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 SAC.

September 2020

CONTENTS

FIGURES

TABLES

ACRONYMS

%	Percent
<	Less Than
>	More Than
µ	Micro
μPA^2s	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 for 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 (now Orsted)
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 Range/Radius
EMF	Electromagnetic Field
EIA	Environmental Impact Assessment
EPS	European Protected Species
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 and formally designated as a Special Area of Conservation (SAC) in February 2019 (JNCC 2019a). The Southern North Sea SAC 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, the law requires certain existing consents to be reviewed, such that existing consents take into account the protections afforded to the new SCI/SAC (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 for 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 Southern North Sea SAC.

The purpose of this Assessment is to determine whether consented offshore wind farm developments will adversely affect the integrity of the Southern North Sea SAC. The consented developments relevant to this assessment are those in the North Sea which may cause a significant effect on the SAC and are not directly connected with, or necessary to, the management of the SAC.

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.

A draft HRA, which took account of stakeholder responses to the Call for Information, was published by BEIS on 1st November 2018 and consulted on until 13 December 2018. Within this consultation period BEIS held a second stakeholder workshop on 29 November 2018.

In light of the consultation responses received in 2018 and due to the need to consult specifically on a proposed modification to a (deemed) marine licence, the MMO and BEIS ran a third consultation exercise between 30 January 2019 and 27 February 2019.

Any additional information gathered through consultations have been used to strengthen the approach used to undertake this HRA. Further information on how the Secretary of State has addressed key issues raised by stakeholders can be found within the Secretary of State's Decision Letter, which accompanies this HRA.

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 SAC. One additional project, East Anglia Three, lies within the SAC 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 SAC, 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 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 or 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 vessels 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 SAC 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) (see Appendix G) will ensure that the parameters used in order to undertake this assessment will not be exceeded without further assessment and consent.

1 INTRODUCTION

1.1 This is a record of the Habitats Regulations Assessment (HRA), undertaken by the Secretary of State for the Department for 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 SAC (Special Area of Conservation).

1.2 The purpose of this Assessment is to determine whether consented offshore wind farm developments will adversely affect the integrity of the Southern North Sea SAC. The consented developments relevant to this assessment are those in the North Sea which may cause a significant effect on the SAC and are not directly connected with, or necessary to, the management of the SAC.

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 SAC overlays the geographical extent of two relevant sets of regulations (the 'Habitats Regulations') that transpose the Habitats Directive and Birds Directive into UK law:

- The Conservation of Habitats and Species Regulations 2017[1]
- The Conservation of Offshore Marine Habitats and Species Regulations 2017[2].

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 (HRA).

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. Under regulation 65(4), nothing in the review can affect anything done under the consent before 30 January 2017 - the date on which the cSAC was notified to the European Commission.

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] S.I. 2017/1012
[2] S.I. 2017/1013.

1.12 Activities consented under the Marine and Coastal Access Act 2009, including deemed marine licences 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). In February 2019 the site was formally designated as a SAC (JNCC 2019a).

2.2 The Southern North Sea SAC 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). 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 and 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 SAC potentially supported 17.5% of the harbour porpoise population within the UK sector of the North Sea Management Unit [3] (JNCC 2017a).

[3] 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.

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 SAC (Heinänen and Skov 2015).

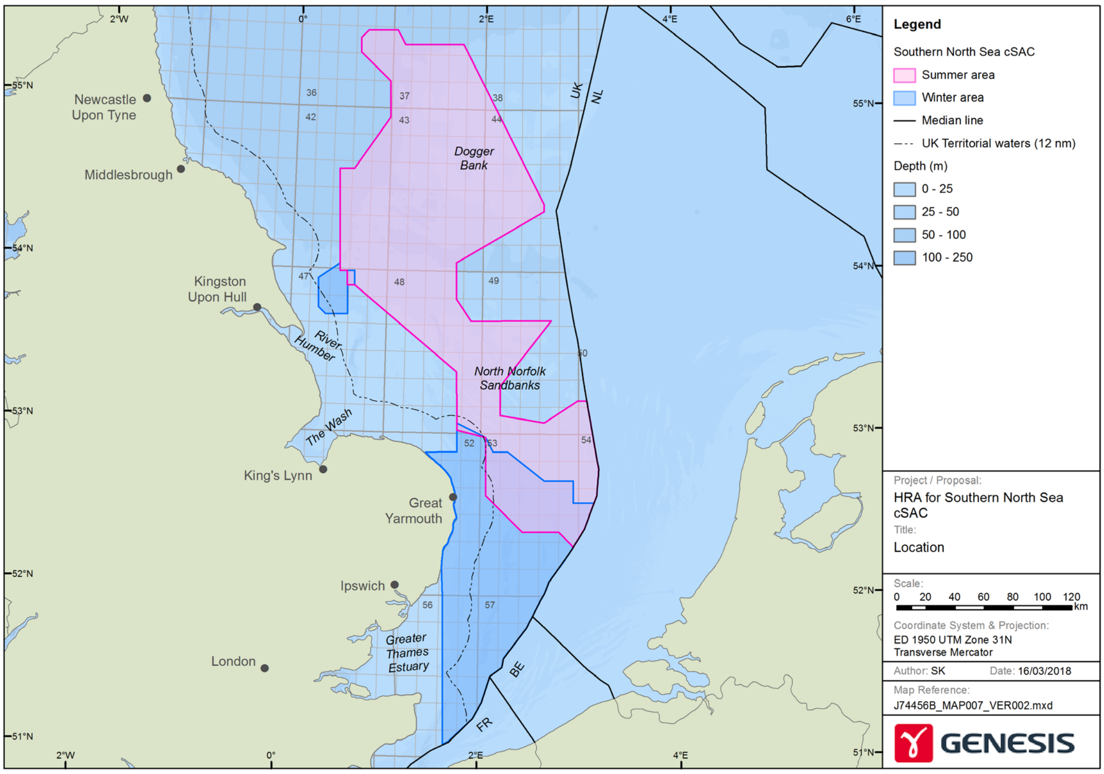


Figure 1: Southern North Sea SAC.

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 A draft HRA (BEIS 2018d), which took account of stakeholder responses to the Call for Information, was published by BEIS on 1st November 2018 and consulted on until 13 December 2018. Within this consultation period BEIS held a second stakeholder workshop on 29 November 2018.

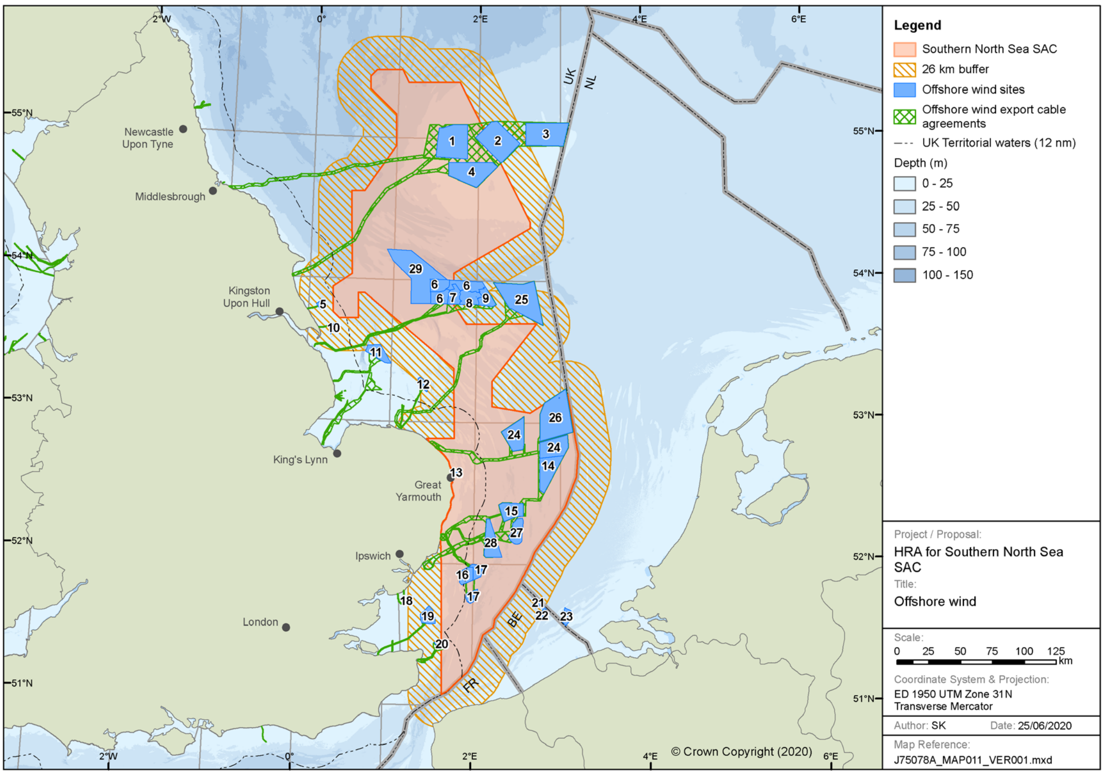
3.4 In light of the consultation responses received in 2018 and due to the need to consult specifically on a proposed modification to certain (deemed) marine licences, the MMO and BEIS ran a third consultation exercise between 30 January 2019 and 27 February 2019 (MMO 2019).

3.5 All additional information gathered through the above consultation methods have been used to strengthen the approach to undertake this HRA. Further information on how the Secretary of State has addressed the key issues raised by stakeholders can be found within the Secretary of State's Decision Letter, which accompanies this HRA.

3.6 There are eleven consented offshore wind farms that lie either wholly within or overlap the SAC: six are operating, three are under construction and two have been consented but are not currently under construction (Table 1). There are a further fifteen wind farms that lie within 26 km of the SAC, which is identified by the JNCC and NE as an area that harbour porpoises may be displaced by noise arising from pile-driving activities (JNCC, NE and DAERA 2020a). 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 (Dogger Bank C), are within 26 km of the SAC boundary, have been consented but are not yet operational (Figure 2).

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

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 SAC.
Round 2/2.5			
Greater Gabbard	Operating	Yes	In-part beyond 12 nm.
Galloper	Operating	Yes	Beyond 12 nm.
Thanet	Operating	No	Within 12 nm, operating prior to site designation as a SAC.
Round 3			
Creyke Beck A (Dogger Bank A)	Consented Onshore construction started	Yes	Beyond 12 nm.
Creyke Beck B (Dogger Bank B)	Consented Onshore construction started	Yes	Beyond 12 nm.
Teesside B (Sofia)	Consented	Yes	Beyond 12 nm.
Hornsea Project One	Under Construction/Operating	No	Has been subject to HRA decisions that considered potential Likely Significant and Adverse effects on the SAC.
Hornsea Two	Under Construction	Yes	Beyond 12 nm.
East Anglia One	Under Construction/Operating	No	Has been subject to HRA decisions that considered potential Likely Significant and Adverse effects on the SAC.
East Anglia Three	Consented	No	Consented following site designation.



1	Dogger Bank - Creyke Beck B	16	Greater Gabbard
2	Dogger Bank - Teesside B (Sofia)	17	Galloper
3	Dogger Bank - Teesside A	18	Gunfleet Sands II
4	Dogger Bank - Creyke Beck A	19	London Array
5	Westermost Rough	20	Thanet
6	Hornsea Project 2	21	THV Mermaid
7	Hornsea 1 (West)	22	Belwind I
8	Hornsea 1 (Centre)	23	Borssele II
9	Hornsea 1 (East)	24	Norfolk Vanguard East
10	Humber Gateway	24	Norfolk Vanguard West
11	Triton Knoll	25	Hornsea Project Three
12	Dudgeon	26	Norfolk Boreas
13	Scroby Sands	27	East Anglia One
14	East Anglia Three	28	East Anglia Two
15	East Anglia One North	29	Hornsea Project Four

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

Table 2: Offshore wind farms located within 26 km of the Southern North Sea SAC 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	Under Construction	No	Has been subject to HRA decisions that considered potential Likely Significant and Adverse effects on the SAC.
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	Operating	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 (Dogger Bank A)	Consented Onshore construction started.	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.
East Anglia One North	Application submitted	No	Application made following designation of the cSAC. No consent decision.
East Anglia Two	Application submitted	No	Application made following designation of the cSAC. No consent decision.
Belgium			
Mermaid	Under Construction	No	Non-UK.
Belwind	Operational	No	Non-UK.
Netherlands			
Borselle II	Consented	No	Non-UK.

3.7 As required under the Habitats 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.

3.8 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 SAC or the 26 km area of effective deterrent range (EDR) (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 Project Two,
- East Anglia One,
- Triton Knoll,
- Creyke Beck A (Dogger Bank A)
- Creyke Beck B (Dogger Bank B),
- Teesside A (Dogger Bank C),
- Teesside B (Sofia). [4]

3.9 Since the publication of the Call for Information both East Anglia One and Hornsea Project One offshore 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 SAC.

3.10 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).

[4] Since being consented the names of Creyke Beck A and Creyke Beck B have been changed to Dogger Bank A and Dogger Bank B respectively. The names of Teesside A and Teesside B have also been changed to Dogger Bank C and Sofia respectively. For the purposes of this assessment the names at the time of consent are used.

3.11 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).

3.12 Triton Knoll Offshore Wind Farm is 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 SAC 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).

3.13 One project, East Anglia Three, lies within the SAC 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 SAC 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).

3.14 As these four wind farms have all been subject to HRA decisions that considered potential likely significant and adverse effects on the SAC, 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.

3.15 There are three consented projects that lie outwith the UK but are within 26 km of the SAC 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).

3.16 BEIS recognises that there is potential for future applications for offshore wind farms that could affect the qualifying features of the Southern North Sea SAC. 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 as part of the application process. HRAs for future projects will assess their potential to have a significant effect on the SAC both alone and in-combination with other plans or projects.

3.17 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.

3.18 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.

3.19 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 SAC 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.

3.20 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 SAC. 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.

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

3.22 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

3.23 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).
- *The Dogger Bank Creyke Beck Offshore Wind Farm.* SI No. 318. UK2015021716 02/2015 19585. http://www.legislation.gov.uk/uksi/2015/318/contents/made. Infrastructure Planning (2015a).
- *The Dogger Bank Teesside A and B Offshore Wind Farm*. SI No. 1592. UK201508054 08/2015 19585. http://www.legislation.gov.uk/uksi/2015/1592/contents/made Infrastructure Planning (2015b).
- *The Hornsea Two Offshore Wind Farm Order 2016*. SI No. 884. http://www.legislation.gov.uk/uksi/2016/844/made. Infrastructure Planning (2016a).
- *East Anglia ONE Offshore Wind Farm (Corrections and Amendments) Order 2016*. https://infrastructure.planninginspectorate.gov.uk/document/EN010025-000042. Infrastructure Planning (2016b).
- *The Triton Knoll Electrical System Order 2016.* SI No. 880. http://www.legislation.gov.uk/uksi/2016/880/contents/made. Infrastructure Planning (2016c).
- *The Hornsea One Offshore Wind Farm (Amendment) Order 2017*. SI No. 464. http://www.legislation.gov.uk/uksi/2017/464/made. Infrastructure Planning (2017a).
- *Record of Habitats Regulations Assessment. East Anglia One Offshore Wind farm – Non-Material Change.* BEIS (2016a).
- *Record of Appropriate Assessment. Hornsea Project One.* MMO (2017a).

- *Application for consent under Section 36 of the Act to construct and operate an offshore wind farm near the Inner Gabbard and Galloper sandbanks in the Outer Thames*. 19 February 2007. Department of Trade and Industry.
- *Electricity Act Section 36. Construction and operation of a wind farm generating station known as Dudgeon off the coast of Norfolk.* Consent decision. Department of Energy and Climate Change (2012).
- *Dogger Bank: Creyke Beck offshore wind farm Environmental Statement.* Forewind. Forewind (2013a).
- *Dogger Bank: Creyke Beck offshore wind farm Environmental Statement. Chapter 5 Appendix A – Underwater Noise Technical Report.* Forewind. Forewind (2013b).
- *Dogger Bank: Teesside A & B offshore wind farm Environmental Statement*. Forewind. Forewind (2014).
- *Hornsea Offshore Wind Farm Project One – Deemed Marine Licence Variation.* DONG Energy. (2016a).
- *Hornsea Offshore Wind Farm Project One - Environmental report hammer energies*. DONG Energy (2016c).
- *Hornsea offshore wind farm. Project One Environmental Statement*. SMart Wind Limited (2013).
- *Hornsea offshore wind farm. Project Two Environmental Statement.* SMart Wind Limited (2015a).
- *Hornsea offshore wind farm. Project Two Environmental Statement Annex 4.3.2. Subsea Noise Technical report.* SMart Wind Limited (2015b).
- *East Anglia One offshore wind farm. Environmental Statement.* Scottish Power Renewables, Vattenfall (EAOWL 2012).
- *East Anglia One offshore wind farm* (2017). Requirement 36 Report. Doc. ref. No. EA1-CON-B-GBE-23782 (EAOWL 2017).
- *East Anglia Three offshore wind farm. Environmental Statement.* Scottish Power Renewables, Vattenfall (EAOWL 2015b).
- *East Anglia Three. Information for the Habitats Regulations Assessment: Interim marine mammals assessment Southern North Sea pSAC.* Scottish Power Renewables. (EAOWL 2017).
- *Triton Knoll Offshore Wind Farm Environmental Statement.* RWE npower renewables. Triton Knoll Offshore Wind Ltd (2011).
- *Triton Knoll Electrical System Environmental Statement*. RWE. April 2015. Revision A. Triton Knoll Offshore Wind Ltd (2015).
- *Natura 2000 – Standard Data Form. Site: UK0030395. Southern North Sea*. JNCC (2016).
- *Harbour Porpoise (Phocoena phocoena) possible Special Area of Conservation: Southern North Sea. Draft Conservation Objectives and Advice on Activities*. JNCC and NE (2016).
- *SAC Selection Assessment: Southern North Sea*. JNCC (2017a).
- *Harbour Porpoise (Phocoena phocoena) Special Area of Conservation: Southern North Sea Conservation Objectives and Advice on Operations*. JNCC & NE (2019).
- *Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs (England, Wales & Northern Ireland).* JNCC, NE and DAERA (2020a).

3.24 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 documentation 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 SAC (Figure 3) (DOWF 2018).

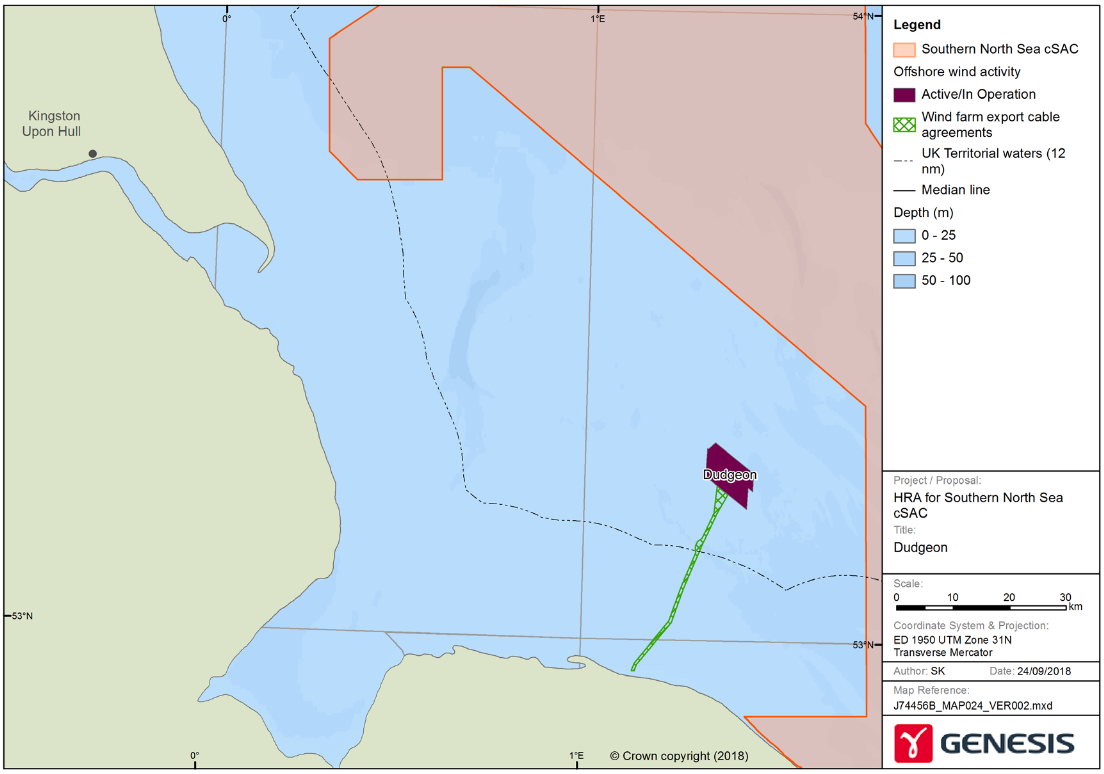


Figure 3: Location of Dudgeon offshore wind farm and the Southern North Sea SAC.

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 completed in August 2016. First electricity to the grid occurred in February 2017 and the project was fully commissioned in October 2017.

Greater Gabbard Offshore Wind Farm

4.5 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) and lies within the SAC.

4.6 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).

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

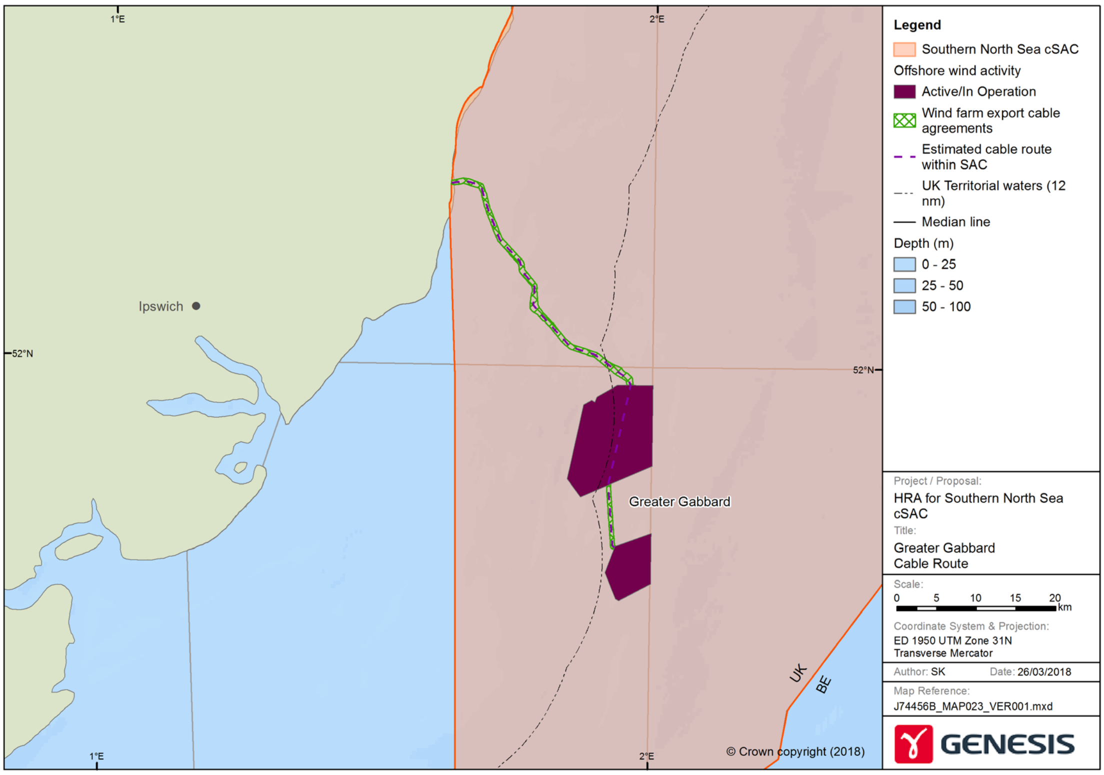


Figure 4: Location of Greater Gabbard offshore wind farm and the Southern North Sea SAC.

Galloper Offshore Wind Farm

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

4.9 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) and lies within the SAC. The project comprises 56 turbines and one offshore substation. Two export cables have been installed each 45 km long.

4.10 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).

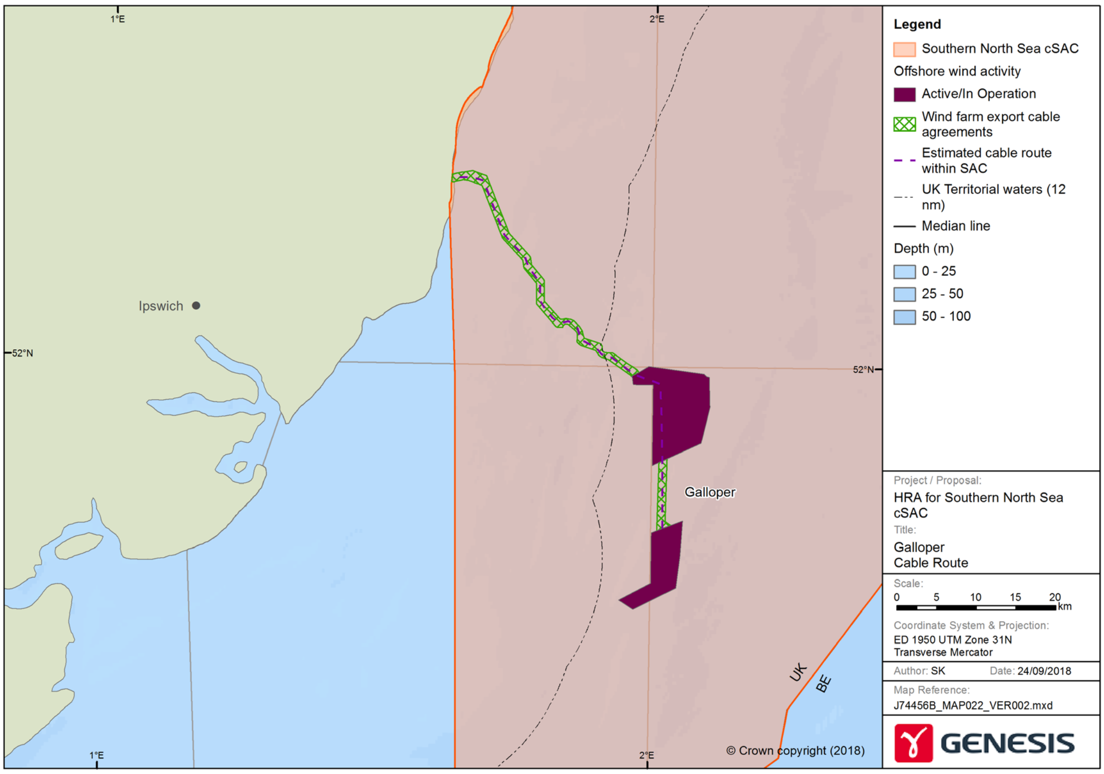


Figure 5: Location of Galloper offshore wind farm and the Southern North Sea SAC.

Hornsea Project Two Offshore Wind Farm

4.11 The Hornsea Project 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 SAC (Figure 6).

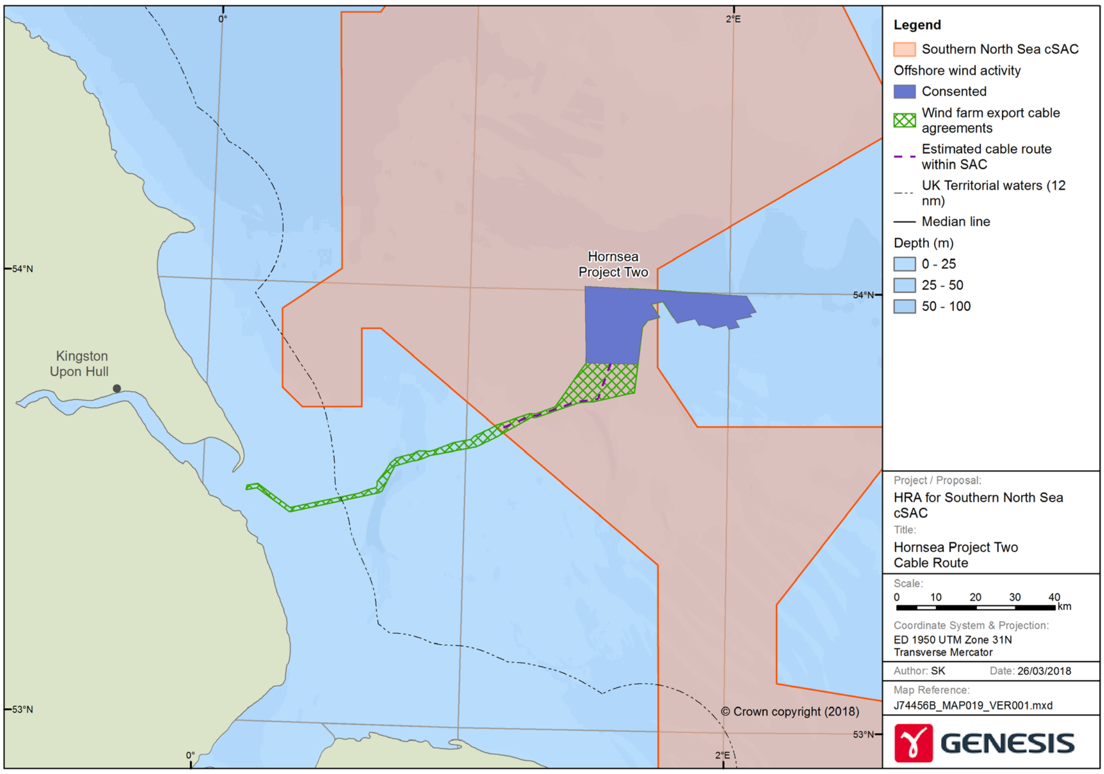


Figure 6: Location of Hornsea Two offshore wind farm and the Southern North Sea SAC.

4.12 The Hornsea Project Two offshore wind farm was consented on 16 August 2016 and offshore construction will commence in 2020 (Infrastructure Planning 2016a, Ørsted 2020a).

4.13 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 request for a non-material change was made to reduce the permitted number of offshore HVAC collector substations from six to three (Ørsted 2018a). The non-material change was approved in May 2018 (Infrastructure Planning 2018).

4.14 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).

Subsequently, Ørsted has committed to installing 165 8 MW turbines (Ørsted 2018b, 2020a) and therefore the final number of turbines that will be installed will be less than the 300 for which the project was consented.

4.15 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).

4.16 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.

4.17 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).

4.18 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).

4.19 The planned development comprises a total of 165 wind turbines (Ørsted 2019). If the selected turbine foundations are monopile, they may have a maximum pile diameter of 8.5 m. (Ørsted 2018b). 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	Monopile 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 (Dogger Bank A and B) Offshore Wind Farms

4.20 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).

4.21 Onshore construction commenced in Q1 2020, with the offshore construction planned to start in 2022. 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 SAC.

4.22 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). Subsequently, following detailed design, the project comprises 95 turbines and one offshore substation (Dogger Bank Windfarm 2020a).

4.23 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). Subsequently, following detailed design, the project comprises 95 turbines and one offshore substation (Dogger Bank Windfarm 2020a).

4.24 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).

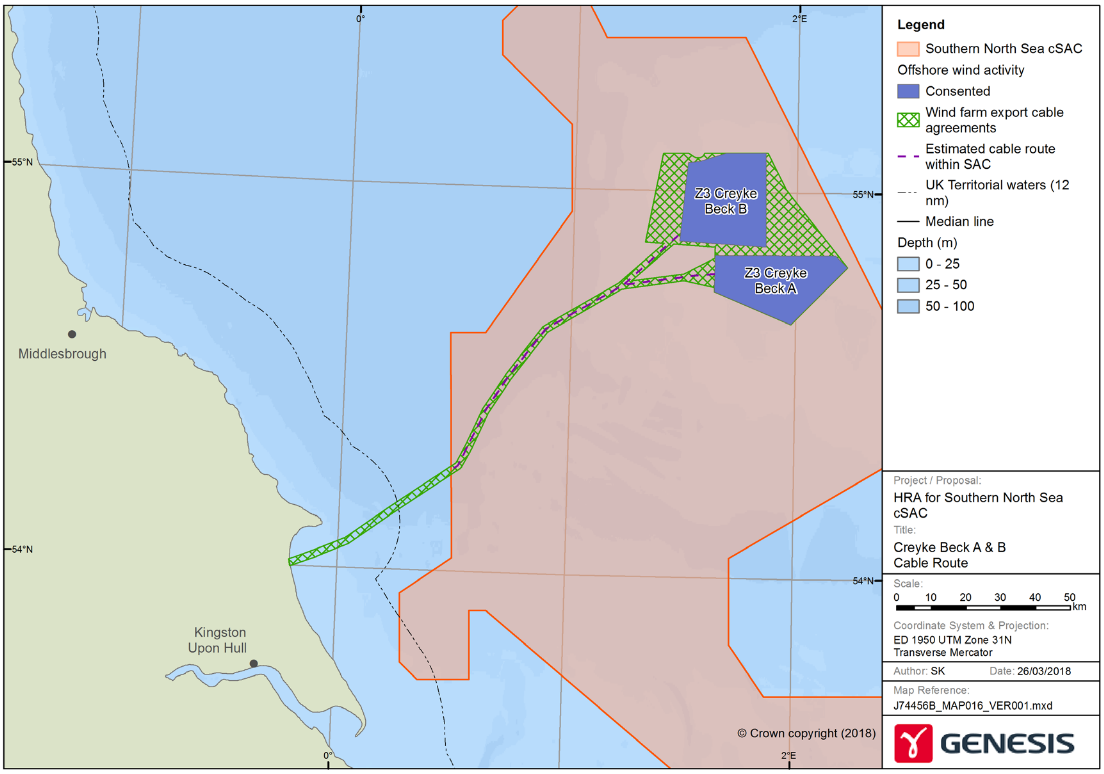


Figure 7: Location of Creyke Beck A and B offshore wind farms and the Southern North Sea SAC.

4.25 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).

4.26 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.

4.27 For each project a total of 325 km of inter-connector cables will connect the wind turbines to the offshore HVDC substations and a total of four export cables (two for each project) will each run approximately 190 km from the substations to landfall (Dogger Bank Windfarm 2020a). 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 5.15 km^2 of seabed could be impacted during trenching of the cables at both Creyke Beck A and and Creyke Beck B. The length of cable protection required is unknown but at the time of application it was estimated to be 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 (Dogger Bank C) and Teesside B (Sofia) Offshore Wind Farms

4.28 The Dogger Bank Teesside A (Dogger Bank C) and Teesside B (Sofia) 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 (Figure 8).

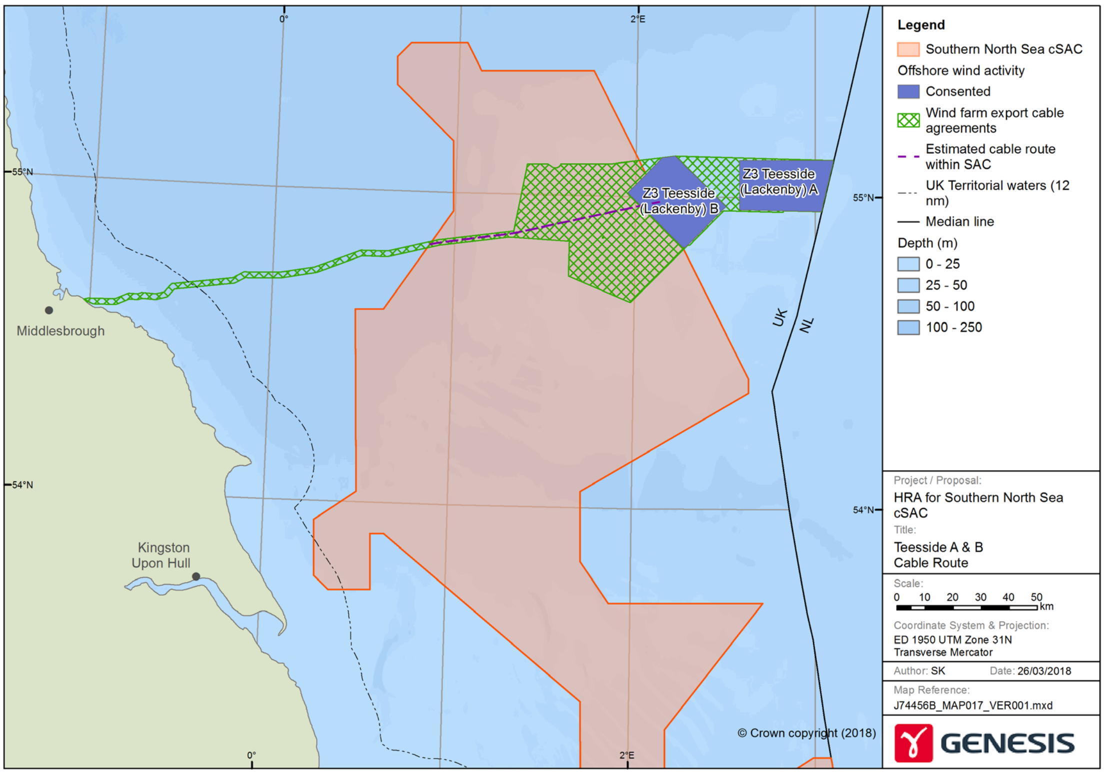


Figure 8: Location of Teesside A and B offshore wind farms and the Southern North Sea SAC.

4.29 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 A development zone lies outwith the boundaries of the SAC, although export cables may cross the site.

4.30 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 at the time of consent was up to 1.2 GW (Infrastructure Planning 2015b, Forewind 2014, 2018). In 2018 Sofia Offshore Wind Limited applied for a non-material change to the DCO which included increase in power generation from 1.2 GW to 1.4 GW (Infrastructure Planning 2019).

4.31 The currently planned number of turbines at Teesside B is for 100 14 MW turbines (Sofia Offshore Wind Farm 2020).

4.32 The wind turbines to be installed at Teesside A and B had at the time of consent not been finalised but ranged in generating capacity from between 6 MW or 10 MW, although larger capacity turbines could be installed. At the time of consent a range of turbine foundations were considered and covered 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). Since consent the wind turbine foundations will be monopole. 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).

4.33 In the event monopiled foundations are used the maximum pile diameter is 12 m and will be installed using a maximum hammer energy at Teesside A of 4,000 kJ (Dogger Bank Wind Farm 2020b). 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.

4.34 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 at the time of consent for wind turbines at Teesside A and B (Source: Forewind 2014).

Parameter	Monopile	Multileg	Platform
Maximum pile diameter (m)	10	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 SAC is the Habitats Directive Annex II species harbour porpoise (*Phocoena phocoena*) (JNCC and NE 2019).

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 upwellings and strong tidal currents and in water depths of predominantly between 20 and 50 m (Clark 2005, Fidler 2019, 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. 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 (Figure 10) (Hammond *et al*. 2013). 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).

