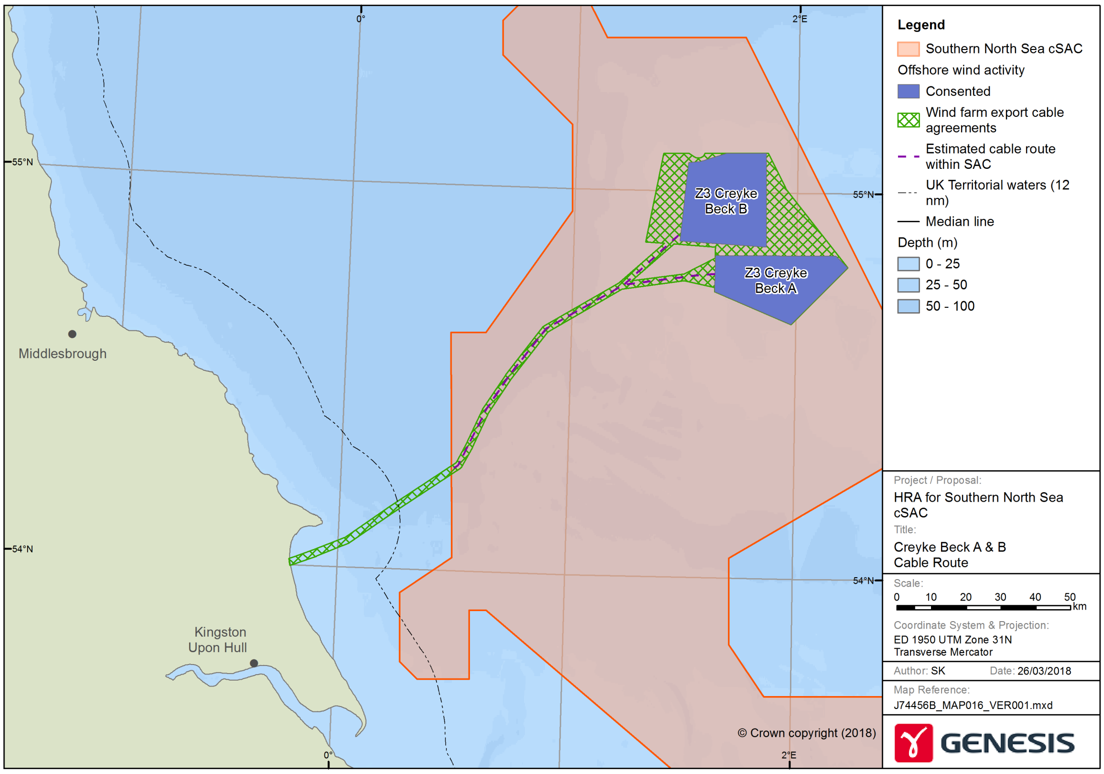


Figure 7: Location of Creyke Beck A and B offshore wind farms and the Southern North Sea SCI.

4.26 Under the DCO the combined maximum area of seabed permitted to be impacted by the wind turbine foundations, including any scour protection, is 1.2306 km^2. For the associated platforms and substations a total area of seabed permitted to be impacted is 0.91819 km^2 (Infrastructure Planning 2015a).

4.27 In the event that monopole foundations are used the maximum pile diameter is 10 m and will be installed using a maximum hammer energy of 3,000 kJ. If multi-leg foundations are used the pile diameters will be no greater than 3.5 m and a maximum hammer energy of 2,300 kJ will be used to install the piles. The indicative pile-driving parameters are presented in Table 4.

4.28 A total of 950 km of HVAC inter array cabling will connect the wind turbines to the offshore collector platforms. A further 320 km of HVAC inter-platform cables will connect the collector platforms to the converter platform. From the converter platform an estimated 420 km of HVDC export cable will connect Creyke Beck A to the transition bays at the onshore landfall. An estimated 378 km of cable will connect Creyke Beck B to landfall. Cables will be trenched and buried at depths up to 3 m. It is estimated that physical impacts from trenching and laying of cables are largely restricted to a width of 2 to 3 m but for the purposes of this assessment it is estimated impact from trenching will occur along a 10 m corridor of seabed (BERR 2008). Consequently, it is estimated that up to 16.9 km^2 of seabed could be impacted during trenching of the cables at Creyke Beck A and 16.5 km^2 at Creyke Beck B. Cable protection, typically using rock, gravel or concrete mattresses, may be required along a total of 2.89 km^2 of seabed at Creyke Beck A and 2.77 km^2 at Creyke Beck B. Additional cable protection will be required at cable crossings. It is estimated that the total footprint of cable crossings will be 0.99 km^2 at Creyke Beck A and 0.123 km^2 at Creyke Beck B (Forewind 2013a).

Table 4: Indicative pile-driving parameters for Creyke Beck A and B (Source: Forewind 2013a, 2017a).

Parameter	Monopile	Multileg	Platform
Maximum pile diameter (m)	10	3.5	2.744
Maximum number of driven piles per foundation	1	6	24
Maximum hammer energy (kJ)	3,000	2,300	1,900
Maximum blows per minute	40	40	40
Indicative soft start duration	0.5	0.5	0.5
Indicative pile-driving time (excluding soft start) (hrs)	3	18	72
Estimated total blows per pile	8,400	8,400	8,400

Dogger Bank Teesside A and B Offshore Wind Farms

4.29 The Dogger Bank Teesside A and B offshore wind farms (hereafter Teesside A and Teesside B) were consented on 4 August 2015 (Infrastructure Planning 2015b). The wind farms are located in Round 3 Offshore Wind Farm Zone; Zone 3: Dogger Bank. The Zone is located between 125 km and 290 km off the coast of Yorkshire.

4.30 The offshore construction start date for either development is currently unknown. However, work on the projects must start no later than August 2022 (Forewind 2014, Infrastructure Planning 2015b). The minimum construction period is three years and the maximum is six. The Teesside B development zone lies outwith the boundaries of the SCI, although export cables may cross the site.

4.31 The Teesside A offshore wind farm is located at its closest point 196 km from shore and covers an area of 560 km^2. The Teesside B offshore wind farm is located, at its closest point, 165 km from shore and covers an area of 593 km^2. Both developments comprise up to 200 wind turbines, four offshore HVAC collector platforms, one HVDC offshore converter platform and two accommodation platforms. Up to five meteorological masts may be installed. The gross electrical output capacity for each wind farm A is up to 1.2 GW (Infrastructure Planning 2015b, Forewind 2014, 2018).

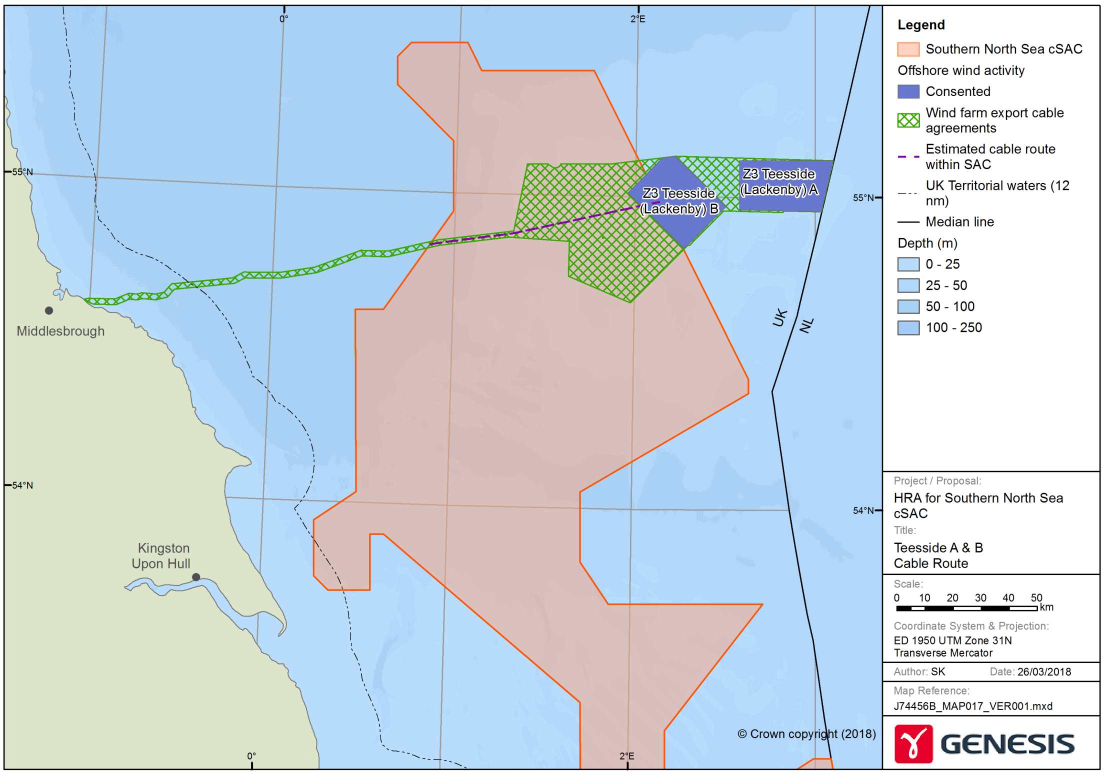


Figure 8: Location of Teesside A and B offshore wind farms and the Southern North Sea SCI.

4.32 The wind turbines to be installed at Teesside A and B have not been finalised but range in generating capacity from between 6 MW or 10 MW, although larger capacity turbines could be installed. A range of turbine foundations are being considered and cover an array of monopole, multi-leg and gravity based options. Within the range of monopole foundations there are monopiles that will be driven and/or drilled into the seabed. The foundation options for the associated offshore platforms include multi-leg, jack-up and gravity based (Forewind 2014).

4.33 Under the DCO the combined maximum area of seabed permitted to be impacted by the wind turbine foundations, including any scour protection, is 1.11685 km^2. For the associated platforms and substations a total area of seabed permitted to be impacted is 0.883 km^2 (Infrastructure Planning 2015b).

4.34 In the event monopiled foundations are used the maximum pile diameter is 10 m and will be installed using a maximum hammer energy of 3,000 kJ. If multi-leg foundations are used the pile diameters will be no greater than 3.5 m and a maximum hammer energy of 2,300 kJ will be used to install the piles (Forewind 2017). The indicative pile-driving parameters are presented in Table 5.

4.35 A total of 950 km of HVAC inter array cabling will connect the wind turbines to the offshore collector platforms. A further 320 km of HVAC inter-platform cables will connect the collector platforms to the converter platform. From the converter platform an estimated 573.2 km of HVDC export cable will connect Teesside A to the onshore landfall. An estimated 484.4 km of cable will connect Teesside B to landfall. Cables will be trenched and buried at depths of up to 3 m. Based on an impact along a 10 m wide corridor it is estimated that up to 18.4 km^2 of seabed could be impacted during trenching of the cables at Teesside A and 17.5 km^2 at Teesside B. Cable protection, typically using rock, gravel or concrete mattresses, may be required along a total of 2.00 km^2 of seabed at both Teesside A and B. Additional cable protection will be required at cable crossings. It is estimated that the total footprint of cable crossings will be 0.245 km^2 at both Teesside A and B (Forewind 2014).

Table 5: Indicative pile-driving parameters for wind turbines at Teesside A and B (Source: Forewind 2014).

Parameter	Monopile	Multileg	Platform
Maximum pile diameter (m)	12	3.5	2.75
Maximum number of driven piles per foundation	1	6	24
Maximum hammer energy (kJ)	3,000	2,300	1,900
Maximum blows per minute	40	40	40
Indicative soft start duration	0.5	0.5	0.5
Indicative pile-driving time (excluding soft start) (hrs)	3	18	72
Estimated total blows per pile	8,400	8,400	8,400

5 QUALIFYING FEATURES OF THE SITE

5.1 The qualifying feature of the Southern North Sea SCI is the Habitats Directive Annex II species harbour porpoise (*Phocoena phocoena*) (JNCC and NE 2016).

Harbour Porpoise

5.2 The harbour porpoise is the smallest and most abundant cetacean species in UK waters. They occur widely across shelf waters predominantly either individually or in small groups but larger aggregations have been reported (Defra 2015), with group sizes varying with season (Clark 2005). Although harbour porpoise have a very broad distribution across the United Kingdom

Continental Shelf (UKCS) they occur predominantly over the continental shelf. Higher densities occur in areas of up-wellings and strong tidal currents and in water depths of predominantly between 20 and 40 m (Clark 2005, Whaley 2004). Their distribution may also be strongly correlated with seabed type, with area of sandy gravel being preferred and this may be linked to prey availability (Clark 2005).

5.3 Data from European Seabirds at Sea (ESAS) and other databases indicate harbour porpoise are widespread across the North Sea and adjacent waters (Reid *et al*. 2003) (Figure 9). It is recognised that ESAS data presented is over 15 years old and collected over many years. The distribution of harbour porpoise may have changed since the time the data were collected. Data from the Small Cetacean Abundance in the North Sea (SCANS) surveys undertaken since the ESAS data were collected indicate that that there may have been a southward shift in the distribution of harbour porpoise in the North Sea. In the early 1990's harbour porpoise were widespread but appear to have occurred predominantly around eastern Scotland and the northern North Sea to the southern North Sea (Figure 10) (Hammond *et al*. 2013). Since the 1990's harbour porpoise continue to be widespread across the North Sea but densities have increased in the southern and central North Sea. The cause of this apparent change in the distribution of harbour porpoises across the North Sea is unclear but may be related to changes in prey availability (IAMMWG *et al.* 2015).

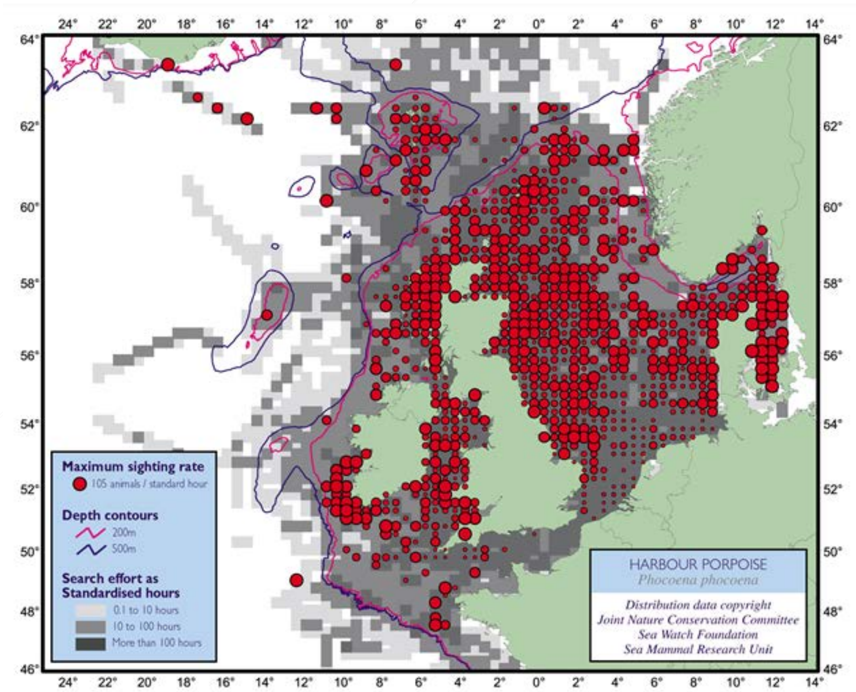


Figure 9: Harbour porpoise distribution in the North Sea and adjacent waters (Reid *et al.* 2003).

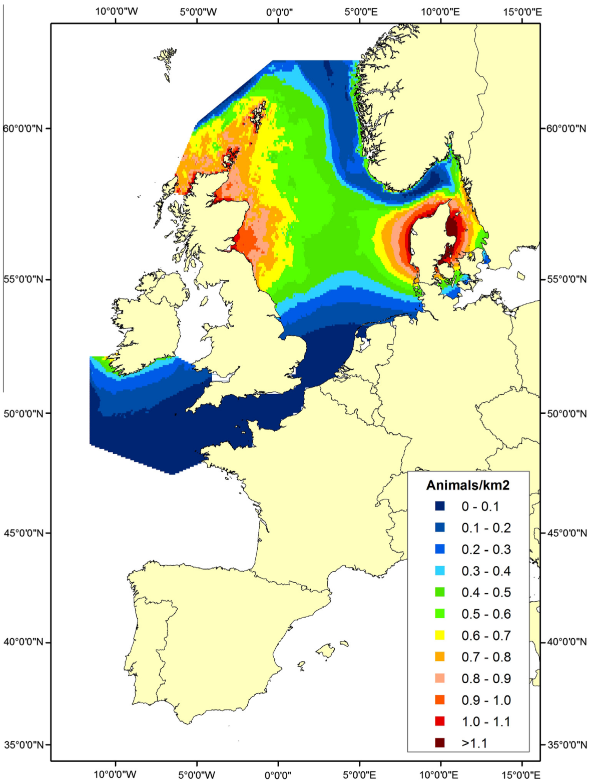


Figure a.

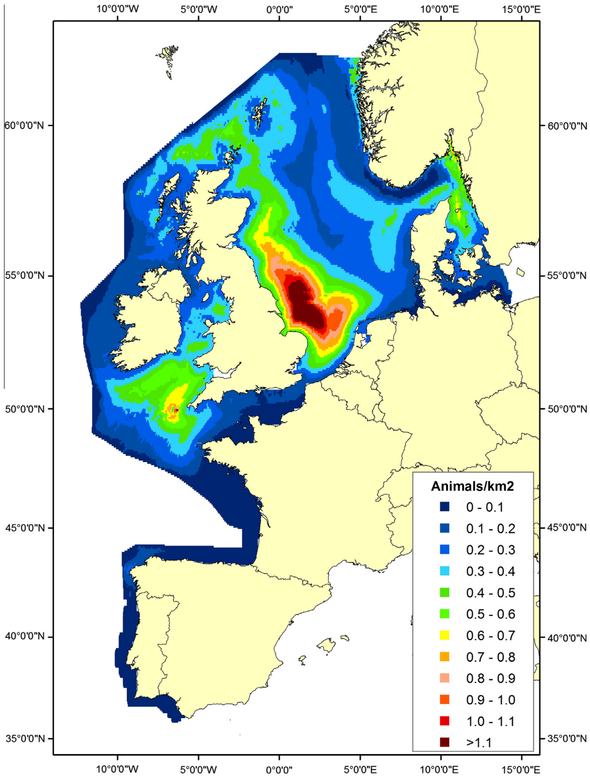


Figure b.

Figure 10: a) Predicted surface density for harbour porpoise in 1994. b) Predicted surface density for harbour porpoise in 2005 (Source Hammond *et al.* 2013).

5.4 Following the completion of the most recent SCANS surveys (SCANS III), a revised approach has been used to estimate the number of harbour porpoise and other cetaceans, from the SCANS survey data. The outcome of this has been an increase in the estimated number of harbour porpoises occurring within the SCANS survey area (Hammond *et al*. 1995, Hammond 2006, Hammond *et al.* 2017). The latest estimated revised estimated harbour porpoise populations within the whole of the SCANS survey area is 424,245 (CV 313,151 – 596,827). Since 1994 the population of harbour porpoises within the SCANS surveyed area has remained relatively stable (Figure 11).

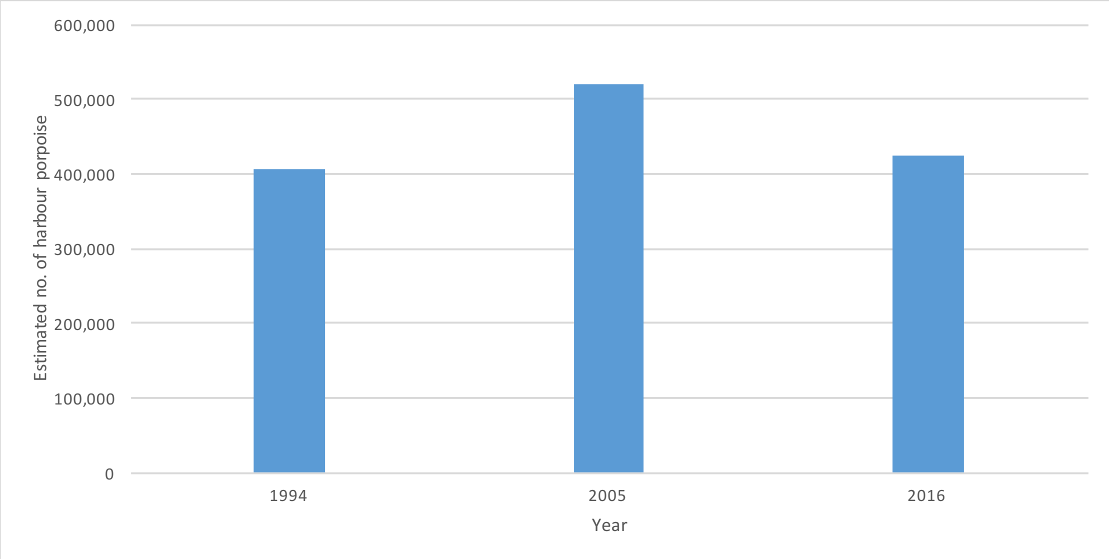


Figure 11: Estimated number of harbour porpoise within the SCANS survey area recorded during SCANS I, II and III surveys (Hammond *et al.* 2017).

5.5 The harbour porpoise within the eastern North Atlantic is considered to be a single biological population (IAMMWG 2015). However, in order to assist in the conservation of the species, their range within the north-east Atlantic is divided into areas called Management Units. The area of each Management Unit has been determined based on both the biological parameters of the species and the political or human activities within the area. The Management Units provide an indication of the spatial scales at which impacts of plans and projects alone, cumulatively and in-combination need to be assessed (IAMMWG 2015).

5.6 There are three Management Units identified for harbour porpoise in the north-east Atlantic, of which, the Southern North Sea SCI lies within North Sea Management Unit (Figure 12). The harbour porpoise population within the North Sea Management Unit was originally estimated to be 227,298 (176,360 – 292,948) individuals (IAMMWG 2015). However, following the revision of the regional SCANS harbour porpoise population figures, the population of harbour porpoise within the North Sea Management Unit has also been revised and is now estimated to be 333,808 individuals (JNCC 2017c).

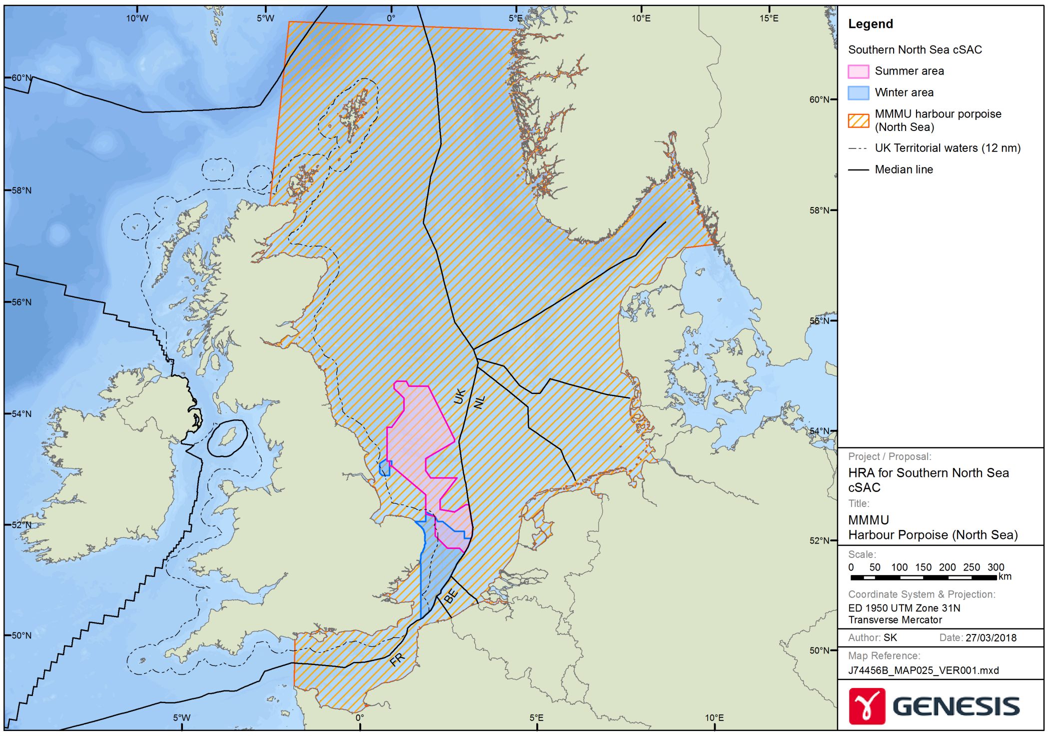


Figure 12: North Sea Management Unit for harbour porpoise as defined by the IAMMWG.

5.7 The SAC selection assessment document estimates that the site holds 17.5% of the UK part of North Sea Management Unit harbour porpoise population with an estimated population of 18,500 individuals (98% C.I. 11,864 – 28,899) (JNCC 2017a). This was equivalent 8.1% of the whole North Sea Management Unit population at the time (Hammond *et al*. 2013, IAMMWG 2015). Based on the latest North Sea Management Unit population of 308,666 individuals the harbour porpoise population within the SCI may be 26,237 individuals. This estimated population of harbour porpoise is recognised to have been derived from data collected in 2005 and 2016 during a single month and that the harbour porpoise population within the SCI will vary across seasons and years.

5.8 Harbour porpoise densities vary seasonally and across the site (Evans and Teilmann 2009). Site-specific surveys undertaken by wind farm developers have shown considerable variation in the spatial and temporal distribution of harbour porpoises across years (e.g. Forewind 2013a, SMart Wind 2017). Typically, peak abundance has been reported to occur between May and July at sites across the Dogger Bank area and between September and April at sites further south (e.g. Forewind 2014, SMart Wind 2015a, EAOWL 2015b). Lowest reported abundance across nearly all sites occurs between November and February, although the poorer survey conditions that occur predominantly during the winter months may be a contributing factor in the lower number of harbour porpoise recorded during this period.

5.9 Based on data in the Joint Cetacean Protocol (JCP) highest densities in the central and northern area of the SCI occur during the summer period with modelled harbour porpoise densities greater than 3.0 per km^2 occurring widely (Figure 13a). During the winter period the distribution of harbour porpoise in the southern North Sea changes, with reduced densities over the central and northern area but an increase in densities in nearshore waters and the southern part of the SCI (Figure 13b) (Heinänen & Skov 2015).

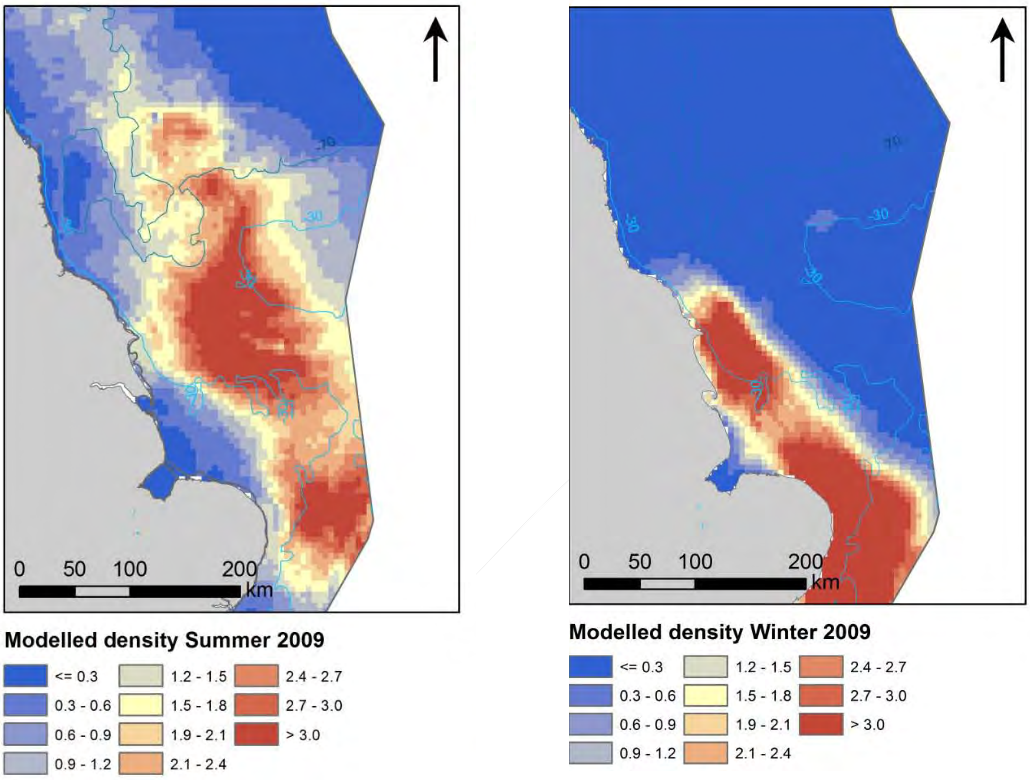


Figure a. Figure b.

Figure 13: a) Estimated summer densities of harbour porpoise in the southern North Sea. b) Estimated winter densities of harbour porpoise in the southern North Sea. (Source: Heinänen & Skov 2015).

5.10 Surveys undertaken across the southern North Sea, including areas within and encompassing the SCI, have reported lower densities of harbour porpoise than that estimated from JCP data. Densities reported from SCANS III surveys are from between 0.888 ind./km^2 in SCANS block O and 0.607 ind./km^2 in SCANS block L (Hammond *et al.* 2017). Similarly, data obtained across the Dogger Bank area in 2011 recorded a density of 1.88 ind./km^2 (Gilles *et al.* 2012). Data obtained from surveys undertaken at proposed offshore wind farms located within or adjacent to the SCI indicate densities vary across the site and across seasons. Mean densities reported range from 0.11 ind./km^2 at Triton Knoll offshore wind farm including a 1 km buffer to 2.87 ind./km^2 within the Hornsea subzone 3 wind farm area plus a 4 km buffer (Table 6).

5.11 It is recognised that due to differing survey methods and data analysis methods, a direct comparison of harbour porpoise densities across sites is not possible. However, it is clear that mean densities of harbour porpoise vary considerably across the SCI with a general trend of relatively lower densities occurring in the southern area of the SCI compared with the northern area. All sites have reported mean densities of harbour porpoise of less than 3.0 ind./km^2, with the majority of sites recording less than 2.0 ind./km^2.

Table 6: Reported mean densities of harbour porpoise recorded within or adjacent to the Southern North Sea SCI.

Location	Harbour porpoise mean density (ind./km^2)	Survey method	Source
Hornsea subzone 3 + 4km buffer	2.87	Acoustic	SMart Wind (2017)
Hornsea subzone 1 + 4 km buffer	2.54	Boat	SMart Wind (2013)
Hornsea subzone 2 + 4 km buffer	2.39	Acoustic	SMart Wind (2015a)
Hornsea Zone + 10 km buffer	2.22	Acoustic	SMart Wind (2015a)
Hornsea subzone 2 + 4 km buffer	1.88	Boat	SMart Wind (2015a)
Dogger Bank and adjacent waters	1.82	Aerial	Gilles (2012)
Hornsea subzone 3 + 4 km buffer	1.77	Boat	SMart Wind (2017)
Hornsea Zone + 10 km buffer	1.72	Boat	SMart Wind (2015a)
Norfolk Vanguard East	1.26	Aerial	Vattenfall (2017)
SCANS III block O	0.89	Aerial	Hammond *et al.* (2017)
Norfolk Vanguard West	0.79	Aerial	Vattenfall (2018)
Dogger Bank Zone	0.64 / 0.71	Aerial	Forewind 2014
Teesside A & B	0.64	Aerial	Forewind 2014
SCANS III block L	0.61	Aerial	Hammond *et al.* (2017)
Thanet Extension	0.59 / 0.61	Aerial	VWPL (2017, 2018)
Creyke Beck A & B	0.57	Aerial	Forewind 2013a
Southern North Sea SCI [1]	0.50 / 0.71	Boat & Aerial	JNCC (2017b)
Greater Wash Area	0.38	Aerial	Sparling (2011)
East Anglia Three + 4 km buffer	0.29	Aerial	EAOWL (2016)
East Anglia One + 4 km buffer	0.19	Aerial	EAOWL (2012)
Triton Knoll	0.11	Aerial	TKOWFL (2011)

1 – Note, the Southern North Sea SCI density is obtained by dividing the estimated harbour porpoise population within the SCI of 18,500 (JNCC 2017a) or 26,237 individuals (See para 5.7) with area of the SCI of 36,951 km^2.

5.12 Tagging studies undertaken in Denmark indicate that harbour porpoises are highly mobile and range widely in the North Sea, with individuals tagged in the Skagerrak travelling up to 100 km per day, with a mean distance of 24.5 km per day (Sveegaard 2011). Individuals tagged in Danish waters were recorded off the east coasts of England and Scotland (Sveegaard 2011).

5.13 Harbour porpoise swimming speeds vary with the highest recorded swimming speeds being 4.3 m/s (Otani *et al.* 2000). Mean recorded speeds are typically around 1 m/s (Otani *et al.* 2000, Kastelein *et al.* 2018). When disturbed by noise harbour porpoise can increase swimming speeds with increasing sound levels. Studies using playback experiments of pile-driving sounds have reported increases in swimming speed from an average of 1.2 m/s to 2.0 m/s at sound levels of 154 dB re 1 μPa that were sustained for at least 30 minutes (Kastelein *et al*. 2018).

5.14 Although harbour porpoises may dive to depths of up to 226 m and remain submerged for up to five minutes, they more frequently undertake relatively shallow dives of a short duration, with a mean depth of 14 m and duration of 44 seconds (Santos and Pierce 2003, Otani *et al*. 1998, 2000). Studies undertaken on 14 tagged harbour porpoise in Danish and adjacent waters reported that on average harbour porpoise spend 55% of the time in the upper 2 m of the surface waters. The most frequent dive depths were between 14 m and 32 m, with the maximum depth dived of 132 m. The number of dives per hour increased from an average of 29 dives hr^{-1} between April and August to 43 dives hr^{-1} in October and November when it was presumed that higher levels of foraging activity occurred to compensate for the higher energy requirements required during the cooler winter period (Teilmann *et al*. 2007).

5.15 Harbour porpoise use echolocation to detect and track individual prey and are opportunistic feeders, foraging close to the seabed or near the sea surface, preying on a wide range of fish species including, herring (*Clupea harengus*), whiting (*Merlandius merlangus*), Gadoids spp. sprats (*Sprattus sprattus*) gobi (*Pomatoschistus minutus*) and sandeels (*Ammodytes* spp.), and their prey will vary during and between seasons (DeRuiter 2008, Santos and Pierce 2003, IAMMWG *et al.* 2015). The prey of harbour porpoise may change over time with a reported long-term shift in prey from clupeid species to sandeels and gadoid species (IAMMWG *et al*. 2015). Indicating that harbour porpoise may be opportunistic feeders capable of feeding on a variety of species.

5.16 Studies undertaken in Denmark indicate that their local distribution may be correlated with prey availability (Sveegaard 2011). Due to the relatively high metabolic rate of harbour porpoise and the relatively small size of their predominant prey it has been suggested that harbour porpoise require reliable source of food and frequent food consumption in order to maintain their body weight, with increased consumption in cooler environments (Kastelein *et al*. 1997, Wisniewska *et al*. 2016, 2018a).

5.17 Harbour porpoise have a maximum life expectancy of 24 years, with an average life expectancy of around 12 years in UK waters (Lockyer 2003, Learmouth *et al.* 2014) Females become sexually mature at between three and five years old (Lockyer 2003, Learmouth *et al*. 2014). Breeding is thought to occur primarily during the summer months between May and September, particularly in August, with calving 10 months later. Calves are nursed for eight to ten months but may remain with the mother until a new calf is born (Defra 2015, Lockyer 2003, Weir *et al*. 2007).

5.18 The range at which marine mammals, including harbour porpoise, may be able to detect sound arising from offshore activities depends on the hearing ability of the species and the frequency of the sound. Other factors that can affect the potential impact include ambient background noise, which can vary depending on water depth, seabed topography and sediment type. Natural conditions such as weather and sea state and existing sources of human produced sound can also reduce the auditory range.

5.19 Porpoises are generally considered to be 'high frequency' specialists with a relatively poor ability to detect lower frequency sounds (Southall *et al.* 2007). Studies undertaken on captive harbour porpoises indicate that porpoises have a functional hearing range of between 250 Hz and 180 kHz with their best hearing between 16 to 140 kHz and their maximum sensitivity between 100 and 140 kHz. It is within the frequency range of 130 to 140 kHz that harbour porpoise echolocate (Miller and Wahlberg 2013).

5.20 Their ability to detect sound below 16 kHz or above 140 kHz falls sharply (Kastelein *et al.* 2012, 2015, Southall *et al*. 2007). Harbour porpoise are therefore most sensitive to sound sources between 16 to 140 kHz and, although audible, they are unlikely to be sensitive to sound either above or below those frequencies.

5.21 Harbour porpoise use echolocation to communicate and detect prey. Reported sound levels produced range from between 166 to 194 re: 1 μPa (rms SPL) and 178 and 205 dB re. 1 μPa (peak – peak SPL), with a mean level of 191 dB re. 1 μPa (peak – peak SPL) and within the peak frequency range of 110 to 150 kHz (Villadsgaard, *et al*. 2007, Miller & Wahlberg 2013, MMO 2015).

Fish

5.22 Fish are not qualifying species for the Southern North Sea SCI. However, potential impacts on fish that are prey for harbour porpoise could affect the integrity of the site by reducing their prey base (JNCC and NE 2016).

5.23 The specific prey for harbour porpoise within the SCI is unknown. However, harbour porpoise prey on a variety of fish that are known to occur within the site, including gobies, sandeel, whiting, herring and sprat (JNCC and NE 2016).

5.24 The most abundant fish caught in surveys undertaken within East Anglia Zone included sprat, solenette (*Buglossidium luteum*), sand goby (*Pomatoschistus minutus*), lesser weaver (*Echiichthys vipera*), whiting, and greater sandeel (*Hyperoplus lanceolatus*) (EAOWL 2015b). Similarly, surveys undertaken within the former Hornsea Zone and across Dogger Bank recorded whiting, dab (*Limanda limanda*), plaice (*Pleuronectes platessa*), solenette and grey gurnard (*Eutrigla gurnardus*) herring and sprats. Greater sandeel and lesser sandeel spp. were also recorded, with more across the Dogger Bank than over the former Hornsea Zone (Forewind 2013a, SMart Wind 2015a, 2017).

5.25 Surveys across wind farm areas have shown seasonal variations in some species. For example a higher abundance of herring, sprats and whiting occurred across the former Hornsea Zone during the spring than in the autumn and dab (*Limanda limanda*) were more abundant during the autumn (SMart Wind 2015a).

5.26 Fish species most frequently recorded during surveys include species typically found in sand, course sand, mixed sand habitats, e.g. sand goby and sandeel spp. Whiting occur over both mud and gravel seabeds as well as sand and rock (Barnes 2008). Herring spawning grounds are restricted to sandy gravel and gravel habitats that occur within the SCI and sandeels preferably spawn in gravelly sand habitats.

5.27 The impacts on fish from offshore wind farms are primarily related to noise arising during the construction period. Fish hearing is based on detecting particle motion directly stimulating the inner ear. However, those with swim bladders are also able to detect pressure waves and can detect a wider range of frequencies and sounds of lower intensity than fishes without swim bladders (Popper 2003). Fish with swim bladders and possess a coupling mechanism between the swim bladder and the auditory system, e.g. herring and sprats, are recognised to be hearing specialists. Fish that have swim bladders but lack a mechanised coupling mechanism or do not have swim bladders, e.g. sandeel spp. are considered hearing generalists and have a relatively lower sensitivity to sound than fish that have swim bladders and a coupling mechanism. Those without, e.g. sandeels, are considered to have a relatively low sensitivity to noise. Most fish with swim bladders are able to detect sound within the 100 Hz to 2 kHz range, those without swim bladders are unlikely to detect sound above 400 Hz (Popper 2012).

5.28 Studies on the behaviour of fish from pile-driving, largely using play-back experiments, have reported a range of behavioural responses including avoidance behaviour, changes in swimming speed and direction (e.g. Hawkins 2014, Mueller-Blenkle *et al.* 2010) and reduced antipredator responses (Everley *et al.* 2016).

5.29 Sandeels are not considered to have sensitive hearing (Popper *et al.* 2014). Studies undertaken using airguns indicate that sandeels have distinct but weak reactions to seismic airguns with initial startle responses reducing in frequency with on-going noise, and no increased mortality was detected (Hassel *et al.* 2004).

5.30 There are limited studies assessing potential impacts on eggs and larvae. Results indicate that there is potential for increase in mortality when larvae are exposed to an airgun sound source with peak sound pressure levels of 220-242 dB re 1 μPa^2 (unknown measure), but only within 5 m of the airgun (Popper *et al*. 2014).

5.31 Although fish occur widely throughout the marine environment, many species are reliant on specific habitats, e.g. sediment types. Impacting on a specific habitat type within the SCI upon which prey species for harbour porpoise rely could impact on the harbour porpoise.

5.32 Other impacts that could affect the prey of harbour porpoise include temporary impacts on the seabed during construction, e.g. cable laying, permanent loss of habitat due to the physical presence of the wind turbines and other associated infrastructure, electromagnetic fields (EMF) from cables and changes in fishing activity around the turbines.

5.33 Electromagnetic fields arising from cables could impact on fish including feeding behaviour, predator avoidance and navigation (Gill and Taylor 2001, Normandeau *et al*. 2011). Species recognised as being most sensitive include elasmobranchs (sharks and rays), lampreys, eels (*Anguilla anguilla*), cod (*Gadus morhua*), plaice and salmon (*Salmo salar*) (Gill *et al*. 2005). Electromagnetic fields are highest within a few metres of the cable and rapidly reduce to very low levels typically within 10 m to 20 m of the cable (Normandeau *et al*. 2011).

Habitats

5.34 There are no qualifying habitats within the SCI. However, habitats within the SCI relevant to harbour porpoise relate to characteristics of the seabed and water column. One of the effects from disturbance is the loss of habitat available to harbour porpoise and the higher densities of porpoises within the site compared to other areas of the UK are linked to the habitats within the site that provide good feeding opportunities (JNCC and NE 2016).

5.35 The site covers an area of 3,695,054 ha (36,951 km^2) (JNCC 2016). Water depths across the site range from between 10 m and 75 m. At the Management Unit level, harbour porpoise are reported to prefer water depths of between 30 m and 50 m and occur most frequently in stable stratified waters with current speeds of between 0.4 and 0.6 m/s and over courser sediments (JNCC and NE 2016).

5.36 The majority of the substrate types within the SCI are categorised as sublittoral sand and sublittoral coarse sediment (JNCC 2017a). Seabed surveys across wind farm sites within the SCI indicate that the predominant seabed sediment types are sandy or sand with gravel and are typical of the SCI as a whole (Table 7).

Table 7: Predominant sediments recorded at offshore wind farms within the SCI.

Location	Predominant Sediment	Source
Creyke Beck A & B (Tranche A)	Sand, gravel and sandy gravel.	Forewind (2013)
Teesside A & B (Tranche B)	Sand, slightly gravelly sand.	Forewind (2014)
Hornsea Subzone 1	Sand, sandy gravel and gravelly sand.	SMart Wind (2013)
Hornsea subzone 2	Sand, slightly gravelly sand, gravelly sand, sandy gravel, gravel.	SMart Wind (2015a)
East Anglia 1	Slightly gravelly sand, gravelly sand, sand, sandy gravels.	EAOWL (2012)
East Anglia 3	Medium sand.	EAOWL (2015a)
Greater Gabbard	Sand, slightly gravelly sand, gravelly sand, sandy gravel, muddy sandy gravel.	GGOWL (2005)
Galloper	Gravelly sand, sandy gravel.	GWFL (2011)
Thanet	Sand, silty sand, gravelly sand, clayey sand.	TOW (2005)

6 EXISTING ACTIVITIES

6.1 The following section identifies the existing activities that are undertaken within or adjacent to the SCI that could cause ongoing impacts on harbour porpoise either directly or indirectly (from impacts on their habitat or prey). These activities have the potential to cause an in-combination impact with the consented offshore wind farms that are subject to this assessment.

6.2 Existing activities that have potential to occur within or adjacent to the SCI and could cause impacts to which harbour porpoise are considered sensitive are identified in the *Draft Conservation Objectives and Advice on Activities* (JNCC and NE 2016) and presented in Table 8. Activities considered to have low risk of an impact are not considered further as either there is limited, if any, overlap in space and time between the pressures and harbour porpoise or there is no direct evidence of an impact (JNCC and NE 2016).

Table 8: Activities occurring within/near to the Southern North Sea SCI to which harbour porpoise is considered sensitive (from JNCC and NE 2016).

Activity	Pressure	Current level of impact risk (across UK waters)
Commercial fisheries with bycatch (predominantly static nets)	Removal of non-target (bycatch) species	High
Discharge/run-off from land-fill, terrestrial/ offshore industries	Contaminants	High
Commercial fisheries (reduction in prey resources)	Removal of target species	Medium
Noise from shipping, drilling, dredging and disposal, aggregate extraction, pile-driving, acoustic surveys, underwater explosion, military activity, acoustic deterrent devices and recreational boating activity	Anthropogenic underwater sound	Medium
Shipping, recreational boating, tidal energy installations	Death or injury by collision	Medium/Low
Agriculture, aquaculture, sewage	Nutrient enrichment	Low
Agriculture, aquaculture, sewage	Organic enrichment	Low
Waste disposal – navigational dredging (capital maintenance)	Physical change (to another seabed type)	Low
Bridges, tunnels, dams, installations, presence of vessels (shipping recreation)	Water flow (tidal current) changes – local	Low
Bridges, tunnels, dams, installations, presence of vessels (shipping recreation)	Litter	Low
Terrestrial and at-sea disposal	Barrier to species movement	Low
Sewage	Introduction of microbial pathogens	Low

High = Good evidence of a significant impact.

Medium = Some evidence of an impact in UK waters.

Low = No direct evidence of an impact in UK waters.

Oil and Gas Industry

6.3 There is a medium risk of an impact from activities associated with the oil and gas industry to harbour porpoise across the North Sea (Table 8), i.e. there is some evidence of an impact on harbour porpoise from noise arising from oil and gas activities in UK waters (JNCC and NE 2016). The oil and gas industry undertakes a number of activities that could cause an in-combination impact. These include noise from geophysical seismic surveys, noise from pile-driving and physical impacts on the seabed.

Oil and gas infrastructure

6.4 There is long history of oil and gas activities within the boundaries of the Southern North Sea SCI. Since 1965, when the first well was spudded (first drilled), there has been extensive oil and gas development with a total of 120 installations installed within the SCI. A further six platforms are currently being planned. The vast majority (94%) of all the installations within the SCI are located in the 'summer' area of the site and all those currently being planned are also in the 'summer' area (Figure 14).

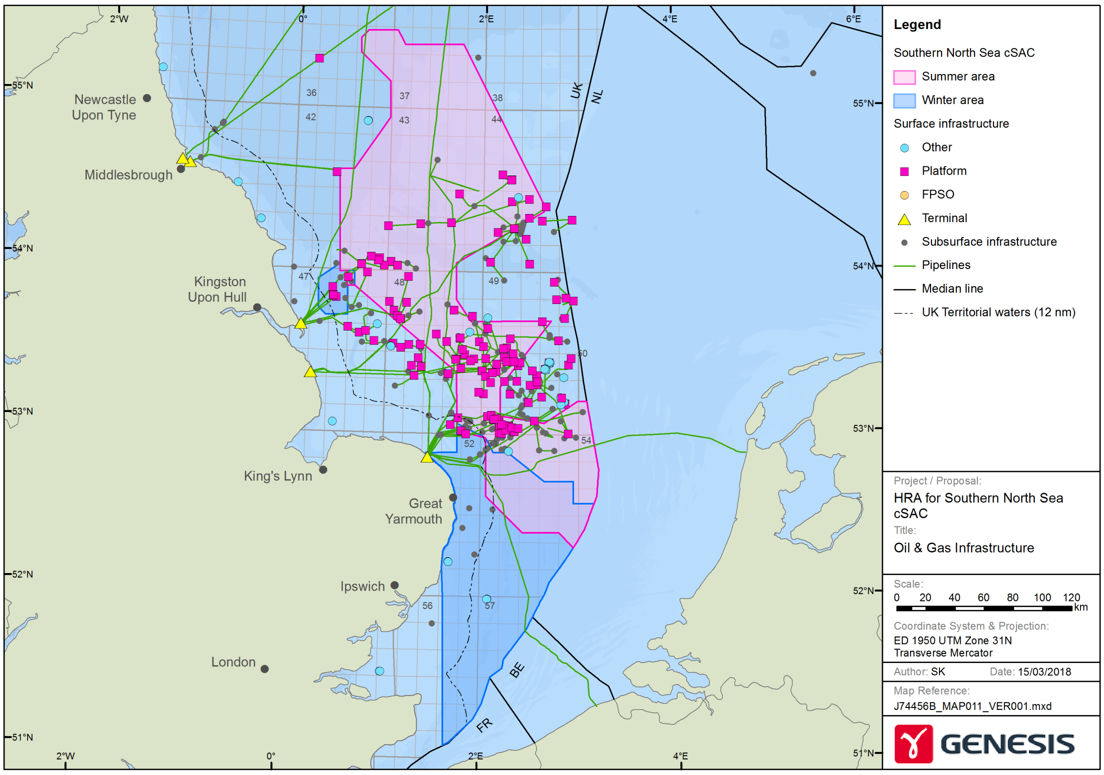


Figure 14: Existing oil and gas infrastructure within the Southern North Sea SCI.

6.5 In addition to the installations, a total of approximately 4,016 km of pipelines and umbilicals have also been laid in the site, of which 89% are within the 'summer' area (Table 9) (UKoilandgas 2018).

6.6 Other infrastructure associated with oil and gas activities installed or placed on the seabed within the SCI includes wellheads, manifolds and rockberm. Since 2005 a total of 88 items of subsea equipment have been installed and a further five items are currently being planned. Over the same period piling events associated with the oil and gas industry occurred on 22 occasions within the SCI (UKoilandgas 2018).

6.7 The placement of infrastructure on the seabed impacts on the seabed habitats and can cause a permanent or semi-permanent loss of habitat within the SCI. Based on a sample size of 36 installations within the SCI, the average area of an oil and gas platform located within the SCI is 812 m^2 (range 306 m^2 – 1,972 m^2). Assuming that the average area of a platform is equivalent to loss of seabed habitat for harbour porpoise, then an estimated 97,440 m^2 (0.1 km^2) of seabed habitat may be impacted by existing oil and gas installations within the SCI. This is precautionary as the physical footprint on the seabed from an installation is considerably smaller than the area of the platform as a whole. The area of other infrastructure on the seabed is unknown but will be considerably smaller than any oil and gas installation.

6.8 Noise arising from drilling is recognised as having the potential to cause behavioural changes in harbour porpoise (IAMMWG *et al*. 2015). Since 1965, a total of 1,373 wells have been drilled within the boundaries of the SCI. Of those, 804 were production wells and the others were either exploration or appraisal wells (UKoilandgas 2018). The maximum number of wells drilled in any single year was 72 in 1989 (Figure 15). A total of 1,279 wells have been spudded in the 'summer' area and 52.1% of those were spudded between April and September. Within the winter area a total of 130 wells have been spudded, of which 46.2% were spudded between October and March (Table 9).

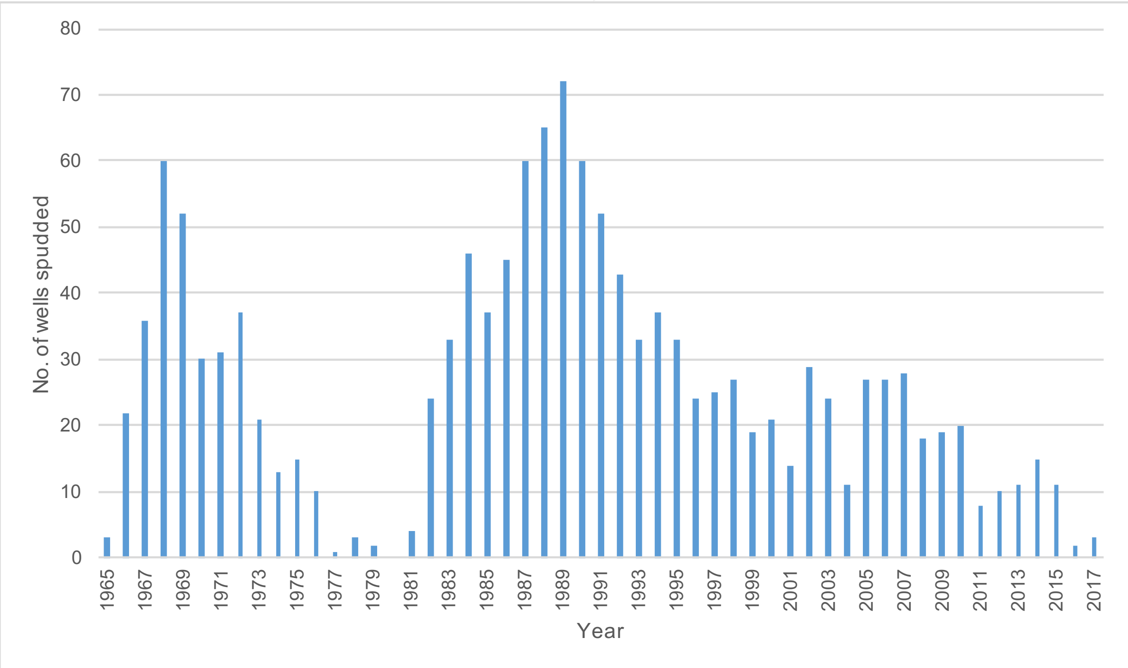


Figure 15: Number of wells spudded each year within the Southern North Sea SCI (Source UKoilandgas 2018).

Table 9: Number of wells spudded and seasonal occurrence of spud dates within the SCI between 1965 and 2017.

Total number of well drilled (1965 – 2017)	'Summer' area	April – September	'Winter' area	October - March
1,373	1,279	52.1%	130	46.2%

Note – Wells spudded in the 'summer' and 'winter' overlap zone are counted for each zone and therefore the combined 'summer' and 'winter' total is higher than the actual number of wells spudded.

Oil and gas pile-driving

6.9 Piling by the offshore oil and gas industry predominantly entails the installation of relatively small diameter piles used for the installation of platforms, anchors and subsea infrastructure, e.g. manifolds. For example, the piles used to install the four Cygnus platforms and the Kelvin platform were all less than 1.5 m in diameter (ConocoPhillips 2006, GDF SUEZ 2011). Typically, the hammer energy used to install the piles is relatively low below 1,000 kJ.

Oil and gas geophysical seismic surveys

6.10 Seismic surveys have regularly been undertaken within the SCI over the last 50 years, with a total of 65 surveys undertaken within the SCI between 2005 and 2014. The majority of surveys during this period took place in the 'summer' area of the SCI, where most oil and gas activity has occurred (Figure 16).

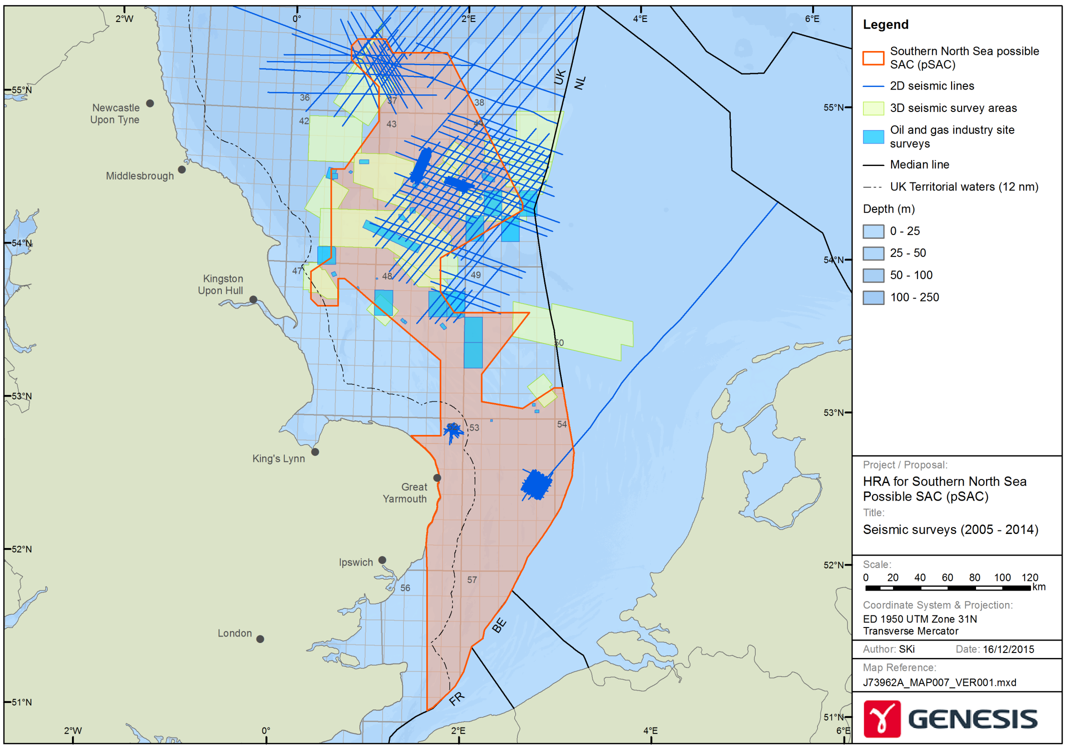


Figure 16: Oil and gas industry related seismic surveys undertaken within the Southern North Sea SCI between 2005 and 2014.

6.11 Impulsive sound arising from all oil and gas related activities, e.g. seismic airgun and pile-driving has occurred in the majority of licence blocks within the boundaries of the SCI. The number of days during which impulsive sounds have occurred provides an indication of the level of historical activity undertaken within each oil and gas licence block prior to the site becoming designated. It provides an historical baseline of impulsive noise that may have impacted on harbour porpoise but has not significantly affected the population of harbour porpoise, for which the conservation status is considered to be favourable (JNCC 2013).

6.12 The majority of the historical pulsed sound arising from oil and gas related activities occurs in the northern half of the SCI with half the blocks within the SCI receiving less than 5 pulse block days over an 11 year period (2005 – 2015)[3]. The highest number of pulsed block days in any single block was between 70 and 75, an average of less than seven days per year (Figure 17 and Table 10).

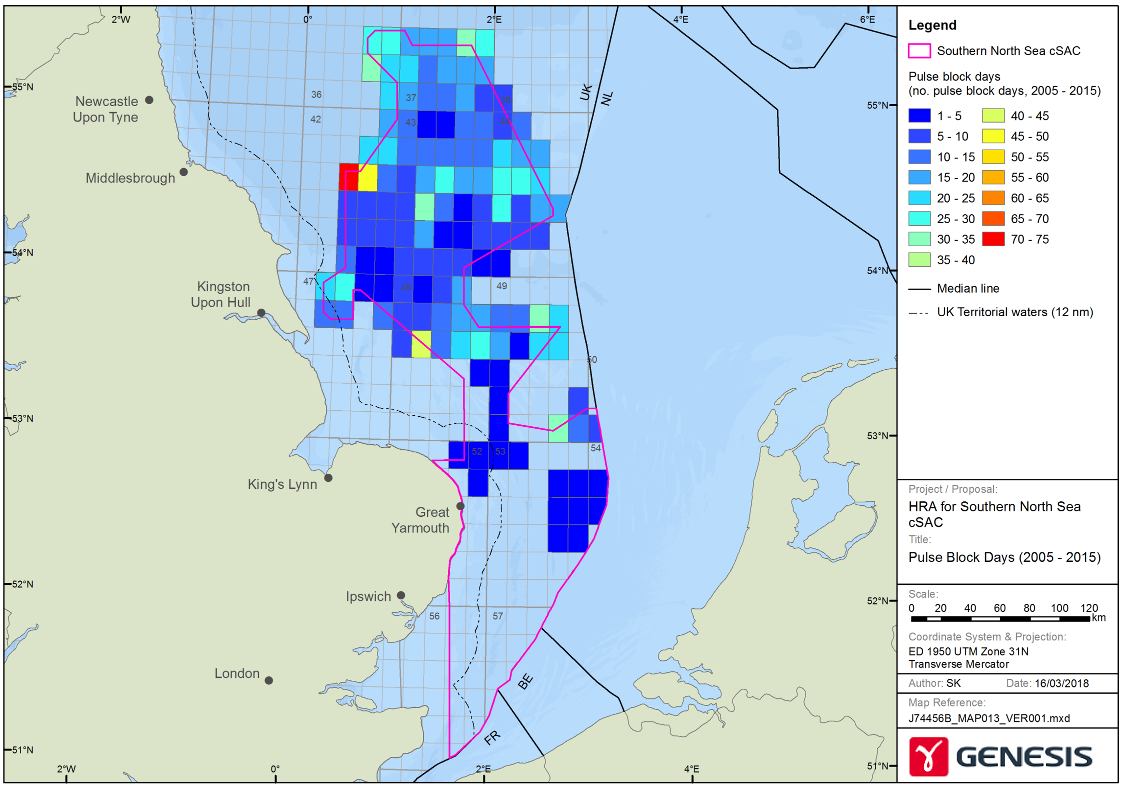


Figure 17: Total number of pulse block days in each license block between 2005 and 2015.

[3] Note: 'Pulse block days' are based on the number of days during which the source of the noise was present within a single block. It is recognised that pulsed sound can and will propagate across more than one block and therefore more than one block could be being impacted for each 'pulse block day'. However, it is not possible from the available data to estimate which additional blocks would be impacted.

Table 10: Number of pulse block days in each licence block within SCI between 2005 to 2015.

Number of pulse days between 2005 to 2015	Number of blocks within SCI	Proportion of blocks within SCI (%)
<1	64	32.3
1-5	30	15.6
5-10	29	14.7
10-15	23	11.8
15-20	21	10.7
20-25	12	6.1
25-30	9	4.6
30-35	5	2.6
35-40	0	0.0
40-45	1	0.5
45-50	1	0.5
50-55	0	0.0
55-60	0	0.0
60-65	0	0.0
65-70	0	0.0
70 – 75	1	0.51

6.13 The number of pulse block days, i.e. the number of days in which pulsed noise occurred, across the whole of the SCI ranges from between 51 and 310 days per year with an average of 170 days per year (Figure 18). Consequently, there has been pulsed noise within the SCI for between 14% and 85% of the days each year, although in many instances the pulsed noise will not be for the whole day.

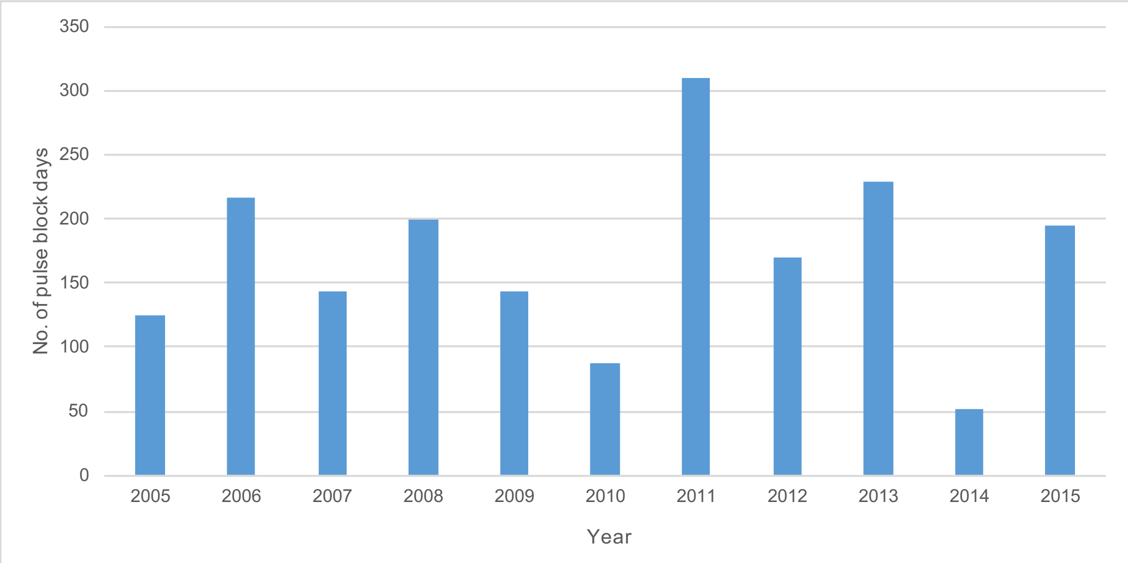


Figure 18: Number of pulse block days per year within the Southern North Sea SCI.

6.14 Between 2005 and 2015 there were a total of 67 seismic surveys undertaken within the boundaries of the SCI, with 64 of them occurring in the 'summer' area and five in the 'winter' area (Table 11).

Table 11: Oil and gas related seismic and site surveys undertaken within the SCI between 2005 and 2015.

Survey type	Number of surveys			Median duration of each survey (days)
	Total SAC	'Summer'	'Winter'	
2D Seismic	12	11	2	19
3D seismic	17	16	1	47
Site survey	38	37	2	8
Total	67	64	5	-

Note some surveys overlapped both 'winter' and 'summer' areas and are included in both, hence the total number of 'summer' and 'winter' surveys are greater than the number of surveys within the SCI as a whole.

6.15 The majority of seismic surveys occurring within the SCI over the last 11 years have lasted less than 30 days. The median duration of each survey type and the proportion of days, on average, impacts occurred for each season are presented in Table 12 for the 'summer' area and Table 13 for the 'winter' area.

6.16 Of the surveys undertaken in the 'summer' area, 38 overlapped the period between April and September, with an average of 59 days of survey occurring within the 'summer' area each summer period, equivalent to 32.2% of the time (Table 12).

Table 12: Number of oil and gas related surveys undertaken within the 'summer' area of the SCI during the summer period (April and September) between 2005 to 2015.

Survey type	'Summer' area (April to September)			Proportion of days impacted (%)
	No. of surveys (2005 – 2016)	Median duration (days)	Average number of days each year	
2D Seismic	11	19	19	10.4
3D seismic	8	39	28	15.3
Site survey	19	7	12	6.5
Total	38	-	59	32.2

6.17 Within the 'winter' area of the SCI a total of five oil and gas related surveys were undertaken over a period of 11 years between 2005 and 2015, of which two overlapped with the period between October and March. On average noise arising from oil and gas related surveys was undertaken within the 'winter' area for 2.3 days each winter period, equivalent to 1.2% of the time (Table 13).

Table 13: Number of oil and gas related surveys undertaken within the 'winter' area of the SCI during the winter period (October and March) between 2005 to 2015.

Survey type	'Winter' area (October to March)			Proportion of days impacted (%)
	No. of surveys (2005 – 2016)	Median duration (days)	Average number of days each year	
2D Seismic	1	7	0.6	0.3
3D seismic	0	0	0	0
Site survey	1	19	1.7	0.9
Total	2	-	2.3	1.2

Oil and gas vessels

6.18 The oil and gas industry is heavily reliant on vessels during all phases of its activities. Over the course of 2013 (The latest year for which data are available), a total of 19,976 vessel passages associated with oil and gas activities occurred within the SCI (MMO 2016a); an average of 55 vessels per day. Oil and gas related vessel traffic accounted for 21.4% of all vessel traffic within the site in 2013. The vast majority of these related to vessels associated with offshore safety or were supply vessels operating between ports and offshore installations and were therefore critical in the safety and the operating of existing offshore infrastructure (Table 14).

Table 14: Total number of vessel passages associated with the oil and gas industry within the SCI in 2013 (Source MMO 2016a).

Vessel Type	Total number of vessel passages in 2013
diving support	241
drill platform	80
drill ship	25
Offshore safety	9,176
Supply	10,454
Total	19,976

Marine Aggregate Dredging

6.19 There is a medium risk of an impact from activities associated with the aggregate dredging to harbour porpoise across the North Sea (Table 8) (JNCC and NE 2016).

6.20 Existing localised aggregate dredging occurs primarily in the southern half of the SCI, along the east coast (Figure 19). In 2017 there were 28 aggregate production areas and three Exploration and Option areas covering an area of 540.5 km^2 (Table 15). Five of the aggregate areas occur in the 'summer' area of SCI covering 78.5 km^2 and the rest occur in the 'winter' area of the SCI and cover an area 495.3 km^2, with some sites occurring in both the 'winter' and 'summer' areas.

Table 15: Aggregate extraction sites within the Southern North Sea SCI.

Aggregate Site	Area number	Area (km^2)
Humber 5	483	28.2
Humber 3	484	17.2
Longsand	510/2	6.2
Longsand	509/3	6.6
Shipwash	507/5	0.8
Shipwash	507/6	4.2
Shipwash	507/2	2.1
Shipwash	507/4	6.8
Shipwash	507/3	0.7
Shipwash	507/1	17.8
North Cross Sands	494	6.1
North Inner Gabbard	498	6.6
Southwold East	430	15.3

Aggregate Site	Area number	Area (km^2)
Off Great Yarmouth	254	11.7
Off Great Yarmouth	511	26.6
Off Great Yarmouth	228	13.1
Off Great Yarmouth Extension	240	31.5
Off Great Yarmouth	512	21.8
Off Great Yarmouth	513/2	8.6
Off Great Yarmouth	513/1	5.9
Yarmouth	401/2A	48.2
Yarmouth	401/2B	2.9
Norfolk	212	3.1
North Inner Gabbard	498	6.6
Southwold East	430	15.3
Longsand	510/1	6.6
Longsand	508	6.6
New 495	525	28.1
Thames D	524	77.5
Cross Sands	242/361	23.7
North Falls East	501	52.3
Inner OTE	528/2	31.8

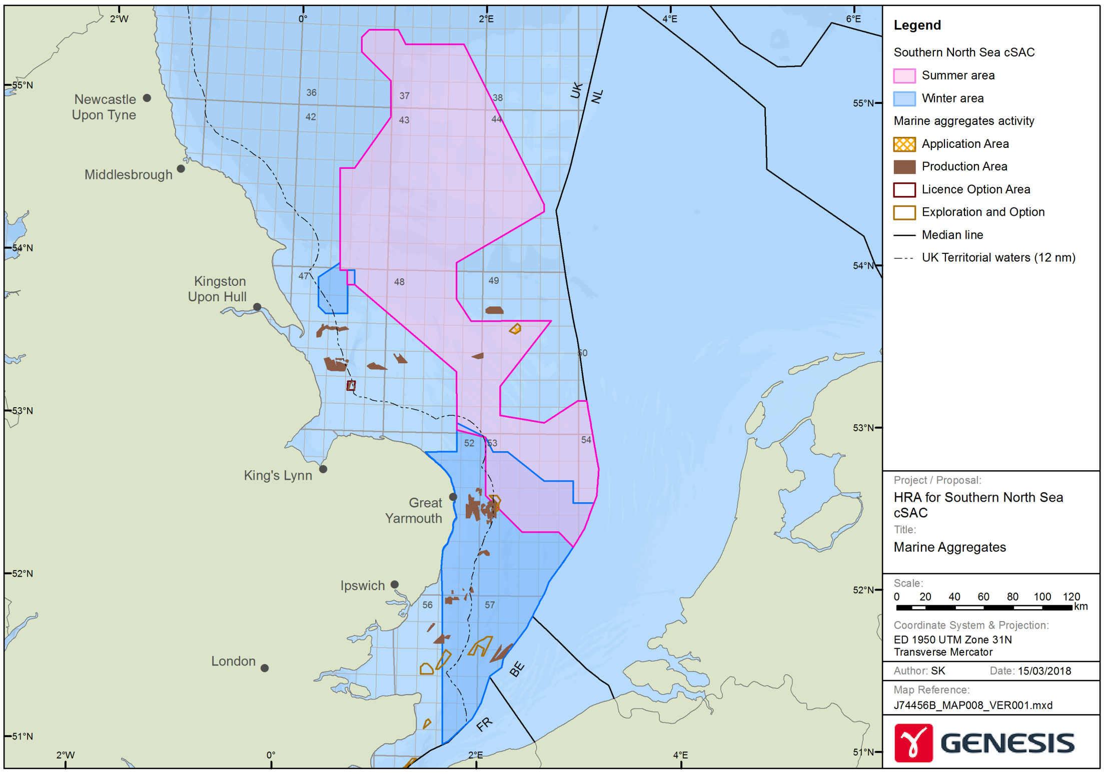


Figure 19: Existing marine aggregate activities in the Southern North Sea SCI.

6.21 The three-year average annual offtake of construction aggregate across the East Coast and Thames Estuary regions was 5.85 million tonnes (TCE 2017a). The level of dredging activity within the region has decreased over the last 15 years. In the East Coast region, the area of seabed dredged has ranged from between 97 km^2 (in 1998) and 30 km^2 (in 2012) and similarly within the Thames Estuary region the area of seabed dredged has decreased from 25 km^2 in 1999 to 3 km^2 in 2012 (TCE 2014). The most recently available published data indicate that recent dredging activity within the region has increased and in 2016 dredging took place across 22.99 km^2 of the East Coast region and 10.34 km^2 of the Thames estuary region (TCE 2017b).

6.22 Studies have indicated that harbour porpoise may be displaced by dredging operations within 600 m of the activities (Diederichs *et al*. 2010). Noise modelling previously undertaken for aggregate assessments have predicted significant levels of avoidance at ranges of 500 m from suction dredging (Parvin *et al* 2008 (referenced in Hanson Aggregates Marine Ltd 2013.)

6.23 On a precautionary assumption that there is a level of behavioural displacement out to 600 m, there is potential for an area of 1.13 km^2 to be affected at each active dredging location. There are currently three aggregate production areas in the 'summer' area and 26 in the 'winter' area. Although the level of dredging activity within each of the active licence areas is unknown, as a worst-case scenario, with dredging occurring within each dredging area, porpoise may be displaced from an area of 3.39 km^2 in the 'summer' area and 29.38 km^2 in the 'winter' area. Therefore, a very small proportion (0.01% of the summer area and 0.2% of the summer area), of the SCI may be impacted by noise arising from dredging activities.

Shipping

6.24 Impacts from shipping on harbour porpoise within the SCI have been identified as arising from shipping noise and collision impacts. Shipping noise is the predominant anthropogenic source of noise within the marine environment and shipping is reported to have a negative effect on harbour porpoise within the SCI when vessel traffic exceeds 80 vessels per day (JNCC and NE 2016). The current level of risk across UK waters to harbour porpoise from activities associated with shipping is medium, i.e. there is some evidence of an impact (Table 8), (JNCC and NE 2016)

6.25 Shipping has been on-going in the southern North Sea for many hundreds of years and the area is important for shipping, with relatively high numbers of vessels occurring within it. Based on vessel track lines, in 2015 a total of 269,018 vessels track lines were recorded transiting across the SCI; an average of 737 vessels per day (MMO 2017b).

6.26 The average weekly vessel density within the SCI is published for 2 x 2 km quadrants (Figure 20) (MMO 2017c). The density of shipping across the SCI is variable, with an average weekly number of vessels from between 0 and 567 weekly vessels occurring in any single quadrant within the SCI (Figure 21) (MMO 2017c). Relatively low levels of shipping occur across much of SCI, with 58.4% of the site as a whole having, on average, a vessel density of less than seven vessels per week, i.e. approximately one vessel per day. Higher average densities of greater than 70 vessels on average per week (10 vessels per day) occur across 4% of the SCI. Based on these data there are no 2 x 2 km quadrants that have up to 80 vessels per day transiting through them.

6.27 The level of vessel activity across the 'summer' and 'winter' areas of the SCI differs. There is relatively widespread vessel activity in low densities across the 'summer' area, with 76% of the quadrants having less than seven vessels per week and 17% having less than one vessel per week. Compared with the 'winter' area of the SCI where 14% of the quadrants had, on average, less than seven vessels per week and only 1% had less than one vessel per week. In contrast 11% of the 'winter' area had more than 70 vessels per week compared with none in the 'summer' area. The areas with relatively higher levels of shipping (>24 vessels per day), occur over 4% of the 'winter' area. Therefore, the 'winter' area has relatively localised, higher density, areas of vessel traffic compared with the 'summer' area that has widespread but low density vessel traffic.

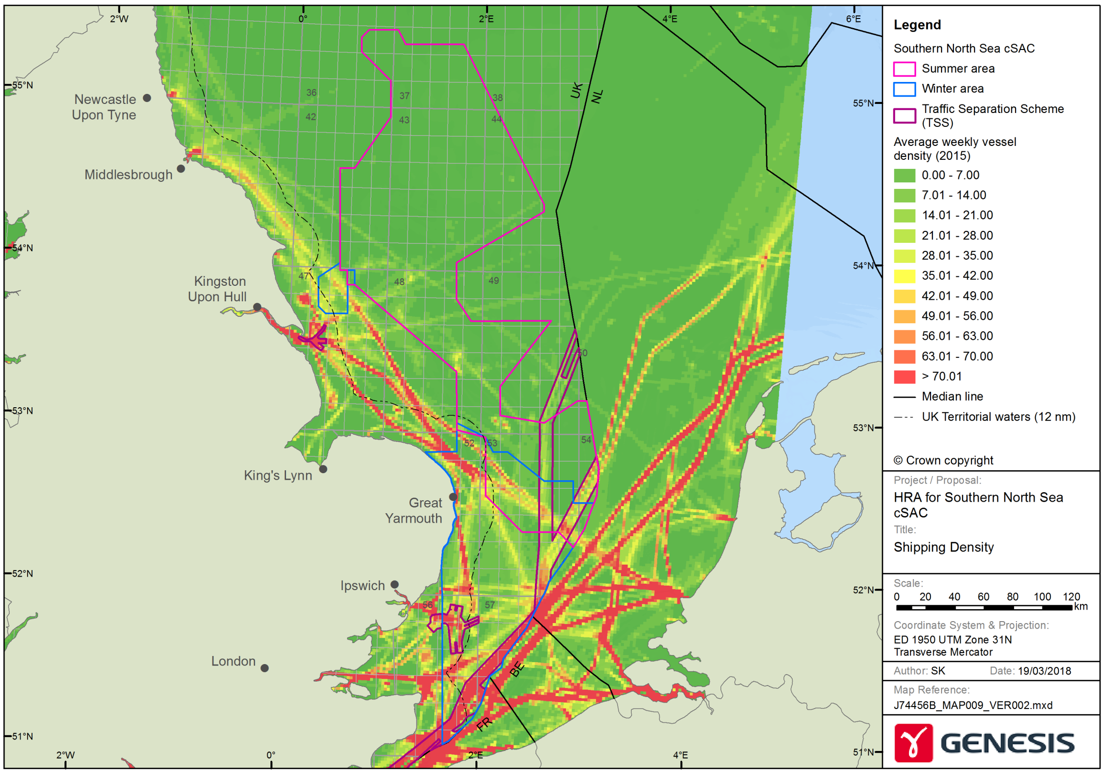


Figure 20: Shipping density within the SCI during 2015.

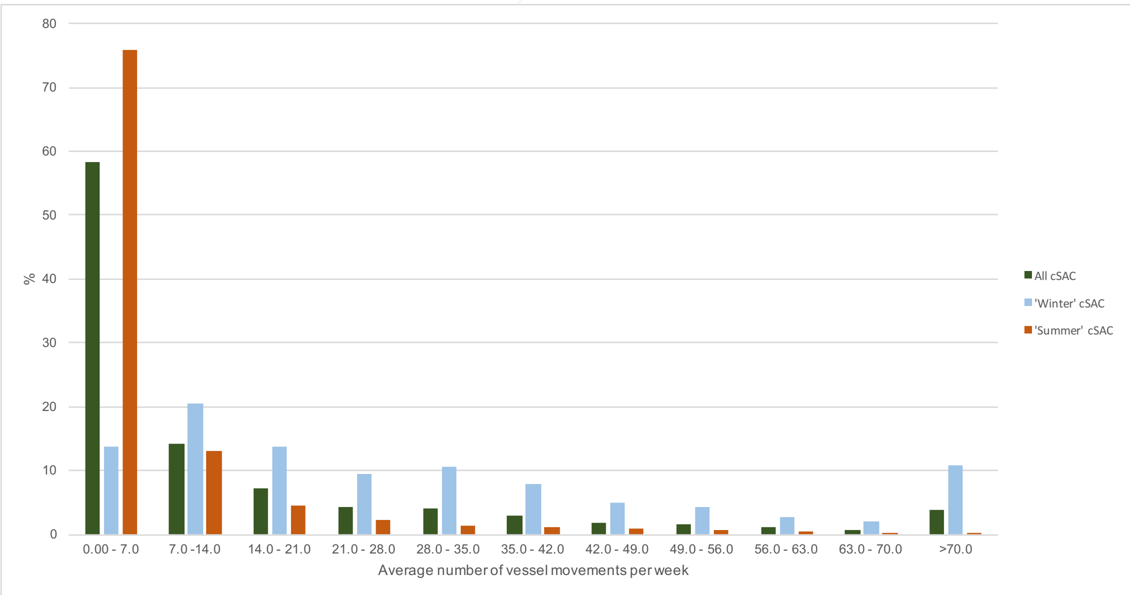


Figure 21: Average number of vessels per week in 2 x 2 km quadrants within the SCI.

6.28 Official shipping lanes have a relatively high level of vessel traffic. The two deep water traffic separation schemes in the southern area of the SCI have reported up to 16 vessels per day (EAOWL 2015b) and 15 vessels per day at Galloper and Greater Gabbard (GWFL 2011).

Elsewhere, the average number of vessel movements along main routes identified in the Hornsea Subzones 1 and 2 was typically less than two per day, with a maximum of four per day (Smart Wind 2013, 2015a). At Creyke Beck A and B, on average less than one commercial vessel every three days passed along each of the main routes identified and at Teesside there was less than one vessel a day (Forewind 2013a, 2014). There is therefore significant variation in the level of vessel activity across the SCI, with official shipping lanes having a higher level of vessel traffic and therefore higher level of potential disturbance to harbour porpoise compared with other areas of the SCI.

6.29 Great Yarmouth and Lowestoft are the two principal ports abutting the SCI and between them a total of 371 vessels arrived in 2016 (DfT 2017). Across the UK sector of the southern North Sea, sizable ports with over a hundred vessel arrivals per year include Hull, Grimsby, Felixtowe, Harwich, London and Medway. Nearly 30,000 vessels per year arrive at these ports, the majority of which will cross through the SCI to and from their destinations (Table 16).

Table 16: Ports adjacent to the SCI with over 100 vessels arrivals per year (Source DfT 2017).

Port	Total number of vessel arrivals in 2016
Hull	2,568
River Trent	695
River Hull and Humber	506
Kings Lynn	221
Sutton Bridge	167
Grimsby & Immingham	8,548
Ipswich	845
Felixtowe	2,506
Harwich	1,456
London	7,829
Medway	2,834
Total	28,175

6.30 Current levels of shipping noise within the SCI has been shown to influence on the presence or absence of harbour porpoise and could cause displacement and disturbance of harbour porpoise within the SCI (Heinänen and Skov 2015).

6.31 Studies undertaken on seven harbour porpoise in Danish waters indicated that was variation in how individual porpoises responded to vessel noise with some individuals showing a behavioural response to vessel noise at levels of 96 dB re 1 μPa (rms SPL), causing changes in the foraging behaviour and others showing no behavioural response. Individuals exposed to relatively high levels of sound ceased foraging and swam to deeper water (Wisniewska *et al*. 2018a). Other studies have indicated that noise arising from shipping is capable of causing disturbance to beyond 1 km from a vessel (Dyndo *et al*. 2015, Hermannsen *et al*. 2014, Wisniewska *et al*. 2018b). Studies on the behavioural effects of shipping on harbour porpoise indicate that the level of displacement effects from shipping on harbour porpoise decrease with increasing distance from the vessel with some levels of displacement occurring out to 400 m from the vessel (Akkaya Bas *et al*. 2017, Polacheck 1990). However, the behavioural impacts are temporary with porpoises resuming activities relatively quickly once the vessel has passed (Hermannsen *et al*. 2014, Wisniewska *et al*. 2018b).

6.32 Shipping lanes are areas where relatively higher levels of shipping traffic compared with surrounding areas and greater levels of disturbance and displacement of harbour porpoise are predicted to occur. Across the whole of the SCI shipping lanes cover an area of 2,974 km^2, of which, 1,164 km^2 are in the ‘summer’ area and 2,358 km^2 are in the ‘winter’ area. This is equivalent to 4.3% of the ‘summer’ area and 18.6% of the ‘winter’ area.

6.33 The duration of any impacts is dependent on the frequency of vessels within the area. In areas of relatively high vessel density porpoises may be regularly displaced or disturbed.

6.34 Physical impacts on harbour porpoise can arise from vessel strikes. Studies from stranded animals indicate that between 4% and 5.4% of deaths are due to physical traumas either from vessels or dolphin attacks (Evans *et al*. 2011, IAMMWG *et al*. 2015).

Commercial Fishing

6.35 There is a high risk of an impact from bycatch associated with the fishing industry to harbour porpoise across the North Sea, i.e. there is good evidence of a significant impact. There is a medium risk of an impact from removal of prey (Table 8) (JNCC and NE 2016). There is potential for impacts to the seabed from fishing gear.

6.36 The bycatch of harbour porpoise in fishing gear is reported to be one of the most significant anthropogenic pressures impacting on the harbour porpoise population (JNCC & NE 2016). It is estimated that between 1,235 and 1,990 harbour porpoise die each year in the North Sea due to bycatch, predominantly in gill nets (ICES 2016, OSPAR 2017a). This is approximately 0.6% of the North Sea Management Unit population.

6.37 Fishing occurs widely across the southern North Sea and has also been on-going for many hundreds of years. The majority of current fish landings are obtained from areas adjacent to the SCI but there is widespread fishing activity in the southern half and north-eastern edge of the SCI and relatively moderate to high level of fishing activity along the western edge of the central part of the SCI (Figure 22) (MMO 2017b). Note however, this does not include the activities of non-UK registered vessels that will occur within the site or vessels less than 10 m in length.

6.38 The predominant fishing activity within the SCI is beam trawling, mainly by Belgian and Dutch vessels targeting Dover sole, plaice and lemon sole (MMO 2017d). Otter trawling and seine netting also occur for flat fish and sandeel fishing is also undertaken by trawling primarily around the western edge of Dogger Bank. The significant majority of fish taken and landed in the UK are plaice, sole, skates and rays caught by demersal and beam trawlers (Table 17).

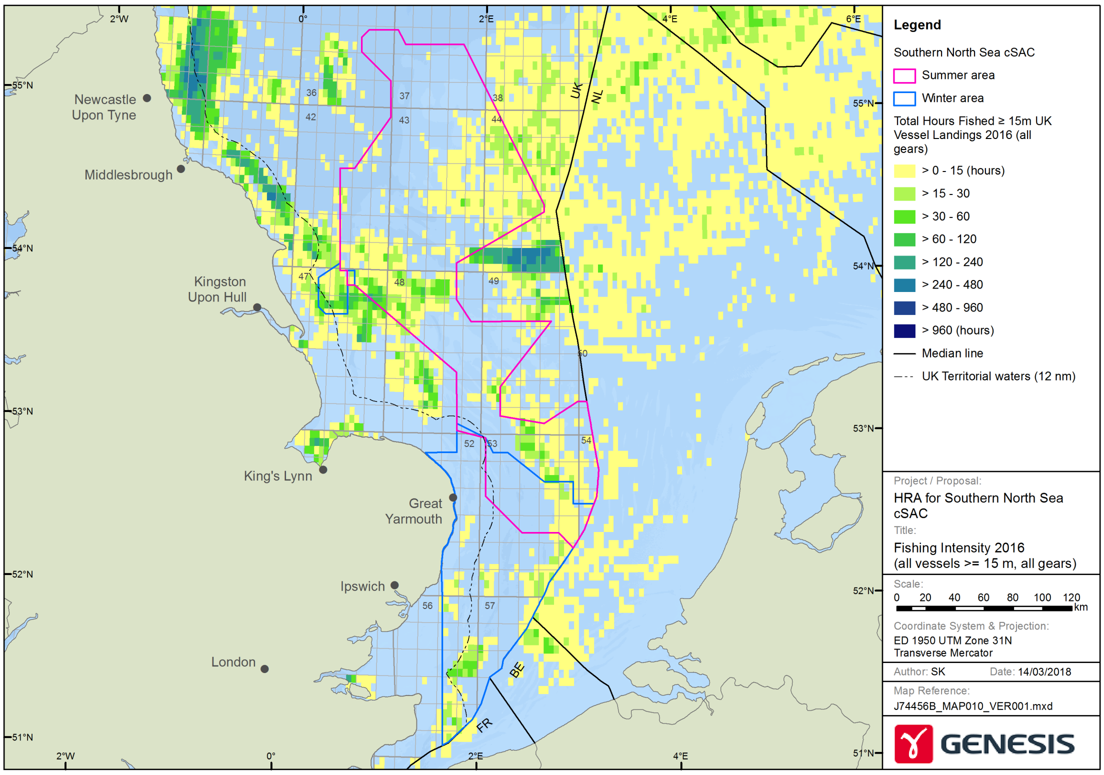


Figure 22: Fishing intensity across the SCI during 2014 by UK registered vessels.

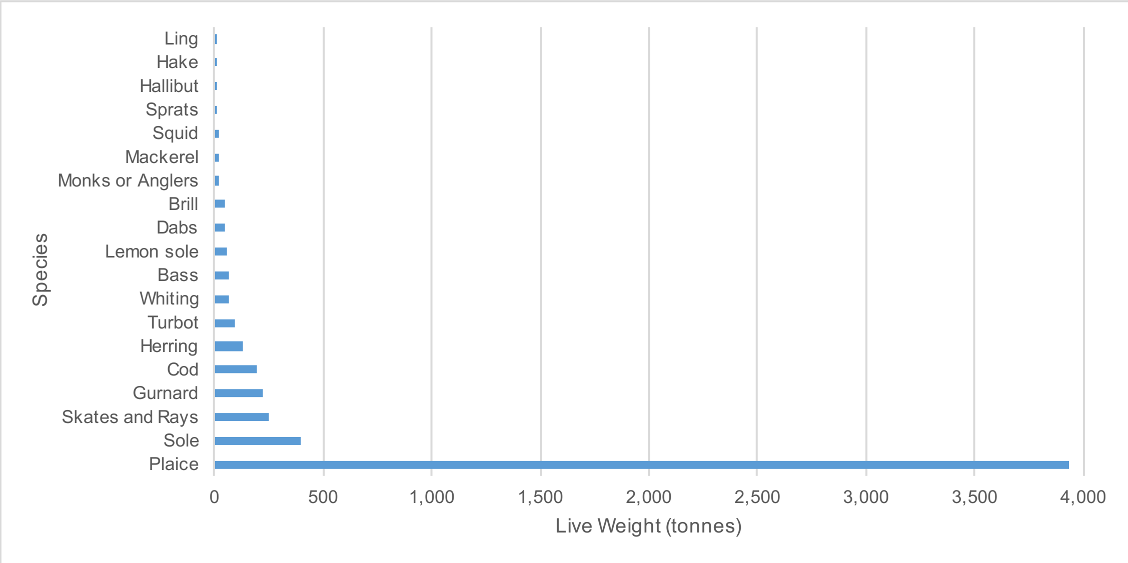


Table 17: Fish species caught within the SCI and landed in the UK during 2016 (Source MMO 2017d).

Unexploded Ordnance Clearance and Blasting Activities

6.39 The level of UXO clearance in UK waters is unclear. However, in adjacent Dutch waters there were 181 detonations of UXO over a two year period in 2010 and 2011 (Von Benda-Beckmann *et al*. 2015). The number of items of UXO required to be disposed of at wind farms within the SCI varies with estimates of 60 at East Anglia One, 40 at Galloper and 21 at Hornsea One (EOWL 2017, GWFL 2015a, Dong 2017b).

6.40 The use of explosives for blasting may also be used by the oil and gas industry during decommissioning or well abandonment. Blasting activities in the UKCS are relatively uncommon and little information is available on the size of charges used.

Discharge and Run-off from Land-fill, Terrestrial and Offshore Industries

6.41 The discharge and run-off from landfill, terrestrial and offshore industries are identified as being at a high level of activity across the North Sea and causing a relatively high level of impact to harbour porpoise (JNCC and NE 2016).

6.42 About 80% of marine pollution comes from land based activities and therefore the highest concentrations of contaminants and potential impacts occur in coastal waters (Defra 2002). A number of coastal activities may discharge contaminants into the sea that could impact on the SAC including agricultural run-off, industrial discharges and artificial radionuclide inputs from coastal nuclear power stations and reprocessing plants (Defra 2002). Inputs from offshore industries include discharges from the oil and gas industry and resuspension of contaminated seabed from dredging or at disposal sites. Discharges can persist in the environment for prolonged periods of time, e.g. heavy metals, polychlorinated biphenyls (PCBs) and plastics which, when ingested, impact on harbour porpoise causing increased reproductive failure or elevated rates of mortality from infectious diseases (e.g. Mafouz *et al*. 2014, Murphy *et al.* 2015).

6.43 Many of the discharges that could affect harbour porpoise have been reduced in recent years. Polychlorinated biphenyl (PCB) concentrations in fish and shellfish have decreased to acceptable biological limits for all but one type of PCB in the Southern North Sea (OSPAR 2017b). Heavy metal concentrations in fish and shellfish, e.g. mercury, cadmium and lead remain above background levels and their longevity may mean that there could be potential effects from contaminants on harbour porpoise for many years (OSPAR 2017c). However, since 1990 the level of trace metal contamination in harbour porpoises have declined (IAMMWG *et al*. 2015)

6.44 It is recognised that most relevant pollutants have been phased out and any future impacts are largely from historical discharges (JNCC and NE 2016).

Recreational Boating Activity

6.45 The current level of impact risk from noise arising from recreational boating on harbour porpoise across UK waters is identified as being medium, i.e. there is some evidence of an impact (Table 8) (JNCC and NE 2016).

6.46 The majority of recreational activity occurs in nearshore waters, within 12 nm of the coast and therefore there is limited overlap between recreational boating activity and the SCI. The area with the greatest potential of interaction between recreational boating and harbour porpoise occurs off the east coast of Norfolk where there are recognised sailing areas in inshore waters to the north of Great Yarmouth and south of Lowestoft. Further offshore, within the SCI there are recognised cruising routes used primarily by sailing yachts. The level of activity along these routes have been reported to be between one and two recreational vessels per day (e.g. EAOWL 2015a, TKOWFL 2011).

Acoustic Deterrent/Mitigation Devices

6.47 The current level of impact risk from noise arising from ADDs across UK waters is identified as being medium, i.e. there is some evidence of an impact (Table 8) (JNCC and NE 2016).

6.48 Acoustic deterrent devices produce relatively high levels of sound in the water column with the aim of causing an avoidance behaviour in marine mammals and discouraging them from a particular area. The extent and duration of any displacement varies across devices and the behaviour of the individual species, with ADDs having less of an effect where marine mammals may be attracted to a site, e.g. seals and fish farms. However, in areas where there is less of an attraction the use of ADDs have been found to be effective at temporarily displacing marine mammals from an area.

6.49 Acoustic deterrent devices such as pingers are used by 'setnet' fishing vessels as a mitigation measure to reduce the risk of harbour porpoise bycatch. There use is limited to vessels greater than 12 metres in length (JNCC & NE 2016). Studies undertaken on two types of pinger, one operating at 10 kHz and a source SPL of 132 dB re 1 µPa (rms SPL) and another operating between 30 and 160 kHz and source level of 155 dB re 1 µPa (rms SPL) indicated a displacement occurs out to 2.5 km from the sound source, although effects could occur to beyond 5 km (Kyhn *et al*. 2015).

6.50 There is also increasing potential for the use of ADDs as mitigation tools to minimise the risk of auditory injury to harbour porpoise during pile-driving at offshore wind farms.

6.51 Two studies undertaken on the most widely used ADD (Lofitech) indicated that there was avoidance behaviour from between 1.9 and 2.4 km that lasted for up to six hours. Behavioural disturbance may occur out to at least 4 km and up to 7.5 km (Brandt *et al.* 2012, 2013). Similar results have been reported from construction at the Dudgeon Offshore Wind Farm (Vattenfall 2017).

7 SOUND SOURCES

7.1 The following section presents information regarding the sound arising from the activities identified in Section 6 as regularly occurring within the SCI. The levels of sound and the frequencies produced affect the potential for an activity to impact on harbour porpoise or their prey.

Wind Farm Pile-driving

7.2 Pile-driving involves the repeated impact of a pile using a hydraulic hammer. The hammer strike occurs above the sea surface but produces radiated noise within the water column.

7.3 Pile-driving generates relatively high levels of underwater noise and the source level is dependent on a number of factors. The diameter of the pile being installed and the hammer energy are the main parameters that influence the source level, with seabed conditions and the hydrodynamic environment being primary influences upon the subsequent propagation of the sound with distance. Based on over fifty datasets, the estimated unweighted source level from impact pile-driving using a 5,000 kJ hammer energy is 244 dB re 1µPa-m (peak SPL) and 241 dB re 1µPa-m (peak SPL) from a 2,500 kJ hammer (Dong 2017a). However, higher source levels have been reported, e.g. an average of 250 dB re 1µPa-m (peak SPL) from five UK wind farms (Nedwell *et al.* 2007). The radiated noise produced is a predominantly low frequency sound within the range of 100-400 Hz, although tones are also produced above 1 kHz (Thomsen *et al*. 2006). The majority of the measurements of underwater sound produced by pile-driving have been the result of research carried out by the renewable energy industry (e.g. Nedwell *et al*. 2007).

7.4 The installation of piles typically requires a ramp-up period at the start of piling, during which time the blow energy delivered by the piling hammer is gradually increased. Both the duration of the ramp-up period and the hammer energy used during this period varies depending on the hammer capacity, type of pile and seabed conditions.

7.5 Piling by the offshore oil and gas industry predominantly entails the installation of relatively small diameter piles used for the installation of platforms, anchors and subsea infrastructure, e.g. subsea manifolds compared with the monopiled foundations installed for offshore wind farms.

Wind Farm Operational Noise

7.6 Noise generated from operating wind farms originates primarily from the gear box and generator and is reported to be relatively low with measured unweighted source levels of between 141 and 146 dB re 1µPa-m (rms SPL) from four UK wind farms and at frequencies of between 16 Hz and 20 kHz (MMO 2015, Cheesman *et al*. 2016).

7.7 Studies undertaken at three operating wind farms in Sweden and Denmark reported noise levels above ambient background levels to only be audible at below 500 Hz with Sound Pressure Level of between 106 and 126 dB re 1µPa-m (rms SPL). The study concluded that noise from operating wind farms would not be audible to harbour porpoise beyond 70 m from the turbines (Tougaard *et al*. 2009). Studies undertaken at two Belgian wind farms reported differences between the sound produced by gravity based foundations and steel monopole foundations. Steel monopole foundations increased SPL by 20 dB re 1µPa-m (rms SPL) for frequencies below 3 kHz and 25 dB re 1µPa-m (rms SPL) for frequencies at 8 kHz. Whereas gravity based foundations produced lower levels of noise and increased the peak SPL by 8 dB re 1µPa-m (Norro *et al*. 2011).

7.8 It is predicted that within a few hundred metres of the foundation that operational noise is broadly comparable with ambient noise (MMO 2014).

Seismic Surveys (Airguns)

7.9 There are predominantly two types of seismic survey: exploration and site surveys, the latter covering a relatively localised area and typically using a lower sound source than an exploration survey that covers a wider area and uses a higher sound source and is typically undertaken by the oil and gas industry. Surveys typically last for relatively short periods of two to three weeks or less, although they can be longer (Stone 2015). Whilst surveying, vessels travel at speeds of between 4.5 to 5 knots and cover an area of seabed of between 25 to 30 km^2/day (OGP and IAGC 2004).

7.10 The airguns used in the seismic surveys are pneumatically-driven impulsive transducers that generate high intensity, low frequency, short duration sound pulses at regular intervals of typically between every 10 to 15 seconds. The seismic source geometry is designed to focus the output from the array vertically downwards minimising any horizontally propagating sounds (OGP/IAGC 2004). The level of sound generated by an airgun array depends on various factors including gun volume, array design, the number of airguns, spacing and air pressure. Field measurements of the sound emitted by airgun arrays used by the oil and gas industry show that levels of source intensity expressed as peak SPL range from 235 to 259 dB re 1µPa-m (Richardson *et al*. 1995, OSPAR 2009). The frequency range of emitted energy is typically in the 5 Hz to 500 Hz range and strongest from 10 to 120 Hz, but with some energy in the 500 Hz to 1 kHz range (Richardson *et al*. 1995, Hermannsen *et al.* 2015).

7.11 Vertical Seismic Profiles (VSP) use geophones located within the wellbore to detect sound from airguns located at the surface near the well or deployed from a vessel. Source volumes are generally smaller (*c*.500 cubic inches) than conventional surveys, but larger than site surveys. The duration of these surveys is typically short with data acquisition taking approximately 1 to 2 days. There are limited data on the sound source level arising from VSP. Typical sound pressure levels have been reported to between 231 and 241 db re 1 µPa-m (0-peak SPL) with maximum output between 20 and 140 Hz (LGL 2006, Shell 2011).

7.12 Within the UK all seismic surveys relating to oil and gas activities require a consent from BEIS. A condition attached to all consents is the requirement to commence surveys using a 'soft-start' procedure following JNCC guidance (JNCC 2017d). The aim of this condition is to allow time for marine mammals swim away from the survey prior to the maximum noise levels commencing and therefore reducing the risk of auditory injury.

Multi-beam Echosounders

7.13 Multi-beam echosounders are widely used in the marine environment and measure water depth by emitting rapid pulses of sound towards the seabed and measuring the sound reflected back. Emitted sound frequencies are typically between 12 – 400 kHz depending on water depth, with surveys in continental shelf applications operating at between 70 to 150 kHz, and in shallower waters of less than 200 m using multi-beam echosounders operating at between 200 and 400 kHz (Danson 2005, Hopkins 2007, Lurton and DeReutier 2011). Sound sources have been reported as ranging from 210-245 dB re 1µPa-m (Genesis 2011, Lurton and DeReutier 2011).

7.14 The water depths within and adjacent to SCI are all less than 200 m. Consequently, it is predicted that multi-beam echosounders will be emitting sound levels above 200 kHz and outwith the hearing frequency range of harbour porpoise. It is therefore predicted that harbour porpoise will be unable to hear the sound arising from an echosounder (Figure 23).

Side-scan Sonar

7.15 Side-scan sonar involves the use of an acoustic beam to obtain an accurate image over a narrow area of seabed to either side of the instrument. The frequencies used by side-scan sonar are relatively very high, typically between 100 and 500 kHz. In shallower waters, such as the southern North Sea side-scan sonar operate at frequencies at the higher end of this spectrum and are predominantly outside of the hearing range of harbour porpoise (Figure 23).

Sub-bottom Profiler

7.16 Sub-bottom profiling is used to determine the stratification of soils beneath the sea floor. Various types of instrument may be used, such as pingers, boomers, sparkers and chirpers, depending on the required resolution and seabed penetration. They produce sound source levels of between 196 and 225 dB re 1 μPa -1 m (rms SPL) and at frequencies ranging from between 0.5 and 300 kHz and are therefore audible to harbour porpoise (Figure 23) (BOEM 2016, King 2013, Danson 2005).

7.17 Chirpers are frequency modulated sub-bottom profilers capable of providing high penetration and high resolution data. They have largely replaced the use of sparkers and boomers when undertaking many surveys. They produce sound levels of between 189 and 214 dB re 1 μPa - m (rms SPL) at frequencies of between 2 and 24 kHz. They cover a relatively broad range of frequencies that are detectable by harbour porpoise. Consequently, parameters relating to the use of chirpers have been used in this HRA.

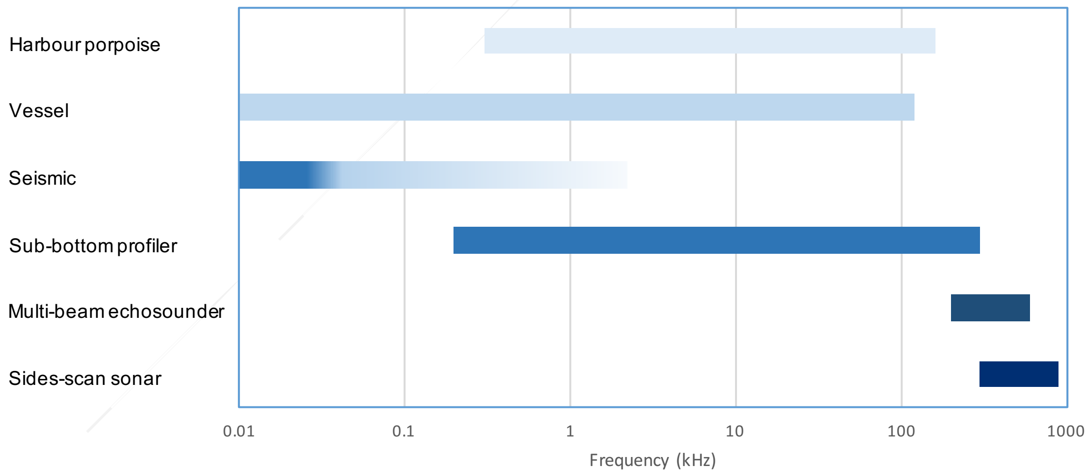


Figure 23: Hearing frequencies for harbour porpoise and sound bandwidths arising from seismic and geophysical survey equipment and vessels.

Shipping

7.18 Shipping noise is continuous and varies depending on the type of vessel being used. The primary sources of sound from vessels are propellers, propulsion and other machinery; the dominant noise source is from propeller cavitation (Ross 1976, Wales and Heitmeyer 2002, Arveson and Vendittis 2000). Source levels typically increase with increasing vessel size, with smaller vessels (< 50 m) having source levels 160-175 dB re 1µPa (rms SPL), medium size vessels (50-100 m) 165-180 dB re 1µPa (rms SPL) and larger vessels (> 100 m) 180-190 dB re 1µPa (rms SPL) (summarised by Richardson *et al*. 1995). Commercial vessels in transit have reported sound source levels of between 178.6 and 190.3 dB re 1 µPa -m (Genesis 2011, Johanson & Anderson 2012), whereas supply and maintenance vessels produce generally lower sound source levels of between 130 and 184 dB re 1 µPa (rms SPL), with frequencies of between 20 Hz and 10 kHz. However, sound levels depend on the operating status of the vessel with vessels equipped with dynamic positioning systems exhibiting increased sound levels in the spectrum from 3 Hz to 30 Hz (Nedwell & Edwards 2004, OSPAR 2009). Most of the acoustic energy from vessels is below 1 kHz, typically within the 50-300 Hz range, although cavitation from propellers produces sounds at frequencies of between 1 kHz and 125 kHz (Genesis 2011, Hermannsen *et al.* 2014). Consequently, vessel noise has historically thought to have a greater potential to impact marine mammals with relatively low frequency sensitivities e.g. seals and baleen whales rather than high frequency specialists, e.g. porpoise (Okeanos 2008). However, more recent studies indicate that high frequency sound from vessels of between 0.25 and 63 kHz and at mean sound levels of 123 dB re 1 µPa (rms SPL) can cause increased porpoising behaviour in harbour porpoise at distances greater than 1 km from the sound source (Dyndo *et al*. 2015).

7.19 Studies undertaken to measure ambient noise levels in the southern North Sea and Irish Sea indicate that at frequencies below 1 kHz, general shipping noise increases background noise levels to above 120 dB re 1 µPa (rms SPL), with levels of exceeding 140 dB re 1 µPa (rms SPL) in areas of intensive shipping (Nedwell *et al*. 2003).

Aggregates

7.20 Aggregate dredging noise levels have been reported to be between 160 and 188 dB re 1 µPa -m (rms SPL) with frequencies ranging from between 10 Hz to greater than 2 kHz (Richardson *et al*, 1995, OSPAR, 2009, MMO 2015).

7.21 Noise arising from vessels undertaking suction bucket dredging have been studied from six different vessels at three locations in the southern North Sea (Robinson *et al*. 2011). The results from the studies indicated that when in transit noise arising from dredging vessels was comparable with that from similar sized merchant vessel. However, when undertaking dredging activities, higher levels of broadband noise at frequencies above 1 kHz are produced due to the impact or abrasion of aggregate material passing through the draghead, suction pipe and pump. The overall level of noise was found to be higher when extracting gravel compared to when extracting sand (Robinson *et al*. 2011).

7.22 Source sound levels vary depending on the dredger and environmental factors, including seabed substrate. Source levels of between 177 and 191 dB re 1µPa-m (rms SPL) were estimated from the six vessels studied in the southern North Sea (Robinson *et al*. 2011).

Drilling

7.23 Sound associated with drilling operations will propagate from rotating equipment such as generators, pumps and the drill string. In general, sound from drilling has been found to be predominantly low frequency (<1kHz) with relatively low source levels. Source levels from platforms range from between 59 and and 171 dB re 1µPa –m (rms SPL) but are typically around 150 dB re 1µPa -m (rms SPL) at frequencies of between 30 to 40 kHz (Richardson *et* al. 1995, MMO 2015). Higher levels of noise have been reported from drill ships at less than 195 dB re 1µPa -m (rms SPL) at frequencies ranging between 10 Hz and 10 kHz (Nedwell & Edwards 2004). A study by Greene (1987) found that the sound generated by drilling activities from a semi-submersible did not exceed local ambient levels beyond 1 km, although weak tones were detectable up to 18 km away. Studies have shown that during drilling, other underwater sound levels increase when compared to periods of non-drilling, which has been related to the use of additional machinery and power demands (McCauley 1998). Drilling sounds, although of a relatively low level, will be continuously generated throughout the drilling activity that may last over a period of many months.

Trenching

7.24 Measurements of noise generated by trenching vessels suggest that the spectrum is dominated by sound at low frequencies of between 10 and 1,000 Hz, with peak source levels at less than 500 Hz (Genesis 2011). Trenching vessels produce continuous sound with strongest levels at low frequencies but with high frequency tones also present. Few measurements are available but peak sound levels may be around 177 dB re 1 µPa -m and levels are likely to fluctuate with operating status of the vessel (Genesis 2011, Nedwell and Edwards 2004, Richardson *et al.* 1995). In general, noise from the vessels required for trenching is likely to be louder than the trenching activity itself (Genesis 2011). Rock dumping is also likely to produce noise. However, measurements of rock placement from a fall pipe rock dumping vessel found no evidence that the rock placement itself contributed to the noise level from the vessel (Nedwell and Edwards, 2004).

7.25 Pipelines and cables are either laid directly on the seabed or trenched and buried. If trenched and buried, sound produced will depend on the equipment used and the nature of the seabed characteristics. Few studies have been undertaken on sound arising from trenching operations. Measurements undertaken during the trenching of a pipeline in water off southern Sweden reported mean source level estimated at 183.5 dB re 1 µPa (rms SPL) (Johannson and

Andersson 2012). Cable trenching at the North Hoyle offshore wind farm reported a source level of 178 dB re 1 µPa -m (Nedwell *et al.* 2003).

Unexploded Ordnance (UXO) Detonation and Use of Explosives (Blasting)

7.26 Explosive sources produce broadband frequencies with very high peak source levels and rapid rise times. The most damaging component from underwater explosions is caused by the high amplitude underwater shock wave and the initial fast rise in pressure which has the potential to cause injury or death to marine mammals (Richardson *et al*. 1995, Lewis 1996, Ketten 2004).

7.27 The peak pressure shortly after an explosion is very high in comparison to other man-made sound sources. At distances close to the charge, a shockwave is formed, after which the wave propagates as a normal sound wave (Parvin *et al.* 2007). The higher frequencies reduce quickly in the water column and the area of impact from the shockwave is limited. Sound propagating out is largely below 1 kHz.

7.28 Shock waves can cause blast injuries due to the short signal rise time and the high peak pressure, which are transmitted through the body causing damage to tissues and gas filled cavities (ASCOBANS 2012). The pressure from a shock wave, and thus the potential for injury depends largely on the charge weight 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.

7.29 The risk of physical injury occurring is affected by the distance the marine mammal is from the sound source at the time of detonation, the water depth with increased risk in shallower water and seabed type and increased risk over hard rocky seabed. (ASCOBANS 2012). In shallow water, rapid pressure changes occur due to the surface reflected pulse occurring milliseconds after the direct pulse. This can cause gas bubbles to form within the soft tissues resulting in physical injury or death.

7.30 The detonation of explosives can produce source levels of 272-287 dB re 1µPa -m (0-peak SPL) at frequencies of between 2 Hz and 1 kHz (Genesis 2011). Studies undertaken during well abandonment have recorded maximum sound pressure levels recorded for a 45 kg charge detonation of 232 dB (0-peak SPL) re 1 µPa at 300 m. Detonations of explosive discharges ranging in size from 36 kg to 81 kg have also been recorded to produce sound pressure levels of up to 226 dB re 1 µPa at 600 m (Genesis 2011). Recorded measurements from the clearance of UXO ranging in size between 10 kg and 1,000 kg in the Dutch sector of the Southern North Sea recorded minimum sound exposure levels of 191 dB re 1µPa^{2}s within 2 km of a detonation (Von Benda-Beckmann *et al*. 2015).

7.31 When clearing UXO sympathetic detonation is frequently used, whereby a relatively small donor charge is placed alongside the ordnance to be cleared.

Acoustic Deterrent Devices

7.32 Acoustic deterrent devices are increasingly being considered as potential mitigation tools to minimise the risk of injury to marine mammals from pile-driving by the offshore wind farm industry. Their use within the SCI may increase in the future.

7.33 To date sound source levels from ADDs used as mitigation tools during the construction of offshore wind farms have been reported as being between 177 and 202 dB re 1µPa (rms SPL), with maximum source levels at frequencies between 8 and 40 kHz (Coram *et al*. 2014, Lepper *et al.* 2014).

Recreational Vessels

7.34 Recreational vessels include small motorised boats, jet skis and sailing yachts. Small motorised vessels (speed boats) produce sound levels between 105 and 156 dB re 1µPa (rms SPL) across a frequency range of between 630 Hz and 20 kHz (MMO 2015).

8 MITIGATION

8.1 Studies have indicated that mitigation measures could reduce the risk of a population decline due to potential cumulative impacts of offshore wind farm construction (Verfuss *et al*. 2016). There are a range of mitigation measures available that reduce the risk of an adverse effect arising on harbour porpoise within the SCI. The following section presents a summary of the measures that are recognised as potential mitigation and how they are managed within the consenting process.

Soft-start Procedures

8.2 Soft-start procedures are where the hammer energy used at the start of pile-driving is at a relatively low level and delivered at a slow rate, it is based on the understanding that the lower the hammer energy the lower the sound level. Following the soft-start, the hammer energy is gradually ramped up and the strike rate increased over a period of time until the maximum hammer energy and strike rate required to install the pile are reached. This soft-start followed by a gradual ramp-up of the hammer energy allows time for marine mammals to move away from the area before sound reaches levels at which physical injury or the onset of PTS are predicted to occur. Each project develops its own soft-start and ramp-up procedure depending on the ground conditions at the site and the equipment being used. Hammer energies of below 10% to 20% of the maximum hammer energy have been proposed and the duration of the soft start and ramp-up typically last for between 20 and 30 minutes (e.g. TKOWFL 2011, Forewind 2013b, SMart Wind 2015).

8.3 Soft-start procedures are included as part of the mitigation in all consented offshore wind farms and their requirement is a condition within the deemed Marine Licence (dML).

Marine Mammal Monitoring

8.4 The use of Marine Mammal Observers and PAM are the most widely used forms of mitigation currently undertaken at offshore wind farms in UK waters.

8.5 Their aim is to reduce the risk of marine mammals, including harbour porpoise, from being within a range of the activity, (500 m for pile-driving and 1 km for UXO detonation), prior to the activity commencing. JNCC guidance provides a protocol on the minimum levels of good practice required to mitigate the potential for causing injury or death to marine mammals from pile-driving and UXO detonation (JNCC 2010b, c). Compliance with this guidance is a requirement made under the conditions within the dML or prior to approving a MMMP.

Acoustic Deterrent Devices

8.6 The use of ADD has the potential to reduce the likelihood of harbour porpoise and other marine mammals being in the area within which physical injury could occur at the start of pile-driving activities and may be considered as an alternative approach to using marine mammals observers and PAM. They have been used regularly during construction of offshore wind farms in the North Sea and Baltic Sea as a form of mitigation to reduce impacts on marine mammals (e.g. Brandt *et al.* 2016, Haelters *et al.* 2012).

8.7 ADDs produce relatively high levels of sound in the water column with the aim of causing an avoidance behaviour in marine mammals and discouraging them from a particular area. The extent and duration of any displacement varies across devices and the behaviour of the individual species, with ADDs having less of an effect where marine mammals may be attracted to a site, e.g. seals and fish farms (e.g. Coram *et al.* 2014). However, in areas where there is less of an attraction, the use of ADDs have been found to be effective at temporarily displacing marine mammals from an area (Brandt *et al.* 2012).

8.8 Two published studies have been undertaken on the effectiveness of using an ADD to displace harbour porpoise (Brandt *et al.* 2012 and 2013). Although the studies showed slightly differing results with one recording a harbour porpoise as close 798 m of an active ADD and the other showing that all harbour porpoise avoided the area within 1.9 km and for half the time between 2.1 and 2.4 km. They both reported a strong avoidance behaviour by harbour porpoise to the ADDs with an effective range of between 1.3 km and 1.9 km. The studies concluded that there appeared to be effective deterrence at levels of 132 dB re 1 μPa (rms SPL) and no clear avoidance at levels below 119 dB re 1 μPa (rms SPL) (Brandt *et al*. 2012). The effects of avoidance lasted approximately six hours.

8.9 It is recognised that the effects of ADD on harbour porpoise may be site specific but the results from these studies indicate that an ADD may effectively mitigate against the risk of harbour porpoise occurring in the area of risk of PTS at the onset of and during pile driving.

8.10 Should ADDs be used they are operated at the pile driving location for a period of time, typically approximately 15 to 20 minutes prior to the start of pile driving (e.g. HOW 2017). They are turned off once pile driving has started.

8.11 Noise arising from the use of ADDs could impact on harbour porpoise within the SCI and their use should be considered carefully (Faulkner *et al.* 2018, JNCC and NE 2016). In the event that the use of an ADD is planned, discussions with the MMO and the SNCBs would be held.

Bubble Curtains

8.12 The use of bubble curtains has been used as a form of mitigation during construction of a number offshore wind farms in the North Sea and in controlled detonation of explosives (e.g. Koshinski and Koch 2015). Bubble curtains placed around a pile or UXO detonation can, if the conditions are suitable, be effective in reducing the level of noise emitted into the water column.

8.13 There are a number of different types of bubble curtain that can be used: little bubble curtains, big bubble curtains and double bubble curtains. Studies have shown that the use of bubble curtains can reduce the level of broadband noise from pile-driving by between 5 and 18 dB re 1 μPa (SEL), depending on the type of curtain used (Koshinski and Ludemann 2013, Rumes *et al*. 2016). In experiments undertaken during controlled explosives the use of a double bubble curtain was found to reduce the area of impact by over 98% (Koshinski and Koch 2015).

8.14 Bubble curtains may not always be technically possible or economically feasible but may be effective in reducing the impacts of noise harbour porpoise.

Physical Barriers

8.15 The use of a physical barrier in the form of a sleeve placed around the pile may reduce the level of sound emitted into the water column. A number of different types of barrier system have been developed including isolation casing, cofferdams and hydro sound dampers (Koshinski and Ludemann 2013).

8.16 The effectiveness of the barrier in reducing sound levels is dependent on the design of the barrier. Studies have shown that noise levels can be reduced by up to 20 dB re 1 μPa (Peak SEL) and therefore be effective at reducing the extent of any impacts (Koshinski and Ludemann 2013).

8.17 However, their use may not always be technically possible or economically feasible but could be effective in reducing the impacts of noise harbour porpoise.

Mitigation Management

8.18 The current consenting regimes have processes that allow mitigation to be legally required in order to reduce the risk of impacts on harbour porpoise and other marine mammals.

8.19 Conditions made within a DCO are legally binding and can be focussed on ensuring that there are no adverse effects on the integrity of a site. For example, conditions attached to the Hornsea Two Offshore Wind Farm Order 2016 include a requirement on the MMO to not approve any plan unless it can be demonstrated that the use of driven or part-driven foundations will not affect the integrity of the site (Infrastructure Planning 2016a).

8.20 A Marine Mammal Mitigation Plan (or Protocol, Programme) (MMMP) maybe a requirement made within the Developer's DCO or a dML made under the Marine and Coastal Access Act 2009 and all projects are required to have an approved MMMP prior to the start of construction activities. The intention of a MMMP is to prevent injury and/or significant disturbance to marine mammals. Consultation with the SNCBs is a requirement prior to the approval of any MMMP.

8.21 The DCO or dML may require the submission of a MMMP at least four months prior to the commencement of offshore construction. Within the MMMP protocols are required to reduce certain impacts as described in the DCO. The protocols may include the requirement for a soft start procedure, the use of marine mammal observers and passive acoustic monitors. It may also be a requirement to consider of the use of noise reduction technologies or the use of ADD (e.g. Infrastructure Planning 2016a, MMO 2016d).

8.22 A MMMP will recognise the risk of an impact arising from the activities for which the plan is prepared and make commitments to implementing measures that reduce those risks. By doing so an effective MMMP should reduce the number of harbour porpoise occurring within the area across which the onset of PTS is predicted to occur and, potentially, the area across which disturbance is predicted. Consequently, a MMMP will reduce the risk of construction causing an adverse effect on the integrity of the site.

8.23 The preparation of a Construction Method Statement (CMS) is a requirement within the DCO and the dML. It is intended to ensure the development is constructed in a way that meets the legislative requirements and requires the developer to undertake construction in accordance with the environmental statement. This may include details of the timing of construction, the foundation installation and vessels to be used.

8.24 An effective CMS will ensure that the construction of a wind farm would meet the legislative requirements including those of the Habitats Regulations. Construction cannot commence without an approved CMS that has to be submitted at least four months prior to commencement of activities. A CMS reduces the risk of construction causing an adverse effect on the integrity of the site.

8.25 The above demonstrates that there are effective mitigation measures that can be used to reduce the risk of an impact on harbour porpoise and that there is a legal structure in place to ensure that, if required, suitable mitigation is undertaken.

9 POTENTIAL IMPACTS FROM NOISE

9.1 The following section provides a summary the potential impacts from noise may have on harbour porpoise.

9.2 There is a substantial volume of literature describing the potential effects of sound on marine mammals, with summaries provided in Thomsen *et al.* (2006), Southall *et al.* (2007) and OSPAR (2009).

9.3 There are four main types of potential effects of noise that are recognised as relevant within the marine environment:

- *Fatal effects* caused by significant levels of noise in close proximity to the receptor.
- *Physical injury*, specifically hearing impairment, which can be permanent or temporary. These effects can impact on the ability of marine mammals to communicate, forage or avoid predators.
- *Behavioural effects* such as avoidance, potentially resulting in displacement from suitable feeding or breeding areas, and changes in travelling routes.
- *Secondary impacts* caused by the direct effects of noise on potential prey causing a reduction in prey availability.

9.4 The range at which marine mammals may be able to detect sound arising from offshore activities depends on the hearing ability of the species and the frequency of the sound. Harbour porpoise are potentially more sensitive to relatively high frequency sounds than other marine mammal species and may also be more sensitive to sound than other marine mammal species (Defra 2015). Other factors affecting the potential impact of sound on marine mammals includes ambient background noise, which can vary depending on water depth, seabed topography and sediment type. Natural conditions such as weather and sea state and other existing sources of human produced sound, e.g. shipping, can also reduce the auditory range.

Fatal Effects

9.5 If source peak pressure levels from the proposed operations are high enough there is the potential for a lethal effect on marine mammals. Studies suggest that potentially lethal effects can occur when the peak pressure level is greater than 240 dB re. 1 μPa (peak to peak SPL)

(Parvin *et al*. 2007). Damage to soft organs and tissues can occur when the peak pressure level is greater than 220 dB re. 1 μPa (peak to peak SPL).

Physical Injury

9.6 Underwater sound has the potential to cause hearing damage in marine mammals, either permanently or temporarily. The potential for either of these conditions to occur is dependent on the hearing bandwidth of the animal, the duty cycle of the sound source and duration of the exposure (Southall *et al*. 2007, OSPAR 2009).

9.7 Physical injury is described as either a permanent loss of hearing range (Permanent Threshold Shift (PTS)) or temporary loss of hearing range (Temporary Threshold Shift (TTS)).

9.8 Sound exposure levels considered capable of causing the onset of either PTS or TTS do not mean that such physical impacts will always occur. The probability of developing PTS or TTS will follow a dose response curve, with increasing risk of physical injury as exposure increases. Studies undertaken on bottlenose dolphin indicate that only between 18% and 19% of bottlenose dolphins exposed to sound exposure levels of 195 dB re 1 μPa^2.s-m, actually resulted in the onset of TTS (Finneran *et al*. 2005).

9.9 A temporary threshold shift may not significantly affect the hearing ability of the impacted individual. Studies on harbour porpoise exposed to pile-driving sounds indicate that the main impacts on hearing thresholds occurred at frequencies of between 4 kHz and 8 kHz, which are below the sound frequencies used by harbour porpoise for echolocation (Kastelein *et al.* 2014). Consequently, a change in hearing threshold may not affect the ability of a harbour porpoise to communicate or locate prey.

9.10 Although PTS is a permanent physical injury impairing the marine mammal's ability to hear, TTS is not and impacts are relatively short-lived. Studies undertaken on harbour porpoise indicate that, depending on the exposure level and duration, hearing ability returns between 4 and 96 minutes after the sound causing the impact has ceased (Kastelein *et al.* 2012, Kastelein *et al*. 2014).

Behavioural Change

9.11 Changes in behaviour arising from noise impacts may be easily detectable, e.g. a significant displacement from an area. Other effects caused by changes in behaviour, e.g. energetic stress, may be more difficult to detect and go unnoticed (OSPAR 2009). Potential changes in behaviour may occur depending on the sound source levels and the species' and individuals' sensitivities. Behavioural changes can include changes in swimming direction, diving duration, reduced communication and avoidance of an area.

9.12 The displacement of harbour porpoise could cause them to relocate to sub-optimal locations where there is lower prey availability or increased inter and intra-specific competition. If permanent or over a long period, this could cause lower fecundity or increased mortality.

9.13 Masking effects may also cause changes in the behaviour as the level of sound may impair their directional hearing, their ability to adjust vocalisation amplitude and frequency and consequently their ability to detect echolocation clicks and other sounds that species use to communicate or detect prey, thus causing them to alter their behaviour (David 2006).

9.14 Harbour porpoise will move away from a sound source if the received level of sound is above a given threshold. However, as individuals move away, the received sound level is likely to decrease and their behaviour may change. The use of dose response curves provides a means to determine the proportion of individuals that may be displaced at any given sound level. A number of studies have used this approach for harbour porpoise (e.g. Brandt *et al*. 2016, BOWL (2017).

Secondary Effects

9.15 There is potential for impacts on prey species to affect harbour porpoise, in particular possible impacts of noise on fish species. The potential effects on fish in the form of physical injury and displacement are predicted to be similar to those for harbour porpoise, although their sensitivity to sound will differ.

Habitat Disturbance

9.16 There is potential for impacts on the habitats within the SCI. Physical impacts on the seabed could arise during construction and decommissioning activities. The extent and duration of any impacts is dependent on the cause of the impact and the sediment type with soft sandy sediments potentially recovering more quickly than muddy sediments.

10 NOISE THRESHOLDS

Marine Mammal Injury

10.1 There are a number of published studies that present a range of possible noise thresholds at which the onset of PTS, TTS and disturbance to marine mammals are predicted to occur. The selection of the most appropriate threshold for the relevant species and source of any noise impact is critical when assessing potential impacts.

10.2 Southall *et al*. (2007) presents a range of thresholds for injury and disturbance on marine mammals. These thresholds are based on a comprehensive review of evidence for impacts of underwater sound on marine mammals and specify precautionary thresholds for injury. Southall *et al*. (2007) proposed that for single pulses and multiple pulsed sound, such as that generated by piling, a sound pressure level of 230 dB re 1µPa (peak SPL) or above will be sufficient to cause the onset of PTS, and a pressure level of 224 dB re 1μPa (peak SPL) sufficient to cause the onset of TTS in cetaceans.

10.3 Since the publication of Southall *et al*. (2007), studies have indicated that harbour porpoise may be more sensitive to sound exposure than had previously been supposed (Lucke *et al.* 2009, Kastelein *et al*. 2014). For single pulsed sound sources the onset of PTS may occur at unweighted sound thresholds of 179 dB *re* 1 μPa^{2}s (Lucke *et al*. 2009).

10.4 The National Oceanic and Atmospheric Administration (NOAA) have produced guidance for assessing the effects of anthropogenic sound on marine mammal hearing and presented revised auditory weightings and alternative weighted thresholds (the 'NOAA' thresholds) for the onset of permanent and temporary threshold shifts (NMFS 2016); this Guidance has since been revised (NMFS 2018).

10.5 For harbour porpoise the threshold at which the onset of PTS is predicted to occur from cumulative sound exposure levels is 155 dB *re* 1 μPa^{2}s. This threshold is lower and provided with different audio weightings than those published in Southall *et al.* (2007) and Lucke *et al*. (2009). Consequently, the extent and area within which the onset of PTS is predicted to occur, based on the NMFS guidance, may be greater than previously considered.

Marine Mammal Disturbance

10.6 The area within which a marine mammal may be displaced or disturbed will vary depending on a number of factors including the level of sound received, the sensitivity of the species and individuals to noise and whether there are suitable areas to which they may move.

10.7 When considering the extent at which disturbance occurs, Southall *et al*. (2007) were not able to define thresholds for multiple-pulse and non-pulse sounds as empirical studies revealed no clear relationship between the received sound level and behavioural response. Similarly, NMFS (2016, 2018) did not present any thresholds at which disturbance to marine mammals may occur.

10.8 A published study on captive harbour porpoise exposed to airgun noise indicated that aversive behaviour, i.e. displacement, could occur in harbour porpoise at levels of unweighted SEL of 145 dB re.1μPa^{2}s (Lucke *et al*. 2009).

10.9 Studies on marine mammals during pile-driving activities have demonstrated that higher levels of displacement or disturbance occur at higher received sound levels. The received sound level decreases with increasing distance from the sound source and there is a corresponding reduction in displacement or disturbance.

10.10 Studies undertaken at eight offshore wind farms in German waters have estimated the proportion of harbour porpoise displaced within a range of SEL (Brandt *et al*. 2016). Based on these findings a dose-response curve has been developed from which it can be estimated the proportion of individuals displaced at any given received sound level (Figure 24).

10.11 A similar study undertaken during pile-driving activities at the Beatrice Offshore Wind Farm also obtained data using C-PODS from which the probability of a harbour porpoise response in relation to distance from pile-driving could be made. The results allow a dose response curve to be developed (Figure 24). Currently, there is no guidance as to which dose response curves are considered most appropriate for use when undertaking an assessment. However, the data from the Beatrice Offshore Wind Farm are unpublished and the analysis of the data is at a preliminary stage (BOWL 2017). Consequently, the use of a dose response curve obtained from the Beatrice Offshore Wind Farm data for the purposes of this HRA is considered premature and the use of the data presented in Brandt *et al* (2016) has been used to produce a dose response curve for this assessment. However, it is recognised that the use of the data from the Beatrice offshore wind farm could be considered in future assessments.

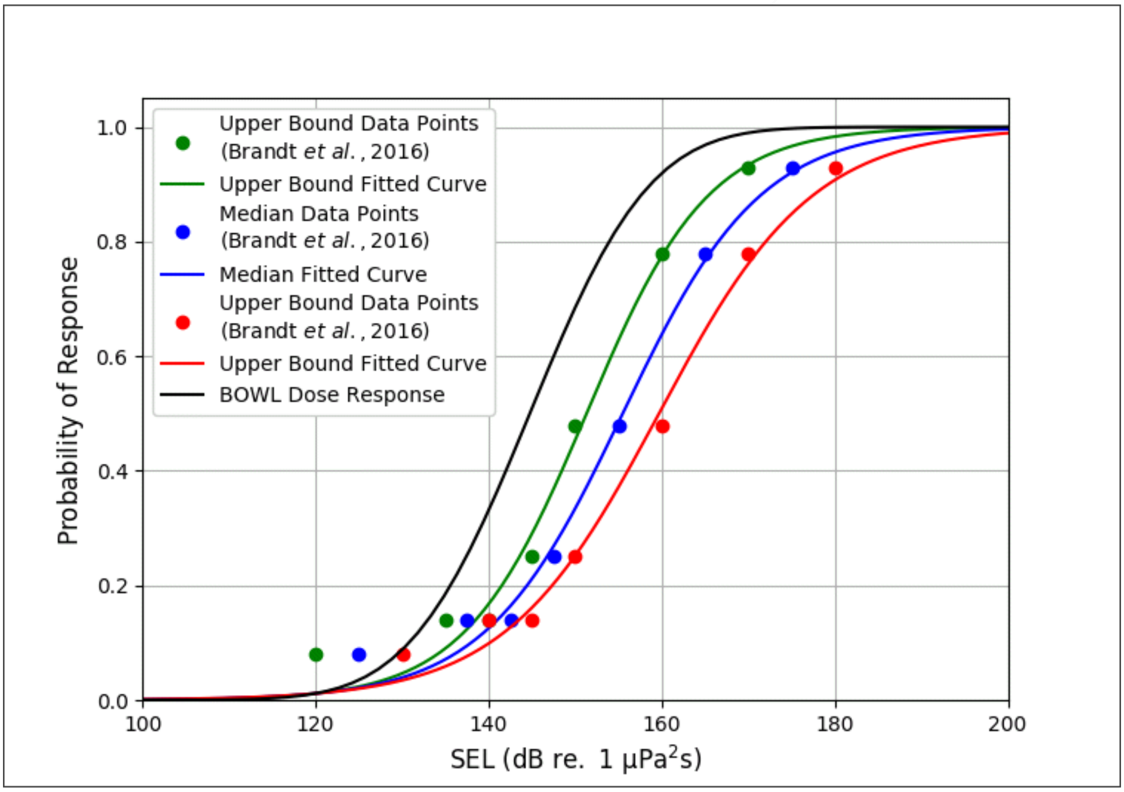


Figure 24: Behavioural response curves considered for assessing potential behavioural disturbance to harbour porpoise (Source Brandt *et al.* 2016, BOWL 2017).

10.12 Potential impacts on harbour porpoise for this assessment have been assessed using un-weighted peak SPL of 202 dB re.1 uPa and weighted SEL of 155 dB *re.*1 μPa^{2}s for injury and unweighted SEL of 145 dB re.1μPa^{2}s for potential displacement; these are based on published studies (Lucke *et al.* 2009).

Fish

10.13 Underwater sound has the potential to cause hearing damage to fish, either permanently or temporarily. The potential for either of these conditions to occur is dependent on the hearing ability of the fish, which will vary across species. Fish hearing is based on detecting particle motion directly stimulating the inner ear. However, those with swim bladders are also able to detect pressure waves and can detect a wider range of frequencies and sounds of lower intensity than fish without swim bladders (Popper 2003). Fish with swim bladders, e.g. herring, are recognised to be hearing specialists and those without, e.g. sandeels, have limited hearing capability.