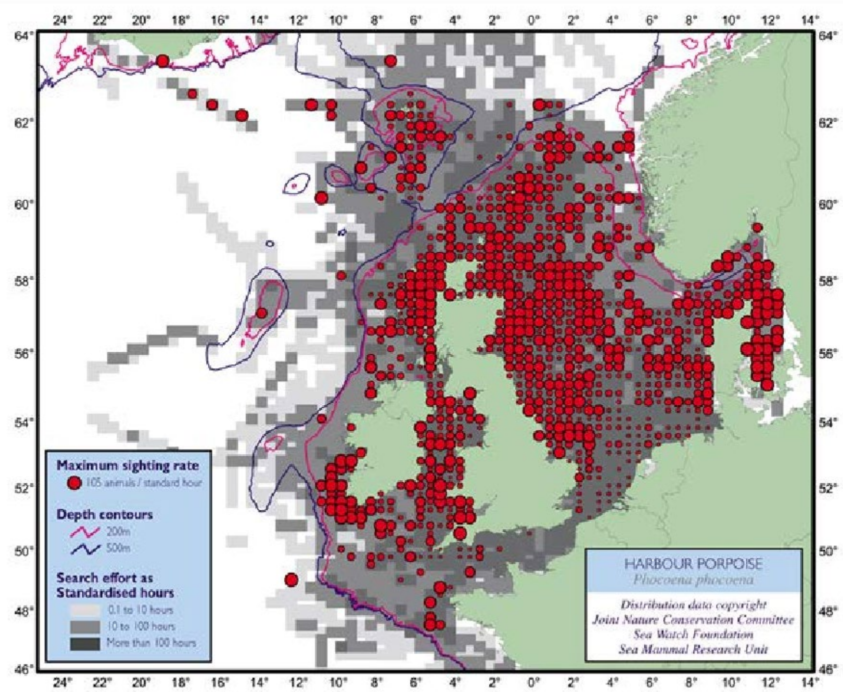


Figure 9: Harbour porpoise distribution in the North Sea and adjacent waters (Reid *et al.* 2003).

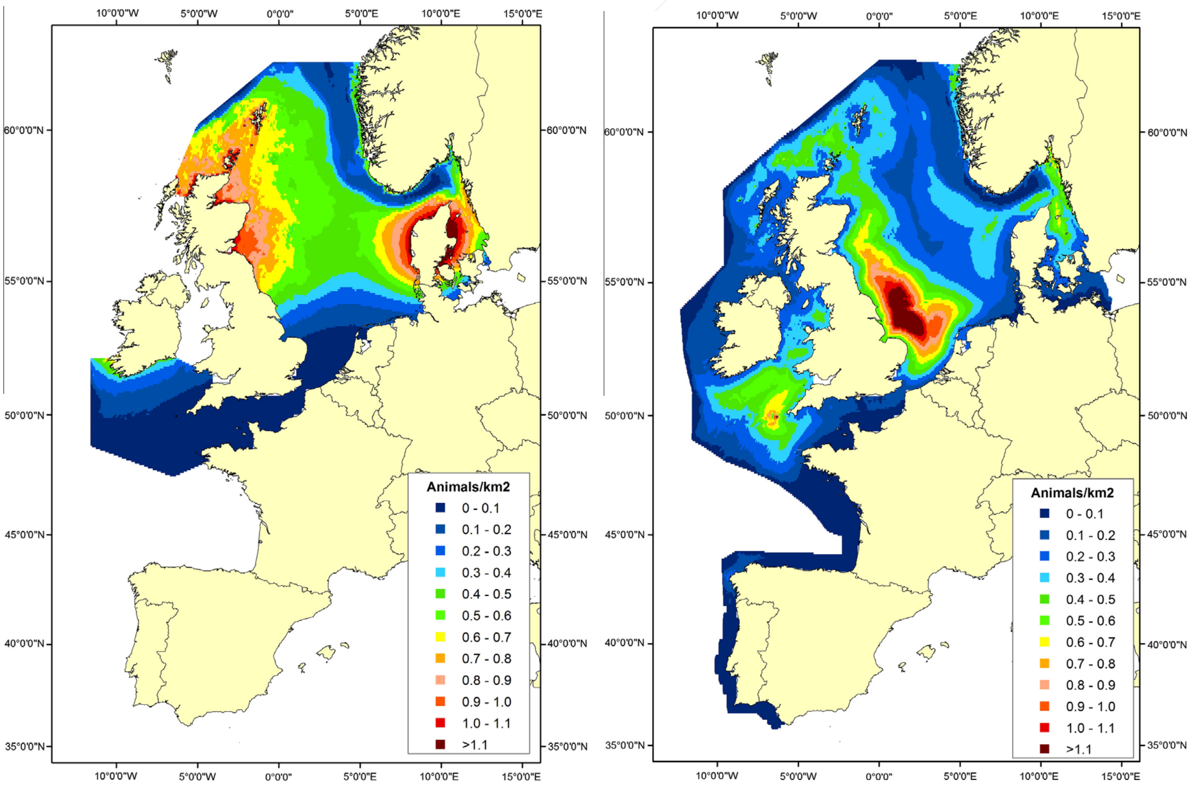


Figure a.

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 revised 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).

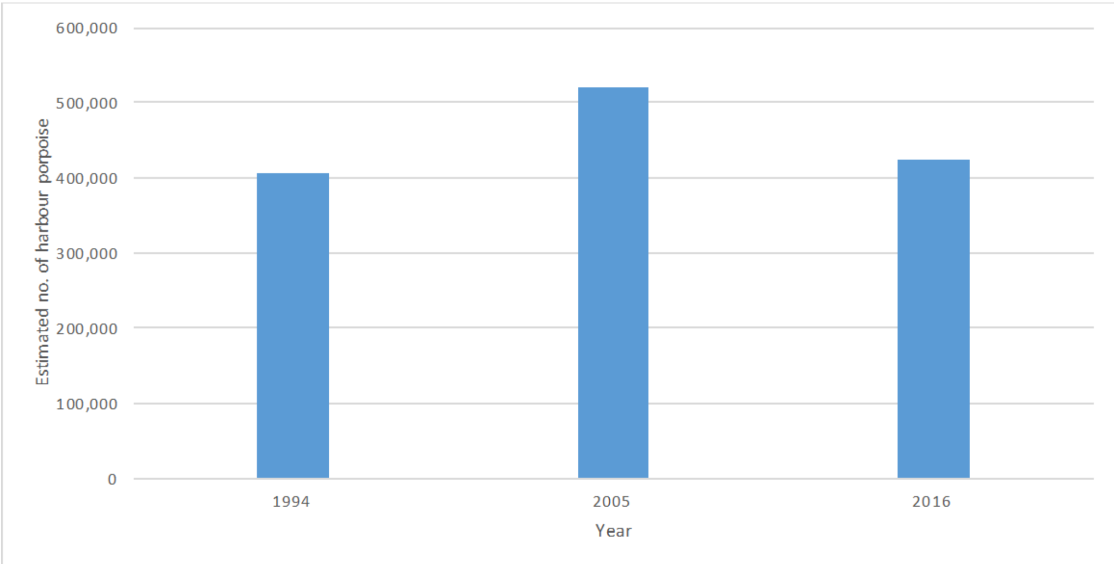


Figure 11: Estimated number of harbour porpoise within the SCANS survey area recorded during SCANS I, II and III surveys (Hammond *et al.* 2017).

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 SAC 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 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 2017b).

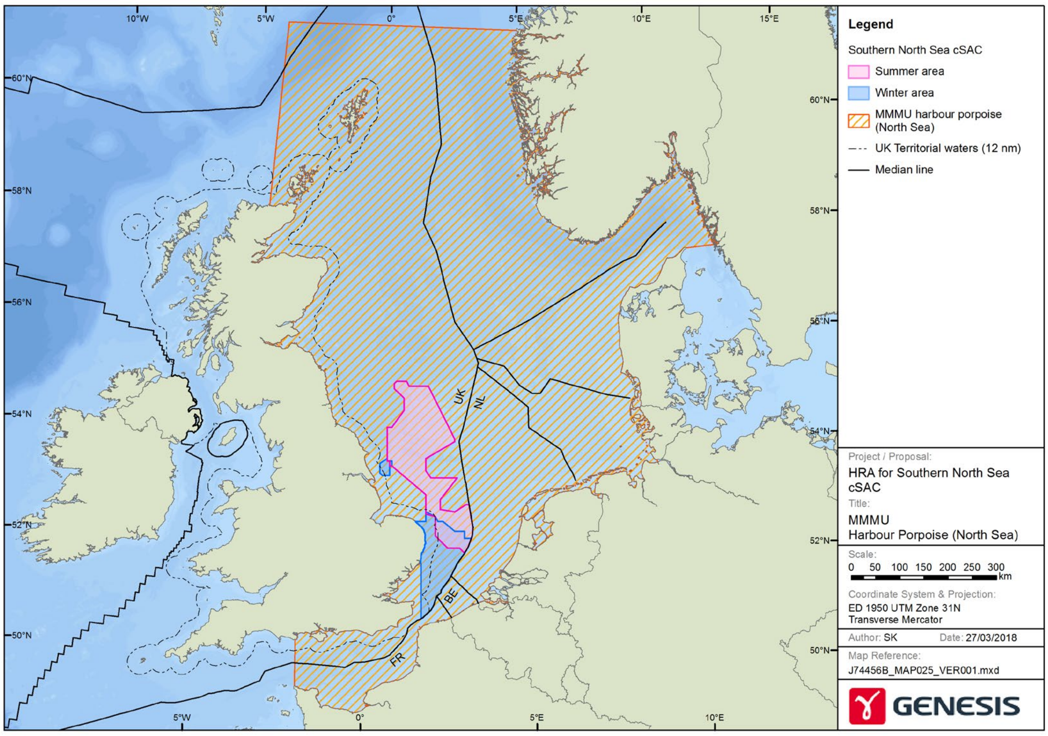


Figure 12: North Sea Management Unit for harbour porpoise as defined by the IAMMWG.

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). Consequently, based on the latest North Sea Management Unit population of 308,666 individuals the harbour porpoise population within the SAC may be 26,237 individuals. It is also recognised that, like all populations, the harbour porpoise population within the SAC 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 SAC 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 SAC (Figure 13b) (Heinänen & Skov 2015).

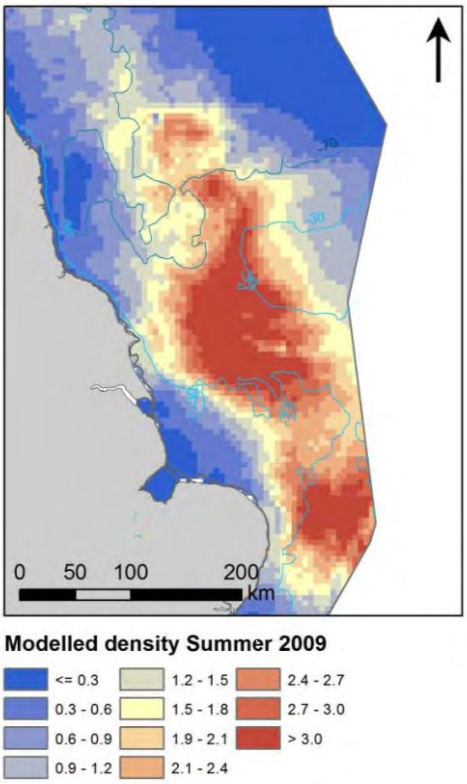


Figure a.

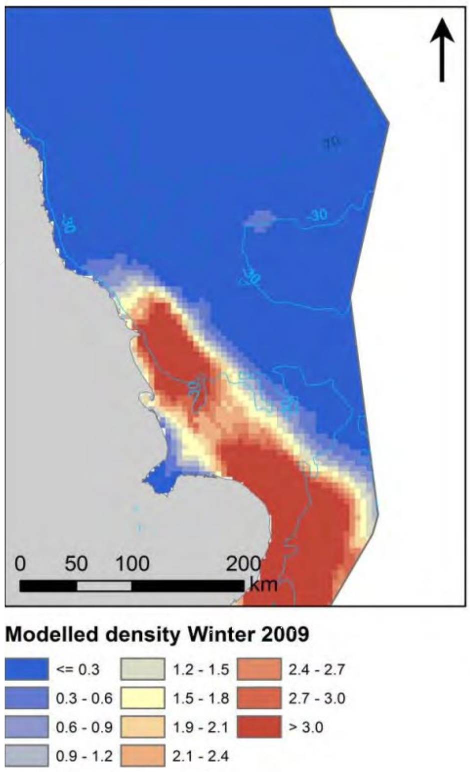


Figure b.

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 SAC, have reported lower densities of harbour porpoise than that modelled using 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 from surveys undertaken at proposed offshore wind farms located within or adjacent to the SAC 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).

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

Location	Harbour porpoise mean density (ind./km^2)	Survey method	Source
Hornsea subzone 3 + 4 km 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	1.76	Boat	SMart Wind (2017)
Hornsea Zone + 10 km buffer	1.72	Boat	SMart Wind (2015a)
Norfolk Vanguard East	1.26	Aerial	Vattenfall (2017)
Norfolk Boreas	1.06	Aerial	Vattenfall (2019)
SCANS III block O	0.89	Aerial	Hammond *et al.* (2017)
Norfolk Vanguard West	0.79	Aerial	Vattenfall (2018)
East Anglia Two	0.73	Aerial	Scottish Power (2019a)
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)
East Anglia One	0.57	Aerial	Scottish Power (2019b)
Southern North Sea SAC [1]	0.50 / 0.71	Boat & Aerial	JNCC (2017a)
Greater Wash Area	0.38	Aerial	Sparling (2011)
East Anglia Three + 4 km buffer	0.29	Aerial	EAOWL (2016)
Galloper	0.20	Boat	GWFL (2011)
East Anglia One + 4 km buffer	0.19	Aerial	EAOWL (2012)
Triton Knoll	0.11	Aerial	TKOWFL (2011)

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

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 SAC with a general trend of relatively lower densities occurring in the southern area of the SAC 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.

5.12 Although harbour porpoises may dive to depths in excess of 200 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).

5.13 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.

5.14 Studies undertaken in Denmark indicate that their local distribution may be correlated with prey availability (Sveegaard 2011, Mikkelsen *et al*. 2013). 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).

5.15 Harbour porpoise have a maximum life expectancy of around 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).

5.16 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.

5.17 Porpoises are generally considered to be 'high frequency' specialists with a relatively poor ability to detect lower frequency sounds (NMFS 2018, Southall *et al.* 2019). 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).

5.18 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.

5.19 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

5.20 Fish are not qualifying species for the Southern North Sea SAC. 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 2019).

5.21 The specific prey for harbour porpoise within the SAC 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 2019).

5.22 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, fish 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).

5.23 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).

5.24 Fish species most frequently recorded during surveys include species typically found in sand, coarse 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 SAC and sandeels preferably spawn in gravelly sand habitats.

5.25 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 which 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).

5.26 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).

5.27 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).

5.28 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).

5.29 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 SAC upon which prey species for harbour porpoise rely could impact on the harbour porpoise.

5.30 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.

5.31 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

5.32 There are no qualifying habitats within the SAC. However, habitats within the SAC 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 2019).

5.33 The site covers an area of 3,695,054 ha (36,951 km^2) (JNCC and NE 2019). 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 2019).

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

5.35 Activities considered to have low risk of an impact are not considered further as the exposure to the pressures associated with these activities is currently very limited (JNCC and NE 2019).

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

Location	Predominant Sediment	Source
Creyke Beck A and B	Sand, gravel and sandy gravel.	Forewind (2013)
Teesside A and 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 One	Slightly gravelly sand, gravelly sand, sand, sandy gravels.	EAOWL (2012)
East Anglia Three	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 SAC 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. Existing activities that have potential to occur within or adjacent to the SAC and could cause impacts to which harbour porpoise are considered sensitive are identified in the *Conservation Objectives and Advice on Activities* (JNCC and NE 2019) and presented in Table 8.

Table 8: Activities occurring within/near to the Southern North Sea SAC to which harbour porpoise is considered sensitive (from JNCC and NE 2019).

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)	Barrier to species movement	Low
Terrestrial and at-sea disposal	Litter	Low
Sewage	Introduction of microbial pathogens	Low

High = Important direct or immediate influence and/or acting over large areas.

Medium = Medium direct or immediate influence, mainly indirect influence and/or acting over moderate part of the area/acting only regionally.

Low = Low direct or immediate influence, indirect influence and/or active over small part of the area/acting only regionally.

6.2 Activities considered to have low risk of an impact are not considered further as the exposure to the pressures associated with these activities is currently very limited (JNCC and NE 2019).

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). 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 SAC. Since 1965, when the first well was spudded (first drilled), there has been extensive oil and gas development with a total of 113 installations currently installed within the SAC. A further four platforms are currently being planned. The vast majority (94%) of all the installations within the SAC are located in the 'summer' area of the site and all those currently being planned are also in the 'summer' area (Figure 14).

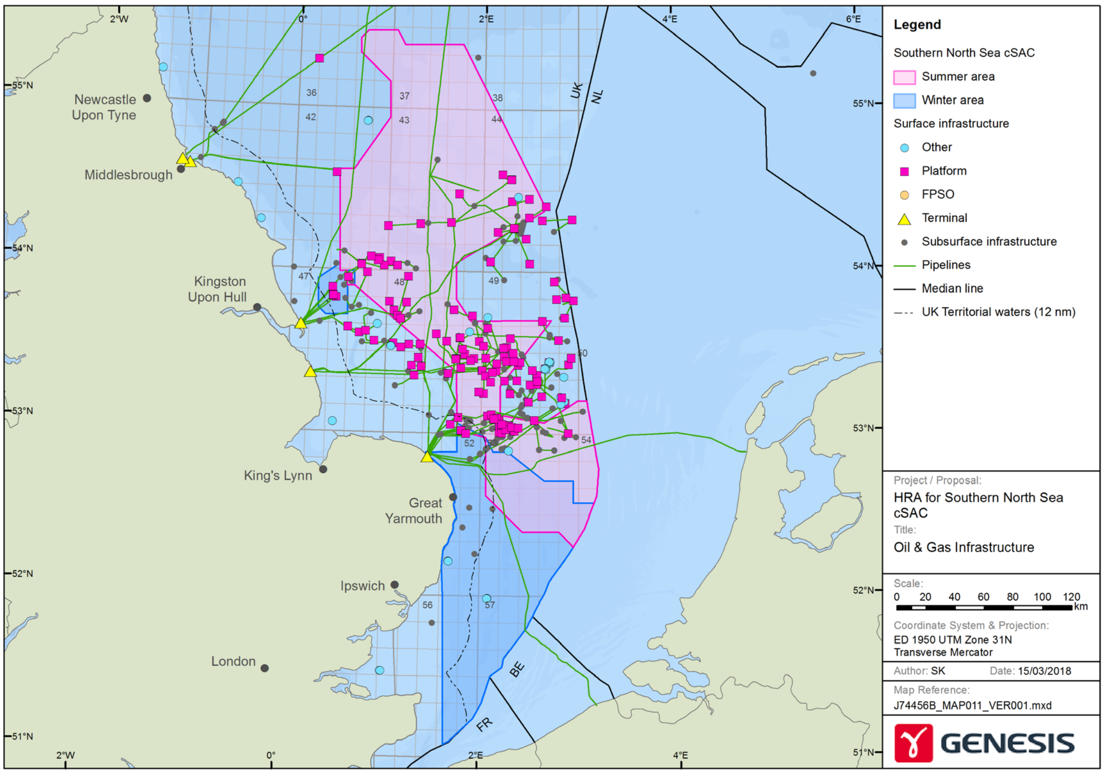


Figure 14: Existing oil and gas infrastructure within the Southern North Sea SAC.

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 SAC 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 SAC (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 SAC. Based on a sample size of 36 installations within the SAC, the average area of an oil and gas platform located within the SAC 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 SAC. 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 SAC. 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).

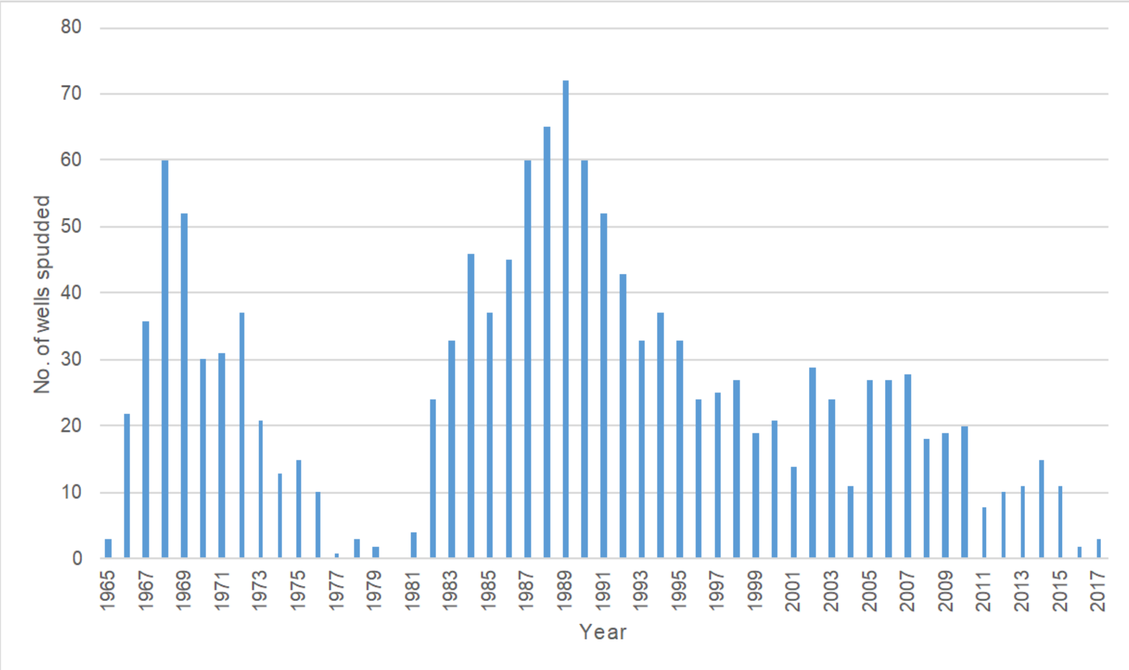


Figure 15: Number of wells spudded each year in the Southern North Sea SAC (Source: UKoilandgas 2018).

Table 9: Number of wells spudded and seasonal occurrence of spud dates within the SAC 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 SAC over the last 50 years, with a total of 65 surveys undertaken within the SAC between 2005 and 2014. The majority of surveys during this period took place in the 'summer' area of the SAC, where most oil and gas activity has occurred (Figure 16).

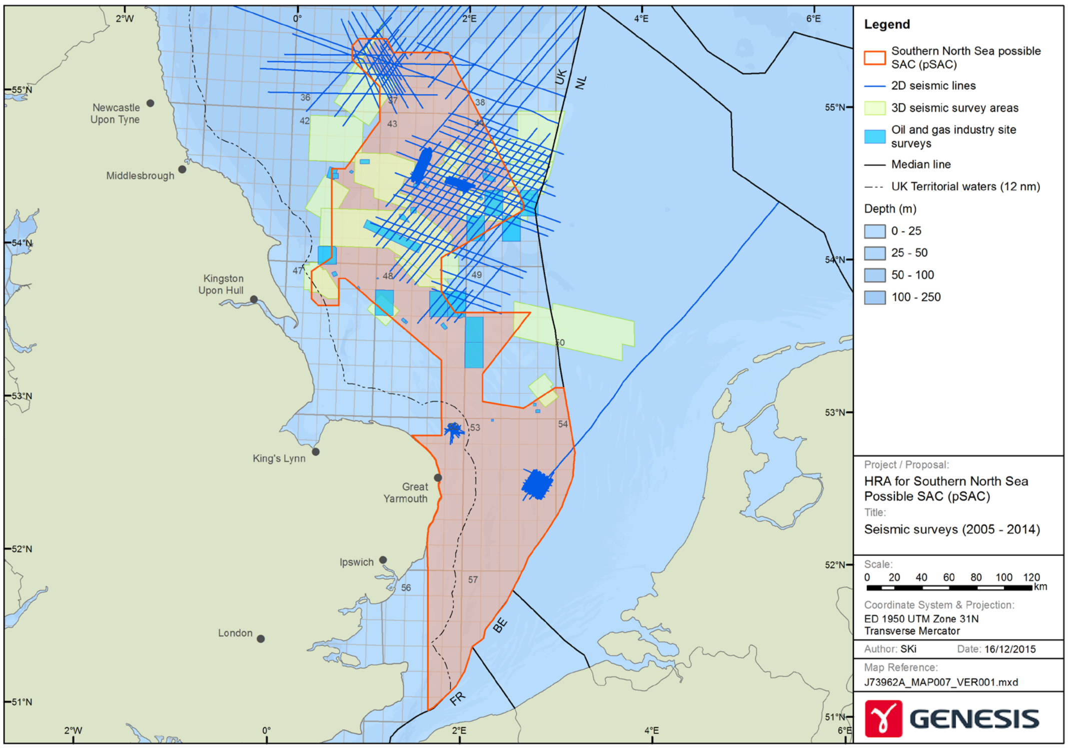


Figure 16: Oil and gas industry related seismic surveys undertaken within the Southern North Sea SAC between 2005 and 2014.

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 SAC. 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 SAC with half the blocks within the SAC receiving less than 5 pulse block days over an 11 year period (2005 – 2015) [5]. 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).

[5] 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.

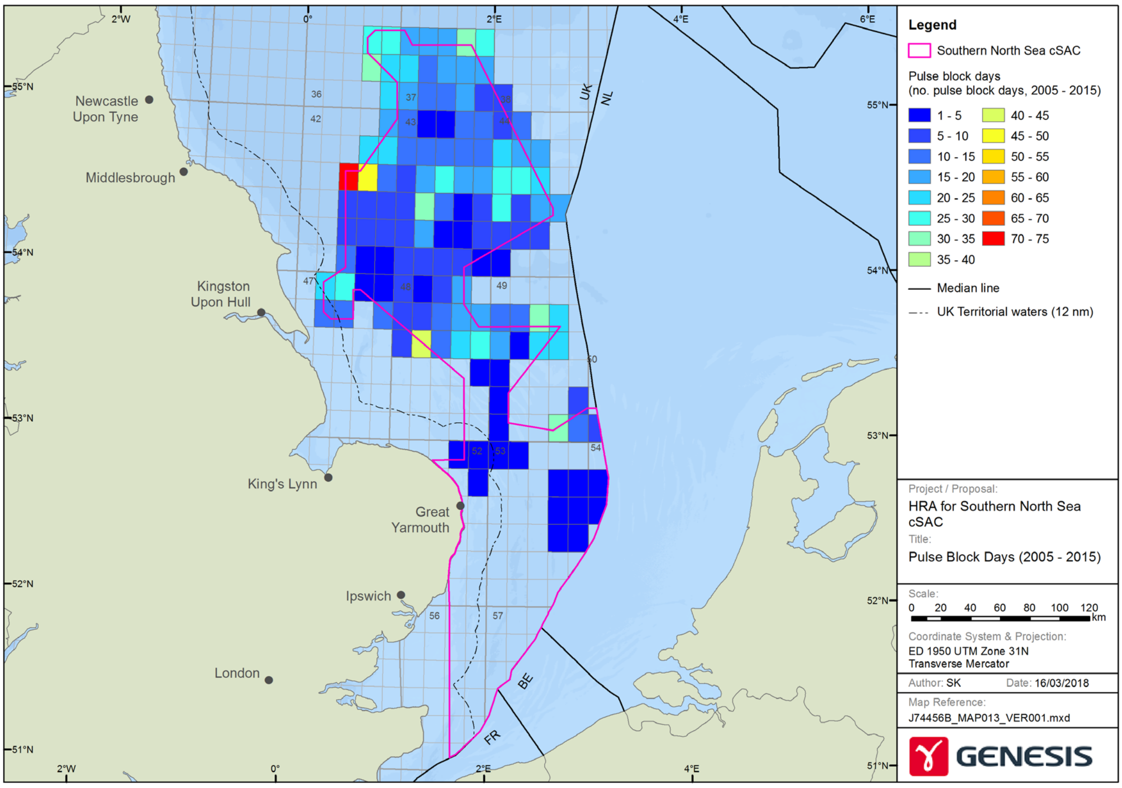


Figure 17: Total number of pulse block days in each licence block between 2005 and 2015.

6.13 The number of pulse block days, i.e. the number of days in which pulsed noise occurred, across the whole of the SAC 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 SAC for between 14% and 85% of the days each year, although in many instances the pulsed noise will not be for the whole day.

6.14 Airguns are not operated throughout the time a survey is undertaken. A review of six seismic surveys undertaken across UK waters during 2018 indicated that out of a total of 171 potential survey days airguns were operated for 52% of the time.

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

Number of pulse days between 2005 to 2015	Number of blocks within SAC	Proportion of blocks within SAC (%)
<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

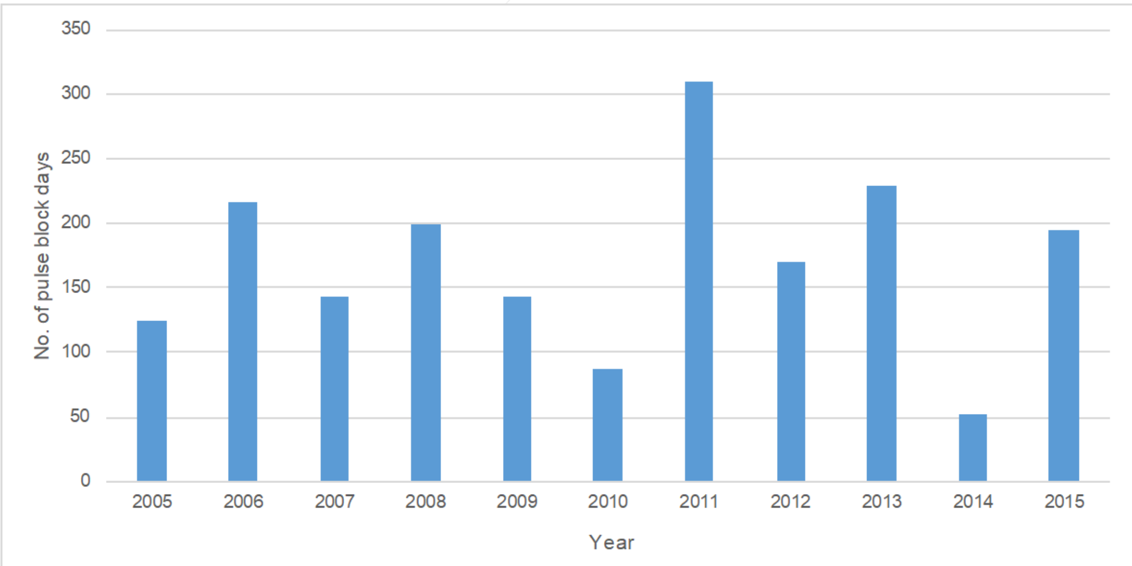


Figure 18: Number of pulse block days per year within the Southern North Sea SAC.

6.15 Between 2008 and 2017 there were a total of 61 seismic surveys undertaken within the boundaries of the SAC, with 59 of them occurring in the 'summer' area and four in the 'winter' area of the SAC (Table 11).

Table 11: Oil and gas related seismic and site surveys undertaken within the SAC between 2008 and 2017.

Survey type	Number of surveys			Median duration of each survey (days)
	Total SAC	'Summer'	'Winter'	
2D Seismic	8	7	2	15
3D seismic	15	15	0	43
Site survey	38	37	2	8
Total	61	59	4	-

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 SAC as a whole.

6.16 The majority of seismic surveys occurring within the SAC between 2008 and 2017 have lasted less than 30 days. The median duration of each survey type and the estimated number of days impacted over ten years from each survey type for each season are presented in Table 12 for the 'summer' area and Table 13 for the 'winter' area.

6.17 Of the surveys undertaken in the 'summer' area, 34 overlapped the period between April and September, with an average of 56.7 days of survey occurring within the 'summer' area each summer period, equivalent to 34.7% of the time (Table 12).

Table 12: Number of oil and gas related surveys undertaken within the 'summer' area of the SAC during the summer period (April - September) between 2008 to 2017.

Survey type		'Summer' area (April to September)	
	No. of surveys (2008 – 2017)	Median duration (days)	Estimated number of days over 10 years
2D Seismic	7	14	98
3D seismic	8	42	336
Site survey	19	7	133
Total	34	-	567

6.18 Within the 'winter' area of the SAC a total of three oil and gas related surveys were undertaken during the winter period over a period of 10 years between 2008 and 2017. An average of 3.7 days of survey occurring within the 'winter' area each winter period, equivalent to 2.3% of the time (Table 13).

Table 13: Number of oil and gas related surveys undertaken within the 'winter' area of the SAC during the winter period (October - March) between 2008 to 2017.

Survey type	'Winter' area (October to March)		
	No. of surveys (2008 – 2017)	Mean duration (days)	Estimated number of days over 10 years
2D Seismic	2	9	18
3D seismic	0	0	0
Site survey	1	19	19
Total	3	-	37

Oil and gas vessels

6.19 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 SAC (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 SAC 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

6.20 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 2019).

6.21 Existing localised aggregate dredging occurs primarily in the southern half of the SAC, along the east coast (Figure 19). In 2017 there were 29 aggregate production areas and five Exploration and Option sites covering an area of 579.3 km^2 (Table 15). Five of the aggregate sites occur in the 'summer' area of SAC and the rest occur in the 'winter' area of the SAC, with some sites occurring in both the 'winter' and 'summer' areas. Of the area of seabed licensed for dredging across the three regions dredging was undertaken over an area of 60.8 km^2, some of which occurred in areas outwith the SAC (TCE 2019a).

6.22 The three-year average annual offtake of construction aggregate across the Humber, East Coast and Thames Estuary regions was 8.13 million tonnes (TCE 2019b).

6.23 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)).

6.24 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 SAC may be impacted by noise arising from dredging activities.

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

Aggregate Site	Area number	Area (km^2)
Humber 5	483	28.24
Humber 3	484	17.20
Longsand	510/2	6.21
Longsand	509/3	6.65
Shipwash	507/5	0.82
Shipwash	507/6	4.25
Shipwash	507/2	2.13
Shipwash	507/4	6.80
Shipwash	507/3	0.68
Shipwash	507/1	17.78
North Cross Sands	494	6.15
North Inner Gabbard	498	6.56
Southwold East	430	15.32
Off Great Yarmouth	254	11.71
TBC	511	26.63
Off Great Yarmouth	228	13.11
Off Great Yarmouth Extension	240	31.54
Yarmouth	401/2A	48.23
Yarmouth	401/2B	2.89
TBC	512	21.76
Norfolk	212	3.12
North Inner Gabbard	498	6.56
Southwold East	430	15.32
Longsand	510/1	6.65
TBC	513/2	8.61
TBC	513/1	5.91
Longsand	508	6.65
New 495	525	28.13
Thames D	524	77.45
North Falls East	501	52.25
Outer OTE	528/2	31.81
Cross Sands	242/361	9.32
Lowestoft Extension	1804	13.97
East Orford Ness	1809	38.86

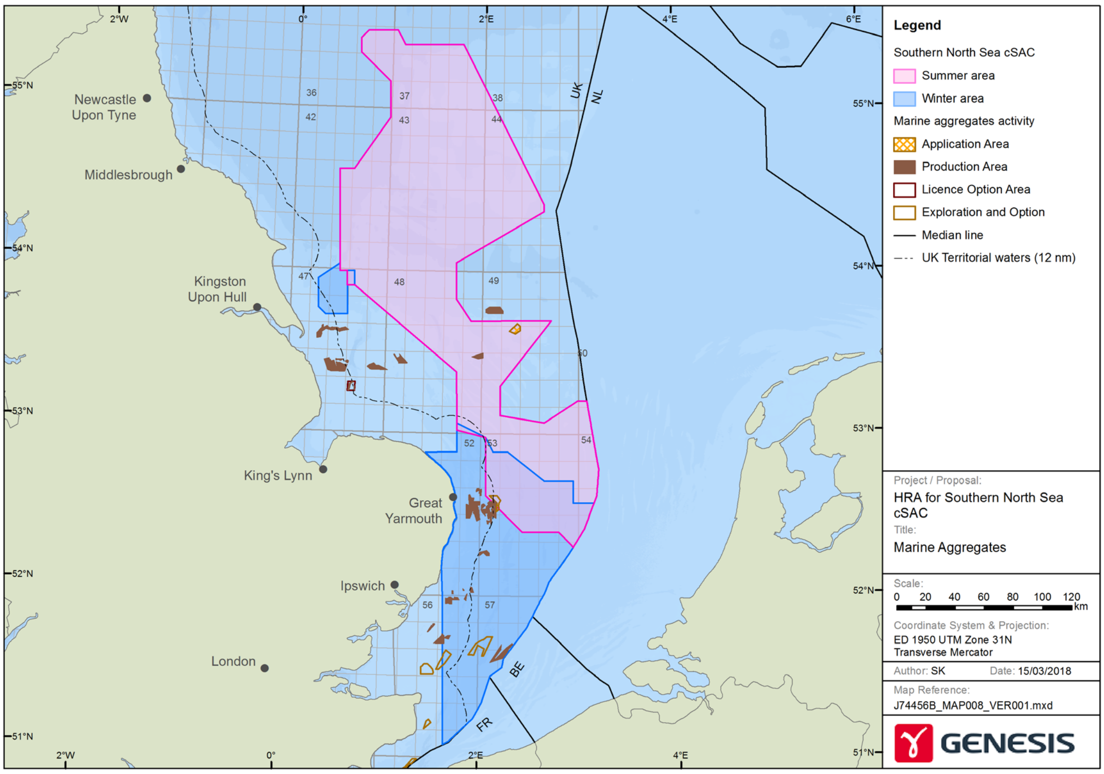


Figure 19: Existing marine aggregate activities in the Southern North Sea SAC.

Shipping

6.25 Impacts from shipping on harbour porpoise within the SAC 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 SAC when vessel traffic exceeds 80 vessels per day (Heinänen and Skov 2015). The current level of risk across UK waters to harbour porpoise from activities associated with shipping is medium/low (Table 8), (JNCC and NE 2019)

6.26 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 SAC; an average of 737 vessels per day (MMO 2017b).

6.27 The average weekly vessel density within the SAC is published for 2 x 2 km quadrants (Figure 20) (MMO 2017c). The density of shipping across the SAC is variable, with an average weekly number of vessels from between 0 and 567 weekly vessels occurring in any single quadrant within the SAC (Figure 21) (MMO 2017c). Relatively low levels of shipping occur across much of SAC, 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 SAC. Based on these data there are no 2 x 2 km quadrants that have up to 80 vessels per day transiting through them.