10.14 Although it is recognised that there will be variation across species, sound levels at a SEL of 207 dB re 1 μPa are thought to cause the onset of physical injury in hearing specialists and 219 dB re 1 μPa in non-hearing specialists (Popper *et al*. 2014).

10.15 There are there are no well-established criteria or thresholds for assessing behavioural disturbance to fish and there are no recommended thresholds at which disturbance to fish are predicted to occur (Popper *et al*. 2014). However, it has been suggested that behavioural effects on fish, from seismic airguns, can occur at peak pressure levels of between 168 and 173 dB re 1 μPa (McCauley *et al*. 2000) and alarm responses at SEL of between 147 – 151 dB re 1 μPa (Fewtrell and McCauley 2012).

11 EFFECTIVE DETTERENT RADIUS

11.1 The Effective Deterrent Radius (EDR) has been proposed by the Statutory Nature Conservation Bodies (SNCBs) as a means to measure potential impacts on harbour porpoise within the SCI (JNCC 2017e). The EDR is an empirically derived generic distance of 26 km within which deterrence, i.e. displacement, of harbour porpoise is predicted to occur from pile-driving. The EDR is based on published studies that have monitored the effects on harbour porpoise during pile-driving at offshore wind farms and reflects the overall loss of habitat if all animals vacate the area around a pile driver (Tougaard *et al.* 2014). It is an area of displacement as opposed to disturbance, which may be greater.

11.2 No EDR are available for other noise sources. However, the use of a 26 km EDR for the detonation of UXO has been previously used and agreed with SNCBs and the use of either a 5 km or 10 km EDR has been used for impacts from seismic surveys (EAOWL 2017).

11.3 The SNCBs recognise that future data may require the suitability of the EDR to be reconsidered if it is found to be inappropriate (JNCC 2017e).

11.4 BEIS have been advised that the use of the EDR should be considered when undertaking this assessment (JNCC and NE 2017). The assessment includes consideration of the potential impacts on harbour porpoise based on there being deterrence of 26 km for pile-driving and UXO clearance and 10 km from seismic surveys.

12 NOISE MODELLING

12.1 In order to undertake an assessment of the estimated impacts from pile-driving at each of the wind farms subject to this review, noise modelling has been undertaken at two locations within each wind farm site. The locations have been selected based on a number of criteria:

- Their proximity within the SCI, i.e. a point furthest within the SCI boundaries or, of outside the boundaries, the point closest to the SCI boundary. This provides the greatest potential area of impact within the SCI.
- Areas of relatively deeper water. Sound generally propagates further in deeper water and therefore a larger area of potential impact is predicted to occur. Although this is complex particularly in shallower waters where other factors, such as seabed type, bathymetry and the presence of thermoclines can have a significant effect on sound propagation (Farcas *et al*. 2016, Spiga 2015).
- Locations previously selected by developers in previous noise modelling. Previous applications have undergone a selection process to identify the worst-case pile locations when undertaking their own noise modelling and whenever possible noise modelling undertaken for this HRA has been carried out at similar locations.

12.2 The modelling for each wind farm project has taken into account both the planned and consented project envelopes where possible, and takes into consideration the impacts resulting from different hammer energies and pile installation durations. The assumptions that have been used in the modelling are largely based on information provided by the wind farm developers, as well as information available in existing Environmental Statements.

12.3 Potential impacts to harbour porpoise have been assessed by comparing the predicted received sound levels in terms of single-pulse peak SPL to both the Southall and NOAA thresholds for PTS and TTS. Cumulative SEL modelling scenarios have also been conducted to estimate the potential onset of PTS and TTS in harbour porpoise due to exposure to multiple pulses throughout the pile-driving event. Potential behavioural disturbance to harbour porpoise has been estimated by firstly comparing the predicted single pulse SEL to the disturbance threshold of 145 dB re 1 μPa^2s proposed by Lucke *et al*. (2009) and Thompson *et al.* (2013). In addition to this behavioural disturbance threshold, the probability of disturbance for different received SEL bands has been evaluated using the dose-response curve. This approach is used to highlight the fact that not all harbour porpoise within the 145 dB re 1 μPa^2s disturbance zone will be displaced.

12.4 The main results of the modelling are presented in section 13, and the full set of propagation model outputs are provided in the *Technical Noise Modelling Report* (Genesis 2018).

12.5 In order to inform the HRA, modelling has also been undertaken for other activities for which there is potential for an in-combination impact. Additional sound modelling has been undertaken for:

- Seismic survey,
- Sub-bottom profiler,
- UXO detonation and blasting.

12.6 Activities for which additional modelling has been undertaken in order to inform the in-combination assessment may also be associated with non-renewable energy projects. As there are no specific known projects that could cause an in-combination impact these activities could occur anywhere within the SCI. For example, seismic surveys, that are more frequently undertaken for oil and gas exploration, generally submit applications no more than six months before the planned start date, therefore it is not known when or where future seismic surveys will be undertaken. To address the uncertainty on where future activities may be undertaken, modelling has been carried out at three locations within the SCI, selected to include a broad geographic spread covering different bathymetric features. The different locations have different sound propagation characteristics due to geographically varying sound speed profiles that are incorporated in the noise model (Table 18, Figure 25).

Table 18: Coordinates of modelling locations and water depth for seismic and sub-bottom profiler surveys.

Location		Latitude (decimal degrees)	Longitude (decimal degrees)	Water depth (m)
1	Outer Silver Pit	54.40318	1.159721	53
2	Norfolk Banks	53.17943	1.964898	13
3	North Foreland	51.36425	1.840928	38

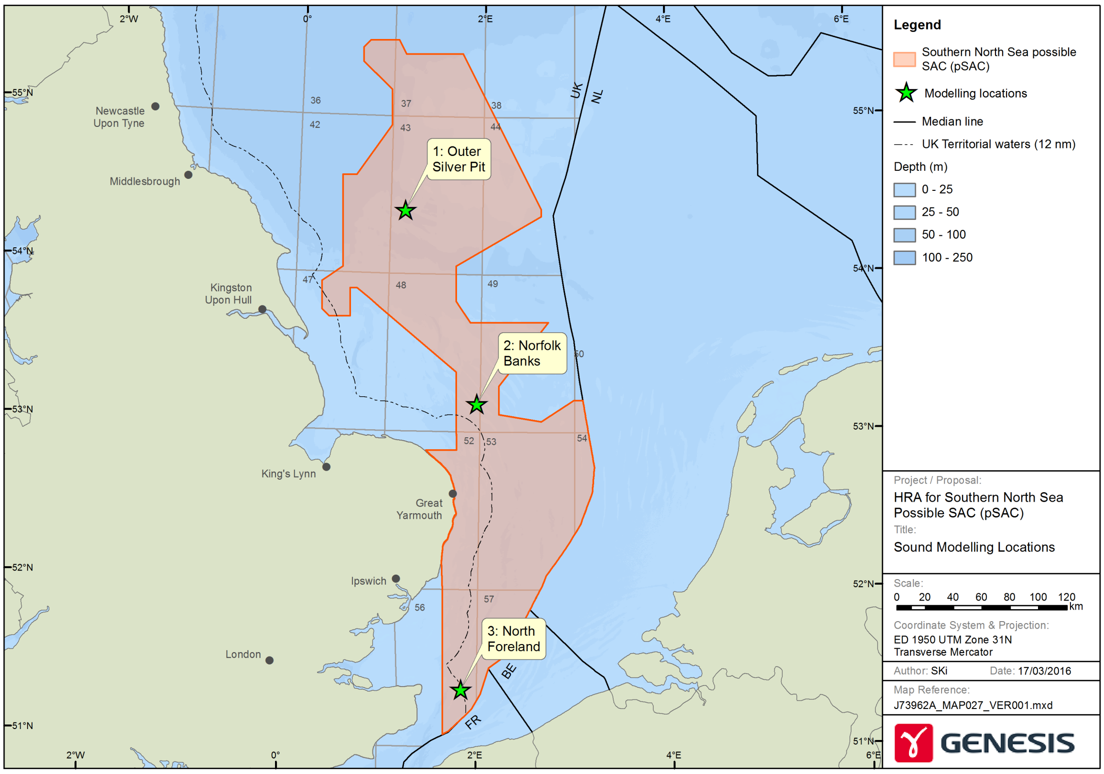


Figure 25: Modelling locations selected within the SCI.

12.7 Sound modelling results based on both zero to peak SPL and weighted SEL are presented for all activities using NOAA thresholds.

12.8 The potential magnitude of any impact on harbour porpoise is dependent on whether or not the individual avoids the area by swimming away from the sound source. The speed and direction it swims has a significant effect on the extent of the potential impact. For the purposes of this assessment the modelling assumes that the harbour porpoise will swim away from the sound source at 1.5 m/s. This is in line with previous assessments undertaken within the SCI, e.g. RWE Renewables 2012, Forewind 2013b, SMart Wind 2015b). This is considered a precautionary swimming speed to be used in this assessment as it is below recorded swimming speeds of harbour porpoise of between 1.9 m/s and of 4.3 m/s but above the mean recorded swimming speed of <1 m/s (Otani *et al.* 2000, Kastelein *et al.* 2018). It is also lower than swimming speeds used in other assessments where swimming speeds of up to 3.4 m/s have been used (e.g. Heinis and Jong 2015). It is assumed that the natural behaviour of harbour porpoise will be to swim away from the sound source at speeds quicker than their usual swimming speed.

12.9 The direction harbour porpoise move away from the sound will vary and depends on a number of factors including the propagation of sound in the environment and the individual's tolerance to the noise. The sound modelling has been conducted for all possible directions that harbour porpoise may swim away from the sound source. Results are presented showing minimum, average and maximum impact distances. The minimum impact distance corresponds to the scenario where a harbour porpoise swims away from the sound source along the route where the lowest sound levels from the sound source exist, whilst the maximum impact distance corresponds to the scenario where a harbour porpoise swims away from the sound source along the inline direction where sound levels are highest. It is considered unlikely that a harbour porpoise would swim away from the source along the route of maximum sound levels since it is expected that they would seek a route away from the sound source where they are not exposed to such high levels of sound. The average impact distance has been calculated by averaging the impact distances over all possible directions that a harbour porpoise may swim away from the airgun array. This is considered suitably precautionary as an individual is likely to select a route along minimal noise levels but also accounts for the variability in the behaviour of individual harbour porpoises.

Noise Modelling – Seismic Surveys

12.10 The sound modelling undertaken to assess potential extent of impacts from seismic airgun noise is based on a 3,000 cu. in. airgun array, comprising four sub-arrays each with eight individual airguns ranging in volume of between 40 cu in and 150 cu. in. The maximum SPL is 261 dB *re* 1 $\mu Pa^2 s$ (0-peak SPL). This is a relatively large airgun array used typically by the oil and gas industry when exploring for hydrocarbons.

12.11 Airgun arrays are designed to be highly directional in order to focus the low-frequency sound energy vertically down into the water column to maximise energy into the seabed and underlying geology. Therefore, the sound levels emitted in horizontal directions is generally lower by at least 10 – 20 dB than the values for vertical propagation (Richardson *et al*. 1995; Nedwell *et al*. 1999). Treating the source array as an omni-directional source (that emits energy equally in all directions) leads to an over estimation of sound levels and consequently an over estimation of potential impacts. The modelling outputs account for the directionality of the airgun noise.

12.12 Modelled outputs for the onset of PTS for an airgun array operating at full power and airgun array operating with a soft-start are presented. The requirement to undertake a soft-start, where the airguns are ramped up over a period of time, is a recommendation made by the JNCC and is a condition within all permits issued for oil and gas related seismic surveys (JNCC 2017d). All seismic surveys undertaken within the SCI will be required to use soft start procedures and therefore the in-combination assessment is based on the realistic scenario of a seismic survey commencing with a soft-start undertaken over a period of 20 minutes during which time the number of airguns operating will be increased, starting with lowest volume airgun and ending with the highest.

12.13 The airgun array that has been modelled in this assessment consists of 4 sub-arrays, with each sub-array comprising eight individual airguns. The total number of airguns in the array is 32, with airgun chamber volumes ranging from 40 cubic inches to 150 cubic inches. The total volume of the airgun array is 3,000 cubic inches.

Table 19: Seismic airgun array details.

Parameter		Value
Array type		Bolt airgun array
Number of airguns		32
Total volume		3,000 cubic inches
Source sound pressure level (SPL)	Peak-to-peak	267 dB re 1 μPa-m
	Zero-to-peak	261 dB re 1 μPa-m
	Root-mean-square (rms)	246 dB re 1 μPa-m (for a time-averaging window of 100 ms)
Source sound exposure level (SEL) (single pulse)		236 dB re 1 $\mu Pa^2 s$-m
Peak frequency		20 Hz
Pulse interval		10 s
Tow depth		6 m
Tow speed		4.6 knots (2.4 m/s)

Noise modelling – Sub-bottom Profilers

12.14 Sub-bottom profilers are regularly used by offshore industries including both the renewable and oil and gas industries. The type of sub-bottom profiler used will vary depending on the requirements of the survey and location. The parameters that have been modelled for the sub-bottom profiler are shown in Table 20. These parameters have been selected from the manufacturer details of chirp sub-bottom profilers and have been chosen to be conservative e.g. the maximum source levels, beam width and bandwidth of the surveyed sub-bottom profilers have been used in the modelling for this assessment.

12.15 Although recommended in JNCC guidance (JNCC 2017d), no soft-start procedures have been included in this assessment as not all equipment is capable of undertaking a soft-start and therefore it is possible that the use of sub-bottom profilers without a soft start could occur within the SCI.

Table 20: Sub-bottom profiler details.

Parameter		Value
Signal type		Source level
Source level	Peak SPL	267 dB re 1 μPa-m
	Root mean square SPL	261 dB re 1 μPa-m
	Bandwidth (-3 dB)	246 dB re 1 μPa-m (for a time-averaging window of 100 ms)
Bandwidth (-3 dB)		Beam width (-3 dB)
Beam width (-3 dB)		Pulse width
Pulse width		Duty cycle
Duty cycle		Pulse rate
Pulse rate		Source level

Noise Modelling –UXO Detonation and Blasting

12.16 UXO clearance could occur anywhere within the SCI. The source level and frequency content of an underwater explosion is dependent on numerous factors, including the charge weight, the type of explosive material, and the depth of the detonation. Sound modelling for blasting and UXO clearance activities within the SCI is based on a range of Net Equivalent Quantity (NEQ) explosive weights ranging from 10 kg to 1,000 kg. The peak SPL source levels used for the modelling range from 282 dB *re* 1 μPa^{2}s (peak SPL) to 297 dB *re* 1 μPa^{2}s (peak SPL). The predicted peak SPL source levels are presented in Table 21.

Table 21: Predicted peak SPL source levels for different explosive weights.

Explosive weight (kg) NEQ	Source peak SPL (dB re 1μPa at 1 m $_{0\text{-peak}}$)
1,000	297
500	294
250	292
100	289
50	287
20	284
10	282

12.17 JNCC guidelines advise *that 'activities that make use of explosions for a relatively short period of time it is considered that there will be a low likelihood of disturbance*' (JNCC 2010b). The results from the sound modelling are therefore focused on the potential for physical injury to occur, i.e. PTS. However, there is potential for UXO clearance that requires detonation to occur anywhere within a wind farm area or along the export cable corridor. It is also possible that more than one piece of UXO will require disposal at each project location. If so, it is predicted that this will be limited to no more than two detonations per day, e.g. EAOWL (2017).

13 NOISE MODELLING RESULTS

13.1 Noise modelling has been undertaken for all projects that were identified within the scoping exercise carried out to inform this HRA and all the results are presented in the *Technical Noise Modelling Report* (Genesis 2018). The following section presents a summary of the noise modelling results for projects that are only subject to this review or those that have been identified as having the potential to cause an in-combination impact with those developments that are subject to this review.

13.2 Although comprehensive noise modelling has previously been undertaken for all the consented offshore wind farms and presented at the time of application, the modelling undertaken by developers in support of their applications have, over time, used differing approaches. Consequently, it is not possible to undertake an in-combination assessment based solely on the outputs from previous modelling as they are not directly comparable. Noise modelling has therefore been undertaken for all the wind farm projects that are subject to this review of consents specifically to inform this HRA.

13.3 Noise modelling has also been undertaken for wind farms, the consents for which are not subject to this review, e.g. Triton Knoll and East Anglia Three. These wind farms have been identified as having the potential for an in-combination impact with projects that are subject to this review and therefore noise modelling has been undertaken to ensure a consistency in approach.

Pile-driving

13.4 The noise modelling undertaken is based on the information provided by developers following requests during Scoping by BEIS (BEIS 2017b). The information was collected specifically for the purposes of this HRA. The exception being East Anglia Three where the relevant information has been obtained from the developer's Environmental Statement (EAOWL 2015b).

13.5 Due to the number of projects and the modelling scenarios required, noise modelling has been limited to either two or three locations within each wind farm area. The locations where modelling has been undertaken were selected based on location within the SCI, i.e. the location furthest within the SCI or, if outside the boundaries of the SCI, a location near to the SCI boundary. Sites were also selected based on water depth, with locations in relatively deeper water being selected on the basis that it is recognised that generally sound propagates further in deeper water than it does in shallower water. Therefore, the potential maximum extent of noise impacts from each of the wind farm areas has been identified for this HRA.

13.6 Modelled outputs are presented for the installation of a pile hammer operating at full energy and include a soft start and ramp-up scenario. The installation of a pile requires the hammer energy to be increased over a period of time until it reaches maximum energy and hammer blows maintained at this energy level until full pile penetration is achieved. This allows time for individual animals to swim away from the sound source as the sound level increases. Ramp-up scenarios vary depending on the pile size and the seabed conditions and will therefore vary from site to site. The information on the duration of pile-driving and the soft start / ramp-up scenarios has been obtained from the developers as part of the request for information and are presented in the *Technical Noise Modelling Report* (Genesis 2018).

13.7 For assessing the potential impacts from the onset of PTS, both unweighted zero to peak SPL and cumulative weighted SEL thresholds are used. The extent of potential impacts for un-weighted zero to peak SPL are based on the maximum sound levels modelled in the water column at each point over distance, whereas those for cumulative SEL and disturbance are based on depth average sound levels within the water column. The approach taken for cumulative SEL takes into consideration the likely behaviour of harbour porpoises over time when swimming away from the sound source, i.e. they will naturally avoid water depths with the highest sound levels. However, the approach is also precautionary as it does not presume that all harbour porpoise will swim near the sea surface where typically the lowest levels of propagating sound occur over distance.

13.8 The hearing thresholds used are the NOAA thresholds published in NMFS (2016, 2018). These thresholds have been arrived at following a comprehensive review of the existing evidence and are considered to to be the most appropriate thresholds to use at the current time.

13.9 The threshold used for this assessment at which displacement and disturbance to harbour porpoise is predicted to occur is an unweighted SEL of 145 dB re.1μPa^{2}s. This threshold is based on published studies (Lucke *et al.* 2009) and has been used previously when undertaking assessments of the impacts from offshore wind farms, e.g. Forewind 2013b and SMart WInd 2015a. Based on the results from the dose response curve it is estimated that there is approximately a 25% probability of displacement occurring at this level.

13.10 The worst-case scenarios are presented, i.e. the location where the greatest distance at which thresholds are exceeded based on the cumulative weighted results have been selected.

13.11 The following presents a summary of the results from the noise modelling undertaken for each of the consented offshore wind farms subject to this review and those that have been identified as potentially causing an in-combination noise impact. Further details of all the noise modelling undertaken in support of this assessment are presented in the supporting *Technical Noise Modelling Report* (Genesis 2018).

Hornsea Two: single pile-driving

13.12 The results from noise modelling for Hornsea Two are based on two hammer energies of 2,300 kJ and 3,000 kJ at two different locations within the wind farm area. The distances and areas across which the onset of PTS is predicted to occur for unweighted SPL and cumulative SEL are presented in Table 22 and Table 23. The potential extent of displacement and disturbance for unweighted SEL thresholds of 145 re 1 μPa^{2}s is presented in Table 24.

Table 22: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Hornsea Two based on maximum hammer energies (unweighted zero to peak SPL).

Location	Unweighted SPL of 202 dB re 1 uPa (0-peak SPL)							
	2,300 kJ				3,000 kJ			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	563	585	608	1.07	689	761	835	1.82
2	491	510	524	0.82	593	621	640	1.21

Table 23: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Hornsea Two based on maximum hammer energies (weighted SEL).

Location	Cumulative weighted SEL of 155 dB re 1 uPa^{2}s							
	2,300 kJ (4 hrs)				3,000 kJ (9 hrs)			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	1,032	1,071	1,117	3.60	1,463	1,534	1,601	7.38
2	834	892	925	2.49	1,222	1,304	1,365	5.34

Table 24: Distances and area within which displacement or disturbance is predicted to occur from pile-driving at Hornsea Two based on maximum hammer energies (unweighted SEL).

Location	Unweighted SEL of 145 SEL dB re.1μPa^{2}s							
	2,300 kJ (4 hrs)				3,000 kJ (9 hrs)			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	15,040	20,678	24,118	1,350	19,181	23,323	38,738	1,659
2	19,962	26,800	48,733	2,251	22,963	29,517	49,747	2,794

Hornsea Two: concurrent pile-driving

13.13 The results from noise modelling for Hornsea Two are based on two hammer energies of 2,300 kJ and 3,000 kJ at two different locations 20 km apart within the wind farm area. The distances and areas across which the onset of PTS is predicted to occur for unweighted zero to peak SPL and cumulative weighted SEL do not overlap and the estimated impacts at each pile-driving location are the same as those estimated for the single pile-driving scenarios.

13.14 The potential area of displacement and disturbance from concurrent pile-driving are presented in Table 25.

Table 25: Area within which displacement or disturbance is predicted to occur from concurrent pile-driving at Hornsea Two based on maximum hammer energies (unweighted SEL).

Area of disturbance (km^2)	
2,300 kJ	3,000 kJ
2,819	3,420

Unweighted SEL: 145 SEL dB re.1μPa^{2}s

Creyke Beck A

13.15 The results from noise modelling for Creyke Beck A are based on two hammer energies of 2,300 kJ and 3,000 kJ at three different locations within the wind farm area. The distances and areas across which the onset of PTS is predicted to occur for unweighted SPL and cumulative SEL are presented in Table 26 and Table 27. The potential extent of displacement and disturbance for unweighted SEL thresholds of 145 re 1 μPa2s is presented in Table 28.

Table 26: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Creyke Beck A based on maximum hammer energies (unweighted zero to peak SPL).

Location	Unweighted SPL of 202 dB re 1 uPa (0-peak SPL)							
	2,300 kJ				3,000 kJ			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	578	622	661	1.21	669	740	819	1.72
2	546	549	560	0.95	696	709	714	1.58
3	610	616	633	1.19	710	740	758	1.72

Table 27: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Creyke Beck A based on maximum hammer energies (weighted SEL).

Location	Cumulative weighted SEL of 155 dB re 1 uPa^2s							
	2,300 kJ (3.5 hrs)				3,000 kJ (5.5 hrs)			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	1,228	1,416	1,648	6.32	1,949	2,223	2,499	15.55
2	1,187	1,305	1,419	5.35	1,971	2,134	2,273	14.31
3	1,310	1,445	1,570	6.57	2,139	2,299	2,471	16.61

Table 28: Distances and area within which displacement or disturbance is predicted to occur from pile-driving at Creyke Beck A based on maximum hammer energies (unweighted SEL).

Location	Unweighted SEL of 145 SEL dB re.1μPa^2s							
	2,300 kJ (3.5 hrs)				3,000 kJ (5.5 hrs)			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	10,380	12,242	14,384	476.9	10,874	13,476	16,649	583.9
2	10,661	14,253	18,833	651.8	12,866	15,760	19,867	791.0
3	10,146	13,717	17,291	598.7	11,129	15,131	19,505	735.9

Creyke Beck A: concurrent pile-driving

13.16 The results from noise modelling for Creyke Beck A offshore wind farm are based on two hammer energies of 2,300 kJ and 3,000 kJ at two different locations at points furthest distances apart and within the SCI. The distances and areas across which the onset of PTS is predicted to occur for unweighted zero to peak SPL and cumulative weighted SEL do not overlap and the estimated impacts at each pile-driving location are the same as those estimated for the single pile-driving scenarios.

13.17 The potential area of displacement and disturbance from concurrent pile-driving are presented in Table 29.

Table 29: Area within which displacement or disturbance is predicted to occur from concurrent pile-driving at Creyke Beck A based on maximum hammer energies (unweighted SEL).

Area of disturbance (km²)	
2,300 kJ	3,000 kJ
1,071	1,281

Unweighted SEL: 145 SEL dB re.1μPa^{2}s

Creyke Beck B

13.18 The results from noise modelling for Creyke Beck B are based on two hammer energies of 2,300 kJ and 3,000 kJ at two different locations within the wind farm area. The distances and areas across which the onset of PTS is predicted to occur for unweighted zero to peak SPL and cumulative SEL are presented in Table 30 and Table 31. The potential extent of displacement and disturbance for unweighted SEL thresholds of 145 re 1 μPa2s is presented in Table 32.

Table 30: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Creyke Beck B based on maximum hammer energies (unweighted zero to peak SPL).

Location	Unweighted SPL of 202 dB re 1 uPa $_{(0\text{-peak SPL})}$							
	2,300 kJ				3,000 kJ			
	Distance (m)			Area (km²)	Distance (m)			Area (km²)
	Min	Mean	Max		Min	Mean	Max	
1	589	634	685	1.26	702	757	806	1.80
2	477	507	532	0.81	608	651	688	1.33

Table 31: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Creyke Beck B based on maximum hammer energies (weighted SEL).

Location	Cumulative weighted SEL of 155 dB re 1 uPa^{2}s							
	2,300 kJ				3,000 kJ (5.5 hrs)			
	Distance (m)			Area (km²)	Distance (m)			Area (km²)
	Min	Mean	Max		Min	Mean	Max	
1	1,201	1,499	1,764	7.10	1,940	2,365	2,718	17.65
2	1,152	1,361	1,508	5.84	1,893	2,227	2,424	15.63

Table 32: Distances and area within which displacement or disturbance is predicted to occur from pile-driving at Creyke Beck B based on maximum hammer energies (unweighted SEL).

Location	Unweighted SEL of 145 SEL dB re.1μPa^{2}s							
	2,300 kJ (3.5 hrs)				3,000 kJ (5.5 hrs)			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	11,686	14,661	18,332	684.1	12,727	16,040	20,517	823.3
2	15,919	19,583	24,699	1,209	17,162	21,813	27,048	1,498

Creyke Beck B: concurrent pile-driving

13.19 The results from noise modelling for Creyke Beck B offshore wind farm are based on two hammer energies of 2,300 kJ and 3,000 kJ at two different locations at points furthest distances apart and within the SCI. The distances and areas across which the onset of PTS is predicted to occur for unweighted zero to peak SPL and cumulative weighted SEL do not overlap and the estimated impacts at each pile-driving location are the same as those estimated for the single pile-driving scenarios.

13.20 The potential area of displacement and disturbance from concurrent pile-driving are presented in Table 33.

Table 33: Area within which displacement or disturbance is predicted to occur from concurrent pile-driving at Creyke Beck B based on maximum hammer energies (unweighted SEL).

Area of disturbance (km^2)	
2,300 kJ	3,000 kJ
1,710	2,042

Unweighted SEL: 145 SEL dB re.1μPa^{2}s

Teesside A

13.21 The results from noise modelling for Teesside A are based on two hammer energies of 3,000 kJ and 5,500 kJ used at two different locations within the wind farm area. The distances and areas across which the onset of PTS is predicted to occur for unweighted zero to peak SPL and cumulative SEL are presented in Table 34 and Table 35. The potential extent of displacement and disturbance for unweighted SEL thresholds of 145 re 1 μPa^{2}s is presented in Table 36.

Table 34: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Teesside A based on maximum hammer energies (unweighted zero to peak SPL).

Location	Unweighted SPL of 202 dB re 1 uPa (0-peak SPL)							
	3,000 kJ				5,500 kJ			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	630	682	716	1.46	957	1,060	1,128	3.53
2	591	646	697	1.31	883	905	962	2.57

Table 35: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Teesside A based on maximum hammer energies (weighted SEL).

Location	Cumulative weighted SEL of 155 dB re 1 uPa^2s							
	3,000 kJ (5.5 hrs)				5,500 kJ (5.5 hrs)			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	1,886	2,169	2,401	14.82	3,945	4,459	4,777	62.52
2	1,749	1,838	1,935	10.60	3,807	3,997	4,242	50.16

Table 36: Distances and area within which displacement or disturbance is predicted to occur from pile-driving at Teesside A based on maximum hammer energies (unweighted SEL).

Location	Unweighted SEL of 145 SEL dB re.1μPa^2s							
	3,000 kJ (5.5 hrs)				5,500 kJ (5.5 hrs)			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	15,477	18,387	21,778	1,072	19,467	23,456	29,330	1,752
2	16,560	19,737	22,904	1,226	20,514	25,003	29,015	1,964

Teesside A: concurrent pile-driving

13.22 The results from noise modelling for Teesside A offshore wind farm are based on two hammer energies of 3,000 kJ and 5,500 kJ at two different locations at points furthest distances apart and closest to the SCI. The distances and areas across which the onset of PTS is predicted to occur for unweighted zero to peak SPL and cumulative weighted SEL do not overlap and the estimated impacts at each pile-driving location are the same as those estimated for the single pile-driving scenarios.

13.23 The potential area of displacement and disturbance from concurrent pile-driving are presented in Table 37.

Table 37: Area within which displacement or disturbance is predicted to occur from concurrent pile-driving at Teesside A based on maximum hammer energies (unweighted SEL).

Area of disturbance (km^2)	
3,000 kJ	5,500 kJ
1,777	2,657

Unweighted SEL: 145 SEL dB re.1μPa^2s

Teesside B

13.24 The results from noise modelling for Teesside B are based on two hammer energies of 3,000 kJ and 5,500 kJ used at two different locations within the wind farm area. The distances and areas across which the onset of PTS is predicted to occur for unweighted zero to peak SPL and cumulative SEL are presented in Table 38 and Table 39. The potential extent of displacement and disturbance for unweighted SEL thresholds of 145 re 1 μPa2s is presented in Table 40.

Table 38: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Teesside B based on maximum hammer energies (unweighted SPL).

Location	Unweighted SPL of 202 dB re 1 uPa $_{\text{(0-peak SPL)}}$							
	3,000 kJ				5,500 kJ			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	618	643	667	1.30	962	1,059	1,115	3.52
2	680	704	753	1.55	1,031	1,082	1,123	3.67

Table 39: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Teesside B based on maximum hammer energies (weighted SEL).

Location	Cumulative weighted SEL of 155 dB re 1 uPa^2s							
	3,000 kJ (5.5 hrs)				5,500 kJ (5.5 hrs)			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	1,798	1,988	2,170	12.43	3,727	4,170	4,477	54.68
2	4,201	4,456	4,708	15.75	4,201	4,456	4,708	62.32

Table 40: Distances and area within which displacement or disturbance is predicted to occur from pile-driving at Teesside B based on maximum hammer energies (unweighted SEL).

Location	Unweighted SEL of 145 SEL dB re.1μPa^{2}s							
	3,000 kJ				5,500 kJ			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	15,170	18,674	23,617	1,098	18,472	24,080	30,007	1,842
2	13,641	16,396	20,275	850.2	16,658	20,663	26,701	1,351

Teesside B: concurrent pile-driving

13.25 The results from noise modelling for Teesside B offshore wind farm are based on two hammer energies of 3,000 kJ and 5,500 kJ at two different locations at points furthest distances apart. The distances and areas across which the onset of PTS is predicted to occur for unweighted zero to peak SPL and cumulative weighted SEL do not overlap and the estimated impacts at each pile-driving location are the same as those estimated for the single pile-driving scenarios.

13.26 The potential area of displacement and disturbance from concurrent pile-driving are presented in Table 41.

Table 41: Area within which displacement or disturbance is predicted to occur from concurrent pile-driving at Teesside B based on maximum hammer energies (unweighted SEL).

Area of disturbance (km^2)	
3,000 kJ	5,500 kJ
1,855	2,806

Unweighted SEL: 145 SEL dB re.1μPa^{2}s

Triton Knoll

13.27 The results from noise modelling for Triton Knoll are based on two hammer energies of 2,700 kJ and 4,000 kJ used at two different locations within the wind farm area. The distances and areas across which the onset of PTS is predicted to occur for unweighted zero to peak SPL and cumulative SEL are presented in Table 42 and Table 43. The potential extent of displacement and disturbance for unweighted SEL thresholds of 145 re 1 μPa2s is presented in Table 44.

Table 42: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Triton Knoll based on maximum hammer energies (unweighted zero to peak SPL).

Location	Unweighted SPL of 202 dB re 1 uPa (0-peak SPL)							
	2,700 kJ				4,000 kJ			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	599	640	722	1.29	834	866	899	2.35
2	402	494	626	0.77	526	642	763	1.30

Table 43: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Triton Knoll based on maximum hammer energies (weighted SEL).

Location	Cumulative weighted SEL of 155 dB re 1 uPa^2s							
	2,700 kJ (4.0 hrs)				4,000 kJ (4.0 hrs)			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	1,169	1,565	1,761	7.78	1,868	2,541	2,854	20.53
2	718	1,732	2,612	10.36	1,353	2,522	2,900	20.47

Table 44: Distances and area within which displacement or disturbance is predicted to occur from pile-driving at Triton Knoll based on maximum hammer energies (unweighted SEL).

Location	Unweighted SEL of 145 SEL dB re.1μPa^2s							
	2,700 kJ (4.0 hrs)				4,000 kJ (4.0 hrs)			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	11,446	14,771	22,287	700.0	8,204	14,187	24,899	689.9
2	12,760	16,923	26,703	934.5	10,175	16,083	27,611	881.1

Triton Knoll: concurrent pile-driving

13.28 The results from noise modelling for Triton Knoll offshore wind farm are based on two hammer energies of 2,700 kJ and 4,000 kJ at two different locations at points furthest distances apart. The distances and areas across which the onset of PTS is predicted to occur for unweighted zero to peak SPL and cumulative weighted SEL do not overlap and the estimated impacts at each pile-driving location are the same as those estimated for the single pile-driving scenarios.

13.29 The potential area of displacement and disturbance from concurrent pile-driving are presented in Table 45.

Table 45: Area within which displacement or disturbance is predicted to occur from concurrent pile-driving at Triton Knoll based on maximum hammer energies (unweighted SEL).

Area of disturbance (km^2)	
2,700 kJ	4,000 kJ
947.1	1,191

Unweighted SEL: 145 SEL dB re.1µPa^2s

East Anglia Three

13.30 The results from noise modelling for East Anglia Three are based on two hammer energies of 2,400 kJ and 3,000 kJ used at two different locations within the wind farm area. The distances and areas across which the onset of PTS is predicted to occur for unweighted zero to peak SPL and cumulative SEL are presented in Table 46 and Table 47. The potential extent of displacement and disturbance for unweighted SEL thresholds of 145 re 1 µPa2s is presented in Table 48.

Table 46: Distances and area within which the onset of PTS is predicted to occur from pile-driving at East Anglia Three based on maximum hammer energies (unweighted zero to peak SPL).

Location	Unweighted SPL of 202 dB re 1 uPa $_{(0\text{-peak SPL})}$							
	2,400 kJ				3,000 kJ			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	481	490	503	0.75	532	626	681	1.23
2	432	511	590	0.83	584	621	718	1.21

Table 47: Distances and area within which the onset of PTS is predicted to occur from pile-driving at East Anglia Three based on maximum hammer energies (weighted SEL).

Location	Cumulative weighted SEL of 155 dB re 1 uPa^2s							
	2,400 kJ (4.0 hrs)				3,000 kJ (5.5 hrs)			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	845	915	973	2.63	1,292	1,394	1,469	6.10
2	638	693	748	1.51	1,020	1,100	1,195	3.80

Table 48: Distances and area within which displacement or disturbance is predicted to occur from pile-driving at East Anglia Three based on maximum hammer energies (unweighted SEL).

Location	Unweighted SEL of 145 SEL dB re.1μPa^{2}s							
	2,400 kJ (4.0 hrs)				3,000 kJ (5.5 hrs)			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	Min	Mean	Max		Min	Mean	Max	
1	21,793	26,100	39,346	2,018	23,070	28,888	42,457	2,452
2	21,451	25,174	29,609	1,985	23,459	27,577	32,251	2,401

East Anglia Three: concurrent pile-driving

13.31 The results from noise modelling for East Anglia Three offshore wind farm are based on two hammer energies of 2,700 kJ and 3,000 kJ at two different locations at points furthest distances apart and within the SCI. The distances and areas across which the onset of PTS is predicted to occur for unweighted zero to peak SPL and cumulative weighted SEL do not overlap and the estimated impacts at each pile-driving location are the same as those estimated for the single pile-driving scenarios.

13.32 The potential area of displacement and disturbance from concurrent pile-driving are presented in Table 49.

Table 49: Area within which displacement or disturbance is predicted to occur from concurrent pile-driving at East Anglia Three based on maximum hammer energies (unweighted SEL).

Area of disturbance (km^2)	
2,400 kJ	3,000 kJ
3,185	3,744

Unweighted SEL: 145 SEL dB re.1μPa^{2}s

Seismic Surveys (Airguns)

13.33 Based on cumulative weighted SEL noise levels, the results from the modelling indicate that the onset of PTS in harbour porpoise may, on average, occur within 470 m of the airguns (Table 50).

13.34 The results from the modelling indicate that noise levels based on disturbance threshold of an unweigthted SEL of 145 dB re: 1 μPa have the potential to cause behavioural disturbance to harbour porpoise out to 33.2 km from the airguns and encompass an area of 767 km^2 (Table 51).

Table 50: Distances from a seismic survey (with soft start procedure) at which the onset of PTS could occur to harbour porpoise at three locations within the SCI.

Location	Distance where PTS injury threshold is exceeded (m)					
	Peak SPL 202			*Weighted Cumulative SEL 155*		
	Max	*Ave*	*Min*	*Max*	*Ave*	*Min*
1: Outer Silver Pit	1,000	275	120	6,600	470	0
2: Norfolk Banks	425	190	120	2,200	130	0
3: North Foreland	755	270	135	5,060	310	0

Peak SPL - dB re 1 μPa

Weighted cumulative SEL - dB re 1 μPa^{2}s

Table 51: Maximum distances from a seismic survey (with soft start procedure) at which behavioural disturbance could occur to harbour porpoise at three locations within the SCI.

Location	Distance and area of potential behavioural disturbance			
	Distance(m)			*Max. Area (km^2)*
	Min.	*Mean*	*Max.*	
1: Outer Silver Pit	8,918	26,292	33,207	767.0
2: Norfolk Banks	2,286	14,612	21,655	313.9
3: North Foreland	6,088	16,318	24,672	522.2

Unweighted SEL – 145 dB re 1 μPa

13.35 Figure 26 to Figure 28 present the area of potential disturbance from seismic surveys for three locations within the SCI.

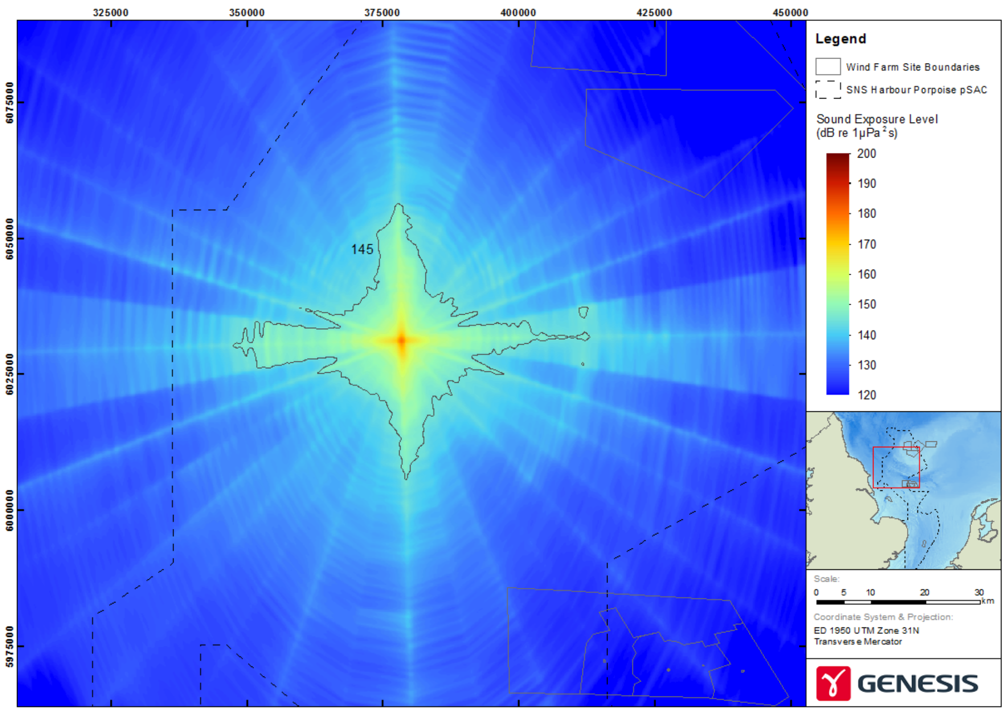


Figure 26: Area of potential disturbance to harbour porpoise from seismic survey at Outer Silver Pit within the SCI.

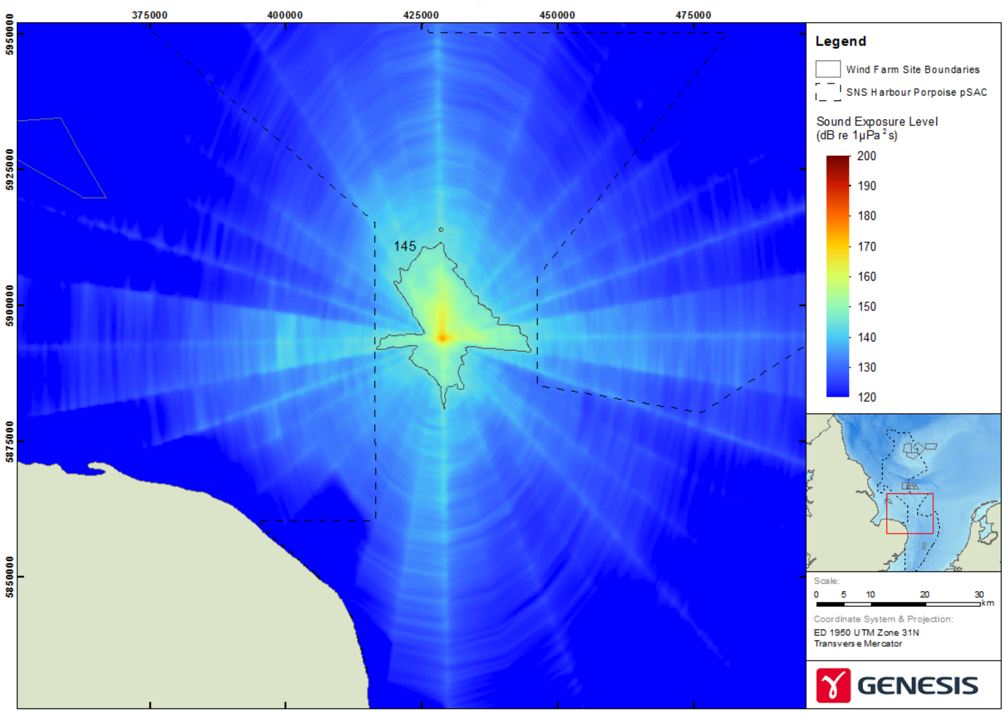


Figure 27: Area of potential disturbance to harbour porpoise from seismic survey at Norfolk Banks within the SCI.

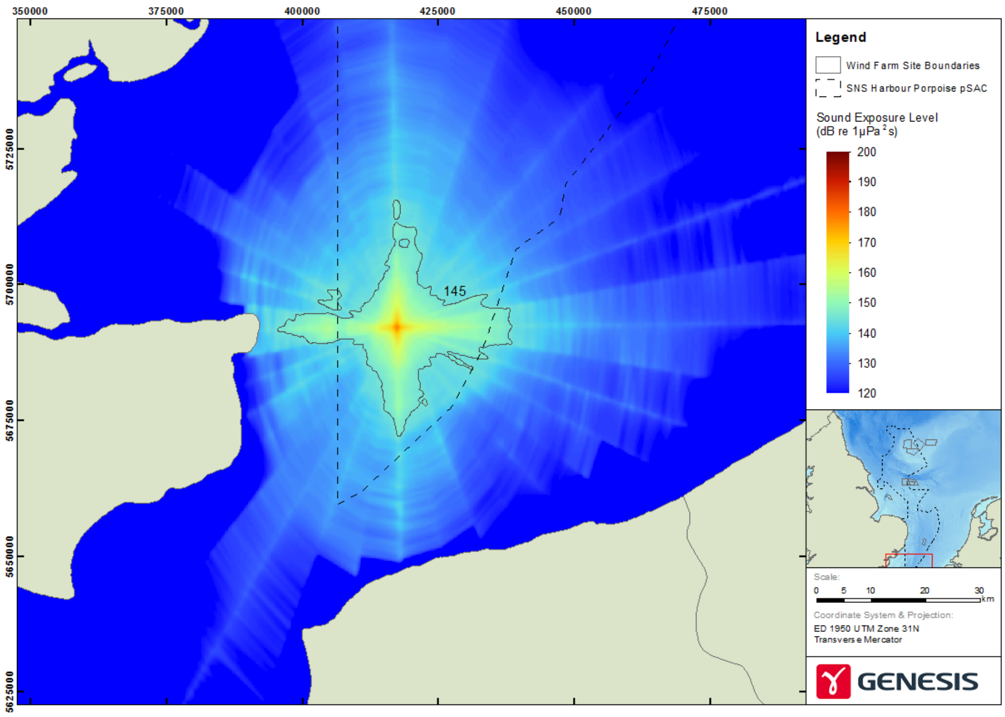


Figure 28: Area of potential disturbance to harbour porpoise from seismic survey at North Foreland within the SCI.

Sub-bottom profiler

13.36 The results from the sound modelling predicted that the onset of PTS could occur within 23 m of a sub-bottom profiler (Table 52).

13.37 The results from the modelling indicate that based on an unweighted rms SPL of 140, noise levels from a sub-bottom profiler have the potential to cause disturbance to harbour porpoise out to a mean distance of 2.5 km and encompass an area of 18.3 km^2 (Table 53).

13.38 Due to the predicted relatively localised area across which disturbance is predicted to occur a dose response curve has not been used to estimate the number of harbour porpoises predicted to be disturbed by sub-bottom profilers.

Table 52: Distances from a sub-bottom profiler at which the onset of PTS could occur to harbour porpoise at three locations within the SCI.

Location	Distance where PTS injury threshold is exceeded (m)					
	Peak SPL 202			*Weighted Cumulative SEL 155*		
	Max	*Ave*	*Min*	*Max*	*Ave*	*Min*
1: Outer Silver Pit	Threshold not exceeded			17	17	17
2: Norfolk Banks	Threshold not exceeded			23	23	23
3: North Foreland	Threshold not exceeded			22	22	22

Peak SPL - dB re 1 μPa

Weighted cumulative SEL - dB re 1 μPa^{2}s

Table 53: Maximum distances from a sub-bottom profiler at which behavioural disturbance could occur to harbour porpoise at three locations within the SCI.

Location	Distance and area of potential behavioural disturbance			
	Distance(m)			*Area (km^2)*
	Min.	*Mean*	*Max.*	
1: Outer Silver Pit	1,858	2,434	3,029	18.1
2: Norfolk Banks	1,683	2,517	3,770	18.2
3: North Foreland	1,835	2,447	3,073	18.3

Unweighted rms SPL 140 dB re 1 μPa

13.39 Figure 29 to Figure 31 present the area of potential disturbance from sub-bottom profilers for three locations within the SCI.

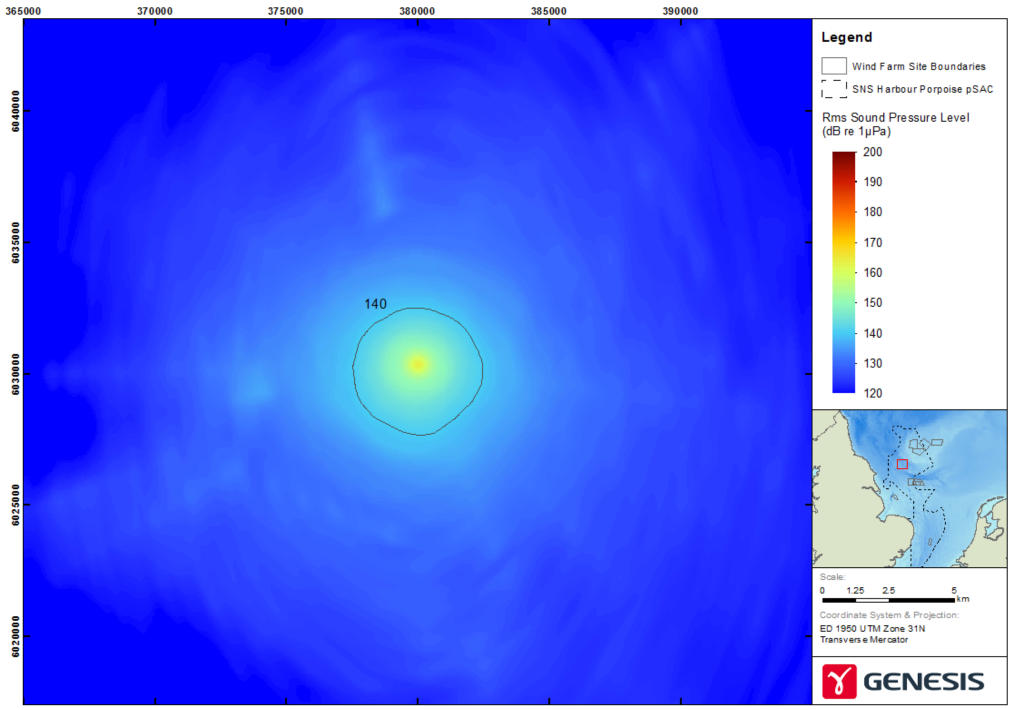


Figure 29: Area of potential disturbance to harbour porpoise from sub-bottom profiler at Outer Silver Pit within the SCI.

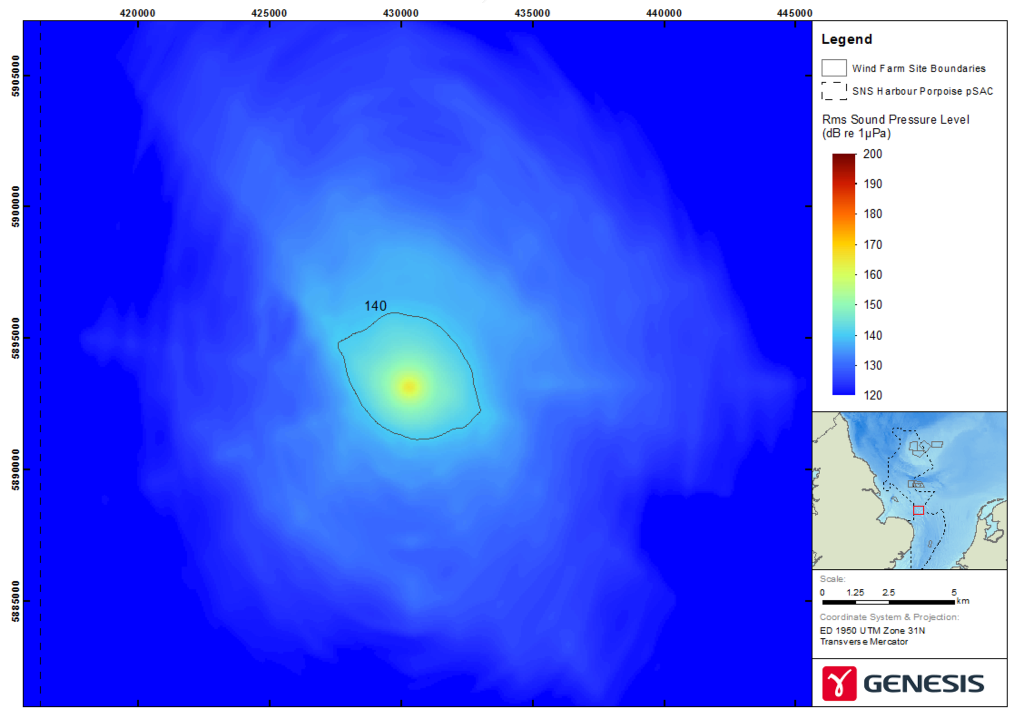


Figure 30: Area of potential disturbance to harbour porpoise from sub-bottom profiler at Norfolk Banks within the SCI.

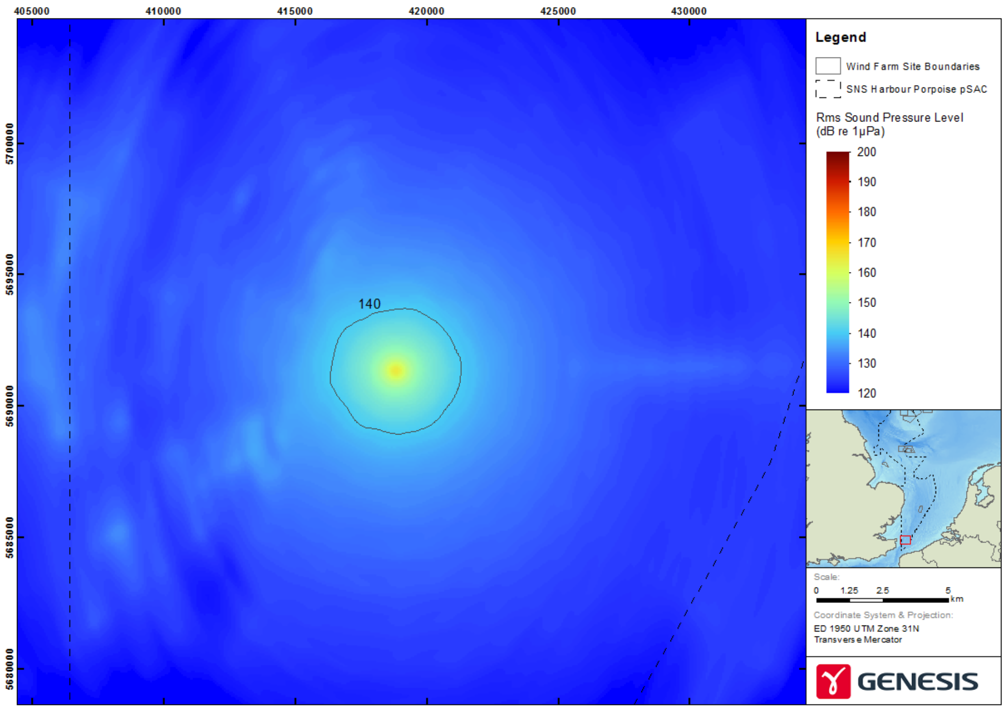


Figure 31: Area of potential disturbance to harbour porpoise from sub-bottom profiler at North Foreland within the SCI.

UXO Detonation and Blasting

13.40 The results from the modelling indicate that, noise levels arising from UXO clearance or blasting activities have the potential to cause the onset of PTS from between 3.3 km out to 15.4 km depending on the weight of the explosive (Figure 32, Table 54). The modelling undertaken is not site specific and therefore the results apply to all locations within the SCI. The results are similar to those presented in existing published studies which have also indicated that water depth can have a significant effect on the extent noise from UXO detonations can propagate (von Benda-Beckmann *et al.* 2015, Ward 2015).

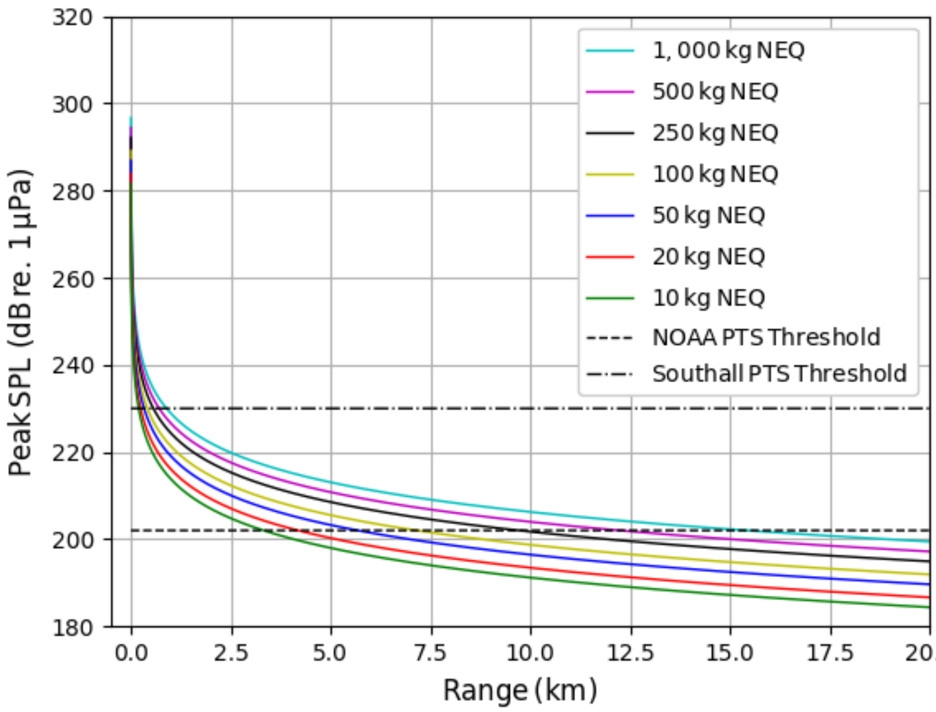


Figure 32: Predicted peak SPL for the detonation of different explosive weights.

Table 54: Distances from a single detonation of explosive at which the onset of PTS could occur in harbour porpoise within the SCI.

Mass of explosives (kg NEQ)	Distance where PTS injury threshold is exceeded (m)
10	3,321
20	4,184
50	5,679
100	7,155
250	9,711
500	12,236
1,000	15,416

Unweighted peak SPL 202 dB re 1 μPa

Impacts on Prey (Fish)

13.41 The results from the modelling indicate that, noise levels from pile-driving have the potential to cause fish mortality or mortal injury within 200 m at all wind farms, based on their maximum hammer energies (Table 55).

Table 55: Estimated extent of impact on fish species from pile-driving from offshore wind farms.

Impact Criterion	Estimated extent of impact (m)				
	Hornsea Two	Creyke Beck A	Creyke Beck B	Teesside A	Teesside B
Fish with no swim bladder (e.g. sandeels, plaice, sole)					
Mortality and potential mortal injury (Unweighted peak SPL of 213 dB re 1 μPa)	81	115	117	181	175
Mortality and potential mortal injury (Unweighted cum. SEL of 219 dB re 1 μPa^{2}s)	0	0	0	0	0
Recoverable injury (Unweighted cum. SEL of 216dB re 1 μPa^{2}s)	0	0	0	0	0
Fish with swim bladder not involved with hearing (e.g. gobies, Atlantic salmon, sea trout)					
Mortality and potential mortal injury (Unweighted peak SPL of 207 dB re 1 μPa)	274	333	348	417	537
Mortality and potential mortal injury (Unweighted cum. SEL of 210 dB re 1 μPa^{2}s)	0	0	0	0	0
Recoverable injury (Unweighted cum. SEL of 203 dB re 1 μPa^{2}s)	9	1	1	4	4
Fish with swim bladder involved with hearing (e.g. Sprat, herring, cod)					
Mortality and potential mortal injury (Unweighted peak SPL of 207 dB re 1 μPa)	274	333	348	417	537
Mortality and potential mortal injury (Unweighted cum. SEL of 207 dB re 1 μPa^{2}s)	0	0	0	0	0
Recoverable injury (Unweighted cum. SEL of 203 dB re 1 μPa^{2}s)	9	1	1	4	4

14 POPULATION MODELLING

14.1 Population modelling can be a useful tool when undertaking assessments to indicate potential population level effects from an impact. Previous assessments have been undertaken on harbour porpoise within the SCI that have used population modelling to estimate population impacts from offshore wind farm pile-driving noise within the SCI (e.g. Booth *et al*. 2017, Verfuss *et al.* 2016). The population model used for these assessments was the Interim Population Consequences of Disturbance (iPCoD) model. The model was developed to evaluate the potential effects of offshore marine renewable energy construction and operation on UK marine mammal populations and therefore could be used to help inform this assessment (Booth *et al*. 2017, King *et al*. 2015). During the preparation of this HRA the model was being updated and the use of the version available at the time was not recommended. '*A bug was found in the code. As a consequence, we have withdrawn the download while the issues are being examined. A new version will be published in due course. Marine Scotland will retain a copy of the code, but does not recommend using it*' (Marine Scotland 2018). In August 2018 a revised model (Version 4) was developed and available upon request with a further revision that incorporates new disturbance expert elicitation functions with a planned release date in early autumn 2018. Consequently, the use of the iPCoD model has not been available during the preparation of this HRA with the revised Version 4 arriving too late to be used for this assessment.

14.2 An alternative model, The Disturbance Effects on the Harbour Porpoise Population in the North Sea (DEPONS) model has been developed specifically to assess the effects of disturbance on harbour porpoise and results from early versions of the model have been presented by wind farm developers but not used as part of their EIAs (e.g. SMart Wind 2015). Until May 2018, there had been no published assessments using the final version of the model and therefore no published evidence that the use of the model would be suitable for the purposes of this assessment. Consequently, the DEPONS model was not used for this assessment.

15 CONSERVATION OBJECTIVES

15.1 Conservation Objectives constitute a necessary reference for identifying site-based conservation measures and for carrying out HRAs of the implications of plans or projects (JNCC and NE 2016). They outline the desired state for any European site, in terms of the features for which it has been designated. If these features are being managed in a way which maintains their nature conservation value, they are assessed as being in a 'favourable condition'. An adverse effect on the integrity of a site is likely to be one which prevents the site from making the same contribution to favourable conservation status for the relevant feature as it did at the time of its designation (English Nature 1997).

15.2 The purpose of an Appropriate Assessment is to determine whether a plan or project adversely affects a site's integrity. The critical consideration in relation to site integrity is whether the plan or project affecting a site, either individually or in-combination, affects the site's ability to achieve its conservation objectives and favourable conservation status (JNCC 2016).

15.3 Harbour porpoise are also protected throughout European waters under the provisions of Annex IV and Article 12 of the Habitats Directive, which are outwith the scope of this assessment. Harbour porpoise in UK waters are considered part of a wider European population and the mobile nature of this species means that the concept of a 'site population' is not thought to be appropriate for this species. Site based conservation measures therefore aim to complement wider ranging measures that are in place for the harbour porpoise (JNCC 2016).

15.4 The Conservation Objectives for harbour porpoise are designed to ensure that human activities do not, in the context of maintaining site integrity:

- kill, or injure harbour porpoise (directly or indirectly);
- prevent their use of significant parts of the site (disturbance / displacement);
- significantly damage relevant habitats; or
- significantly reduce the prey base.

Southern North Sea cSAC Conservation Objectives

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

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

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

Source JNCC and NE 2016

15.5 Harbour porpoises are considered to be a 'viable component' of the site if they are able to survive and live successfully within it. Killing, injuring or significantly disturbing harbour porpoise have the potential to affect species viability within the site (JNCC and NE 2016).

15.6 The '*integrity of the site*' is not defined in the draft Conservation Objectives. However, EU and UK Government guidance defines the integrity of a site as ''*the coherence of the site's ecological structure and function, across its whole area, or the habitats, complex of habitats and/or populations of species for which the site is or will be classified*' (EC 2000, Defra 2012). Therefore, the integrity of the site applies to the whole of the site and it is the potential impacts across the whole of the site that are required to be appropriately assessed.

15.7 Within the draft Conservation Objectives '*no significant disturbance of the species'* is described as '*any disturbance should not lead to the exclusion of harbour porpoise from a significant portion of the site for a significant period of time'*. Although there is no definition within the draft Conservation Objectives of what is a significant portion or significant period. The aim is to ensure that the site '*contributes, as best it can, to maintaining the Favourable Conservation Status of the wider harbour porpoise population. As such, how the impacts within the site translate into effects on the North Sea Management Unit population are of greatest concern'* (JNCC and NE 2016).

15.8 *'Supporting habitats and processes'* relate to the seabed and water column along with the harbour porpoise prey.

15.9 JNCC advise that it is not appropriate to use the site population estimates in any assessments of effects of plans or projects (i.e. Habitats Regulation Assessments), as it is necessary to take into consideration population estimates at the Management Unit level to account for daily and seasonal movements of the animals (JNCC 2017a).

15.10 There are no formal thresholds at which impacts on site integrity are considered to be adverse. However, a threshold of 1.7% of the relevant harbour porpoise population above which a population decline is inevitable has been agreed with Parties to the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS), with an intermediate precautionary objective of reducing the impact to less than 1% of the population (Defra 2003, ASCOBANS 2015). This threshold relates to impacts from fisheries by-catch on harbour porpoise where the impact on the harbour porpoise is permanent, i.e. up to 1.7% of the population may be caught as by-catch before a population decline is inevitable. An equivalent level of impact from disturbance, which is temporary and non-lethal, on a population will have a lower level of impact on the population compared to that from a fisheries by-catch.

15.11 The lack of agreed population thresholds either at the Management Unit level or site level, below which evidence demonstrates there would not be an adverse effect, does not prevent objective judgements to be made on site integrity.

15.12 Thresholds to assess and manage the effects of noise on site integrity have been proposed by Statutory Nature Conservation Bodies (SNCBs) (JNCC 2017b, e). The proposed approach by the SNCBs is not based on a population level impact but is instead based on a temporal and spatial level where a proportion of the area within the SCI may be affected over a period of time.

15.13 The SNCB approach to site integrity is:

- '*Ultimately, the purpose of the cSACs is to contribute to maintaining FCS for harbour porpoise and in order to do this, the site's integrity needs to be maintained in line with the site's Conservation Objectives.*
- *Noise disturbance within a cSAC from a plan/project individually or in combination will not exclude harbour porpoises from a maximum of 20% of the relevant area of the cSAC for a period of 1 day. And,*

- *Over a season, the noise disturbance within a cSAC from a plan/project individually or in combination per day will not exclude harbour porpoises from an average of 10% of the relevant area of the cSAC.'*

15.14 The potential extent of noise causing disturbance that would meet these proposed thresholds and therefore impact on the integrity of the site are presented in Table 56. The results indicate that should the impact occur wholly inside the SCI that, within the 'summer' area a sound source alone or in-combination causing disturbance for one day over an area of 7,390 km^2 would risk impacting site integrity. This is equivalent to a circular radius of noise out to 41.5 km. To exceed the threshold for the 'winter' area, noise in any one day should not extend over an area of more than 2,537 km^2; equivalent to a circular radius of 28.4 km.

15.15 Over the course of a season the total extent of potential disturbance on average per day should, in the 'summer' area, not extend over an area of more than 3,695 km^2; equivalent to a radius of noise of 29.3 km and in the 'winter' area should not extend over an area of more than 1,269 km^2, equivalent to a radius of 20.1 km.

Table 56: Estimated extent sound levels capable of causing displacement disturbance occur in order to impact on site integrity.

Site	Area (km^2)	1 day threshold		Seasonal threshold	
		20% of area (km^2)	Range of disturbance to meet threshold (km)	10% of area (km^2)	Range of disturbance to meet threshold (km)
Southern North Sea SCI	36,951	7,390	48.5	3,695	34.3
'summer' area April - September	27,000	5,400	41.5	2,700	29.3
'winter' area October - March	12,687	2,537	28.4	1,269	20.1

Area of 'summer' and 'winter' zones obtained from shapefiles provided by JNCC.

The range of disturbance assumes sound propagation is circular in shape, i.e. the range is the equivalent to a radius of circular noise.

15.16 Unlike the daily threshold, the area of the SCI that can be affected over the course of a season is an average over the season. The seasonal average is calculated by summing the proportion of the site impacted (for the relevant season) over the number of days the impact will occur and then averaging across the total number of days within that season, i.e. 183 days in the summer period and 182 days in the winter period. This provides a seasonal average daily spatial effect. This approach to determining a seasonal average has been used in the assessments undertaken for East Anglia One, East Anglia Three and Hornsea Project One; the approach and conclusions of which were agreed with by Natural England (EAOWL 2017, BEIS 2017a, BEIS 2018b, MMO 2017a).

15.17 This assessment is based on both the potential impact on the North Sea Management Unit population using both the ASCOBANS thresholds and the proposed SNCB approach.

15.18 The threshold approach proposed by the SNCBs has not been agreed with the competent authorities but has been used in recent offshore wind HRAs (e.g. Hornsea Project Three and East Anglia ONE R36 assessment). However, the thresholds have been noted within the assessment as a high-level management tool to limit the spatial distribution of noise from offshore wind piling for a large offshore SCI, such as the Southern North Sea SCI.

15.19 The HRA has been carried out in light of best scientific knowledge with reference to the Conservation Objectives of the SCI and the potential impacts on the integrity of the site (EC 2010).

16 IN-COMBINATION IMPACTS

16.1 Under the Habitats Regulations, it is necessary to consider the in-combination effects of development proposals on European Sites. These refer to effects, which may or may not interact with each other, but which could affect the same receptor or interest feature (i.e. a habitat or species for which a European site is designated).

16.2 The in-combination assessment must include known developments that are:

- Under construction,
- Permitted, but not yet implemented,
- Submitted application(s) not yet determined,
- Projects identified in the relevant Development Plan (and emerging Development Plans),
- Projects identified in other policy documents, as reasonably likely to come forward.

16.3 Plans or projects that have been identified as meeting these criteria have been considered within this HRA.

16.4 It is recognised that the potential on-going impacts on harbour porpoise from current activities that have had a long historical presence within the SCI (summarised in Section 6) are captured within the baseline and are not considered to be significantly affecting the harbour porpoise population, which is in favourable condition.

16.5 For on-going activities, e.g. fishing and shipping, it is not possible to determine what the baseline conditions would be without the impacts that these activities have on the current harbour porpoise populations or their prey. However, the activities may be considered as plans and therefore are included within the HRA; this includes on-going impacts from fishing and shipping.

16.6 For future plans or projects that are reasonably likely to come forward there may be limited or no information available in order to undertake a robust assessment. For these projects or plans only a generic assessment is possible. However, should they become submitted applications, they would be subject to the requirements of the Habitats Regulations and be assessed appropriately by the competent authority prior to any determination of the application being made.

Tiered Approach to In-combination Assessment

16.7 For the purposes of this HRA a tiered approach has been adopted that identifies offshore wind farm developments based on the level of confidence there is in the project or plan being taken forward and the level of information available to support the HRA (Table 57).

- Tier 1 developments are offshore wind farms that have completed construction. These include: Round 1 and Round 2 offshore wind farms including the Dudgeon, Greater Gabbard and Galloper offshore wind farms.

- Tier 2 developments are projects that are either under construction or have CfD. Consequently, there is a high probability of the wind farm being constructed and therefore there is a relatively high level of confidence in the final design envelope and the construction schedule. Tier 2 projects include Hornsea Project One, Hornsea Two, East Anglia One and Triton Knoll.

- Tier 3 developments are projects with consents but do not have a CfD. There is a high expectation that these projects will be constructed but a relatively low level of confidence in final design envelope and the construction schedule. These include the Creyke Beck A and B, Teesside A and B and East Anglia Three wind farms.

- Tier 4 developments are projects for which an application has been made but has yet to be determined or potential developments that have not submitted an application but for which a scoping opinion has been sought or preliminary environmental information have been published on the PINS site (https://infrastructure.planninginspectorate.gov.uk) or the developers website, these include the Hornsea Project Three, Norfolk Vanguard and the Thanet Extension wind farms. There is a low level of confidence in the final design envelope and construction schedule.

- Tier 5 developments are projects that are planned but for which no information on proposed construction methods are available. This include: Hornsea Project Four, Norfolk Vanguard West, East Anglia Norfolk Boreas, East Anglia One North, East Anglia Two wind farms. For these developments there is not enough information available to consider construction noise impacts or impacts on the habitat other than using generic information.

16.8 In 2017 The Crown Estate announced a wind farm extension project inviting applications for extensions to existing offshore wind farms (TCE 2018a). On 4 October 2018 The Crown Estate published a list of eight project applications, five of which are either within the SCI or within 26 km of the boundary. The five proposed project extensions that may have the potential to impact on the SCI are at:

- Sheringham Shoal,
- Dudgeon,
- Greater Gabbard,
- Galloper,
- Thanet.

16.9 All eight proposed extensions, including the five listed above will be subject to a plan level HRA to be undertaken by The Crown Estate. The HRA will assess any possible impacts of the proposed extensions on relevant nature conservation sites and the granting of Agreements for Lease will be subject to outcomes of the HRA (TCE 2018b). No further information is currently available upon which to undertake an HRA and the proposed extensions are therefore categorised as Tier 5 developments for which no, or very limited, information is available.

16.10 All other activities likely to cause an in-combination impact are considered as being equivalent to either Tier 1 or Tier 2 projects, i.e. they are either on-going activities, e.g. fishing, shipping and aggregate extraction or have a high probability of occurring, e.g. seismic surveys.

Table 57: Tiered offshore wind farms.

Tier	Description	Wind farm
1	Developments that have completed construction.	Scroby Sands, Greater Gabbard, Galloper, Thanet, Westermost Rough, Humber Gateway, Dudgeon, Gunfleet Sands II, London Array Phase I, Belwind I.
2	Developments under construction or have been awarded a CfD.	Hornsea One, Hornsea Two, East Anglia One, Triton Knoll.
3	Consented developments without CfD.	Creyke Beck A and B, Teesside A and B, East Anglia Three, (Mermaid, Borselle II).
4	Developments which have made an application but have not received a decision or projects for which preliminary environmental information has been published.	Hornsea Three, Norfolk Vanguard, Thanet Extension.
5	Planned developments which may come forward in the future for which little or no relevant information is available.	Hornsea Project Four, Norfolk Vanguard West, East Anglia Norfolk Boreas, East Anglia One North, East Anglia Two, The Crown Estate Offshore Wind Extension Projects.

Note the Mermaid and Borselle II offshore wind farms are not in UK waters and therefore not able to receive a CfD.

17 LIKELY SIGNIFICANT EFFECTS TEST

17.1 The Conservation of Offshore Marine Habitats and Species Regulations (2017) requires the Competent Authority to consider whether a development is likely to have a significant effect on a European site, either alone or in-combination with other plans or projects. A likely significant effect is, in this context, any effect that may be reasonably predicted as a consequence of a plan or project to affect the Conservation Objectives of the features for which the site was designated, but excluding trivial or inconsequential effects.

17.2 There are no recognised criteria as to what can be considered to be trivial or inconsequential impacts. Where predicted impacts are relatively very small compared to either the population of the management unit or the area of the site or the duration of the impact, it was determined that the impact would not cause a likely significant effect.

17.3 An HRA is required if a plan or project is likely to have a significant effect on a European site, either alone or in-combination with other plans or projects. A judgement of likely significant effect in no way pre-supposes a judgement of adverse effect on site integrity.

17.4 This section addresses the first step of the HRA and considers the potential impacts, both alone and in-combination with other plans and projects, on harbour porpoise from the sound sources and physical impacts identified in Section 3, to determine whether there will be a likely significant effect.

Pile-driving

17.5 Based on a peak SPL the results from the sound modelling indicate that noise arising from pile-driving activities could cause the onset of PTS on average from between 507 m and 1,082 m depending on the location and the maximum hammer energy. Based on weighted SEL the distances at which the onset of PTS is predicted to occur increase to between 892 m and 4,459m. Displacement of harbour porpoise due to noise from pile-driving could occur out to between 12.2 km and 29.5 km (See Section 13).

17.6 Consequently, based on the predicted extent of potential impacts, it is concluded that there is potential for a likely significant effect on harbour porpoise from pile-driving activities within or adjacent to the SCI and the impacts from pile-driving are therefore considered further both alone and in-combination with other activities in the Appropriate Assessment.

Wind turbine operating noise

17.7 The level of noise generated by the presence of the wind turbines will be continuous throughout the lifetime of the developments. It is predicted that the levels of noise produced will be relatively low and at frequencies predominantly below that at which harbour porpoise can hear (see paragraphs 7.6 and 7.7). Studies undertaken at Princes Amalia wind farm in the Netherlands concluded that noise generated by an operational wind farm did not significantly increase the local ambient underwater noise from shipping and wind (Jansen and de Jong 2014). Measurements undertaken at Barrow offshore wind farm indicated that the level of underwater noise produced by operating wind turbines is below that which would cause behavioural disturbance to marine mammals. Evidence from post-construction monitoring studies indicate that noise from operating wind farms do not cause the displacement of harbour porpoises (BOWind 2008). At the Egmond aan Zee wind farm in the Netherlands an increase in the number of harbour porpoise present was recorded when the wind farm was operating (Scheidat *et al*. 2011). Consequently, although underwater noise from operating wind turbines may be audible to harbour porpoise at relatively close ranges, evidence from existing studies indicate little, if any, displacement effects on harbour porpoise. Therefore, there will not be a likely significant effect on harbour porpoise from wind farm operational noise either alone or in-combination with other plans or projects. Therefore, no further assessment is required.

Seismic surveys (airguns)

17.8 Based on the cumulative weighted SEL thresholds, the results from modelling indicate noise arising from seismic surveys may cause the onset of PTS within 470 m of the sound source (Table 50).

17.9 Possible significant levels of disturbance to harbour porpoise could occur out to 33.2 km and extend over an area of 767 km^2 (Table 51).

17.10 Consequently, based on the predicted extent of potential impacts, it is concluded that there is potential for a likely significant effect on harbour porpoise from seismic surveys within or adjacent to the SCI and the potential in-combination impacts from seismic surveys are therefore considered further in the Appropriate Assessment.

Sub-bottom profiler

17.11 Results from the sound modelling indicate noise arising from sub-bottom profilers will not exceed the injury threshold for PTS beyond 23 m from the sound source (Table 52). and significant disturbance or displacement of harbour porpoises could extend out to 2.5 km and cover an area of 18.3 km^2 (Table 53).

17.12 Consequently, based on the predicted extent of potential impacts, it is concluded that there is potential for a likely significant in-combination effect on harbour porpoise from sub-bottom profilers within or adjacent to the SCI and the potential in-combination impacts are therefore considered further in the Appropriate Assessment.

Multi-beam echosounder

17.13 Multi-beam echosounders and single beam echosounders are widely used in the marine environment and measure water depth by emitting rapid pulses of sound towards the seabed and measuring the sound reflected back. Emitted sound frequencies are typically between 12 – 400 kHz depending on water depth, with surveys undertaken in shallower waters of less than 200 m operating at between 300 and 400 kHz (Danson 2005, Hopkins 2007, Lurton and DeReutier 2011). Sound sources have been reported as ranging from 210-245 dB re 1µPa-m (Genesis 2011, Lurton and DeReutier 2011).

17.14 The water depths within and adjacent to the SCI are all less than 200 m. Consequently, multi-beam echosounders are predicted to be operating using sound levels predominantly above 300 kHz and outwith the hearing frequency range of harbour porpoise. Studies undertaken on the potential impacts from vessels have indicated that ship echosounders operating at above 200 kHz do not cause a behavioural response in harbour porpoise (Dyndo *et al*. 2015). It is therefore predicted that as harbour porpoise will be unable to hear the sound arising from a multi-beam echosounder, there will be no likely significant effect on harbour porpoise arising from the use of multi-beam echosounders within the SCI and no further assessment is required.

Side-scan sonar

17.15 Side-scan sonar is widely used in the marine environment, and used to map areas of interest, for example to assist in the optimal positioning of infrastructure and to detect potential seabed hazards.

17.16 The frequencies used by side-scan sonar range from between 100 and 600 kHz, with the higher frequencies providing a greater resolution but shorter range measurements. The relatively high frequencies at which side-scan sonars operate are generally outside the main hearing range of all marine species (Genesis 2011, JNCC 2010a). Maximum source levels can be up to 228 dB re 1 μPa-m (Peak SPL) (SCAR 2002).

17.17 There is very little evidence of any potential impact on harbour porpoise from side-scan sonar. The relatively high frequencies at which side-scan sonar are operated indicate that the noise will not propagate far from the sound source and only sound in the lower frequency range will be detectable by harbour porpoise. Surveys using side-scan sonar are usually of short duration, typically two weeks or less, and any impact will be localised and temporary. Although there is recognised to be potential for disturbance it is predicted that it will be very localised and at a level that would not cause a likely significant effect. Consequently, no further assessment has been undertaken.

Cutting equipment

17.18 The use of cutting equipment is predicted to be required primarily during future decommissioning activities.

There is limited information on the level of noise arising from cutting equipment. However, one published study measured the level of noise from a diamond wire cutter during the cutting of 0.76 m diameter conductor at an offshore gas platform. The results indicated that increases in noise of between 4 dB and 15 dB at frequencies predominantly above 5 kHz could be attributed to the cutting equipment. No increases in sound above that from the associated vessels were detected at lower frequencies (Pangerc *et al*. 2017). Other equipment that may be used includes high pressure water jets for which one study reported sound levels of of 175.5 (A) re 1 μPa (Molvaer and Gjestland 1981).

17.19 Although the information available is limited, it is predicted that noise from cutting equipment would not occur at levels at which the onset of PTS is predicted to occur. There is potential for a localised disturbance impact but it will not be significantly greater than that arising from the accompanying vessels and therefore no additional impacts beyond those estimated to arise from the accompanying vessels are predicted to occur. Any impacts, should they occur, will be temporary with porpoises returning to the area once the noise has stopped.

On this basis it is concluded that there will not be a likely significant effect arising from the future use of cutting equipment and no further assessment in required.

Vessel activity

17.20 The offshore wind farm industry and other industries have used, and will continue to use, vessels in support of the vast majority of offshore activity. Vessels are extensively used during construction and maintenance of offshore wind farms and supply vessels support operating oil and gas platforms along with safety vessels permanently present in development areas.

17.21 Vessel movements are the largest contributor to anthropogenic ocean noise and in deeper water are the dominant noise source in the lower frequencies, between 50-300 Hz (Ulrick 1967). Measurements undertaken in the Southern North Sea indicate that shipping noise is the dominant anthropogenic noise in the region predominantly in the frequency range of between 40 and 200 Hz (de Haan *et al.* 2007). In general, vessels that use dynamic positioning thrusters tend to generate higher levels of underwater sound. The individual noise output produced by a vessel is dependent upon a number of factors including the speed of the vessel, age, load, maintenance and oceanographic conditions.

17.22 Between 1,033 and 2,278 additional vessel movements are estimated to occur per year during the construction of a consented offshore wind farm within the SCI (Table 58). Assuming that two wind farms may be constructed simultaneously within the SCI then there may be between 2,200 and 4,400 additional vessel movements per year (less than 12 additional vessels per day) associated with the construction of offshore wind farms.

Table 58: Estimated number of vessel movements during the construction and operation of consented wind farms within the SCI.

Wind farm	Construction		Operation	
	Total	Per year	Per year	Ave. per day
Scroby Sands	Unknown	Unknown	Unknown	Unknown
Thanet	Unknown	Unknown	(1,417)	(4)
Galloper	(1,294)	(1,294)	1,460	4
Greater Gabbard	1,294	1,294	(1,460)	(4)
Hornsea One	7,000	1,400	2,600	7
Hornsea Two	6,200	1,033	2,817	8
East Anglia One	5,695	2,278	2,160	6
East Anglia Three	8,000	2,133	4,000	11
Creyke Beck A	5,150	1,717	683	2
Creyke Beck B	5,150	1,717	683	2
Teesside A	5,150	1,717	730	2
Teesside B	5,150	1,717	730	2
Total	50,083	-	18,740	52

Note: No figure for the number of vessels during construction could be located for Galloper. An assumed estimate based on Greater Gabbard has been used.

No figure for the number of vessels during construction or operation for Thanet could be located. The figure for operations is based on Thanet Extension PEIR (Vattenfall 2017).

Galloper estimates up to five vessels per day associated with the wind farm when operating. The same estimate has been presumed for Greater Gabbard.

17.23 Between 683 and 4,000 vessel movements per year are estimated to occur during the operating period of each wind farm (Table 58). Assuming all wind farms are constructed, there may be an estimated additional 52 vessel movements per day within the SCI.

17.24 The level of vessel activity associated with the consented offshore wind farms within the SCI during construction and operation is relatively very small, estimated to be no more than eight movements per day for any individual wind farm and less than 52 vessel movements per day as a whole within the SCI. Assuming that potential displacement effects occur within 400 m of each vessel (Akkaya Bas *et al*. 2017, Polacheck 1990) then an estimated total area of 26 km^2 may be impacted by vessel noise associated with offshore wind farm developments within the SCI at any one time. This is equivalent to 0.07% of the SCI area being impacted by vessels. The effects from displacement within any particular location will be temporary and harbour porpoise will return to the area once the vessels move away (Hermannsen *et al*. 2014, Wisniewska *et al*. 2018b).

17.25 This additional level of impact will not cause a likely significant effect. However, there is evidence within the SCI that harbour porpoise avoid areas of relatively high vessel traffic (JNCC and NE 2016). Therefore, the additional vessels associated with the consented wind farms could cause a likely significant effect in-combination with existing vessel activity. Consequently, the in-combination impacts of vessel activity are considered in the Appropriate Assessment.

Drilling

17.26 Noise from drilling activities is largely dependent on the type of drilling platform being used. Jack-up rigs are the most frequently used drilling platform in the Southern North Sea and produce the lowest levels of sound. Studies in Danish waters reported sound source levels of 148 re 1µPa-m $_{(rms)}$ from drilling activities undertaken from a fixed platform (Bach *et al.* 2010). Drill-ships produce the highest levels of sound (Genesis 2011), but are extremely unlikely to be used in the area due to the relatively shallow waters making the use of jack-up drill rigs being more widely used. The level of sound arising from drilling is relatively low and occurs predominantly at a low frequency and is a continuous sound source (Greene 1987; McCauley 1998; Nedwell and Edwards 2004). Sound arising from drilling is outwith the main hearing frequencies for harbour porpoise.

17.27 Sorensen *et al.* (1984) (cited in Hammond *et al.* 2003) reported that, although there was little data on the reactions of marine mammals to drilling noise, there was no clear evidence of avoidance behaviour by small odontocetes. Bottlenose dolphins, Risso's dolphins and common dolphins were all recorded close to platforms and sighting rates were similar in areas with and without rigs.

17.28 Studies using Passive Acoustic Monitoring (PAM) at platforms located on the Dogger Bank did not record any decrease in harbour porpoise activity at the platforms when drilling was being undertaken, compared with when there was no drilling and indicated that harbour porpoises appeared to use oil and gas platforms as feeding refuges (Todd *et al.* 2007, Todd *et al*. 2009). Similar results have been reported from studies undertaken at two platforms in Danish waters (Bach *et al.* 2010).

17.29 The levels of sound reported from drilling are below that which would be predicted to cause PTS and although audible to harbour porpoises, studies indicate no adverse behavioural response to drilling noise.

17.30 Drilling noise has occurred within the SCI for nearly fifty years with a total of 1,373 wells drilled within the boundaries of the site (UKoilandgas 2018). During this period, the number of harbour porpoises within the SCI area appears to have increased (Hammond *et al.* 2013). There is no evidence that current or historical levels of drilling have significantly affected harbour porpoises. Future drilling activity is not predicted to be significantly greater than historical levels and therefore no significant increase in the levels of drilling noise within the SCI is predicted to occur.

17.31 It is concluded that based on the low frequencies and levels of sound produced by drilling and evidence to indicate that harbour porpoises are not displaced by drilling activity, that there will not be a likely significant effect from drilling noise on harbour porpoise within or adjacent to the SCI and no further assessment is required.

Cable and pipeline trenching noise

17.32 Trenching of cables and pipelines produces a continuous sound source for the duration of the activity. Although audible to harbour porpoise the mean source level is less than 183.5 dB re 1 μPa (rms SPL) and similar to, or below, the level of sound produced by harbour porpoise when echolocating (Villadsgaard, *et al*. 2007, Johannson and Andersson 2012,). Consequently, sound produced from trenching activities is predicted to occur below a level that will cause any physical injury.

17.33 No sound modelling for trenching has been undertaken for the purposes of this assessment. However, existing sound modelling studies undertaken elsewhere have indicated that no PTS will occur from trenching activities but behavioural responses could occur out to 640 m from the trenching activities (MORL 2012, Nedwell *et al.* 2003, Nedwell *et al.* 2012, NBDL 2014). Should this occur, a relatively localised area of approximately 1.28 km^2 (0.003%) of the SCI may be impacted during any trenching activities. If the behavioural response is displacement from the area, it is predicted that harbour porpoise will return once the trenching activity has been completed and therefore any impacts from noise generated by trenching are both localised and temporary.

17.34 The placement of rock on the seabed along a cable or pipeline will produce noise. However, studies have reported no evidence that the rock placement itself contributes to the level of noise from this activity, with vessel noise being the dominant sound source (Nedwell and Edwards 2004).

17.35 It is concluded that based on the low levels of sound produced by trenching activities that there will not be a likely significant effect on harbour porpoise within or adjacent to the SCI and no further assessment is required.

UXO detonation and blasting

17.36 The most damaging component from blasting activities is caused by the underwater shock wave and the initial fast rise in pressure. However, the higher frequencies reduce quickly in the water column and the area of impact from the shockwave is limited. Sound propagating out is largely below 1 kHz.

17.37 Sound modelling undertaken for this assessment indicates that noise levels capable of causing the onset of PTS from an explosive weight (NEQ) of 10 kg could occur out to 3.3 km and a 1,000 kg NEQ out to 15.4 km (Table 54).

17.38 Based on the predicted extent of potential impacts, it is concluded that there is potential for a likely significant effect on harbour porpoise from explosive detonations within or adjacent to the SCI and the potential impacts are therefore considered further in the Appropriate Assessment both alone an in-combination with other activities.

Physical impacts on the seabed

17.39 Physical impacts to the seabed could cause a likely significant effect on the supporting habitats and processes relevant to harbour porpoises and their prey.

17.40 Physical impacts to the seabed from the consented projects have been identified as occurring primarily from the physical presence of wind turbines and associated infrastructure. For the purposes of this assessment, this is identified as a permanent impact to the seabed as the infrastructure will be present at least for the duration of the consented development, i.e. for at least 25 years.

17.41 Cable trenching will also cause a physical disturbance to the seabed. This is predicted to occur across a 10 m corridor along the length of the cable (BERR 2008). The impacts to the seabed are considered to be temporary except in areas where cable protection has been undertaken by the placement of rock, mattresses or grout bags on the seabed.

17.42 The estimated extent of habitat loss for each of the consented developments within the SCI are presented in Table 59. These figures are based on various sources of information associated with the applications and are indicative of the extent of potential impacts on the seabed based on monopiled foundations being used for all except East Anglia One and East Anglia Three where a jacket foundations are being, or may be, installed.

17.43 Hornsea Project One and East Anglia One have already been assessed under HRA (MMO 2017a, BEIS 2018b). However, their impacts on the seabed, based on what is being built, have been included as part of the in-combination assessment. East Anglia Three has also been subject to a HRA that included potential impacts on the SCI (BEIS 2017a). There is potential for an in-combination impact with the consented developments that are subject to this review and therefore the potential impacts on the habitat are included in this assessment.

17.44 Based on all the currently known consented wind farm developments, i.e. including the Hornsea One, East Anglia One and East Anglia Three projects, the area of permanent physical impact on the seabed is estimated to be 3.52 km^2 (Table 59). The predicted area of physical impact is based on the use of monopile or pin piled foundations. Other options for foundations exist, e.g. suction buckets and gravity based foundations, and these options have larger footprints on the seabed. However, to-date, these foundation types have not been used in the UK sector of the Southern North Sea; consequently, an assessment based on alternative foundation types has not been undertaken.

17.45 In addition to the turbines foundations there is associated infrastructure that will impact on the seabed. The infrastructure includes HVAC collector platforms, HVDC converter platforms, accommodation platforms and meteorological masts. The number of platforms to be installed will depend on whether HVAC or HVDC export options are selected (Table 60). Where it is not known which export option is to be selected, for the purposes of this assessment, the worst-case scenario has been selected, i.e. the maximum likely number of platforms.

17.46 Based on the currently available information it is estimated that between 0.61 km^2 and 0.92 km^2 of seabed could be impacted by consented and planned infrastructure (Table 61). It is recognised that for Hornsea One and East Anglia One the consented scenarios cannot be built and therefore a realistic physical impact from consented offshore wind farm infrastructure is 0.61 km^2.

Table 59: Estimated extent of seabed permanently impacted by the physical presence of wind turbine foundations and associated scour protection within the SCI.

Wind farm	Turbine			Comment
	Turbine Number and size (MW)	Footprint per turbine (m^2)	Total footprint area (km^2)	
Galloper	56 x 6.3	1,700	0.097	1,700 m^2 scour protection (GWFL 2011). Turbine footprint 31.2 m^2.
Greater Gabbard	140 x 3.6	796	0.116	796 m^2 scour protection (GGOWL 2005). Turbine footprint 33.2m^2.
Hornsea One	174 x 7	1,419	0.247	SMart Wind (2013).
Hornsea Two consented	225 x 8	1,963	0.442	SMart Wind (2015).
Hornsea Two planned	177 x 8.5	1,963	0.347	Ørsted (2017b).
East Anglia One planned	102 x 6	1,225	0.125	Based on footprint of 35 m x 35m (EAOWL 2012).
East Anglia Three	172 x 12	1,893	0.325	Based on pin piled foundations EAOWL (2015b).
Creyke Beck A	120 x 10	4,739	0.568	962 m^2 turbine footprint + 3,777 m^2 scour protection (Forewind 2013a).
Creyke Beck B	120 x 10	4,739	0.568	962 m^2 turbine footprint + 3,777 m^2 scour protection (Forewind 2013a).
Teesside B	120 x 10	5,675	0.681	Forewind (2014).

Note.

This is based on the largest monopiled foundations that have the largest footprint and therefore greatest area of impact. Consequently, to not exceed the maximum capacity of the wind farm the number of turbines may be less than the maximum number consented. In the event other foundation types are selected, e.g. gravity based, that may have a larger footprint, further assessment may be required.

No scour is predicted to occur at East Anglia One with the use of jacket foundations but the consented total of scour protection for wind turbines and associated infrastructure is 3.529 km^2.

Galloper area of impact calculated based on information presented in HRA report Document Ref 6.3 (GWFL 2011).

Table 60: Consented and planned wind farm infrastructure within the SCI.

Wind farm	Infrastructure consented	Infrastructure planned
Galloper	Offshore substation, collection platform and accommodation platform 3 x met masts	1 x Offshore substation (constructed)
Greater Gabbard	2 x offshore substation	2 x Offshore substations (constructed)
Hornsea One	5 x HVAC collector, 2 x HVDC converter, 2 x Accommodation or 5 x HVAC collector, 1 x HVAC reactor, 2 x Accommodation	3 x HVAC collector, 1 x HVAC reactor 1 x Accommodation
Hornsea Two	6 x HVAC collector, 2 x HVDC converter, 2 x Accommodation or 6 x HVAC, 2 x HVAC reactor, 2 x Accommodation	3 x HVAC collector, 2 x HVAC reactor (or 2 x HVDC converter) , 2 x Accommodation
East Anglia One	3 x HVAC collector, 2 x HVDC converter, 1 x Met mast	1 x HVAC, 1 x Met mast
East Anglia Three	4 x HVAC collector, 2 x HVDC converter, 2 x Met mast	Currently as consented
Creyke Beck A	4 x HVAC collector, 1 x HVDC, 2 x Accommodation, 5 x Met masts	Currently as consented
Creyke Beck B	4 x HVAC collector, 1 x HVDC, 2 x Accommodation, 5 x Met masts	Currently as consented
Teesside B	4 x HVAC Collector, 1 x HVDC converter, 2 x Accommodation	Currently as consented

Table 61: Estimated area of 'permanent' seabed impact within the SCI from infrastructure associated with consented offshore wind farms.

Wind farm	Infrastructure	Number	Area per platform including scour (m^2)	Total area (km^2)
Galloper	Offshore substation	1	452	0.0005
Greater Gabbard	Offshore substation	2	2,300	0.005
Hornsea One planned	HVAC collector	3	12,723	0.064
	HVAC reactor substation	1	6,362	0.006
	HVAC reactor substation	1	6,362	0.013
Hornsea Two consented	HVAC collector	6	12,723	0.039
	HVAC reactor substation	2	6,362	0.038
	Accommodation	2	6,362	0.006
	HVDC converter substation	2	19,500	0.006
Hornsea Two planned	HVAC collector	1	12,723	0.076
	HVAC reactor substation	1	6,362	0.013
East Anglia One planned	HVAC collector	1	29,000	0.013
	Met mast	1	unknown	0.039
East Anglia Three	HVAC	4	15,855	0.013
	HVDC	2	15,855	0.006
	Accommodation	1	15,855	0.087
	Met mast	2	900	0.058
Creyke Beck A	HVAC collector	4	14,367	0.057
	Accommodation	2	21,242	0.042
	HVDC converter	1	21,242	0.021
	Met masts	5	4,350	0.022
Creyke Beck B	HVAC collector	4	14,367	0.057
	Accommodation	2	21,242	0.042
	HVDC converter	1	21,242	0.021
	Met mast	5	4,350	0.022
Teesside B	HVAC collector	4	9,025	0.036
	Accommodation	2	17,400	0.035
	HVDC converter	1	17,400	0.017
	Met mast	5	4,657	0.023

17.47 Trenching can cause a localised area of physical disturbance on the seabed. The extent of trenching within the SCI has been estimated for each of the consented wind farms that have cables within the SCI. For the purposes of this assessment it is estimated that the trenching and laying of cables impacts on a 10 m wide corridor of seabed (BERR 2008). However, it is noted that some applications may have assessed smaller areas of impact from trenching activities. Assuming that trenching cables impacts along a 10 m corridor (5 m either side of the trench), it is estimated that 21.75 km^2 of seabed within the SCI may be temporarily disturbed during the laying of export cables and a further 69.1 km^2 of seabed may be disturbed by inter array and platform cables. A total of 90.8 km^2 of seabed may be disturbed by the trenching and burying of offshore cables. A total of 13.6 km^2 of cable protection may be required although, this is a worst-case and assumes that all cable protection required for each of the wind farms occurs within the SCI; this would not be the case as protection along the export cable routes will occur outwith the SCI.

Table 62: Estimated area of seabed impacted within the SCI from cable laying activities associated with consented offshore wind farms.

Wind farm	Export cable			Inter array / platform cables		
	Length (km)	No. of cable trenches	Area of seabed impacted (km^2)	Length (km)	Area of seabed impacted (km^2)	Cable Protection (km^2)
Galloper	45	2	0.90	300	3	0.003
Greater Gabbard	42	3	1.26	173	1.73	-
Creyke Beck A	101.4	2	2.03	1,270	12.7	2.89
Creyke Beck B	97.18	2	1.94	1,270	12.7	2.77
Teesside A	76.51	2	1.53	0	0	0
Teesside B	83.36	2	1.67	1,270	12.7	2
Hornsea One	44.98	4	1.80	450	4.5	2.03
Hornsea Two	35.86	8	2.87	675	6.75	3.37
East Anglia One	55.87	2	1.12	620	6.2	-
East Anglia Three	166	4	6.64	882	8.82	0.55
Total	767.66	31	21.75	6,910	69.1	13.61

Note – the extent of cable protection used at Greater Gabbard and East Anglia One is unknown.

17.48 The figures presented above have been obtained from a variety of documents relating to each application and should be considered as likely indicative magnitude of any impacts on the seabed from cable laying. The figures are estimated areas of impact and may change depending on a number of factors including the foundation type, size and number of turbines installed and the amount of scour and cable protection required.

17.49 Other industries that could cause an in-combination likely significant effect include the oil and gas, aggregates and fishing industries.

17.50 Existing infrastructure within the SCI is primarily from oil and gas installations. There are a total of 120 installations within the SCI impacting an estimated area of 0.1 km^2 (Para. 6.7).

17.51 The extent of trenching undertaken by the oil and gas industry within the SCI is unknown. A total of 4,067 km of pipeline has been laid within the SCI, of which approximately 3,997 km has been trenched and buried (UKoilandgas 2018). Based on an area of impact from trenching pipelines extending 5 m either side of the line, since the first lines were installed fifty years ago trenching activities have temporarily impacted on approximately 40 km^2 of seabed.

17.52 Existing licenced aggregate dredging areas cover an area of 540.77 km^2 within the SCI. However, only a relatively small proportion of the licenced areas are active and a total of 31.33 km^2 was actively dredged in the East Coast and Thames regions during 2016, with some dredged locations outwith the SCI.

17.53 Based on the planned level of activity within the SCI by the offshore wind farm industry it is concluded that there may be a likely significant effect from the physical impacts on the supporting habitats within the SCI from the consented offshore wind farm projects alone and in-combination with other offshore activities. Potential in-combination impacts from physical impacts on the supporting habitats within the SCI are therefore considered further in the Appropriate Assessment.

Commercial fishing

17.54 Commercial fishing has historically impacted, and continues to have an impact on, harbour porpoise directly due to the bycatch and indirectly by physically impacting on the seabed or the removal of prey species. Based on the potential impacts from commercial fisheries there is potential for an in-combination impact on harbour porpoise and supporting habitats.

Effects on water quality

17.55 Impacts on water quality could impair the ability of harbour porpoise to detect prey due to increase sediment within the water column.

17.56 During construction, there is potential for increased sedimentation particularly from the installation of the turbines, where dredging of the seabed or drilling may be required. There is also seabed disturbance arising from trenching activities associated with cable laying.

17.57 The duration of any suspended sediment concentrations within the water column is dependent on a number of factors including the water depth and the size of the particles disturbed, with finer muds remaining in the water column for longer than heavier sandy sediments. The extent the plume is highly dependent on the currents that cause the plume to disperse. Sandy sediments are predicted to remain in the water column from between 20 minutes to less than

24 hrs depending on the size of the particles. The extent of any plume is predicted to remain largely within 1 km from the area of disturbance although fine material may disperse at above background levels out to 64 km (EAOWL 2012, Forewind 2013a, 2014, SMart Wind 2013, 2015).

17.58 Although there is potential for disturbed sediments to impact on the water quality, the extent and duration of any impacts are predominantly localised and temporary. The larger areas of potential impact predicted by some developments are based on suspended sediment concentrations at relatively low levels but still above background concentrations. These extended areas of low suspended sediment concentrations may not be detectable.

17.59 Harbour porpoise detect prey using echolocation and therefore localised and temporary increased sediment loads are not predicted to impact on their ability to detect prey. Noise arising from construction activities may also cause harbour porpoise and their prey to avoid the areas of highest suspended sediment concentrations. Consequently, it is predicted that there will be no likely significant effect on harbour porpoise from the increased sediment loads impacting on water quality.

17.60 Based on the relatively localised area of potential impact on water quality within the SCI and the temporary nature of any effects, it is concluded that there will not be a likely significant effect from offshore wind farm activities on the water quality within or adjacent to the SCI either alone or in-combination and no further assessment is required.

Likely Significant Effects - Conclusions

17.61 Based on the above it is concluded that there is potential for a likely significant effect alone or in-combination on harbour porpoise from:

- Pile-driving (alone and in-combination),
- Sub-bottom profilers (alone and in-combination),
- UXO detonation (alone and in-combination),
- Physical impacts to the seabed (alone and in-combination),
- Seismic surveys (in-combination),
- Vessel activity (in-combination),
- Commercial fisheries (in-combination).

17.62 The above activities are considered further in the Appropriate Assessment to determine whether they have potential to cause an adverse effect on the integrity of the site.

17.63 The following activities have been identified as not causing a likely significant effect on the qualifying features of the site on the basis that the extent of any impacts are predicted to be relatively localised and inconsequential, impacting on a very small proportion of the harbour porpoise population or their supporting habitats.

- Wind farm operational noise,
- Multi-beam echosounder,
- Side-scan sonar,
- Drilling,
- Cutting equipment,
- Cable and pipeline trenching noise,
- Construction impacts on water quality.

17.64 With the exception of physical impacts to the seabed, the likely significant effects identified alone, relate to the construction phase of an offshore wind farm. The construction of the Dudgeon, Greater Gabbard and Galloper offshore wind farms is complete and the wind farms are operating and potential impacts relating to construction activities are not predicted to occur at these three wind farms, i.e. there are no known plans for further pile-driving, UXO clearance or activities that will cause additional physical impacts to the seabed. However, it is recognised that there is potential for physical impacts from the existing infrastructure to impact on the habitats within the SCI.

17.65 There is also potential for on-going activities associated with these wind farms, e.g. vessel movements, to cause an in-combination impact with other consented wind farms that are subject to this review. These in-combination impacts are addressed in the relevant in-combination sections of the Appropriate Assessment.

18 APPROPRIATE ASSESSMENT

18.1 The HRA has been undertaken based on the best available information at the time of undertaking the assessment. This includes information provided during the Call for Information (BEIS 2018a).

18.2 It is recognised that there is potential for the information provided to undertake this HRA to change overtime. For this reason a pre-construction condition (requiring a Site Integrity Plan (SIP)) will be attached to each relevant project's Marine Licence by the MMO. The effect of the SIP will be to limit each wind farm to the parameters that have been assessed by this HRA. Prior to construction, developers will be required to provide a SIP demonstrating that the parameters used in this HRA will not be exceeded. If these parameters are to be exceeded, then further assessment will be required. In such a circumstance, the project will only proceed if the MMO, in consultation with relevant bodies, has satisfied itself that the SCI will not be adversely affected. This condition will be attached to all wind farm consents under review including operational projects, as any capacity to build out further needs to be subject to assessment.

18.3 A dual approach has been used in order to determine whether an adverse effect on the integrity of the South North Sea SCI with respect to impacts from noise and physical impacts set out in paragraph 17.61.

18.4 The assessment on the potential impacts from pile-driving is based on the results from noise modelling undertaken at each wind farm. This approach takes into account project specific factors that can affect the level of sound produced and its propagation within the water column. From this it is possible to estimate the number of harbour porpoise that may be affected and the overall duration of the potential impacts. Based on the study published by ASCOBANS an annual reduction in the population of 1.7% could cause a population level decline (Para. 15.10). Consequently, a similar level of impact from disturbance is predicted to not cause a population level of decline.

18.5 Following advice received during scoping, a second approach to the assessment has also been undertaken based on recommendations by the SNCBs. This approach is based on the use of a generic 26 km EDR for all pile-driving activities irrespective of the location. The extent and duration of the pile-driving is then measured against draft thresholds above which a likely significant effect cannot be ruled out, as described in Section 11.

18.6 For the purposes of this assessment it is assumed that impacts based on the EDR approach occur over the maximum possible area within the SCI at all turbine locations. This approach is overly precautionary and unrealistic as many of the turbines will be installed closer to, or outwith, the boundary of the SCI and therefore have less of a spatial effect. The turbine locations within each of the wind farm areas are unknown and alternative approaches, i.e. using an average area based on the maximum and minimum extent of overlap, risks underestimating the extent and duration of impacts occurring within the SCI. The is because the boundaries of the wind farm areas and the SCI are irregular in shape and the distribution of turbines across each wind farm area may not be even.

18.7 In addition to the above, it is presumed that once pile-driving has commenced there will be one turbine foundation installed every day until all foundations have been installed. This is precautionary as breaks in construction activities will occur due to weather down-time and project logistics, such that this scenario is unlikely to occur. Gaps in pile-driving could reduce the overall levels of noise over the course of the season. For example, Hornsea Project Three estimate that, on average, there will be 20 days pile-driving per month and therefore during the summer period there could be 120 days of pile-driving out of a total of 183 days; this reduces the level of impact during a season, i.e. the seasonal spatial overlap (Dong 2017d). The precise pile-driving schedules for all the wind farms are unknown and it is likely that some may undertake more pile-driving each month or season than would be predicted if an average was used. Furthermore, if pile-driving is not continuously undertaken on a daily basis, consideration of the recovery period is required as this increases the number of days during which the impacts from disturbance are predicted to occur. The approach taken in this assessment is therefore precautionary and a worst-case scenario.

Offshore Wind Farms

Dudgeon

18.8 The Dudgeon offshore wind farm was fully commissioned in October 2017. The installation of the turbines was completed in August 2016.

18.9 No known additional construction activities are planned to be undertaken and no further assessment on the impacts from construction noise is required. However, there are on-going and potential future activities that could cause an in-combination impact (See Section 19).

18.10 The wind farm is located outwith the SCI (Figure 3) and therefore does not have any physical impact on the supporting habitat within the SCI.

Dudgeon: Conclusions

18.11 There are no impacts arising from the constructed Dudgeon offshore wind farm alone likely to cause an adverse effect on harbour porpoise.

18.12 It is concluded that Dudgeon offshore wind farm on its own will not have an adverse effect upon the integrity of the Southern North Sea SCI.

Greater Gabbard

18.13 The Greater Gabbard offshore wind farm was commissioned in August 2013. The installation of the turbine foundations was completed in August 2010.

18.14 No additional construction activities are planned to be undertaken and no further assessment on the impacts from construction noise is required. However, there are on-going and potential future activities that could cause an in-combination impact (See Section 19).

18.15 The wind farm lies wholly within the SCI and there is potential for an impact on the supporting habitats within the SCI both alone and in-combination with other plans or projects. Further assessment on the potential effects from physical impacts on the supporting habitats and processes has been undertaken.

Physical impact to the seabed

18.16 The estimated area of permanent physical impact on the seabed arising from the installation of 140 x 3.6 MW monopiled turbines is 0.116 km^2 (Table 59) and further 0.005 km^2 of has been impacted by the presence of an offshore substations (Table 61) (GGOWL 2005). A total area of seabed permanently physically impacted by the Greater Gabbard offshore wind farm is estimated to be 0.121 km^2. The total area of habitat permanently impacted within the SCI is estimated to be 0.121 km^2. It is not known whether additional cable protection has been required at this wind farm. If cable protection has been required the area impacted will be greater than that estimated here. However, experience at the adjacent Galloper offshore wind farm indicates the extent of rock required in order to protect the cables has been limited (Table 60).

18.17 The seabed habitat across the wind farm area varies with sand being predominantly located on the sand banks with a mixed sediments comprising mud, gravel and sand occurring between the sandbanks (GGOWL 2005). These habitats are widespread and found across the whole of the SCI.

18.18 The potential loss of permanent loss of 0.121 km^2 of habitat is 0.0003% of the site. The loss of a relatively very small area of habitat that occurs widely within the SCI is not predicted to impact on harbour porpoise or their prey.

18.19 There is potential for temporary seabed disturbance to have been caused by trenching and the laying of cables within the wind farm area and the along the export cable route. It is estimated that a total area of 3.0 km^2 of seabed may have been disturbed by the trenching and burying of the cables (Table 62) The impacts from cable trenching are recognised to be temporary as the seabed will overtime recover and there will be no loss of habitat.

Greater Gabbard: Conclusions

18.20 There are no impacts arising from the constructed greater Gabbard offshore wind farm alone likely to cause an adverse effect on harbour porpoise.

18.21 The loss of up to 0.0003% of habitat that occurs widely across the SCI will not significantly impact the supporting habitats and processes or prey base upon which harbour porpoise depend and will therefore not cause an adverse effect on its own. However, there is potential for an in-combination impact with other plans or projects.

18.22 It is concluded that Greater Gabbard offshore wind farm on its own will not have an adverse effect upon the integrity of the Southern North Sea SCI.

Galloper

18.23 Construction of Galloper offshore wind farm was completed in April 2018, with the installation of the turbine foundations completed by March 2017.

18.24 No additional construction activities are planned to be undertaken and no further assessment on the impacts from construction noise is required. However, there are on-going and potential future activities that could cause an in-combination impact (See Section 19).

18.25 The wind farm lies wholly within the SCI and there is potential for an impact on the supporting habitats within the SCI both alone and in-combination with other plans or projects. Further assessment on the potential effects from physical impacts on the supporting habitats and processes has been undertaken.

Physical impact to the seabed

18.26 The estimated area of permanent physical impact on the seabed arising from the installation of 56 x 6.3 MW monopiled turbines is 0.097 km^2 (Table 59) and further 0.005 km^2 of seabed may be impacted by the presence of a single offshore substation (Table 61) (GWFL 2011). A total area of seabed permanently physically impacted by the Galloper offshore wind farm is estimated to be 0.102 km^2. In addition to the physical presence of the turbine foundations and associated infrastructure, a further 0.003 km^2 of seabed may be permanently impacted by cable protection (Table 62). The total area of habitat permanently impacted within the SCI is estimated to be 0.105 km^2.

18.27 Galloper offshore wind farm is located on the Outer Gabbard Sand Bank. The internal structure of the bank comprises stiff clays overlain by sand. Sand waves occur across the wind farm area. The predominant seabed habitat likely to be impacted is predominantly gravely sand or sandy gravel habitat types, with sand and silty sand occurring widely across the sand banks (GWFL 2011). These habitats are widespread and found across the whole of the SCI.

18.28 The potential loss of permanent loss of 0.105 km^2 of habitat is 0.0003% of the site. The loss of a relatively very small area of habitat that occurs widely within the SCI is not predicted to impact on harbour porpoise or their prey.

18.29 There is potential for temporary seabed disturbance caused by trenching and laying of cables within the wind farm area and the along the export cable route. Based on a predicted area of impact along a 10 m corridor along all cable routes, it is estimated that a total area of 3.9 km^2 of seabed may have been disturbed by the trenching and burying of the cables (Table 62). However, an estimated 5.9 km of cable required pre-sweeping before the cable could be laid. The area impacted by the pre-sweep was predicted to be slightly wider with a 15 m wide corridor (GWFL 2015b). This causes a very small increase in the potential area impacted by cable trenching. The impacts from cable trenching are recognised to be temporary as the seabed will overtime recover and there will be no loss of habitat.

Galloper: Conclusions

18.30 There are no impacts arising from the constructed Galloper offshore wind farm alone likely to cause an adverse effect on harbour porpoise.

18.31 The loss of up to 0.0003% of habitat that occurs widely across the SCI will not significantly impact the supporting habitats and processes or prey base upon which harbour porpoise depend and will therefore not cause an adverse effect on its own. However, there is potential for an in-combination impact with other plans or projects.

18.32 It is concluded that Galloper offshore wind farm on its own will not have an adverse effect upon the integrity of the Southern North Sea SCI.

Hornsea Two

18.33 The Hornsea Two offshore wind farm lies partially within the SCI (Figure 35). There is no confirmed construction date but construction must commence prior to 6 September 2021. Final details on the timing and duration of pile-driving are not available. In the event concurrent pile-driving is undertaken the installation of foundations will be no further than 20 km apart (DONG 2017c).

Physical Injury

18.34 Results from the sound modelling indicate that there is potential for sound levels arising from pile-driving to cause the onset of PTS out from between 0.9 km and 1.5 km depending on the hammer energy used to install the pile and the location of the pile-driving within the wind farm area. This equates to an area of between 2.5 km^2 and 7.4 km^2 (Table 23).

18.35 The harbour porpoise density across the wind farm area is estimated to be 2.39 ind./km^2 (Table 6). Based on this density, between 6 and 18 harbour porpoise could be affected by the onset of PTS at the start of pile-driving activity. The potential worst-case impact, using a larger 3,000 kJ hammer, indicates that up to 0.005% of the North Sea Management Unit population may be impacted.

Displacement

18.36 Displacement or disturbance is predicted to occur from between 20.7 km and 29.5 km and cover an area of between 1,350 km^2 and 2,794 km^2 depending on the location of the pile-driving and the hammer energy (Table 24, Figure 33).

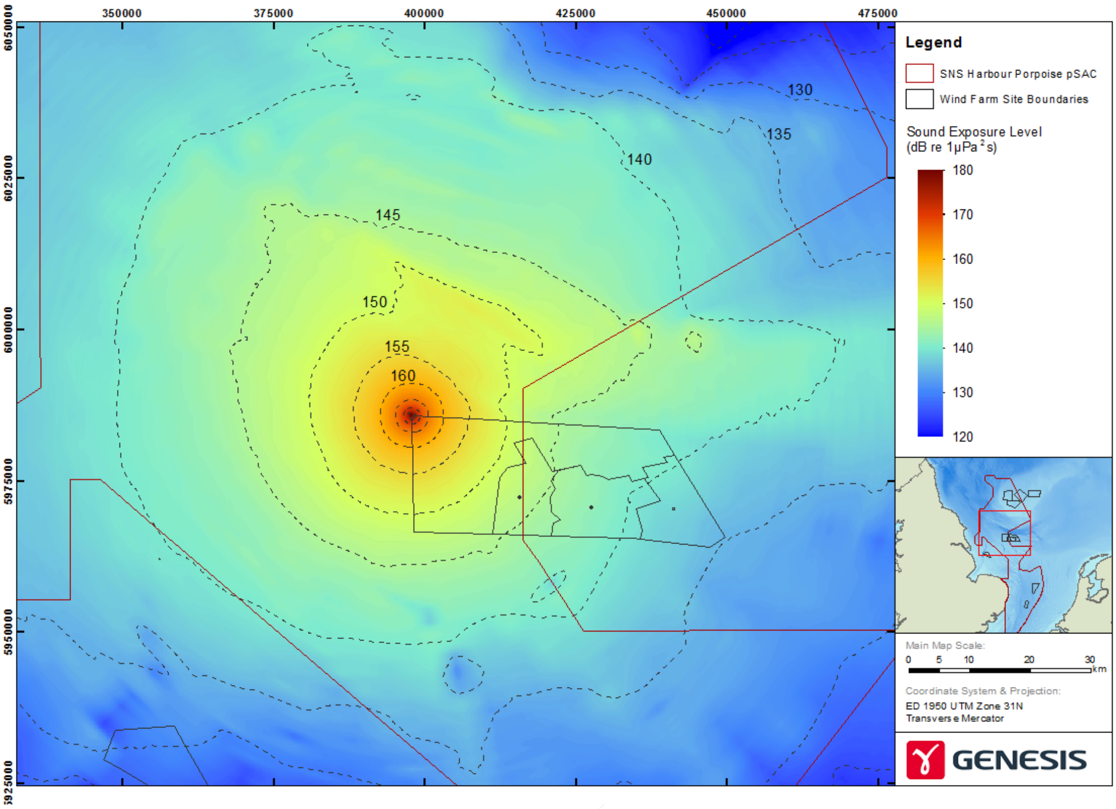


Figure 33: Hornsea Two single pile-driving (unweighted SEL for pile-driving 3,000 kJ).

18.37 Based on a site specific mean density of 2.22 ind./km^2 (Hornsea Zone + 10 km buffer (Table 6)), the estimated number of harbour porpoise predicted to be displaced is between 1,049 and 2,119 individuals; equivalent to between 0.31% and 0.63% of the North Sea Management Unit population. Within the SCI between 1,034 and 1,982 harbour porpoise may be displaced depending on the hammer energy (Table 63).

Table 63: Estimated number of harbour porpoise predicted to be displaced by pile-driving from Hornsea Two offshore wind farm in total and within the SCI.

Location	Hornsea Two							
	2,300 kJ				3,000 kJ			
	Area (km^2)	No. of Ind.	Area within SCI (km^2)	No. of Ind. within SCI	Area (km^2)	No. of Ind.	Area within SCI (km^2)	No. of Ind. within SCI
1	1,350	1,049	1,325	1,034	1,659	1,299	1,587	1,256
2	2,251	1,683	2,133	1,612	2,794	2,119	2,564	1,982
Con.	2,819	2,226	2,685	2,146	3,420	2,735	3,159	2,579

Harbour porpoise density of 2.22 ind./km^2

Con. = concurrent pile-driving

18.38 Concurrent pile-driving may be undertaken, with activities a maximum of 20 km apart (SMart Wind 2015a) (Figure 34).

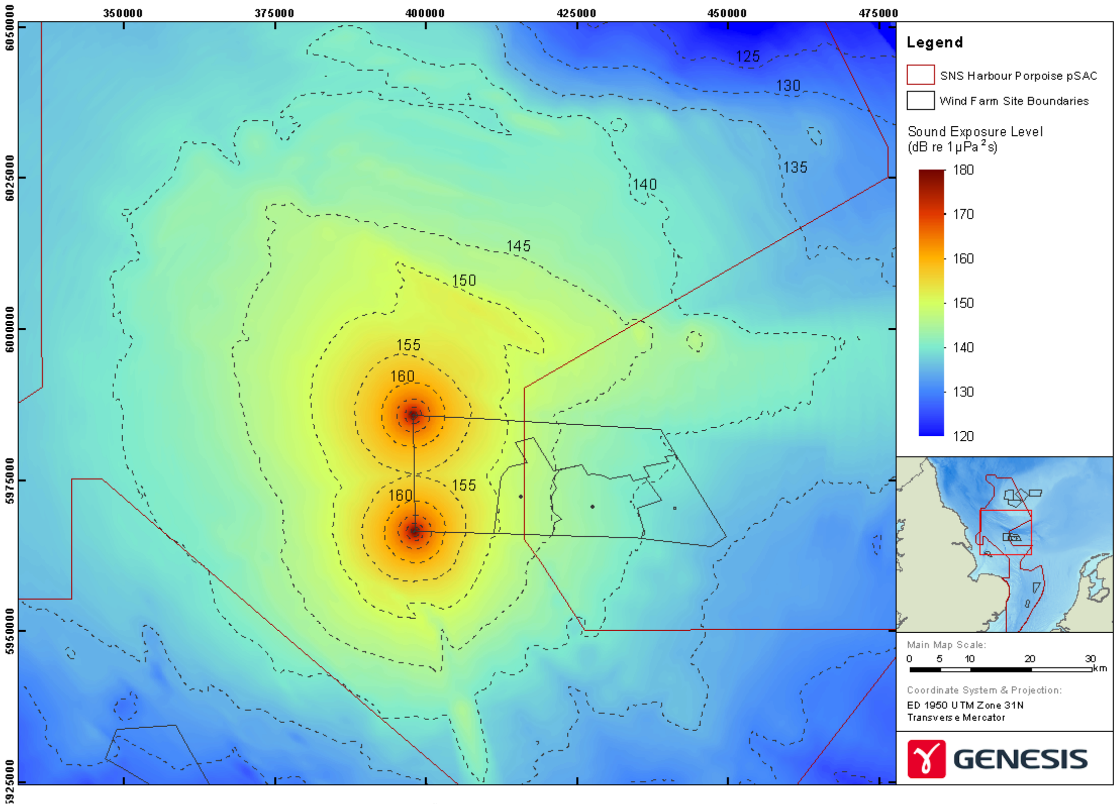


Figure 34: Hornsea Two concurrent pile-driving (unweighted SEL for pile-driving 3,000 kJ).

18.39 If this occurs between 2,226 and 2,735 harbour porpoise may be displaced or disturbed (Table 63); equivalent to between 0.67% and 0.82% of the North Sea Management Unit population.

Effective Deterrent Radius

18.40 The Hornsea Two offshore wind farm lies partially within the SCI and, under the worst-case scenario, the 26 km EDR could impact over an area of 1,976 km^2 within the 'summer' area of the SCI (Figure 35). Turbines installed outwith the SCI or nearer the SCI boundary will have a smaller EDR overlapping the SCI. Consequently, the assessment based on all turbines impacting a maximum area within the SCI is worst-case.

18.41 As a worst-case, noise from pile-driving at Hornsea Two could cause displacement of harbour porpoise over 5.3% of the SCI as a whole and 7.3% of the 'summer' area. There will be no impacts on the 'winter' area.

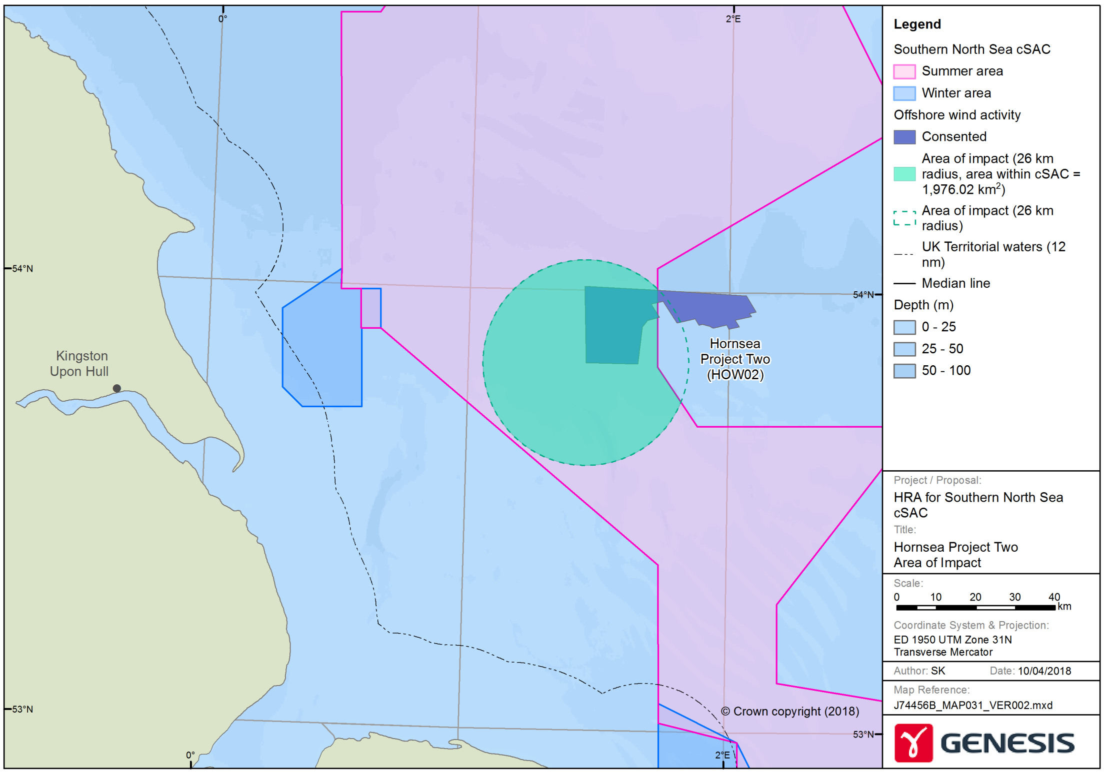


Figure 35: Maximum area of effective deterrence within the Southern North Sea SCI from single pile-driving at Hornsea Two.

18.42 The consented project was for the installation of up to 300 turbines. However, following the awarded of a CfD in September 2017 the maximum generating capacity was limited to 1,386 MW (LCCC 2017). This effectively reduces the number of turbines that could be installed within the wind farm area, with a realistic maximum of 231 x 6 MW turbines a possible worst-case scenario. However, it is also recognised that it is planned that a total of 177 turbines will be installed over a nine month period and therefore the impacts will likely be lower than those consented (Ørsted 2017b).

18.43 As construction for Hornsea Two has not started this assessment considers both the consented number of turbines, a possible scenario of 231 turbines and the planned scenario of 177 turbines.

18.44 For the build out scenarios used for the purposes of this assessment it is assumed that one turbine is installed per day over a period of either 300 days, 231 days or 177 days, with pile-driving occurring throughout the summer period. The installation of all turbines impact on the maximum possible area of 1,976 km^2.

18.45 During any one day, a maximum area equivalent to 7.3% of the 'summer' area may be affected. Over the course of a season the average seasonal spatial overlap is also 7.3% (Table 64). The average seasonal impact during the summer period is lower for the planned scenario as pile-driving is not predicted to occur throughout this period.

18.46 In the event that concurrent pile-driving occurs at two locations 20 km apart, the maximum area within the SCI that could be impacted at any one time is 2,874 km^2 (Figure 36). Based on the consented number of turbines, over the course of one day, up to 10.6% of the SCI could be impacted and over the course of a summer period the average seasonal spatial overlap is 8.8%. Based on the CfD maximum capacity the worst-case scenario is for 10.6% of the SCI to be impacted during any one day and the average seasonal spatial overlap to be 6.8% and the realistic planned scenario the seasonal spatial overlap is 5.3% (Table 64).

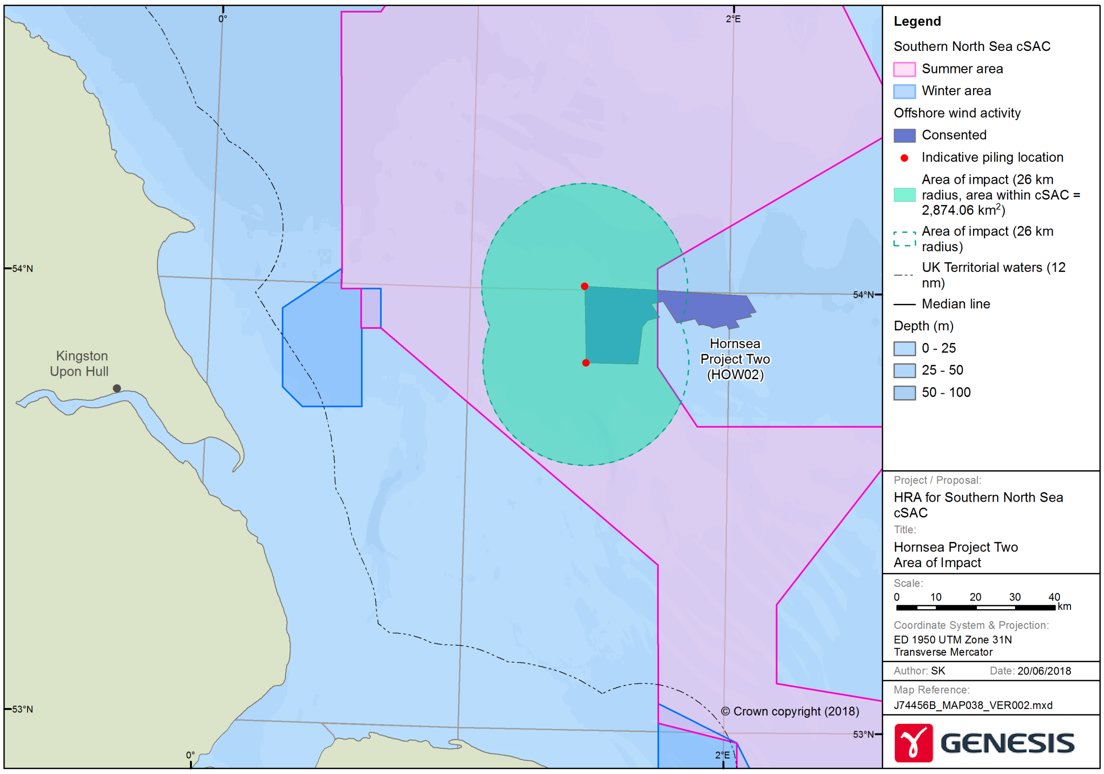


Figure 36: Maximum area of effective deterrence within the Southern North Sea SCI from concurrent pile-driving at Hornsea Two.

Table 64: Seasonal spatial overlap for Hornsea Two offshore wind farm within the SCI.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
Single pile-driving (Worst-case consented)					
'summer'	1,976	7.3	300	183	7.3
Single pile-driving (Worst-case possible (CfD))					
'summer'	1,976	7.3	231	183	7.3
Single pile-driving (Realistic worst-case planned)					
'summer'	1,976	7.3	177	179	7.1
Concurrent pile-driving (Worst-case consented)					
'summer'	2,874	10.6	300	152	8.8
Concurrent pile-driving (Worst-case possible (CfD))					
'summer'	2,874	10.6	231	118	6.8
Concurrent pile-driving (Realistic worst-case planned)					
'summer'	2,874	10.6	177	91	5.3

Physical impacts to the seabed

18.47 Hornsea Two offshore wind farm lies partially within the SCI and a total area of 298.0 km^2 of the wind farm occurs within the site.

18.48 The estimated area of permanent physical impact on the seabed arising from the consented development and the installation of 225 x 8 MW monopiled turbines is 0.44 km^2 (Table 59) and a further 0.141 km^2 of seabed may be impacted by the presence of associated infrastructure (Table 61). A total area of seabed permanently impacted by Hornsea Two is estimated to be 0.581 km^2. In addition to the physical presence of the turbine foundations and associated infrastructure, a further 3.37 km^2 of seabed may be lost due to cable protection (Table 62). Assuming that all impacts occur within the SCI the total area of habitat lost is estimated to be 3.9 km^2. However, 33.5% of the wind farm area lies outwith the site and physical impacts resulting in a loss of habitat within this area will not affect the SCI. A worst-case scenario is that all impacts are within the SCI.

18.49 Seabed surveys undertaken by the developer indicate that the seabed habitat likely to be impacted is predominantly sand, slightly gravelly sand, gravely sand or sandy gravel habitat types (SMart Wind 2015a). This is a widespread habitat found across the whole of the SCI.

18.50 The area of the Southern North Sea SCI is 36,951 km^2 and the potential worst-case loss of 3.9 km^2 of habitat is 0.01% of the site. The loss of a relatively very small area of habitat that occurs widely within the SCI is not predicted to impact on harbour porpoise or their prey.

18.51 There is potential for temporary seabed disturbance caused by trenching and laying of cables within the wind farm area and the along the export cable route. It is estimated that a total area of 7.37 km^2 of seabed may be disturbed by trenching (Table 62). The impacts from cable trenching are recognised to be temporary as the seabed will overtime recover and there will be no loss of habitat.

Hornsea Two: Conclusions

18.52 It is concluded that based on the results from the noise modelling and the use of the threshold approach, pile-driving during the construction of Hornsea Two offshore wind farm on its own will not have an adverse effect upon the integrity of the Southern North Sea SCI.

18.53 For all consented offshore wind farms there are conditions attached to the Marine Licence that require effective mitigation measures to be in place that reduce the risk of any harbour porpoise occurring within the range at which it is predicted the onset of PTS could occur. The mitigation measures to be used are included in each Project's MMMP, which requires consultation with the SNCB and approval from the MMO before construction can commence. Consequently, it is predicted that no harbour porpoise will be impacted by PTS during the construction of the Hornsea Two offshore wind farm.

18.54 The estimated potential temporary displacement or disturbance from single pile-driving of no more than 0.82% of the North Sea Management Unit population over the construction period is predicted to not cause an adverse effect on the favourable conservation status of the species nor the integrity of the site. The draft thresholds proposed by the SNCBs are not exceeded.

18.55 The potential loss of up to 0.002% of habitat that occurs widely across the SCI will not significantly impact the supporting habitats and processes or prey base upon which harbour porpoise depend and will therefore not cause an adverse effect on its own. However, there is potential for an in-combination impact with other plans or projects.

18.56 A pre-construction Marine Licence condition requiring a SIP will ensure that the wind farm parameters used in order to undertake this assessment will not be exceeded.

Creyke Beck A

18.57 The Creyke Beck A offshore wind farm lies wholly within the SCI. There is no confirmed construction date but pile-driving is unlikely to start before March 2020. Precise information on the timing and duration of pile-driving is not available.