6.28 The level of vessel activity across the 'summer' and 'winter' areas of the SAC 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 SAC 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.

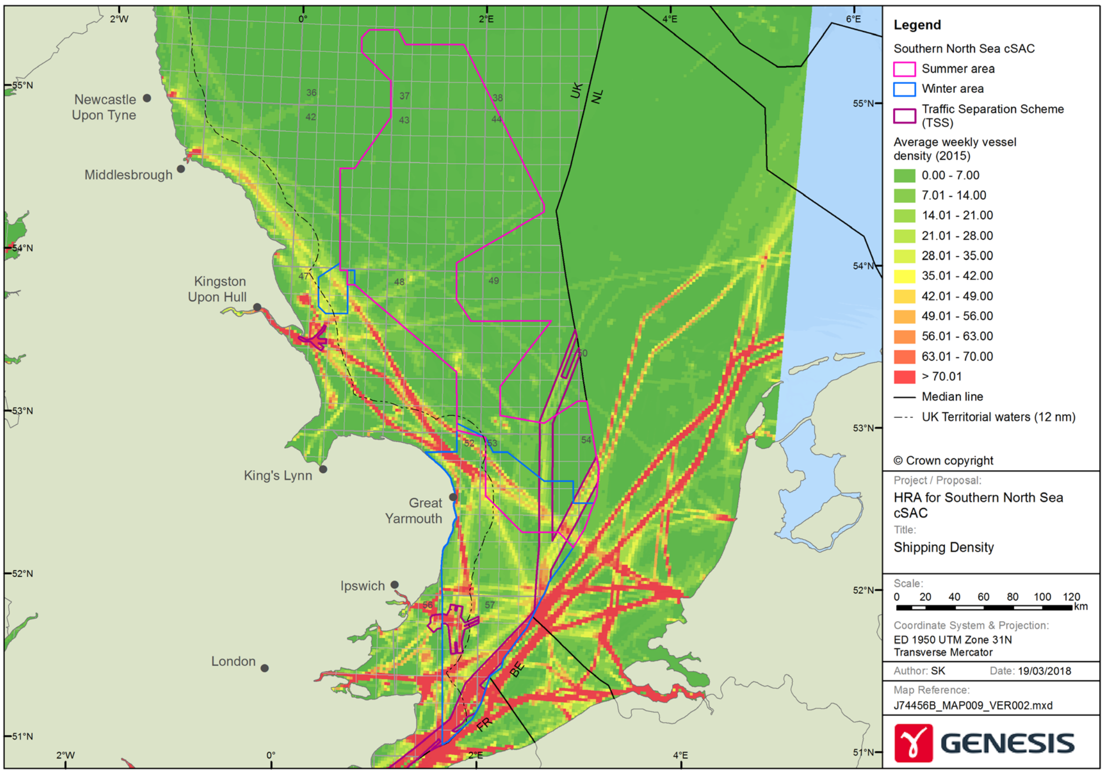


Figure 20: Shipping density within the SAC during 2015.

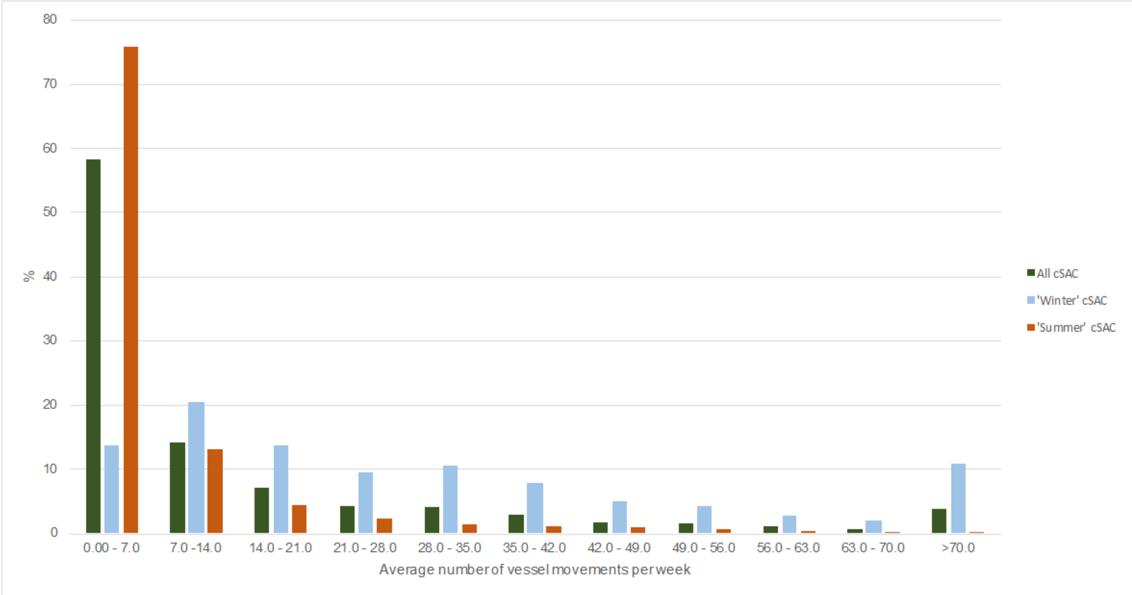


Figure 21: Average number of vessels per week in 2 x 2 km quadrants within the SAC.

6.29 Official shipping lanes have a relatively high level of vessel traffic. The two deep water traffic separation schemes in the southern area of the SAC 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 SAC, 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 SAC.

6.30 Great Yarmouth and Lowestoft are the two principal ports abutting the SAC and between them a total of 165 vessels arrived in 2018 (DfT 2019). Across the UK sector of the southern North Sea, sizable ports with over a thousand vessel arrivals per year include Hull, Grimsby, Felixtowe, Harwich and London. Nearly 23,000 vessels per year arrive at these ports, the majority of which will cross through the SAC to and from their destinations (Table 16).

Table 16: Ports adjacent to the SAC with over 1,000 vessels arrivals per year (Source DfT 2019).

Port	Total number of vessel arrivals in 2017
Grimsby & Immingham	7,197
London	7,045
Hull	3,217
Felixtowe	2,070
Medway	1,788
Harwich	1,403
Total	22,720

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

6.32 Studies undertaken on seven harbour porpoise in Danish waters indicated that there is 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 $_{\text{(rms SPL)}}$, causing changes in the foraging behaviour and others showing no behavioural response to the same level of noise. 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).

6.33 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 SAC 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.

6.34 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.

6.35 Physical impacts on harbour porpoise can arise from vessel strikes. Studies from stranded animals indicate that between 4.0% 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

6.36 There is a high risk of an impact from bycatch associated with the fishing industry to harbour porpoise across the North Sea and a medium risk from the removal of prey (Table 8) (JNCC and NE 2019). There is potential for impacts to the seabed from fishing gear.

6.37 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 and NE 2019). 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.

6.38 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 SAC but there is widespread fishing activity in the southern half and north-eastern edge of the SAC and relatively moderate to high level of fishing activity along the western edge of the central part of the SAC (Figure 22) (MMO 2017b). Note however, this does not include the activities of vessels less than 10 m in length.

6.39 The predominant fishing activity within the SAC 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).

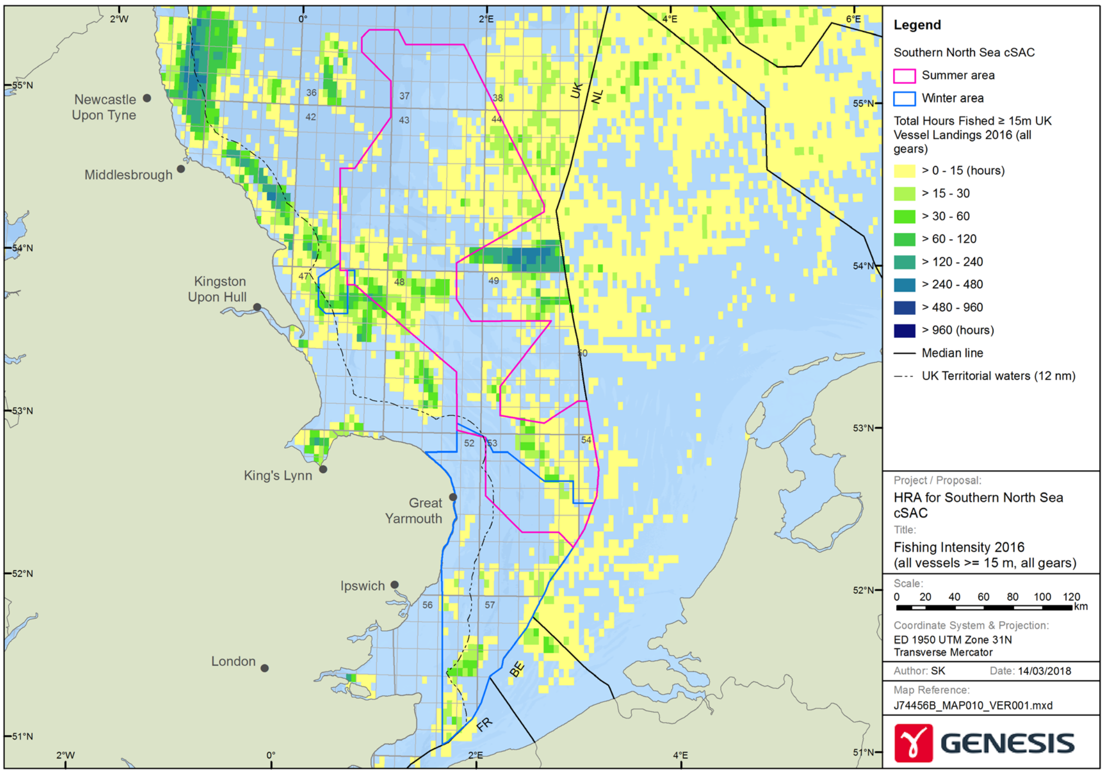


Figure 22: Fishing intensity across the SAC during 2014 by UK registered vessels.

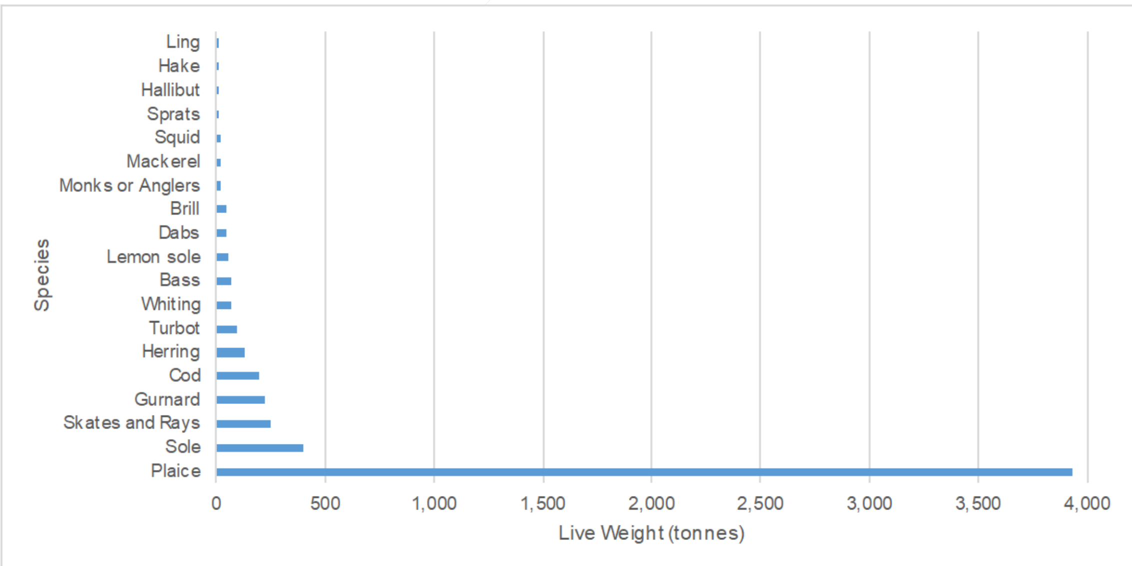


Table 17: Fish species caught within the SAC and landed in the UK during 2016 (Source MMO 2017d).

Unexploded Ordnance Clearance and Blasting Activities

6.40 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 SAC varies. Data from six previous UXO clearance campaigns within the Southern North Sea have reported the detonation of between 8 and 36 items of UXO, with the most frequently occurring charge weight being between 101 and 250 Kg NEQ (Net Explosive Quantity); broadly equivalent to between a 500 Ib and 1,000 Ib bomb (Figure 23).

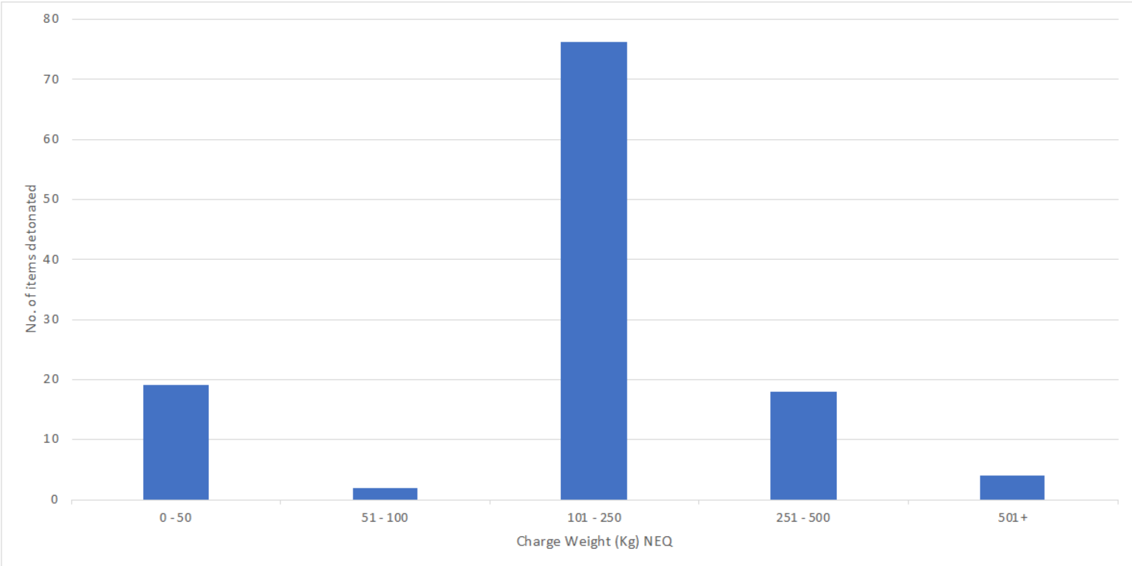


Figure 23: Reported charge weights of UXO cleared at offshore wind farms in the southern North Sea.

6.41 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

6.42 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 2019).

6.43 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).

6.44 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)

6.45 It is recognised that most relevant pollutants have been phased out and any future impacts are largely from historical discharges (JNCC and NE 2019).

Recreational Boating Activity

6.46 The current level of impact risk from noise arising from recreational boating on harbour porpoise across UK waters is identified as being medium (Table 8) (JNCC and NE 2019).

6.47 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 SAC. 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 SAC 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

6.48 The current level of impact risk from noise arising from ADDs across UK waters is identified as being medium, (Table 8) (JNCC and NE 2019).

6.49 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.

6.50 Acoustic deterrent devices such as pingers are used by ‘setnet’ fishing vessels as a mitigation measure to reduce the risk of harbour porpoise bycatch. Their use is limited to vessels greater than 12 metres in length and under an EC Regulation 812/2004 their effectiveness at reducing the by-catch of marine mammals has to be reported (JNCC and NE 2019). 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).

6.51 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.

6.52 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 SAC. 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 $_{\text{(peak SPL)}}$ and 241 dB re 1µPa-m $_{\text{(peak SPL)}}$ 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 $_{\text{(peak SPL)}}$ 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 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 $_{\text{(0-peak SPL)}}$ 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 2017c). The aim of this condition is to allow time for marine mammals to 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 SAC 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 (Figure 24). It is therefore predicted that harbour porpoise will be unable to hear the sound arising from an echosounder.

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 greater than 200 kHz and are therefore operating at frequencies predominantly outside of the hearing range of harbour porpoise (Figure 24).

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 24) (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.

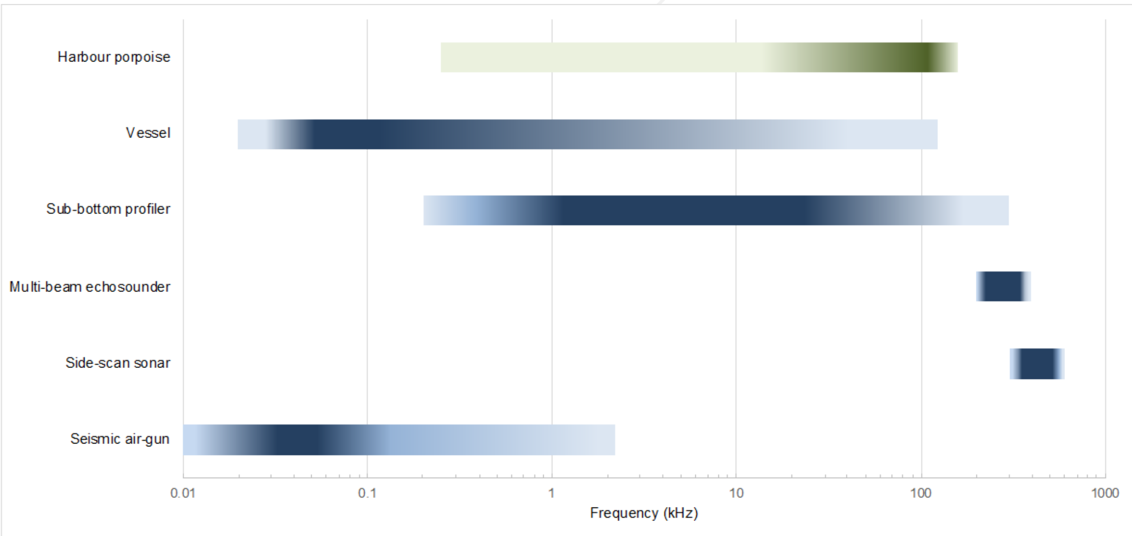


Figure 24: Hearing frequencies for harbour porpoise and sound bandwidths arising from seismic and geophysical survey equipment and associated vessels.

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 and 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 and 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 (<1 kHz) with relatively low source levels. Source levels from platforms range from between 59 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) and at frequencies ranging between 10 Hz and 10 kHz (Nedwell and 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 $_{\text{(0-peak SPL)}}$ 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 re 1 μPa at 300 m $_{\text{(0-peak SPL)}}$. 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 SAC 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, McGarry *et al*. 2017).

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 Mitigation measures may be proposed by the plan or project proponent and/or required by the competent national authorities in order to avoid the potential impacts identified in the appropriate assessment or reduce them to a level where they will no longer adversely affect the site's integrity (EC 2019).

8.2 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 SAC. The following section presents a summary of the measures that are recognised as potential mitigation for pile-driving noise and how they are managed within the consenting process. Two detailed studies have been published reviewing the available technologies and their effectiveness in reducing noise during construction of offshore wind farms (Verfuss *et al*. 2019, TCE 2020).

Use of alternative foundations

8.3 There are a number of foundations types that can be used for offshore wind farms including the use of suction buckets and gravity based foundations and are considered as potential foundation options within wind farm applications (e.g. Forewind 2013a, 2014, SMart Wind 2015a). These foundation types avoid the extensive use of pile-driving and therefore reduce the level and duration of noise produced during the construction period. Other types of wind farm such as floating wind farms also reduce the need for extensive pile-driving.

8.4 The choice of foundation types is dependent on a number of factors including the type of foundation to be installed, water depth, seabed conditions, metocean conditions, wind and wave loads. The choice of foundation type is therefore project and site specific (Malhotra 2011).

Soft-start Procedures

8.5 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. An effective soft-start reduces the cumulative sound exposure to harbour porpoise providing that the individuals move away from the sound source (Ainslie and von Benda-Beckmann 2012, Robinson *et al* 2007).

8.6 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 starting at below 10% or 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).

8.7 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

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

8.9 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 [6]), 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

8.10 Reviews of ADDs and their potential effectiveness to mitigate impacts to harbour porpoise and other marine mammals have been published (e.g. Sparling *et al.* 2015, McGarry *et al.* 2017, 2018).

8.11 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 and auditory injury could occur at the start of pile-driving activities and may be considered as an alternative approach to using marine mammal 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).

8.12 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

[6] Note that although typically the standard mitigation zone is either 500 m or 1,000 m, these can be adjusted depending on the findings of the impact assessment (JNCC 2010b).

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).

8.13 Published studies have been undertaken on the effectiveness of using an ADD to displace harbour porpoise (Brandt *et al.* 2012 and 2013, Dähne *et al.* 2017). The studies have reported differing levels of effectiveness with one recording a harbour porpoise within 798 m of an active ADD and another showing that all harbour porpoise avoided the area within 1.9 km and for half the time between 2.1 and 2.4 km (Brandt *et al.* 2012 and 2013). Both these studies 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 reported a strong avoidance behaviour by harbour porpoise to the ADDs, with one study reporting a 96% reduction in the number of detections out to 7.5 km (Brandt *et al*. 2013, Coram *et al*. 2014). The studies concluded that there appeared to be effective deterrence at levels of 132 dB re 1 µPa $_{\text{(rms SPL)}}$ and no clear avoidance at levels below 119 dB re 1 µPa $_{\text{(rms SPL)}}$ (Brandt *et al*. 2012). The effects of avoidance lasted approximately six hours.

8.14 A study undertaken by Dähne *et al.* (2017) reported a significant reduction in the number of harbour porpoise detected out to 12 km from the sound source with near total avoidance of the area within 3 km.

8.15 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 (Sparling *et al.* 2015, McGarry *et al*. 2018).

8.16 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.

8.17 Noise arising from the use of ADDs could impact on harbour porpoise within the SAC and their use should be considered carefully (Faulkner *et al.* 2018, JNCC and NE 2019). In the event that the use of an ADD is planned, discussions with the MMO and the SNCBs would be held.

Bubble Curtains

8.18 The use of bubble curtains has been used as a form of mitigation during construction at 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.

8.19 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 (Lucke *et al*. 2011, Koshinski and Ludemann 2013, Rumes *et al*. 2016, Dähne *et al.* 2017). 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).

8.20 Modelling undertaken using data from existing and tested bubble curtains (Bellmann 2014) and based on pile-driving using a 3,000 kJ hammer indicates that bubble curtains could reduce both the distance and extent of disturbance to harbour porpoise may occur (Table 18).

Table 18: Distance at which disturbance is predicted to arise from pile-driving with and without the use of a bubble curtain.

Bubble curtain type	Average distance (km)	% difference in distance	Average area (km^2)	% difference in area
No Bubble curtain	40.1	0	5,352	0
BBC	17.9	55.4	1,022	80.9
LBC	15.2	62.1	732.4	86.3
SBC	6.7	83.3	142.8	97.3
DBBC	5.2	87.0	86.8	98.4

BBC = Big Bubble Curtain. *SBC = Small Bubble Curtain.*
LBC = Little Bubble Curtain. *DBBC – Double Big Bubble Curtain.*

8.21 The effective use of bubble curtains may not always be technically possible with a complete curtain of bubbles required that encloses the pile-driving activity. Where there are gaps in the bubble curtain, formed by bubbles drifting, noise will propagate into the water column uninhibited (Theobold and Wood 2011). Small bubble curtains in particular may be more affected by currents that cause bubble drift which can decrease their effectiveness (Verfuss *et al*. 2019). They are routinely used in German waters during the installation of wind turbine foundations where BBC and DBBC have been used in water depths of between 4 m and 40 m (Philipp 2020). In the UK they have been used during UXO clearance undertaken within the Southern North Sea SAC.

Physical Barriers

8.22 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).

8.23 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 $_{\text{(Peak SEL)}}$ and therefore be effective at reducing the extent of any impacts (Koshinski and Ludemann 2013).

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

Alternative installation techniques

8.25 Technologies are being developed to install piles using alternative pile-driving technology. Amongst these is BLUE piling technology that, instead of steel, uses a column of water to strike on the pile and could reduce the level of SEL noise produced during pile-driving by between 19 and 24 dB (Verfuss *et al.* 2019, TCE 2020). The technology is still being developed but could have future potential for mitigation.

8.26 Vibro-piling is an existing technology whereby the pile is vibrated into the seabed reducing the need for pile-driving. However, it is rarely used in the installation of wind farm foundations and where it has been used has required the use of a pile-driving hammer during part of the installation to ensure secure foundations (TCE 2020).

Mitigation Management

8.27 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.

8.28 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).

8.29 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.

8.30 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).

8.31 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.

8.32 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.

8.33 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.

8.34 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.

Monitoring

8.35 It is recognised that in order to determine that consented or future offshore wind farm activities do not have an adverse effect on the designated site and potential mitigation measures in place to eliminate or reduce adverse effects are effective monitoring may be required (EC 2019). Monitoring may be undertaken by individual projects or by means of a strategic monitoring programme and can be made a condition to a Marine Licence.

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, 2019) 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 $_{\text{(peak to peak SPL)}}$ (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 $_{\text{(peak to peak SPL)}}$.

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 defined 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.

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, 2019) 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*. (2019) proposed that for single pulses and multiple pulsed sound, such as that generated by piling, a sound pressure level of 202 dB re 1µPa (unweighted peak SPL) or above will be sufficient to cause the onset of PTS, and a pressure level of 196 dB re 1µPa (unweighted peak SPL) sufficient to cause the onset of TTS in porpoises. 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 $\mu Pa^2 s$.

10.3 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 was revised in 2018 (NMFS 2018). The thresholds for harbour porpoise in the NMFS (2018) guidance are the same as those presented in Southall *et al.* (2019).

10.4 The revised thresholds are lower and provided with different audio weightings than those published in Southall *et al.* (2007) and Lucke *et al*. (2009) and which were used in some of the wind farm applications. Consequently, the extent and area within which the onset of PTS is predicted to occur, based on the NMFS and updated Southall *et al*. guidance, may be greater than previously considered.

Marine Mammal Disturbance

10.5 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, which can vary with their behaviour at the time and whether there are suitable areas to which they may move.

10.6 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) and the updated Southall *et al*. (2019) did not present any thresholds at which disturbance to marine mammals may occur.

10.7 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). Although other studies have shown that behavioural changes can occur at both higher and lower noise levels, the unweighted threshold of 145 dB re.1μPa^{2}s is widely used as a threshold in impact assessments and has therefore been used for this HRA.

10.8 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. 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 25).

10.9 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 also allowed a dose response curve to be developed (Figure 25) (BOWL 2017). Further data obtained during pile-driving at the Beatrice Offshore Wind Farm has shown that the proportion of harbour porpoise responding to pile-driving noise decreases over time. At the beginning of construction 50% or more of the harbour porpoise responded within 7.4 km of the pile-driving, this reduced to 4.0 km after 47 piles and 1.3 km after the final 86th pile. Similarly, 50% or more harbour porpoise responded to an unweighted SEL of 144 dB re.1μPa^{2}s (95% CI. 142.1–146.8) at the start of construction and this increased over time to 150.0 dB re.1μPa^{2}s (95% CI. 147.5–153.6) after 47 piles and to 160.4 dB re.1μPa^{2}s s (95% CI. 153.2–178.9) after 86 piles (Graham *et al*. 2019). Consequently, the response by harbour porpoise to pile-driving noise may decline overtime.

10.10 Currently, there is no guidance as to which dose response curves are considered most appropriate for use when undertaking an assessment. At the time of undertaking the assessment for this HRA the data from the Beatrice Offshore Wind Farm were unpublished and the analysis of the data was at a preliminary stage and therefore not used in this HRA. Consequently, the use of a dose response curve published in Brandt *et al.* (2016) has been used for this assessment. It is recognised that the data used to develop the curve does include results from wind farms where noise mitigation measures may have been used and that this could affect the range at which disturbance could arise. However, it also includes data from wind farms that have also been used to determine the Effective Deterrent Range of 26 km (Tougaard *et al.* 2013, Brandt *et al*. 2016, JNCC, NE and DAERA 2020a).

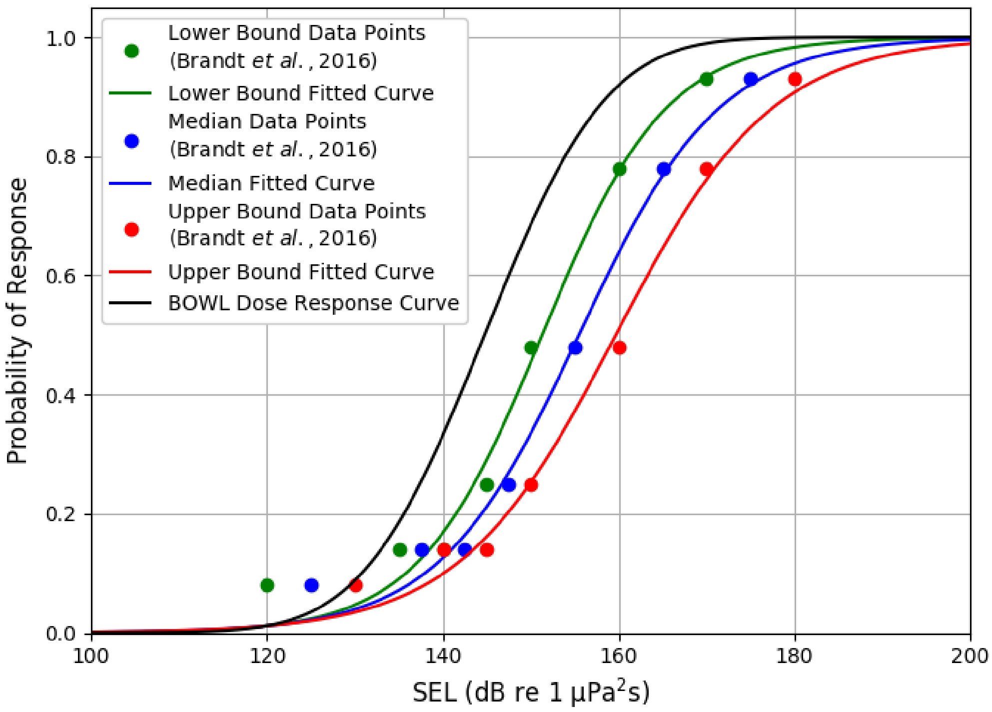


Figure 25: Behavioural response curves considered for assessing potential behavioural disturbance to harbour porpoise (Source Brandt *et al*. 2016, BOWL 2017).

10.11 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 μPa²s for injury and unweighted SEL of 145 dB re.1μPa²s for potential displacement; these are based on published studies (Lucke *et al.* 2009, NMFS 2018, Southall *et al.* 2019).

Fish

10.12 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.

10.13 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).

10.14 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 RANGE

11.1 The Effective Deterrent Range / Radius (EDR) has been proposed by the Statutory Nature Conservation Bodies (SNCBs) as a means to measure potential impacts on harbour porpoise within the SAC (JNCC, NE and DAERA 2020a,b). 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 26 km 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 The EDR for all activities presented in the SNCB guidance are presented in Table 19.

Table 19: Recommended Effective Deterrence Ranges (EDRs) (Source JNCC, NE and DAERA 2020a).

Activity	EDR (km)
Monopile	26
Monopile with noise abatement	15
Pin-pile (with and without noise abatement)	15
Conductor piling for oil & gas wells	15
UXO	26
Seismic (airguns) survey	12
Other geophysical surveys	5

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, NE and DAERA 2020a).

11.4 BEIS have been advised that the use of the EDR and the thresholds (see Section 14) should be used when assessing the risk of significant disturbance as a result of noise and should be considered when undertaking this assessment (JNCC and NE 2017, JNCC, NE and DAERA 2020a).

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 SAC, i.e. a point furthest within the SAC boundaries or, of outside the boundaries, the point closest to the SAC boundary. This provides the greatest potential area of impact within the SAC.
- 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 those 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 and associated documents.

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 $\mu Pa^2 s$ 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 $\mu Pa^2 s$ 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 noise 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 SAC. 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, noise modelling has been carried out at three locations within the SAC, 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 20, Figure 26).

Table 20: 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

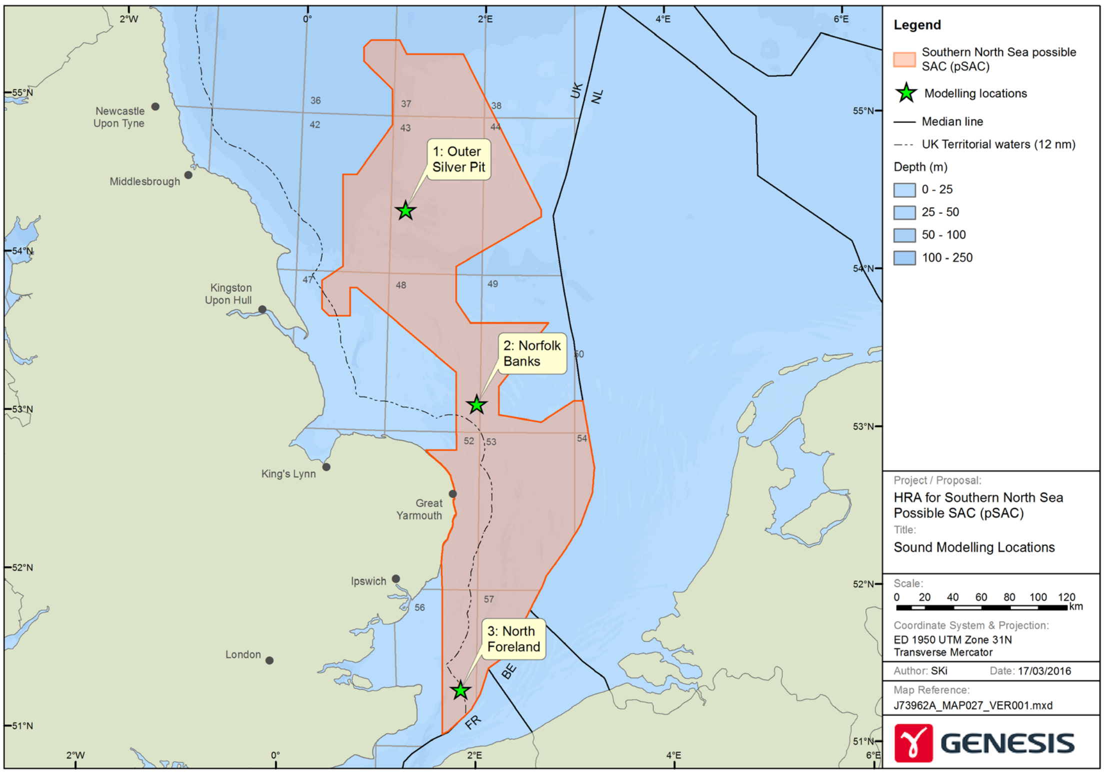


Figure 26: Noise modelling locations selected within the SAC for activities other than pile-driving.

12.7 Noise 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 SAC, 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, undisturbed, 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 noise 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 the highest 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 noise 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 μPa^{2}s $_{\text{(0-peak SPL)}}$. This is a relatively large airgun array used typically by the oil and gas industry when exploring for hydrocarbons. The parameters used to undertake the noise modelling are presented in Table 21.

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 2017c). All seismic surveys undertaken within the SAC 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.

Table 21: Seismic airgun array parameters used for noise modelling.

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

12.13 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 22. 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.

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

Table 22: Sub-bottom profiler parameters used for noise modelling.

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

12.15 UXO clearance could occur anywhere within the SAC. The source level and frequency content of an underwater explosion is dependent on numerous factors, including the charge weight (also called the Net Explosive Quantity (NEQ)), the type of explosive material, and the depth of the detonation. Noise modelling for blasting and UXO clearance activities within the SAC is based on a range of charge 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$_{\text{(peak SPL)}}$ to 297 dB *re* 1 μPa^{2}s$_{\text{(peak SPL)}}$. The predicted peak SPL source levels are presented in Table 23.

Table 23: Predicted peak SPL source levels for different explosive weights.

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

12.16 JNCC guidelines advise that for '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 noise modelling are therefore focused on the potential for permanent auditory injury to occur, i.e. PTS. 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 recognised that over a course of a UXO clearance campaign there is potential for repeated detonations to occur over a period of time, which could cause a level of displacement from an area. The number of detonations per day will vary with no more than two detonations per day at some sites e.g. EAOWL (2017) but with a potential for up to five detonations per day at Hornsea Two (Ørsted 2018d, e; Ørsted 2020b).

13 NOISE MODELLING RESULTS

13.1 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. To address this and to ensure a consistent approach across all relevant wind farms, noise modelling has been undertaken for all projects that were identified within the scoping exercise carried out to inform this HRA and 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.

Pile-driving

13.2 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).

13.3 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 SAC, i.e. the location furthest within the SAC or, if outside the boundaries of the SAC, a location near to the SAC 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.

13.4 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).

13.5 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.

13.6 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 be the most appropriate thresholds to use at the current time.

13.7 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, SMart WInd 2015a, Vattenfall 2018). 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.

13.8 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.

Hornsea Two: single pile-driving

13.9 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 24 and Table 25. The potential extent of displacement and disturbance for unweighted SEL thresholds of 145 re 1 μPa^{2}s is presented in Table 26.

Table 24: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Hornsea Two (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 25: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Hornsea Two (weighted SEL).

Location	Cumulative weighted SEL of 155 dB re 1 uPa^2s							
	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 26: Distances and area within which displacement or disturbance is predicted to occur from pile-driving at Hornsea Two (unweighted SEL).

Location	Unweighted SEL of 145 SEL dB re.1μPa^2s							
	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

13.10 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.

13.11 The potential area of displacement and disturbance from concurrent pile-driving are presented in Table 27.

Table 27: Area within which displacement or disturbance is predicted to occur from concurrent pile-driving at Hornsea Two (unweighted SEL).

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

Unweighted SEL: 145 SEL dB re.1μPa²s

Creyke Beck A

13.12 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 28 and Table 29. The potential extent of displacement and disturbance for unweighted SEL thresholds of 145 re 1 μPa2s is presented in Table 30.

Table 28: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Creyke Beck A (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 29: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Creyke Beck A (weighted SEL).

Location	Cumulative weighted SEL of 155 dB re 1 uPa²s							
	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 30: Distances and area within which displacement or disturbance is predicted to occur from pile-driving at Creyke Beck A (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	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

13.13 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 SAC. 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 31.

Table 31: Area within which displacement or disturbance is predicted to occur from concurrent pile-driving at Creyke Beck A (unweighted SEL).

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

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

Creyke Beck B

13.15 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 32 and Table 33. The potential extent of displacement and disturbance for unweighted SEL thresholds of 145 re 1 μPa2s is presented in Table 34.

Table 32: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Creyke Beck B (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	589	634	685	1.26	702	757	806	1.80
2	477	507	532	0.81	608	651	688	1.33

Table 33: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Creyke Beck B (weighted SEL).

Location	Cumulative weighted SEL of 155 dB re 1 uPa^2s							
	2,300 kJ				3,000 kJ (5.5 hrs)			
	Distance (m)			Area (km^2)	Distance (m)			Area (km^2)
	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 34: Distances and area within which displacement or disturbance is predicted to occur from pile-driving at Creyke Beck B (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	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

13.16 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 SAC. 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 35.

Table 35: Area within which displacement or disturbance is predicted to occur from concurrent pile-driving at Creyke Beck B (unweighted SEL).

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

Unweighted SEL: 145 SEL dB re.1μPa²s

Teesside A

13.18 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 36 and Table 37. The potential extent of displacement and disturbance for unweighted SEL thresholds of 145 re 1 μPa²s is presented in Table 38.

Table 36: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Teesside A (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 37: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Teesside A (weighted SEL).

Location	Cumulative weighted SEL of 155 dB re 1 uPa²s							
	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 38: Distances and area within which displacement or disturbance is predicted to occur from pile-driving at Teesside A (unweighted SEL).

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

13.19 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 SAC. 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 39.

Table 39: Area within which displacement or disturbance is predicted to occur from concurrent pile-driving at Teesside A (unweighted SEL).

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

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

Teesside B

13.21 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 40 and Table 41. The potential extent of displacement and disturbance for unweighted SEL thresholds of 145 re 1 μPa2s is presented in Table 42.

Table 40: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Teesside B (unweighted 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	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 41: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Teesside B (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	2,107	2,240	2,339	15.75	4,201	4,456	4,708	62.32

Table 42: Distances and area within which displacement or disturbance is predicted to occur from pile-driving at Teesside B (unweighted SEL).

Location	Unweighted SEL of 145 SEL dB re.1μPa^2s							
	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

13.22 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.

13.23 The potential area of displacement and disturbance from concurrent pile-driving are presented in Table 43.

Table 43: Area within which displacement or disturbance is predicted to occur from concurrent pile-driving at Teesside B (unweighted SEL).

Area of disturbance (km²)	
3,000 kJ	5,500 kJ
1,855	2,806

Unweighted SEL: 145 SEL dB re.1μPa²s

Triton Knoll

13.24 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 44 and Table 45. The potential extent of displacement and disturbance for unweighted SEL thresholds of 145 re 1 μPa2s is presented in Table 46.

Table 44: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Triton Knoll (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 (km²)	Distance (m)			Area (km²)
	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 45: Distances and area within which the onset of PTS is predicted to occur from pile-driving at Triton Knoll (weighted SEL).

Location	Cumulative weighted SEL of 155 dB re 1 uPa²s							
	2,700 kJ (4.0 hrs)				4,000 kJ (4.0 hrs)			
	Distance (m)			Area (km²)	Distance (m)			Area (km²)
	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 46: Distances and area within which displacement or disturbance is predicted to occur from pile-driving at Triton Knoll (unweighted SEL).

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

13.25 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.

13.26 The potential area of displacement and disturbance from concurrent pile-driving are presented in Table 47.

Table 47: Area within which displacement or disturbance is predicted to occur from concurrent pile-driving at Triton Knoll (unweighted SEL).

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

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

East Anglia Three

13.27 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 48 and Table 49. The potential extent of displacement and disturbance for unweighted SEL thresholds of 145 re 1 μPa2s is presented in Table 50.

Table 48: Distances and area within which the onset of PTS is predicted to occur from pile-driving at East Anglia Three (unweighted zero to peak SPL).

Location	Unweighted SPL of 202 dB re 1 uPa (0-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 49: Distances and area within which the onset of PTS is predicted to occur from pile-driving at East Anglia Three (weighted SEL).

Location	Cumulative weighted SEL of 155 dB re 1 uPa^{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	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 50: Distances and area within which displacement or disturbance is predicted to occur from pile-driving at East Anglia Three (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

13.28 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 SAC. 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 51.

Table 51: Area within which displacement or disturbance is predicted to occur from concurrent pile-driving at East Anglia Three (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)

13.30 Details of the parameters used in the noise modelling undertaken for seismic surveys are presented in Table 21.

13.31 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 52).

13.32 The results from the modelling indicate that noise levels based on disturbance threshold of an unweighted 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 53).

Table 52: 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 SAC.

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

Location	Distance and area of potential behavioural disturbance			
	Distance(m)			*Max. Area (km²)*
	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

13.33 Figure 27 to Figure 29 present the area of potential disturbance from seismic surveys for three locations within the SAC.

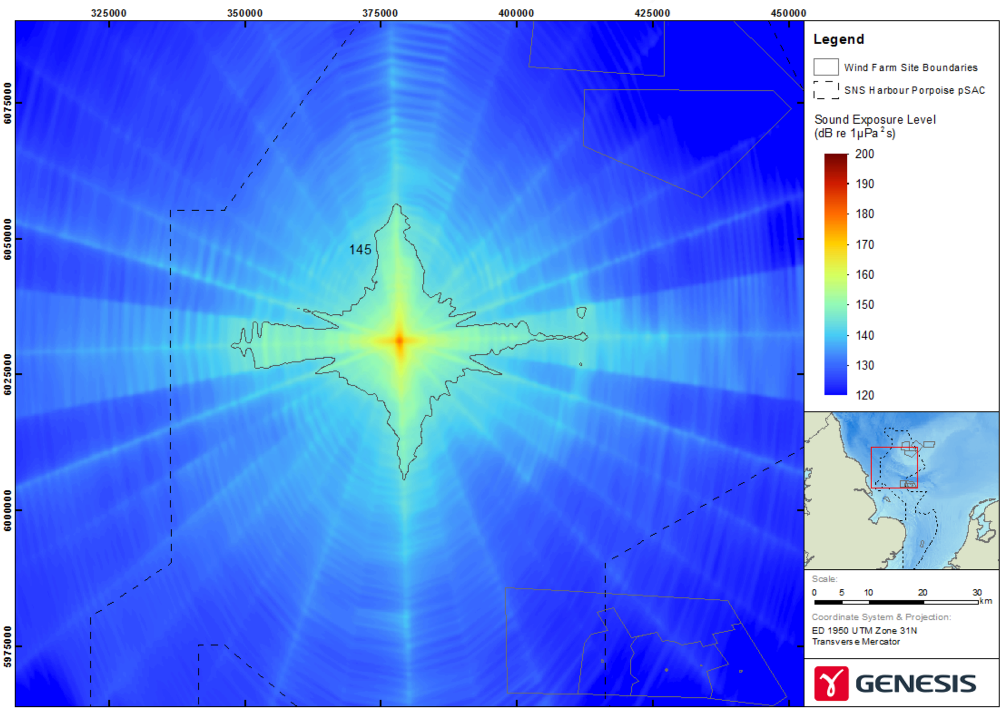


Figure 27: Area of potential disturbance to harbour porpoise from seismic survey at Outer Silver Pit within the SAC.

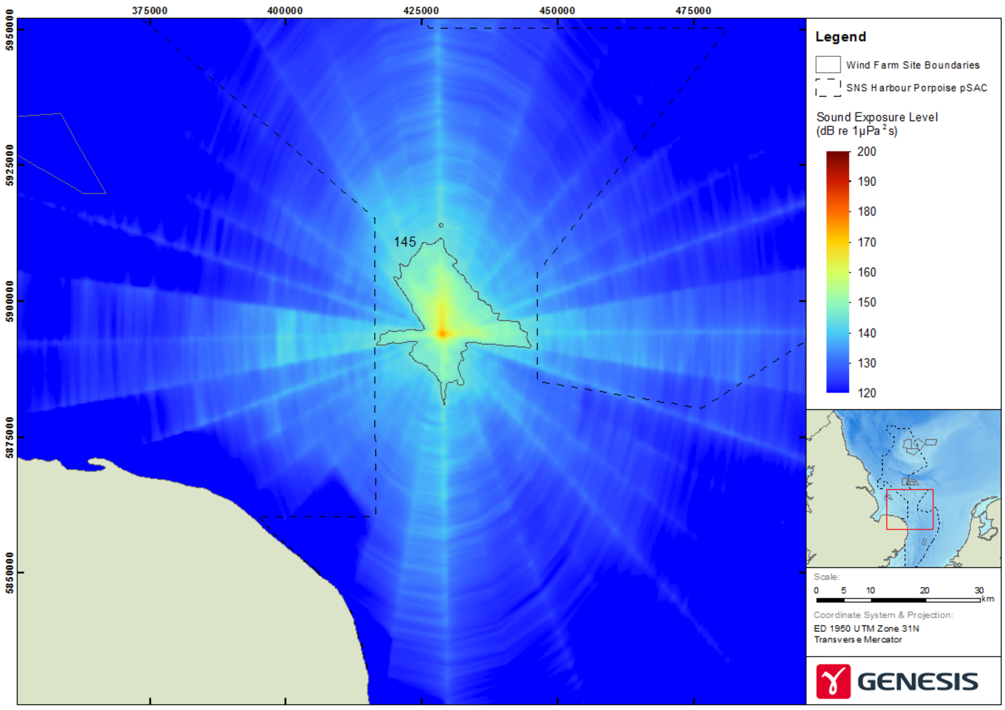


Figure 28: Area of potential disturbance to harbour porpoise from seismic survey at Norfolk Banks within the SAC.

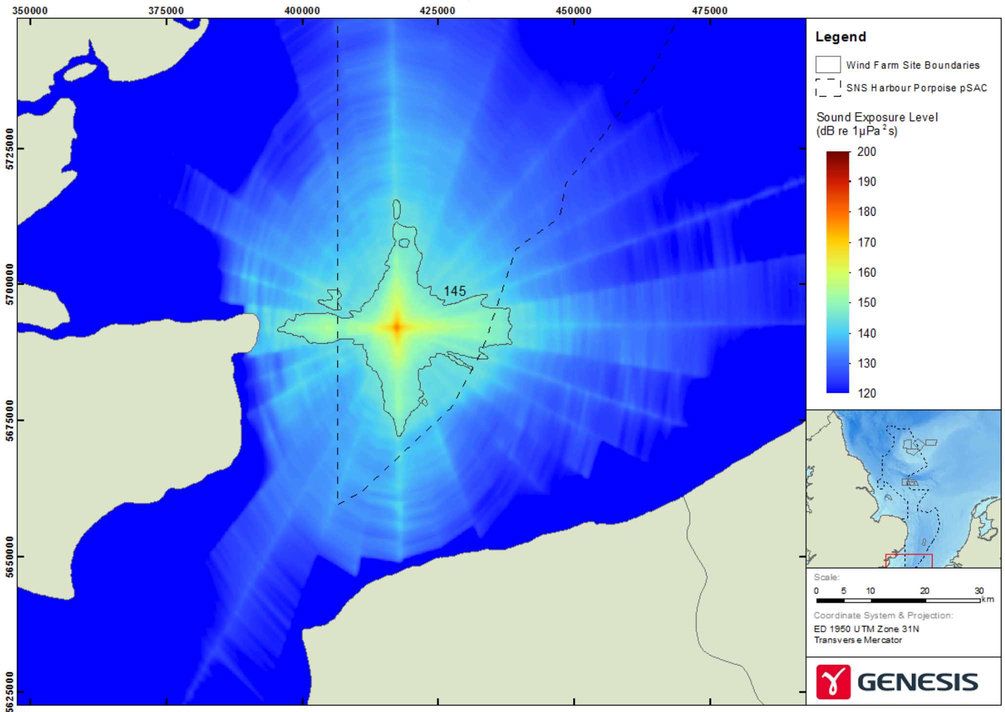


Figure 29: Area of potential disturbance to harbour porpoise from seismic survey at North Foreland within the SAC.

Sub-bottom profiler

13.34 Details of the parameters used in the noise modelling undertaken for sub-bottom profilers are presented in Table 22.

13.35 The results from the noise modelling predicted that the onset of PTS could occur within 23 m of a sub-bottom profiler (Table 54).

13.36 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 55).

13.37 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 54: Distances from a sub-bottom profiler at which the onset of PTS could occur to harbour porpoise at three locations within the SAC.

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

Location	Distance and area of potential behavioural disturbance			
	Distance(m)			Area (km2)
	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

13.38 Figure 30 to Figure 32 present the area of potential disturbance from sub-bottom profilers for three locations within the SAC.

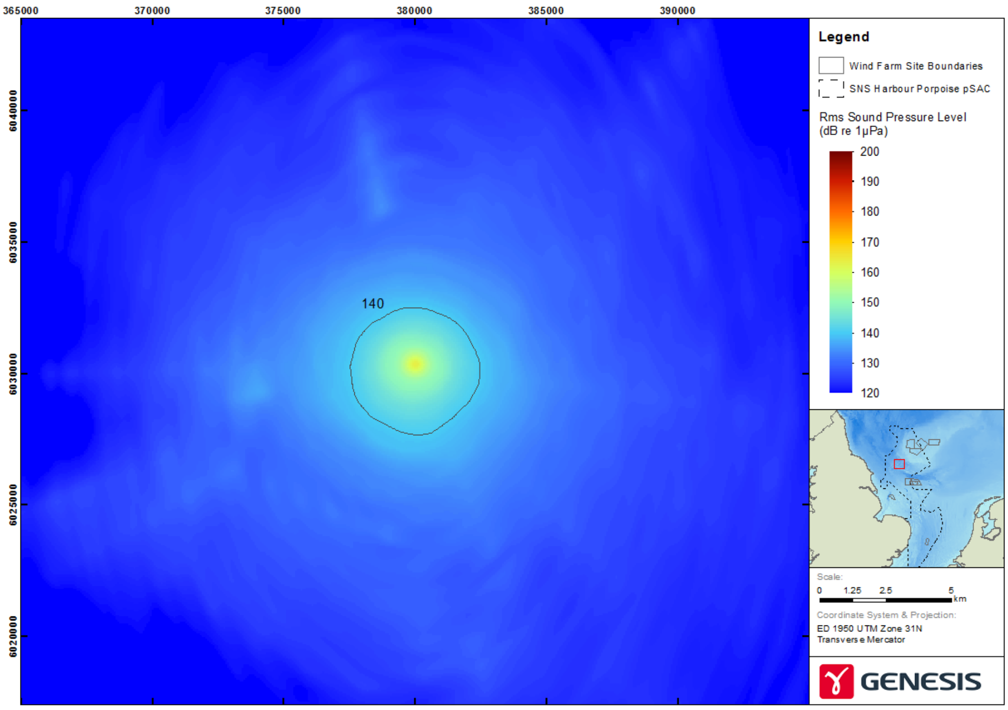


Figure 30: Area of potential disturbance to harbour porpoise from sub-bottom profiler at Outer Silver Pit within the SAC.

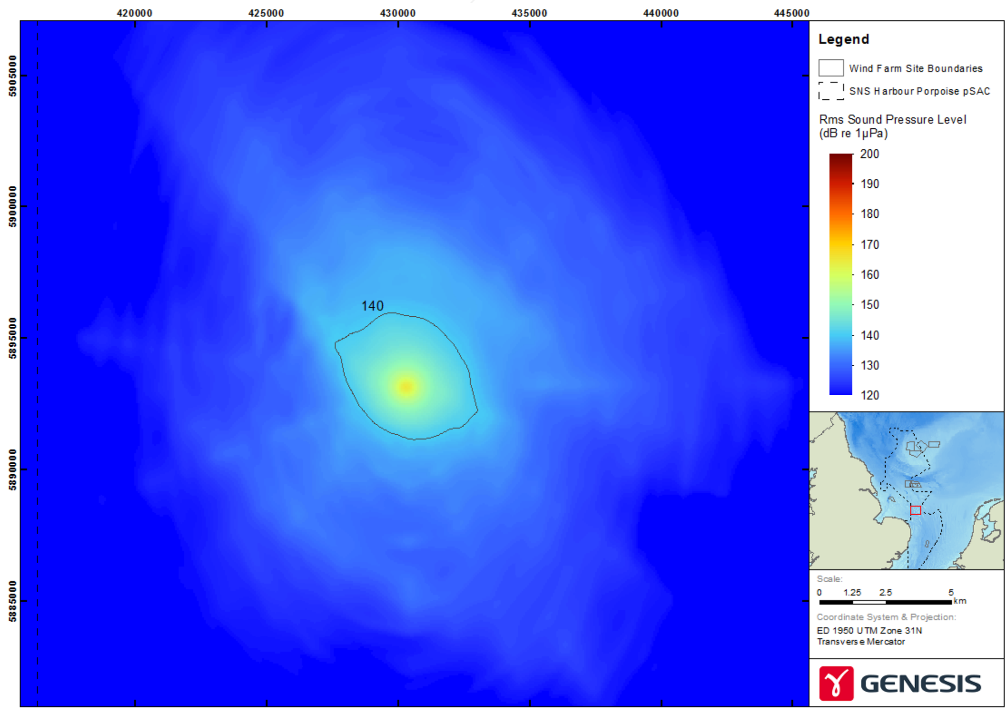


Figure 31: Area of potential disturbance to harbour porpoise from sub-bottom profiler at Norfolk Banks within the SAC.

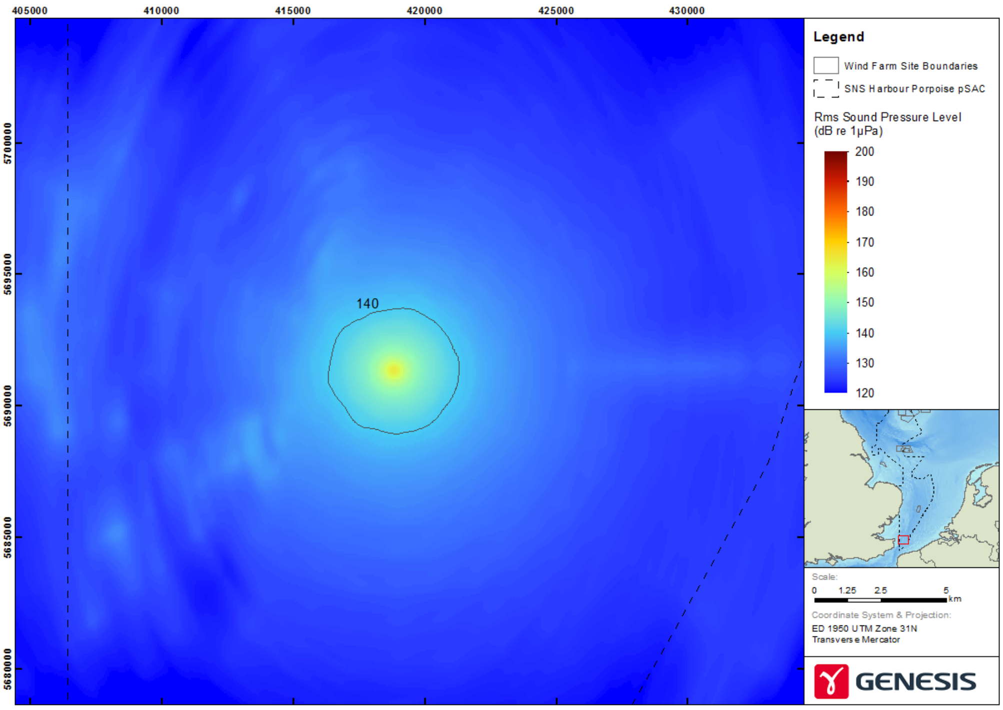


Figure 32: Area of potential disturbance to harbour porpoise from sub-bottom profiler at North Foreland within the SAC.

UXO Detonation and Blasting

13.39 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 33, Table 56). The modelling undertaken is not site specific and therefore the results apply to all locations within the SAC. 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).

13.40 It is recognised that due to the paucity of data collected during UXO clearance activities there is uncertainty over the results from noise modelling. Monitoring of UXO clearance along the Nord Stream 2 gas pipeline in the Baltic has indicated that noise models can over-estimate the extent PTS and TTS with increasing distance from sound source, particularly at distances of greater than 5 km (Nord Stream 2018). Furthermore, the predicted area of impact is dependent on the peak pressure level used for the noise model and this can vary across sites and ordnance, with no correlation between the peak pressure level and the size of the ordnance (Nord Stream 2018, Meriläinen *et al.* 2018). The measured results from Nord Stream 2 indicated that the noise model over-estimated the area of impact by an average of

24% due to the precautionary peak pressure levels used in the modelling. Consequently, the results from noise modelling undertaken for this HRA are considered worst-case and it is predicted that the extent of potential effect will be smaller than predicted by the modelling.

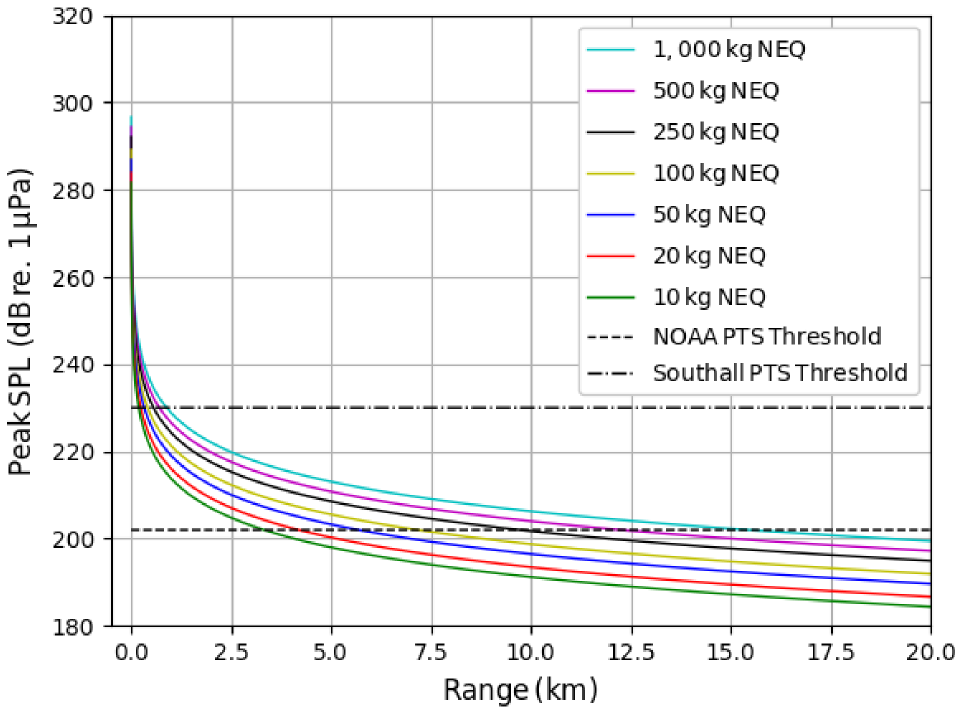


Figure 33: Predicted peak SPL for the detonation of different explosive weights.

Table 56: Distances from a single detonation of explosive at which the onset of PTS could occur in harbour porpoise.

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 57).

Table 57: 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 µPa²s)	0	0	0	0	0
Recoverable injury (Unweighted cum. SEL of 216dB re 1 µPa²s)	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 µPa²s)	0	0	0	0	0
Recoverable injury (Unweighted cum. SEL of 203 dB re 1 µPa²s)	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 µPa²s)	0	0	0	0	0
Recoverable injury (Unweighted cum. SEL of 203 dB re 1 µPa²s)	9	1	1	4	4

14 CONSERVATION OBJECTIVES

14.1 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 2019). They outline the desired state for any European site, in terms of the features for which it has been designated to contribute in the best possible way to achieving favourable conservation status at the national, bio-geographical and European level (JNCC and NE 2019). 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).

14.2 To ensure the site contributes in the best possible way to achieving favourable conservation status, management of human activities occurring in or around the site is required if these activities are likely to have an adverse impact (directly or indirectly) on the integrity of the site, with regards to its Conservation Objectives (JNCC and NE 2019).

14.3 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 2019b).

14.4 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 2019b, JNCC and NE 2019).

14.5 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 availability of prey.

Southern North Sea SAC Conservation Objectives

To ensure that the integrity of the site is maintained and that it makes the best possible contribution to maintaining Favourable Conservation Status for Harbour Porpoise in UK waters.

In the context of natural change, this will be achieved by ensuring that:

1. Harbour porpoise is a viable component of the site,
2. There is no significant disturbance of the species, and
3. The condition of supporting habitats and processes, and the availability of prey is maintained.

Source: JNCC and NE 2019

14.6 The 'integrity of the site' is not defined in the Conservation Objectives. However, EU and UK Government guidance defines the integrity of a site as '*the coherent sum of the site's ecological structure, function and ecological processes, across its whole area, which enables it to sustain the habitats, complex of habitats and/or populations of species for which the site is designated*' (Defra 2012, EC 2019). 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.

14.7 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 2019). Unacceptable levels of impact are those that could affect the favourable conservation status of the harbour porpoise within their natural range; the North Sea Management Unit population (JNCC and NE 2019).

14.8 Within the Conservation Objectives '*…significant disturbance of the species'* is defined as significant '*if it leads to the exclusion of harbour porpoise from a significant portion of the site'* (JNCC and NE 2019).

14.9 *'Supporting habitats and processes'* relate to maintaining the characteristics of the seabed and water column '*…ensuring that prey is maintained within the site and is available to harbour porpoises using the site*' (JNCC and NE 2019).

14.10 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).

14.11 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.

14.12 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.

14.13 Thresholds to assess and manage the effects of noise on site integrity have been published by Statutory Nature Conservation Bodies (SNCBs) (JNCC, NE and DAERA 2020a,b). 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 SAC may be affected over a period of time.

14.14 Noise disturbance within the SAC from a plan/project, individually or in combination, is considered to be significant if it excludes harbour porpoises from more than:

- 20% of the relevant area of the site in any given day, or
- an average of 10% of the relevant area of the site over a season.

14.15 Any plan or project which, individually or in combination, could breach the area/time thresholds as set out above could be deemed to have an adverse effect on site integrity necessitating noise management measures such as adjustment of activity schedules, the use of alternative technologies and noise abatement. The aim of noise management should be to keep below the thresholds as much as possible (JNCC, NE and DAERA 2020a).

14.16 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 58. The results indicate that should the impact occur wholly inside the SAC 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.

14.17 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 58: Estimated extent sound levels capable of causing displacement disturbance occur in order to impact on site integrity.

Site area	Area (km^2)	Daily 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 SAC	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

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

14.18 Unlike the daily threshold, the area of the SAC 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 an average seasonal footprint (JNCC, NE and DAERA 2020a). 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 and Hornsea Project Two; the approach and conclusions of which were agreed with by Natural England (EAOWL 2017, BEIS 2016b, BEIS 2017a, BEIS 2018b, MMO 2017a).

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

14.20 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). The thresholds have been noted within the assessment as a high-level management tool to limit the spatial distribution of noise from offshore wind farm pile-driving and other activities for a large offshore SAC, such as the Southern North Sea SAC.

14.21 The HRA has been carried out in light of best scientific knowledge with reference to the Conservation Objectives of the SAC and the potential impacts on the integrity of the site (EC 2019).

15 IN-COMBINATION IMPACTS

15.1 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).

15.2 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.

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

15.4 It is recognised that the potential on-going impacts on harbour porpoise from current activities that have had a long historical presence within the SAC (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.

15.5 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. However, it is noted that guidance from SNCB regarding the management of noise within the SAC excludes noise from shipping (JNCC, NE, DAERA 2020a).

15.6 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

15.7 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 59).

- 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 a CfD but not yet started construction. 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 (under construction and due to be fully commissioned in 2020), East Anglia One (under construction and due to be fully commissioned in 2020), Hornsea Project Two (offshore construction starts in 2020), Triton Knoll (under construction and due to be fully commissioned in 2020/21), Creyke Beck A and B, Teesside A and B (offshore construction not yet started).
- 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. The only Tier 3 project at this time is the East Anglia Three wind farm.
- 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. Tier 4 projects include the Hornsea Project Three, Norfolk Vanguard East and West, Norfolk Boreas, East Anglia One North and East Anglia Two offshore wind farms. There is a low level of confidence in the final design envelope and/or the construction schedule.
- Tier 5 developments are projects that are planned but for which there is little, if any, information regarding the project that is relevant to this HRA, e.g. information on proposed construction methods. The Hornsea Project Four wind farm is a Tier 5 project. For this development there is not enough information available to consider construction noise impacts or impacts on the habitat other than using generic information.

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

- Sheringham Shoal,
- Dudgeon,
- Greater Gabbard,
- Galloper,
- Thanet [7].

15.9 All eight proposed extensions have been subject to a plan level HRA undertaken by The Crown Estate for the 2017 Offshore Wind Plan. The HRA assessed the possible impacts of the proposed extensions on relevant nature conservation sites (TCE 2019c). The plan level HRA undertaken concluded that there would be no adverse effect on the integrity of the Southern North Sea SAC from the proposed extension projects relating to the plan. There is no further information on any of the proposed extension projects, in particular the period of potential construction is unknown. Consequently, there is currently no available information relevant to this HRA upon which to undertake an in-combination assessment and the proposed extensions are therefore categorised as Tier 5 developments for which no, or very limited, information is available.

15.10 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.

[7] An application for a Development Consent Order for the Thanet Extension project was refused by the Secretary of State on 2 June 2020 for reasons unrelated to this HRA.

Table 59: 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, (Mermaid, Borselle II).
2	Developments under construction or have been awarded a CfD.	East Anglia One, Hornsea Projects One and Two, Triton Knoll, Creyke Beck A and B, Teesside A and B,
3	Consented developments without CfD.	East Anglia Three
4	Developments which have made an application but have not received a decision or projects for which preliminary environmental information has been published.	Hornsea Project Three, Norfolk Vanguard East and West, Norfolk Boreas, East Anglia One North, East Anglia Two.
5	Planned developments which may come forward in the future for which little or no relevant information is available.	Hornsea Project Four, 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.

16 LIKELY SIGNIFICANT EFFECTS TEST

16.1 The Habitats Regulations require 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.

16.2 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.

16.3 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.

16.4 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

16.5 Based on a peak SPL the results from the noise modelling indicate that noise arising from pile-driving activities could cause the onset of PTS on average from between 490 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 693 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).

16.6 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 SAC 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

16.7 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)

16.8 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 52).

16.9 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 53).

16.10 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 SAC and the potential in-combination impacts from seismic surveys are therefore considered further in the Appropriate Assessment.

Sub-bottom profiler

16.11 Results from the noise modelling indicate noise arising from sub-bottom profilers will not exceed the injury threshold for PTS beyond 23 m from the sound source (Table 54). 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 55).

16.12 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 SAC and the potential in-combination impacts are therefore considered further in the Appropriate Assessment.

Multi-beam echosounder

16.13 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).

16.14 The water depths within and adjacent to the SAC 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 SAC and no further assessment is required.

Side-scan sonar

16.15 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.

16.16 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 $_{\text{(Peak SPL)}}$ (SCAR 2002).

16.17 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

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

16.19 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 175.5 (A) re 1 µPa (Molvaer and Gjestland 1981).

16.20 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.

16.21 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

16.22 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.

16.23 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.

16.24 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 SAC (Table 60).

Assuming that two wind farms may be constructed simultaneously within the SAC 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 60: Estimated number of vessel movements during the construction and operation of consented wind farms within the SAC.

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.

16.25 Between 683 and 4,000 vessel movements per year are estimated to occur during the operating period of each wind farm (Table 60). Assuming all wind farms are constructed, there may be an estimated additional 52 vessel movements per day within the SAC.

16.26 The level of vessel activity associated with the consented offshore wind farms within the SAC 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 SAC. 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 SAC at any one time; this is equivalent to 0.07% of the SAC. 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).

16.27 This additional level of impact will not cause a likely significant effect. However, there is evidence within the SAC that harbour porpoise avoid areas of relatively high vessel traffic (JNCC and NE 2019). 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

16.28 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.

16.29 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.

16.30 Studies using Passive Acoustic Monitoring at platforms located on the Dogger Bank did not record any decrease in harbour porpoise activity at the platforms when drilling was being undertaken 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).

16.31 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.

16.32 Drilling noise has occurred within the SAC 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 SAC area appears to have increased (Hammond *et al.* 2013, 2017). 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 SAC is predicted to occur.

16.33 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 SAC and no further assessment is required.

Cable and pipeline trenching noise

16.34 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.

16.35 No noise modelling for trenching has been undertaken for the purposes of this assessment. However, existing noise modelling studies undertaken elsewhere have indicated that no PTS will occur 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 SAC may be impacted during any trenching activity. 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.

16.36 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).

16.37 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 SAC and no further assessment is required.

UXO detonation and blasting

16.38 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.

16.39 Noise 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 56).

16.40 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 SAC 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

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

16.42 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 either a long-term but temporary impact to the seabed if at the time of decommissioning the infrastructure is removed, or a permanent impact if any of the infrastructure is to remain in place following decommissioning.

16.43 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 carried out by the placement of rock, mattresses or grout bags on the seabed. Where cable protection is required the impacts are long-term but temporary if the protection is removed or permanent if it is left in place following decommissioning.

16.44 The estimated extent of habitat loss for each of the consented developments within the SAC are presented in Table 61. 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 jacket foundations are being, or may be, installed.

16.45 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 an HRA that included potential impacts on the SAC (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.

16.46 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 2.70 km^2 (based on planned build out scenarios) (Table 61). 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 physical 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.

16.47 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 62). 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.

16.48 Based on the currently available information it is estimated that 0.42 km^2 of seabed could be impacted by consented and planned infrastructure (Table 63).

Table 61: Estimated extent of seabed permanently impacted by the physical presence of wind turbine foundations and associated scour protection within the SAC.

Wind farm	Turbine			Comment
	Turbine Number and size (MW)	Footprint and scour per turbine (m^2)	Total footprint area (km^2)	
Galloper	56 x 6.3	1,744	0.098	1,700 m^2 scour protection (GWFL 2011). Turbine footprint 44 m^2 (GWFL 2017).
Greater Gabbard	140 x 3.6	829	0.116	796 m^2 scour protection (GGOWL 2005). Turbine footprint 33.2 m^2.
Hornsea One	174 x 7.0	1,419	0.247	SMart Wind (2013).
Hornsea Two (planned)	165 x 8.5	1,963	0.324	Ørsted (2017b, 2019).
East Anglia One planned	102 x 6	1,225	0.125	Based on maximum footprint of 35 m x 35 m (EAOWL 2012).
East Anglia Three	172 x 12	1,893	0.326	Based on pin piled foundations EAOWL (2015b).
Creyke Beck A (planned)	95 x 10	4,739	0.450	962 m^2 turbine footprint + 3,777 m^2 scour protection (Forewind 2013a, Dogger Bank Windfarm 2020).
Creyke Beck B (planned)	95 x 10	4,739	0.450	962 m^2 turbine footprint + 3,777 m^2 scour protection (Forewind 2013a Dogger Bank Windfarm 2020).
Teesside B (planned)	100 x 12	5,675	0.568	Forewind (2014), Sofia Offshore Wind Farm (2020).

Table 62: Consented and planned wind farm infrastructure within the SAC.

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	1 x HVDC
Creyke Beck B	4 x HVAC collector, 1 x HVDC, 2 x Accommodation, 5 x Met masts	1 x HVDC
Teesside B	4 x HVAC Collector, 1 x HVDC converter, 2 x Accommodation	Currently as consented

Table 63: Estimated area of 'permanent' seabed impact within the SAC 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	2,262	0.002
Greater Gabbard	Offshore substation	2	2,300	0.005
Hornsea One planned	HVAC collector	3	12,723	0.038
	HVAC reactor substation	1	6,362	0.006
	Accommodation	1	6,362	0.006
Hornsea Two consented	HVAC collector	6	12,723	0.076
	HVAC reactor substation	2	6,362	0.013
	Accommodation	2	6,362	0.013
	HVDC converter substation	2	50,894	0.102
Hornsea Two planned	HVAC collector	3	12,723	0.038
	HVAC reactor substation	2	6,362	0.013
	Accommodation	2	6,362	0.013
East Anglia One planned	HVAC collector	1	29,000	0.029
	Met mast	1	900	0.001
East Anglia Three	HVAC	4	15,855	0.063
	HVDC	2	15,855	0.032
	Accommodation	1	15,855	0.016
	Met mast	2	900	0.002
Creyke Beck A	HVDC converter	1	21,242	0.021
Creyke Beck B	HVDC converter	1	21,242	0.021
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

16.49 Trenching can cause a localised area of physical disturbance on the seabed. The extent of trenching within the SAC has been estimated for each of the consented wind farms that have cables within the site. 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 estimated smaller areas of impact from trenching activities. Assuming that trenching cables impacts along a 10 m corridor (5 m either side of a trench), it is estimated that 21.75 km^2 of seabed within the SAC may be temporarily disturbed during the laying of export cables and a further 72.90 km^2 of seabed may be disturbed by inter array and platform cables. A total of 94.65 km^2 of seabed may be disturbed by the trenching and burying of offshore cables within the SAC. An estimated total of 4.73 km^2 of cable protection may be required.

Table 64: Estimated area of seabed impacted within the SAC from cable laying activities associated with consented offshore wind farms.

Wind farm	Export cable			Inter array / platform cables		All Cable Protection (km^2)
	Length (km)	No. of cable trenches	Area of seabed impacted (km^2)	Length (km)	Area of seabed impacted (km^2)	
Greater Gabbard	42	3	1.26	173	1.73	0.15
Galloper	45	2	0.9	300	3.00	0.20
Hornsea One	44.98	4	1.80	530	5.30	0.35
Hornsea Two	35.86	8	2.87	975	9.75	0.63
East Anglia One	55.87	2	1.12	620	6.20	0.37
East Anglia Three	166	4	6.64	882	8.82	0.77
Creyke Beck A	101.4	2	2.03	1,270	12.70	0.74
Creyke Beck B	97.18	2	1.94	1,270	12.70	0.73
Teesside A	76.51	2	1.53	0	0	0.08
Teesside B	83.36	2	1.67	1,270	12.7	0.72
Total	**748.16**	**31**	**21.75**	**7,290**	**72.90**	**4.73**

Note – the extent of cable protection within the SAC from each of the projects is unknown. For the purposes of this assessment it has been presumed that 10% of the total cable length requires some form of protection and the impacts extend over a 5 m wide corridor for all cables.

16.50 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.

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

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

16.53 The extent of trenching undertaken by the oil and gas industry within the SAC is unknown. A total of 4,067 km of pipeline has been laid within the SAC, 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 relating to the oil and gas industry have temporarily impacted on approximately 40 km^2 of seabed.

16.54 The extent of existing cables within the SAC is unknown. However, the proposed Viking Links project will lay a 1,400 MW cable between Denmark and the UK, part of which will cross the SAC (NGVL 2017). An HRA undertaken for the project concluded that the project would not have an adverse effect on the SAC (MMO 2017e).

16.55 Existing licenced aggregate dredging areas cover an area of 579.3 km^2 within the SAC. However, only a relatively small proportion of the licenced areas are active and a total of 60.8 km^2 was actively dredged in the East Coast and Thames regions during 2018, with some dredged locations outwith the SAC.