Physical injury

18.58 Results from the sound modelling indicate that there is potential for sound levels arising from pile-driving to cause the onset of PTS from between 1.4 km and 2.2 km depending on the hammer energy used to install the pile and the location of the pile-driving within the wind farm area. Noise capable of causing the onset of PTS may extend over an area of between 6.57 km^2 and 16.1 km^2 (Table 27).

18.59 The harbour porpoise density across the wind farm area is estimated to be 0.57 ind./km^2 (Table 6). Based on this density, between 4 and 9 harbour porpoise are predicted to be at risk of PTS at the start of pile-driving activity, this is equivalent to no more than 0.003% of the North Sea Management Unit population.

Displacement

18.60 Displacement may extend from between 12.2 km and 15.76 km and cover an area of between 599 km^2 and 791 km^2 depending on the pile-driving location and the hammer energy used to install the pile (Table 28, Figure 37).

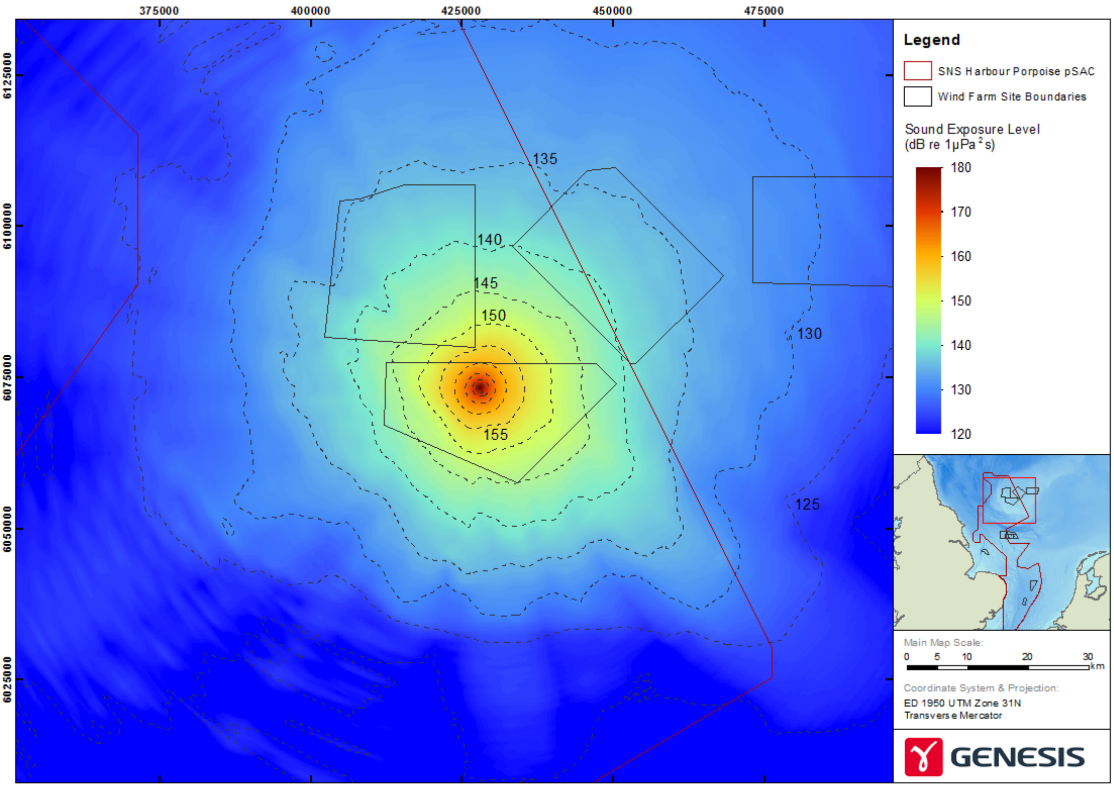


Figure 37: Creyke Beck A single pile-driving (unweighted SEL for pile-driving 3,000 kJ)

18.61 Based on results using a dose response curve and a zonal mean density of 0.71 ind./km^2 (Table 6), the estimated number of harbour porpoise predicted to be displaced is between 128 and 210 individuals; 0.04% and 0.06% of the North Sea Management Unit population (Table 65). The number of harbour porpoise estimated to be impacted by displacement within the SCI is between 128 and 210 individuals.

18.62 In the event concurrent pile-driving is undertaken at two locations within the SCI the estimated number of harbour porpoise predicted to be impacted is between 228 and 331 individuals. Between 0.06% and 0.10% of the North Sea Management Unit population may be impacted. Within the SCI no more than 331 harbour porpoise are predicted to be impacted from concurrent pile-driving (Figure 38, Table 65).

Table 65: Estimated number of harbour porpoise predicted to be displaced by pile-driving from Creyke Beck A offshore wind farm in total and within the SCI.

Location	Creyke Beck A							
	2,300 kJ				3,000 kJ			
	Area (km^2)	No. of Ind.	Area within SCI (km^2)	No. of Ind. within SCI	Area (km^2)	No. of Ind.	Area within SCI (km^2)	No. of Ind. within SCI
1	476.9	128	476.9	128	583.9	156	583.9	156
2	651.8	172	651.8	172	791.0	210	791.0	210
3	598.7	155	598.7	155	735.8	190	735.8	190
Con.	1,071	281	1,071	281	1,281	338	1,281	338

Harbour porpoise density of 0.71 ind./km^2

Con. = Concurrent pile-driving

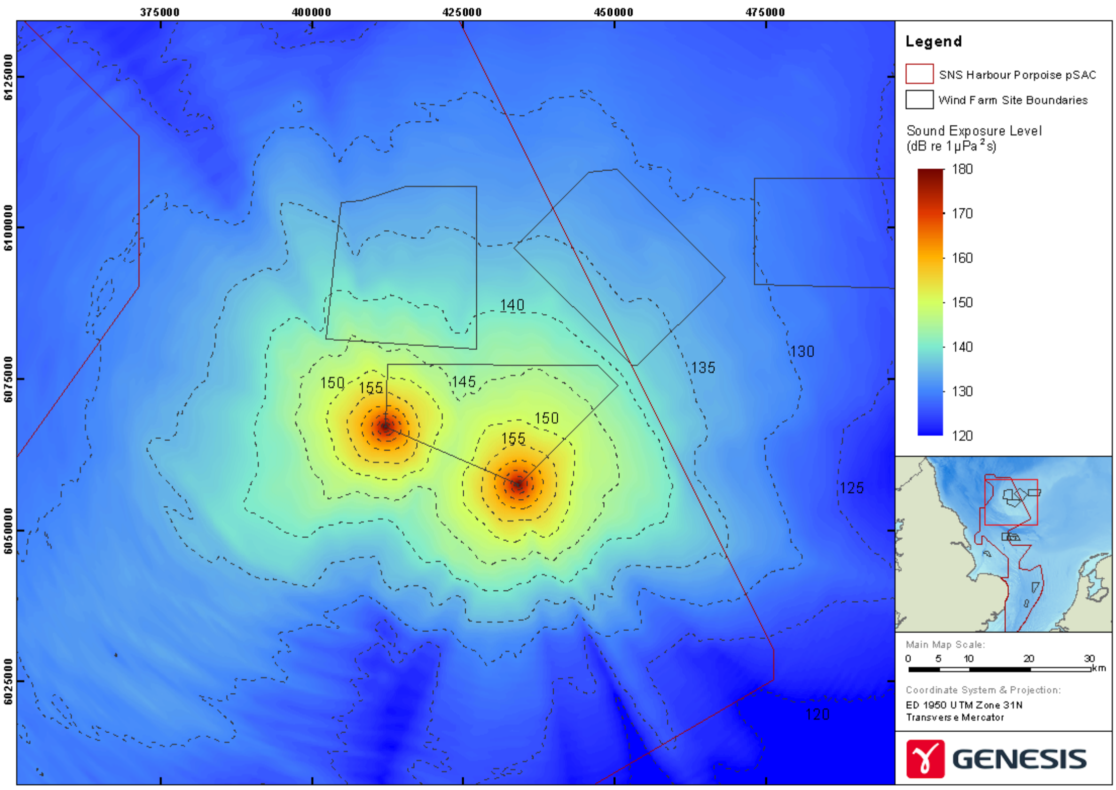


Figure 38: Creyke Beck A concurrent pile-driving (unweighted SEL for pile-driving 3,000 kJ).

Effective Deterrent Radius

18.63 The Creyke Beck A offshore wind farm lies wholly within the SCI and, under the worst-case scenario, the whole of a 26 km EDR will be within the 'summer' area of the SCI and impact an area of 2,124 km^2 (Figure 39). However, the EDR for turbines installed towards the eastern part of the wind farm area only partially overlaps the SCI. Consequently, the assessment based on all turbines impacting the maximum EDR is worst-case.

18.64 As a worst-case, noise from pile-driving at Creyke Beck A may cause displacement over 5.7% of the SCI as a whole and 7.9% of the 'summer' area. There will be no impacts on the 'winter' area.

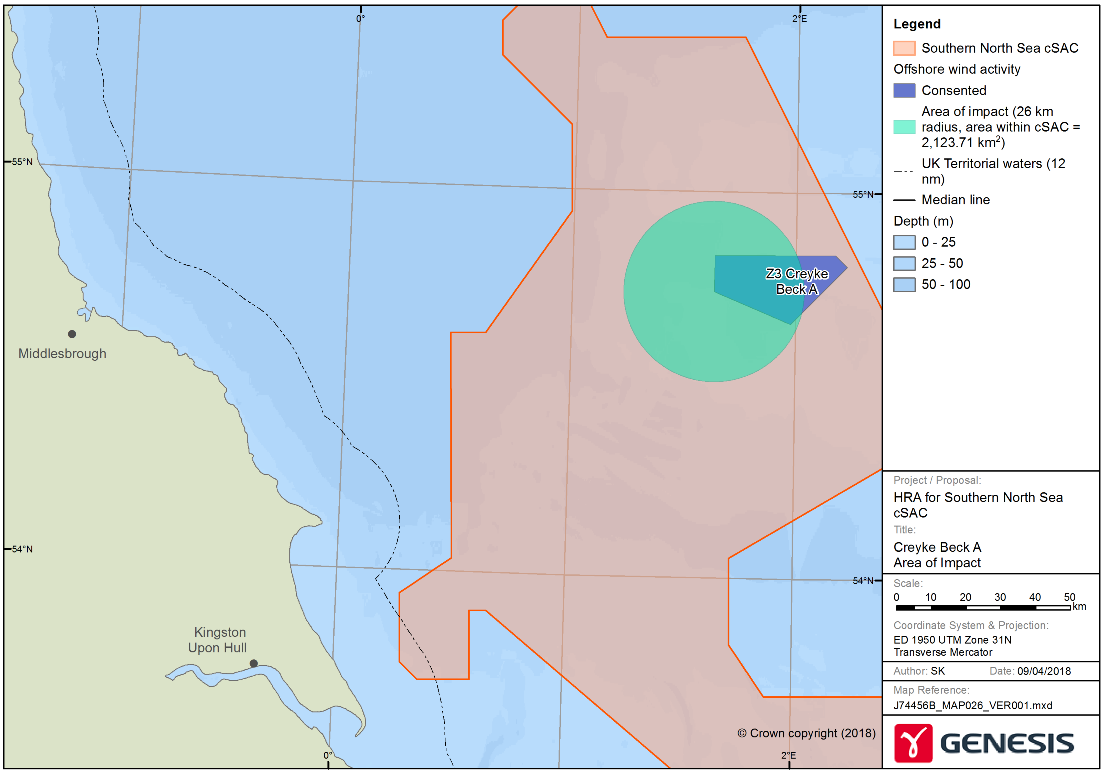


Figure 39: Maximum area of effective deterrence within the Southern North Sea SCI from single pile-driving at Creyke Beck A.

18.65 The timing and duration of the installation of the wind turbine foundations are not known. However, construction of the wind farm must commence no later than March 2020, although the installation of turbines may occur after this date. The maximum number of turbines consented is 200 and the worst-case average duration of installation assessed in the application is three hours (Infrastructure Planning 2015a, Forewind 2013a).

18.66 The worst-case scenario used for the purposes of this assessment assumes that one turbine is installed per day over a period of 200 days, with pile-driving occurring throughout the 183 days of the summer period. The installation of all turbines impact on the maximum EDR of 26 km.

18.67 During any one day it is estimated that a maximum area equivalent to 7.9% of the ‘summer’ area may be affected. Over the course of a season the average seasonal spatial overlap is also 7.9% (Table 66).

Table 66: Seasonal spatial overlap for Creyke Beck A offshore wind farm within the SCI

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (%)
Single pile-driving					
'summer'	2,124	7.9	200	183	7.9
Concurrent pile-driving (worst-case)					
'summer'	3,569	13.2	200	102	7.4

18.68 In the event concurrent pile-driving occurs there is potential for a larger area of the SCI to be impacted over a shorter period of time. The maximum area within the SCI that could be impacted is presented in Figure 40. The scenario used for the purposes of this concurrent pile-driving assessment assumes that two turbines are installed per day over a period of 100 days (plus two days recovery period), with pile-driving occurring throughout the summer period. The largest possible area impacted is calculated to be 3,569 km^2.

18.69 In the event that concurrent pile-driving occurs, the worst-case scenario is that during any one day a maximum area equivalent to 13.2% of the 'summer' area may be impacted. Over the course of a season the average seasonal spatial overlap is 7.4% (Table 66).

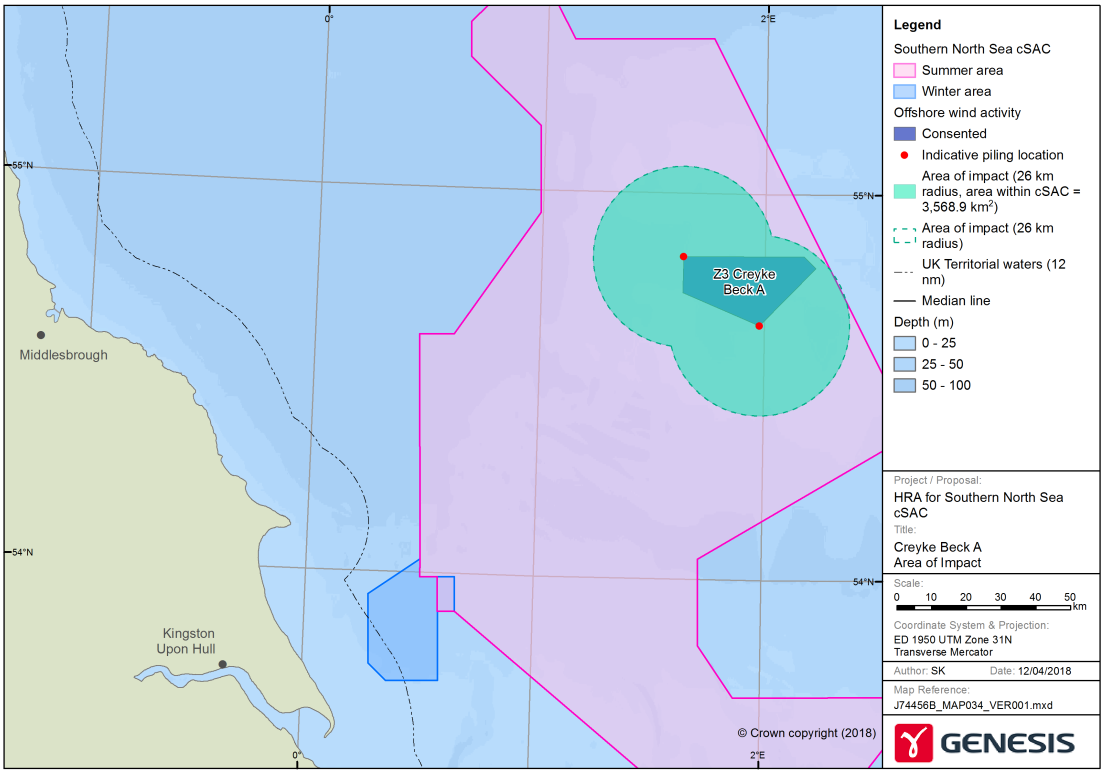


Figure 40: Maximum area of effective deterrence within the Southern North Sea SCI from concurrent pile-driving at Creyke Beck A.

Physical impacts to the seabed

18.70 Creyke Beck A offshore wind farm area lies wholly within the SCI. An estimated 0.7 km^2 of seabed may be physically impacted by the presence of turbines and associated infrastructure and a further 2.9 km^2 of cable protection may be required (Table 59, Table 61 and Table 62). The area of the Southern North Sea SCI is 36,951 km^2 and the potential loss of 3.6 km^2 of habitat is 0.01% of the site. The habitats within Creyke Beck A are subtidal sands and gravels and are widespread across the SCI (JNCC 2017a).

18.71 There is potential for temporary seabed disturbance caused by trenching and laying of cables within the wind farm area and the along the export cable route. It is estimated that a total area of 14.73 km^2 of seabed may be disturbed by trenching (Table 62). The impacts from cable trenching are recognised to be temporary as the seabed will overtime recover and there will be no loss of habitat.

Creyke Beck A: Conclusions

18.72 It is concluded that based on the results from the noise modelling and the use of the threshold approach, pile-driving during the construction of Creyke Beck A offshore wind farm on its own will not have an adverse effect upon the integrity of the Southern North Sea SCI.

18.73 For all consented offshore wind farms there are conditions attached to the Marine Licence that require effective mitigation measures to be in place that reduce the risk of any harbour porpoise occurring within the range at which it is predicted the onset of PTS could occur. The mitigation measures to be used are included in each Project's MMMP, which requires consultation with the SNCB and approval from the MMO before construction can commence. Consequently, it is predicted that no harbour porpoise will be impacted by PTS by noise arising from pile-driving during the construction of the Creyke Beck A offshore wind farm.

18.74 The estimated potential displacement of no more than 0.06% of the population over the construction period from single pile-driving and 0.10% from concurrent pile-driving, is predicted to not cause an adverse effect on the favourable conservation status of the species nor the integrity of the site. The draft thresholds proposed by the SNCBs are not exceeded.

18.75 The potential physical loss of up to 0.01% of habitat that occurs widely across the SCI will not significantly impact the supporting habitats and processes or prey base upon which harbour porpoise depend and will not cause an adverse effect on its own. However, there is potential for an in-combination impact with other plans or projects.

18.76 A pre-construction Marine Licence condition requiring a SIP will ensure that the wind farm parameters used in order to undertake this assessment will not be exceeded.

Creyke Beck B

18.77 The Creyke Beck B offshore wind farm lies wholly within the SCI. There is no confirmed construction date but pile-driving is unlikely to start before March 2020. Precise information on the timing and duration of pile-driving is not available.

Physical Injury

18.78 Results from the sound modelling indicate that there is potential for sound levels arising from pile-driving to cause the onset of PTS from between 1.4 km and 2.4 km depending on the hammer energy used to install the pile and the location of the pile-driving within the wind farm area. Noise capable of causing the onset of PTS may extend over an area of between 5.8 km^2 and 17.6 km^2 (Table 31).

18.79 The harbour porpoise density across the wind farm area is estimated to be 0.57 ind./km^2 (Table 6). Based on this density, between 3 and 10 harbour porpoise are predicted to be at risk of PTS at the start of pile-driving activity, this is equivalent to no more than 0.003% of the North Sea Management Unit population.

Displacement

18.80 Displacement of harbour porpoise may extend from between 14.6 km and 21.8 km and cover an area of between 684 km^2 and 1,498 km^2 depending on the pile-driving location and the hammer energy used to install the pile (Table 67, Figure 41). Based on results using a dose response curve and a zonal specific mean density of 0.71 ind./km^2 (Table 6), the estimated number of harbour porpoise predicted to be displaced is between 176 and 376 individuals; 0.05% and 0.11% of the North Sea Management Unit population. Within the SCI it is estimated that between 176 and 376 harbour porpoise may be displaced by pile-driving during construction of the wind farm.

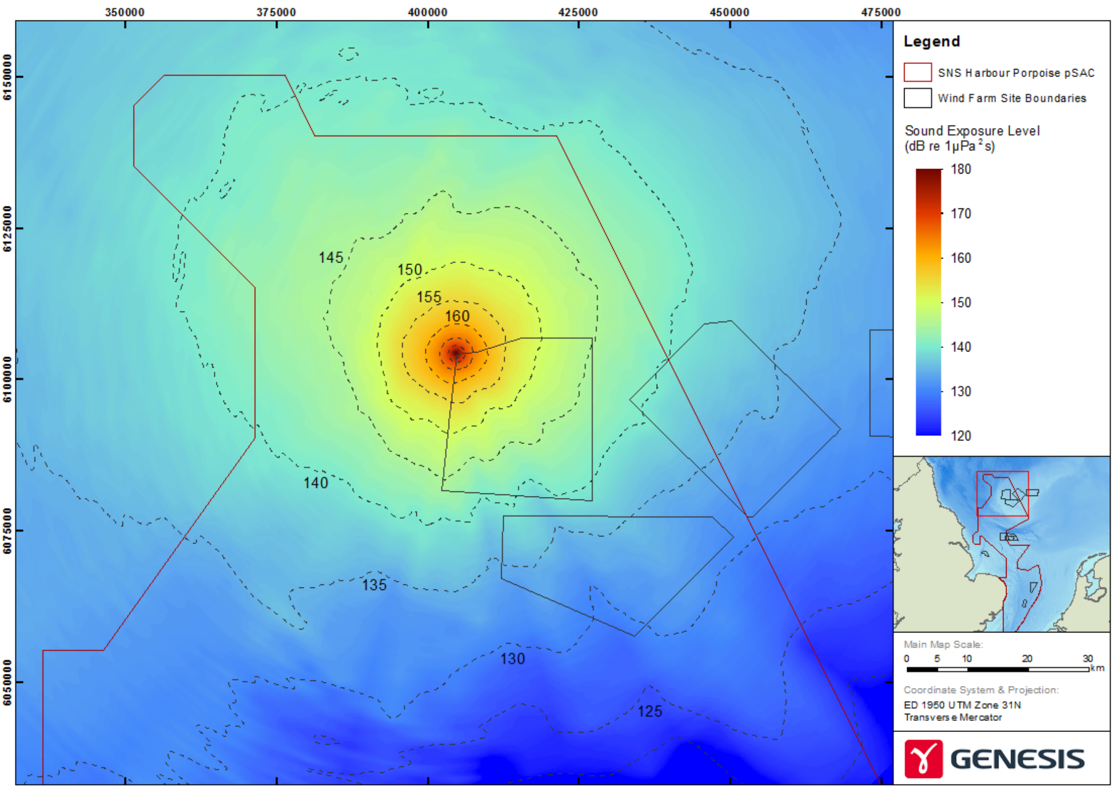


Figure 41: Creyke Beck B single pile-driving (unweighted SEL for pile-driving 3,000 kJ).

Table 67: Estimated number of harbour porpoise predicted to be displaced by pile-driving from Creyke Beck B offshore wind farm in total and within the SCI.

Location	Creyke Beck B							
	2,300 kJ				3,000 kJ			
	Area (km^2)	No. of Ind.	Area within SCI (km^2)	No. of Ind. Within SCI	Area (km^2)	No. of Ind.	Area within SCI (km^2)	No. of Ind. Within SCI
1	684	176	684	176	823	214	823	214
2	1,209	303	1,209	303	1,498	376	1,498	376
Con.	1,709	444	1,709	444	2,042	536	2,042	536

Harbour porpoise density of 0.71 ind./km^2

Con. = Concurrent pile-driving

18.81 In the event concurrent pile-driving is undertaken at two locations within the SCI (Figure 42) the estimated number of harbour porpoise predicted to be impacted is between 444 and 536 individuals. Between 0.13% and 0.16% of the North Sea Management Unit population may be impacted. Within the SCI no more than 1,171 harbour porpoise are predicted to be impacted from concurrent pile-driving (Table 67).

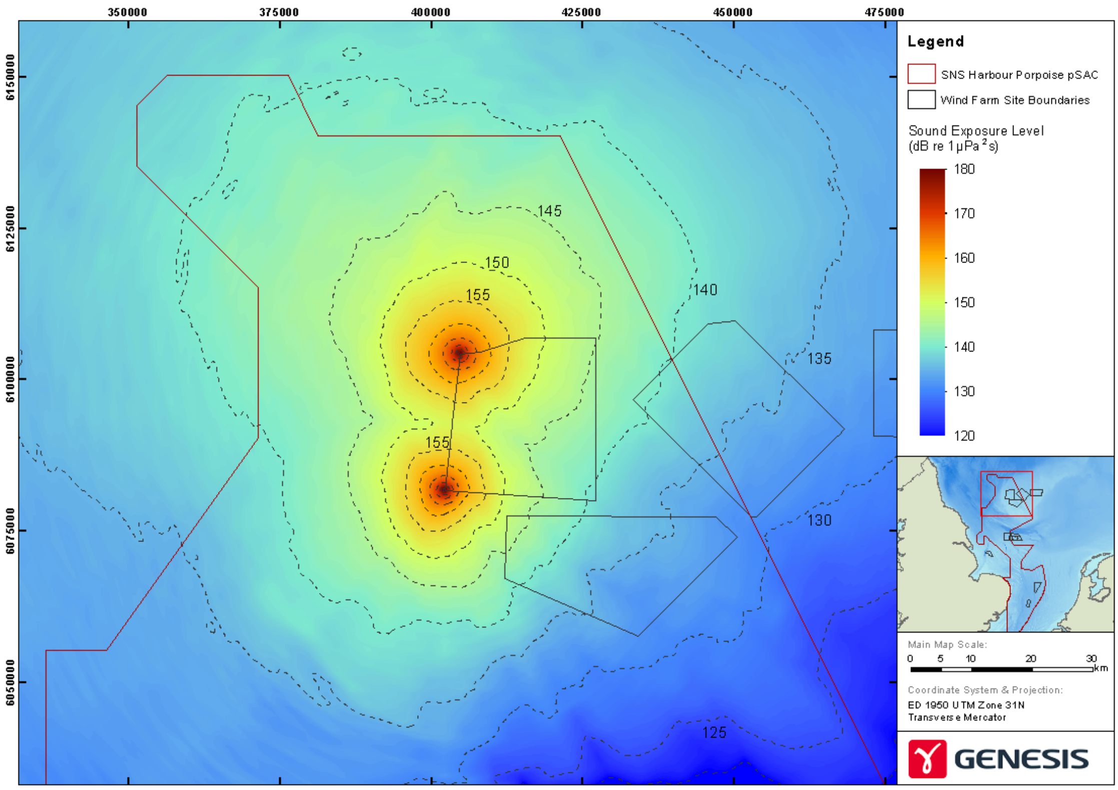


Figure 42: Creyke Beck B concurrent pile-driving (unweighted SEL for pile-driving 3,000 kJ).

Effective Deterrent Radius

18.82 The Creyke Beck B offshore wind farm lies wholly within the SCI and, under the worst-case scenario, the whole of a 26 km EDR will be within the 'summer' area of the SCI and impact an area of 2,123.7 km^2 (Figure 43). However, the EDR for turbines installed towards the eastern area of the wind farm area only partially overlaps the SCI. Consequently, the assessment based on all turbines impacting the maximum EDR is worst-case.

18.83 As a worst-case, noise from pile-driving at Creyke Beck B may cause displacement over 5.7% of the SCI as a whole and 7.9% of the 'summer' area. There will be no impacts on the 'winter' area.

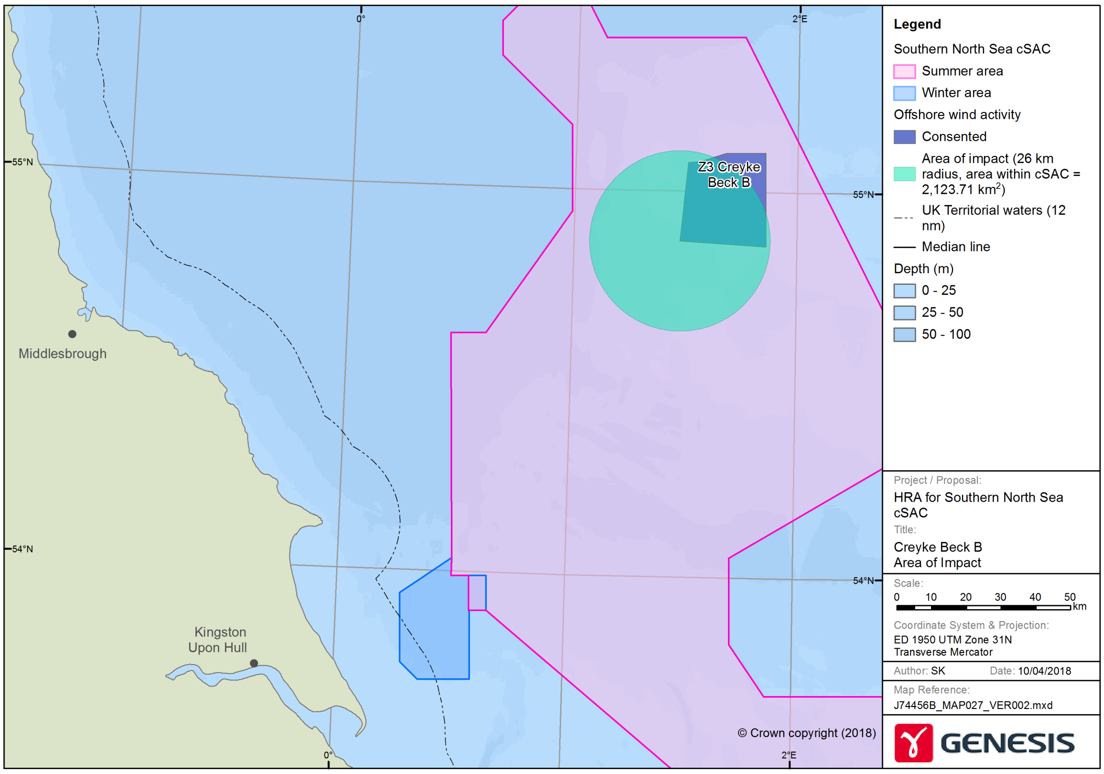


Figure 43: Area of effective deterrence within the Southern North Sea SCI from pile-driving at Creyke Beck B.

18.84 The timing and duration of the installation of the wind turbine foundations is not known. However, construction of the wind farm must commence no later than March 2020, although the installation of turbines may occur after this date. The maximum number of turbines consented is 200 and the worst-case average duration of installation assessed in the application is three hours (Infrastructure Planning 2015a, Forewind 2013a).

18.85 The worst-case scenario used for the purposes of this assessment assumes that one turbine is installed per day over a period of 200 days, with pile-driving occurring throughout the 183 days of the summer period. The installation of all turbines impact on the maximum EDR of 26 km. Consequently, during any one day, a maximum area equivalent to 7.9% of the ‘summer’ area may be affected. Over the course of a season the average seasonal spatial overlap is also 7.9% (Table 68).

18.86 In the event concurrent pile-driving occurs there is potential for a larger area of the SCI to be impacted over a shorter period of time. The maximum area within the SCI that could be impacted is presented in Figure 44. The scenario used for the purposes of this concurrent pile-driving assessment assumes that two turbines are installed per day over a period of 100 days, with pile-driving occurring throughout the summer period. The maximum total area impacted by concurrent pile-driving is calculated to be 3,576.5 km^2.

18.87 In the event that concurrent pile-driving occurs, the worst-case scenario is that during any one day a maximum area equivalent to 13.2% of the 'summer' area may be impacted. Over the course of a season the average seasonal spatial overlap is 7.4 % (Table 68).

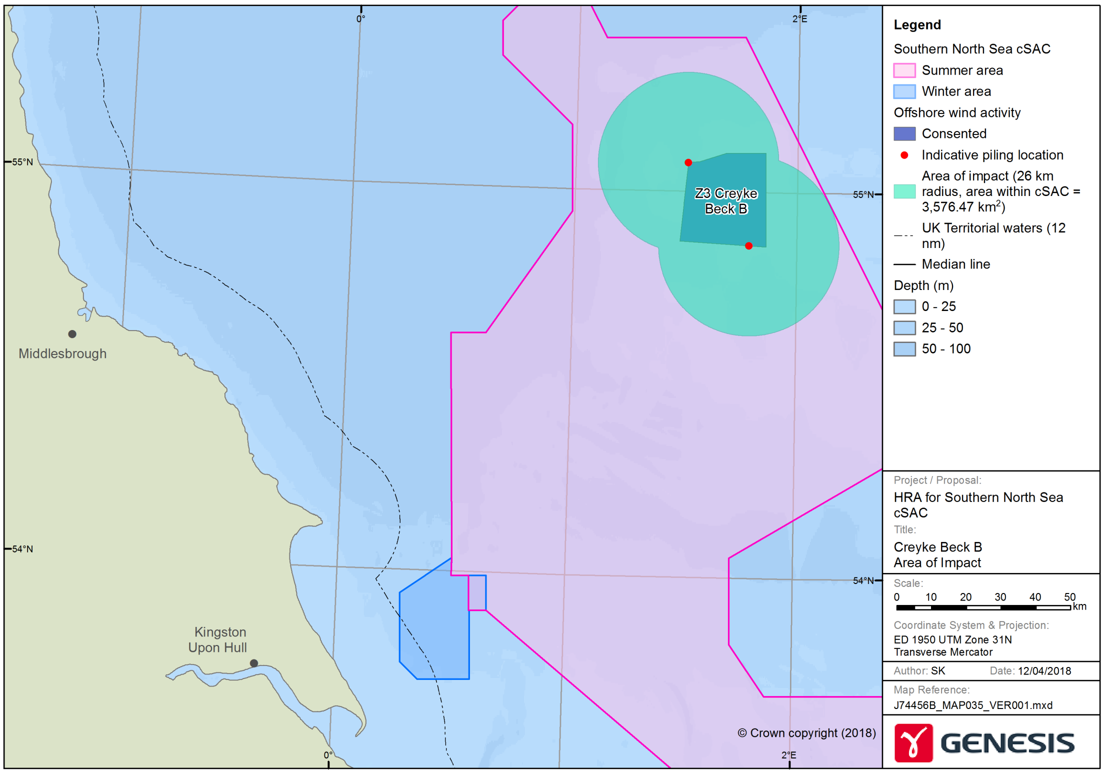


Figure 44: Area of effective deterrence within the Southern North Sea SCI from concurrent pile-driving at Creyke Beck B

Table 68: Seasonal spatial overlap for Creyke Beck B offshore wind farm within the SCI.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
Single pile-driving					
'summer'	2,124	7.9	200	183	7.9
Concurrent pile-driving (worst-case)					
'summer'	3,577	13.2	200	102	7.4

Physical impact to the seabed

18.88 Creyke Beck B offshore wind farm area lies wholly within the SCI. An estimated 0.71 km^2 of seabed may be physically impacted by the presence of turbines and associated infrastructure and a further 2.7 km^2 of cable protection may be required. Consequently, an estimated 0.01% of the SCI habitat could be physically impacted.

18.89 An estimated 14.63 km^2 of seabed may be temporarily impacted by the inter array cables and the export cable route within the SCI (Table 62). The impacts on the habitat from the trenching of cable will be temporary with the habitat recovering following completion of the activities.

18.90 The habitats within Creyke Beck B are similar to those in Creyke Beck A, i.e. subtidal sands and gravels and are widespread across the SCI (JNCC 2017a). The potential loss of 0.01% of habitat from the physical presence of the wind turbines, associated infrastructure and cable protection will not cause a likely significant effect on harbour porpoise or their prey.

18.91 It is concluded that, based on the threshold approach to assessing adverse effects, pile-driving during the construction of Creyke Beck B offshore wind farm on its own will not have an adverse effect upon the integrity of the Southern North Sea SCI. The potential loss of up to 0.01% of habitat that occurs widely across the SCI will not significantly impact the supporting habitats and processes or prey base upon which harbour porpoise depend and will therefore not cause an adverse effect on its own. However, there is potential for an in-combination impact with other plans or projects.

Creyke Beck B: Conclusions

18.92 It is concluded that based on the results from the noise modelling and the use of the threshold approach, pile-driving during the construction of Creyke Beck B offshore wind farm on its own will not have an adverse effect upon the integrity of the Southern North Sea SCI.

18.93 For all consented offshore wind farms there are conditions attached to the Marine Licence that require effective mitigation measures to be in place that reduce the risk of any harbour porpoise occurring within the range at which it is predicted the onset of PTS could occur. The mitigation measures to be used are included in each Project's MMMP, which requires consultation with the SNCB and approval from the MMO before construction can commence. Consequently, it is predicted that no harbour porpoise will be impacted by PTS by noise arising from pile-driving during the construction of the Creyke Beck B offshore wind farm.

18.94 The estimated potential displacement of no more than 0.11% of the harbour porpoise population over the construction period from single pile-driving and 0.16% from concurrent pile-driving is predicted to not cause an adverse effect on the favourable conservation status of the species nor the integrity of the site. The draft thresholds proposed by the SNCBs are not exceeded.

18.95 The potential physical loss of up to 0.01% of habitat that occurs widely across the SCI will not significantly impact the habitat or prey base upon which harbour porpoise depend and will therefore not cause an adverse effect on its own. However, there is potential for an in-combination impact with other plans or projects.

18.96 A pre-construction Marine Licence condition requiring a SIP will ensure that the wind farm parameters used in order to undertake this assessment will not be exceeded.

Teesside A

18.97 The Teesside A offshore wind farm lies wholly outwith the SCI (Figure 47). There is no confirmed construction date but pile-driving is unlikely to start before June 2021. Precise information on the timing and duration of pile-driving is not available.

18.98 The maximum consented hammer energy to be used is 3,000 kJ. However, there is potential for the use of an increased hammer energy up to 5,500 kJ. Consequently, both the consented and the potential maximum hammer energies have been considered in this assessment.

Physical injury

18.99 Results from the sound modelling indicate that there is potential for sound levels arising from pile-driving to cause the onset of PTS out from between 1.8 km and 4.5 km depending on the hammer energy used to install the pile and the location of the pile-driving within the wind farm area. Noise capable of causing the onset of PTS may extend over an area of between 10.6 km^2 and 62.5 km^2 (Table 35).

18.100 The harbour porpoise density across the wind farm area is estimated to be 0.64 ind./km^2 (Table 6). Based on this density between 7 and 40 harbour porpoise could be affected at the start of pile-driving activity. This is equivalent to between 0.003% and 0.01% of the North Sea Management Unit population.

Displacement

18.101 Displacement may extend on average to 18.4 km and cover an area of 1,072 km^2, based on a 3,000 kJ hammer energy. This increases to 25.0 km and an area of 1,964 km^2 in the event a 5,500 kJ hammer is used (Table 36). Based on results from the dose response curve used and a zonal harbour porpoise density of 0.71 ind./km^2 (Table 6), the estimated number of harbour porpoise predicted to be displaced is between 275 and 505 individuals (Table 69). Between 0.08% and 0.15% of the North Sea Management Unit population may be impacted.

18.102 The location of the Teesside A wind farm is such that no harbour porpoises within the SCI will be at risk of the onset of PTS and and no more than one individual is predicted to be displaced within the SCI.

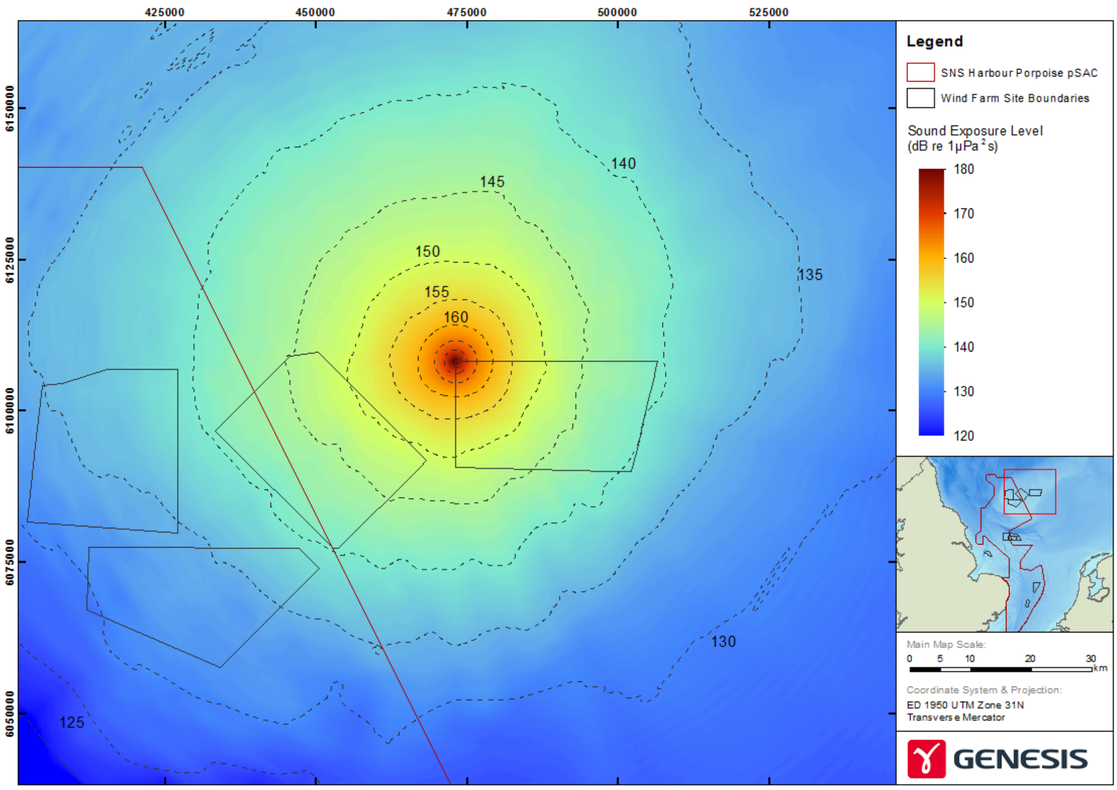


Figure 45: Teesside A single pile-driving (unweighted SEL for pile-driving 5,500 kJ).

Table 69: Estimated number of harbour porpoise predicted to be displaced by pile-driving from Teesside A offshore wind farm in total and within the SCI.

Location	Teesside A							
	3,000 kJ				5,500 kJ			
	Area (km^2)	No. of Ind.	Area within SCI (km^2)	No. of Ind. Within SCI	Area (km^2)	No. of Ind.	Area within SCI (km^2)	No. of Ind. Within SCI
1	1,072	275	0	0	1,752	449	2.8	1
2	1,226	312	0	0	1,964	505	0	0
Con.	1,777	480	0	0	2,657	726	2.8	1

Harbour porpoise density of 0.71 ind./km^2

Con. = Concurrent pile-driving

18.103 In the event concurrent pile-driving is undertaken at two locations (Figure 46) the estimated number of harbour porpoise predicted to be impacted is between 480 and 726 individuals. Between 0.14% and 0.22% of the North Sea Management Unit population may be impacted. Within the SCI no more than one harbour porpoise is predicted to be impacted from concurrent pile-driving.

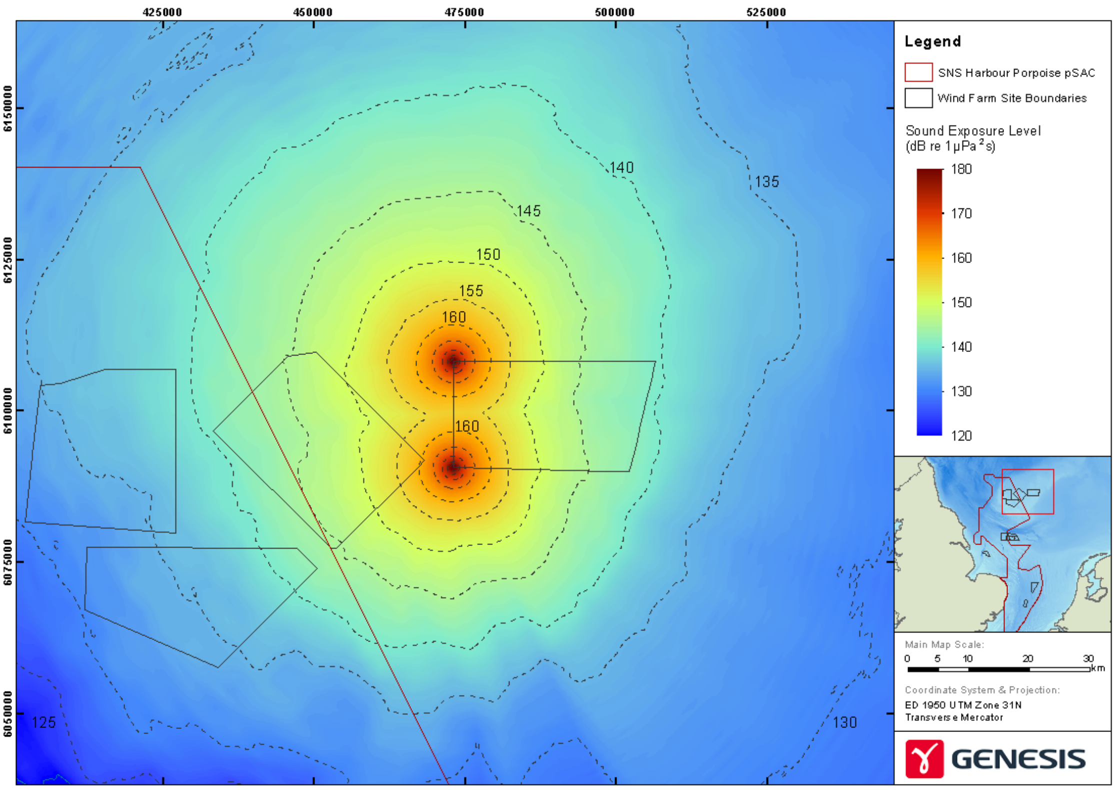


Figure 46: Teesside A concurrent pile-driving (unweighted SEL for pile-driving 5,500 kJ)

Effective Deterrent Radius

18.104 The Teesside A offshore wind farm lies wholly outwith the SCI and, under the worst-case scenario, a relatively small area of the 26 km EDR will be overlap the ‘summer’ area of the SCI and impact, at most, an area of 22.8 km^2 (Figure 47).

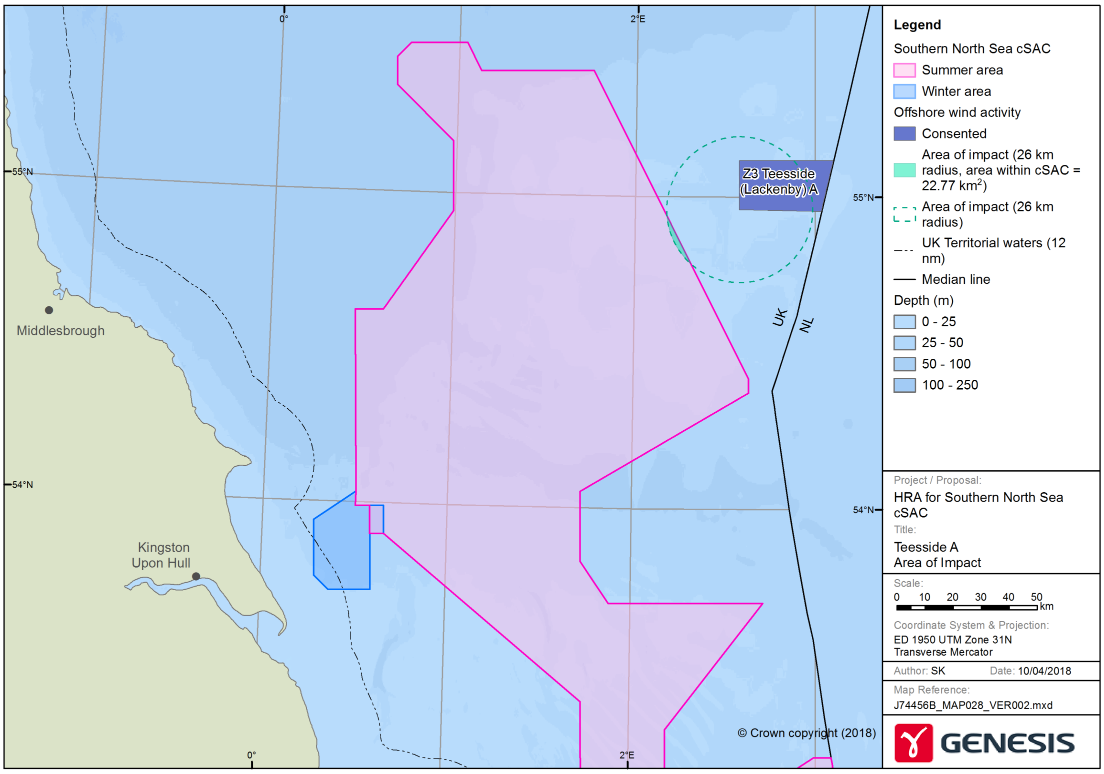


Figure 47: Maximum area of effective deterrence within the Southern North Sea SCI from single pile-driving at Teesside A.

18.105 As a worst-case, noise from pile-driving at Teesside A may cause displacement over 0.06% of the SCI as a whole and 0.08% of the 'summer' area. There will be no impacts on the 'winter' area.

18.106 The timing and duration of the installation of the wind turbine foundations is not known. However, construction of the wind farm must commence no later than August 2022, although the installation of turbines may occur after this date.

18.107 The maximum number of turbines consented is 200 and therefore the average density of turbines within the wind farm area is one turbine every 2.8 km^2. The total area within the wind farm site that could cause an impact on the SCI is 4.33 km^2. Based on an average density of one turbine every 2.8 km^2 an estimated two turbines may be located within the area of the wind farm that could cause an impact on the SCI.

18.108 The scenario used for the purposes of this assessment assumes that one turbine is installed per day over a period of two days, with pile-driving occurring within the summer period. There are two further days following cessation of pile-driving during which harbour porpoises are absent. The installation of all turbines impact to the maximum extent within the SCI of 22.8 km^2. During any one day, a maximum area equivalent to 0.08% of the 'summer' area may be affected. Over the course of a season the average seasonal spatial overlap is 0.002% (Table 70).

18.109 There is potential for concurrent pile-driving to occur. However, the relatively very small area within which impacts to the SCI could occur indicate that there will be a very low likelihood of concurrent pile-driving impacting on the SCI. In the unlikely event that it does occur, the area of the SCI impacted will be very small and the duration of impacts reduced. The seasonal spatial overlap will be lower.

Table 70: Seasonal spatial overlap for Teesside A offshore wind farm within the SCI.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (%)
Single pile-driving					
'summer'	22.8	0.08	2	4	0.002

Physical impacts to the seabed

18.110 Teesside A offshore wind farm lies outwith the SCI. Therefore, there will be no permanent physical impact on the seabed within the SCI from the wind turbines and associated infrastructure. The export cables may impact on the SCI and an estimated 1.53 km^2 of seabed within the SCI may be disturbed during the installation of cables (Table 62). The disturbance of the seabed by cable laying will be temporary with the seabed habitat recovering. Consequently, there will be no permanent loss of habitat from cable laying. There is potential for cable protection to be required and an estimated 2.89 km^2 of seabed could be affected. It is not known where along the export cable route protection will be required. A worst case scenario is that it occurs within the SCI and therefore impacts a total of 0.008% of the SCI.

18.111 Seabed surveys undertaken by the developer indicate that the seabed habitat likely to be impacted along the export cable route is relatively uniform with predominantly slightly gravelly sand, gravely sand or sandy gravel habitat types (Forewind 2014). This is a widespread habitat found across the whole of the SCI.

18.112 The area of the Southern North Sea SCI is 36,951 km^2 and the potential loss of 2.9 km^2 of habitat is 0.008% of the site. The loss of a relatively very small area of habitat that occurs widely within the SCI is not predicted to impact on harbour porpoise or their prey.

Teesside A: Conclusions

18.113 It is concluded that based on the results from the noise modelling and the use of the threshold approach, pile-driving during the construction of Teesside A offshore wind farm on its own will not have an adverse effect upon the integrity of the Southern North Sea SCI.

18.114 For all consented offshore wind farms there are conditions attached to the Marine Licence that require effective mitigation measures to be in place that reduce the risk of any harbour porpoise occurring within the range at which it is predicted the onset of PTS could occur. The mitigation measures to be used are included in each Project's MMMP, which requires consultation with the SNCB and approval from the MMO before construction can commence. Consequently, it is predicted that no harbour porpoise will be impacted by PTS by noise arising from pile-driving during the construction of the Teesside A offshore wind farm.

18.115 The estimated potential impact on no more 0.15% of the North Sea Management Unit population, or 0.22% of the population should concurrent pile-driving occur, is predicted to not cause an adverse effect on the favourable conservation status of the species nor the integrity of the site. The draft thresholds proposed by the SNCBs are not exceeded.

18.116 The potential loss of up to 0.008% of habitat that occurs widely across the SCI will not significantly impact the supporting habitats and processes or prey base upon which harbour porpoise depend and will not cause an adverse effect on its own. However, there is potential for an in-combination impact with other plans or projects.

18.117 A pre-construction Marine Licence condition requiring a SIP will ensure that the wind farm parameters used in order to undertake this assessment will not be exceeded.

Teesside B

18.118 The Teesside B offshore wind farm lies partially within the SCI with 127.4 km of the wind farm area overlapping the SCI (Figure 50). There is no confirmed construction date but pile-driving is unlikely to start before June 2021. Precise information on the timing and duration of pile-driving is not available.

18.119 The maximum consented hammer energy to be used is 3,000 kJ. However, there is potential for the use an increase in hammer energy up to 5,500 kJ. Consequently, both the consented and the potential maximum hammer energies have been considered in this assessment.

Physical injury

18.120 Results from the sound modelling indicate that there is potential for sound levels arising from pile-driving to cause the onset of PTS out from between 2.0 km and 4.5 km depending on the hammer energy used to install the pile and the location of the pile-driving within the wind farm area. Noise capable of causing the onset of PTS may extend over an area of between 12.4 km^2 and 62.3 km^2 (Table 39).

18.121 The harbour porpoise density across the wind farm area is estimated to be 0.64 ind./km^2 (Table 6). Based on this density between 8 and 40 harbour porpoise could be affected at the start of pile-driving activity. This is equivalent to between 0.002% and 0.012% of the North Sea Management Unit population.

Displacement

18.122 Displacement may extend on average to 16.4 km and cover an area of 850.2 km^2, based on a 3,000 kJ hammer energy. This increases to 24.1 km and an area of 1,842 km^2 in the event a 5,500 k hammer is used (Table 40). Based on results from the dose response curve used and a zonal specific density of 0.71 ind./km^2 (Table 6), the estimated number of harbour porpoise predicted to be displaced is between 221 and 461 individuals (Table 71). Between 0.07% and 0.14% of the North Sea Management Unit population may be impacted.

18.123 The location of the Teesside B wind farm is such that fewer porpoises within the SCI may be at risk of the onset of PTS at wind turbine located outwith the SCI and and no more than 342 individuals are predicted to be displaced within the SCI.

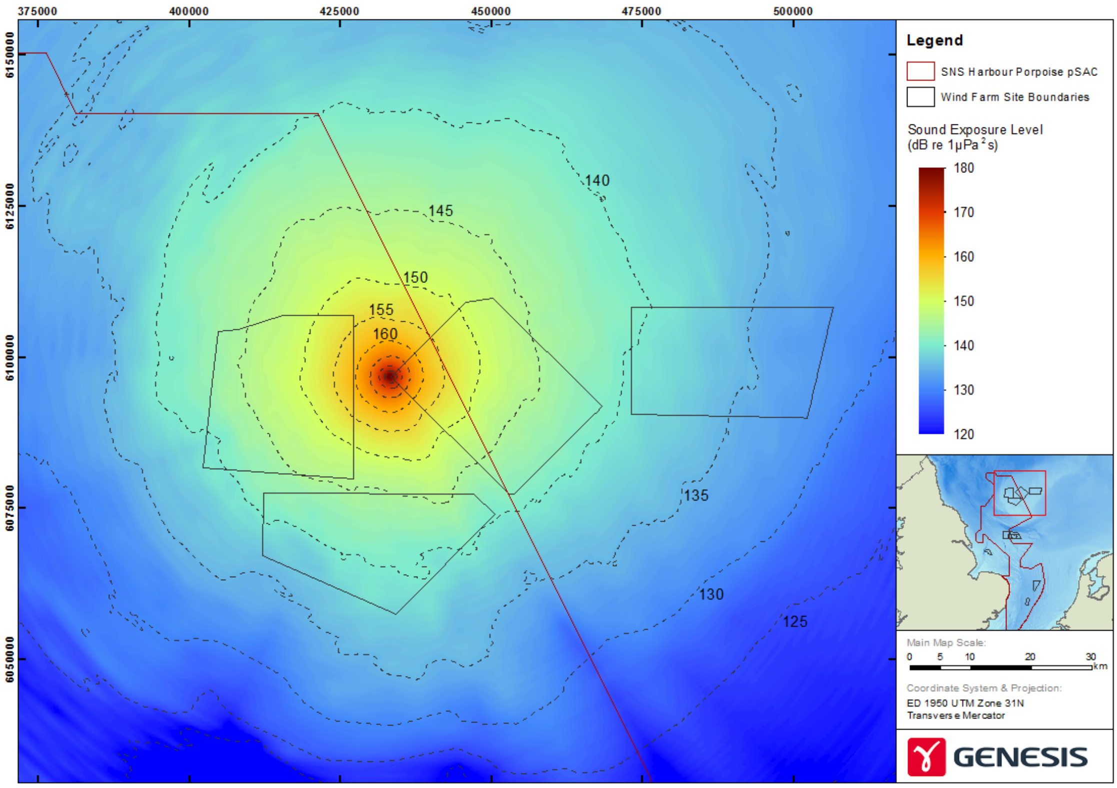


Figure 48: Teesside B single pile-driving (unweighted SEL for pile-driving 5,500 kJ).

Table 71: Estimated number of harbour porpoise predicted to be displaced by pile-driving from Teesside B offshore wind farm in total and within the SCI.

Location	Teesside B							
	3,000 kJ				5,500 kJ			
	Area (km^2)	No. of Ind.	Area within SCI (km^2)	No. of Ind. within SCI	Area (km^2)	No. of Ind.	Area within SCI (km^2)	No. of Ind. within SCI
1	1,097	276	837	223	1,842	461	1,277	342
2	850.2	221	265	97	1,351	351	575	152
Con.	1,855	479	1,135	307	2,806	739	1,633	453

Harbour porpoise density of 0.71 ind./km^2

Con. = Concurrent pile-driving

18.124 In the event concurrent pile-driving is undertaken at two locations the estimated number of harbour porpoise predicted to be impacted is between 479 and 739 individuals. Between 0.14% and 0.22% of the North Sea Management Unit population may be impacted. Within the SCI up to 453 harbour porpoise are predicted to be impacted from concurrent pile-driving.

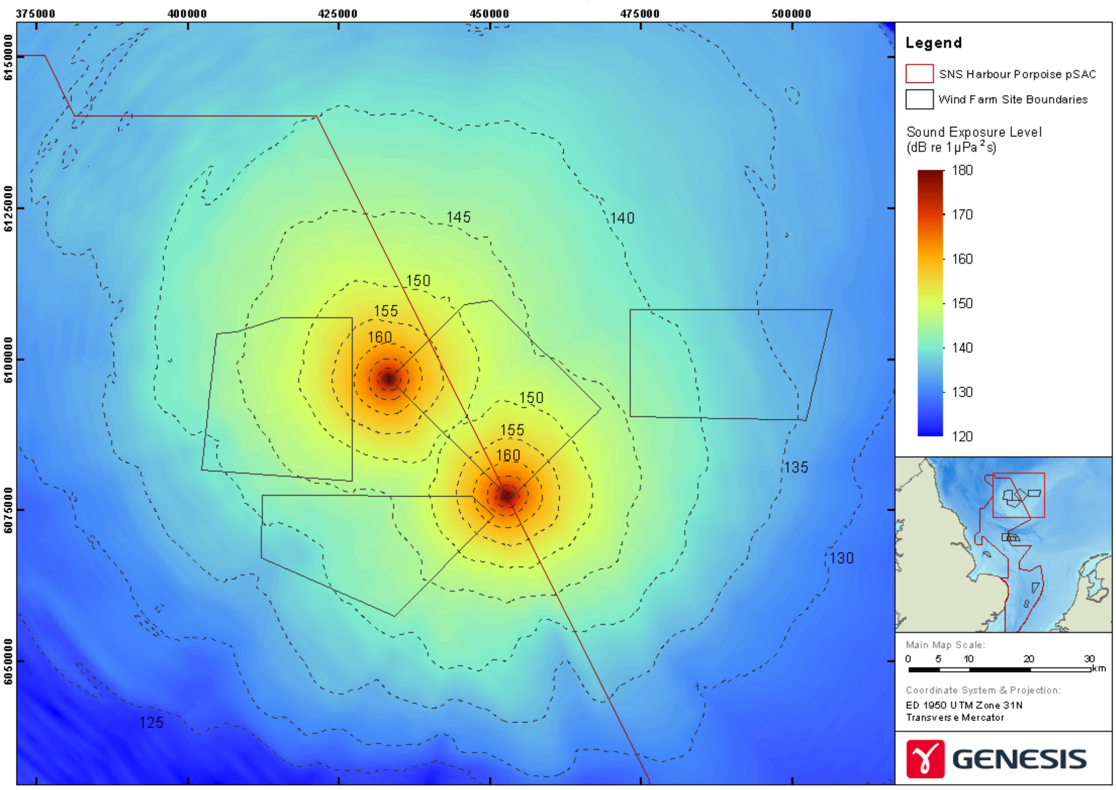


Figure 49: Teesside B concurrent pile-driving (unweighted SEL for pile-driving 5,500 kJ).

Effective Deterrent Radius

18.125 The Teesside B offshore wind farm lies partially within the SCI and, under the worst-case scenario, displacement over an area of 1,508.8 km^2 could occur within 'summer' area of the SCI of the (Figure 50). Noise from pile-driving at Teesside B may cause displacement of harbour porpoise over 4.1% of the SCI as a whole and 5.6% of the 'summer' area. There will be no impacts in the 'winter' area.

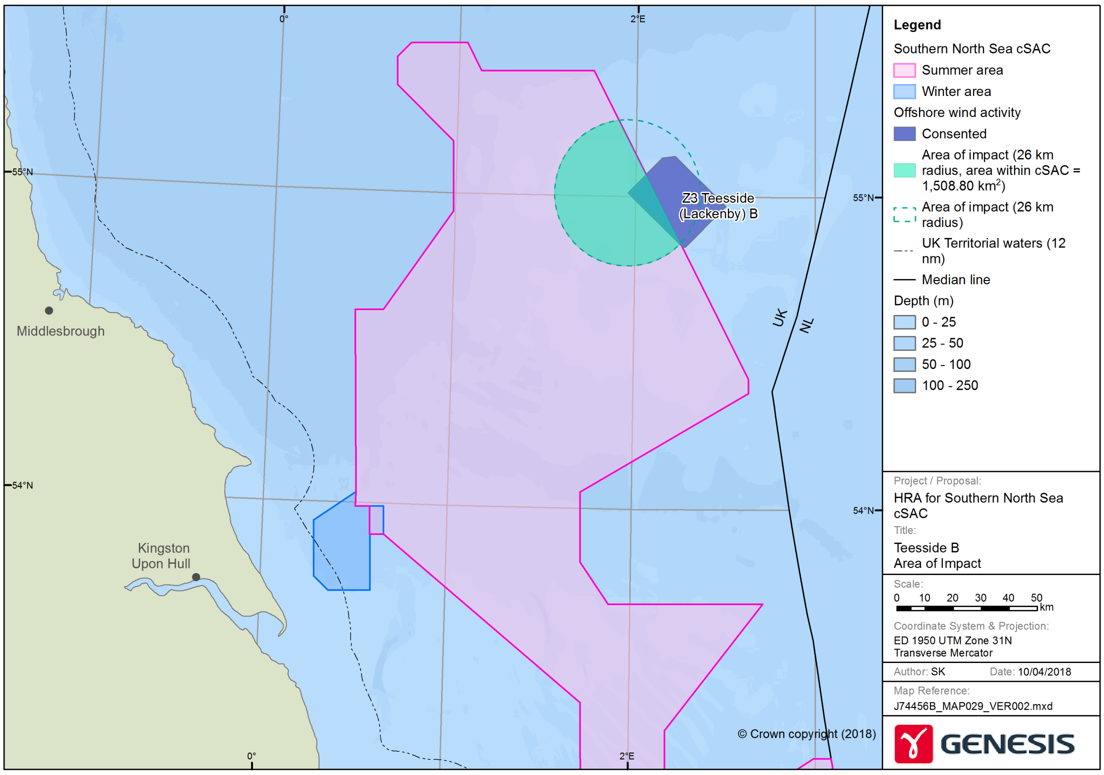


Figure 50: Maximum area of effective deterrence within the Southern North Sea SCI from single pile-driving at Teesside B.

18.126 The timing and duration of the installation of the wind turbine foundations is unknown. However, construction of the wind farm must commence no later than August 2022, although the installation of turbines may occur after this date. The maximum number of turbines consented is 200.

18.127 The scenario used for the purposes of this assessment assumes that one turbine is installed per day over a period of 200 days, with pile-driving occurring throughout the summer period. The installation of all turbines impact to the maximum extent within the SCI of 1,508.8 km^2.

18.128 Consequently, during any one day, a maximum area equivalent to 5.6% of the 'summer' area may be affected. Over the course of a season the average seasonal spatial overlap is also 5.6% (Table 72).

Table 72: Seasonal spatial overlap for Teesside B offshore wind farm within the SCI.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (%)
Single pile-driving					
'summer'	1,509	5.6	183	183	5.6
Concurrent pile-driving (worst-case)					
'summer'	2,080	7.7	200	102	4.3

18.129 In the event concurrent pile-driving occurs there is potential for a larger area of the SCI to be impacted over a shorter period of time. The estimated maximum area within the SCI that could be impacted is 2,080 km^2 (Figure 51). The scenario used for the purposes of this concurrent pile-driving assessment assumes that two turbines are installed per day over a period of 100 days, with pile-driving occurring throughout the summer period.

18.130 In the event that concurrent pile-driving occurs, the worst-case scenario is that during any one day a maximum area equivalent to 7.7% of the 'summer' area may be impacted. Over the course of a season the average seasonal spatial overlap is 4.3% (Table 72).

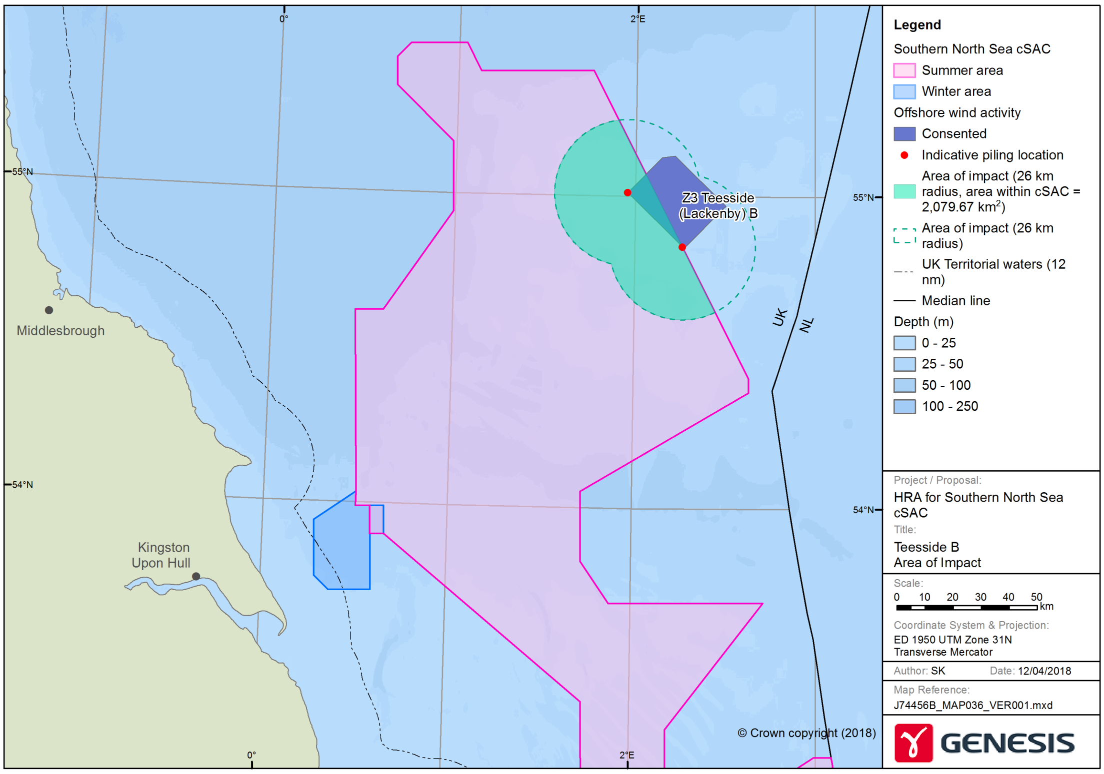


Figure 51: Maximum area of effective deterrence within the Southern North Sea SCI from concurrent pile-driving at Teesside A.

Physical impacts to the seabed

18.131 Teesside B offshore wind farm lies partially within the SCI with a total area of 127.4 km^2 of the wind farm lying within the SCI.

18.132 The estimated area of permanent physical impact on the seabed arising from the installation of 120 x 10 MW monopiled turbines is 0.681 km^2 (Table 59) and a further 0.111 km^2 of seabed may be impacted by the presence of associated infrastructure (Table 61). A total of area of seabed impacted by Teesside A is estimated to be 0.79 km^2. In addition to the physical presence of the turbine foundations and associated infrastructure, a further 2.0 km^2 of seabed may be lost due to cable protection (Table 62). Assuming that all cable protection occurs within the SCI the total area of habitat lost is estimated to be 2.9 km^2. This assumes that all impacts relating to the installation of the turbines and associated infrastructure are within the SCI. However, 87.4% of the wind farm area lies outwith the site and physical impacts resulting in a loss of habitat within this area will not affect the SCI. A worst-case scenario is that all impacts are within the SCI.

18.133 Seabed surveys undertaken by the developer indicate that the seabed habitat likely to be impacted is predominantly slightly gravelly sand, gravely sand or sandy gravel habitat types (Forewind 2014). This is a widespread habitat found across the whole of the SCI.

18.134 The area of the Southern North Sea SCI is 36,951 km^2 and the potential loss of 2.9 km^2 of habitat is 0.008% of the site. The loss of a relatively very small area of habitat that occurs widely within the SCI is not predicted to impact on harbour porpoise or their prey.

18.135 There is potential for temporary seabed disturbance caused by trenching and laying of cables within the wind farm area and the along the export cable route. It is estimated that a total area of 14.37 km^2 of seabed may be disturbed by trenching (Table 62). The impacts from cable trenching are recognised to be temporary as the seabed will overtime recover and there will be no loss of habitat.

Teesside B: Conclusions

18.136 It is concluded that, based on the results from the noise modelling and the use of the threshold approach, pile-driving during the construction of Teesside B offshore wind farm on its own will not have an adverse effect upon the integrity of the Southern North Sea SCI.

18.137 For all consented offshore wind farms there are conditions attached to the Marine Licence that require effective mitigation measures to be in place that reduce the risk of any harbour porpoise occurring within the range at which it is predicted the onset of PTS could occur. The mitigation measures to be used are included in each Project's MMMP, which requires consultation with the SNCB and approval from the MMO before construction can commence.

Consequently, it is predicted that no harbour porpoise will be impacted by PTS by noise arising from pile-driving during the construction of the Teesside B offshore wind farm

18.138 The estimated potential impact on no more than 0.3% of the North Sea Management Unit population from single pile-driving or 0.45% of the population from concurrent pile-driving is predicted to not cause an adverse effect on the favourable conservation status of the species nor the integrity of the site. The draft thresholds proposed by the SNCBs are not exceeded.

18.139 The potential loss of up to 0.008% of habitat that occurs widely across the SCI will not significantly impact the supporting habitats and processes or prey base upon which harbour porpoise depend and will therefore not cause an adverse effect to the integrity of the site on its own. However, there is potential for an in-combination impact with other plans or projects.

18.140 A pre-construction Marine Licence condition requiring a SIP will ensure that the wind farm parameters used in order to undertake this assessment will not be exceeded.

Impacts on Prey

18.141 Harbour porpoises are considered viable components of the site if they are able to survive and live successfully within it. In order to do so they must have suitable prey within the site. Harbour porpoise feed on a broad range of fish species including herring, cod, whiting and sandeels and impacts on these species from noise arising from the construction of offshore wind farms could impact the viability of the site for harbour porpoise.

18.142 Sound modelling undertaken for the purposes of this assessment indicate the potential impact from pile-driving on fish could cause injury or mortality to fish with swim bladders out to 537 m and for fish without swim bladder to a range of 181 m (Table 55).

18.143 Studies undertaken during pile-driving at offshore wind farms indicate that fish will show avoidance behaviour during piling activities, this includes changes in swimming speed and direction (Mueller-Blenkle *et al.* 2010). There are limited studies on the behavioural responses to fish from pile-driving noise and the range at which behavioural impacts may occur will depend on the species being affected and the location of the pile-driving. Studies undertaken during seismic surveys have reported localised and temporary changes in behaviour with fish swimming away from the area or into deeper water but fish populations returning to pre-survey levels shortly after the seismic has stopped (e.g. Peña *et al*. 2013, Slotte *et al*. 2004, Wardle *et al*. 2001).

18.144 Sandeels are an important prey item for harbour porpoise and are not considered to have sensitive hearing (Popper *et al.* 2014). Studies undertaken using airguns indicate that sandeels have distinct but weak reactions to seismic airguns with initial startle responses reducing in frequency with on-going noise, and no increased mortality detected (Hassel *et al.* 2004).

18.145 There are few studies that assess the potential impacts on eggs and larvae from pile-driving. Results from a study undertaken on common sole indicated that at cumulative sound exposure levels of 206 dB re 1 μPa^2 from pile-driving there were no significant differences in the mortality of larvae compared with the control groups (Bolle *et al*. 2012). Other studies have indicated that there is potential for an increase in mortality when larvae are exposed to an airgun sound source with peak sound pressure levels of 220-242 dB re 1 μPa^2, but only when within 5 m of the airgun (Popper *et al*. 2014).

18.146 Sound arising from pile-driving will have an effect on prey species for harbour porpoise. The level of impact is dependent on the level of the sound source and the species of fish. Published studies indicate that the impacts will be localised and temporary, with fish populations returning to background levels following cessation of the noise. Consequently, it is predicted that there will be no significant adverse effect on the harbour porpoise due to impacts on prey species.

Impacts on prey: Conclusions

18.147 It is concluded that, based on the results from the noise modelling that the impacts from noise on the prey of harbour porpoise will not have an adverse effect upon the integrity of the Southern North Sea SCI.

Sub-bottom profiler

18.148 There is no information as to when surveys using sub-bottom profilers will be undertaken within the SCI. However, it is predicted that they will be used during geophysical surveys undertaken at all offshore wind farms.

18.149 The results from the noise modelling indicate that the extent at which the onset of PTS is predicted to occur ranges from between 17 m and 23 m (Table 52). There is therefore a very low risk of any harbour porpoise being physically impacted by the use of sub-bottom profilers.

18.150 There is potential for disturbance of harbour porpoise to occur out to 2.5 km and impact an area of 18.3 km^2 (Table 53). The estimated number of harbour porpoise at risk of disturbance at each of the wind farms subject to this review is presented in Table 74. The results indicate that no more than 41 harbour porpoise may be disturbed by the use of a sub-bottom profiler at any wind farm, equivalent to no more than 0.01% of the North Sea Management Unit population

Table 73: Estimated number of harbour porpoises at risk of disturbance from the use of a sub-bottom profiler at each wind farm.

Wind farm	Harbour porpoise zonal density (ind./km^2)	Number of porpoise disturbed	Proportion of Management Unit population (%)
Hornsea Two	2.22	41	0.01
Creyke Beck A	0.71	13	0.004
Creyke Beck B	0.71	13	0.004
Teesside A	0.71	13	0.004
Teesside B	0.71	13	0.004

18.151 The duration of any geo-physical survey operating a sub-bottom profiler is unknown, but will vary depending on the requirements of the survey. The potential impacts from disturbance will be temporary with no disturbance occurring once the vessel operating the sub-bottom profiler moves from the location or the survey is completed.

18.152 Prior to undertaking any survey requiring the use of a sub-bottom profiler a Marine Licence is required from the MMO. As part of the Marine Licence, conditions may be attached obligating the developer to include mitigation measures to reduce the potential impacts arising from the sub-bottom profiler. Typically, these may include the use of a Marine Mammal Observer or Passive Acoustic Monitoring (PAM) to ensure no marine mammals are at risk of PTS. The exact conditions attached to each licence are made on a case-by-case basis.

Impacts from sub-bottom profiler noise: Conclusions

18.153 It is concluded that, based on the results from the noise modelling and the relatively very small proportion of the North Sea Management Unit population predicted to be temporarily disturbed, the impacts from noise arising from sub-bottom profilers at each of the wind farms will not have an adverse effect upon the integrity of the Southern North Sea SCI.

UXO Detonation

18.154 UXO clearance that could result in the detonation of ordnance is predicted to occur at most offshore wind farms located within, or adjacent to, the SCI. Neither the number of detonations required at each wind farm nor the size of the UXO are known, although estimates for the clearance of up to 60 items of UXO have been reported and detonations of UXO up to 1,000 kg NEQ have occurred in the Southern North Sea (EAOWL 2017, von Benda-Beckmann *et al.* 2015). A total of 36 detonations were undertaken at Race Bank Offshore Wind Farm with largest item being a ground mine with a NEQ of 698 kg (Ørsted 2015).

18.155 The results from the noise modelling indicate that the area of potential impact from PTS ranges from between 3.3 km for a 10 kg NEQ detonation and 15.1 km in the event a 1,000 kg

NEQ detonation is undertaken. (Table 54). Existing guidance suggests that disturbance behaviour is not predicted to occur from UXO clearance if undertaken over a short period of time (JNCC 2010b).

18.156 The estimated number of harbour porpoise at risk of blasting or UXO clearance across a range of explosive weights is presented in Table 74. The results indicate that the number of harbour porpoise at risk of being impacted varies considerably depending on the location of the wind farm and the weight of explosive charge.

Table 74: Estimated number of harbour porpoises at risk of PTS from UXO clearance at each wind farm.

Wind farms	Harbour porpoise zonal density (ind./km^2)	UXO NEQ (kg)						
		10	20	50	100	250	500	1,000
Hornsea Two	2.22	77	122	225	357	658	1,044	1,657
Creyke Beck A	0.71	25	39	72	114	210	334	530
Creyke Beck B	0.71	25	39	72	114	210	334	530
Teesside A	0.71	25	39	72	114	210	334	530
Teesside B	0.71	25	39	72	114	210	334	530

18.157 It is estimated that between 0.001 and 0.5% of the harbour porpoise Management Unit population may be at risk of the onset of PTS depending on the weight of the explosive and wind farm location.

18.158 Prior to undertaking any UXO clearance a Marine Licence is required from the MMO. As part of the Marine Licence, conditions are attached obligating the developer to include mitigation measures to reduce the potential impacts arising from the detonation of UXO. These include agreed mitigation identified within the Marine Mammal Mitigation Plan (MMMP). To date, when undertaking UXO detonations, mitigation measures have included the use of Marine Mammal Observers, Passive Acoustic Monitoring (PAM), ADDs and bubble curtains (e.g. MMO 2016b, 2016c). Consequently, to reduce the potential impacts on marine mammals from UXO detonation mitigation will be required when undertaking UXO detonation. Further consideration of mitigation is presented in Section 8. The level of mitigation required will be determined for each Marine Licence and will depend on the wind farm location, the size of the UXO to be detonated and the predicted level of impact.

18.159 The mitigation will reduce the predicted level of impact to levels below which there will be no adverse effect. Therefore, it is concluded that UXO detonation on its own will not cause an adverse effect on the integrity of the site on its own. However, there is potential for an in-combination impact with other plans or projects.

Impacts from UXO detonation: Conclusions

18.160 It is concluded that, based on the Marine Licence condition requiring suitable mitigation measures to reduce the risk of any harbour porpoise within range at which the onset of PTS is predicted to occur. The impacts from noise arising from UXO detonation will not have an adverse effect upon the integrity of the Southern North Sea SCI.

19 IN-COMBINATION ASSESSMENT

19.1 It is recognised for there to be many potential in-combination scenarios to arise between consented offshore wind farms and other activities undertaken within or adjacent to the SCI. It is not realistic, to assess all the potential in-combination scenarios that could theoretically occur [4]. For the purposes of this assessment realistic scenarios that may likely occur have been assessed based on currently available information. However, it is recognised that these may not be the theoretically worst-case scenarios but they do provide a broad range of possible in-combination assessments. Future activities that could cause a potentially greater level of effect than has been considered in this assessment would be subject to an assessment at the time.

In-combination noise impacts with other offshore wind farms

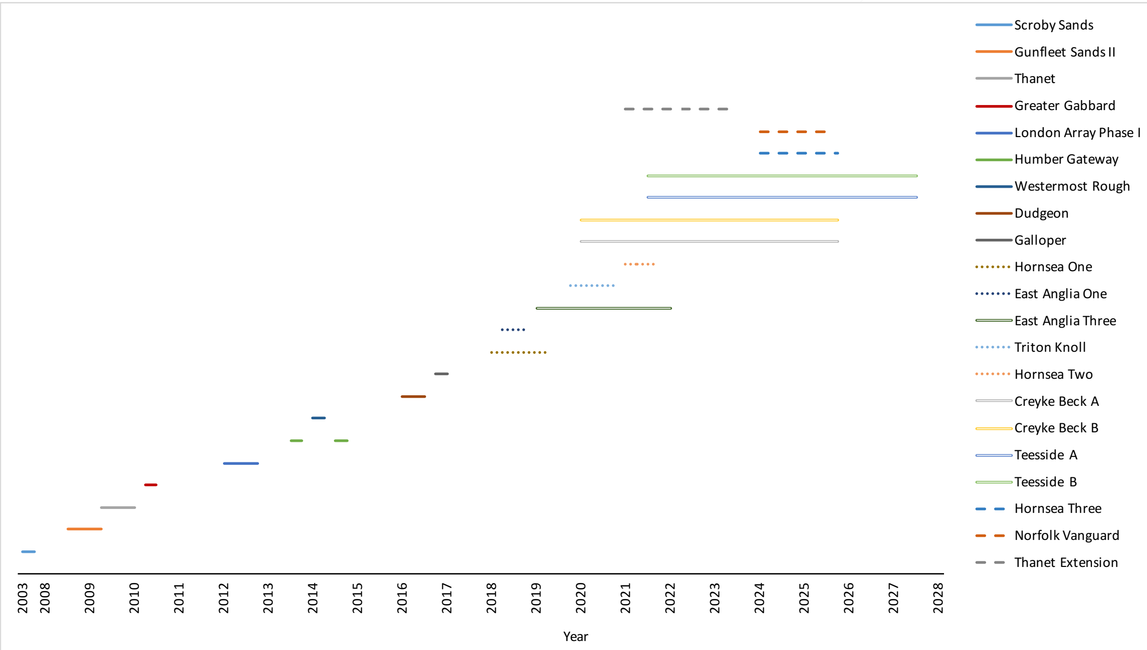
19.2 In-combination impacts across offshore wind farms have been identified as arising from construction pile-driving noise and the cumulative impacts on habitat. This section identifies the likely in-combination scenarios that could cause an adverse effect. Table 75 presents the wind farms within the SCI or 26 km of the boundary and their potential for an in-combination impact.

[4] For example, during Q3 and Q4 of 2021 there is a theoretical, but unrealistic, possibility that up to seven wind farms may be being constructed simultaneously (see Figure 52). In order to assess all possible construction scenarios that consider the no pile-driving, single pile-driving and concurrent pile-driving options at each of the sites, a minimum total of 343 assessments would need to be undertaken. This would increase further if more than one pile-driving location or more than one hammer energy was assessed for each wind farm.

Table 75: Wind farm projects to be considered in the in-combination impact assessment.

Tier	Project	In-combination	
		Construction Noise	Physical impact on habitat
1	Scroby Sands	No (construction completed)	Yes (within SCI)
1	Greater Gabbard	No (construction completed)	Yes (within SCI)
1	Thanet	No (construction completed)	Yes (within SCI)
1	Westermost Rough	No (construction completed)	No (outwith SCI)
1	Humber Gateway	No (construction completed)	No (outwith SCI)
1	Dudgeon	No (construction completed)	No (outwith SCI)
1	Gunfleet Sands II	No (construction completed)	No (outwith SCI)
1	London array Phase I	No (construction completed)	No (outwith SCI)
1	Belwind I	No (construction completed)	No (outwith SCI)
1	Galloper	No (construction completed)	Yes (within SCI)
2	Hornsea Project One	Yes (construction started)	Yes (within SCI)
2	Hornsea Two	Yes (construction not started)	Yes (within SCI)
2	East Anglia One	Yes (construction started)	Yes (within SCI)
2	Triton Knoll	Yes (construction not started)	No (outwith SCI)
3	Creyke Beck A	Yes (construction not started)	Yes (within SCI)
3	Creyke Beck B	Yes (construction not started)	Yes (within SCI)
3	Teesside A	Yes (construction not started)	Yes (within SCI)
3	Teesside B	Yes (construction not started)	Yes (within SCI)
3	East Anglia Three	Yes (previously assessed)	Yes (within SCI)
3	Mermaid	Yes (construction not started)	No (outwith SCI)
3	Borselle II	Yes (construction not started)	No (outwith SCI)
4	Hornsea Project Three	No (new application subject to future assessment)	No (new application subject to future assessment)
4	Norfolk Vanguard	No (new application subject to future assessment)	No (new application subject to future assessment)
4	Thanet Extension	No (new application subject to future assessment)	No (new application subject to future assessment)
5	Hornsea Project Four, Norfolk Vanguard West, East Anglia Norfolk Boreas, East Anglia One North, East Anglia Two, The Crown Estate Offshore wind extension project.	No (no application and no information)	No (no application and no information)

19.3 To identify realistic in-combination impacts for wind farms identified as having potential for an in-combination impact, the construction schedules for each of the relevant developments has been used (Figure 52). For Tier 1 developments that have completed construction there will be no in-combination construction noise impacts, provided there is no further build out. But there may be physical impacts within the SCI and there is a relatively high degree of confidence in the information available. For Tier 2 developments there can be a relatively high degree of confidence for when construction activities will start and be completed. For other developments that do not have a CfD there is a high degree of uncertainty as to when construction will commence or their physical impacts on the SCI. For Creyke Beck A and B and Teesside A and B it is unknown when pile-driving could occur and therefore it is assumed that it could occur over anytime within a six year period with the predicted start dates based on information provided by the developer and within the DCO.



Note: Solid line = Tier 1: Constructed
Dotted line = Tier 2: Consented and with a CfD
Open line = Tier 3: Consented without a CfD
Dashed line = Tier 4: Application submitted

Figure 52: Estimated pile-driving schedules for offshore wind farms within or adjacent to the Southern North Sea SCI.

19.4 Tier 1 projects (See Table 57) have completed construction and therefore, provided there is no further build out, there will be no in-combination impact relating to construction noise. If the wind farm lies within the SCI there could be an in-combination impact on habitats.

19.5 Tier 2 projects are either currently under construction or have been awarded a CfD and therefore there is a relatively high degree of confidence as to when construction make occur.

- The Hornsea Project One and East Anglia One wind farms are currently under construction. Both projects have been subject to Appropriate Assessments relating to the impacts on the qualifying features of the SCI and both assessments concluded that there would be no adverse effects alone or in-combination (MMO 2017a, BEIS 2018b); consequently, their consents are not subject to this review. For both projects construction is predicted to be completed in 2019 and therefore no in-combination impact is predicted to arise from pile-driving noise with other offshore wind farm projects that are subject to this consent review (Figure 52). However, there is potential for an in-combination impact on habitat within the SCI and their impacts on habitats within the SCI are included in the in-combination assessment.
- Hornsea Two has not started construction and has not been subject to HRA with respect to the SCI. There is potential for an in-combination impact with the potential for construction to occur at the same time as other offshore wind farms (Figure 52).
- Triton Knoll has not started construction but, following the submission of a non-material change, the project has been subject to an HRA with respect to this SCI (BEIS 2018c); consequently, the consent for this project is not subject to this review. However, the construction period for this wind farm may occur at the same time as other developments that are subject to this review and therefore there is potential for an in-combination impact to occur from construction noise. The wind farm lies outwith the SCI and there will be no impact on habitats within the site and therefore no in-combination impacts on habitats.

19.6 Tier 3 projects have received consent but have not been awarded a CfD and there is a high level of uncertainty as to when construction may occur. Construction periods are based on the DCO requirement of construction commencing within five years from the date of the Order.

- Creyke Beck A and B and Teesside A and B wind farms have not started construction and there is potential for an in-combination impact to occur.
- East Anglia Three has been subject to an Appropriate Assessment that included the potential impacts on the qualifying features of the SCI. The assessment concluded that there would be no adverse effect alone or in-combination (BEIS 2017a); consequently, the consent for East Anglia Three is not subject to this review. However, the construction period for this wind farm may occur at the same time as other developments, the consents for which are subject to this review and therefore there is potential for an in-combination impact from construction noise. The wind farm lies within the SCI and there is potential for in-combination impacts upon the habitat within the site.
- The Mermaid offshore wind farm lies within Belgian waters and outwith the SCI. The construction period for this wind farm is unknown and should construction occur before

2028 there is potential for an in-combination impact in the 'winter' area of the SCI (Appendix A). Construction will have to start before the end of 2020 for an in-combination impact to arise with Triton Knoll and 2022 for an in-combination impact with East Anglia Three. None of the consents for Triton Knoll, East Anglia Three or the Mermaid offshore wind farm are subject to this review. Consequently, no further assessment has been undertaken.

- The Borssele II offshore wind farm is combined with the Borselle I development that lies within Dutch waters and outwith the SCI (Appendix A). Construction for Borselle II is planned to commence in 2019 and be completed by 2020. There is potential for an in-combination impact in the 'winter' area of the SCI with Triton Knoll offshore wind farm and East Anglia Three. None of the consents for Triton Knoll, East Anglia Three or the Borssele II offshore wind farm are subject to this review. Consequently, no further assessment has been undertaken.

19.7 Tier 4 projects have either made an application or submitted preliminary information to the Planning Inspectorate. There is limited information on when construction could take place in the event that consent is given.

- Hornsea Project Three is a Tier 4 development and there is uncertainty as to when construction may occur, although the onshore construction may start in 2020 or 2021, with foundation installation anticipated to start four years later, i.e. in 2024 or 2025 (Ørsted 2018c). Prior to determination an Appropriate Assessment will be undertaken by the competent authority that will assess the potential impacts on the SCI for the project alone and in-combination and no assessment is required at this time.
- An application has been made for the Norfolk Vanguard offshore wind farm in July 2018. (Vattenfall 2018). The main installation of foundations is scheduled to commence in 2024 and continue over a single 20 month period or, if in two phases, over two eight month periods, with completion in 2028. Prior to determination an Appropriate Assessment will be undertaken by the competent authority that will assess the potential impacts on the SCI for the project alone and in-combination and no assessment is required at this time.
- An application for the construction of the Thanet Extension offshore wind farm was made in July 2018 (VWPL 2018). Offshore construction is planned to commence in 2021 and take up to 28 months (VWPL 2017). There is potential for an in-combination impact. Prior to determination an Appropriate Assessment will be undertaken by the competent authority that will assess the potential impacts on the SCI for the project alone and in-combination and no assessment is required at this time.

19.8 Tier 5 projects are plans or planned developments. However, there is little or no information available in order to undertake an in-combination assessment. It is recognised that future applications would be subject to assessments prior to any determination. No in-combination assessment is possible.

19.9 For the purposes of this assessment scenarios based on likely project schedules, a predicted limitation on the number of available suitable vessels and the worst-case EDR impacts have been assessed based on currently available information. Assumptions made when undertaking this in-combination assessment include:

- no-concurrent pile-driving within a wind farm in-combination with other projects,
- With one exception (presented as an example), no more than two projects may be constructing at any one time,
- All wind turbine locations impact over the maximum possible extent within the SCI,
- Pile-driving occurs over the maximum possible number of days within each season,
- Only one foundation is installed each day.

19.10 Table 76 presents the potential in-combination scenarios for pile-driving noise from the wind farms subject to this review and is based on the information currently available.

19.11 Three wind farms: Galloper, Greater Gabbard and Dudgeon have completed their construction and therefore will not cause an in-combination impact with respect to construction noise.

Table 76: Potential in-combination pile-driving scenarios for consented offshore wind farms subject to this review.

Wind Farms Subject to Review	Consented Wind Farms													
	Galloper	Greater Gabbard	Dudgeon	Hornsea Project One	Hornsea Two	East Anglia One	East Anglia Three	Triton Knoll	Creyke Beck A	Creyke Beck B	Teesside A	Teesside B	Mermaid	Borssele II
Galloper	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Greater Gabbard	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dudgeon	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Hornsea Two	X	X	X	X	X	**Y**	**Y**	X	**Y**	**Y**	**Y**	**Y**	X	X
Creyke Beck A	X	X	X	X	**Y**	**Y**	**Y**	**Y**	X	**Y**	**Y**	**Y**	X	X
Creyke Beck B	X	X	X	X	**Y**	**Y**	**Y**	**Y**	**Y**	X	**Y**	**Y**	X	X
Teesside A	X	X	X	X	**Y**	**Y**	**Y**	X	**Y**	**Y**	X	**Y**	X	X
Teesside B	X	X	X	X	**Y**	**Y**	**Y**	X	**Y**	**Y**	**Y**	X	X	X

19.12 Based on the predicted construction schedules of each of the wind farms the following potential in-combination impacts with respect to construction noise have been assessed.

- Hornsea Two and Creyke Beck A,
- Hornsea Two and East Anglia Three,
- Creyke Beck A and Triton Knoll,
- Creyke Beck A and East Anglia Three,
- Creyke Beck A and Creyke Beck B,
- Teesside B and Creyke Beck A,
- Teesside A and Teesside B,
- Teesside B and East Anglia Three,
- Creyke Beck A, Creyke Beck B and Teesside B.

19.13 Not all potential in-combination scenarios have been assessed using noise modelling or EDR However, in-combination assessments have been undertaken for each of the developments subject to this review. The scenarios were selected on a number of criteria including their location within the SCI, their relative proximity to one another and potential for construction occurring at the same time based on reported project schedules. The scenarios selected aim to provide a representative sample of the potential in-combination impacts.

In-combination Impacts Pile-driving Noise Modelling Results

19.14 Based on the modelling results undertaken for each wind farm on its own, it is clear that there will be no overlap in the areas within which the onset of PTS is predicted to occur (Section 13). Consequently, the potential in-combination effects relating to PTS are simply the combined totals for each of the individual wind farms.

19.15 The area of potential displacement or disturbance that is predicted to occur for each of the individual wind farms has potential to overlap. Consequently, noise modelling has been undertaken for each of the in-combination pile-driving scenarios. The results from the modelling help inform the possible extent of displacement or disturbance impacts on harbour porpoise.

19.16 The mean density of harbour porpoise varies across wind farms (Table 6). In order to estimate the number of harbour porpoise at risk of displacement from in-combination impacts an average of the combined densities obtained from the relevant wind farm zones has been used, i.e. 2.22 ind./km^2 for all wind farms in the Hornsea zone, 0.71 ind./km^2 for all wind farms in the Dogger Bank zone, 0.11 ind./km^2 for Triton Knoll and 0.29 ind./km^2 for East Anglia Three. The use of a maximum density across the whole SCI would be unrealistic as there are considerable differences in the densities reported at each wind farm site. A dose response curve has then been used to estimate the total number of harbour porpoise at risk of displacement.

19.17 Table 77 presents the estimated areas of disturbance for each of the modelled in-combination scenarios and the number of harbour porpoise that may be displaced. Further information on the modelling undertaken can be found in the *Technical Noise Modelling Report* (Genesis 2018).

Table 77: Areas within which displacement or disturbance is predicted to occur from in-combination pile-driving (unweighted SEL).

Wind farm in-combination	Averaged harbour porpoise density (ind./km^2)	Area (km^2)	Estimated no. of porpoises displaced	Area overlapping SCI (km^2)	Estimated no. of porpoises displaced in SCI
Hornsea Two and Creyke Beck A	1.46	3,585	1,825	3,354	1,735
Hornsea Two and East Anglia Three	1.25	5,246	2,261	5,015	2,184
Creyke Beck A and Triton Knoll	0.41	1,672	265	791	121
Creyke Beck A and East Anglia Three	0.50	3,243	575	3,243	575
Creyke Beck A and Creyke Beck B	0.71	2,289	586	2,289	586
Creyke Beck A and Teesside B	0.71	2,404	627	1,838	508
Teesside B and East Anglia Three	0.50	4,294	752	3,728	668
Teesside A and Teesside B	0.71	3,417	876	1,277	342
Creyke Beck A and B and Teesside B	0.71	3,436	914	2,871	796

Hammer energies: Hornsea Two = 3,000 kJ, Triton Knoll = 4,000 kJ, Creyke Beck A and B = 3,000 kJ, Teesside A and B = 5,500 kJ, East Anglia Three 3,000 kJ.

In-combination Offshore Wind Farm Pile-driving

19.18 The following section assesses the potential in-combination impacts arising from pile-driving noise for nine potential in-combination scenarios.

Hornsea Two and Creyke Beck A

19.19 The Hornsea Two offshore wind farm lies partially within the SCI with 34% of the wind farm area lying outwith the SCI. Creyke Beck A offshore wind farm lies wholly within the SCI. There are no confirmed construction dates for either development and final details on the timing and duration of pile-driving are not available. Based on currently available information there is potential for pile-driving to occur at both sites during 2021 (Figure 52). Results from the noise modelling indicate that there will be no overlap in the areas within which the onset of PTS is predicted to occur. However, there is potential for the areas across which displacement is predicted to occur to overlap (Figure 53).

Physical Injury

19.20 The estimated number of harbour porpoise at risk of the onset of PTS from Hornsea Two is between 6 and 18 individuals (Para. 18.35) and for Creyke Beck A is between 4 and 9 (Para. 18.59). A combined total of between 10 and 27 harbour porpoise may be at risk of PTS in the event that Hornsea Two and Creyke Beck A both undertake pile-driving.

19.21 The North Sea Management Unit population is estimated to be 333,808 individuals and therefore up to 0.008% of the North Sea Management Unit population may be at risk of the onset of PTS.

Displacement

19.22 Displacement is predicted to occur over an area of up to 5,426 km^2. Based on results from the dose response curve used and an estimated averaged density of 1.46 ind./km^2, the estimated number of harbour porpoise predicted to be displaced is 1,825 individuals (Table 77). An estimated 0.55% of the North Sea Management Unit population may be impacted.

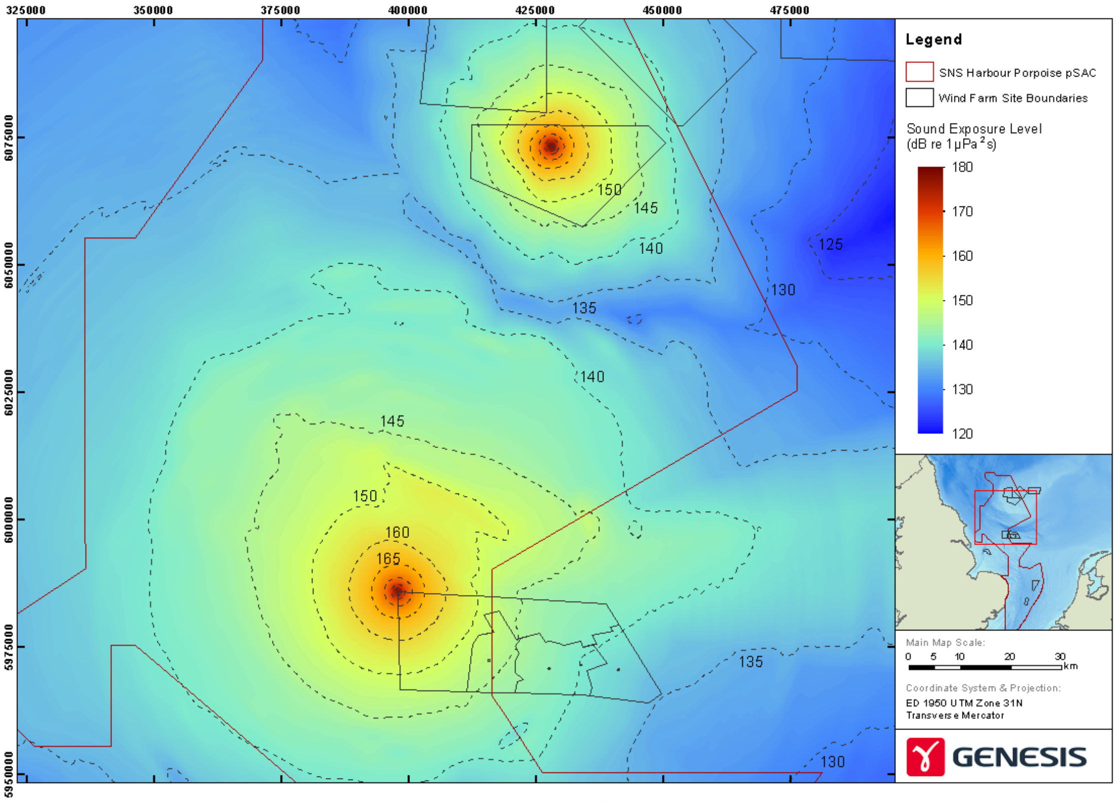


Figure 53: Predicted area of in-combination noise impacts from pile-driving at Hornsea Two and Creyke Beck A offshore wind farms.

Effective Deterrent Radius

19.23 The combined EDR for Hornsea Two and Creyke Beck A could potentially impact an area of 4,100 km^2. This is based on pile-driving occurring at two locations within the SCI impacting over the greatest possible area (Figure 54).

19.24 As a worst-case, noise from in-combination pile-driving at Hornsea Two and Creyke Beck A could cause displacement of harbour porpoise over 11.1% of the SCI as a whole and 15.2% of the 'summer' area. There will be no impacts on the 'winter' area.

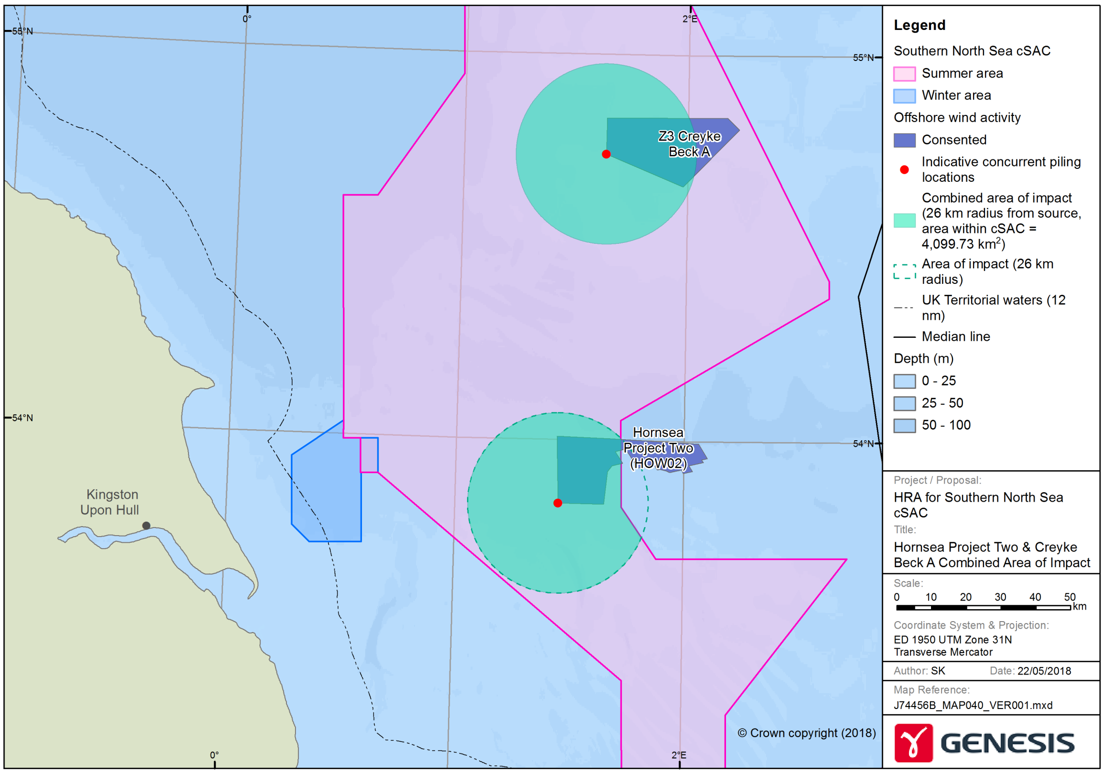


Figure 54: Maximum area of effective deterrence within the Southern North Sea SCI from in-combination pile-driving at Hornsea Two and Creyke Beck A.

19.25 A number of potential build out scenarios are possible for Hornsea Two. The consent was for the installation of 300 turbines but following the award of a CfD the maximum worst-case scenario would be 231 turbines. The most likely scenario is for 177 turbines to be installed over a nine month period between February and October (Ørsted 2017b). Assuming that one turbine foundation is installed per day and that all pile-driving occurs within one season it is theoretically possible that over the 183 day summer period pile-driving could occur between 97% and 100% of the time.

19.26 The consented maximum number of turbines for Creyke Beck A is 200 and therefore pile-driving could occur throughout the 183 day summer period.

19.27 The worst-case scenarios used for the purposes of this in-combination assessment assumes that in-combination impacts from pile-driving occur over a period of either 177 days or throughout the 183 days of the summer period. It is assumed that the maximum area of potential impact within the SCI occurs at each turbine location and that there is a two day recovery period following cessation of pile-driving during which time harbour porpoise are absent from the area. Over the course of a season the average seasonal spatial overlap is between 14.9% and 15.2% (Table 78).

Table 78: Worst-case in-combination seasonal spatial overlap for Hornsea Two and Creyke Beck A offshore wind farms within the SCI.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
In-combination pile-driving (consented)					
'summer'	4,100	15.2	300	183	15.2
In-combination pile-driving (Planned)					
'summer'	4,100	15.2	177	179	14.9

19.28 The results from the assessment indicate that the area of disturbance within the SCI across one day would not exceed the draft daily threshold of 20%. There is potential for the draft seasonal threshold of 10% to be exceeded in the event that Hornsea Two and Creyke Beck A undertake pile-driving over the same season. This is based on an unrealistic worst-case scenario that the same level of impact within the SCI will arise from all pile-driving locations within the wind farm areas; this will not occur. The installation of piles outwith the SCI or closer to the boundary will decrease the impacts within the SCI and reduce the spatial overlap.

19.29 A total of 34% of Hornsea Two wind farm area lies outwith the SCI and when pile-driving occurs at the eastern boundary of the wind farm site an area of 83 km^2 within the SCI may be impacted. Turbines at locations furthest away from the SCI will impact 0.3% of the 'summer' area. Similarly, turbines installed along the eastern edge of the Creyke Beck A wind farm site will impact an area of 1,246.5 km^2 within the SCI, equivalent to 4.6% of the 'summer' area. The best-case scenario, i.e. the lowest level of in-combination impact indicates that the seasonal spatial overlap does not exceed 4.9% (Table 79).

Table 79: Estimated minimum in-combination seasonal spatial overlap for Hornsea Two and Creyke Beck A offshore wind farms.

SCI area	Minimum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
In-combination pile-driving (consented)					
'summer'	1,330	4.9	300	183	4.9
In-combination pile-driving (Planned)					
'summer'	1,330	4.9	177	179	4.8

19.30 It is not known where the turbines within the wind farm areas will be located and therefore further detailed analysis cannot be undertaken. However, there is high degree of certainty that over the course of the season the seasonal spatial overlap will be significantly lower than the worst-case scenario suggests.

Hornsea Two and Creyke Beck A In-combination: Conclusions

19.31 It is concluded that based on the results from the noise modelling and the use of the threshold approach, pile-driving during the construction of Hornsea Two offshore wind farm in-combination with Creyke Beck A will not have an adverse effect upon the integrity of the Southern North Sea SCI.

19.32 For all consented offshore wind farms there are conditions attached to the Marine Licence that require effective mitigation measures to be in place that reduce the risk of any harbour porpoise occurring within the range at which it is predicted the onset of PTS could occur. The mitigation measures to be used are included in each Project's MMMP, which requires consultation with the SNCB and approval from the MMO before construction can commence. Consequently, it is predicted that no harbour porpoise will be impacted by PTS by noise arising from in-combination pile-driving during the construction of the Hornsea Two and Creyke Beck A offshore wind farms.

19.33 The estimated potential displacement of no more 0.55% of the North Sea Management Unit population over the construction periods is predicted to not cause an adverse effect on the favourable conservation status of the species nor the integrity of the site.

19.34 A pre-construction licence condition requiring a SIP will ensure that the wind farm parameters used in order to undertake this assessment will not be exceeded. Management of the spatio-temporal impacts developed and secured in a SIP will further ensure that draft thresholds are not exceeded.

Hornsea Two and East Anglia Three

19.35 The Hornsea Two offshore wind farm lies partially within the SCI with 66% of the wind farm area within the SCI. East Anglia Three offshore wind farm lies wholly within the SCI. There are no confirmed construction dates for either development and final details on the timing and duration of pile-driving are not available. However, there is potential for pile-driving to occur at both sites during 2021 (Figure 52). Results from the noise modelling indicate that there will be no overlap in the areas within which the onset of PTS or displacement is predicted to occur.

Physical Injury

19.36 The estimated number of harbour porpoise at risk of the onset of PTS from Hornsea Two is between 6 and 18 individuals and for East Anglia Three is between <1 and 2 individuals (Appendix B). A combined total of between 6 and 20 harbour porpoise may be at risk of PTS in the event that Hornsea Two and East Anglia Three both undertake pile-driving. Up to 0.005% of the North Sea Management Unit population may be at risk of the onset of PTS.

Displacement

19.37 Displacement is predicted to occur over an area of up to 5,246 km^2. Based on an averaged density of 1.25 ind./km^2, the estimated number of harbour porpoise predicted to be displaced is 2,261 individuals (Table 77). An estimated 0.68% of the North Sea Management Unit population may be impacted by the in-combination impacts.

Effective Deterrent Radius

19.38 The combined EDR for Hornsea Two and East Anglia Three could potentially impact an area of 4,892 km^2. This is based on pile-driving occurring at two locations within the SCI (Figure 55). Within the 'summer' area the estimated impacted area is 4,090 km^2.

19.39 As a worst-case, noise from in-combination pile-driving at Hornsea Two and East Anglia Three could cause displacement of harbour porpoise over 13.2% of the SCI as a whole and 15.1% of the 'summer' area. There will be no in-combination impacts on the 'winter' area.

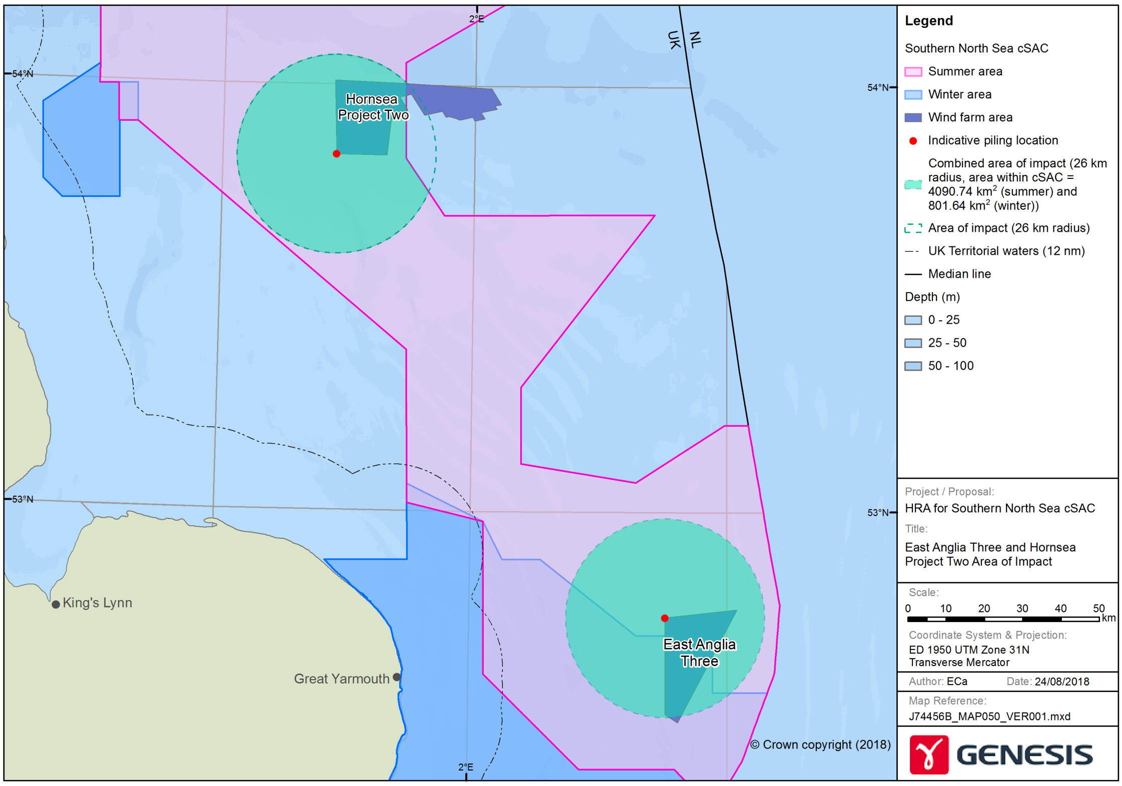


Figure 55: Maximum area of effective deterrence within the Southern North Sea SCI from in-combination pile-driving at Hornsea Two and East Anglia Three.

19.40 The most likely build-out scenario for Hornsea Two is for 177 turbines to be installed over a nine month period between February and October (Ørsted 2017b). It is therefore possible that over the 183 day summer period pile-driving could occur for 97% of the time.

19.41 The consented maximum number of turbines for East Anglia Three is 172, which may be built over two phases or as a single phase. Therefore, pile-driving could occur over 94% of the summer period. This is a worst-case scenario as it is unlikely that all the pile-driving will occur over the course of one season and therefore the proportion of time pile-driving occurs during each season will be lower.

19.42 The worst-case consented scenario used for the purposes of this in-combination assessment assumes that in-combination impacts from pile-driving occur over a period of the duration of the summer period and therefore the average seasonal spatial overlap will be 15.1%. Based on the realistic planned scenario of 172 turbines impacting over 174 days the average seasonal spatial overlap may be up to 14.3% (Table 80).

Table 80: Worst-case in-combination seasonal spatial overlap for Hornsea Two and East Anglia Three offshore wind farms within the SCI.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
In-combination pile-driving (Worst-case consented)					
'summer'	4.090	15.1	300	183	15.1
In-combination pile-driving (Planned)					
'summer'	4.090	15.1	172	174	14.3

19.43 The results from the assessment indicate that the area of disturbance on harbour porpoise within the SCI across one day would not exceed the draft daily threshold of 20%. There is potential for the seasonal threshold of 10% to be exceeded in the event that Hornsea Two and East Anglia Three undertake pile-driving over the same season. This is based on an unrealistic worst-case scenario that the same level of impact within the SCI will arise from all pile-driving locations within the wind farm areas. This will not occur as the installation of piles outwith the SCI or closer to the boundary will decrease the impacts within the SCI and reduce the spatial overlap.

19.44 A total of 34% of Hornsea Two wind farm area lies outwith the SCI and the area of the SCI impacted by pile-driving foundations on the eastern edge of the wind farm site is 83.5 km^2; which is 0.3% of the 'summer' area. Similarly, the installation of turbines to the south or east of East Anglia Three wind farm site could reduce the area impacted to an area of 1,538 km^2 within the 'summer' area. The best-case scenario, i.e. the lowest level of in-combination impact indicates that the seasonal spatial overlap would not exceed 9.0% (Table 81).

Table 81: Estimated minimum in-combination seasonal spatial overlap for Hornsea Two and East Anglia Three offshore wind farms.

SCI area	Minimum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
In-combination pile-driving (consented)					
'summer'	1,621.5	9.5	300	183	9.5
In-combination pile-driving (planned)					
'summer'	1,621.5	9.5	172	174	9.0

19.45 It is not known where the turbines within the wind farm areas will be located and therefore further detailed analysis cannot be undertaken. However, over the course of the season, the spatial overlap will be significantly lower than the worst-case scenario suggests. Management of the spatio-temporal impacts developed and secured in a site integrity plan will ensure that draft thresholds are not exceeded.

Hornsea Two and East Anglia Three In-combination: Conclusions

19.46 It is concluded that based on the results from the noise modelling and the use of the threshold approach, pile-driving during the construction of Hornsea Two offshore wind farm in-combination with East Anglia Three will not have an adverse effect upon the integrity of the Southern North Sea SCI.

19.47 For all consented offshore wind farms there are conditions attached to the Marine Licence that require effective mitigation measures to be in place that reduce the risk of any harbour porpoise occurring within the range at which it is predicted the onset of PTS could occur. The mitigation measures to be used are included in each Project's MMMP, which requires consultation with the SNCB and approval from the MMO before construction can commence. Consequently, it is predicted that no harbour porpoise will be impacted by PTS by noise arising from in-combination pile-driving during the construction of the Hornsea Two and East Anglia Three offshore wind farms.

19.48 The estimated potential displacement of no more than 0.68% of the North Sea Management Unit population over the construction periods is predicted to not cause an adverse effect on the favourable conservation status of the species nor the integrity of the site.

19.49 A pre-construction licence condition requiring a SIP will ensure that the wind farm parameters used in order to undertake this assessment will not be exceeded. Management of the spatio-temporal impacts developed and secured in a SIP will further ensure that draft thresholds are not exceeded.

Creyke Beck A and Triton Knoll

19.50 The Creyke Beck A offshore wind farm lies wholly within the SCI and the Triton Knoll offshore wind farm lies outwith the SCI. Construction at Triton Knoll is planned to start in Q4 2019 and continue to Q4 2020 and there is potential for an in-combination impact with Creyke Beck A. However, Creyke Beck A does not have a CfD and therefore there is less certainty as to when it may be developed. It is considered highly improbable that simultaneous construction across the two wind farms will occur.

Physical Injury

19.51 The estimated number of harbour porpoise at risk of the onset of PTS from Creyke Beck A is between 4 and 9 individuals and at Triton Knoll it is estimated to be between one and two individuals (Appendix C). Therefore, a combined total of between 5 and 11 harbour porpoise may be at risk of PTS in the event that Creyke Beck A and Triton Knoll both undertake pile-driving simultaneously. It is therefore estimated that up to 0.003% of the North Sea Management Unit population may be at risk of the onset of PTS.

Displacement

19.52 Displacement is predicted to occur over an area of up to 1,672 km^2 (Table 77). Based on a density of 0.41 ind./km^2 across the area impacted, the number of harbour porpoise predicted to be displaced is 265 individuals (Table 77). An estimated 0.08% of the North Sea Management Unit population may be impacted.

Effective Deterrent Radius

19.53 The combined EDR for Creyke Beck A and Triton Knoll could potentially impact an area of 2,172 km^2 within the SCI. (Figure 56).

19.54 As a worst-case, noise from in-combination pile-driving could cause displacement of harbour porpoise over 5.9% of the SCI as a whole and 8.0% of the 'summer' area. There will be no in-combination impacts on the 'winter' area.

19.55 The consented maximum number of turbines for Creyke Beck A is 200 and based on the consented project design, up to 49 wind turbines could be installed at Triton Knoll that are within the range at which the EDR overlaps the 'summer' area of the SCI (TKOWFL 2018). Therefore, in-combination pile-driving could occur over 49 days during the summer period. Consequently, over the course of a season the average seasonal spatial overlap is 2.2% (Table 82).

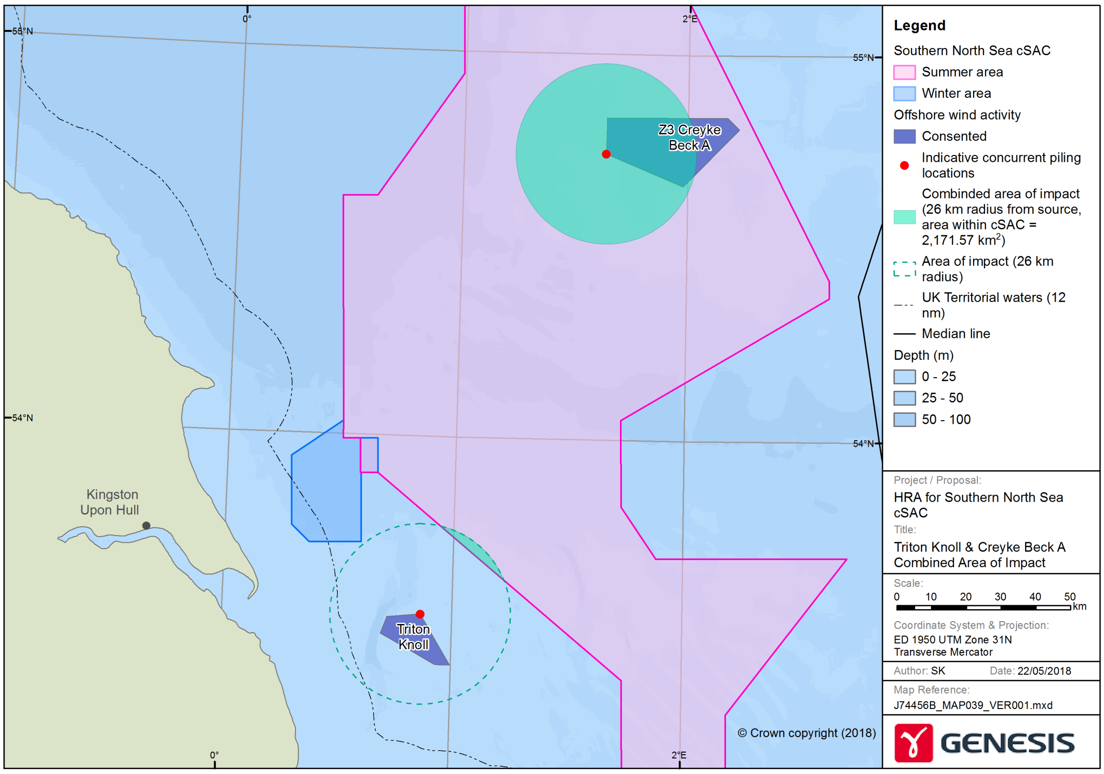


Figure 56: Maximum area of effective deterrence within the Southern North Sea SCI from in-combination pile-driving at Triton Knoll and Creyke Beck A.

Table 82: In-combination seasonal spatial overlap for Creyke Beck A and Triton Knoll offshore wind farms.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
In-combination pile-driving					
'summer'	2,172	8.0	49	51	2.2

19.56 The results from the assessment indicate that the area of in-combination disturbance on harbour porpoise within the SCI would not exceed the daily or seasonal draft thresholds.

Creyke Beck A and Triton Knoll In-combination: Conclusions.

19.57 It is concluded that based on the results from the noise modelling and the use of the threshold approach, pile-driving during the construction of Creyke Beck A offshore wind farm in-combination with Triton Knoll will not have an adverse effect upon the integrity of the Southern North Sea SCI.

19.58 For all consented offshore wind farms there are conditions attached to the Marine Licence that require effective mitigation measures to be in place that reduce the risk of any harbour porpoise occurring within the range at which it is predicted the onset of PTS could occur. The mitigation measures to be used are included in each Project's MMMP, which requires consultation with the SNCB and approval from the MMO before construction can commence. Consequently, it is predicted that no harbour porpoise will be impacted by PTS by noise arising from in-combination pile-driving during the construction of the Creyke Beck A and Triton Knoll offshore wind farms.

19.59 The estimated potential displacement of no more than 0.08% of the North Sea Management Unit population over the construction periods is predicted to not cause an adverse effect on the favourable conservation status of the species nor the integrity of the site.

19.60 A pre-construction licence condition requiring a SIP will ensure that the wind farm parameters used in order to undertake this assessment will not be exceeded. Management of the spatio-temporal impacts developed and secured in a SIP will further ensure that draft thresholds are not exceeded.

Creyke Beck A and East Anglia Three

19.61 The Creyke Beck A and East Anglia Three wind farms lie within the SCI. They are both Tier 3 developments and there are no confirmed construction dates for either development. Finalised details on the timing and duration of pile-driving are not available. However, based on current information there is potential for pile-driving to occur at both sites between 2020 and 2022 (Figure 64).

Physical injury

19.62 The estimated number of harbour porpoise at risk of the onset of PTS from Creyke Beck A is between is between 4 and 9 individuals and between <1 and 2 individuals at East Anglia Three. In the event that both Creyke Beck A and East Anglia Three undertake pile-driving an estimated total of between 4 and 10 harbour porpoise may be at risk of PTS. It is estimated that up to 0.003% of the North Sea Management Unit population may be at risk of the onset of PTS.

Displacement

19.63 Displacement is predicted to occur over an area of up to 3,243 km^2 (Table 77). Based on an averaged density of 0.50 ind./km^2, the estimated number of harbour porpoise predicted to be displaced is 575 individuals, which is 0.17% of the North Sea Management Unit population.

Effective Deterrent Radius

19.64 The combined EDR for Creyke Beck A and East Anglia Three could potentially impact an area of 4,247 km^2 within the SCI, all of which could occur within the 'summer' area and 801.6 km^2 is within the 'winter' area (Figure 57).

19.65 As a worst-case, noise from in-combination pile-driving at Creyke Beck A and East Anglia Three could cause displacement of harbour porpoise over 11.5% of the SCI as a whole and 15.7% of the 'summer' area. There will be no in-combination impacts on the 'winter' area.

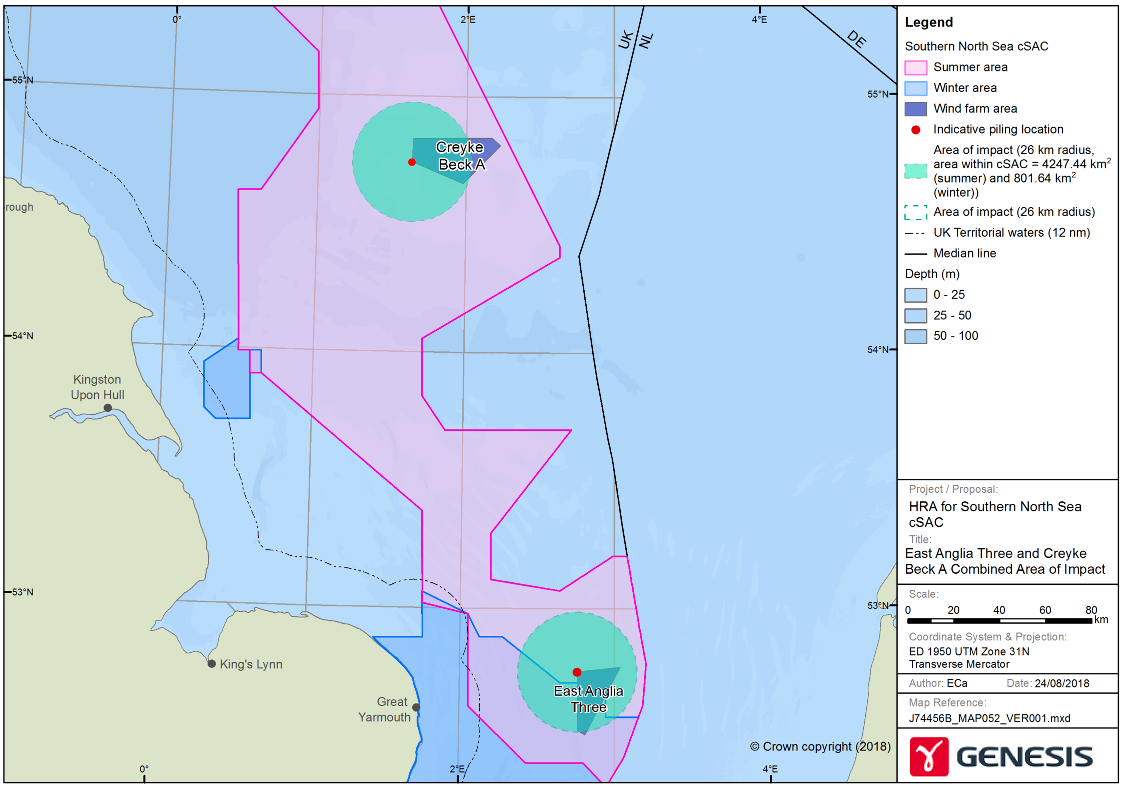


Figure 57: Maximum area of effective deterrence within the Southern North Sea SCI from in-combination pile-driving at Creyke Beck A and East Anglia Three.

19.66 Based on the consented project design, up to 200 wind turbines will be installed within the 'summer' area of the SCI at Creyke Beck A and 172 at East Anglia Three.

19.67 The worst-case scenarios used for the purposes of this in-combination assessment assumes that one turbine is installed per day at each wind farm location and that the maximum area of potential impact occurs at each turbine location and all impacts occur across one season. The maximum period of in-combination impacts during the summer period is therefore 172 days, plus a two day recovery period following cessation of pile-driving during which time harbour porpoise may be absent within 26 km of the pile-driving location. Over the course of a season the seasonal spatial overlap is 14.9% (Table 83).

Table 83: In-combination seasonal spatial overlap for Creyke Beck A and East Anglia Three offshore wind farms within the SCI.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
In-combination pile-driving					
'summer'	4,247	15.7	172	174	14.9

19.68 The results from the assessment indicate that the area of disturbance on harbour porpoise within the SCI across one day would not exceed the draft daily thresholds but could exceed the seasonal thresholds.

19.69 The assessment is based on an unrealistic worst-case scenario that all the pile-driving will cause the same level of impact within the SCI, this will not occur. The installation of piles closer to the boundary will decrease the area impacted within the SCI and reduce the seasonal spatial overlap.

19.70 Pile-driving foundations on the eastern edge of the Creyke Beck A reduces the area within the SCI impacted to 1,247 km^2 and similarly, the installation of turbines to the south or east of East Anglia Three wind farm site will reduce the area impacted within the SCI to 1,538 km^2. The potentially best-case in-combination impact is estimated to impact over 10.3% of the 'summer' area during any one day and 9.8% across the season (Table 84).

Table 84: Estimated minimum in-combination seasonal spatial overlap for Creyke Beck A and East Anglia Three offshore wind farms.

SCI area	Minimum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
In-combination pile-driving (consented)					
'summer'	2,785	10.3	172	174	9.8

19.71 There is still uncertainty over the number of turbines that may be installed but, based on the experiences from other projects the eventual number of turbines installed at either of the wind farms will be lower than the number consented and this would reduce the number of days during which pile-driving is undertaken. It is also considered highly unlikely that all turbine foundations will be installed during the summer period with activities undertaken during the winter period considered to not have an adverse effect on porpoises in the 'summer' area.

19.72 It is not known when or where the turbines within the wind farm areas will be located and therefore further detailed analysis is not possible. However, over the course of the season, the spatial overlap will be significantly lower than the worst-case scenario suggests. Management of the spatio-temporal impacts developed and secured in a site integrity plan will ensure that draft thresholds are not exceeded.

Creyke Beck A and East Anglia Three In-combination: Conclusions

19.73 It is concluded that based on the results from the noise modelling and the use of the threshold approach, pile-driving during the construction of Creyke Beck A offshore wind farm in-combination with East Anglia Three will not have an adverse effect upon the integrity of the Southern North Sea SCI.

19.74 For all consented offshore wind farms there are conditions attached to the Marine Licence that require effective mitigation measures to be in place that reduce the risk of any harbour porpoise occurring within the range at which it is predicted the onset of PTS could occur. The mitigation measures to be used are included in each Project's MMMP, which requires consultation with the SNCB and approval from the MMO before construction can commence. Consequently, it is predicted that no harbour porpoise will be impacted by PTS by noise arising from in-combination pile-driving during the construction of the Creyke Beck A and East Anglia Three offshore wind farms.

19.75 The estimated potential displacement of no more than 0.17% of the North Sea Management Unit population over the construction period is predicted to not cause an adverse effect on the favourable conservation status of the species nor the integrity of the site.

19.76 A pre-construction licence condition requiring a SIP will ensure that the wind farm parameters used in order to undertake this assessment will not be exceeded. Management of the spatio-temporal impacts developed and secured in a SIP will further ensure that draft thresholds are not exceeded.

Creyke Beck A and Creyke Beck B

19.77 The Creyke Beck A and Creyke Beck B wind farms lie within the SCI. They are both Tier 3 developments and there are no confirmed construction dates for either development and final details on the timing and duration of pile-driving are not available. However, there is potential for pile-driving to occur at both sites between 2020 and 2025 (Figure 52).

Physical injury

19.78 The estimated number of harbour porpoise at risk of the onset of PTS from Creyke Beck A is between 4 and 9 individuals and between 3 and 10 at Creyke Beck B (Para. 18.79). In the event that both wind farms undertake pile-driving an estimated total of between 7 and 19 harbour porpoise may be at risk of PTS, which is equivalent to to 0.005% of the North Sea Management Unit population.

Displacement

19.79 Displacement is predicted to occur over an area of up to 2,288 km^2 (Figure 58). Based on an averaged density of 0.71 ind./km^2, the estimated number of harbour porpoise predicted to be displaced is 586 individuals (Table 77). An estimated 0.17% of the North Sea Management Unit population may be impacted.

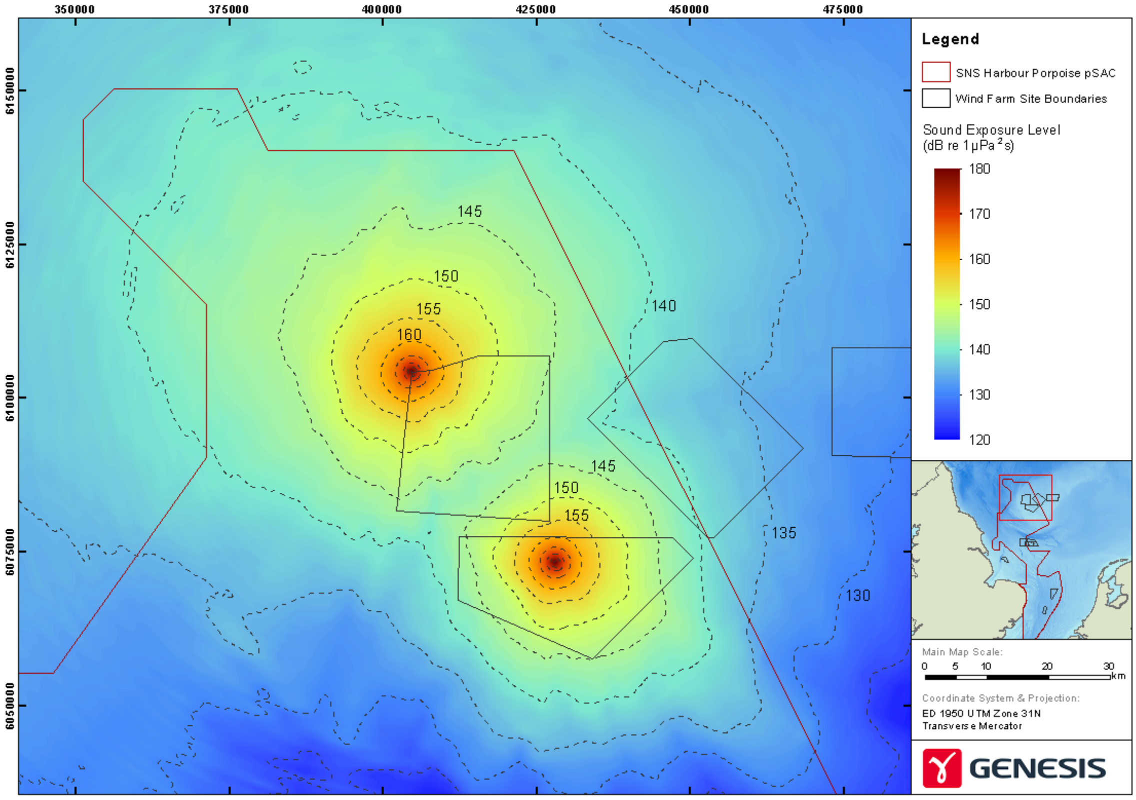


Figure 58: Predicted area of in-combination noise impacts from pile-driving at Creyke Beck A and Creyke Beck B offshore wind farms.