16.56 Based on the planned level of activity within the SAC 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 SAC from the consented offshore wind farm projects alone and in-combination with other offshore activities. Potential impacts from physical impacts on the supporting habitats within the SAC are therefore considered further in the Appropriate Assessment.

Commercial fishing

16.57 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

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

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

16.60 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).

16.61 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.

16.62 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.

16.63 Based on the relatively localised area of potential impact on water quality within the SAC 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 SAC either alone or in-combination and no further assessment is required.

Likely Significant Effects - Conclusions

16.64 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).

16.65 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.

16.66 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.

16.67 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. There is potential for physical impacts from the existing infrastructure to impact on the habitats within the SAC.

16.68 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.

17 APPROPRIATE ASSESSMENT

17.1 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).

17.2 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 ensure that each wind farm does not exceed the thresholds within this HRA that have been deemed not to cause an adverse effect, alone or in combination. Prior to construction, developers will be required to provide a SIP demonstrating that the above is achieved. If the thresholds 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 SAC 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.

17.3 A dual approach has been used in order to determine whether an adverse effect on the integrity of the South North Sea SAC with respect to impacts from noise and physical impacts set out in paragraph 16.64.

17.4 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. 14.11). Consequently, a similar level of impact from disturbance is predicted to not cause a population level of decline.

17.5 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 thresholds above which a likely significant effect cannot be ruled out, as described in Section 11.

17.6 For the purposes of this assessment it is assumed that impacts based on the threshold approach occur over the maximum possible area within the SAC 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 SAC 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 SAC. The is because the boundaries of the wind farm areas and the SAC are irregular in shape and the distribution of turbines across each wind farm area may not be evenly spaced.

17.7 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, and the gaps in pile-driving could reduce the overall levels of noise over the course of a season. For example, Hornsea Project Three estimate that, on average, there will be 20 days pile-driving per month. Consequently, 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 average seasonal footprint (Dong 2017c). 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 overall 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

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

17.9 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 18).

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

Dudgeon: Conclusions

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

17.12 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 SAC.

Greater Gabbard

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

17.14 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 18).

17.15 The wind farm lies wholly within the SAC and there is potential for an impact on the supporting habitats within the SAC 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

17.16 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 61) and further 0.005 km^2 of has been impacted by the presence of an offshore substations (Table 63) (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. It is not known whether additional cable protection has been required at this wind farm. For the purposes of this assessment it is presumed 10% of the cable required protection and impacted across a 5 m wide corridor. On this basis an estimated area of 0.15 km^2 of seabed within the SAC has been impacted by rock used for cable protection. In total 0.27 km^2 of seabed may have been physically impacted by the presence of turbines, scour protection and cable protection.

17.17 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 SAC.

17.18 The potential permanent loss of 0.27 km^2 of habitat is 0.0007% of the site. The loss of a relatively very small area of habitat that occurs widely within the SAC is not predicted to impact on harbour porpoise or their prey.

17.19 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 64). 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

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

17.21 The loss of up to 0.0007% of habitat that occurs widely across the SAC 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 (See Section 18).

17.22 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 SAC.

Galloper

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

17.24 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 18).

17.25 The wind farm lies wholly within the SAC and there is potential for an impact on the supporting habitats within the SAC 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

17.26 The estimated area of permanent physical impact on the seabed arising from the installation of 56 x 6.3 MW monopiled turbines is 0.098 km^2 (Table 61) and further 0.002 km^2 of seabed may be impacted by the presence of a single offshore substation (Table 63) (GWFL 2011). A total area of seabed permanently physically impacted by the Galloper offshore wind farm is estimated to be 0.100 km^2. In addition to the physical presence of the turbine foundations and associated infrastructure, a further 0.15 km^2 of seabed may be permanently impacted by cable protection (Table 64). The total area of habitat permanently impacted within the SAC is estimated to be 0.29 km^2.

17.27 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 SAC.

17.28 The potential loss of permanent loss of 0.29 km^2 of habitat is 0.0008% of the site. The loss of a relatively very small area of habitat that occurs widely within the SAC is not predicted to impact on harbour porpoise or their prey.

17.29 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 64). 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 2015). This causes a 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

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

17.31 The loss of up to 0.0008% of habitat that occurs widely across the SAC 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 (See Section 18).

17.32 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 SAC.

Hornsea Two

17.33 The Hornsea Two offshore wind farm lies partially within the SAC (Figure 36). In the event concurrent pile-driving is undertaken the installation of foundations will be no further than 20 km apart (DONG 2017b).

Physical Injury

17.34 Results from the noise 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 25).

17.35 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

17.36 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 26, Figure 34).

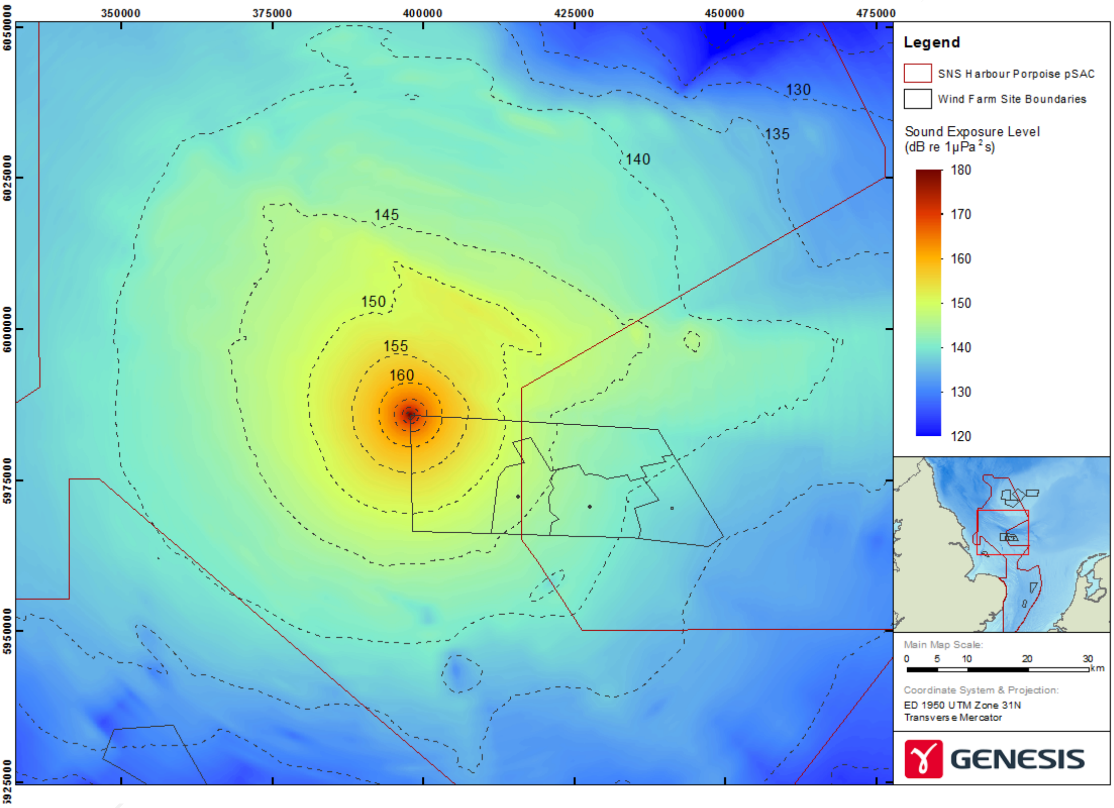


Figure 34: Hornsea Two single pile-driving (unweighted SEL for pile-driving 3,000 kJ).

17.37 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 SAC between 1,034 and 1,982 harbour porpoise may be displaced depending on the hammer energy (Table 65).

Table 65: Estimated number of harbour porpoise predicted to be displaced by pile-driving from Hornsea Two offshore wind farm in total and within the SAC.

Location	Hornsea Two							
	2,300 kJ				3,000 kJ			
	Area (km^2)	No. of Ind.	Area within SAC (km^2)	No. of Ind. within SAC	Area (km^2)	No. of Ind.	Area within SAC (km^2)	No. of Ind. within SAC
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

17.38 Concurrent pile-driving may be undertaken, with activities a maximum of 20 km apart (SMart Wind 2015a) (Figure 35). If this occurs between 2,226 and 2,735 harbour porpoise may be displaced or disturbed (Table 65); equivalent to between 0.67% and 0.82% of the North Sea Management Unit population.

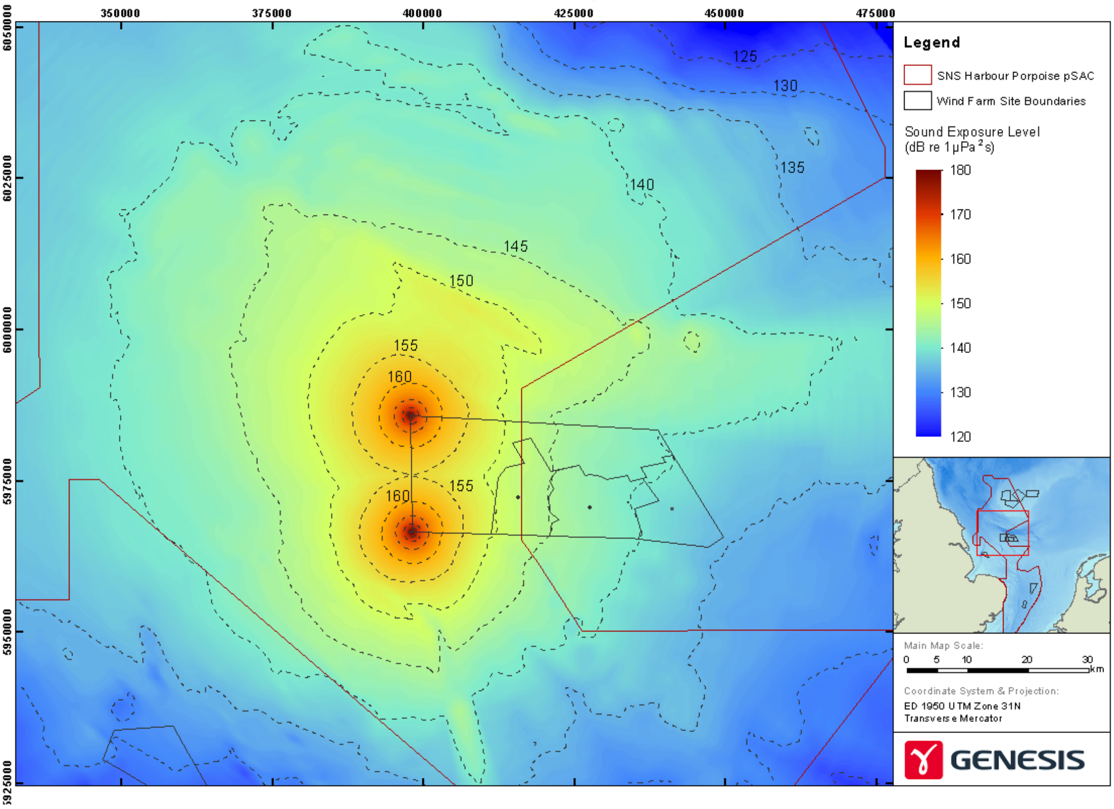


Figure 35: Hornsea Two concurrent pile-driving (unweighted SEL for pile-driving 3,000 kJ).

Effective Deterrent Range

17.39 The Hornsea Two offshore wind farm lies partially within the SAC 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 SAC (Figure 36). Turbines installed outwith the SAC or nearer the SAC boundary will have a smaller EDR overlapping the SAC. Consequently, the assessment based on all turbines impacting a maximum area within the SAC is worst-case.

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

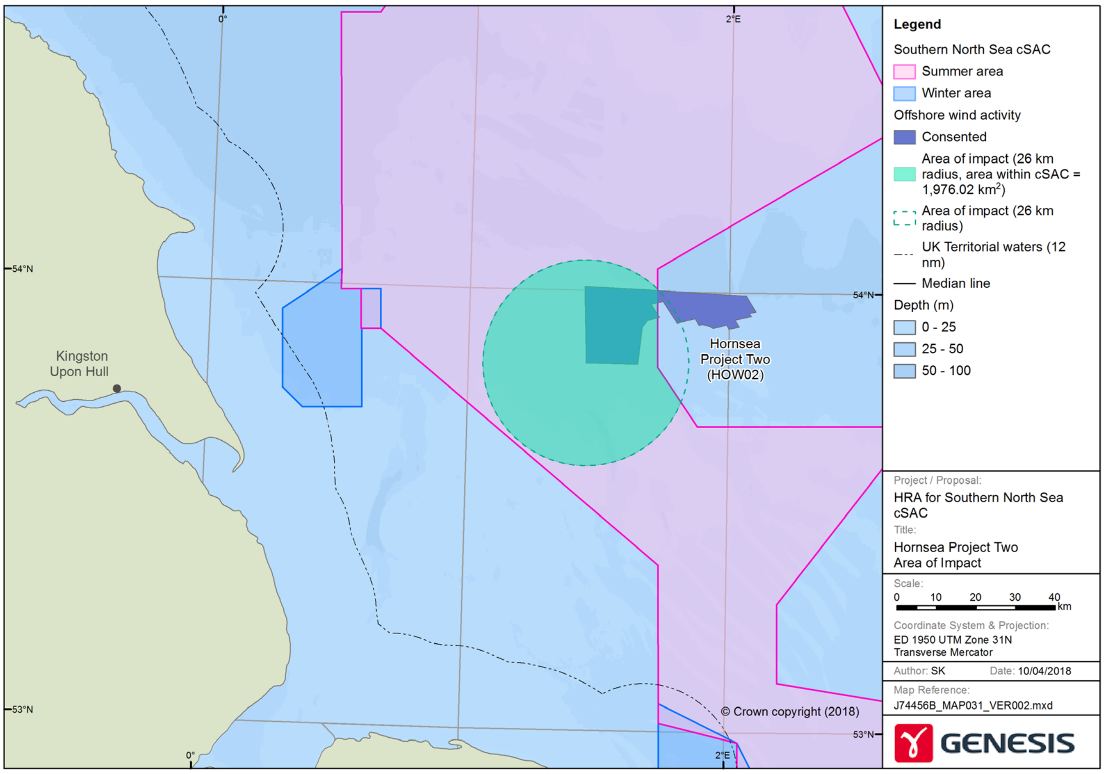


Figure 36: Maximum area of effective deterrence within the Southern North Sea SAC from single pile-driving at Hornsea Two.

17.41 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). It is planned that a total of 165 turbines will be installed over a nine month period and therefore the impacts will likely be lower than those consented (Ørsted 2019).

17.42 This assessment considers both the consented number of turbines and the planned scenario of 165 turbines.

17.43 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 (for the consented wind farm) and 165 days for the planned wind farm, with pile-driving occurring throughout the summer period. The installation of all turbines impact on the maximum possible area of 1,976 km^2.

17.44 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 footprint is between 7.1% and 6.7% depending on the build out scenario (Table 66). The average seasonal impact during the summer period is lower for the planned scenario as pile-driving is not predicted to occur throughout the summer period.

17.45 In the event that concurrent pile-driving occurs at two locations 20 km apart, the maximum area within the SAC that could be impacted at any one time is 2,874 km^2 (Figure 37). Based on the consented number of turbines, over the course of one day, up to 10.6% of the SAC could be impacted with an average seasonal footprint of 8.8% based on the consented number of turbines and 4.9% based on actual number of planned turbines (Table 66).

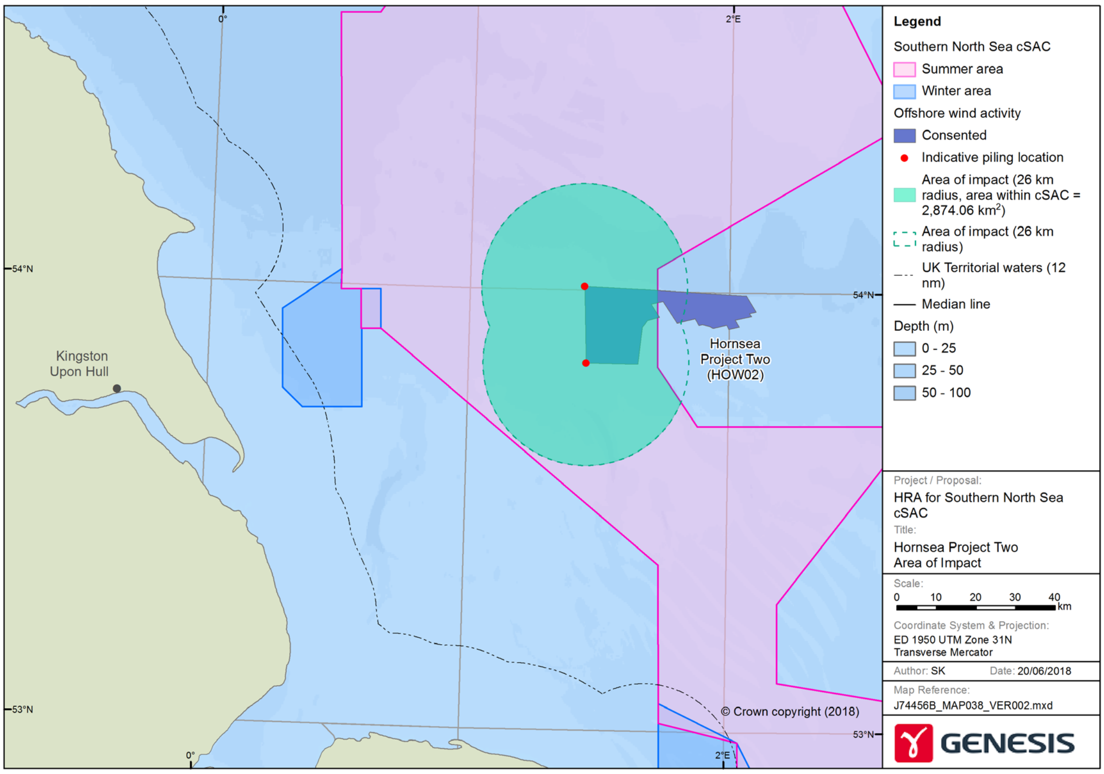


Figure 37: Maximum area of effective deterrence within the Southern North Sea SAC from concurrent pile-driving at Hornsea Two.

Table 66: Average seasonal footprint for Hornsea Two offshore wind farm within the SAC.

SAC area	Maximum area of SAC impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Average seasonal footprint (%)
Single pile-driving (300 turbines consented)					
'summer'	1,976	7.3	300	183	7.3
Single pile-driving (165 turbines planned)					
'summer'	1,976	7.3	165	167	6.7
Concurrent pile-driving (300 turbines consented)					
'summer'	2,874	10.6	300	152	8.8
Concurrent pile-driving (165 turbines planned)					
'summer'	2,874	10.6	165	85	4.9

Physical impacts to the seabed

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

17.47 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 61) and a further 0.20 km^2 of seabed may be impacted by the presence of associated infrastructure, based on the planned build out scenario (Table 63). A total area of seabed permanently impacted by the consented Hornsea Two is estimated to be 0.64 km^2.

17.48 The actual area of seabed predicted to be impacted based on the planned build out scenario is 0.39 km^2 from turbines and associated infrastructure.

17.49 In addition to the physical presence of the turbine foundations and associated infrastructure, a further 0.63 km^2 of seabed habitat may be lost due to cable protection (Table 64). Assuming that all impacts occur within the SAC the total area of habitat lost is estimated to be 1.02 km^2 based on the planned build out. 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 SAC. A worst-case scenario is that all impacts on the seabed are within the SAC.

17.50 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 SAC.

17.51 The area of the Southern North Sea SAC is 36,951 km^2 and the potential worst-case loss of 1.02 km^2 of habitat is 0.002% of the site. The loss of a relatively very small area of habitat that occurs widely within the SAC is not predicted to impact on harbour porpoise or their prey.

17.52 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 12.62 km^2 of seabed may be disturbed by trenching (Table 64). 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

17.53 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 SAC.

17.54 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.

17.55 The estimated potential temporary displacement or disturbance from single pile-driving of no more than 0.63% of the North Sea Management Unit population and 0.82% from concurrent pile-driving 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 thresholds proposed by the SNCBs are not exceeded.

17.56 The potential loss of up to 0.002% of habitat that occurs widely across the SAC 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 (See Section 18).

Creyke Beck A

17.57 The Creyke Beck A offshore wind farm lies wholly within the SAC. There is no confirmed construction date and precise information on the timing and duration of pile-driving is not available.

Physical injury

17.58 Results from the noise 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 16.6 km^2 (Table 29).

17.59 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

17.60 Displacement may extend from between 12.2 km and 15.76 km and cover an area of between 477 km^2 and 791 km^2 depending on the pile-driving location and the hammer energy used to install the pile (Table 30, Figure 38).

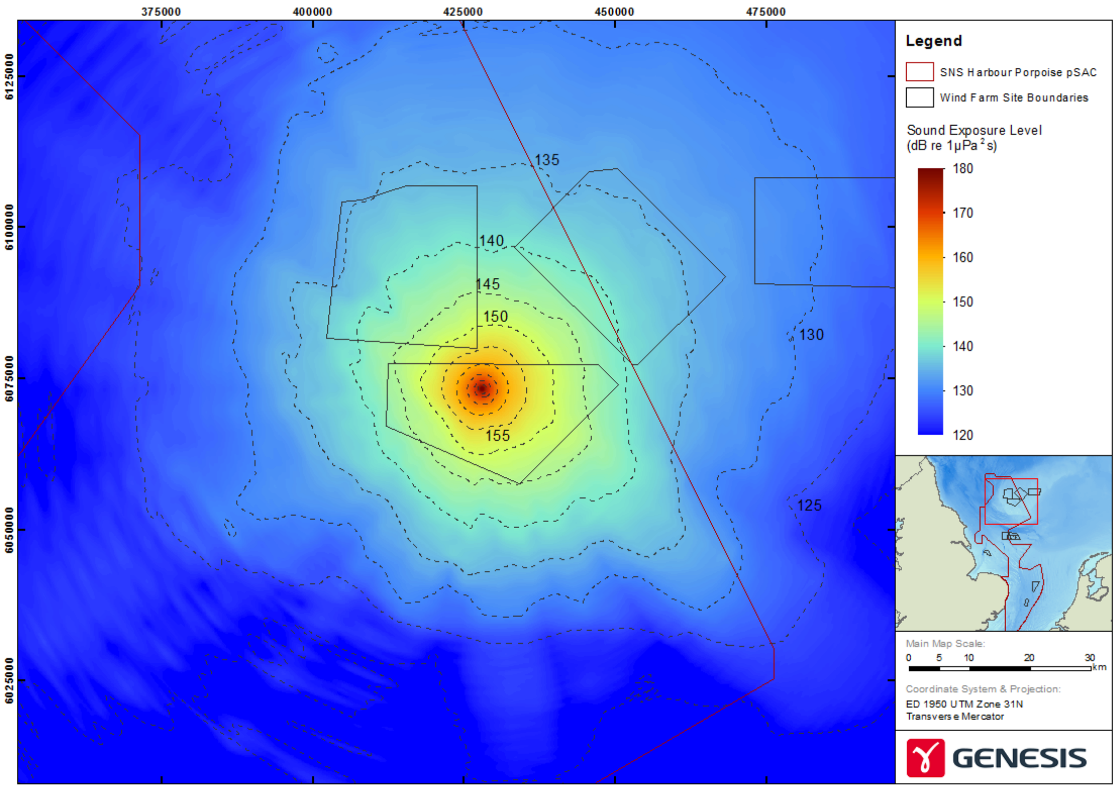


Figure 38: Creyke Beck A single pile-driving (unweighted SEL for pile-driving 3,000 kJ)

17.61 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 67). The number of harbour porpoise estimated to be impacted by displacement within the SAC is between 128 and 210 individuals.

17.62 In the event concurrent pile-driving is undertaken at two locations within the SAC the estimated number of harbour porpoise predicted to be impacted is between 281 and 338 individuals. Between 0.08% and 0.10% of the North Sea Management Unit population may be impacted. Within the SAC no more than 338 harbour porpoise are predicted to be impacted from concurrent pile-driving (Figure 39, Table 67).

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

Location	Creyke Beck A							
	2,300 kJ				3,000 kJ			
	Area (km^2)	No. of Ind.	Area within SAC (km^2)	No. of Ind. within SAC	Area (km^2)	No. of Ind.	Area within SAC (km^2)	No. of Ind. within SAC
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

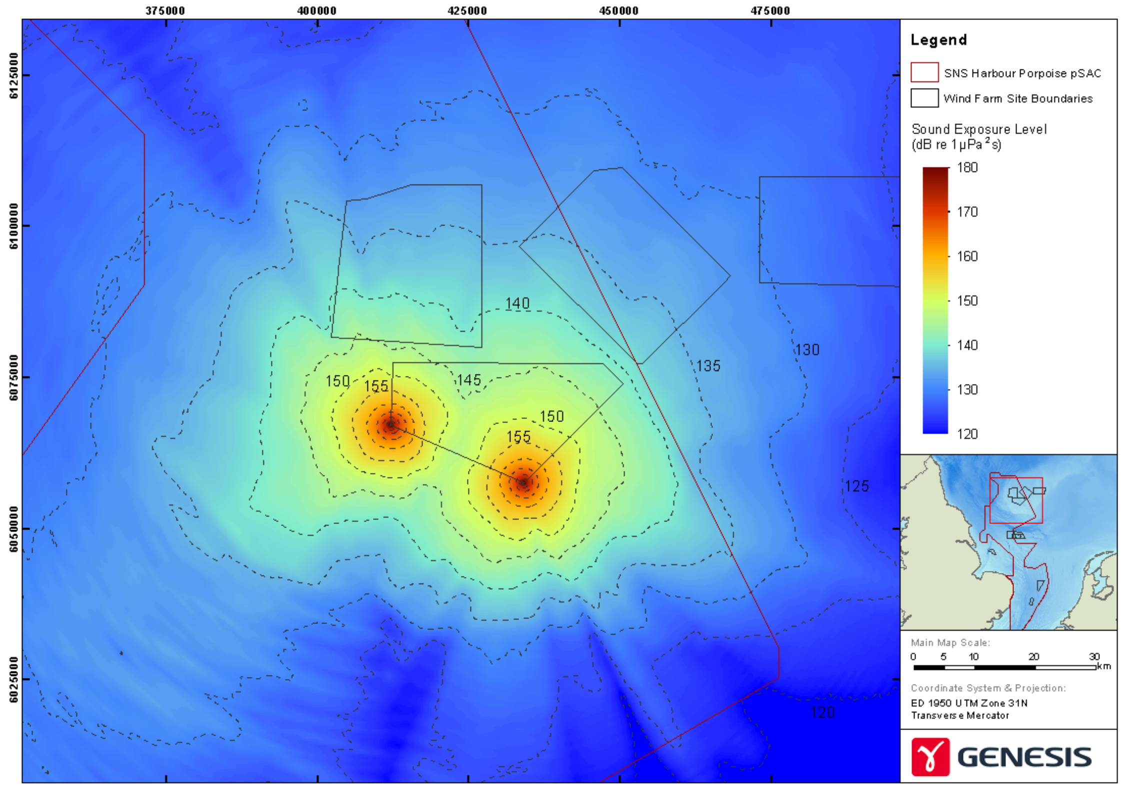


Figure 39: Creyke Beck A concurrent pile-driving (unweighted SEL for pile-driving 3,000 kJ).

Effective Deterrent Range

17.63 The Creyke Beck A offshore wind farm lies wholly within the SAC and, under the worst-case scenario, the whole of a 26 km EDR will be within the ‘summer’ area of the SAC and impact an area of 2,124 km^2 (Figure 40). However, the EDR for turbines installed towards the eastern part of the wind farm area only partially overlap the SAC. Consequently, the assessment based on all turbines impacting the maximum EDR is worst-case.

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

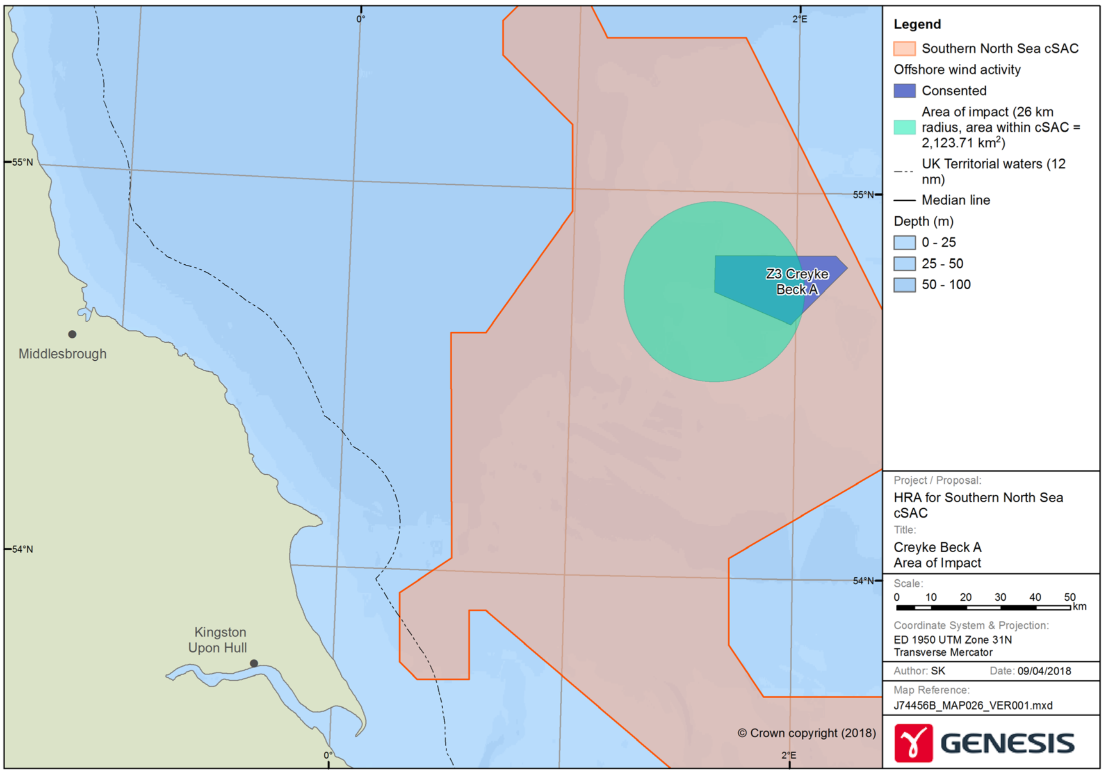


Figure 40: Maximum area of effective deterrence within the Southern North Sea SAC from single pile-driving at Creyke Beck A.

17.65 The timing and duration of the installation of the wind turbine foundations are not known. 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). The planned number of turbines is 95 (Dogger Bank Windfarm 2020).

17.66 The worst-case scenario is 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.

17.67 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 footprint is also 7.9% (Table 68).

17.68 Under the planned scenario of 95 turbines the average seasonal impact is 4.2%.

Table 68: Average seasonal footprint for Creyke Beck A offshore wind farm within the SAC.

SAC area	Maximum area of SAC impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Average seasonal footprint (%)
Single pile-driving (consented)					
'summer'	2,124	7.9	200	183	7.9
Concurrent pile-driving (consented)					
'summer'	3,569	13.2	200	102	7.4
Single pile-driving (planned)					
'summer'	2,124	7.9	95	97	4.2
Concurrent pile-driving (planned)					
'summer'	3,569	13.2	95	50	3.6

17.69 In the event concurrent pile-driving occurs there is potential for a larger area of the SAC to be impacted over a shorter period of time. The maximum area within the SAC that could be impacted is presented in Figure 41. 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.

17.70 In the event that concurrent pile-driving occurs, the worst-case consented 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 footprint is 7.4% (Table 68). Under the planned scenario of 95 turbines the average seasonal impact is 3.6%.

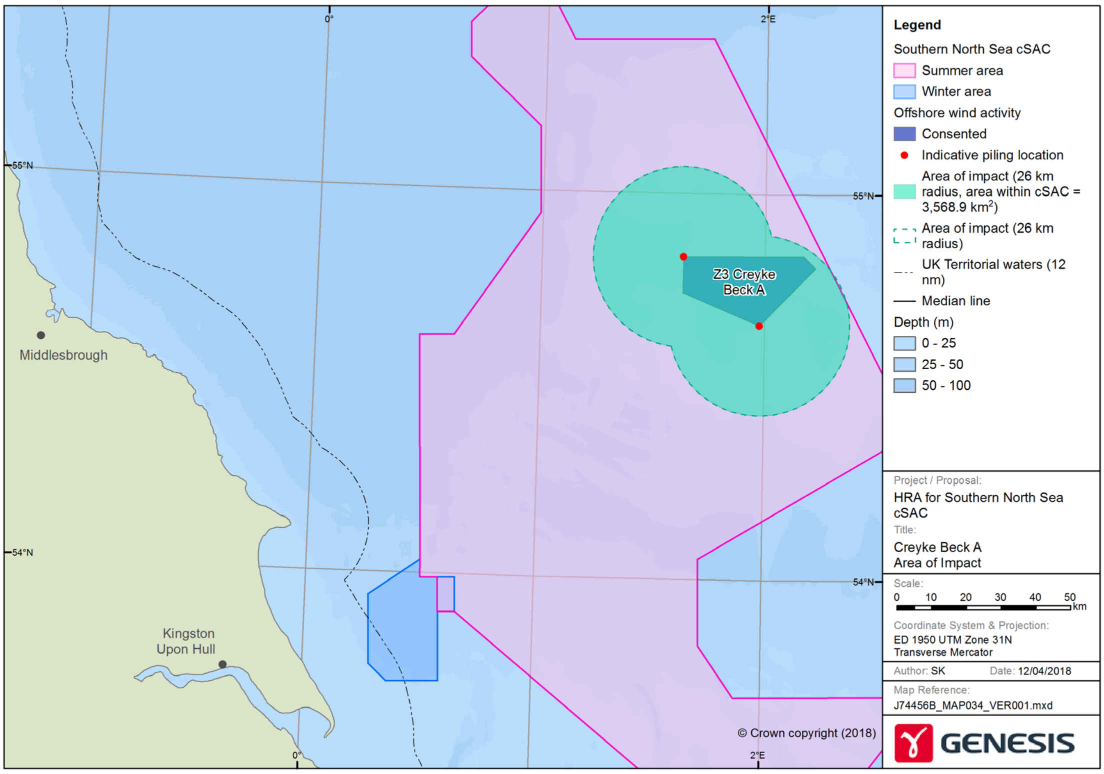


Figure 41: Maximum area of effective deterrence within the Southern North Sea SAC from concurrent pile-driving at Creyke Beck A.

Physical impacts to the seabed

17.71 Creyke Beck A offshore wind farm area lies wholly within the SAC. Under the planned build out scenario an estimated 0.47 km^2 of seabed may be physically impacted by the presence of turbines and associated infrastructure and a further 0.74 km^2 of cable protection may be required (Table 61, Table 63 and Table 64). The area of the Southern North Sea SAC is 36,951 km^2 and the potential loss of 1.21 km^2 of habitat is 0.003% of the site. The habitats within Creyke Beck A are subtidal sands and gravels and are widespread across the SAC (JNCC 2017a). The developer has committed to complete removal of all infrastructure and associated deposits at the time of decommissioning. Consequently, the impacts are long-term but temporary, with recovery predicted following decommissioning.

17.72 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 64). 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

17.73 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 on its own will not have an adverse effect upon the integrity of the Southern North Sea SAC.

17.74 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 pile-driving during the construction of the Creyke Beck A offshore wind farm.

17.75 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 thresholds proposed by the SNCBs are not exceeded.

17.76 The potential long-term but temporary physical loss of up to 0.003% of habitat that occurs widely across the SAC 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 (See Section 18).

Creyke Beck B

17.77 The Creyke Beck B offshore wind farm lies wholly within the SAC. There is no confirmed construction date and precise information on the timing and duration of pile-driving is not available.

Physical Injury

17.78 Results from the noise 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 33).

17.79 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

17.80 Displacement of harbour porpoise may extend from between 14.6 km and 21.8 km and cover an area of between 684 km² and 1,498 km² depending on the pile-driving location and the hammer energy used to install the pile (Table 69, Figure 42). Based on results using a dose response curve and a zonal specific mean density of 0.71 ind./km² (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 SAC it is estimated that between 176 and 376 harbour porpoise may be displaced by pile-driving during construction of the wind farm.

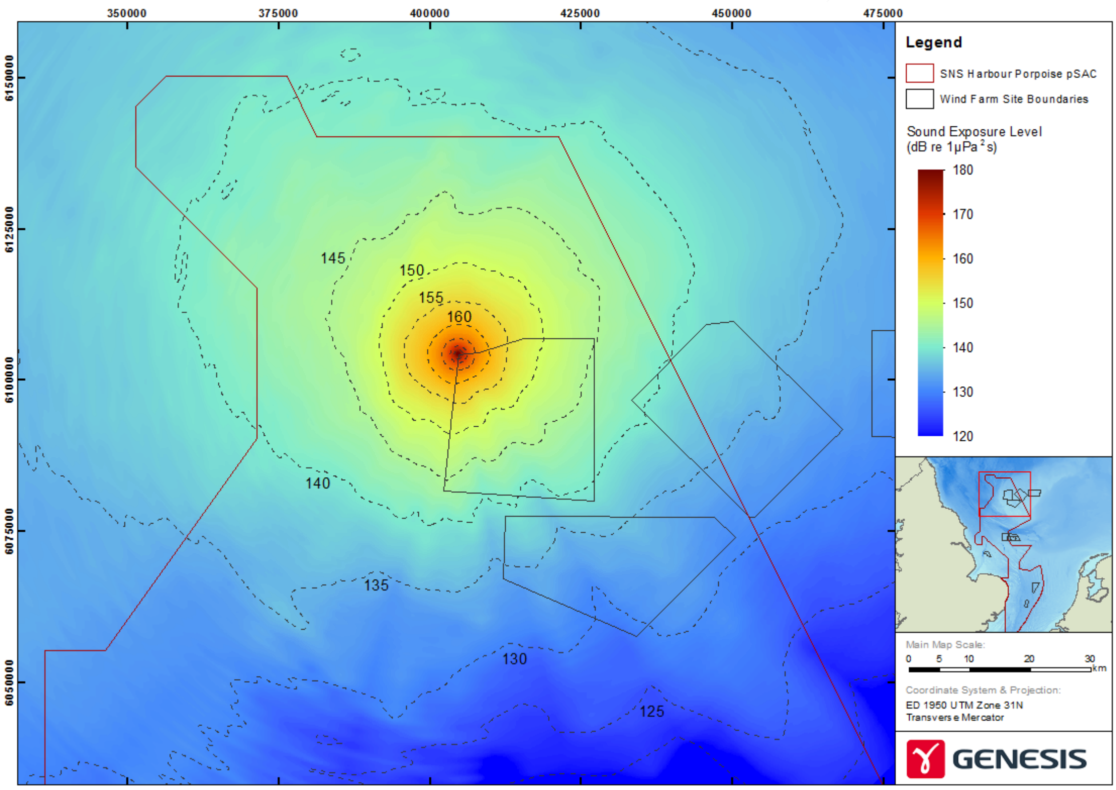


Figure 42: Creyke Beck B single pile-driving (unweighted SEL for pile-driving 3,000 kJ).