Effective Deterrent Radius

19.80 The combined EDR for Creyke Beck A and Creyke Beck B could potentially impact an area of up to 4,247 km^2 within the SCI (Figure 59).

19.81 As a worst-case, noise from in-combination pile-driving at Creyke Beck A and Creyke Beck B could cause displacement of harbour porpoise over 11.5% of the SCI as a whole and 15.7% of the 'summer' area. There will be no in-combination impacts on the 'winter' area.

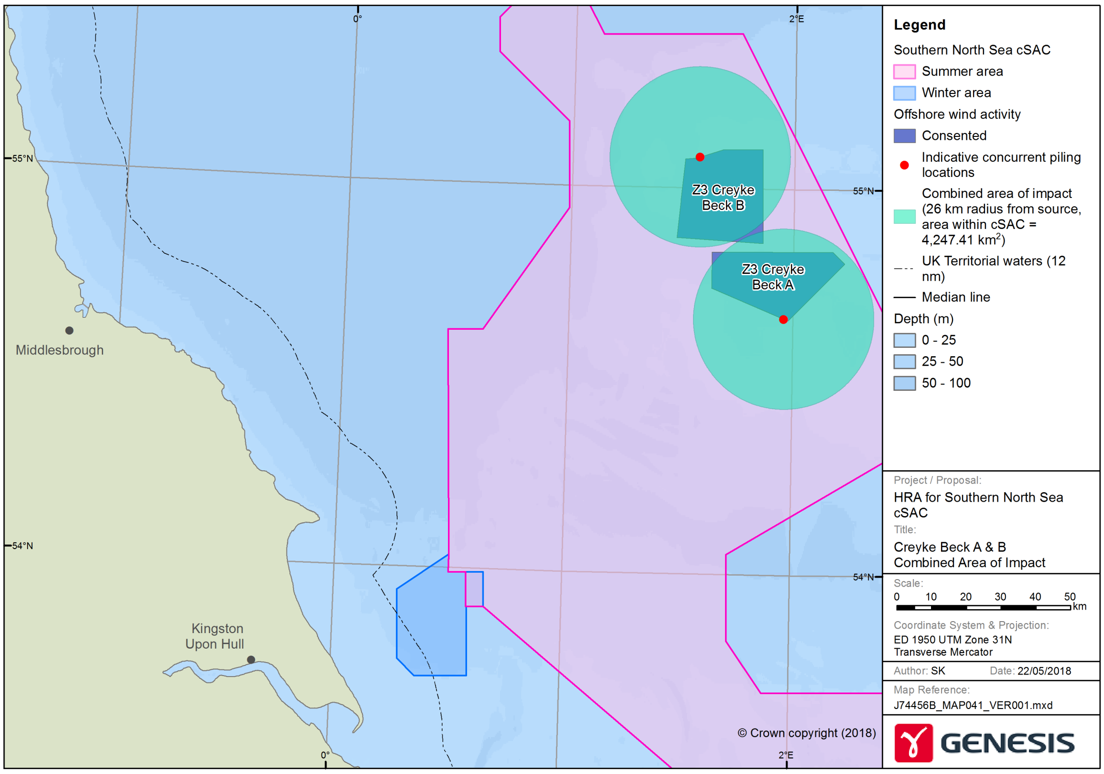


Figure 59: Maximum area of effective deterrence within the Southern North Sea SCI from in-combination pile-driving at Creyke Beck A and Creyke Beck B.

19.82 Based on the consented project designs, up to 200 wind turbines may be installed within the 'summer' area of the SCI at both Creyke Beck A and Creyke Beck B. Pile-driving could occur throughout the 183 day summer period.

19.83 The worst-case scenarios used for the purposes of this in-combination assessment assumes that one turbine is installed per day at each wind farm location and that the maximum area of potential impact occurs at each turbine location. The maximum period of in-combination impacts during the summer period is therefore 183 days. Over the course of a season the average seasonal spatial overlap is 15.7% (Table 85).

Table 85: In-combination seasonal spatial overlap for Creyke Beck A and Creyke Beck B offshore wind farms within the SCI.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
In-combination pile-driving					
'summer'	4,247	15.7	200	183	15.7

19.84 The results from the assessment indicate that the area of disturbance on harbour porpoise within the SCI across one day would not exceed the draft daily thresholds but could exceed the seasonal thresholds.

19.85 The assessment is based on an unrealistic worst-case scenario that all the pile-driving will cause the same level of impact within the SCI, which will not occur. The installation of piles in closer proximity to each other or closer to the SCI boundary will decrease the area impacted within the SCI and reduce the seasonal spatial overlap.

19.86 Pile-driving on the eastern edge of the Creyke Beck A reduces the area within the SCI impacted to 1,247 km^2 and similarly, the installation of turbines to the north-east of Creyke Beck B will reduce the area impacted within the SCI to 1,557 km^2. However, the lowest area of in-combination impact is predicted to arise when both pile-driving is undertaken at their closest locations and therefore there is the greatest area of spatial overlap (Figure 60). In this scenario the in-combination impact could be 8.0% of the 'summer' area during any one day and 8.0% across the season (Table 86).

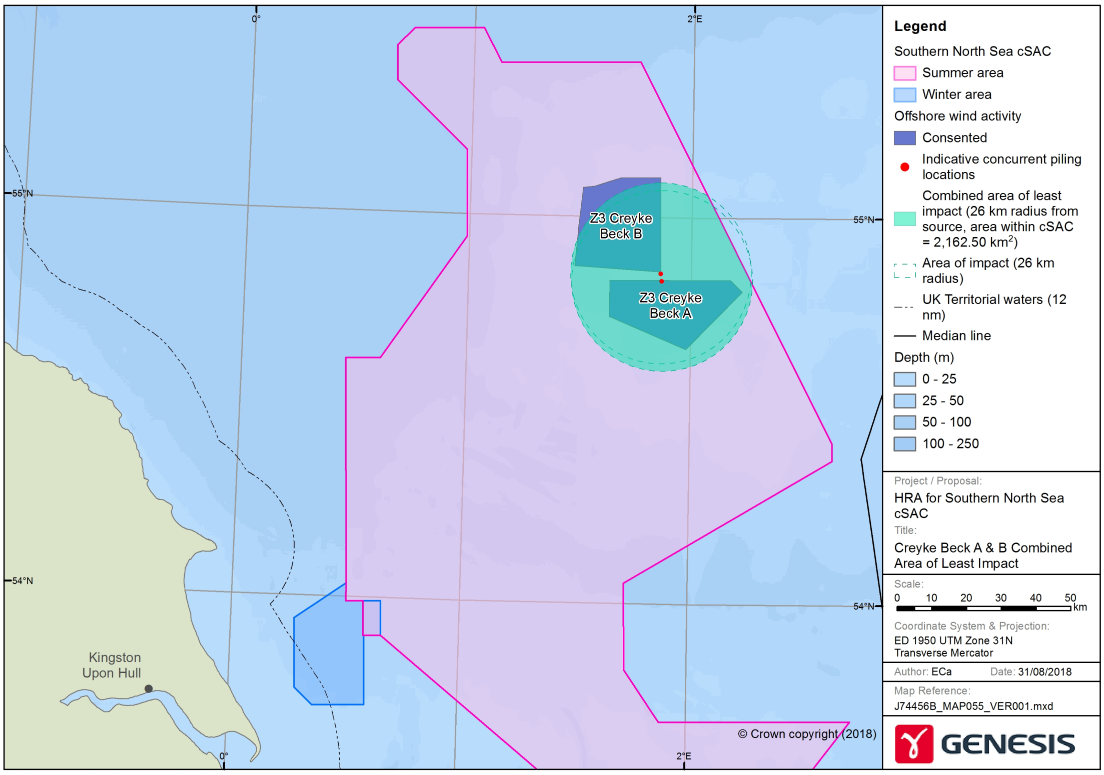


Figure 60: Minimum area of effective deterrence within the Southern North Sea SCI from in-combination pile-driving at Creyke Beck A and Creyke Beck B.

Table 86: Estimated minimum in-combination seasonal spatial overlap for Creyke Beck A and Creyke Beck B offshore wind farms.

SCI area	Minimum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
In-combination pile-driving (consented)					
‘summer’	2,162	8.0	200	183	8.0

19.87 There is still uncertainty over the number of turbines that may be installed but, based on the experiences from other projects the number of turbines that may eventually be installed could be lower than the number consented. This would reduce the number of days during which pile-driving is undertaken. It is also considered highly unlikely that all the turbines would be installed during the summer period with the installation of turbines during the winter period considered to not have an adverse effect on porpoises in the ‘summer’ area.

19.88 It is not known when or where the turbines within the wind farm areas will be located and therefore further detailed analysis is not possible. However, over the course of the season, the spatial overlap will be lower than the worst-case scenario suggests. Management of the spatio-temporal impacts developed and secured in a site integrity plan will ensure that draft thresholds are not exceeded.

Creyke Beck A and Creyke Beck B in-combination: Conclusions

19.89 It is concluded that based on the results from the noise modelling and the use of the threshold approach, pile-driving during the construction of Creyke Beck A offshore wind farm in-combination with Creyke Beck B will not have an adverse effect upon the integrity of the Southern North Sea SCI.

19.90 For all consented offshore wind farms there are conditions attached to the Marine Licence that require effective mitigation measures to be in place that reduce the risk of any harbour porpoise occurring within the range at which it is predicted the onset of PTS could occur. The mitigation measures to be used are included in each Project’s MMMP, which requires consultation with the SNCB and approval from the MMO before construction can commence. Consequently, it is predicted that no harbour porpoise will be impacted by PTS by noise arising from in-combination pile-driving during the construction of the Creyke Beck A and Creyke Beck B offshore wind farms.

19.91 The estimated potential displacement of no more than 0.17% of the North Sea Management Unit population over the construction period is predicted to not cause an adverse effect on the favourable conservation status of the species nor the integrity of the site.

19.92 A pre-construction licence condition requiring a SIP will ensure that the wind farm parameters used in order to undertake this assessment will not be exceeded. Management of the spatio-temporal impacts developed and secured in a SIP will further ensure that draft thresholds are not exceeded.

Creyke Beck A and Teesside B

19.93 Creyke Beck A lies wholly within the SCI and Teesside B partially overlaps the site. There are no confirmed construction dates for either development and final details on the timing and duration of pile-driving are not available. However, there is potential for pile-driving to occur at both wind farm locations between 2020 and 2025 (Figure 52).

Physical Injury

19.94 The estimated number of harbour porpoise at risk of the onset of PTS at Creyke Beck A is between 4 and 9 individuals and between 8 and 40 at Teesside B (Para. 18.121). In the event that both Creyke Beck A and Teesside B undertake pile-driving a combined total of between 12 and 49 harbour porpoise may be at risk of PTS; up to 0.01% of the North Sea Management Unit population may be at risk.

Displacement

19.95 Displacement is predicted to occur over an area of up to 2,404 km^2 (Figure 61). Based on results from the dose response curve used and an estimated average density of 0.71 ind./km^2, the estimated number of harbour porpoise predicted to be displaced is 627 individuals (Table 77). An estimated 0.19% of the North Sea Management Unit population may be impacted.

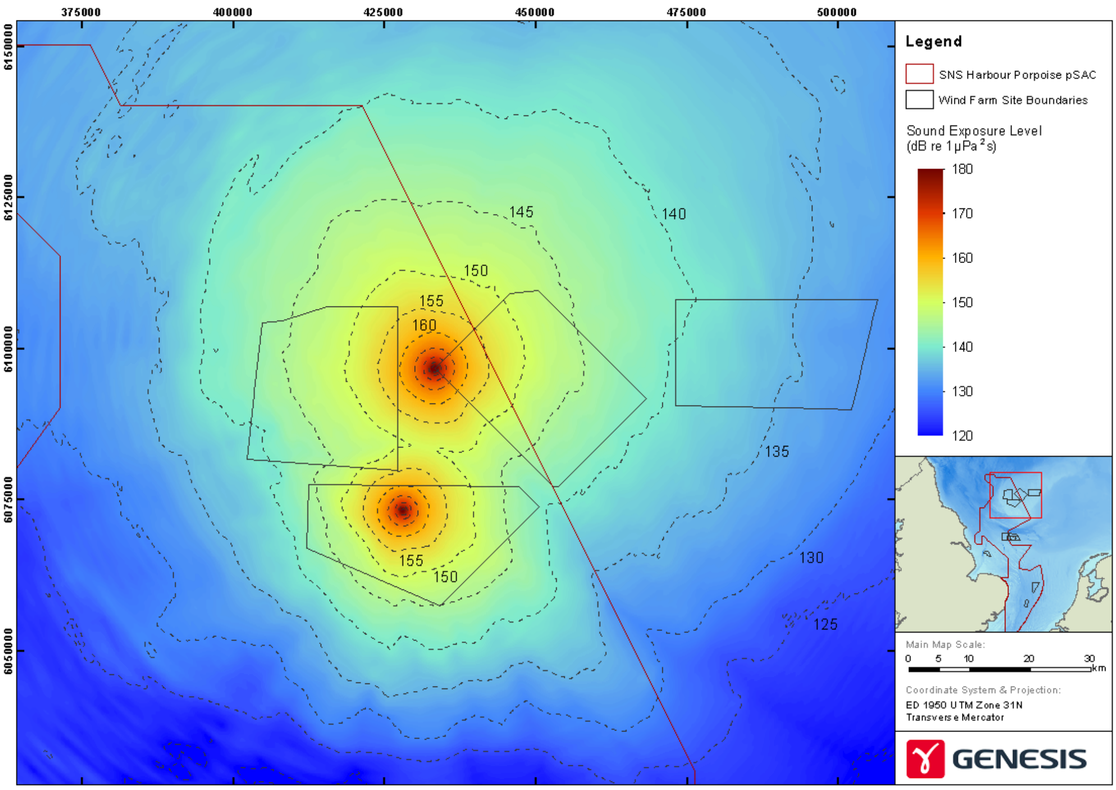


Figure 61: Predicted area of in-combination noise impacts from pile-driving at Creyke Beck A and Teesside B offshore wind farms.

Effective Deterrent Radius

19.96 The combined EDR for Creyke Beck A and Teesside B could potentially impact an area of 3,314 km^2 within the SCI (Figure 62).

19.97 As a worst-case, noise from in-combination pile-driving at Creyke Beck A and Teesside B could cause displacement of harbour porpoise over 9.0% of the SCI as a whole and 12.3% of the 'summer' area. There will be no in-combination impacts on the 'winter' area.

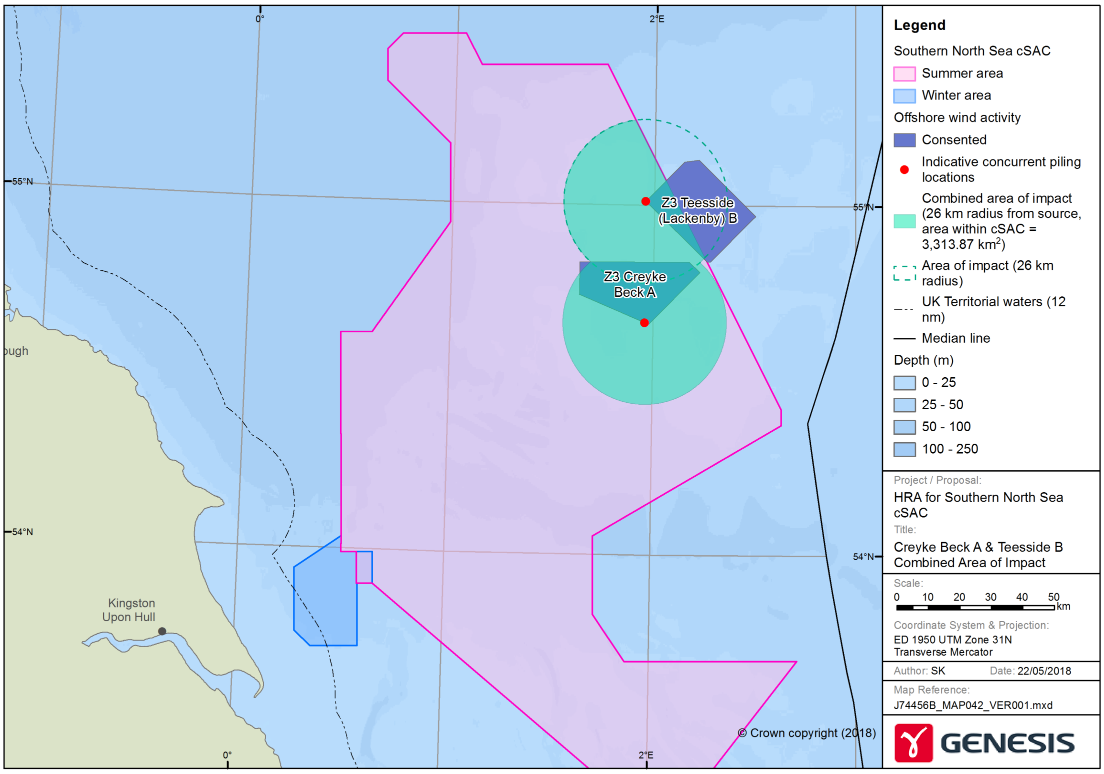


Figure 62: Maximum area of effective deterrence within the Southern North Sea SCI from in-combination pile-driving at Creyke Beck A and Teesside B.

19.98 Based on the consented project design, up to 200 wind turbines will be installed within the 'summer' area of the SCI at Creyke Beck A. Of the 200 potential turbines to be installed at Teesside B the number to be installed within the SCI is unknown.

19.99 For the purposes of this assessment the worst-case scenario assumes that there will be in-combination pile-driving throughout the 183 day summer period and that the maximum area of potential impact occurs at each turbine location. Over the course of a season the average seasonal spatial overlap is 12.3% (Table 87).

19.100 The results from the assessment indicate that the area of combined disturbance on harbour porpoise within the SCI across one day would not exceed the draft daily thresholds but could exceed the seasonal thresholds.

Table 87: In-combination seasonal spatial overlap for Creyke Beck A and Teesside B offshore wind farms within the SCI.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
In-combination pile-driving					
'summer'	3,314	12.3	200	183	12.3

19.101 A total of 79% of Teesside B wind farm area lies outwith the SCI. Therefore, the area of impact within the SCI will be lower than the scenario assessed. Pile-driving on the eastern edge of the Creyke Beck A wind farm area reduces the area impacted within the SCI to 1,247 km^2 and similarly, the installation of turbines to the north-east of the Teesside B wind farm area could reduce the area estimated to be impacted within the SCI to 123 km^2. However, the lowest in-combination impact occurs when both pile-driving locations are at their closest locations (Figure 63). In this scenario the in-combination impact could be 4.9% of the 'summer' area during any one day and 4.9% across the season (Table 88).

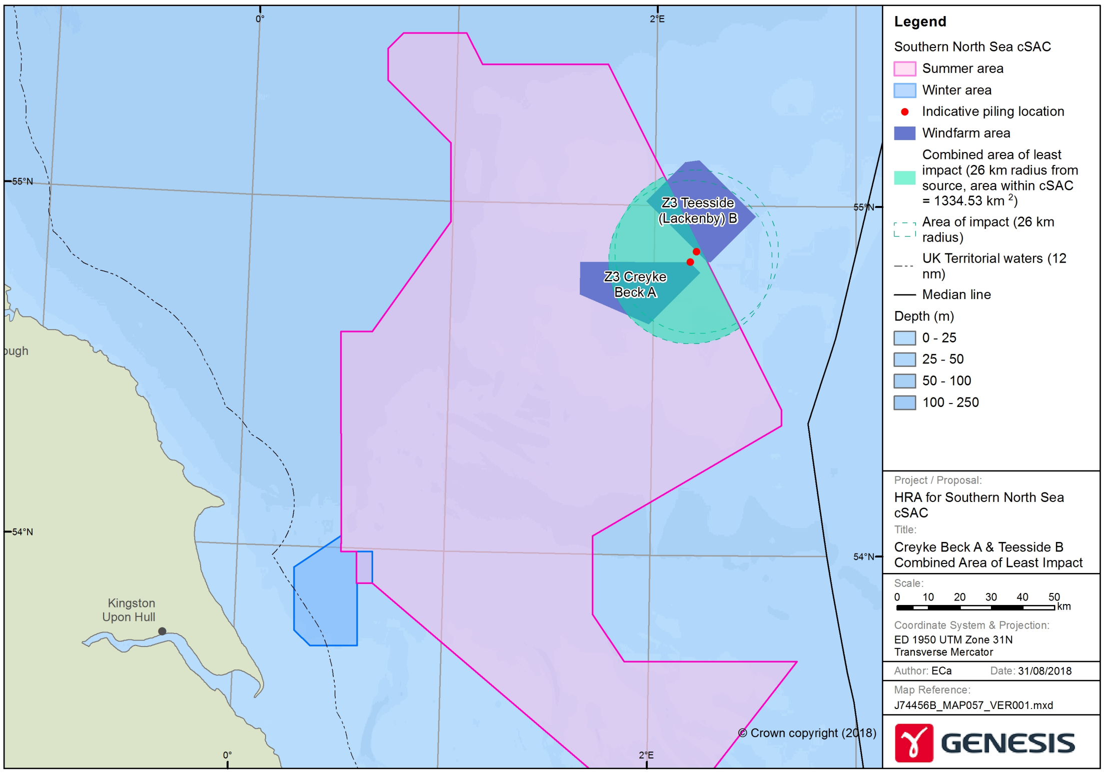


Figure 63: Minimum area of effective deterrence within the Southern North Sea SCI from in-combination pile-driving at Creyke Beck A and Teesside B.

Table 88: Best-case in-combination seasonal spatial overlap for Creyke Beck A and Teesside B offshore wind farms.

SCI area	Minimum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
In-combination pile-driving (consented)					
'summer'	1,335	4.9	183	183	4.9

19.102 It is not known when or where the turbines within the wind farm areas will be located and therefore further detailed analysis is not possible. However, over the course of the season, the seasonal spatial overlap will be significantly lower than the worst-case scenario suggests. Management of the spatio-temporal impacts developed and secured in a site integrity plan will ensure that draft thresholds are not exceeded.

Creyke Beck A and Teesside B in-combination: Conclusions

19.103 It is concluded that based on the results from the noise modelling and the use of the threshold approach, pile-driving during the construction of Creyke Beck A offshore wind farm in-combination with Teesside B will not have an adverse effect upon the integrity of the Southern North Sea SCI.

19.104 For all consented offshore wind farms there are conditions attached to the Marine Licence that require effective mitigation measures to be in place that reduce the risk of any harbour porpoise occurring within the range at which it is predicted the onset of PTS could occur. The mitigation measures to be used are included in each Project's MMMP, which requires consultation with the SNCB and approval from the MMO before construction can commence. Consequently, it is predicted that no harbour porpoise will be impacted by PTS by noise arising from in-combination pile-driving during the construction of the Creyke Beck A and Teesside B offshore wind farms.

19.105 The estimated potential displacement of no more than 0.02% of the North Sea Management Unit population over the construction periods is predicted to not cause an adverse effect on the favourable conservation status of the species nor the integrity of the site.

19.106 A pre-construction licence condition requiring a SIP will ensure that the wind farm parameters used in order to undertake this assessment will not be exceeded. Management of the spatio-temporal impacts developed and secured in a SIP will further ensure that draft thresholds are not exceeded.

Teesside A and Teesside B

19.107 The Teesside A wind farm lies wholly outwith the SCI and Teesside B partially overlaps the site. There are no confirmed construction dates for either development and final details on the timing and duration of pile-driving are not available. However, there is potential for pile-driving to occur at both wind farm locations between 2021 and 2027 (Figure 52).

Physical Injury

19.108 The estimated number of harbour porpoise at risk of the onset of PTS at Teesside A is between is between 7 and 40 individuals (Para. 18.100) and between 8 and 40 at Teesside B. In the event that both Teesside A and Teesside B undertake pile-driving an estimated total of between 15 and 80 harbour porpoise may be at risk of PTS. It is therefore estimated that up to 0.19% of the North Sea Management Unit population may be at risk of the onset of PTS.

Displacement

19.109 Displacement is predicted to occur over an area of up to 3,417 km^2. Based on results from the dose response curve used and an estimated averaged density of 0.71 ind./km^2, the estimated number of harbour porpoise predicted to be displaced is 876 individuals (Table 77). An estimated 0.26% of the North Sea Management Unit population may be impacted.

Effective Deterrent Radius

19.110 The combined EDR for Teesside A and Teesside B could potentially impact an area of 1,518 km^2 within the SCI (Figure 64).

19.111 As a worst-case, noise from in-combination pile-driving at Teesside A and Teesside B could cause displacement of harbour porpoise over 4.1% of the SCI as a whole and 5.6% of the ‘summer’ area. There will be no in-combination impacts on the ‘winter’ area.

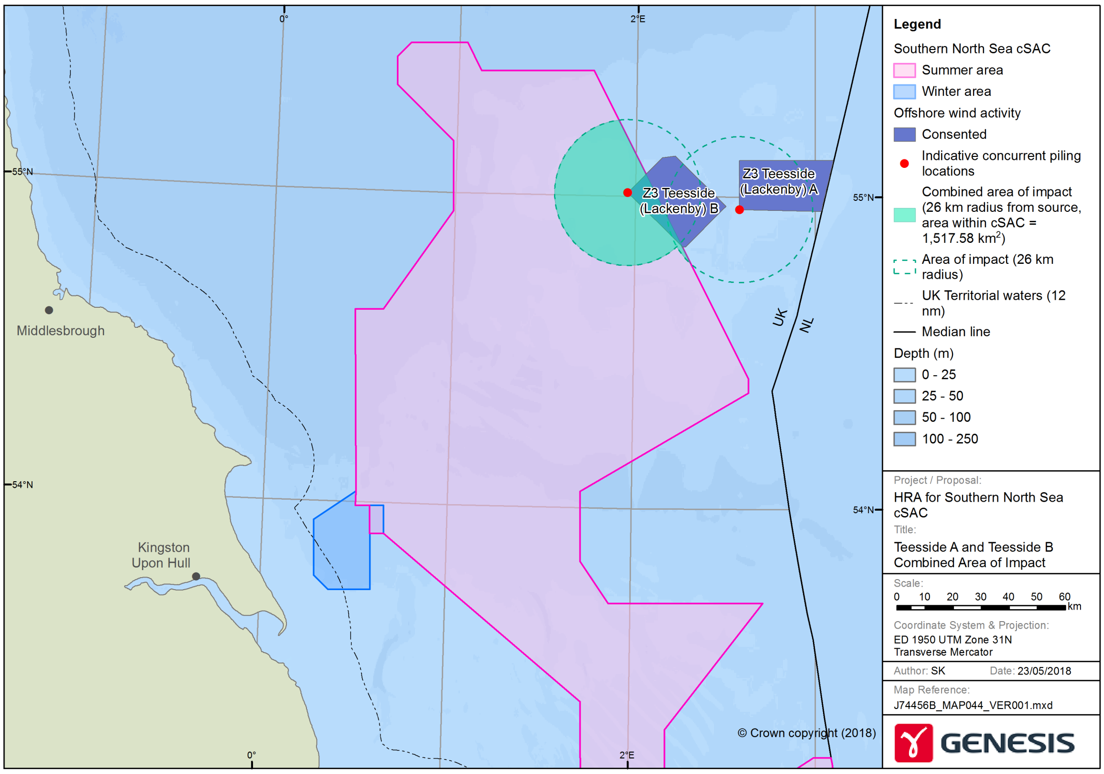


Figure 64: Maximum area of effective deterrence within the Southern North Sea SCI from in-combination pile-driving at Teesside A and Teesside B.

19.112 Based on the consented project design, up to 200 wind turbines will be installed at both Teesside A and Teesside B. The number of potential turbines to be installed at Teesside B within the SCI are unknown.

19.113 For the purposes of this assessment the worst-case scenario assumes that there will be in-combination pile-driving throughout the 183 day summer period and that the maximum area of potential impact occurs at each turbine location. Over the course of a season the average seasonal spatial overlap is 5.6% (Table 89).

Table 89: In-combination seasonal spatial overlap for Teesside A and Teesside B offshore wind farms within the SCI.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
In-combination pile-driving					
'summer'	1,518	5.6	183	183	5.6

19.114 The results from the assessment indicate that the area of combined disturbance on harbour porpoise within the SCI would not exceed the draft daily or seasonal thresholds.

Teesside A and Teesside B in-combination: Conclusions

19.115 It is concluded that based on the results from the noise modelling and the use of the threshold approach, pile-driving during the construction of Teesside A offshore wind farm in-combination with Teesside B wind farm will not have an adverse effect upon the integrity of the Southern North Sea SCI.

19.116 For all consented offshore wind farms there are conditions attached to the Marine Licence that require effective mitigation measures to be in place that reduce the risk of any harbour porpoise occurring within the range at which it is predicted the onset of PTS could occur. The mitigation measures to be used are included in each Project's MMMP, which requires consultation with the SNCB and approval from the MMO before construction can commence. Consequently, it is predicted that no harbour porpoise will be impacted by PTS by noise arising from in-combination pile-driving during the construction of the Teesside A and Teesside B offshore wind farms.

19.117 The estimated potential displacement of no more than 0.26% of the North Sea Management Unit population over the construction periods is predicted to not cause an adverse effect on the favourable conservation status of the species nor the integrity of the site.

19.118 A pre-construction licence condition requiring a SIP will ensure that the wind farm parameters used in order to undertake this assessment will not be exceeded. Management of the spatio-temporal impacts developed and secured in a SIP will further ensure that draft thresholds are not exceeded.

Teesside B and East Anglia Three

19.119 Teesside B partially overlaps the SCI and East Anglia Three lies wholly within it. There are no confirmed construction dates for either development and final details on the timing and duration of pile-driving are not available. However, there is potential for pile-driving to occur at both wind farm locations between 2021 and 2022 (Figure 52).

Physical Injury

19.120 The estimated number of harbour porpoise at risk of the onset of PTS at Teesside B is between 8 and 40 individuals and between <1 and 2 at East Anglia Three. In the event that both Teesside B and East Anglia Three undertaking pile-driving simultaneously an estimated total of between 8 and 42 harbour porpoise may be at risk of PTS. It is therefore estimated that up to 0.01% of the North Sea Management Unit population may be at risk of the onset of PTS.

Displacement

19.121 Displacement is predicted to occur over an area of up to 4,294 km^2. Based on an estimated averaged density of 0.50 ind./km^2, the estimated number of harbour porpoise predicted to be displaced is 752 individuals (Table 77); an estimated 0.22% of the North Sea Management Unit population may be impacted.

Effective Deterrent Radius

19.122 The combined EDR for Teesside B and East Anglia Three could potentially impact across an area of 3,633 km^2 within the SCI (Figure 65) and, as a worst-case, could cause displacement of harbour porpoise over 9.8% of the SCI as a whole and 13.4% of the 'summer' area. There will be no in-combination impacts on the 'winter' area.

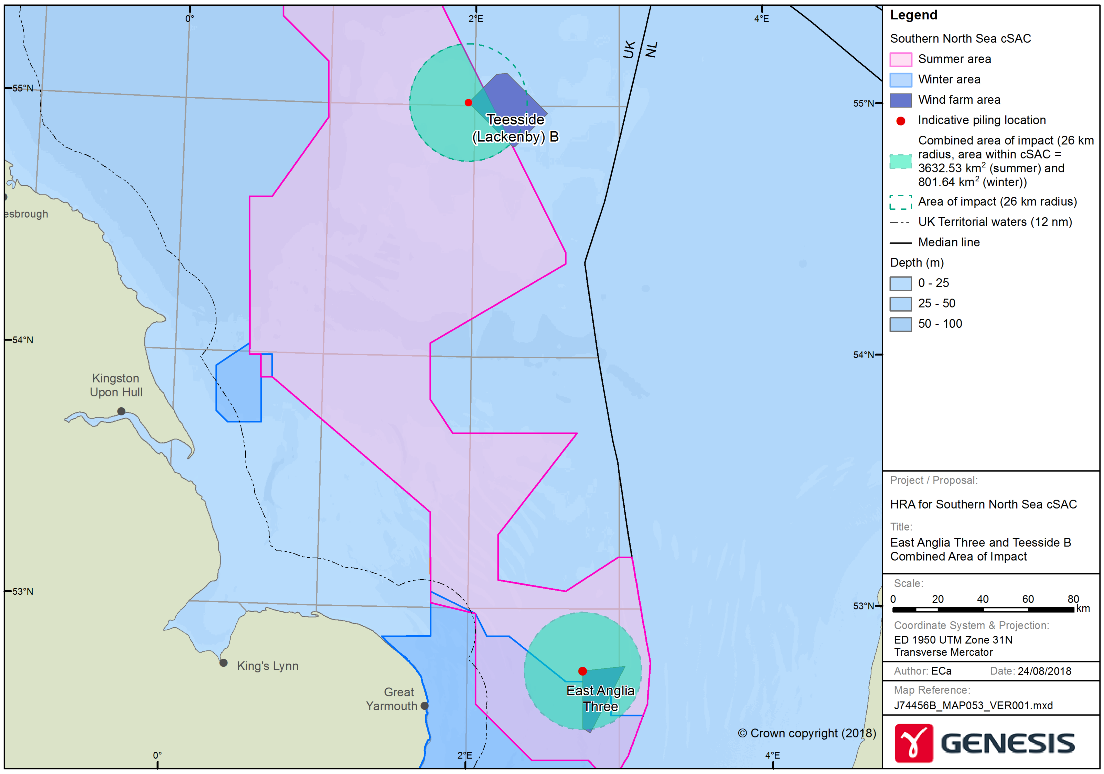


Figure 65: Maximum area of effective deterrence within the Southern North Sea SCI from in-combination pile-driving at Teesside B and East Anglia Three.

19.123 Based on the consented project design, up to 200 wind turbines could be installed within Teesside B. However, the number of potential turbines to be installed within the SCI are unknown. Up to 172 turbines may be installed at East Anglia Three, all of which will be in the SCI.

19.124 For the purposes of this assessment the worst-case scenario assumes that there will be in-combination pile-driving over 172 days of the 'summer' period and that the maximum area of potential impact occurs at each turbine location. Over the course of a season the average seasonal spatial overlap is 12.7% (Table 90).

Table 90: In-combination seasonal spatial overlap for Teesside B and East Anglia Three offshore wind farms within the SCI.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
In-combination pile-driving					
'summer'	3,633	13.4	172	174	12.7

19.125 The results from the assessment indicate that the area of disturbance on harbour porpoise within the SCI would not exceed the draft daily thresholds but could, in theory, exceed the draft seasonal threshold.

19.126 However, this a worst-case scenario and assumes the maximum area of impact will occur at each of the wind turbine locations and that all pile-driving activities will occur across a single summer season. This worst-case scenario is highly unlikely to occur as only 127.4 km^2 of the 593 km^2 Teesside B wind farm area lies within the SCI and therefore 78.5% of the wind farm area is outwith the SCI. The remaining 21.5% of the wind farm is within 26 km of the boundary of the SCI. Consequently, all turbines installed within the Teesside B site boundary will have less of an impact than has been considered for this assessment. A wind turbine installed on north-eastern edge of the Teesside B site boundary impacts on approximately 127 km^2 of the SCI; a considerably smaller area than the 1,508 km^2 used for the worst-case scenario.

19.127 The minimum area of in-combination impact is estimated to be 1,651 km^2 which would impact on 6.1% of the 'summer' area during any one day and 5.8% across the season (Table 91).

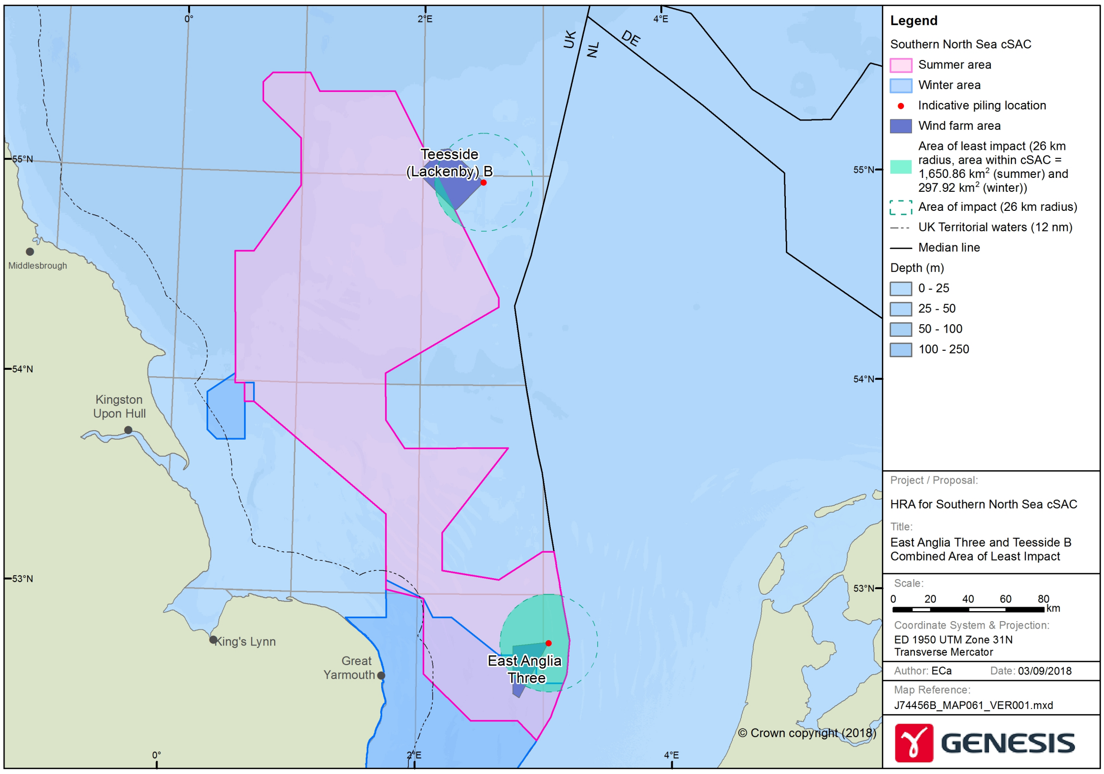


Figure 66: Minimum area of effective deterrence within the Southern North Sea SCI from in-combination pile-driving at Teesside B and East Anglia Three.

Table 91: Minimum in-combination seasonal spatial overlap for Teesside B and East Anglia Three offshore wind farms.

SCI area	Minimum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal Spatial overlap (as % spatial overlap)
In-combination pile-driving (consented)					
'summer'	1,651	6.1	172	174	5.8

19.128 It is not known when, how many or where the turbines within the wind farm areas will be located and therefore further detailed analysis is not possible. However, over the course of the season, the seasonal spatial overlap will be significantly lower than the worst-case scenario suggests. Management of the spatio-temporal impacts developed and secured in a site integrity plan will ensure that draft thresholds are not exceeded.

Teesside B and East Anglia Three In-combination: Conclusions

19.129 It is concluded that based on the results from the noise modelling and the use of the threshold approach, pile-driving during the construction of Teesside B offshore wind farm in-combination with East Anglia Three wind farm will not have an adverse effect upon the integrity of the Southern North Sea SCI.

19.130 For all consented offshore wind farms there are conditions attached to the Marine Licence that require effective mitigation measures to be in place that reduce the risk of any harbour porpoise occurring within the range at which it is predicted the onset of PTS could occur. The mitigation measures to be used are included in each Project's MMMP, which requires consultation with the SNCB and approval from the MMO before construction can commence. Consequently, it is predicted that no harbour porpoise will be impacted by PTS by noise arising from in-combination pile-driving during the construction of the Teesside B and East Anglia Three offshore wind farms.

19.131 The estimated potential displacement of no more than 0.22% of the North Sea Management Unit population over the construction periods is predicted to not cause an adverse effect on the favourable conservation status of the species nor the integrity of the site.

19.132 A pre-construction licence condition requiring a SIP will ensure that the wind farm parameters used in order to undertake this assessment will not be exceeded. Management of the spatio-temporal impacts developed and secured in a SIP will further ensure that draft thresholds are not exceeded.

Creyke Beck A, Creyke Beck B and Teesside B

19.133 The Creyke Beck A and Creyke Beck B wind farms are wholly within the SCI and Teesside B wind farm partially overlaps the site. There are no confirmed construction dates for any of the developments and final details on the timing and duration of pile-driving are not available. However, there is potential for pile-driving to occur at all three sites between 2020 and 2025 and therefore there is potential for an in-combination impact (Figure 68).

Physical Injury

19.134 The estimated number of harbour porpoise at risk of the onset of PTS at Creyke Beck A is between 4 and 9 individuals, for Creyke Beck B the estimated number is between 3 and 10 individuals and at Teesside B between 8 and 40 individuals. In the event that pile-driving occurs across all three wind farms a combined total of between 15 and 59 harbour porpoise may be at risk of PTS. Up to 0.02% of North Sea Management Unit harbour porpoise population may be at risk of the onset of PTS.

Displacement

19.135 Displacement is predicted to occur over an area of up to 3,436 km^2 (Figure 67). Based on an averaged density of 0.71 ind./km^2, the estimated number of harbour porpoise predicted to be displaced is 914 individuals (Table 77); a total of 0.27% of the North Sea Management Unit population may be impacted.

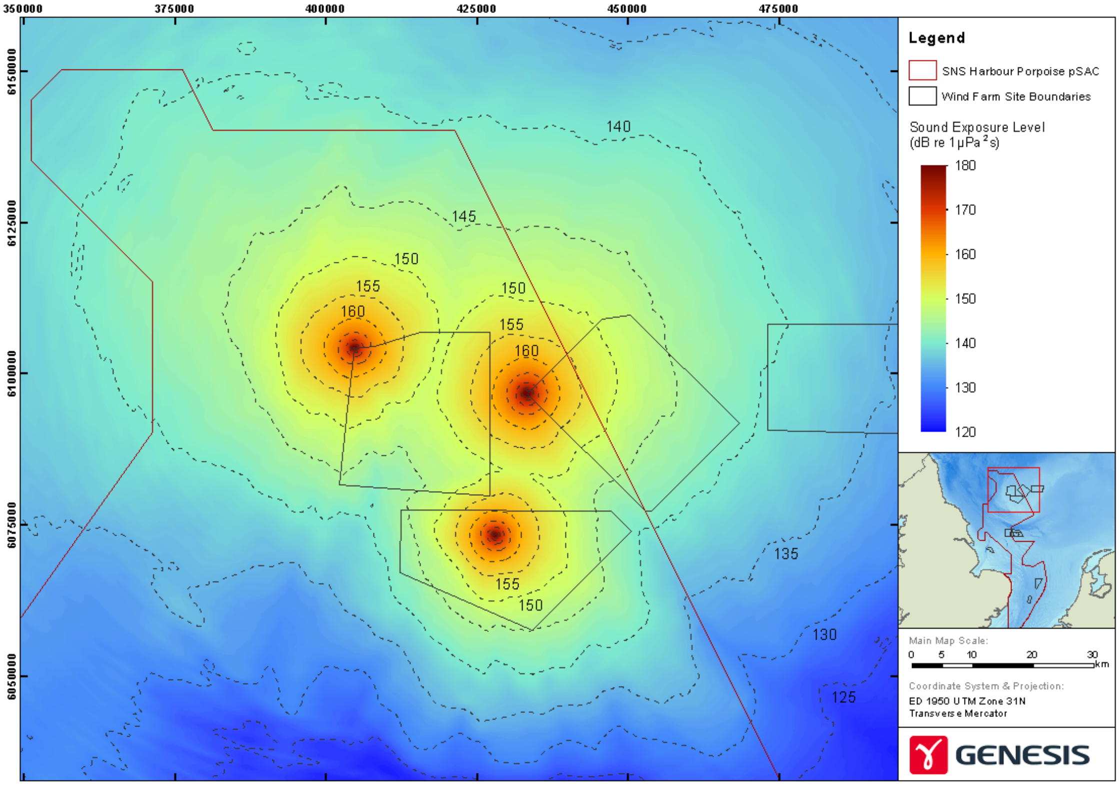


Figure 67: Predicted area of in-combination noise impacts from pile-driving at Creyke Beck A, Creyke Beck B and Teesside B offshore wind farms.

Effective Deterrent Radius

19.136 The combined EDR for Creyke Beck A, Creyke Beck B and Teesside B could potentially impact an area of 4,740 km^2 within the SCI (Figure 68).

19.137 As a worst-case, noise from in-combination pile-driving at Creyke Beck A, Creyke Beck B and Teesside A could cause displacement of harbour porpoise over 12.8% of the SCI as a whole and 17.5 % of the 'summer' area. There will be no in-combination impacts on the 'winter' area.

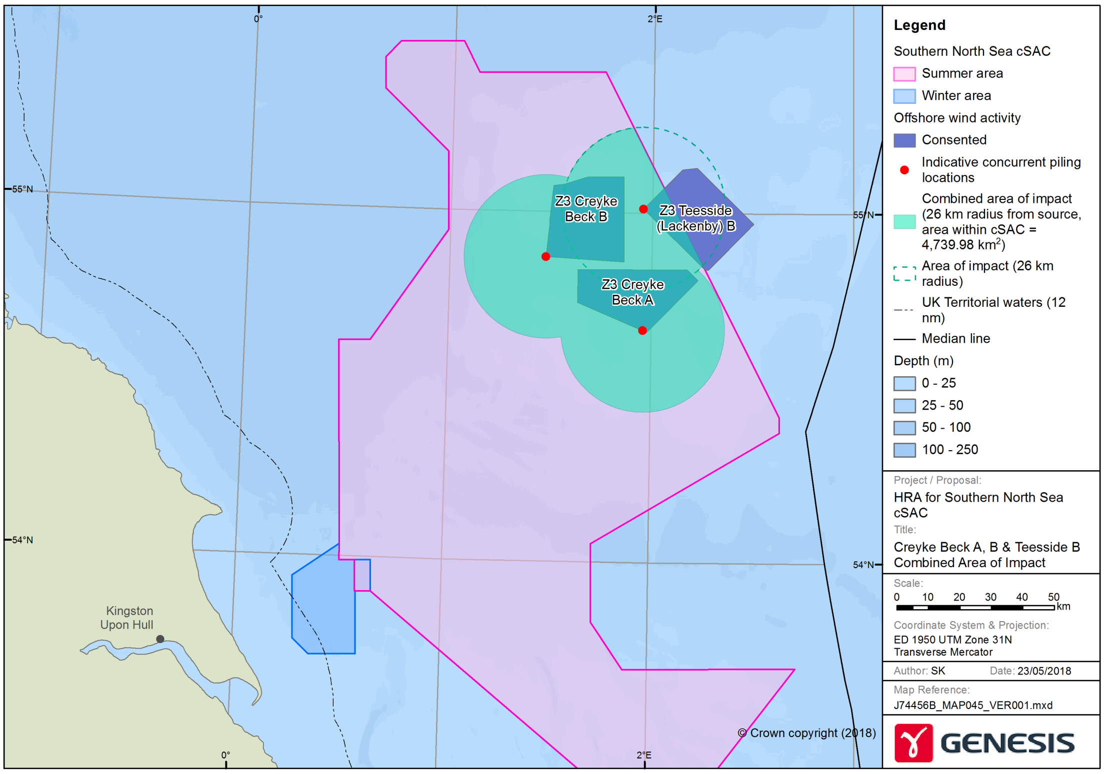


Figure 68: Maximum area of effective deterrence within the Southern North Sea SCI from in-combination pile-driving at Creyke Beck A, Creyke Beck B and Teesside B.

19.138 Based on the consented project design, up to 200 wind turbines will be installed within the 'summer' area of the SCI at both Creyke Beck A and Creyke Beck B and 200 turbines within Teesside B wind farm area. In-combination pile-driving could occur throughout the 183 day summer period. Based on the worst-case scenario, over the course of a season the average seasonal spatial overlap is 17.5% (Table 92).

Table 92: In-combination seasonal spatial overlap for Creyke Beck A, Creyke Beck B and Teesside B offshore wind farms within the SCI.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
In-combination pile-driving					
'summer'	4,740	17.5	200	183	17.5

19.139 The results from the assessment indicate that the area of disturbance on harbour porpoise within the SCI across one day would not exceed the draft daily thresholds but could exceed the seasonal thresholds.

19.140 The assessment is based on the potential for pile-driving to occur at all three wind farms simultaneously and in areas where the maximum area of impact within the SCI could occur. The installation of piles outwith the SCI or within 26 km of the boundary will decrease the area impacted within the SCI and reduce the seasonal spatial overlap. Combined pile-driving in closer proximity to each location will also reduce the spatial footprint. An estimated minimum area of impact is presented in Figure 69. In the event that this scenario arises the average seasonal spatial overlap is 8.1% (Table 93).

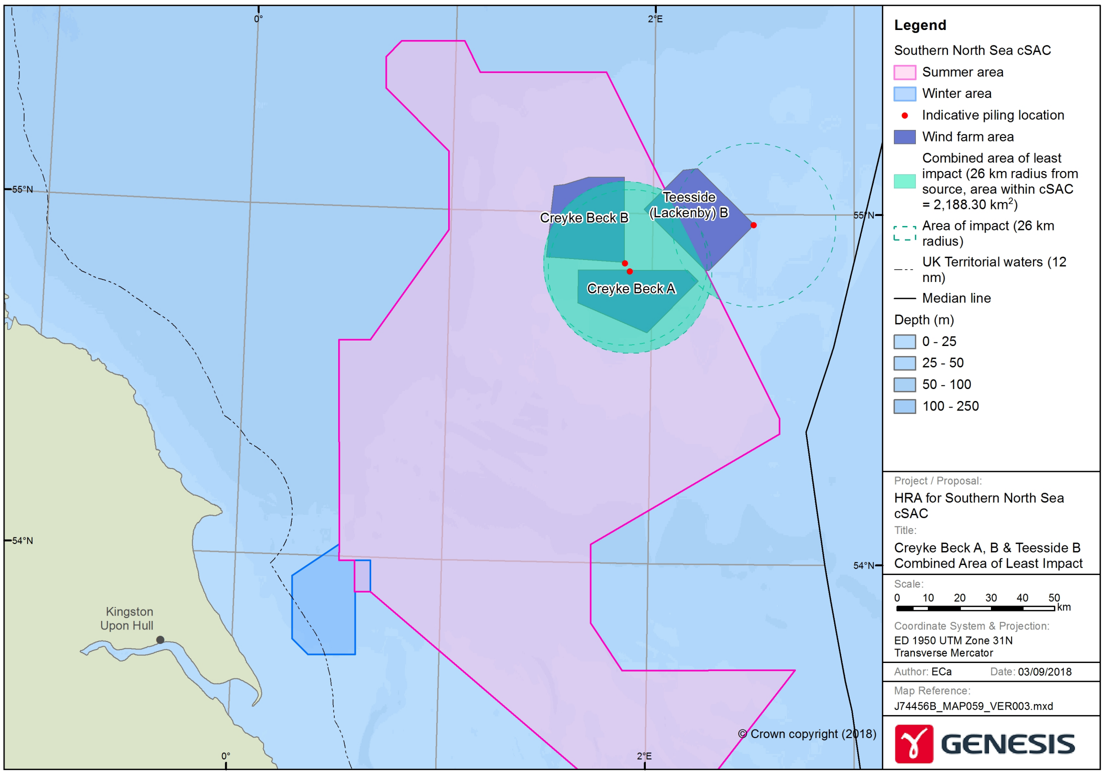


Figure 69: Estimated minimum area of effective deterrence within the Southern North Sea SCI from in-combination pile-driving at Creyke Beck A, Creyke Beck B and Teesside B.

Table 93: Estimated minimum in-combination seasonal spatial overlap for Creyke Beck A, Creyke Beck B and Teesside B offshore wind farms within the SCI.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
In-combination pile-driving					
‘summer’	2,188	8.1	183	183	8.1

19.141 It is not known how many or where the turbines within the wind farm areas will be located and therefore further detailed analysis is not possible. However, over the course of the season, the seasonal spatial overlap will be significantly lower than the worst-case scenario suggests. Management of the spatio-temporal impacts developed and secured in a site integrity plan will ensure that draft thresholds are not exceeded.

Creyke Beck A, Creyke Beck B and Teesside B in-combination: Conclusions

19.142 It is concluded that based on the results from the noise modelling and the use of the threshold approach, the in-combination impacts from pile-driving of Creyke Beck A, Creyke Beck B and Teesside B offshore wind farms will not have an adverse effect upon the integrity of the Southern North Sea SCI.

19.143 For all consented offshore wind farms there are conditions attached to the Marine Licence that require effective mitigation measures to be in place that reduce the risk of any harbour porpoise occurring within the range at which it is predicted the onset of PTS could occur. The mitigation measures to be used are included in each Project’s MMMP, which requires consultation with the SNCB and approval from the MMO before construction can commence. Consequently, it is predicted that no harbour porpoise will be impacted by PTS by noise arising from in-combination pile-driving during the construction of the Creyke Beck A, Creyke Beck B and Teesside B offshore wind farms.

19.144 The estimated potential displacement of no more than 0.27% of the North Sea Management Unit population over the construction periods is predicted to not cause an adverse effect on the favourable conservation status of the species nor the integrity of the site.

19.145 A pre-construction licence condition requiring a SIP will ensure that the wind farm parameters used in order to undertake this assessment will not be exceeded. Management of the spatio-temporal impacts developed and secured in a SIP will further ensure that draft thresholds are not exceeded.

Offshore wind farm in-combination noise impacts: Summary

19.146 Table 94 presents a summary of the estimated impacts from the potential worst-case in-combination impacts arising from offshore wind farm pile-driving on harbour porpoise.

19.147 The results from the noise modelling indicate that no more than 0.02% of the North Sea Management Unit harbour porpoise population is at risk of the onset of PTS and 0.68% of the population could be disturbed.

19.148 The results from using an EDR of 26 km at all locations indicates that under all scenarios the area of the SCI impacted during any single day will be below the draft threshold of 20%. The proportion of the SAC impacted over the course of each season varies from between 2.2% and 17.5% and therefore there are in-combination scenarios where the impacts exceed the draft seasonal thresholds of 10%. These results are highly precautionary and based on the worst-case scenario assuming that impacts from the installation of all the turbine foundations occur over the maximum possible extent within the SCI and for the maximum duration. Further assessment presented above indicates that the seasonal spatial overlaps will be lower than the worst-case scenarios.

Table 94: Summary of the in-combination impacts arising from the construction of offshore wind farms on harbour porpoise based on noise modelling and EDR results.

Worst-case wind farm in-combination	% MU population at risk of:		EDR area of impact (%)			Seasonal spatial overlap (%)	
	PTS	Disp.	SCI	Sum.	Win.	Sum.	Win.
Hornsea Two + Creyke Beck A	0.008	0.55	11.1	15.2	0	15.2	0
Hornsea Two + East Anglia Three	0.005	0.68	13.2	15.1	0	14.3	0
Creyke Beck A + Triton Knoll	0.003	0.08	5.9	8.0	0	2.2	0
Creyke Beck A + East Anglia Three	0.003	0.17	11.5	15.7	0	14.9	0
Creyke Beck A + Creyke Beck B	0.005	0.17	11.5	15.7	0	15.7	0
Creyke Beck A + Teesside B	0.01	0.20	9.0	12.3	0	12.3	0
Teesside A + Teesside B	0.02	0.26	4.1	5.6	0	5.6	0
Teesside B + East Anglia Three	0.01	0.22	9.8	13.4	0	12.7	0
Creyke Beck A + B and Teesside A	0.02	0.27	12.8	17.5	0	17.5	0

In-combination Offshore Wind Farm Habitat Impacts

19.149 The following section assesses the potential in-combination impacts on the habitats that support harbour porpoise within the SCI.

19.150 The estimated area of impact arising from offshore wind farms within the SCI are presented in Table 95. The potential area of seabed within the SCI estimated to be permanently impacted by the physical presence of the turbines, associated infrastructure and scour protection is 17.54 km^2. A total of 90.85 km^2 of seabed may be temporarily impacted by cable trenching.

Table 95: Estimated area of impact from consented offshore wind farms within the SCI.

Wind farm	Estimated area of physical impact (km^2)				
	Turbines & scour	Infrastructure	Cable protection	Total permanent impact	Cable trenching
Galloper	0.11	0.00	0.00	0.11	3.90
Greater Gabbard	0.13	0.00	-	0.13	2.99
Creyke Beck A (monopiles)	0.57	0.14	2.89	3.60	14.73
Creyke Beck B (monopiles)	0.57	0.14	2.77	3.48	14.64
Teesside A	0.00	0.00	-	0.00	1.53
Teesside B (monopiles)	0.68	0.11	2.00	2.79	14.37
Hornsea One Planned (monopiles)	0.25	0.05	2.03	2.33	6.30
Hornsea Two consented(monopiles)	0.44	0.14	3.37	3.95	9.62
Hornsea Two planned (monopiles)	0.35	0.02	3.37	3.74	9.62
East Anglia One Planned (jacket)	0.13	0.03	-	0.15	7.32
East Anglia Three consented (jacket)	0.33	0.11	0.55	0.99	15.46

19.151 The estimated area of seabed potentially impacted by existing activities within the SCI is presented in Table 96.

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. Given to the extent and type of fishing activities within the SCI, the largest area of potential impact on the seabed is likely to be from beam trawling fishing gear, which is widely used across the site (See Table 17 and Figure 22). Licenced aggregate activities may also impact over a relatively large area of the SCI although, the actual area of seabed impacted within each licenced area is considerably smaller.

19.153 Existing offshore wind farms within the SCI that are not subject to this review include the Thanet and Scroby Sands Offshore wind farms. Thanet offshore wind farm comprises 100 turbines using 5.1 m diameter foundations (Vattenfall undated). There has been no requirement for scour protection at Thanet offshore wind farm. There has been extensive scour at the 30 turbines installed at Scroby Sands offshore wind farm. No quantified figures on the amount of scour protection that has been required have been found during this assessment.

Table 96: Estimated area of physical impact from existing activities within the SCI.

Activity	Estimated area of impact (km^2)	Reference	Comment
Scour protection and turbine footprint at existing wind farms			
Scroby Sands	Unknown	-	Extensive scour has been reported at Scroby Sands.
Thanet	0.02	Vattenfall (undated)	-
Other activities			
Oil and gas pipelines and umbilicals	40.1	Para 6.5	Impacts are temporary unless surface laid or pipeline protection is required.
Oil and gas Installations	0.1	Para. 6.7	Impacts are permanent until installations are decommissioned.
Aggregate licence areas	541	Para. 6.20	Area impacted within each site is smaller than actual licenced area.
Fishing	Unknown	Para. 6.38	Impacts are predicted to be widespread and ongoing.

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.

19.155 Permanent physical impacts on the seabed from all consented offshore wind farms are estimated to impact 0.05% of the SCI. Relatively, this is a very small potential loss of habitat within the site and due to the extent of the type of habitat impacted, primarily sandy, gravelly sand type substrates, the loss of a very small proportion of this widespread habitat will not affect the harbour porpoise or their prey within the SCI.

19.156 Temporary impacts from the trenching of pipelines and cables impact a larger area of 91.4 km^2. However, the area impacted is still a very small proportion (0.25%) of the site and the habitat will begin to recover once the lines are buried and there will be no permanent impact on the habitat that will affect harbour porpoise or their prey.

In-combination offshore wind farm habitat impacts: Conclusions

19.157 The area impacted by each of the consented offshore wind farms will contribute to a small proportion of the total impacts predicted to occur within the SCI. Although, this does make for a larger in-combination impact the extent of the impact and the widespread nature of the habitat impacted is not predicted to impact on harbour porpoise or their prey. Consequently, it is concluded that the in-combination impacts on the habitat within the SCI from the consented offshore wind farms will not have an adverse effect upon the integrity of the Southern North Sea SCI.

In-combination Assessment: Wind Farm Pile-driving and Geophysical Seismic Surveys

19.158 Applications to undertake geophysical seismic surveys are typically submitted less than six months prior to the planned surveys being undertaken. Consequently, there are no known plans or projects to undertake seismic surveys that could cause an in-combination impact beyond 2018.

19.159 Data on the recent historical seismic survey activities within the SCI indicate that on average there are 3.4 surveys (2D, 3D and geophysical) undertaken in the 'summer' area between April and September each year and there is seismic survey activity within the area for 32.3% of the season (Table 12). Within the 'winter' area there has historically been a lower level of seismic survey activity between October and March, with two surveys undertaken over an 11 year period and an average of 2.3 days per year impacted during the winter period (Table 13). Consequently, there is a relatively high likelihood for an in-combination impact to occur between noise arising from wind farm construction activities and oil and gas related seismic surveys within the 'summer' area but a relatively low likelihood of a similar in-combination impact to occur in the 'winter' area.

19.160 There is potential for a number of in-combination impact scenarios to arise across the various consented offshore wind farms and oil and gas related seismic surveys. The most likely in-combination scenario is for a single pile-driving activity to be undertaken at the same time as a single seismic survey and this has been assessed.

19.161 The results from the noise modelling indicate that the area of potential impact from PTS is within 500 m of the airgun array (Table 50) and therefore within the radius which, if marine mammals are detected during a pre-shooting search, the commencement of the firing of the airguns must be delayed by a minimum of 20 minutes, as per the JNCC guidance (JNCC 2017d). Consequently, the risk of any harbour porpoise being impacted by sound from seismic airguns at levels capable of causing the onset of PTS is low.

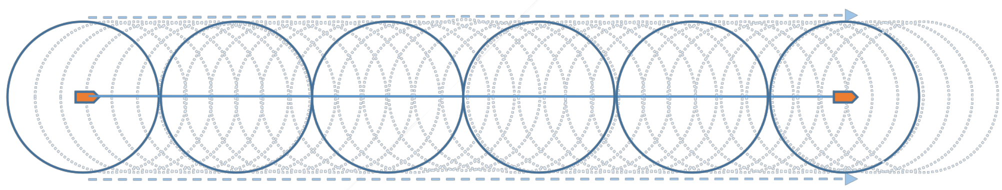
19.162 All seismic surveys relating to oil and gas activities require consent from the competent authority. Every consent issued has, as a condition, a requirement for mitigation measures to be complied with in order to reduce the risk of physical injury to marine mammals. Specific mitigation conditions included in the consents are based on the JNCC *guidelines for minimising the risk of injury to marine mammals from geophysical surveys* (JNCC 2017d). Therefore, there is predicted to be no in-combination impacts with regard to physical injury to harbour porpoise.

Disturbance

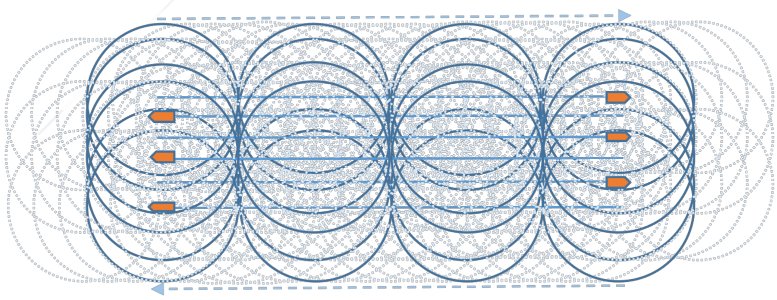
19.163 The area of potential disturbance of harbour porpoise varies depending on the location of the survey (Table 51). The greatest extent of any disturbance is predicted to occur in the Outer Silver Pit area where sound levels capable of causing significant disturbance could propagate out to 33.2 km from the airguns and cover an area of 767 km^2. This is equivalent to 2.1% of the SCI, 2.8% of the 'summer' area and 6.0% of the 'winter' area.

19.164 Based on a peak recorded site density of 2.87 ind./km^2, an estimated 2,201 harbour porpoise could be disturbed by a seismic survey at any one time.

19.165 A seismic vessel will transit across an area and therefore over the duration of a survey the total number of harbour porpoises disturbed will be greater. However, the disturbance effects are transient and once the vessel has moved away from an area there is, in effect, no significant disturbance in areas where porpoises were previously impacted. However, there is potential for repeated noise to occur in the same area over a period of time depending on the type of survey being undertaken. Seismic surveys are frequently undertaken along a series of transect lines that may be separated by a distance of a few hundred metres to more than one kilometre, depending on the aim of the survey. During these surveys the overall area of disturbance will be lower but the duration of impacts within the area will be greater (Figure 70).



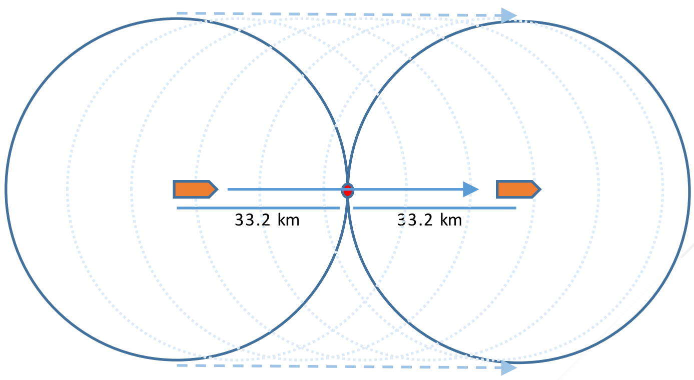
Noise propagation along a single line seismic survey covering a wider area but with a shorter duration of noise at any one location.



Noise propagation along multiple transect lines from a seismic survey covering a smaller area but with a longer duration of noise at any one location.

Figure 70: Diagram showing potential differences in area and duration of impacted areas from seismic surveys based on single transect and multiple transect surveys.

19.166 When undertaking seismic surveys, vessels travel at approximately 4.5 – 5.0 knots (8.3 km/h – 9.2 km/h) (OGP/IAGC 2004). Noise capable of causing disturbance will, depending on its location within the SCI, occur between 21.6 km and 33.2 km from the airguns (Table 51). Consequently, as a vessel undertakes a survey, disturbance in any area will last less than eight hours in any one location (Figure 71). Once the vessel has left the area, sound levels will reduce to background levels.



= Location of harbour porpoise in order for maximum duration of disturbance to occur.
Maximum extent of disturbance from seismic survey at 145 dB re 1 μPa – 33.2 km.
Total distance – 66.4 km.
Vessel speed – 8.3 km/h.
Maximum duration of disturbance impact = 8.0 hrs.

Figure 71: Diagram showing potential duration of disturbance to harbour porpoise from seismic survey.

19.167 It is not possible to predict the areas across which future seismic surveys may be undertaken. For the purposes of this in-combination assessment it is estimated that at any one time displacement effects from seismic surveys could occur over 2.8% of the ‘summer’ area for 32.2% of the summer period (Table 12). To take into consideration the uncertainty over where future seismic surveys may be undertaken within the SCI the estimated number of harbour porpoise displaced by seismic surveys is based on both the average density of harbour porpoise across the SCI as a whole and the mean densities reported for the relevant wind farm zones.

19.168 Results from the noise modelling indicate that in the event that a seismic survey is undertaken using a 3,000 cu in. airgun array at the same time as pile-driving is being carried out at an offshore wind farm, there is potential for an in-combination impact to occur across an area of between 1,558 km^2 and 3,561 km^2 and impact on between 755 and 3,822 harbour porpoise (Table 97). This is equivalent to between 0.23% and 1.14% of the North Sea Management Unit population.

19.169 In the event that concurrent pile-driving is being undertaken at an offshore wind farm at the same time as a seismic survey the estimated number of harbour porpoise predicted to be displaced is between 883 and 4,438 individuals, equivalent to between 0.26% and 1.33% of the North Sea Management Unit population (Table 98).

19.170 There is potential for a seismic survey to be undertaken in-combination with two offshore wind farms pile-driving at the same time. In the event that this occurs the estimated number of harbour porpoises predicted to be displaced is between 579 and 3,220 individuals, equivalent to between 0.17% and 0.96% of the North Sea Management Unit population (Table 99).

Table 97: Estimated area of impact and number of porpoises disturbed from single pile-driving in-combination with a 3,000 cu in. airgun seismic survey.

Wind farm	Wind farm alone		Seismic in-combination		
	Area of impact (km^2)	No. of ind. displaced (Zonal density)	Area of impact (km^2)	No. of ind. displaced (Ave. density)	No. of ind. displaced (Zonal density)
Hornsea Two	2,794	2,119	3,561	2,664	3,822
Creyke Beck A	791	210	1,558	755	755
Creyke Beck B	1,498	376	2,267	921	921
Teesside A	1,964	505	2,731	1,050	1,050
Teesside B	1,842	461	2,609	1,006	1,006

Estimated area of impact from seismic survey (worst-case) = 767 km^2.

'Ave. density' is the estimated average density of harbour porpoise across SCI as a whole of 0.71 ind.km^2 (for seismic airgun impacts only).

'Zonal density' is the wind farm zonal harbour porpoise density: Hornsea Zone of 2.22 ind.km^2 and Doggerbank Zone of 0.71 ind./km^2 (for seismic airgun impacts only).

Table 98: Estimated area of impact and number of porpoises disturbed from concurrent pile-driving in-combination with a 3,000 cu in. airgun seismic survey.

Wind farm	Wind farm alone		Seismic in-combination		
	Area of impact (km^2)	No. of ind. displaced (Zonal density)	Area of impact (km^2)	No. of ind. displaced (Ave. density)	No. of ind. displaced (Zonal density)
Hornsea Two	3,420	2,735	4,187	3,280	4,438
Creyke Beck A	1,281	338	2,048	883	883
Creyke Beck B	2,042	536	2,809	1,081	1,081
Teesside A	2,657	726	3,424	1,271	1,271
Teesside B	2,806	739	3,573	1,284	1,284

Estimated area of impact from seismic survey (worst-case) = 767 km^2.

'Ave. density' is the estimated average density of harbour porpoise across SCI as a whole of 0.71 ind.km^2.

'Zonal density' is the wind farm zonal harbour porpoise density: Hornsea Zone of 2.22 ind.km^2 and Doggerbank Zone of 0.71 ind./km^2.

Table 99: Estimated area of impact and number of porpoises disturbed from two wind farms pile-driving in-combination with a 3,000 cu in. airgun seismic survey.

Wind farm	Wind farm alone		Seismic in-combination		
	Area of impact (km^2)	No. of ind. displaced (Ave. Zonal density)	Area of impact (km^2)	No. of ind. displaced (Ave. density)	No. of ind. displaced (Ave. zonal density)
Hornsea Two + Creyke Beck A	3,585	1,825	4,352	2,370	2,945
Hornsea Two + East Anglia Three	5,246	2,261	6,013	2,806	3,220
Creyke Beck A + Triton Knoll	1,672	265	2,439	810	579
Creyke Beck A + East Anglia Three	3,243	575	4,010	1,120	959
Creyke Beck A + Creyke Beck B	2,289	586	3,056	1,131	1,131
Teesside B + Creyke Beck A	2,404	627	3,171	1,172	1,172
Teesside A + Teesside B	4,294	752	5,061	1,297	1,136
Teesside B + East Anglia Three	3,417	876	4,184	1,421	1,421
Creyke Beck A, Creyke Beck B + Teesside A	3,436	914	4,203	1,459	1,459

Estimated area of impact from seismic survey (worst-case) = 767 km^2.

'Ave. density' is the estimated average density of harbour porpoise across SCI as a whole of 0.71 ind.km^2 (for seismic airgun impacts only).

'Ave. zonal density' are those presented for in-combination wind farms (Table 77) (for seismic airgun impacts only).

Effective Deterrent Radius

19.171 There is no published figure for an EDR for seismic surveys. However, previous assessments have been based on an EDR of 5 km and 10 km (e.g. MMO 2017a, EAOWL 2017). The results from the studies undertaken in the Moray Firth indicated displacement of harbour porpoise could occur beyond 5 km from an airgun (Thompson *et al.* 2013). Therefore, the more precautionary EDR of 10 km has been used for this assessment. It is assumed that the area of impact from the seismic survey is wholly within either the 'summer' or 'winter' areas and each survey lasts for 39 days, which is the median duration for a 3D seismic survey in the 'summer' area during the summer period and 2.3 days in the winter period (Table 12). The assessment is also based on the total number of days seismic surveys have been undertaken across the SCI summer and winter areas, based on historical data (Table 12).

19.172 The results from the in-combination assessment for each of the consented wind farm developments are presented in Table 100.

19.173 Within the ‘summer’ area of the SCI the maximum area of combined impact arises in the event that either Creyke Beck A or Creyke Beck B carry out concurrent pile-driving at the same time as a seismic survey is undertaken. If this arises there is potential for up to 11.1% of the SCI ‘summer’ area to be impacted during any single day. and East Anglia Three are pile-driving at the same time as a seismic survey is being undertaken. The total combined area of EDR impacted each day is 2,438 km^2, which is equivalent to 9% of the summer area. In the event that this arises the area of impact could be 14.4% of the ‘summer’ area, whilst the average seasonal overlap is no more than 4.8%.

19.174 There will be no in-combination impacts arising from the wind farms subject to this assessment and seismic surveys within the ‘winter’ area of the SCI.

Table 100: Seasonal spatial overlap in-combination with pile-driving and seismic survey.

Wind farm construction scenario	Max. area impacted (km^2)	% of area (1 day)	duration of impact (days)	Seasonal spatial overlap (%)	duration of impact (days)	Seasonal spatial overlap (%)
			Single seismic survey		All seismic surveys	
Hornsea Two						
Single pile-driving (Consented)	2,291	8.5	41	1.9	61	2.8
Single pile-driving (CfD)	2,291	8.5	41	1.9	61	2.8
Single pile-driving (planned)	2,291	8.5	41	1.9	61	2.8
Concurrent pile-driving (Consented)	3,188	11.8	41	2.6	61	3.9
Concurrent pile-driving (CFD)	3,188	11.8	41	2.6	61	3.9
Concurrent pile-driving (planned)	3,188	11.8	41	2.6	61	3.9
Creyke Beck A						
Single pile-driving	2,438	9.0	41	2.0	61	3.0
Concurrent pile-driving	3,883	14.4	41	3.2	61	4.8
Creyke Beck B						
Single pile-driving	2,438	9.0	41	2.0	61	3.0
Concurrent pile-driving	3,891	14.4	41	3.2	61	4.8
Teesside A						
Single pile-driving	337	1.2	41	0.3	61	0.4
Teesside B						
Single-pile-driving	1,823	6.8	41	1.5	61	2.3
Concurrent pile-driving	2,394	8.9	41	2.0	61	3.0

The maximum area of SAC impacted is the combined area impacted by pile-driving and seismic survey with no areas of overlapping disturbance.

The duration of impacts is based on the installation of one pile per day (+ 2 day recovery period) and 39 days of seismic in the summer period.

19.175 Data obtained by marine mammal observers during seismic surveys show a significant decrease in the number of harbour porpoise detections when airguns are operating, indicating that harbour porpoise are displaced from an area during a seismic survey (Stone *et al*. 2017). However, there is not total displacement during a survey, with the median closest distance harbour porpoises being detected increasing from approximately 650 m when no airguns are operating to 1,050 m when the airguns are operating (Stone *et al.* 2017).

19.176 Studies undertaken in the Moray Firth during 10 days of 2D seismic surveys using a 470 cu in airgun with peak-to-peak source levels estimated to be 242–253 dB re 1 μPa -m, reported a decrease in the relative densities of harbour porpoises within 10 km of the airgun and an increase in densities at greater distances. However, porpoises continued to occur at sites within the impacted area during the seismic survey and there was a decline in the level of displacement over the ten day period that surveys were undertaken, indicating an increasing level of acclimation during the surveys. Once the surveys had ceased the number of detections returned to baseline levels within a day (Thompson *et al.* 2013, Pirotta *et al.* 2014). Therefore, any displacement effects caused by seismic surveys are predicted to be temporary, with porpoises returning to the area impacted within 24 hrs.

19.177 Although, the effects on harbour porpoises from displacement are unknown, displaced harbour porpoise will relocate elsewhere. Studies have shown an increase in the number of porpoise occurring in areas beyond an area of disturbance during seismic surveys (Pirotta *et al.* 2014).

19.178 There is a high degree of certainty that harbour porpoise will be disturbed and displaced by seismic surveys and therefore there could be an in-combination impact. However, the in-combination impacts will be temporary and harbour porpoise will return to the area once either a seismic survey has relocated or finished or pile-driving ceases.

19.179 The site supports 17.5% of the North Sea Management Unit harbour porpoise population within UK waters and the population is in *favourable condition* (JNCC 2016). Consequently, the historical widespread impact of seismic surveys has not resulted in a significant adverse effect on the harbour porpoise population within the SCI.

In-combination offshore wind farm pile-driving and seismic surveys: Conclusions

19.180 It is concluded that, based on the results from the noise modelling and the use of the threshold approach, potential in-combination impacts between offshore wind farm pile-driving and seismic surveys will not have an adverse effect upon the integrity of the Southern North Sea SCI.

In-combination Assessment: Wind Farm Pile-driving and Sub-bottom profilers

19.181 Applications to undertake geophysical surveys requiring the use of sub-bottom profilers are typically submitted less than six months prior to the planned surveys being undertaken. Consequently, there are no known plans or projects to use sub-bottom profilers that could cause an in-combination impact beyond 2018.

19.182 The historical use of sub-bottom profilers by the oil and gas industry within the SCI is unknown. However, the equipment is widely used by offshore industries, including the renewables and oil and gas sectors and there is a relatively high likelihood for an in-combination impact to occur between noise arising from wind farm construction activities and the use of a sub-bottom profiler during a survey. For the purposes of this assessment the most-likely in-combination scenario of a single pile-driving activity being undertaken at the same time as the use of sub-bottom profiler has been assessed.

19.183 The results from the noise modelling indicate that the area of potential impact from PTS is within 23 m of the airgun array (Table 52) and therefore the risk of any harbour porpoise being impacted by sound from a sub-bottom profiler at levels capable of causing the onset of PTS is extremely low. Consequently, there is predicted to be no in-combination impacts with regard to physical injury to harbour porpoise.

Disturbance

19.184 The area of potential disturbance of harbour porpoise is estimated to be 18.3 km^2 (Table 53). This is equivalent to 0.04% of the SCI, 0.68% of the ‘summer’ area and 0.14% of the ‘winter’ area.

19.185 Based on a peak recorded site density of 2.87 ind./km^2, an estimated 53 harbour porpoise could be disturbed by the use of a sub-bottom profiler at any one time. However, the disturbance effects are transient and once the vessel has moved away from an area there is, in effect, no significant disturbance in areas where porpoises were previously impacted.

19.186 Results from the noise modelling indicate that in the event that a sub-bottom profiler is used at the same time as pile-driving is being carried out at an offshore wind farm, there is potential for an in-combination impact to occur across an area of between 800 km^2 and 2,182 km^2 and impact on between 223 and 2,132 harbour porpoise (Table 101). This is equivalent to between 0.07% and 0.63% of the North Sea Management Unit population.

19.187 In the event that concurrent pile-driving is being undertaken at an offshore wind farm at the same time as a sub-bottom profiler is operated, the estimated number of harbour porpoise predicted to be displaced is between 341 and 2,776 individuals, equivalent to between 0.10% and 0.83% of the North Sea Management Unit population (Table 102).

19.188 There is potential for the use of a sub-bottom profiler to be used in-combination with two offshore wind farms pile-driving at the same time. In the event that this occurs the estimated number of harbour porpoises predicted to be displaced is between 273 and 2,284 individuals, equivalent to between 0.08% and 0.68% of the North Sea Management Unit population (Table 103).

Table 101: Estimated area of impact and number of porpoises disturbed from single pile-driving in-combination with a sub-bottom profiler.

Wind farm	Wind farm alone		Sub-bottom profiler in-combination		
	Area of impact (km^2)	No. of ind. displaced (Zonal density)	Area of impact (km^2)	No. of ind. displaced (Ave. density)	No. of ind. displaced (Zonal density)
Hornsea Two	2,794	2,119	2,812	2,132	2,160
Creyke Beck A	791	210	800	223	223
Creyke Beck B	1,498	376	1,516	389	389
Teesside A	1,964	505	1,982	518	518
Teesside B	1,842	461	1,860	474	474

Estimated area of impact from sub-bottom profiler (worst-case) = 18.3 km^2.

'Ave. density' is the estimated average density of harbour porpoise across SCI as a whole of 0.71 ind.km^2 (for sub-bottom profiler impacts only).

'Zonal density' is the wind farm zonal harbour porpoise density: Hornsea Zone of 2.22 ind.km^2 and Doggerbank Zone of 0.71 ind./km^2 (for sub-bottom profiler impacts only).

Table 102: Estimated area of impact and number of porpoises disturbed from concurrent pile-driving in-combination with a sub-bottom profiler.

Wind farm	Wind farm alone		Sub-bottom profiler in-combination		
	Area of impact (km^2)	No. of ind. displaced (Zonal density)	Area of impact (km^2)	No. of ind. displaced (Ave. density)	No. of ind. displaced (Zonal density)
Hornsea Two	3,420	2,735	3,438	2,748	2,776
Creyke Beck A	1,281	338	1,299	341	341
Creyke Beck B	2,042	536	2,060	549	549
Teesside A	2,657	726	2,675	739	739
Teesside B	2,806	739	2,824	752	752

Estimated area of impact from sub-bottom profiler (worst-case) = 18.3 km^2.

'Ave. density' is the estimated average density of harbour porpoise across SCI as a whole of 0.71 ind.km^2 (for sub-bottom profiler impacts only).

'Zonal density' is the mean wind farm zonal harbour porpoise density: Hornsea Zone of 2.22 ind.km^2 and Doggerbank Zone of 0.71 ind./km^2 (for sub-bottom profiler impacts only).

Table 103: Estimated area of impact and number of porpoises disturbed from two wind farms pile-driving in-combination with a sub-bottom profiler.

Wind farm	Wind farm alone		Sub-bottom profiler in-combination		
	Area of impact (km^2)	No. of ind. displaced (Ave. zonal density)	Area of impact (km^2)	No. of ind. displaced (Ave. density)	No. of ind. displaced (Ave. zonal density)
Hornsea Two + Creyke Beck A	3,585	1,825	3,603	1,838	1,852
Hornsea Two + East Anglia Three	5,246	2,261	5,264	2,274	2,284
Creyke Beck A + Triton Knoll	1,672	265	1,690	278	273
Creyke Beck A + East Anglia Three	3,243	575	3,261	588	584
Creyke Beck A + Creyke Beck B	2,289	586	2,307	599	599
Teesside B + Creyke Beck A	2,404	627	2,422	640	640
Teesside A + Teesside B	4,294	752	4,312	765	765
Teesside B + East Anglia Three	3,417	876	3,435	889	885
Creyke Beck A, Creyke Beck B + Teesside A	3,436	914	3,454	927	927

Estimated area of impact from sub-bottom profiler (worst-case) = 18.3 km^2.

'Ave. density' is the estimated average density of harbour porpoise across SCI as a whole of 0.71 $ind.km^2$ (for sub-bottom profiler impacts only).

'Ave. Zonal density' are those presented for in-combination wind farms (Table 77) (for sub-bottom profiler impacts only).

19.189 There is no published figure for an EDR for sub-bottom profilers. The modelling indicates a relatively localised area of no more than 2.5 km in extent within which disturbance is predicted to occur. The area of potential deterrence will therefore likely be smaller than this. The duration of surveys using sub-bottom profilers is also unknown and therefore it is not possible to undertake an assessment based on an EDR and threshold approach.

19.190 The results from the modelling and the assessment above indicate that the use of sub-bottom profilers in-combination with potential pile-driving activities will not significantly increase the area of disturbance from pile-driving on its own and cause potential disturbance to no more than an additional 41 harbour porpoises. Consequently, although there is a potential in-combination impact, the number of individuals predicted to be impacted and the temporary nature of those impacts will not cause an adverse effect.

In-combination offshore wind farm pile-driving and sub-bottom profiler: Conclusions

19.191 It is 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 upon the integrity of the Southern North Sea SCI.

In-combination Assessment: Wind Farm Vessels and Commercial Shipping

19.192 The noise arising from vessels, or their physical presence, can cause the displacement of harbour porpoise from an area. Approximately 4% of SCI and 11% of the 'winter' area has relatively high levels of vessel activity, i.e. greater than ten vessels per day and 4% of the 'winter' area has more than 24 vessels per day. Less than 1% of the 'summer' area has more than seven vessels per day (Figure 20). A total of 269,018 vessel movements were recorded within the SCI in 2015, an average of 737 vessel movements per day (MMO 2017b).

19.193 In 2015 there was, on average, 737 vessel movements per day within the SCI (Para. 6.25). If displacement occurs out to 400 m from each vessel the total area within the SCI that harbour porpoise are displaced is estimated to be 369 km^2. Harbour porpoise are displaced by existing levels of shipping across approximately 1% of the SCI at any one time. Based on an average density of harbour porpoise across the SCI of 0.71 ind./km^2 an estimated 262 harbour porpoise may be temporarily displaced by existing levels of shipping (Table 6); this is equivalent to 0.08% of the North Sea Management Unit population.

19.194 The offshore wind farm industry requires the extensive use of vessels during the construction, operation and decommissioning of offshore wind farms. Between 1,033 and 2,278 vessel movements per year are estimated to be required for each of the consented wind farms during the construction period. During the period of operation between 683 and 4,000 vessels for each consented wind farm may transit the SCI per year (Table 58). Should all the consented offshore wind farms be constructed an estimated 18,740 additional vessel movements per year could occur within the SCI. Therefore, there is the potential for an in-combination impact with existing shipping and other offshore activities within the SCI.

19.195 A precautionary assumption is that all construction at each wind farm will occur within a 12 month period. If this occurs the worst-case scenario is for a potential increase of vessel activity within the SCI by up to 0.8% per year. However, this is unlikely to arise as construction periods may extend over more than one year and therefore the proportion of the overall number of vessel movements within the SCI each year will be lower. The additional vessels associated with the construction of consented offshore wind farms will cause a relatively small increase in the overall number of vessels within the SCI. Once construction is completed there will be no impacts from construction vessels.

19.196 During the operating period an estimated 52 vessels per day associated with offshore wind farm operations may occur within the SCI (Table 58) and therefore increase the daily average number of vessels within the SCI from 737 to 789 (based on the 2015 shipping levels). This could increase the number of harbour porpoise being displaced by shipping from an estimated 262 to 280 individuals; this is equivalent to 0.08% of the North Sea Management Unit population. There is effectively no difference in the proportion of the North Sea Management Unit population displaced by the additional vessel activity associated with operating offshore wind farms within the SCI compared with current levels of shipping within the SCI (See Para. 19.193).

19.197 The additional vessel movements associated with operation of consented offshore wind farms will not contribute significantly to the existing levels of shipping across the SCI and any potential displacement effects to harbour porpoise will be temporary and localised to within 400 m of a transiting vessel (Akkaya Bas *et al.* 2017, Polacheck 1990, Hermannsen *et al*. 2014, Wisniewska *et al*. 2018b).

19.198 Within the site selection document a negative impact on harbour porpoises is reported to occur in areas where 80 vessels per day occur (JNCC and NE 2017). This level of vessel activity is not predicted to arise in areas where vessels associated with the offshore wind farm industry are likely to occur and therefore the additional vessels associated with offshore wind farms will not cause an in-combination impact that will have a negative effect on harbour porpoise.

In-combination offshore wind farm and commercial shipping: Conclusions.

19.199 It is concluded that, based on the estimated number of vessel movements associated with the construction and operation of the consented offshore wind farms and the predicted localised and temporary impacts this may cause within the SCI, potential in-combination impacts between vessels associated with offshore wind farms and existing levels of shipping activity will not have an adverse effect upon the integrity of the Southern North Sea SCI.

In-combination Assessment: Wind Farm Pile-driving and UXO Detonation

19.200 Due to the nature of the sound arising from the detonation of UXO, i.e. a number of single discrete events undertaken over an extended period of time with each blast lasting for a very short duration, harbour porpoise are not predicted to be significantly displaced from an area. Should they occur, any changes in behaviour are predicted to be very short-lived. Existing guidance suggests that disturbance behaviour is not predicted to occur from UXO clearance if undertaken over a short period of time (JNCC 2010b). This assessment is therefore based on the potential for the impacts to cause physical injury to harbour porpoise.

19.201 UXO clearance could be undertaken at the same time as pile-driving at an offshore wind farm is being undertaken such that there is the potential for an in-combination impact. It is recognised that in the event that detonation of UXO is required during construction the developer may stop pile-driving to avoid simultaneous UXO detonation and pile-driving, e.g. EAOWL (2017).

19.202 There are no known planned UXO activities for which Marine Licence applications have been submitted beyond 2018. However, there may be future requirements to clear UXO and there is potential for a number of in-combination impact scenarios to arise during UXO clearance and the construction of offshore wind farms. The most probable in-combination scenario is predicted to be the detonation of a single item of UXO at the same time as a single pile-driving operation is being undertaken at another offshore wind farm. Each future UXO clearance program will require a Marine Licence and will be subject to HRA requirements at the time the application is made. In the event that alternative in-combination scenarios arise, e.g. more than one pile driving activity or more than one UXO clearance programme is being undertaken, the HRA for the yet unplanned activity will address the in-combination impacts at the time.

19.203 Table 104 presents the estimated number of harbour porpoise at risk of the onset of PTS across a range of potential in-combination impacts on harbour porpoise from UXO detonation and pile-driving. The potential for an in-combination impact occurring is based on the currently known construction schedules presented in Figure 52. Although there is a theoretical possibility for other in-combination impacts to arise, due to the uncertainty over the construction schedules for Tier 3 developments that do not have a CfD, it is considered unlikely that in-combination impacts will arise between projects in Tiers 1 and 2 and those in Tier 3. The estimated number of harbour porpoise at risk of PTS from UXO is presented in Table 74 and for pile-driving is the worst-case scenario based on maximum hammer energies presented in Section 18. It is assumed that there is no overlap in the areas potentially impacted.

Table 104: Estimated number of harbour porpoise at risk from the onset of PTS in-combination with UXO detonation and pile-driving at consented offshore wind farms.

Wind farm		UXO NEQ (kg)						
UXO location	Pile-driving	10	20	50	100	250	500	1,000
Hornsea Two	Creyke Beck A	86	132	234	366	667	1,053	1,667
	Creyke Beck B	87	132	235	367	668	1,054	1,667
	Teesside A	117	162	265	397	698	1,084	1,697
	Teesside B	117	162	265	397	697	1,084	1,697
	East Anglia Three	79	124	227	359	659	1,046	1,659
Creyke Beck A	Hornsea Two	42	57	90	132	228	352	548
	Triton Knoll	27	41	74	116	213	336	532
	Creyke Beck B	35	49	82	124	220	344	540
	Teesside A	65	79	112	154	250	374	570
	Teesside B	64	79	112	154	250	374	570
	East Anglia Three	26	41	74	116	212	336	532
Creyke Beck B	Hornsea Two	42	57	90	132	228	352	548
	Triton Knoll	27	41	74	116	213	336	532
	Creyke Beck A	34	39	72	114	210	334	530
	Teesside A	65	79	112	154	250	374	570
	Teesside B	41	64	79	112	154	250	374
	East Anglia Three	26	41	74	116	212	336	532
Teesside A	Hornsea Two	42	57	90	132	228	352	548
	East Anglia Three	26	41	74	116	212	336	532
	Teesside B	64	79	112	154	250	374	570
	Creyke Beck A	34	49	81	124	220	343	539
	Creyke Beck B	35	49	82	124	220	344	540
Teesside B	Hornsea Two	42	57	90	132	228	352	548
	Teesside A	65	79	112	154	250	374	570
	Creyke Beck A	34	49	81	124	220	343	539
	Creyke Beck B	35	49	82	124	220	344	540
	East Anglia Three	26	41	74	116	212	336	532

19.204 The results indicate a large range of potential impacts depending on the size of the explosive charge and the in-combination scenario. The worst-case scenario indicates that up to 1,667 harbour porpoise could be at risk of PTS from an in-combination impact. This is equivalent to

0.5% of the North Sea Management Unit population. This is below the 1.0% or 1.7% levels at which ASCOBANS indicates a population level decline is likely to occur.

19.205 The number of individuals at risk of PTS arises predominantly from the detonation of UXO without any mitigation in place. However, as discussed in Paragraph 18.158, mitigation measures to reduce the level of impact from UXO detonation is a Marine Licence condition and therefore significantly reduces the potential in-combination impact to a level below which there will not be an adverse effect.

In-combination offshore wind farm pile-driving and UXO detonation: Conclusions.

19.206 It is concluded that Marine Licence conditions will be in place that require effective mitigation to reduce the risk of any harbour porpoise being in the area within which the onset of PTS is predicted to arise from both UXO detonations and pile-driving. Consequently, potential in-combination impacts between offshore wind farm pile-driving and UXO detonations will not have an adverse effect upon the integrity of the Southern North Sea SCI.

In-combination assessment: offshore wind farm UXO detonation and seismic surveys

19.207 Within the SCI there is potential for the detonation of UXO and a seismic survey to occur simultaneously resulting in an in-combination impact. Due to the nature of the sound arising from the detonation of UXO, i.e. a number of single discrete events undertaken over an extended period of time with each blast lasting for a very short duration, harbour porpoise are not predicted to be significantly displaced from an area. Any changes in behaviour, due to disturbance, will also be very short-lived. Existing guidance suggests that disturbance behaviour is not predicted to occur from UXO clearance if undertaken over a short period of time (JNCC 2010b). This assessment is therefore based on the potential for the impacts to cause physical injury to harbour porpoise.

19.208 The results from the noise modelling undertaken for the seismic surveys indicate that mean distance at which the onset of PTS will arise is within 500 m of the airgun (Table 50).

19.209 All seismic surveys relating to oil and gas activities require consent from the competent authority. Every consent issued has, as a condition, a requirement for mitigation measures to be complied with in order to reduce the risk of physical injury to marine mammals. Specific mitigation conditions included in the consents are based on the JNCC *guidelines for minimising the risk of injury to marine mammals from geophysical surveys* (JNCC 2017d). The guidelines require the use of Marine Mammal Observers and, if appropriate, the use of PAM technology to reduce the risk of marine mammals being present within 500 m of the airguns at the start of the survey. All seismic surveys are also required to undertake a soft-start procedure. The firing of airguns is therefore started at relatively low energy levels, and the energy levels are gradually increased over a period of time. This soft-start is designed to allow marine mammals, including harbour porpoise, to move away from the airguns before the sound levels capable of causing physical injury are reached. Consequently, there is a very low likelihood of any marine mammals being within the area where the onset of PTS is predicted to occur. Therefore, there are no in-combination impacts between UXO detonation and seismic surveys.

In-combination offshore wind farm UXO detonation and seismic surveys: Conclusions.

19.210 It is concluded that licence conditions will be in place that require effective mitigation to reduce the risk of any harbour porpoise being in the area within which the onset of PTS is predicted to arise from both UXO detonations and seismic surveys. Consequently, potential in-combination impacts between UXO detonations and seismic surveys will not have an adverse effect upon the integrity of the Southern North Sea SCI.

In-combination Assessment: Wind Farm Pile-driving and Commercial Fisheries

19.211 Between 1,235 and 1,990 harbour porpoise are estimated to die each year due to entanglement in fishing nets across the North Sea and the current level of impact risk from bycatch is considered to be high (JNCC & NE 2016, OSPAR 2017a). No direct mortality is predicted to occur from the construction of offshore wind farms but there is potential for physical impacts and disturbance effects that could cause a potential in-combination impact.

19.212 Studies undertaken using population modelling indicate that impacts from disturbance due to wind farm construction across the North Sea will not cause a significant increase in harbour porpoise mortality (e.g. Nabe-Nielsen *et al.* 2018). Therefore, it is predicted that there will not be any significant additive in-combination mortality with impacts from commercial fisheries that would affect the population of harbour porpoise.

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.

In-combination offshore wind farm pile-driving and commercial fisheries: Conclusions.

19.215 Based on published modelling studies indicating no significant increase in harbour porpoise mortality due to wind farms and the existing levels of fishing not impacting on the conservation status of harbour porpoise within the SCI it is concluded that the potential in-combination impacts between commercial fisheries bycatch and offshore wind farm pile-driving will not have an adverse effect upon the integrity of the Southern North Sea SCI.

20 CONCLUSIONS

20.1 The Secretary of State has carefully considered all of the information available in order to undertake a Habitats Regulations Assessment. He considers the Projects subject to this Review of Consents have the potential to cause a Likely Significant Effect alone and in-combination with other plans or projects on the qualifying species of the Southern North Sea SCI.

20.2 The Secretary of State has undertaken an Appropriate Assessment in respect of the site's Conservation Objectives to determine whether the Projects, either alone or in-combination with other plans or projects, will result in an adverse effect on integrity.

20.3 The Secretary of State has undertaken a robust assessment using all of the information available to him.

20.4 Having considered all of the information available to him and the mitigation measures secured through the DCOs and dMLs, including those that require effective mitigation measures to be in place that reduce the risk of any harbour porpoise occurring within the range at which it is predicted the onset of PTS could occur and a pre-construction condition (requiring a Site Integrity Plan (SIP)) to be attached to each relevant project's Marine Licence by the MMO that limit each wind farm to the parameters that have been assessed by this HRA. The Secretary of State has concluded that the Projects subject to this review will not have an adverse effect on integrity on the Southern North Sea SCI, either alone or in-combination with other plans or projects.

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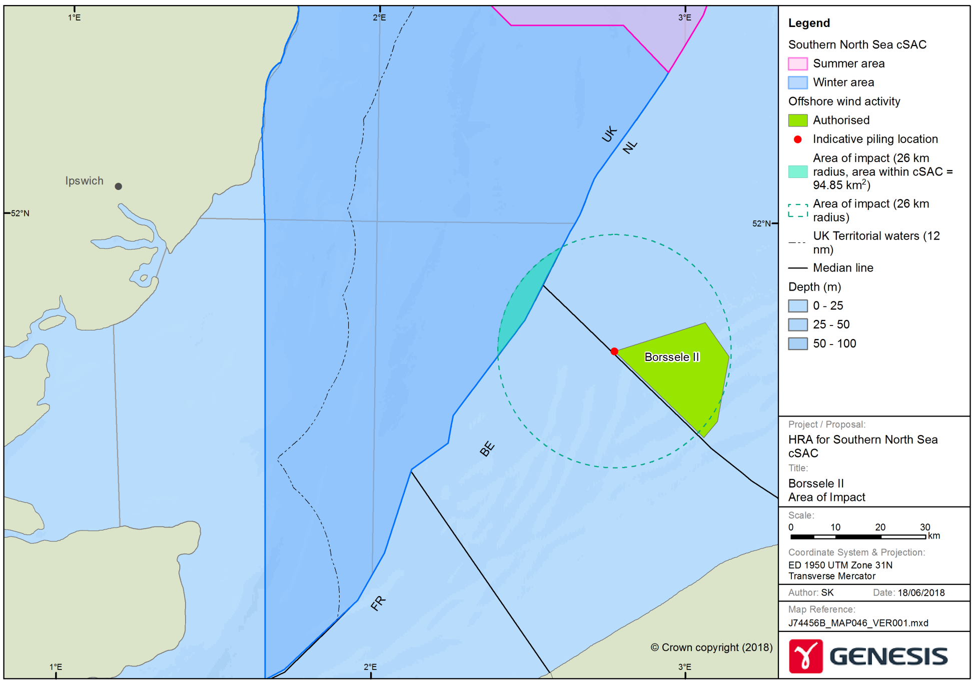
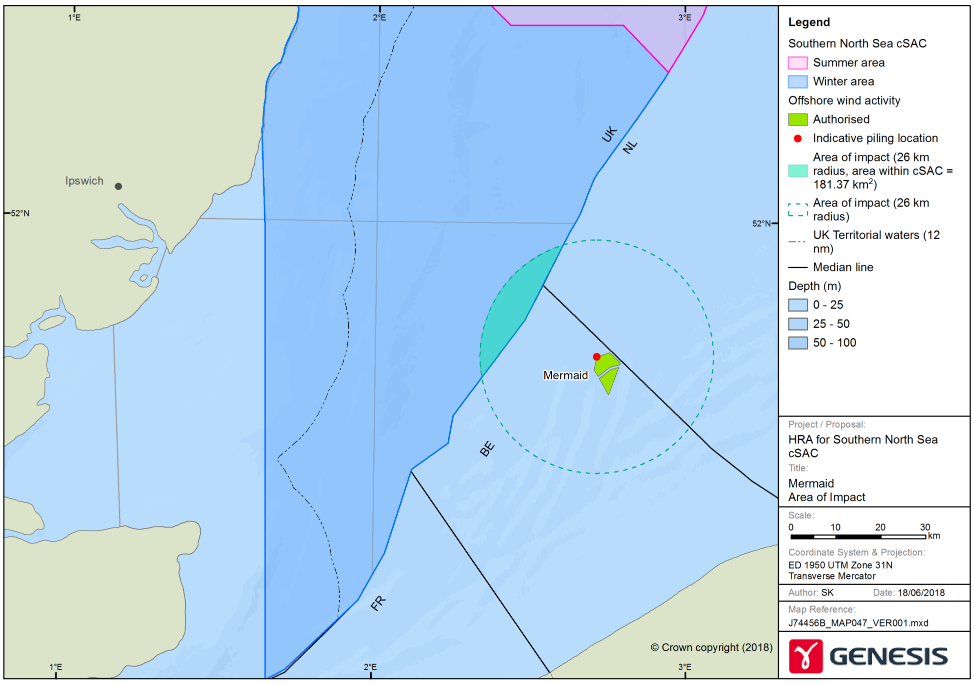
APPENDIX A: EFFECTIVE DETERRENT RADIUS FOR BORSSELE II AND MERMAID OFFSHORE WIND FARMS



Appendix A. Figure 1: The maximum area of SCI overlapping within 26 km of the Borssele II offshore wind farm.



Appendix A. Figure 2: The maximum area of SCI overlapping within 26 km of the Mermaid offshore wind farm.

APPENDIX B: EAST ANGLIA THREE NOISE MODELLING RESULTS AND HABITAT IMPACTS.

The consent for East Anglia Three Wind Farm is not subject to this review. The results from the noise modelling and EDR approach are presented here to support potential in-combination impacts that may arise with other offshore wind farms the consents for which are subject to this review.

The East Anglia Three offshore wind farm lies wholly within the SCI. There is no confirmed construction date but pile-driving is unlikely to start before 2020. Precise information on the timing and duration of pile-driving is not available.

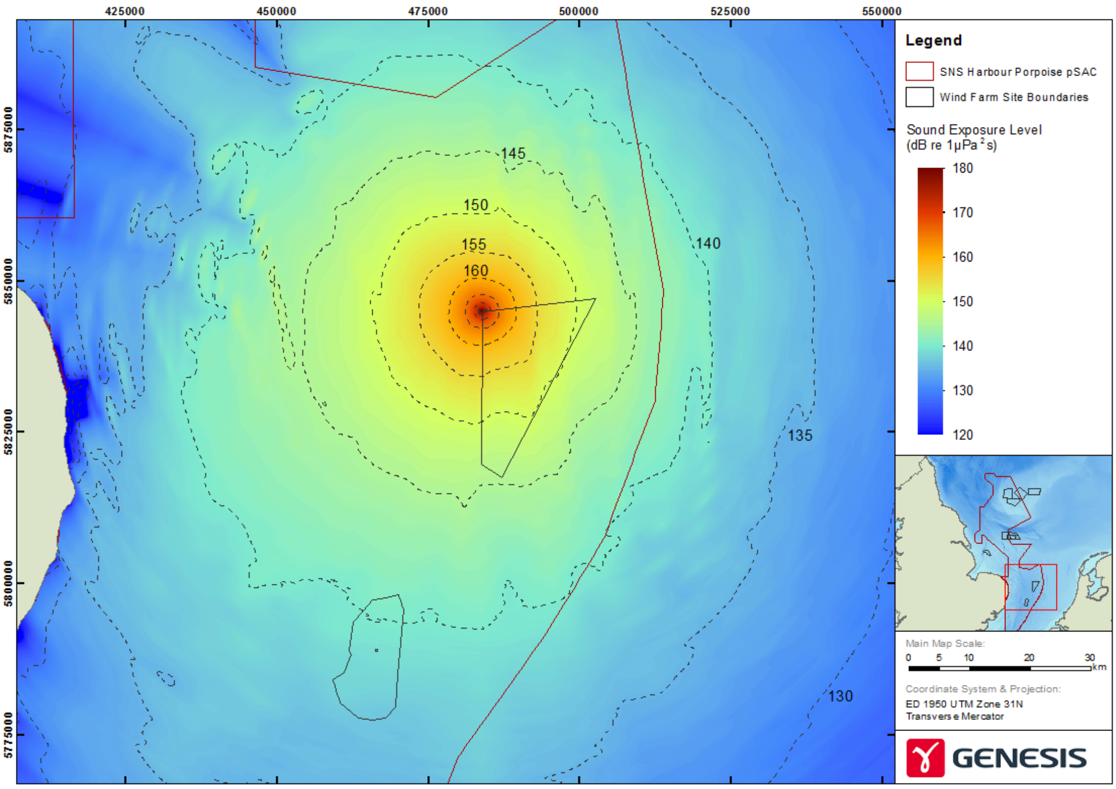
Physical Injury

Results from the sound modelling indicate that there is potential for sound levels arising from pile-driving to cause the onset of PTS from between 0.69 km and 1.39 km depending on the hammer energy used to install the pile and the location of the pile-driving within the wind farm area. Noise capable of causing the onset of PTS may extend over an area of between 1.5 km^2 and 6.1 km^2 (Table 47).

The harbour porpoise density across the wind farm area is estimated to be 0.29 ind./km^2 (Table 6). Based on this density, between <1 and 2 harbour porpoise are predicted to be at risk of PTS at the start of pile-driving activity, this is equivalent to no more than 0.0005% of the North Sea Management Unit population.

Displacement

Displacement of harbour porpoise may extend from between 25.1 km and 28.9 km and cover an area of between 1,985 km^2 and 2,452 km^2 depending on the pile-driving location and the hammer energy used to install the pile (Appendix B. Figure 1, Appendix B. Table 1). Based on results using a dose response curve and a zonal specific mean density of 0.29 ind./km^2, the estimated number of harbour porpoise predicted to be displaced is between 198 and 248 individuals; 0.06% and 0.07% of the North Sea Management Unit population. Within the SCI it is estimated that between 198 and 248 harbour porpoise may be displaced by pile-driving during construction of the wind farm.



Appendix B. Figure 1: East Anglia Three single pile-driving (unweighted SEL for pile-driving 3,000 kJ).

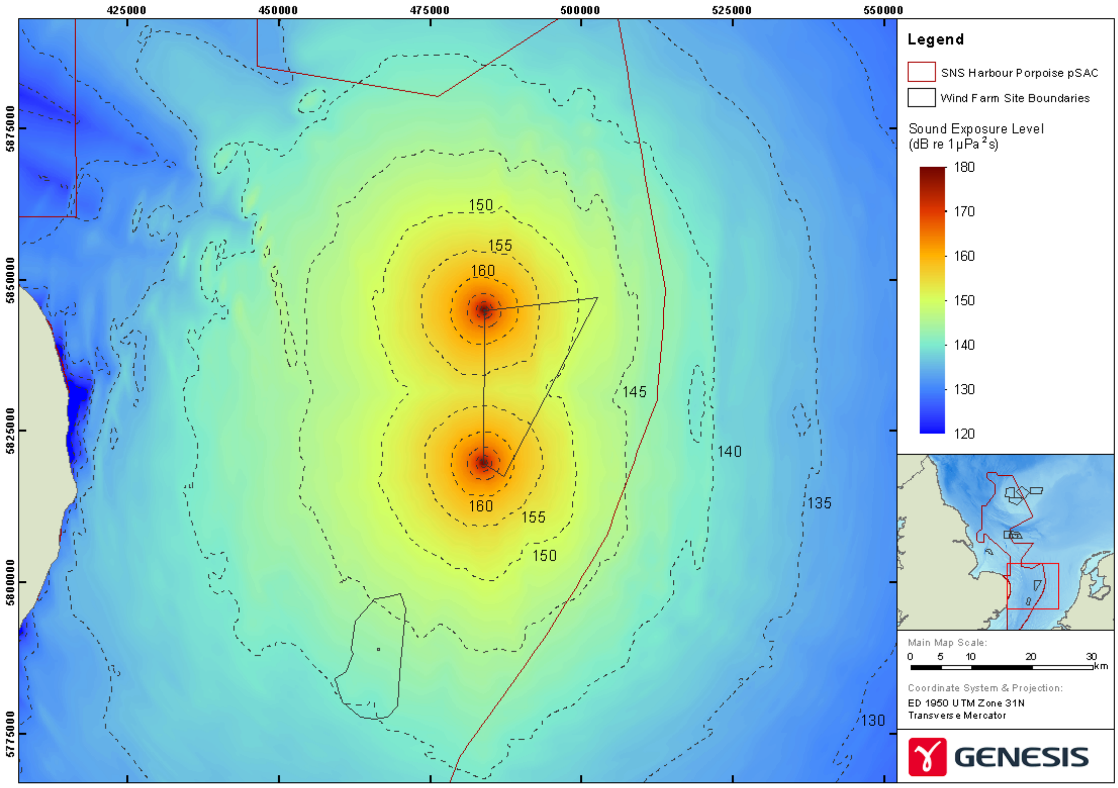
Appendix B. Table 1: Estimated number of harbour porpoise predicted to be displaced by pile-driving from East Anglia Three offshore wind farm in total and within the SCI

Location	East Anglia Three							
	2,400 kJ				3,000 kJ			
	Area (km^2)	No. of Ind.	Area within SCI (km^2)	No. of Ind. Within SCI	Area (km^2)	No. of Ind.	Area within SCI (km^2)	No. of Ind. Within SCI
1	2,018	203	2,018	203	2,452	248	2,452	248
2	1,985	198	1,985	198	2,401	241	2,370	238
Con.	3,185	335	3,185	335	3,744	396	3,713	394

Harbour porpoise density of 0.29 ind./km^2

Con. = Concurrent pile-driving

In the event concurrent pile-driving is undertaken at two locations within the SCI (Appendix B. Figure 2) the estimated number of harbour porpoise predicted to be impacted is between 335 and 396 individuals. Between 0.10% and 0.12% of the North Sea Management Unit population may be impacted. Within the SCI no more than 394 harbour porpoise are predicted to be impacted from concurrent pile-driving.

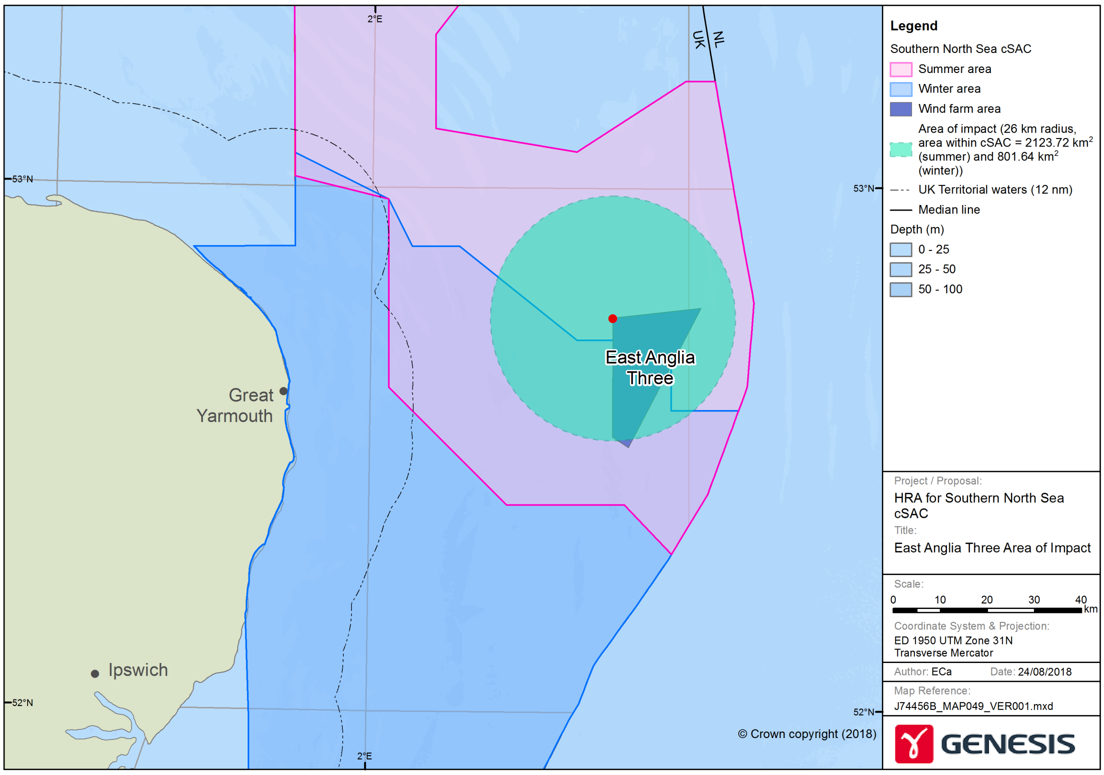


Appendix B. Figure 2: East Anglia Three concurrent pile-driving (unweighted SEL for pile-driving 3,000 kJ).

Effective Deterrent Radius

21.1 The East Anglia Three offshore wind farm lies wholly within the SCI and, under the worst-case scenario, the whole of a 26 km EDR will be within the 'summer' area of the SCI and impact an area of 2,123.7 km^2 (Appendix B. Figure 3). However, the EDR for turbines installed towards the north-eastern area of the wind farm area only partially overlaps the SCI. Consequently, the assessment based on all turbines impacting the maximum EDR is worst-case.

21.2 As a worst-case, noise from pile-driving at East Anglia Three may cause displacement over 5.7% of the SCI as a whole and 7.9% of the 'summer' area. Within the 'winter' area the area impacted is 801.6 km^2, equivalent to 6.3% of the 'winter' area.



Appendix B. Figure 3: Area of effective deterrence within the Southern North Sea SCI from pile-driving at East Anglia Three.

21.3 The timing and duration of the installation of the wind turbine foundations is not known. However, construction of the wind farm may start between 2020 and 2025, although the installation of turbines may occur after these dates.

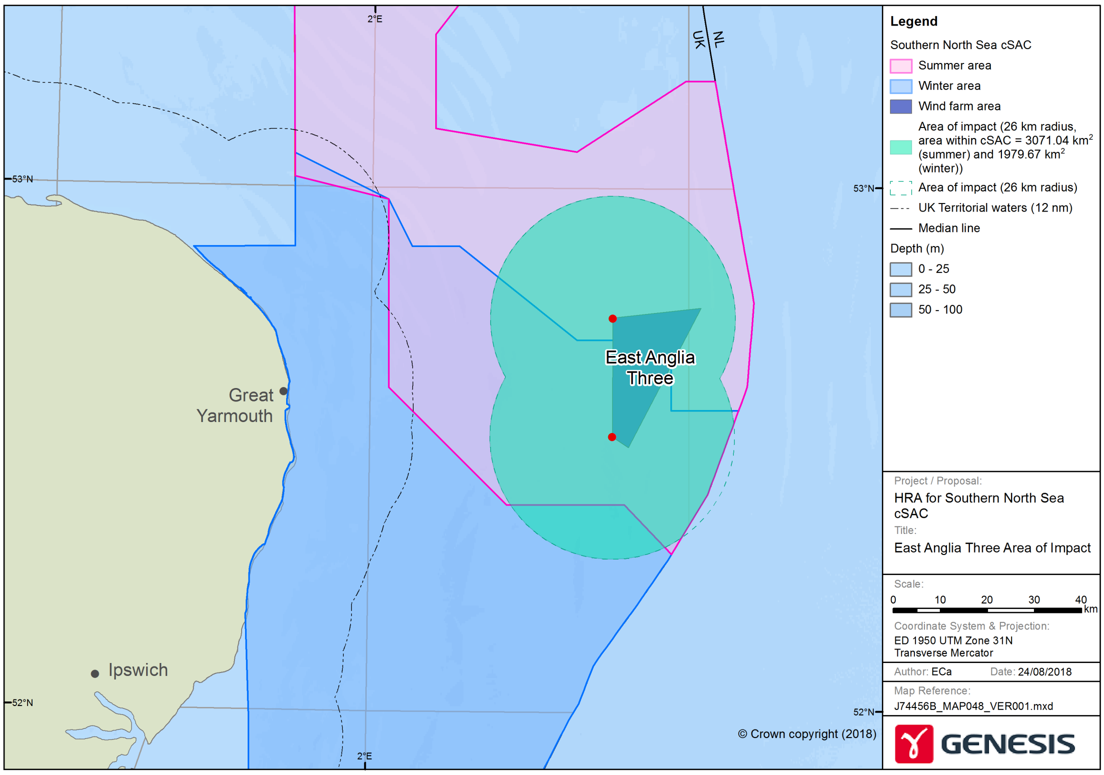
21.4 The worst-case scenario used for the purposes of this assessment assumes that one turbine is installed per day over a period of 172 days and the installation of all turbines impact on the maximum EDR of 26 km. Consequently, during any one day, a maximum area equivalent to 7.9% of the ‘summer’ area or 6.3% of the ‘winter’ area may be affected. Over the course of a season the average seasonal spatial overlap during the summer is also 7.5% and during the winter 6.0% (Appendix B. Table 2).

Appendix B. Table 2: Seasonal spatial overlap for East Anglia Three offshore wind farm within the SCI.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
Single pile-driving					
'summer'	2,123.7	7.9	172	174	7.5
'winter'	801.6	6.3	172	174	6.0
Concurrent pile-driving (worst-case)					
'summer'	3,071.4	11.4	172	88	5.4
'winter'	1,979.7	15.6	172	88	7.5

21.5 In the event concurrent pile-driving occurs there is potential for a larger area of the SCI to be impacted over a shorter period of time. The maximum area within the SCI that could be impacted is presented in Appendix B. Figure 4. The scenario used for the purposes of this concurrent pile-driving assessment assumes that two turbines are installed per day over a period of 86 days, with pile-driving occurring only within either the summer or winter periods. The maximum total area impacted during the summer by concurrent pile-driving is calculated to be 3,071 km^2 and in the winter 1,979.7 km^2.

21.6 The worst-case scenario is that during any one day a maximum area equivalent to 11.4% of the 'summer' area may be impacted. Over the course of a season the average seasonal spatial overlap is 5.4%. Similarly, in the winter area the maximum area impacted is equivalent to 15.6% of the winter area and a seasonal spatial overlap of 7.5%.



Appendix B. Figure 4: Area of effective deterrence within the Southern North Sea SCI from concurrent pile-driving at East Anglia Three.

Physical impact to the seabed

21.7 East Anglia Three offshore wind farm area lies wholly within the SCI. An estimated 0.33 km^2 of seabed may be physically impacted by the presence of turbines and associated infrastructure (based on 172 pin-piled jacket foundations) and a further 0.55 km^2 of cable protection may be required (Table 95). Consequently, an estimated 0.002% of the SCI habitat could be physically impacted.

21.8 An estimated 15.46 km^2 of seabed may be temporarily impacted by the inter array cables and the export cable route within the SCI. The impacts on the habitat from the trenching of cable will be temporary with the habitat recovering following completion of the activities.

APPENDIX C: TRITON KNOLL NOISE MODELLING RESULTS.

The consent for Triton Knoll offshore Wind Farm is not subject to this review. The results from the noise modelling and EDR approach are presented here to support potential in-combination impacts that may arise with other offshore wind farms the consents for which are subject to this review.

The Triton Knoll offshore wind farm lies wholly outwith the SCI. There is no confirmed construction date but pile-driving is unlikely to start before 2020. Precise information on the timing and duration of pile-driving is not available.

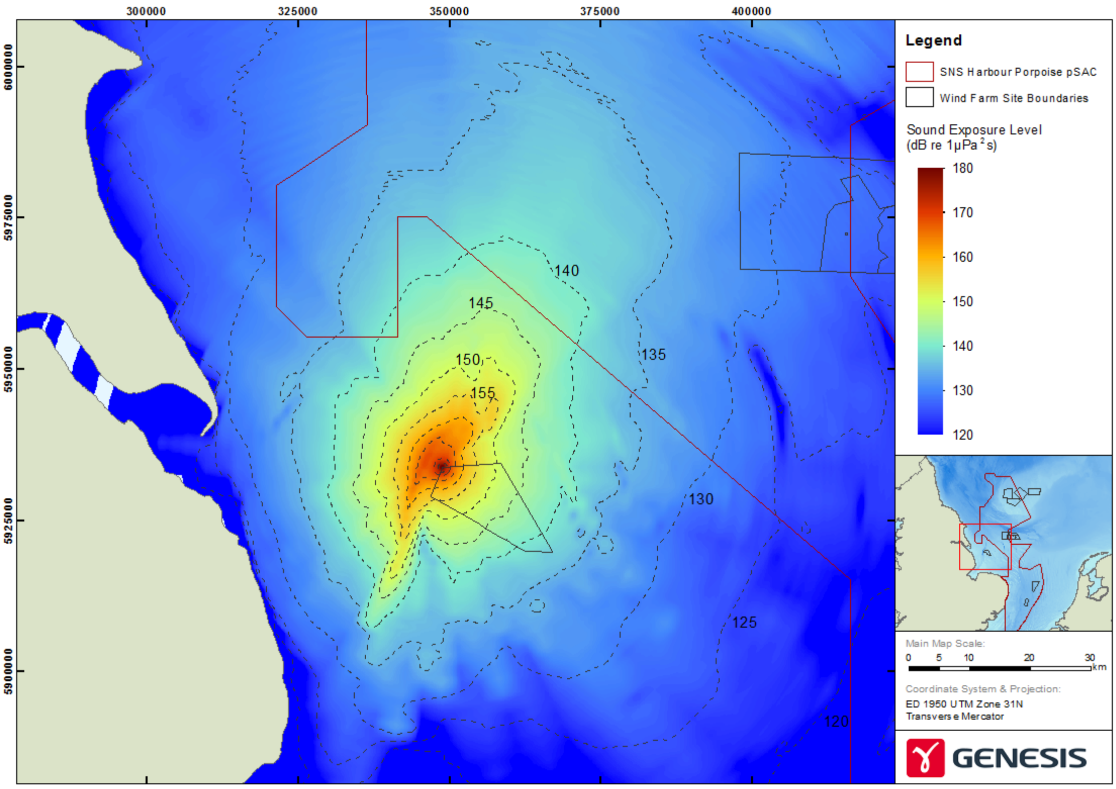
Physical Injury

Results from the sound modelling indicate that there is potential for sound levels arising from pile-driving to cause the onset of PTS from between 1.56 km and 2.54 km depending on the hammer energy used to install the pile and the location of the pile-driving within the wind farm area. Noise capable of causing the onset of PTS may extend over an area of between 7.8 km^2 and 20.5 km^2 (Table 43).

The harbour porpoise density across the wind farm area is estimated to be 0.11 ind./km^2 (Table 6). Based on this density, between one and two harbour porpoise are predicted to be at risk of PTS at the start of pile-driving activity, this is equivalent to no more than 0.0005% of the North Sea Management Unit population.

Displacement

Displacement of harbour porpoise may extend from between 16.1 km and 16.9 km and cover an area of between 689.9 km^2 and 934.5 km^2 depending on the pile-driving location and the hammer energy used to install the pile (Appendix C. Figure 1, Appendix C. Table 1). Based on results using a dose response curve and a zonal specific mean density of 0.11 ind./km^2, the estimated number of harbour porpoise predicted to be displaced is between 27 and 39 individuals; 0.008% and 0.01% of the North Sea Management Unit population. Within the SCI it is estimated that no harbour porpoise will be displaced by pile-driving during construction of the wind farm.



Appendix C. Figure 1: Triton Knoll single pile-driving (unweighted SEL for pile-driving 3,000 kJ).

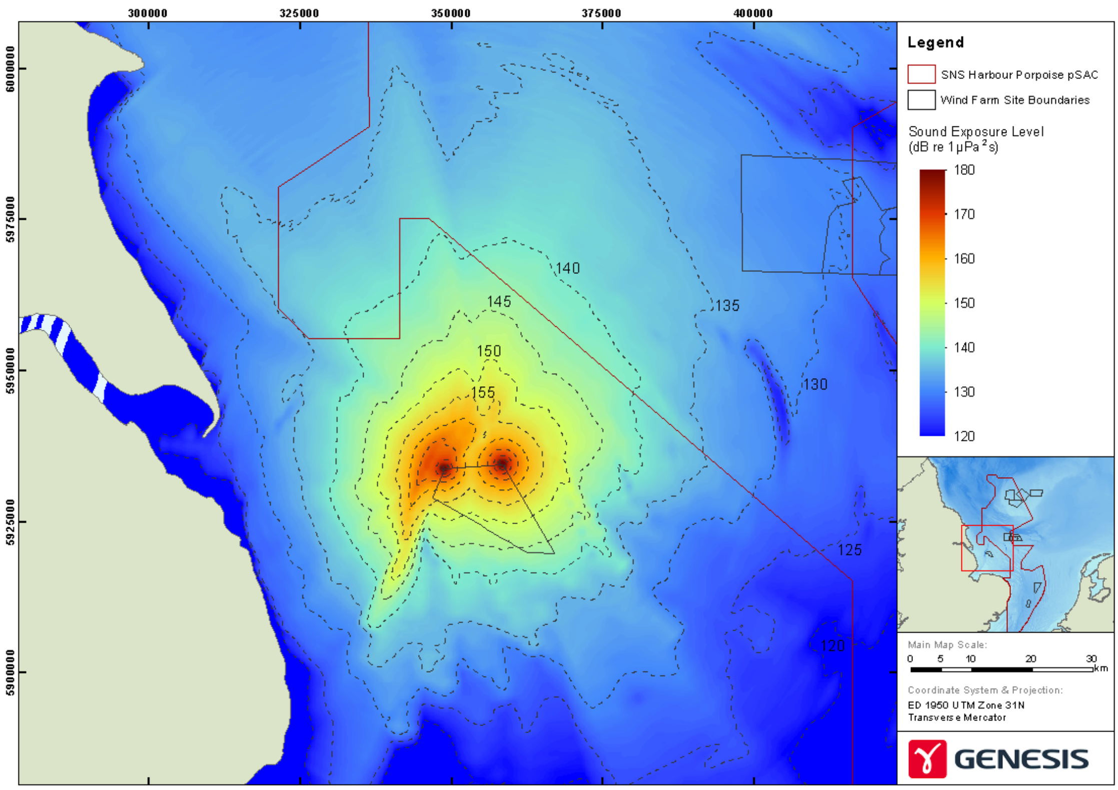
Appendix C. Table 1: Estimated number of harbour porpoise predicted to be displaced by pile-driving from Triton Knoll offshore wind farm in total and within the SCI.

Location	Triton Knoll							
	2,700 kJ				4,000 kJ			
	Area (km^2)	No. of Ind.	Area within SCI (km^2)	No. of Ind. Within SCI	Area (km^2)	No. of Ind.	Area within SCI (km^2)	No. of Ind. Within SCI
1	699.9	27	0	0	934.5	37	0	0
2	689.9	30	0	0	881.0	39	0	0
Con.	947.1	43	0	0	1,192	54	0	0

Harbour porpoise density of 0.11 ind./km^2

Con. = Concurrent pile-driving

In the event concurrent pile-driving is undertaken at two locations within the SCI (Appendix C. Figure 2) the estimated number of harbour porpoise predicted to be impacted is between 43 and 55 individuals. Between 0.01% and 0.02% of the North Sea Management Unit population may be impacted. Within the SCI no harbour porpoise are predicted to be impacted from concurrent pile-driving.



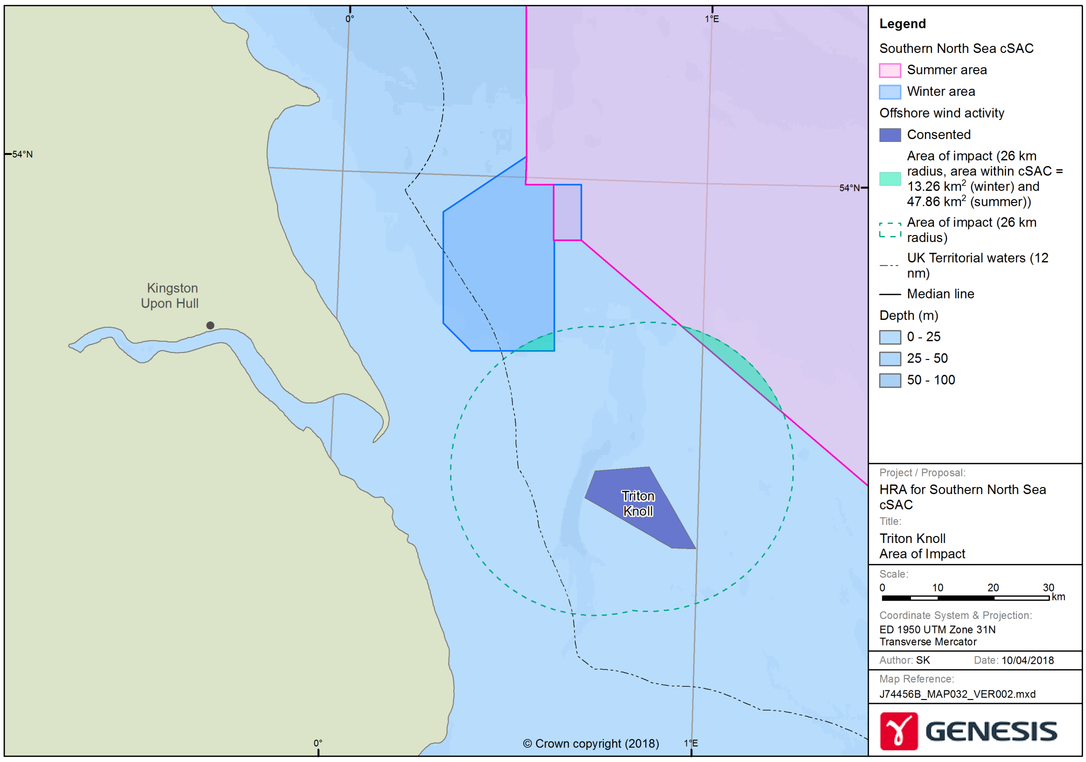
Appendix C. Figure 2: Triton Knoll concurrent pile-driving (unweighted SEL for pile-driving 3,000 kJ).

Effective Deterrent Radius

A total of 31.7 km^2 of the Triton Knoll wind farm area (the Triton Knoll Order Limits) lies within 26 km of the SCI (TKOWFL 2018).

The 26 km EDR overlaps a total area of 61.12 km^2 of the SCI, of which 47.86 km^2 is within the 'summer' area and 13.26 km^2 is within the 'winter area (Appendix C. Figure 3). It is noted that these figures produced for this assessment are higher than those previously produced by the developer, where it has been calculated that between 37.43 km^2 and 45.59 km^2 of the 'summer' area may be impacted and between 9.15 km^2 and 12.63 km^2 of the 'winter' area (TKOWFL 2017, 2018). For the purposes of in-combination assessments the larger values have been used. However, the differences between the two sets of calculations are slight and do not affect this assessment.

As a worst-case, noise from pile-driving may cause displacement over 0.16% of the SCI as a whole, 0.18% of the 'summer' area and 0.10% of the winter area. This is based on pile-driving a turbine foundation at the closest boundary to either the 'summer' or 'winter' areas. The installation of other turbines within the Triton Knoll wind farm area will have a reduced level of impact within the SCI.



Appendix C. Figure 3: Area of effective deterrence within the Southern North Sea SCI from pile-driving at Triton Knoll offshore wind farm.

Installation of the wind turbine foundations is planned to take place over a period of 12 months between 1 December 2019 and 31 November 2020 and therefore encompass both summer (April to September) and winter (October to March) seasons. Based on the consented project design, up to 49 wind turbines will occur within the EDR area that overlaps the 'summer' area of the SCI and 45 turbines within the area that overlaps the 'winter' area, this includes four turbines that occur in an area that the EDR overlaps both 'summer' and 'winter' areas and are therefore included in both (TKOWFL 2018).

It is anticipated that it will take approximately four hours to install each pile and, assuming concurrent pile-driving is not occurring, one pile will be installed per day (TKOWFL 2018). It is not known when each of the turbines will be installed and, although unlikely, it is possible that all 49 wind turbines that could impact the 'summer' area will be installed during the summer period. Likewise, all 45 turbines that could impact the 'winter' area could be installed during the winter period. Assuming that once pile-driving has commenced and displacement has occurred, harbour porpoise do not return to the impacted area within 48 hrs, the worst-case scenario is that there will be displacement of harbour porpoise within the summer area for a period of 51 days during the summer period and 47 days in the 'winter' during the winter season. This is based on an assumption that pile-driving occurs sequentially every day and that the effects of displacement occur for two extra days following cessation of pile-driving.

Over the course of a summer period it is estimated that 0.18% of the 'summer' area will be affected for 50 days. Therefore, over the course of a season the seasonal spatial overlap is 0.05%. Over the course of a winter period it is estimated that 0.1% of the 'winter' area will be affected for 46 days. Therefore, over the course of a season the seasonal spatial overlap is 0.02% (Appendix C. Table 2).

The final project design envelope is smaller than the consented project and the number of wind turbines within the area that could affect the SCI is reduced to no more than 14 turbines (TKOWFL 2018). Based on the similar assumptions made above, disturbance within 'winter' or 'summer' areas could occur over a period of 16 days. Therefore, over the course of a season, the seasonal spatial overlap within the 'summer' area is 0.02% and 0.009% of the 'winter' area (Appendix C. Table 2).

Appendix C. Table 2: Seasonal spatial overlap for Triton Knoll offshore wind farm within the SCI.

SCI area	Maximum area of SCI impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Seasonal spatial overlap (as % spatial overlap)
Consented					
'summer'	47.86	0.18	49	51	0.05
'winter'	13.26	0.10	45	47	0.02
CfD final project design					
'summer'	47.86	0.18	14	16	0.02
'winter'	13.26	0.10	14	16	0.009

Physical impacts to the seabed

The Triton Knoll offshore wind farm lies outwith the boundaries of the SCI and there will be no physical impacts to the site.