Table 69: Estimated number of harbour porpoise predicted to be displaced by pile-driving from Creyke Beck B offshore wind farm in total and within the SAC.

Location	Creyke Beck B							
	2,300 kJ				3,000 kJ			
	Area (km^2)	No. of Ind.	Area within SAC (km^2)	No. of Ind. Within SAC	Area (km^2)	No. of Ind.	Area within SAC (km^2)	No. of Ind. Within SAC
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./km²
Con. = Concurrent pile-driving

17.81 In the event concurrent pile-driving is undertaken at two locations within the SAC (Figure 43) 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 SAC no more than 536 harbour porpoise are predicted to be impacted from concurrent pile-driving (Table 69).

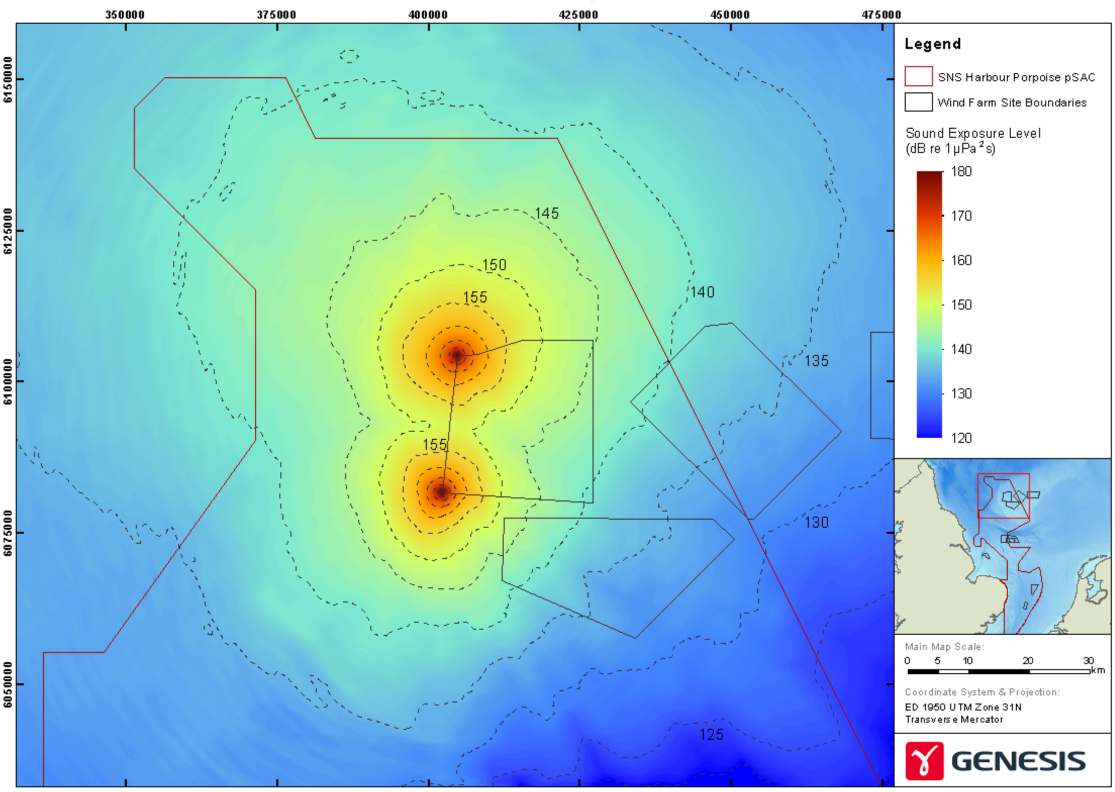


Figure 43: Creyke Beck B concurrent pile-driving (unweighted SEL for pile-driving 3,000 kJ).

Effective Deterrent Range

17.82 The Creyke Beck B offshore wind farm lies wholly within the SAC and, under the worst-case scenario, the whole of a 26 km EDR will be within the 'summer' area of the SAC and impact an area of 2,124 km^2 (Figure 44). However, the EDR for turbines installed towards the eastern area of the wind farm area only partially overlaps the SAC. Consequently, the assessment based on all turbines impacting the maximum EDR is worst-case.

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

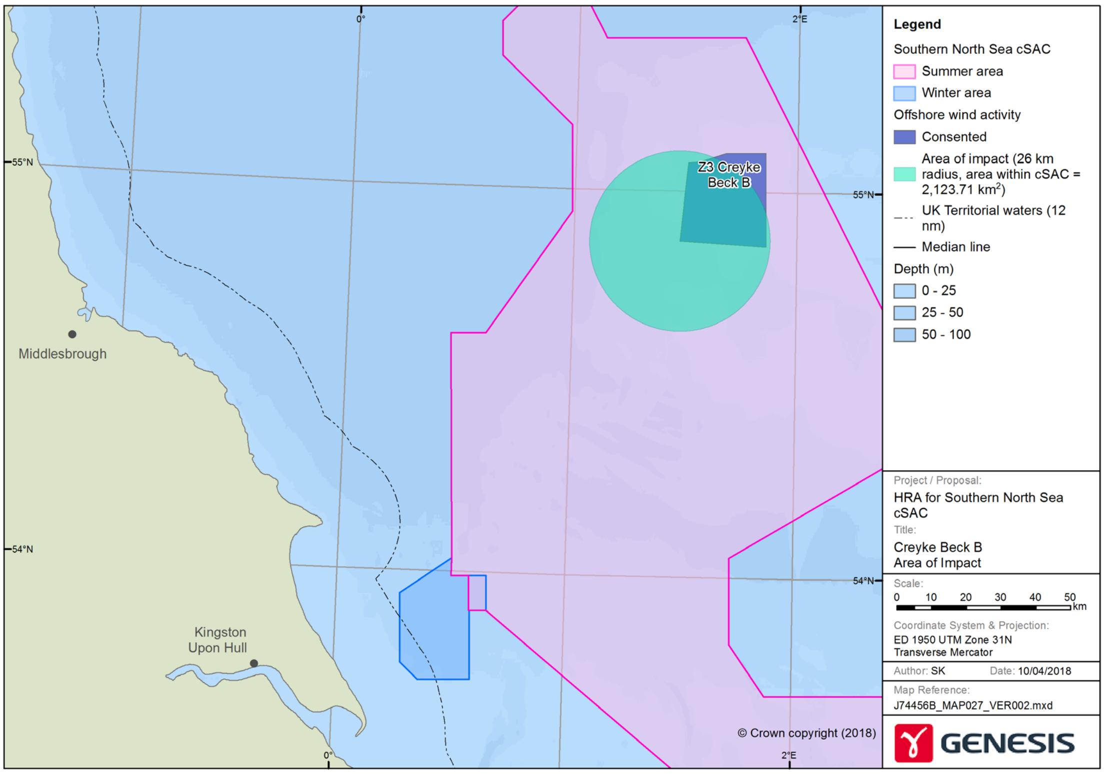


Figure 44: Area of effective deterrence within the Southern North Sea SAC from pile-driving at Creyke Beck B.

17.84 The timing and duration of the installation of the wind turbine foundations is not known. 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). The planned number of turbines is 95 (Dogger Bank Windfarm 2020).

17.85 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 footprint is also 7.9%. Under the planned scenario of 95 turbines the average seasonal impact is 4.2% (Table 70).

17.86 In the event concurrent pile-driving occurs there is potential for a larger area of the SAC to be impacted over a shorter period of time. The maximum area within the SAC that could be impacted is presented in Figure 45. 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.

17.87 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 footprint is 7.4% Under the planned scenario of 95 turbines the average seasonal impact is 3.6% (Table 70).

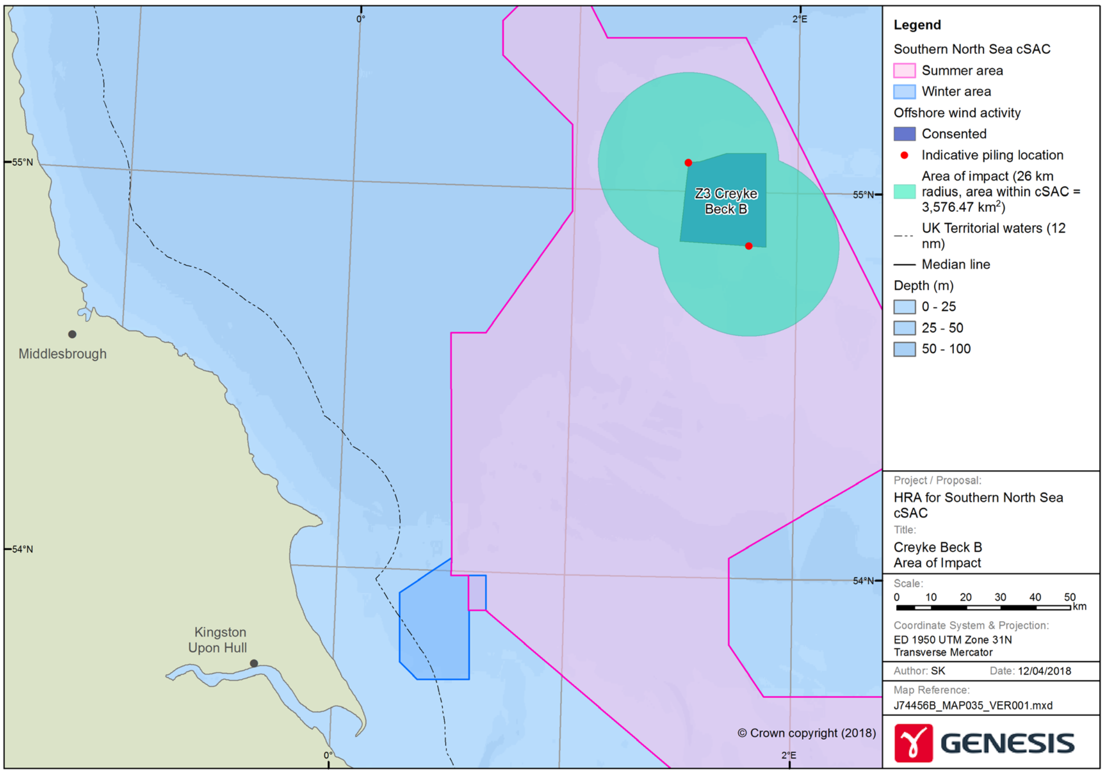


Figure 45: Area of effective deterrence within the Southern North Sea SAC from concurrent pile-driving at Creyke Beck B

Table 70: Average seasonal footprint for Creyke Beck B offshore wind farm within the SAC.

SAC area	Maximum area of SAC impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Average seasonal footprint (%)
Single pile-driving (consented)					
'summer'	2,124	7.9	200	183	7.9
Concurrent pile-driving (consented)					
'summer'	3,577	13.2	200	102	7.4
Single pile-driving (planned)					
'summer'	2,124	7.9	95	97	4.2
Concurrent pile-driving (planned)					
'summer'	3,577	13.2	95	50	3.6

Physical impact to the seabed

17.88 Creyke Beck B offshore wind farm area lies wholly within the SAC. An estimated 0.47 km^2 of seabed may be physically impacted by the presence of turbines and associated infrastructure and a further 0.73 km^2 of cable protection may be required (Table 61, Table 63 and Table 64). Consequently, an estimated 1.20 km^2 of habitat may be physically impacted; 0.003% of the SAC. The developer has committed to complete removal of all infrastructure and associated deposits at the time of decommissioning. Consequently, the impacts are long-term but temporary, with recovery predicted following decommissioning.

17.89 An estimated 14.7 km^2 of seabed may be temporarily impacted by the inter array cables and the export cable route within the SAC (Table 64). The impacts on the habitat from the trenching of cable will be temporary with the habitat recovering following completion of the activities.

17.90 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 SAC (JNCC 2017a). The potential loss of 0.003% 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.

Creyke Beck B: Conclusions

17.91 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 SAC.

17.92 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.

17.93 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 thresholds proposed by the SNCBs are not exceeded.

17.94 The potential long-term but temporary physical loss of up to 0.003% of habitat that occurs widely across the SAC 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 (See Section 18).

Teesside A

17.95 The Teesside A offshore wind farm lies wholly outwith the SAC (Figure 48). Information on the timing and duration of pile-driving is not available.

17.96 The maximum consented hammer energy to be used is 3,000 kJ, although an application for a non-material change has been submitted to increase the hammer energy to 4,000 kJ (Dogger Bank Windfarm 2020b). 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

17.97 Results from the noise 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 37).

17.98 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

17.99 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 38). 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 71). Between 0.08% and 0.15% of the North Sea Management Unit population may be impacted.

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

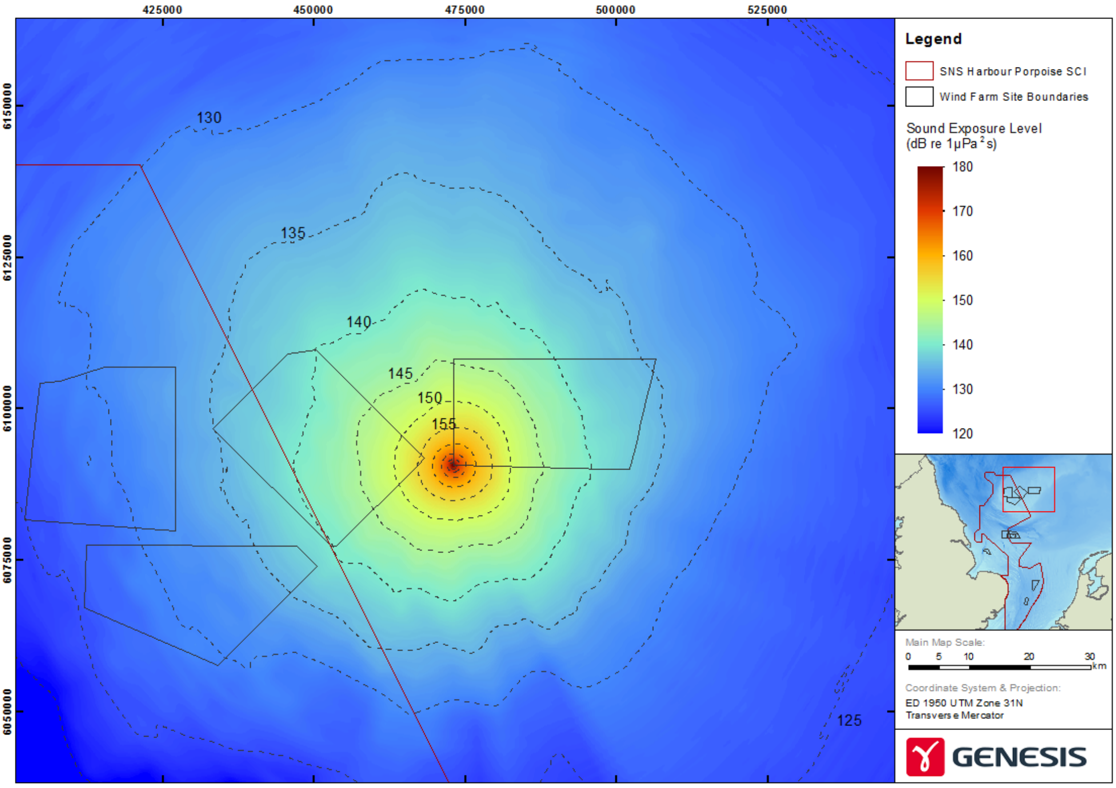


Figure 46: Teesside A single pile-driving (unweighted SEL for pile-driving 5,500 kJ).

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

Location	Teesside A							
	3,000 kJ				5,500 kJ			
	Area (km^2)	No. of Ind.	Area within SAC (km^2)	No. of Ind. Within SAC	Area (km^2)	No. of Ind.	Area within SAC (km^2)	No. of Ind. Within SAC
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./km²
Con. = Concurrent pile-driving

17.101 In the event concurrent pile-driving is undertaken at two locations (Figure 47) 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 SAC no more than one harbour porpoise is predicted to be impacted from concurrent pile-driving.

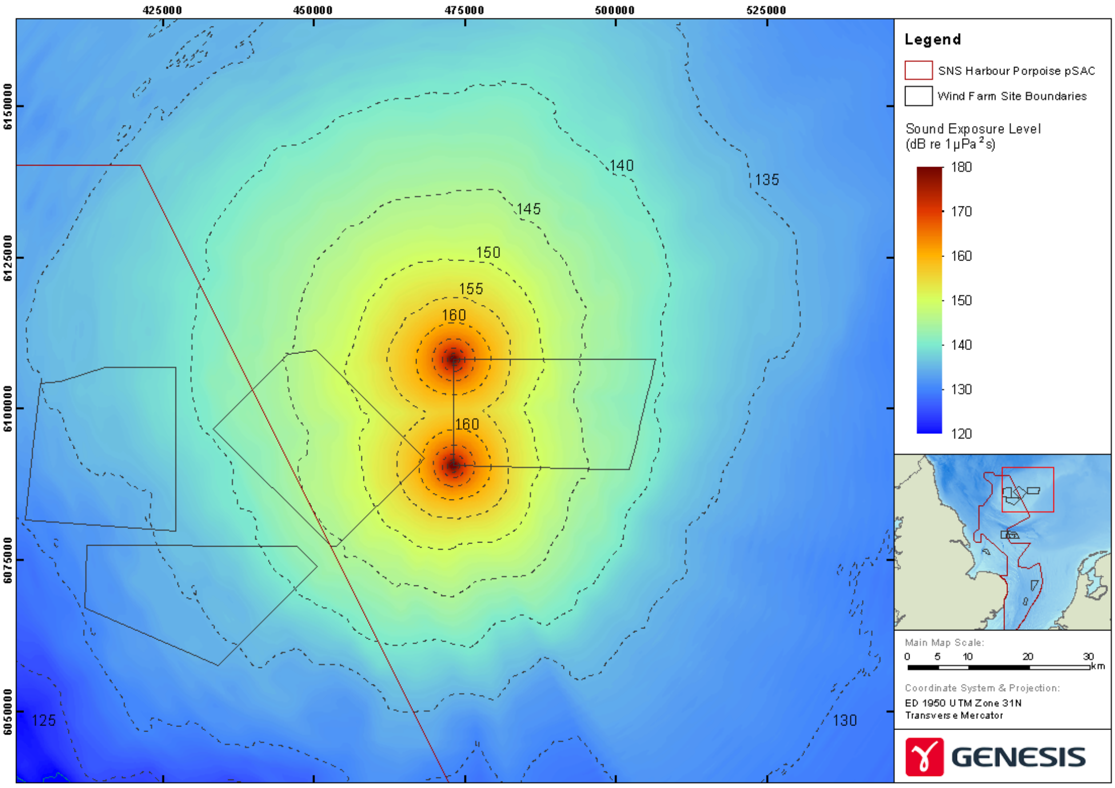


Figure 47: Teesside A concurrent pile-driving (unweighted SEL for pile-driving 5,500 kJ)

Effective Deterrent Range

17.102 The Teesside A offshore wind farm lies wholly outwith the SAC and, under the worst-case scenario, a relatively small area of the 26 km EDR will overlap the 'summer' area of the SAC and impact, at most, an area of 22.8 km^2 (Figure 48).

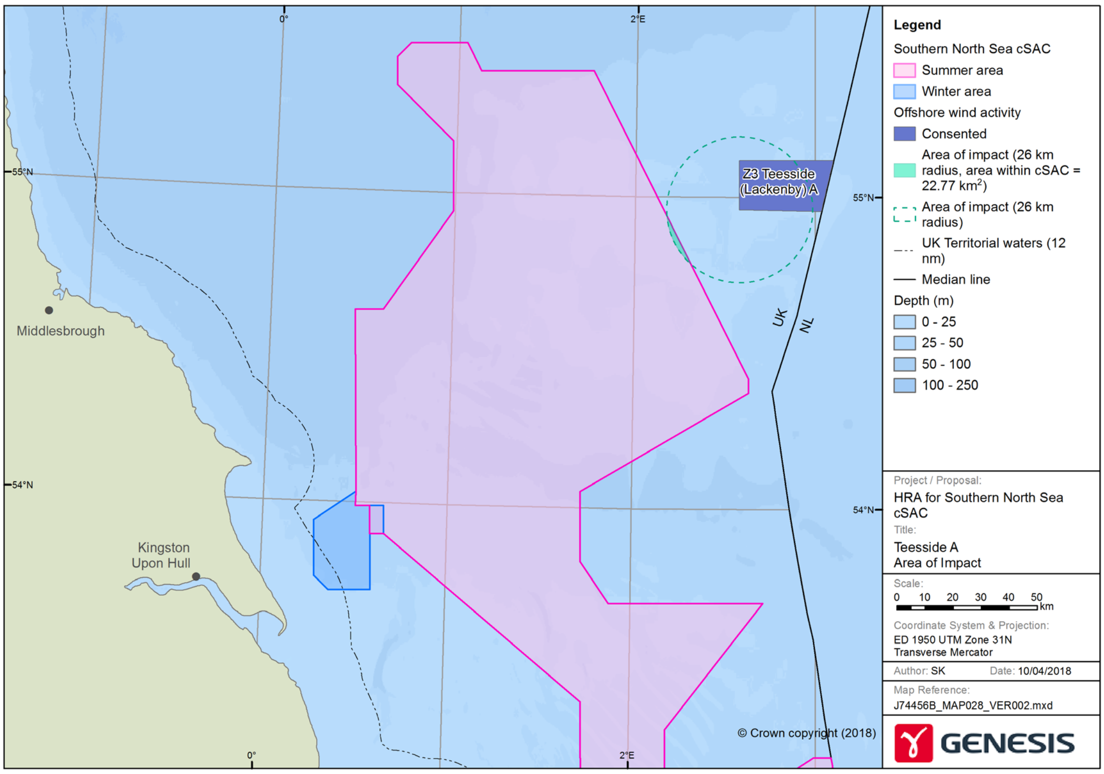


Figure 48: Maximum area of effective deterrence within the Southern North Sea SAC from single pile-driving at Teesside A.

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

17.104 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.

17.105 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 SAC 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 SAC.

17.106 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 SAC 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 footprint is 0.002% (Table 72).

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

Table 72: Average seasonal footprint for Teesside A offshore wind farm within the SAC.

SAC area	Maximum area of SAC impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Average seasonal footprint (%)
Single pile-driving					
'summer'	22.8	0.08	2	4	0.002

Physical impacts to the seabed

17.108 Teesside A offshore wind farm lies outwith the SAC. Therefore, there will be no permanent physical impact on the seabed within the SAC from the wind turbines and associated infrastructure. The export cables may impact on the SAC and an estimated 1.53 km^2 of seabed within the SAC may be disturbed during the installation of cables (Table 64). 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 along the export cable route and an estimated 0.08 km^2 of seabed could be affected, impacting on . It is not known where along the export cable route protection will be required. A worst case scenario is that it occurs within the SAC and therefore impacts a total of 0.0002% of the SAC.

17.109 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 SAC.

17.110 The area of the Southern North Sea SAC is 36,951 km^2 and the potential loss of 0.08 km^2 of habitat is 0.0002% of the site. The loss of a relatively very small area of habitat that occurs widely within the SAC is not predicted to impact on harbour porpoise or their prey.

Teesside A: Conclusions

17.111 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 SAC.

17.112 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.

17.113 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 thresholds proposed by the SNCBs are not exceeded.

17.114 The potential loss of up to 0.002% of habitat that occurs widely across the SAC 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 (See Section 18).

17.115 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

17.116 The Teesside B offshore wind farm lies partially within the SAC with 127.4 km of the wind farm area overlapping the SAC (Figure 51). Information on the precise timing and duration of pile-driving is not available.

17.117 The maximum consented hammer energy to be used is 3,000 kJ. However, there is potential for 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

17.118 Results from the noise 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 41).

17.119 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

17.120 Displacement may extend on average to 18.7 km and cover an area of 1,098 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 42). 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 73). Between 0.07% and 0.14% of the North Sea Management Unit population may be impacted.

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

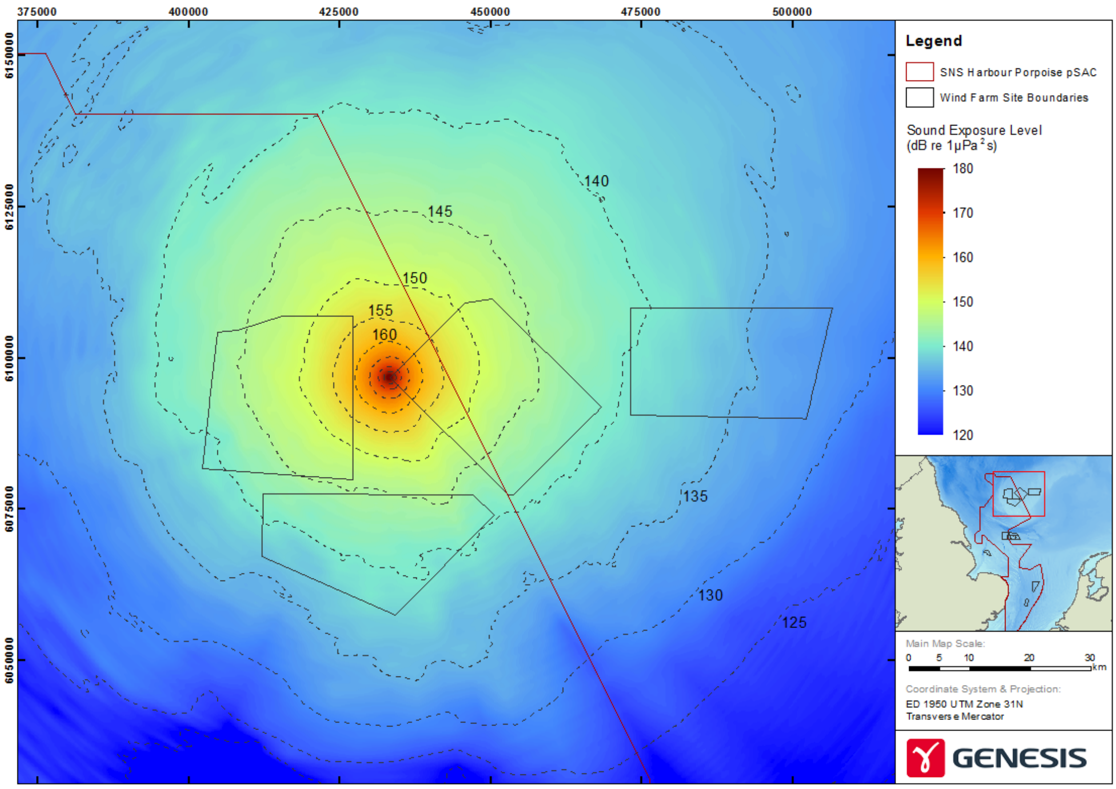


Figure 49: Teesside B single pile-driving (unweighted SEL for pile-driving 5,500 kJ).

Table 73: Estimated number of harbour porpoise predicted to be displaced by pile-driving from Teesside B offshore wind farm in total and within the SAC.

Location	Teesside B							
	3,000 kJ				5,500 kJ			
	Area (km^2)	No. of Ind.	Area within SAC (km^2)	No. of Ind. within SAC	Area (km^2)	No. of Ind.	Area within SAC (km^2)	No. of Ind. within SAC
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

17.122 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 SAC up to 453 harbour porpoise are predicted to be impacted from concurrent pile-driving.

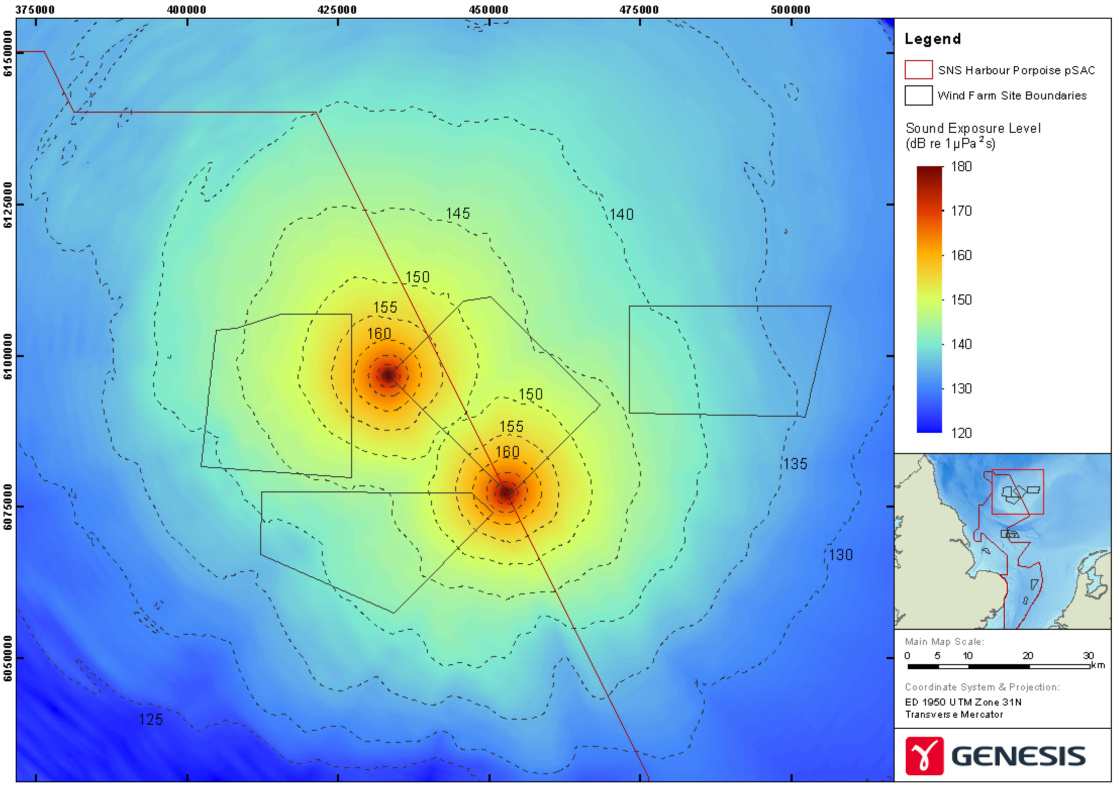


Figure 50: Teesside B concurrent pile-driving (unweighted SEL for pile-driving 5,500 kJ).

Effective Deterrent Range

17.123 The Teesside B offshore wind farm lies partially within the SAC and, under the worst-case scenario, displacement over an area of 1,508.8 km^2 could occur within ‘summer’ area of the SAC (Figure 51). Noise from pile-driving at Teesside B may cause displacement of harbour porpoise over 4.1% of the SAC as a whole and 5.6% of the ‘summer’ area. There will be no impacts in the ‘winter’ area.

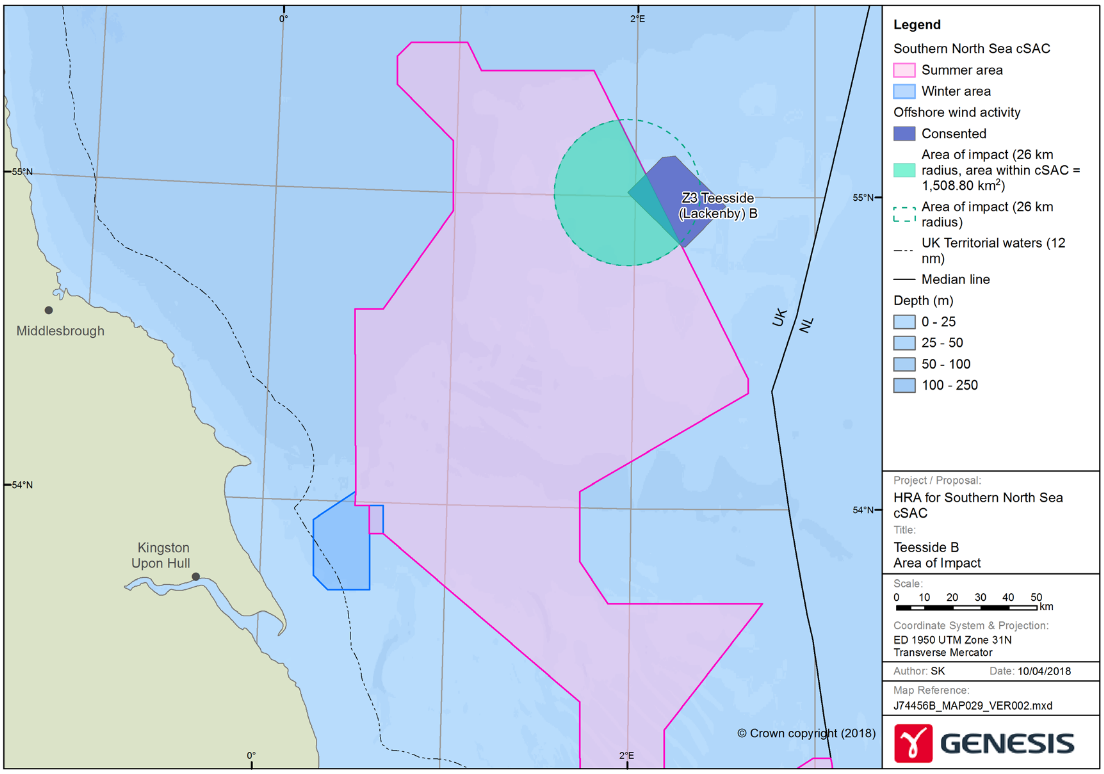


Figure 51: Maximum area of effective deterrence within the Southern North Sea SAC from single pile-driving at Teesside B.

17.124 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, although the actual number to be installed will very likely be lower than this.

17.125 The scenarios used for the purposes of this assessment assume that one turbine is installed per day over a period of either 200 days (consented) or 100 days (planned), with pile-driving occurring throughout the summer period. The installation of all turbines impact to the maximum extent within the SAC of 1,508.8 km^2.

17.126 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 footprint is between 3.1% and 5.6% depending on the scenario (Table 74).

Table 74: Average seasonal footprint for Teesside B offshore wind farm within the SAC.

SAC area	Maximum area of SAC impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Average seasonal footprint (%)
Single pile-driving (consented)					
'summer'	1,509	5.6	200	183	5.6
Single pile-driving (planned)					
'summer'	1,509	5.6	100	102	3.1
Concurrent pile-driving (consented) (					
'summer'	2,080	7.7	200	102	4.3
Concurrent pile-driving (planned)					
'summer'	2,080	7.7	100	52	2.2

17.127 In the event concurrent pile-driving occurs there is potential for a larger area of the SAC to be impacted over a shorter period of time. The estimated maximum area within the SAC that could be impacted is 2,080 km^2 (Figure 52). The scenario used for the purposes of this concurrent pile-driving assessment assumes that two turbines are installed per day over a period of either 50 or 100 days, with pile-driving occurring throughout the summer period.

17.128 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 footprint is either 2.2% or 4.3% depending on the scenario (Table 74).

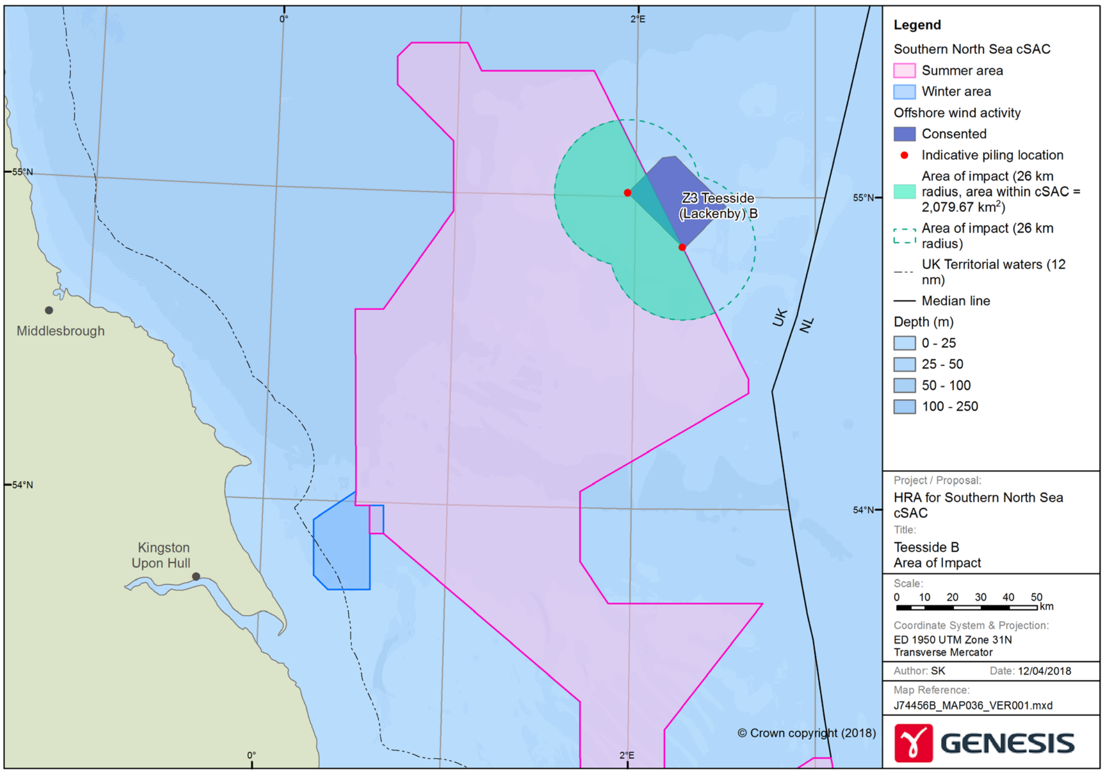


Figure 52: Maximum area of effective deterrence within the Southern North Sea SAC from concurrent pile-driving at Teesside B.

Physical impacts to the seabed

17.129 Teesside B offshore wind farm lies partially within the SAC, with a total area of 127.4 km^2 of the wind farm lying within the SAC.

17.130 The estimated area of permanent physical impact on the seabed arising from the installation of 100 x 10 MW monopiled turbines is 0.568 km^2 (Table 61) and a further 0.111 km^2 of seabed may be impacted by the presence of associated infrastructure (Table 63). A total of area of seabed impacted by Teesside B is estimated to be 0.68 km^2. In addition to the physical presence of the turbine foundations and associated infrastructure, a further 0.72 km^2 of seabed may be lost due to cable protection (Table 64). Assuming that all cable protection occurs within the SAC the total area of habitat lost is estimated to be 1.40 km^2. This assumes that all impacts relating to the installation of the turbines and associated infrastructure are within the SAC. 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 SAC. A worst-case scenario is that all impacts are within the SAC.

17.131 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 SAC.

17.132 The area of the Southern North Sea SAC is 36,951 km^2 and the potential loss of 1.5 km^2 of habitat is 0.004% of the site. The loss of a relatively very small area of habitat that occurs widely within the SAC is not predicted to impact on harbour porpoise or their prey.

17.133 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 64). 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

17.134 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 SAC.

17.135 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.

17.136 The estimated potential impact on no more than 0.14% of the North Sea Management Unit population from single pile-driving or 0.22% 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 thresholds proposed by the SNCBs are not exceeded.

17.137 The potential loss of up to 0.004% of habitat that occurs widely across the SAC 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 (See Section 18).

Impacts on Prey

17.138 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.

17.139 Noise 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 57).

17.140 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).

17.141 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).

17.142 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).

17.143 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

17.144 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 SAC.

Sub-bottom profiler

17.145 There is no information as to when surveys using sub-bottom profilers will be undertaken within the SAC. However, it is predicted that they will be used during geophysical surveys undertaken at all offshore wind farms as well as by other industries.

17.146 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 54). There is therefore a very low risk of any harbour porpoise being physically impacted by the use of sub-bottom profilers.

17.147 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 55). The estimated number of harbour porpoise at risk of disturbance at each of the wind farms subject to this review is presented in Table 77. 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 75: 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

17.148 The EDR for geophysical equipment is 5 km (JNCC, NE and DAERA 2020). Consequently, at any one point in time a total area of 78.54 km^2 could be impacted, equivalent to 0.29% of the ‘summer’ area and 0.6% of the ‘winter’ area. If, in the unlikely event that a sub-bottom profiler is used continuously over a period of 24 hrs with a vessel speed of 4 knots (7.4 km/h) a total area of 256.1 km^2 per day could be affected, equivalent to 0.9% of the ‘summer’ area and 2% of the ‘winter’ area (Table 76).

17.149 This is a highly precautionary scenario as it is very unlikely that a sub-bottom profiler would be undertaken along a single transect line of 178 km in a single day.

17.150 The duration of a typical geophysical survey undertaken by the offshore wind farm industry is unknown and therefore it is not possible to estimate the average seasonal impact a geophysical survey using a sub-bottom profiler may have. However, an example of the what the seasonal impact could be based on a 14 day survey is presented in Table 76.

Table 76: Average seasonal footprint from a sub-bottom profiler within the SAC.

SAC area	Maximum area of SAC impacted (km^2)	% of area	Example duration of impact (days)	Average seasonal footprint (%)
Sub-bottom profiler				
'summer'	256.1	0.9	14	0.06
'winter'	256.1	2.0	14	0.15

Impacts from sub-bottom profiler noise: Conclusions

17.151 It is concluded that, based on the results from the noise modelling and the relatively very small proportion of the North Sea Management Unit harbour porpoise 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 SAC. The SNCB thresholds will not be exceeded.

Unexploded Ordnance Detonation

17.152 Unexploded ordnance clearance that could result in the detonation of ordnance is predicted to occur at most offshore wind farms located within, or adjacent to, the SAC. Neither the number of detonations required at each wind farm nor the size of the UXO are known, although applications for the clearance of up to 120 items of UXO have been made and detonations of UXO with charge weights up to 1,000 kg have occurred in the Southern North Sea. However, the most frequently cleared UXO at UK wind farms have had charge weights of been between 100 kg and 250 kg (Figure 23) (Ørsted 2018e, EAOWL 2017, von Benda-Beckmann *et al.* 2015).

17.153 The results from noise modelling indicate that the extent 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 56).

17.154 The estimated number of harbour porpoise at risk of PTS from UXO clearance across a range of explosive charge weights is presented in Table 77. The results indicate that the number of harbour porpoise at risk of being impacted varies depending on the location of the wind farm and the weight of explosive charge.

Table 77: 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

17.155 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.

17.156 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 may not be significantly displaced from an area. Existing guidance suggests that disturbance behaviour is not predicted to occur from UXO clearance if undertaken over a short period of time (JNCC 2010). However, it is also recognised that frequent UXO clearance in a relatively localised area could cause displacement and disturbance.

17.157 To date the highest number of UXO items reported to have been detonated from a wind farm within the SNS SAC is 36. If there is one detonation per day and the EDR is 26 km then the maximum area of impact from a single detonation will be 2,124 km^2. If wholly within the SAC this is equivalent to 7.9% of the ‘summer’ area and 16.7% of the ‘winter’ area. The maximum seasonal footprint from the detonation of 36 items of UXO is 1.8% of the ‘summer’ area and 3.9% of the ‘winter’ area (Table 78).

17.158 In the event that two items of UXO are detonated per day within the ‘summer’ area neither the daily nor the seasonal thresholds are exceeded. A similar scenario in the ‘winter’ area could exceed the daily threshold but not the seasonal thresholds (Table 78).

17.159 In the event that three items of UXO are detonated per day within the ‘summer’ area the daily thresholds for both the ‘summer’ and ‘winter’ areas could, in theory, be exceeded but not the seasonal thresholds (Table 78). For this to arise each of the items of UXO will each be required to be at least 26 km apart and wholly within the SAC. This scenario is unlikely to arise.

Table 78: Average seasonal footprint for UXO clearance within the SAC.

SAC area	Maximum area of SAC impacted (km^2)	% of area	No. of detonations	Estimated duration of impact (days)	Average seasonal footprint (%)
UXO Clearance (one per day)					
'summer'	2,124	7.9	36	38	1.8
'winter'	2,124	16.7	36	38	3.9
UXO Clearance (two per day)					
'summer'	4,248	15.7	36	20	1.9
'winter'	4,248	33.5	36	20	4.1
UXO Clearance (three per day)					
'summer'	6,372	23.6	36	14	2.0
'winter'	6,372	50.2	36	14	4.3

Note – the number of detonations is based on the highest number of reported items of UXO cleared by a wind farm in the UK sector of the Southern North Sea. All other wind farms have reported lower numbers of UXO.

17.160 The scenarios presented in Table 78 presume that the clearance of each item of UXO impacts on the maximum area within the SAC and that the EDR for each item of UXO does not overlap, i.e. each item of UXO cleared in a single day is further than 26 km apart and that the whole area of impact is within the SAC. This is an unrealistic scenario as multiple clearances of UXO each day will likely occur in clusters and the EDR will very likely overlap. To reduce the area of potential impact from multiple detonations two or more items of UXO may be cleared in proximity to each other where there will be overlapping EDR; by doing so, this would reduce the area within the SAC impacted each day.

17.161 Prior to undertaking any UXO clearance both a Marine Licence and a European Protected Species (EPS) licence is required from the MMO. Conditions attached to the licences obligate 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, soft-starts and, if conditions are suitable, bubble curtains (e.g. Ørsted 2018e, TKOWFL 2018, MMO 2016b, 2016c). Consequently, to reduce the potential impacts on marine mammals from UXO detonation mitigation will be required when undertaking UXO detonation. The level of mitigation required will be identified within the EPS and Marine Licences and the MMMP and will depend on the wind farm location, the size of the UXO to be detonated and the predicted level of impact.

17.162 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

17.163 It is concluded that, based on Marine Licence and EPS Licence conditions requiring suitable mitigation measures to reduce the risk of any harbour porpoise within range at which the onset of PTS is predicted to occur and ensuring items are cleared in relatively close proximity, the impacts from noise arising from UXO detonation will not have an adverse effect upon the integrity of the Southern North Sea SAC.

18 IN-COMBINATION ASSESSMENT

18.1 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 SAC. It is not realistic to assess all the potential in-combination scenarios that could theoretically occur [8]. For the purposes of this assessment realistic scenarios with a reasonable likelihood of occurrence have been included in the assessment based on currently available information. However, it is recognised that there might be other theoretical worst-case scenarios that are highly unlikely to occur. The scenarios that have been assessed 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

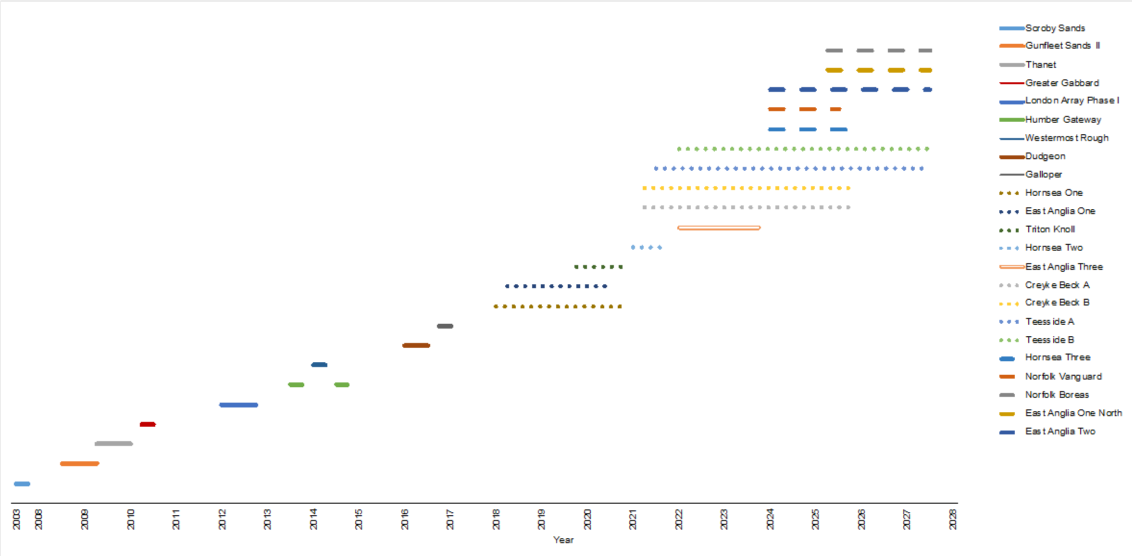
18.2 In-combination impacts across offshore wind farms have been identified as arising from construction pile-driving noise and the cumulative impacts on habitat. This section identifies the likely in-combination scenarios that could cause an adverse effect. Table 79 presents the wind farms within the SAC or 26 km of the boundary and their potential for an in-combination impact.

18.3 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 53). 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 SAC 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 SAC. For Creyke Beck A and B and Teesside A and B it is unknown when pile-driving could occur.

[8] For example, during 2024 there is a theoretical, but unrealistic, possibility that up to seven wind farms may be being constructed simultaneously (see Figure 53). 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 total of 343 in-combination 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 79: 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 SAC)
1	Greater Gabbard	No (construction completed)	Yes (within SAC)
1	Thanet	No (construction completed)	Yes (within SAC)
1	Westermost Rough	No (construction completed)	No (outwith SAC)
1	Humber Gateway	No (construction completed)	No (outwith SAC)
1	Dudgeon	No (construction completed)	No (outwith SAC)
1	Gunfleet Sands II	No (construction completed)	No (outwith SAC)
1	London array Phase I	No (construction completed)	No (outwith SAC)
1	Belwind I	No (construction completed)	No (outwith SAC)
1	Galloper	No (construction completed)	Yes (within SAC)
1	Mermaid	Yes (construction not started)	No (outwith SAC)
1	Borselle II	Yes (construction not started)	No (outwith SAC)
2	East Anglia One	Yes (construction completed)	Yes (within SAC)
2	Hornsea Project One	Yes (construction started)	Yes (within SAC)
2	Hornsea Two	Yes (construction started)	Yes (within SAC)
2	Triton Knoll	Yes (construction started)	No (outwith SAC)
2	Creyke Beck A	Yes (construction not started)	Yes (within SAC)
2	Creyke Beck B	Yes (construction not started)	Yes (within SAC)
2	Teesside A	Yes (construction not started)	Yes (within SAC)
2	Teesside B	Yes (construction not started)	Yes (within SAC)
3	East Anglia Three	Yes (previously assessed)	Yes (within SAC)
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	Norfolk Boreas	No (new application subject to future assessment)	No (new application subject to future assessment)
4	East Anglia One North	No (new application subject to future assessment)	No (new application subject to future assessment)
4	East Anglia Two	No (new application subject to future assessment)	No (new application subject to future assessment)
5	The Crown Estate Offshore wind extension projects	No (new application subject to future assessment)	No (new applications subject to future assessment)
5	Hornsea Project Four	No (no application and no information)	No (no application and no information)



Note: Solid line = Tier 1: Constructed
Dotted line = Tier 2: Consented and with a CfD / under construction
Open line = Tier 3: Consented without a CfD
Dashed line = Tier 4: Application submitted

Figure 53: Estimated pile-driving schedules for offshore wind farms within or adjacent to the Southern North Sea SAC.

18.4 Tier 1 projects (See Table 59) 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 SAC there could be an in-combination impact on habitats from Tier 1 developments.

18.5 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.

- East Anglia One has planned completion date of offshore construction in 2020.
- Hornsea Project One has planned completion of offshore construction for 2020.
- Hornsea Two has not started turbine installation and has not been subject to HRA with respect to the SAC. 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 53).
- Triton Knoll has started but not completed construction. Following the submission of a non-material change, the project has been subject to an HRA with respect to this SAC (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

SAC and there will be no impact on habitats within the site and therefore no in-combination impacts on habitats.

- 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.

18.6 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.

- East Anglia Three has been subject to an Appropriate Assessment that included the potential impacts on the qualifying features of the SAC. 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 SAC and there is potential for in-combination impacts upon the habitat within the site.
- 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 SAC for the project alone and in-combination and no assessment is required at this time.
- An application was 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. A determination was made on the 1st July 2020 following an Appropriate Assessment to assess the potential impacts on the SAC for the project alone and in-combination and no further assessment is required at this time.
- Norfolk Boreas application was submitted to PINS on 4 July 2019. The application is currently under examination. Offshore works are anticipated to commence no earlier than 2025 (NBL 2019). Prior to determination an Appropriate Assessment will be

undertaken by the competent authority that will assess the potential impacts on the SAC for the project alone and in-combination and no assessment is required at this time.

- East Anglia One North application was submitted to PINS on 22 November 2019. The application is currently under examination. Offshore works are anticipated to commence no earlier than 2025 (SPR 2020). Prior to determination an Appropriate Assessment will be undertaken by the competent authority that will assess the potential impacts on the SAC for the project alone and in-combination and no assessment is required at this time.
- East Anglia Two application was submitted to PINS on 22 November 2019. The application is currently under examination. Offshore works are anticipated to commence no earlier than 2024. Prior to determination an Appropriate Assessment will be undertaken by the competent authority that will assess the potential impacts on the SAC for the project alone and in-combination and no assessment is required at this time.

18.7 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.

18.8 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:

- 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 SAC,
- Pile-driving occurs over the maximum possible number of days within each season,
- Only one foundation is installed each day unless concurrent pile-driving is undertaken.

18.9 Table 80 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.

18.10 Five wind farms: Galloper, Greater Gabbard, Dudgeon, East Anglia One and Hornsea Project One have completed their construction and therefore will not cause an in-combination impact with respect to construction noise.

Table 80: 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	East Anglia One	Triton Knoll	Hornsea Two	East Anglia Three	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	X	X	X	**Y**	**Y**	**Y**	**Y**	X	X
Creyke Beck A	X	X	X	X	X	X	**Y**	**Y**	X	**Y**	**Y**	**Y**	X	X
Creyke Beck B	X	X	X	X	X	X	**Y**	**Y**	**Y**	X	**Y**	**Y**	X	X
Teesside A	X	X	X	X	X	X	**Y**	**Y**	**Y**	**Y**	X	**Y**	X	X
Teesside B	X	X	X	X	X	X	**Y**	**Y**	**Y**	**Y**	**Y**	X	X	X

18.11 Based on the predicted construction schedules of each of the wind farms (See Figure 53) the following potential in-combination impacts with respect to construction noise have been assessed for the purposes of this HRA.

- Hornsea Two and Creyke Beck A,
- 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.

18.12 Due to the large number of potential scenarios it is not possible to undertake noise modelling for all potential in-combination scenarios. However, in-combination assessments using both noise modelling and EDR have been undertaken for each development subject to this review. The in-combination scenarios for noise modelling were selected on a number of criteria including:

- Their location within the SAC, with projects within the SAC preferentially selected over those outwith the SAC, e.g. Teesside B was selected over Teesside A.

- Their relative proximity to one another with a selection of sites in relatively close proximity to each other, e.g. Creyke Beck A and Creyke Beck B and also relatively far apart, e.g. Teesside B and East Anglia Three.
- The potential for simultaneous construction based on reported project schedules, e.g. Hornsea two and Creyke Beck A or Creyke Beck A, Creyke Beck B and Teesside B (See Figure 53).

18.13 The scenarios selected aim to provide a representative sample of the potential in-combination impacts.

In-combination Impacts – Offshore Wind Farm Pile-driving

18.14 Based on advice received during consultation and 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 and for all but four scenarios there will be limited, if any, overlapping areas of displacement or disturbance (Section 13). For these scenarios, the potential in-combination effects are simply the combined totals for each of the individual wind farms. However, for developments in relatively close proximity, i.e. those in the Dogger Bank zone, there is an overlapping area of disturbance. For these scenarios adding the total number of individuals impacted at each site is inappropriate and the assessment for these scenarios is based on the combined areas of disturbance.

18.15 In order to estimate the number of harbour porpoise at risk of displacement from in-combination impacts the densities 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 (Table 6). A dose response curve has then been used to estimate the total number of harbour porpoise at risk of displacement (Figure 25).

18.16 Table 81 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).

18.17 Following comments received on the draft HRA in December 2018 additional in-combination daily and seasonal footprints based on a 26 km EDR and the threshold approach have been calculated. These have been undertaken for single pile-driving events at two wind farms, concurrent pile-driving at one wind farm with single pile-driving at another and concurrent pile-driving at two wind farms. The results are presented in Appendix F.

Table 81: Estimated number of harbour porpoise displaced or disturbed from in-combination pile-driving (unweighted SEL).

Wind farm in-combination	Area (km^2)	Estimated no. of porpoises displaced	Total number displaced	% of NSMU
Hornsea Two and Creyke Beck A	2,794 791	2,119 210	2,329	0.70
Creyke Beck A and East Anglia Three	791 2,452	210 248	458	0.13
Creyke Beck A and Creyke Beck B	2,288	586	586	0.17
Teesside B and East Anglia Three	1,842 2,452	461 248	709	0.21
Creyke Beck A and Teesside B	2,404	627	627	0.19
Teesside A and Teesside B	3,417	876	876	0.20
Creyke Beck A and Creyke Beck B and Teesside B	3,436	914	914	0.27

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

18.18 The following section assesses the potential in-combination impacts arising from pile-driving noise for nine potential in-combination scenarios based on both the outputs from noise modelling and the threshold approach.

Hornsea Two and Creyke Beck A

18.19 The Hornsea Two offshore wind farm lies partially within the SAC with 34% of the wind farm area lying outwith the site. Creyke Beck A offshore wind farm lies wholly within the SAC. 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 53). 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 and limited overlap in the area across which potential displacement is predicted to occur (Figure 54).

Physical Injury

18.20 The estimated number of harbour porpoise at risk of the onset of PTS from Hornsea Two is between 6 and 18 individuals (Para. 17.35) and for Creyke Beck A is between 4 and 9 (Para. 17.59). 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.

18.21 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

18.22 A combined area of displacement is predicted to occur over an area of up to 3,585 km^2. Based on results from the dose response curve used and the zonal densities for each wind farm, the estimated number of harbour porpoise predicted to be displaced is 2,329 individuals (Table 81). An estimated 0.70% of the North Sea Management Unit population may be impacted.

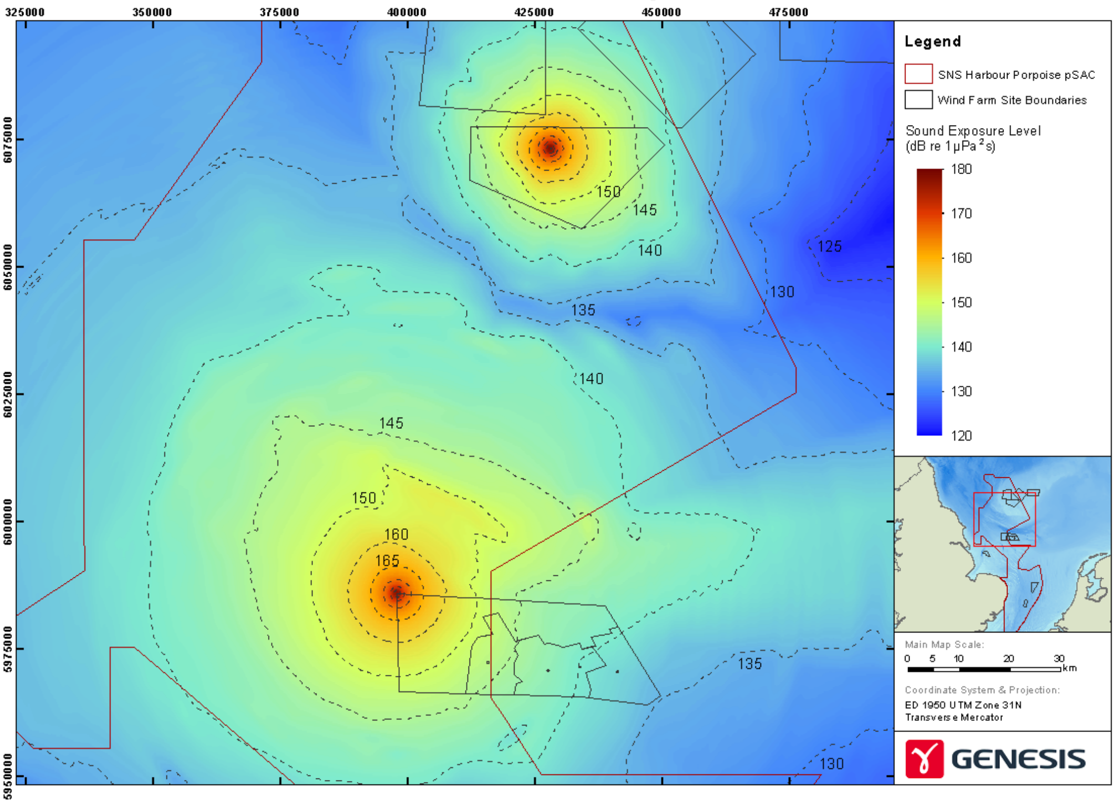


Figure 54: Predicted area of in-combination noise impacts from pile-driving at Hornsea Two and Creyke Beck A offshore wind farms.

Effective Deterrent Range

18.23 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 SAC impacting over the greatest possible area (Figure 55).

18.24 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 SAC as a whole and 15.2% of the 'summer' area. There will be no in-combination impacts on the 'winter' area.

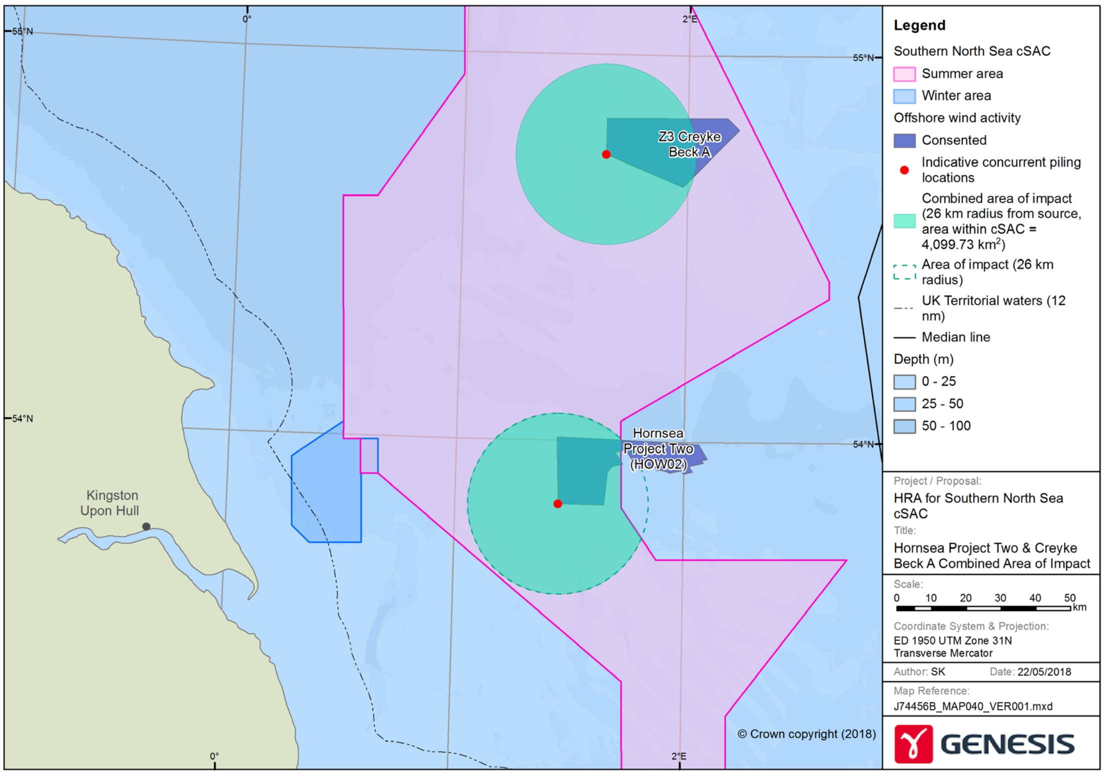


Figure 55: Maximum area of effective deterrence within the Southern North Sea SAC from in-combination pile-driving at Hornsea Two and Creyke Beck A.

18.25 A number of potential build out scenarios are possible for Hornsea Two. The consent was for the installation of 300 turbines but the planned scenario is for 165 turbines to be installed over a nine month period between February and October (Ørsted 2017b, 2019).

18.26 The consented maximum number of turbines for Creyke Beck A is 200, although the planned scenario is for 95 turbines.

18.27 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 95 days based on the planned scenario, or throughout the 183 days of the summer period based on the consented scenario. It is assumed that the maximum area of potential impact within the SAC 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 footprint is between 8.0% and 15.2% (Table 82). In the event that concurrent pile-driving is undertaken at Hornsea Two this potentially reduces the duration pile-driving will be undertaken and therefore the reduces the average seasonal footprint.

Table 82: Worst-case in-combination average seasonal footprint for Hornsea Two and Creyke Beck A offshore wind farms within the SAC.

SAC area	Maximum area of SAC impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Average seasonal footprint (%)
In-combination pile-driving (consented)					
‘summer’	4,100	15.2	200	183	15.2
In-combination pile-driving (Planned)					
‘summer’	4,100	15.2	95	97	8.0
In-combination concurrent pile-driving at Hornsea Two (consented)					
‘summer’	4,998	18.5	200	102	10.3
In-combination concurrent pile-driving at Hornsea Two (planned)					
‘summer’	4,998	18.5	95	50	5.0

Note – the number of turbines is the number that could be installed in-combination.

18.28 The results from the assessment indicate that the area of disturbance within the SAC 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 based on the consented scenarios. Under the planned build-out scenarios neither the daily nor the seasonal thresholds are exceeded.

18.29 This assessment is based on an unrealistic worst-case scenario that the same level of impact within the SAC will arise from all pile-driving locations within the wind farm areas; this will not occur. The installation of piles outwith the SAC or closer to the boundary will decrease the impacts within the SAC and reduce the spatial overlap. A total of 34% of Hornsea Two wind farm area lies outwith the SAC and when pile-driving occurs at the eastern boundary of the wind farm site an area of 83 km^2 within the SAC may be impacted. Turbines at locations furthest away from the SAC 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 SAC, equivalent to 4.6% of the ‘summer’ area.

18.30 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 average seasonal footprint will be significantly lower than the worst-case scenario suggests.

Hornsea Two and Creyke Beck A In-combination: Conclusions

18.31 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 SAC.

18.32 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.

18.33 The estimated potential displacement of no more 0.70% 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. Under the planned construction scenarios the draft daily and seasonal thresholds are not exceeded.

18.34 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 thresholds are not exceeded.

Creyke Beck A and East Anglia Three

18.35 The Creyke Beck A and East Anglia Three wind farms lie within the SAC. They are both Tier 3 developments and specific 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 2022 and 2023 (Figure 61).

Physical injury

18.36 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

18.37 Displacement is predicted to occur over an area of up to 3,243 km^2 (Table 81). Based on the Zonal densities the estimated number of harbour porpoise predicted to be displaced is 458 individuals, which is 0.13% of the North Sea Management Unit population.

Effective Deterrent Range

18.38 The combined EDR for Creyke Beck A and East Anglia Three could potentially impact an area of 4,247 km^2 within the SAC, all of which could occur within the 'summer' area and 801.6 km^2 is within the 'winter' area (Figure 56) [9].

18.39 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 SAC as a whole and 15.7% of the 'summer' area. There will be no in-combination impacts on the 'winter' area.

18.40 Based on the consented project design, up to 200 wind turbines will be installed within the 'summer' area of the SAC at Creyke Beck A and 172 at East Anglia Three. The planned scenario is for 95 turbines at Creyke Beck A.

18.41 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 average seasonal footprint is 15.0% (Table 83). Under the planned scenario with 95 turbines at Creyke Beck A the average seasonal footprint is reduced to 8.3%.

18.42 In the event that concurrent pile-driving takes place at Creyke Beck A the 200 turbine foundations could be installed over a period of 100 days and the estimated duration of the in-combination impact is therefore 102 days. The average seasonal footprint is 11.8%, under the planned scenario of 95 turbines this is reduced to 5.7%.

[9] Note, this is based on a 26 km EDR for both developments. The latest guidance on EDR was published in June 2020 and advises the use of a 15 km EDR for pin-piled jacket foundations (JNCC, NE and DAERA 2020a). This was published following the completion of this EDR assessment. In the event that East Anglia Three uses jacket foundations the EDR will be reduced.

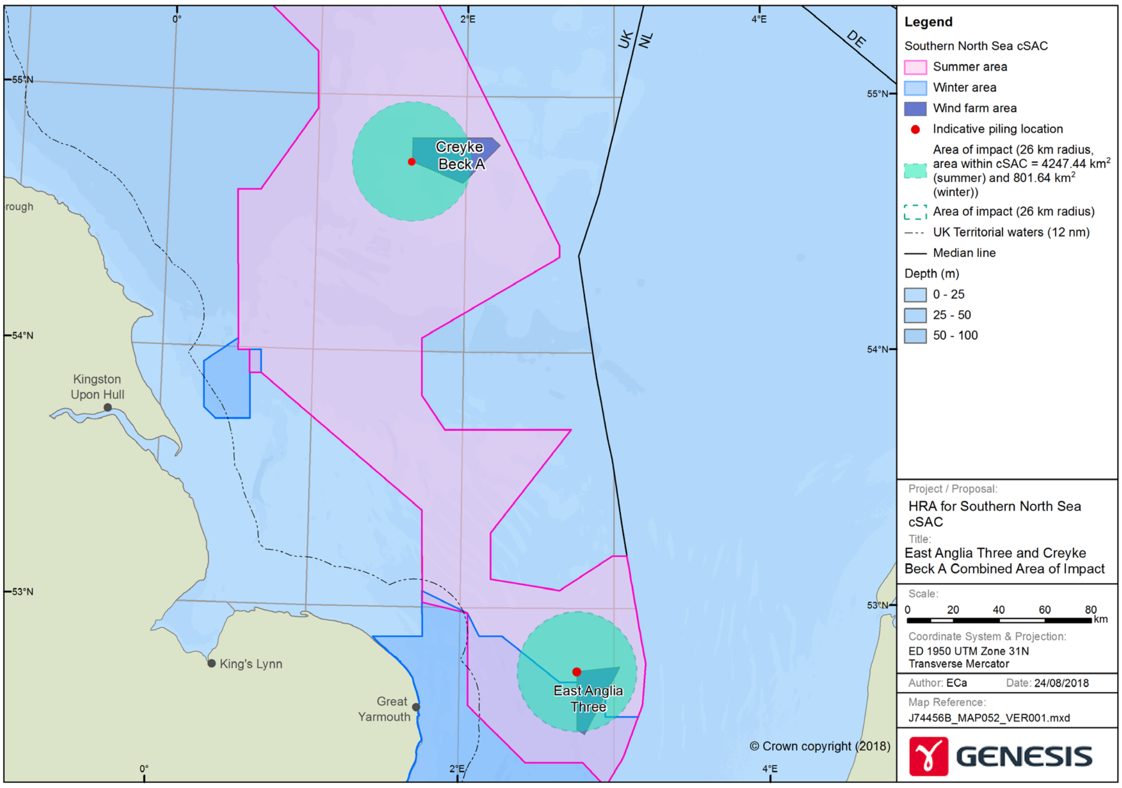


Figure 56: Maximum area of effective deterrence within the Southern North Sea SAC from in-combination pile-driving at Creyke Beck A and East Anglia Three.

Table 83: In-combination average seasonal footprint for Creyke Beck A and East Anglia Three offshore wind farms within the SAC.

SAC area	Maximum area of SAC impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Average seasonal footprint (%)
In-combination pile-driving (consented)					
'summer'	4,247	15.7	172	174	15.0
In-combination pile-driving (planned)					
'summer'	4,247	15.7	95	97	8.3
In-combination concurrent pile-driving at Creyke Beck A (consented)					
'summer'	5,692	21.1	200	102	11.8
In-combination concurrent pile-driving at Creyke Beck A (planned)					
'summer'	5,692	21.1	95	50	5.7

Note – the number of turbines is the number that could be installed in-combination.

18.43 The results from the assessment indicate that the area of disturbance on harbour porpoise within the SAC across one day would not exceed the draft daily thresholds but could exceed the seasonal threshold under the consented scenario but not under the planned scenario.

18.44 The assessment is based on an unrealistic worst-case scenario that all the pile-driving will cause the same level of impact within the SAC, this will not occur. It also presumes that monopile foundations will be used at East Anglia Three which, based on constructed offshore wind farms adjacent to the project, is unlikely and pin-piled jacket foundations may be expected be used, which would reduce the EDR. The installation of piles closer to the boundary will decrease the area impacted within the SAC and reduce the average seasonal footprint. 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.

18.45 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 thresholds are not exceeded.

Creyke Beck A and East Anglia Three In-combination: Conclusions

18.46 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 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 SAC.

18.47 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 Creyke Beck A and East Anglia Three offshore wind farms.

18.48 The estimated potential displacement of no more than 0.13% 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 seasonal threshold could, in theory, be exceeded under the unrealistic worst-case scenario.

18.49 A pre-construction licence condition requiring a SIP will ensure that the spatio-temporal impacts developed and secured in a SIP will ensure that thresholds are not exceeded.

Creyke Beck A and Creyke Beck B

18.50 The Creyke Beck A and Creyke Beck B wind farms lie within the SAC. 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 2021 and 2025 (Figure 53).

Physical injury

18.51 The estimated number of harbour porpoise at risk of the onset of PTS from Creyke Beck A is between 4 and 9 individuals and between 3 and 10 at Creyke Beck B (Para. 17.79). 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 0.005% of the North Sea Management Unit population.

Displacement

18.52 Displacement is predicted to occur over an area of up to 2,289 km^2 (Figure 57). Based on a zonal density of 0.71 ind/km^2, the estimated number of harbour porpoise predicted to be displaced is 586 individuals (Table 81). An estimated 0.17% of the North Sea Management Unit population may be impacted.

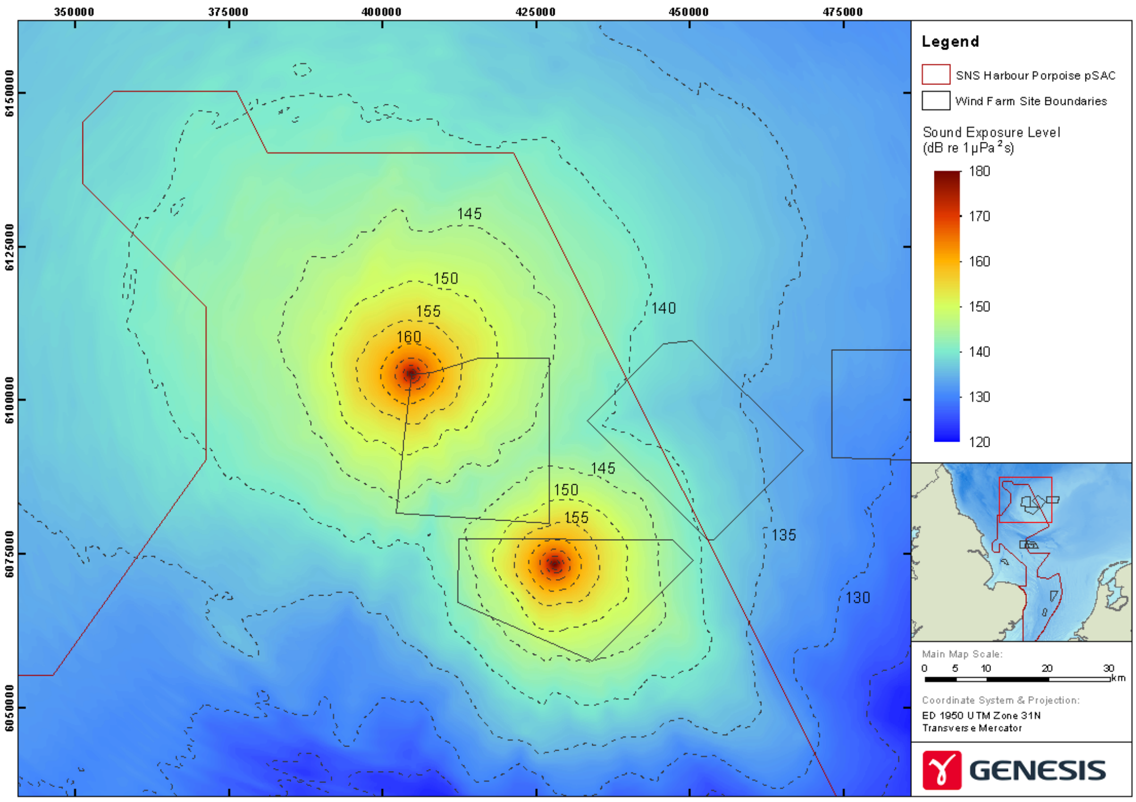


Figure 57: Predicted area of in-combination noise impacts from pile-driving at Creyke Beck A and Creyke Beck B offshore wind farms.

Effective Deterrent Range

18.53 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 SAC (Figure 58).

18.54 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 SAC as a whole and 15.7% of the 'summer' area. There will be no in-combination impacts on the 'winter' area.

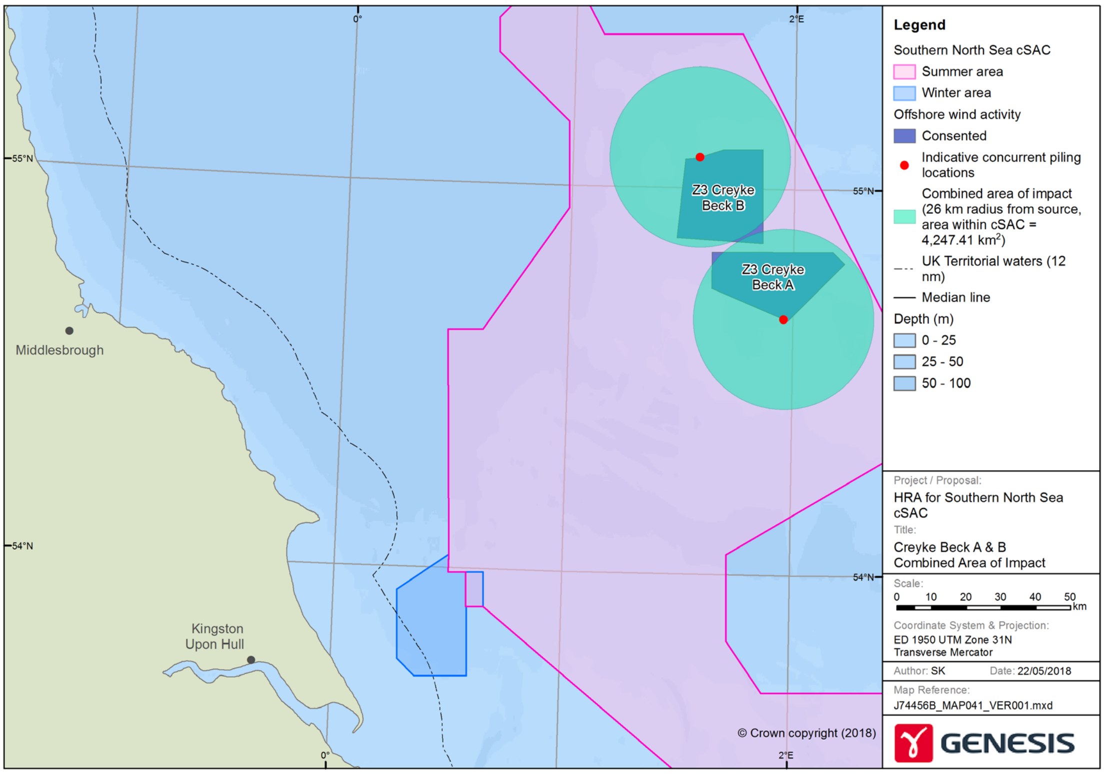


Figure 58: Maximum area of effective deterrence within the Southern North Sea SAC from in-combination pile-driving at Creyke Beck A and Creyke Beck B.

18.55 Based on the consented project designs, up to 200 wind turbines may be installed within the 'summer' area of the SAC at both Creyke Beck A and Creyke Beck B. Pile-driving could occur throughout the 183 day summer period. The planned number of turbines at each wind farm is 95.

18.56 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 for the consented scenario and 97 for the planned scenario. Over the course of a season the average seasonal footprint is either 8.3% or 15.7% depending on the scenario (Table 84).

Table 84: In-combination average seasonal footprint for Creyke Beck A and Creyke Beck B offshore wind farms within the SAC.

SAC area	Maximum area of SAC impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Average seasonal footprint (%)
In-combination pile-driving (consented)					
'summer'	4,247	15.7	200	183	15.7
In-combination pile-driving (planned)					
'summer'	4,247	15.7	95	97	8.3
In-combination concurrent pile-driving at Creyke Beck A (consented)					
'summer'	5,693	21.1	200	102	11.8
In-combination concurrent pile-driving at Creyke Beck A (planned)					
'summer'	5,693	21.1	95	50	5.7

18.57 The results from the assessment indicate that the area of disturbance on harbour porpoise within the SAC across one day would not exceed the draft daily threshold but could exceed the seasonal threshold.

18.58 The assessment is based on an unrealistic worst-case scenario that all the pile-driving will cause the same level of impact within the SAC, which will not occur. The installation of piles in closer proximity to each other or closer to the SAC boundary will decrease the area impacted within the SAC and reduce the average seasonal footprint. 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.

18.59 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 and consequently the average seasonal footprint 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 thresholds are not exceeded.

Creyke Beck A and Creyke Beck B in-combination: Conclusions

18.60 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 SAC.

18.61 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.

18.62 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. The draft daily threshold is not exceeded but the seasonal threshold would be under the worst-case scenario.

18.63 A pre-construction licence condition requiring a SIP will ensure that the spatio-temporal impacts developed and secured in a SIP will ensure that thresholds are not exceeded.

Creyke Beck A and Teesside B

18.64 Creyke Beck A lies wholly within the SAC 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 2022 and 2025 (Figure 53).

Physical Injury

18.65 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. 17.119). 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

18.66 Displacement is predicted to occur over an area of up to 2,404 km^2 (Figure 59). Based on results from the dose response curve used and a zonal density of 0.71 ind./km^2, the estimated number of harbour porpoise predicted to be displaced is 627 individuals (Table 81). An estimated 0.19% of the North Sea Management Unit population may be impacted.

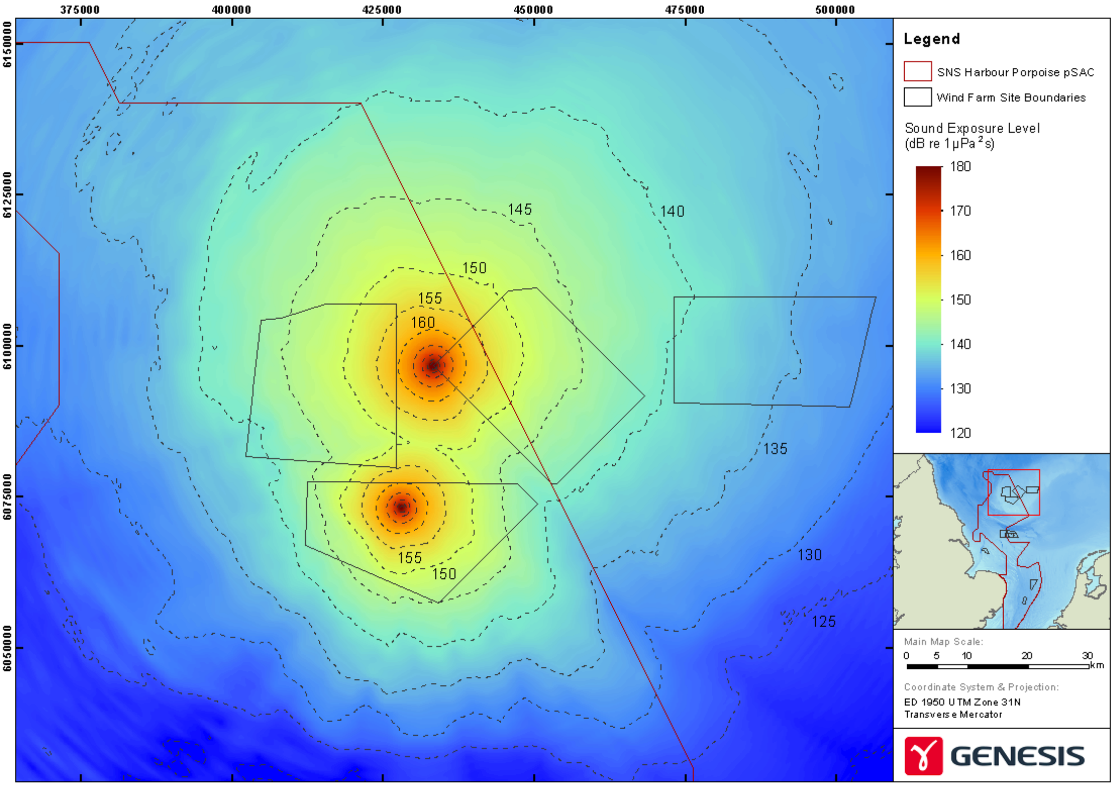


Figure 59: Predicted area of in-combination noise impacts from pile-driving at Creyke Beck A and Teesside B offshore wind farms.

Effective Deterrent Range

18.67 The combined EDR for Creyke Beck A and Teesside B could potentially impact an area of 3,314 km^2 within the SAC (Figure 60).

18.68 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 SAC as a whole and 12.3% of the 'summer' area. There will be no in-combination impacts on the 'winter' area.

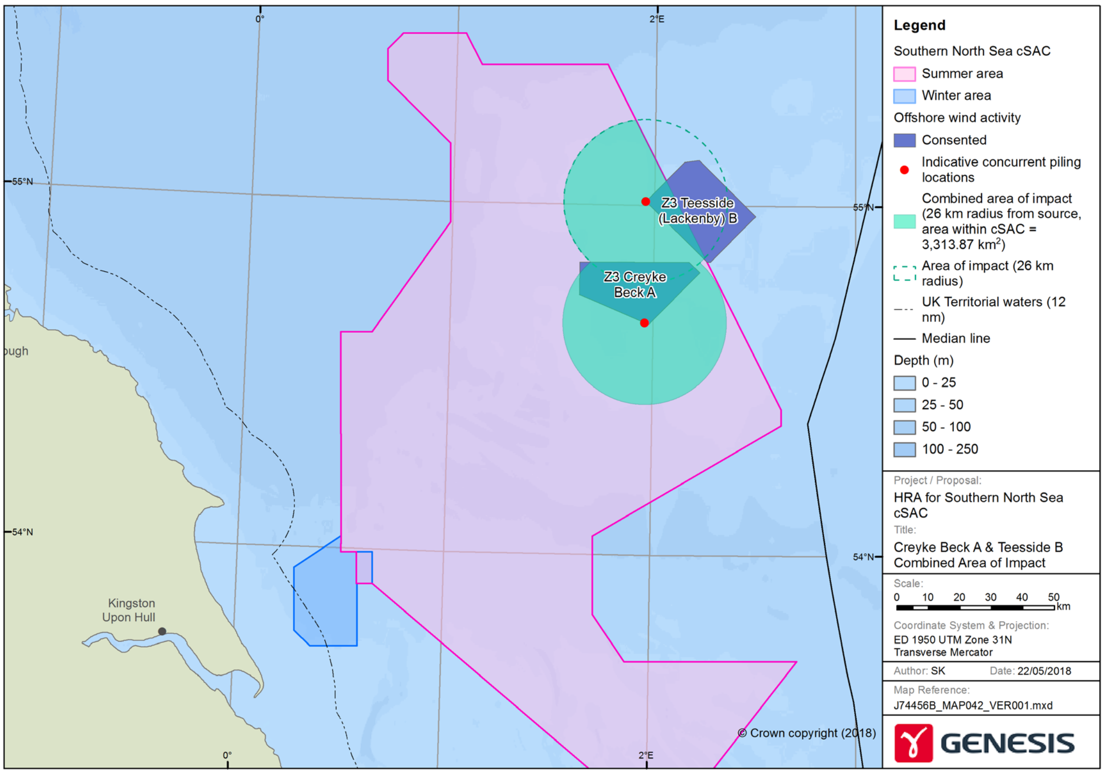


Figure 60: Maximum area of effective deterrence within the Southern North Sea SAC from in-combination pile-driving at Creyke Beck A and Teesside B.

18.69 Based on the consented project design, up to 200 wind turbines will be installed at Creyke Beck A and Teesside B. The planned number of turbines at Creyke Beck A is 95 and 100 at Teesside B.

18.70 For the purposes of this assessment the worst-case scenario (as consented) 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 footprint is 12.3%. Based on the planned build-out scenario the average seasonal footprint is 6.5% (Table 85).

18.71 The results from the assessment indicate that the area of combined disturbance on harbour porpoise within the SAC across one day would not exceed the draft daily thresholds but could, under the consented scenario exceed the seasonal thresholds but not under the planned build-out scenario.

Table 85: In-combination average seasonal footprint for Creyke Beck A and Teesside B offshore wind farms within the SAC.

SAC area	Maximum area of SAC impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Average seasonal footprint (%)
In-combination pile-driving (consented)					
'summer'	3,314	12.3	200	183	12.3
In-combination pile-driving (planned)					
'summer'	3,314	12.3	95	97	6.5

18.72 A total of 79% of Teesside B wind farm area lies outwith the SAC. Therefore, the area of impact within the SAC 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 SAC 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 SAC to 123 km^2.

18.73 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 average seasonal footprint 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 thresholds are not exceeded.

Creyke Beck A and Teesside B in-combination: Conclusions

18.74 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 SAC.

18.75 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.

18.76 The estimated potential displacement of no more than 0.19% 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. The draft daily threshold will not be exceeded but the seasonal threshold could be under the worst-case scenario as consented.

18.77 A pre-construction licence condition requiring a SIP will ensure that the spatio-temporal impacts developed and secured in a SIP will ensure that thresholds are not exceeded.

Teesside A and Teesside B

18.78 The Teesside A wind farm lies wholly outwith the SAC 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 2022 and 2027 (Figure 53).

Physical Injury

18.79 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. 17.98) 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

18.80 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 81). An estimated 0.26% of the North Sea Management Unit population may be impacted.

Effective Deterrent Range

18.81 The combined EDR for Teesside A and Teesside B could potentially impact an area of 1,518 km^2 within the SAC (Figure 61).

18.82 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 SAC as a whole and 5.6% of the 'summer' area. There will be no in-combination impacts on the 'winter' area.

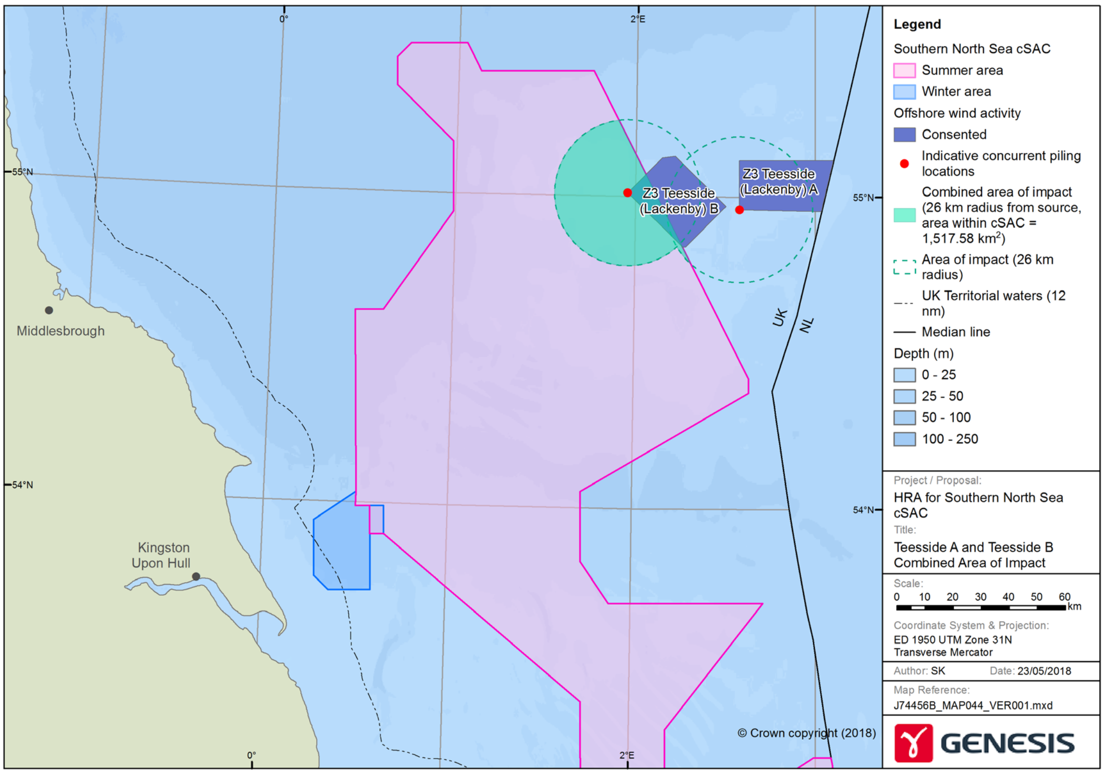


Figure 61: Maximum area of effective deterrence within the Southern North Sea SAC from in-combination pile-driving at Teesside A and Teesside B.

18.83 Based on the consented project design, up to 200 wind turbines will be installed at both Teesside A and Teesside B, although the planned build-out of Teesside B is for 100 turbines (Sofia Offshore Wind Farm 2020). The number of potential turbines to be installed at Teesside B within the SAC are unknown and an estimated two turbines could be installed at Teesside A within the area of potential EDR overlap of the SAC.

18.84 For the purposes of this assessment the worst-case scenario assumes that there will be in-combination pile-driving over four days (two days pile-driving at Teesside A plus two days recovery period). Over the course of a season the average seasonal footprint is 0.1% (Table 86).

18.85 The results from the assessment indicate that the area of combined disturbance on harbour porpoise within the SAC would not exceed the draft daily or seasonal thresholds.

Table 86: In-combination average seasonal footprint for Teesside A and Teesside B offshore wind farms within the SAC.

SAC area	Maximum area of SAC impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Average seasonal footprint (%)
In-combination pile-driving					
'summer'	1,518	5.6	2	4	0.1

Teesside A and Teesside B in-combination: Conclusions

18.86 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 SAC.

18.87 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.

18.88 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. The draft daily or seasonal thresholds are not exceeded.

18.89 A pre-construction licence condition requiring a SIP will ensure that the spatio-temporal impacts developed and secured in a SIP will ensure that thresholds are not exceeded.

Teesside B and East Anglia Three

18.90 Teesside B partially overlaps the SAC and East Anglia Three lies wholly within it. 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 2022 and 2023 (Figure 53).

Physical Injury

18.91 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

18.92 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 81); an estimated 0.22% of the North Sea Management Unit population may be impacted.

Effective Deterrent Range

18.93 The combined EDR for Teesside B and East Anglia Three could potentially impact across an area of 3,633 km^2 within the SAC (Figure 62) and, as a worst-case, could cause displacement of harbour porpoise over 9.8% of the SAC as a whole and 13.4% of the 'summer' area. There will be no in-combination impacts on the 'winter' area.

18.94 Based on the consented project design, up to 200 wind turbines could be installed within Teesside B, although the planned number of turbines is 100. Up to 172 turbines may be installed at East Anglia Three, all of which will be in the SAC.

18.95 For the purposes of this assessment the worst-case scenario (consented) 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 footprint is 12.8%. Under the planned build-out scenario in-combination pile-driving could occur over a period of 100 days having an average seasonal footprint of 7.5% (Table 87).

18.96 In the event that concurrent pile-driving is undertaken at Teesside B the duration of the impact is reduced to an estimated 102 days and the average seasonal footprint is 8.7%, this is reduced under the planned construction scenario to 4.4% (Table 87).

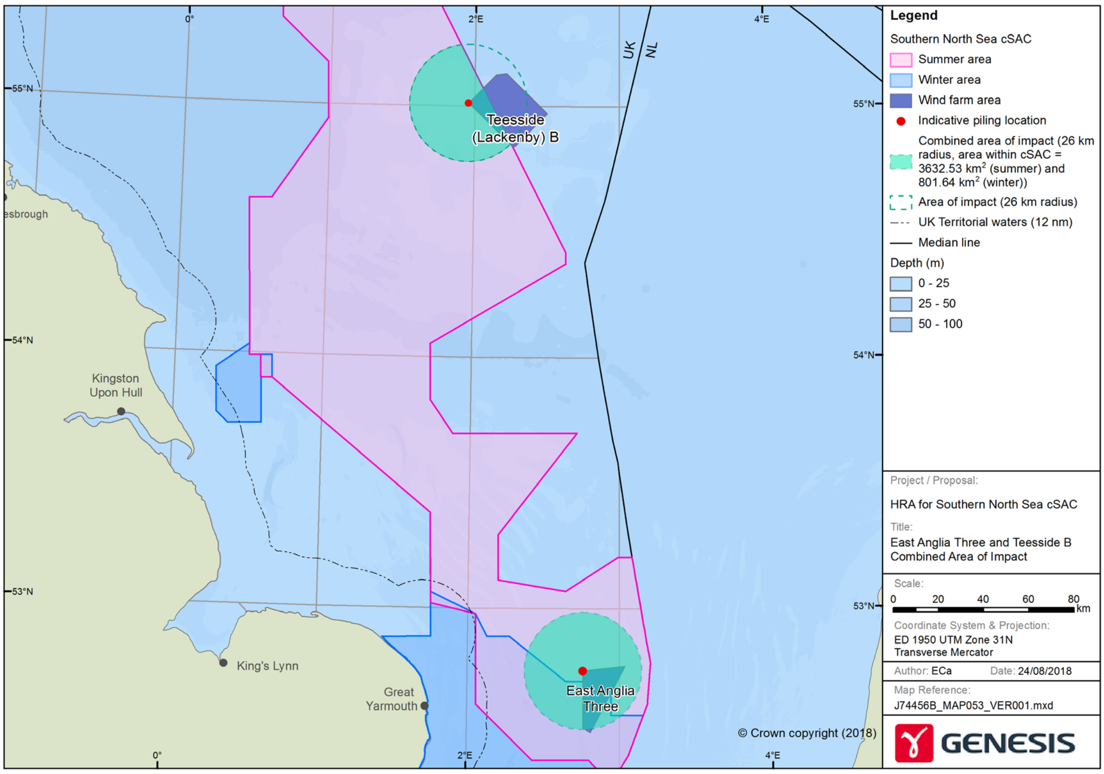


Figure 62: Maximum area of effective deterrence within the Southern North Sea SAC from in-combination pile-driving at Teesside B and East Anglia Three.

Table 87: In-combination average seasonal footprint for Teesside B and East Anglia Three offshore wind farms within the SAC.

SAC area	Maximum area of SAC impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Average seasonal footprint (%)
In-combination pile-driving (consented)					
'summer'	3,633	13.4	172	174	12.8
In-combination pile-driving (planned)					
'summer'	3,633	13.4	100	102	7.5
In-combination concurrent pile-driving at Teesside B (consented)					
'summer'	4,203	15.5	100	102	8.7
In-combination concurrent pile-driving at Teesside B (planned)					
'summer'	4,203	15.5	50	52	4.4

18.97 The results from the assessment indicate that the area of disturbance on harbour porpoise within the SAC would not exceed the draft daily thresholds but could, in theory, exceed the draft seasonal threshold under the consented scenario.

18.98 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 SAC and therefore 78.5% of the wind farm area is outwith the SAC. The remaining 21.5% of the wind farm is within 26 km of the boundary of the SAC. Consequently, 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 SAC; a considerably smaller area than the 1,508 km^2 used for the worst-case scenario.

18.99 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 average seasonal footprint 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 thresholds are not exceeded.

Teesside B and East Anglia Three In-combination: Conclusions

18.100 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 SAC.

18.101 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.

18.102 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. The draft daily thresholds will not be exceeded but under the worst-case consented scenario the seasonal threshold could be exceeded but this scenario is not considered likely to occur.

18.103 A pre-construction licence condition requiring a SIP will ensure that the spatio-temporal impacts developed and secured in a SIP will ensure that thresholds are not exceeded.

Creyke Beck A, Creyke Beck B and Teesside B

18.104 The Creyke Beck A and Creyke Beck B wind farms are wholly within the SAC and Teesside B wind farm partially overlaps the site. 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 2022 and 2025 and therefore there is potential for an in-combination impact (Figure 64).

Physical Injury

18.105 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

18.106 Displacement from each individual wind farm is predicted to occur over an area 3,436 km^2 (Figure 63). 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 81); a total of 0.27% of the North Sea Management Unit population may be impacted.

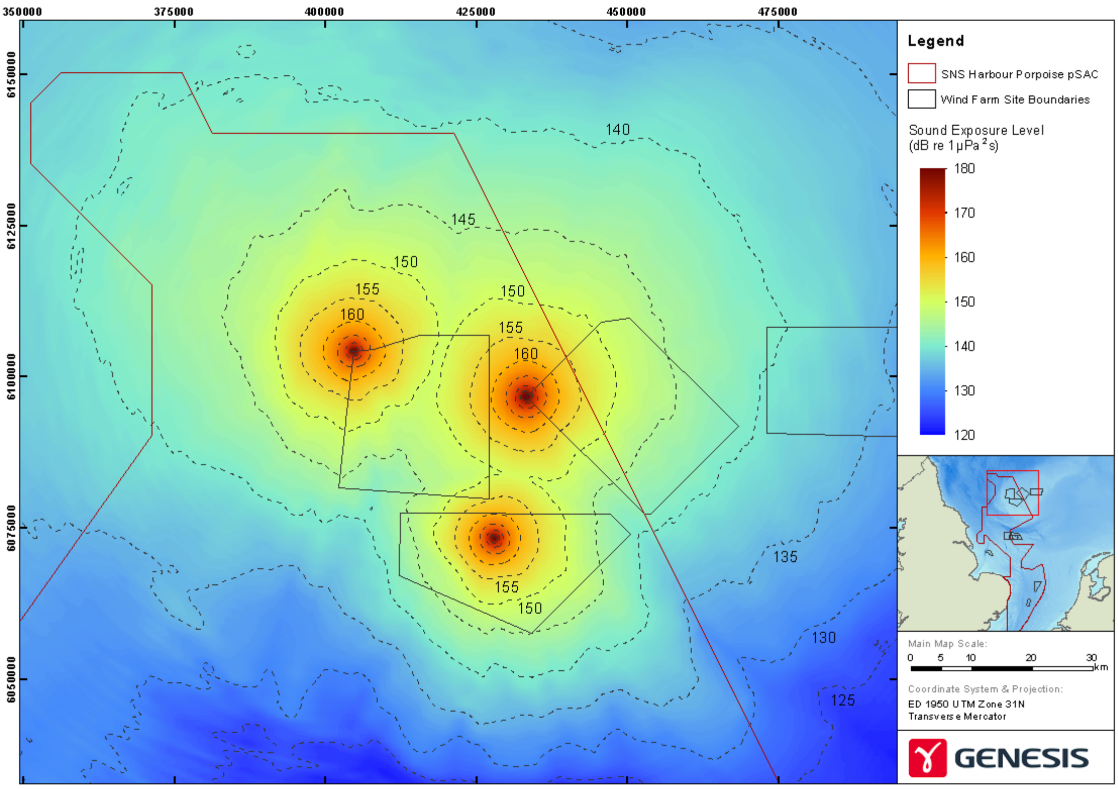


Figure 63: Predicted area of in-combination noise impacts from pile-driving at Creyke Beck A, Creyke Beck B and Teesside B offshore wind farms.

Effective Deterrent Range

18.107 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 SAC (Figure 64).

18.108 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 SAC as a whole and 17.5 % of the 'summer' area. There will be no in-combination impacts on the 'winter' area.

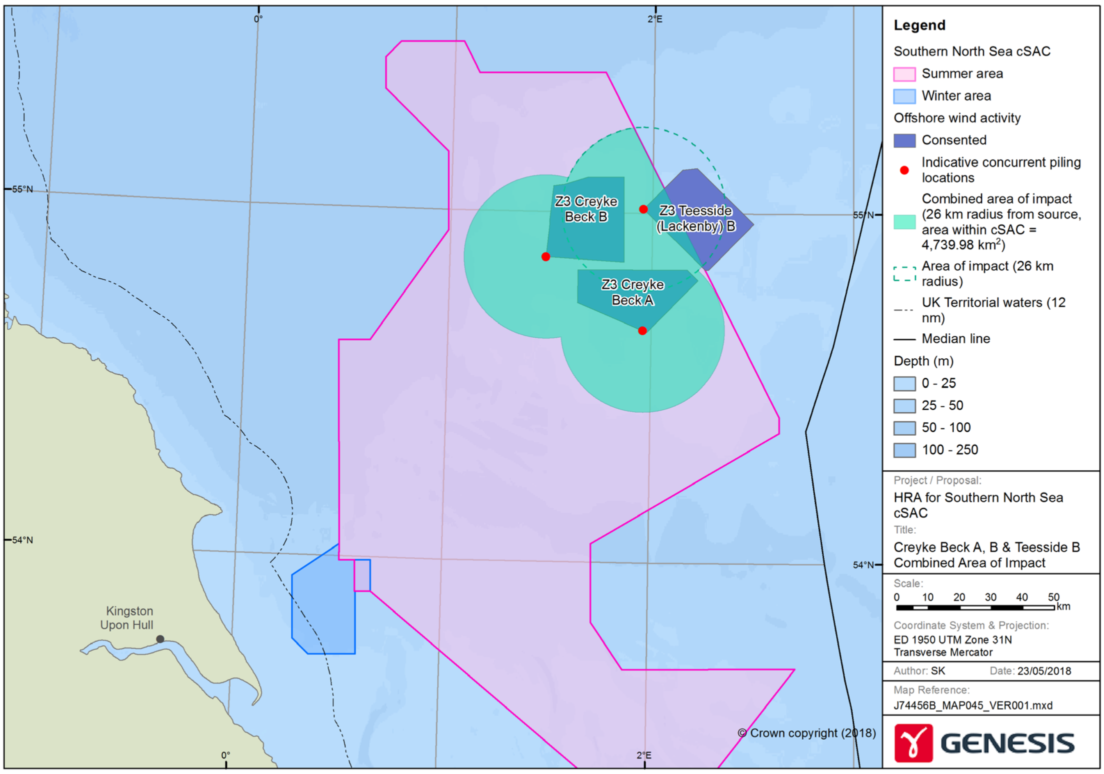


Figure 64: Maximum area of effective deterrence within the Southern North Sea SAC from in-combination pile-driving at Creyke Beck A, Creyke Beck B and Teesside B.

18.109 Based on the consented project designs, up to 200 wind turbines will be installed within the 'summer' area of the SAC 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 footprint is 17.5%. Based on the planned build-out plans of 95 turbines at Creyke Beck A and B and 100 turbines at Teesside B the average seasonal footprint is 9.3% (Table 88).

Table 88: In-combination average seasonal footprint for Creyke Beck A, Creyke Beck B and Teesside B offshore wind farms within the SAC.

SAC area	Maximum area of SAC impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Average seasonal footprint (%)
In-combination pile-driving (consented)					
'summer'	4,740	17.5	200	183	17.5
In-combination pile-driving (planned)					
'summer'	4,740	17.5	95	97	9.3

18.110 The results from the assessment indicate that the area of disturbance on harbour porpoise within the SAC across one day would not exceed the draft daily thresholds but could exceed the seasonal thresholds based on the consented scenario. However, under the planned scenarios the average seasonal footprint is not exceeded.

18.111 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 SAC could occur. The installation of piles outwith the SAC or within 26 km of the boundary will decrease the area impacted within the SAC and reduce the average seasonal footprint. Combined pile-driving in closer proximity to each location will also reduce the spatial footprint.

18.112 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 average seasonal footprint 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 thresholds are not exceeded.

Creyke Beck A, Creyke Beck B and Teesside B in-combination: Conclusions

18.113 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 SAC.

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 in-combination pile-driving during the construction of the Creyke Beck A, Creyke Beck B and Teesside B offshore wind farms.

18.115 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.

18.116 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 thresholds are not exceeded.

In-combination Offshore Wind Farm Habitat Impacts

18.117 The following section assesses the potential in-combination impacts on the habitats that support harbour porpoise within the SAC.

18.118 The estimated area of impact arising from offshore wind farms within the SAC are presented in Table 89. The potential area of seabed within the SAC estimated to be permanently impacted by the physical presence of the turbines, associated infrastructure and scour protection is 8.13 km^2 (based on the planned construction of Hornsea Two, East Anglia One, and Creyke Beck A and B). A total of 94.65 km^2 of seabed may be temporarily impacted by cable trenching.

Table 89: Estimated area of impact from consented offshore wind farms within the SAC.

Wind farm	Estimated area of physical impact (km^2)				
	Turbines & scour	Infrastructure	Cable protection	Total 'permanent' impact	Cable trenching
Galloper	0.98	0.00	0.20	0.29	3.90
Greater Gabbard	0.11	0.005	0.15	0.27	2.99
Creyke Beck A consented (monopiles)	0.57	0.14	0.74	1.45	14.73
Creyke Beck A planned (monopiles)	0.45	0.02	0.74	1.33	14.73
Creyke Beck B consented (monopiles)	0.57	0.14	0.73	1.44	14.64
Creyke Beck B planned (monopiles)	0.45	0.02	0.73	1.32	14.64
Teesside A	0.00	0.00	0.08	0.08	1.53
Teesside B (monopiles)	0.68	0.11	0.72	1.51	14.37
Hornsea One planned (monopiles)	0.25	0.05	0.27	0.57	7.10
Hornsea Two consented (monopiles)	0.44	0.14	0.63	1.28	12.62
Hornsea Two planned (monopiles)	0.32	0.06	0.63	1.02	12.62
East Anglia One planned (jacket)	0.13	0.03	0.37	0.52	7.32
East Anglia Three consented (jacket)	0.33	0.11	0.77	1.21	15.46

18.119 The estimated area of seabed potentially impacted by existing activities within the SAC is presented in Table 90.

18.120 There have been no quantified assessments undertaken on the extent impacts from commercial fishing may have within the SAC and therefore information to inform this assessment is not available. Given the extent and type of fishing activities within the SAC, 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 SAC although, the actual area of seabed impacted within each licenced area is considerably smaller.

18.121 Existing offshore wind farms within the SAC 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 90: Estimated area of physical impact from existing activities within the SAC.

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. 6.21	Area impacted within each site is smaller than actual licenced area.
Fishing	Unknown	Para. 6.39	Impacts are predicted to be widespread and ongoing.

18.122 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 SAC.

18.123 Physical impacts on the seabed from all consented offshore wind farms are estimated to impact 0.02% of the SAC. However, following decommissioning a significant proportion of all the infrastructure will be removed, leaving at most buried cables and some of the associated cable protection, consequently, the impacts will be long-term but temporary. There will be a relatively very small potential loss of habitat within the site but 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 SAC.

18.124 Temporary impacts from the trenching of pipelines and cables impact a larger area of 94.65 km^2. However, the area impacted during construction will occur over a period stretching over approximately 20 years. The habitat will begin to recover once the lines are buried and therefore the impacts will be short-term and temporary 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

18.125 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 SAC. 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 SAC from the consented offshore wind farms will not have an adverse effect upon the integrity of the Southern North Sea SAC.

In-combination Assessment: Wind Farm Pile-driving and Geophysical Seismic Surveys

18.126 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 the summer of 2020.

18.127 Data on the recent historical seismic survey activities within the SAC indicate that on average there are 3.4 surveys (2D, 3D and site-surveys) undertaken in the ‘summer’ area between April and September each year and there is seismic survey activity within the area for 34.7% 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 three surveys undertaken over an 10 year period and an average of 3.7 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.

18.128 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. However, the assessment also considers the less likely scenarios of a wind farm undertaking concurrent pile-driving or two wind farms being constructed at the same time along with a seismic survey.

18.129 The results from the noise modelling indicate that the area of potential impact from PTS is within 500 m of the airgun array (Table 52) 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 2017c). 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.

18.130 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 2017c). Therefore, there is predicted to be no in-combination impacts with regard to physical injury to harbour porpoise.

Disturbance

18.131 The area of potential disturbance of harbour porpoise varies depending on the location of the survey (Table 53). 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 SAC, 2.8% of the ‘summer’ area and 6.0% of the ‘winter’ area.

18.132 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. This is equivalent to 0.66% of the Management Unit population.

18.133 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. 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 an area could be greater.

18.134 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 SAC, occur between 21.6 km and 33.2 km from the airguns (Table 53). Consequently, as a vessel undertakes a survey, disturbance in any area will last less than eight hours in any one location (Figure 65). Once the vessel has left the area, sound levels will reduce to background levels and harbour porpoise will return to the area. Consequently, any impacts are predicted to be temporary and short-term.

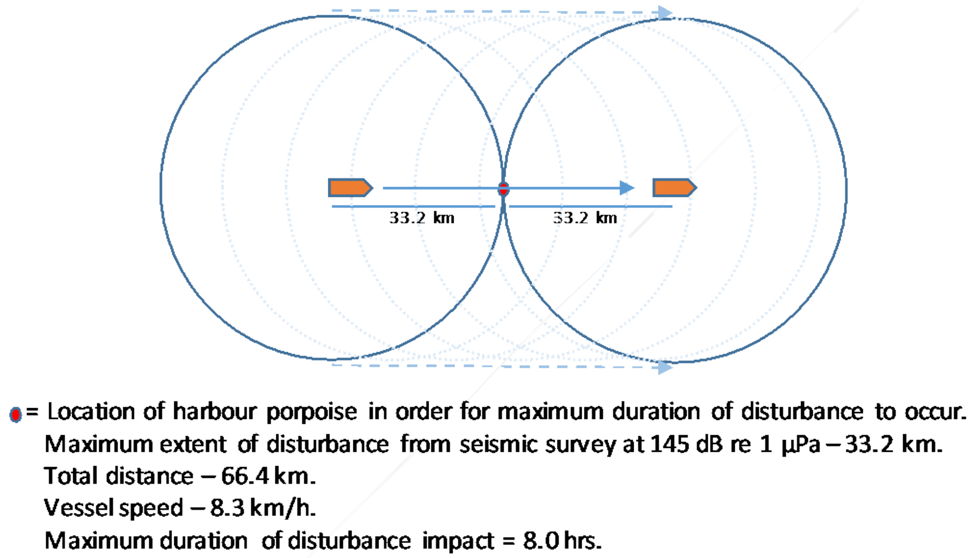


Figure 65: Diagram showing potential duration of disturbance to harbour porpoise from seismic survey.

18.135 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 34.7% of the summer period (Table 12). As it is unknown where future seismic surveys may occur within the SAC the estimated number of harbour porpoise displaced by seismic surveys is based on both the average density of harbour porpoise across the SAC as a whole and the relevant zonal density.

18.136 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 91). This is equivalent to between 0.23% and 1.14% of the North Sea Management Unit population.

18.137 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 92).

Table 91: 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		Wind farm + 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) at any one time = 767 km^2.

'Ave. density' assumes that a seismic survey could be undertaken anywhere within the SAC and therefore the estimated number of harbour porpoise impacted by the seismic survey is calculated based on the average density of harbour porpoise across SAC as a whole of 0.71 ind.km^2.

'Zonal density' assumes that a seismic survey is being undertaken within the same wind farm zone as the one undertaking pile-driving and therefore the wind farm zonal harbour porpoise densities (Hornsea Zone of 2.22 ind.km^2 and Dogger Bank Zone of 0.71 ind./km^2) are used for both wind farm and seismic estimates.

Table 92: 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		Wind farm + 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) at any one time = 767 km^2.

'Ave. density' assumes that a seismic survey could be undertaken anywhere within the SAC and therefore the estimated number of harbour porpoise impacted by the seismic survey is calculated based on the average density of harbour porpoise across SAC as a whole of 0.71 ind.km^2.

'Zonal density' assumes that a seismic survey is being undertaken within the same wind farm zone as the one undertaking pile-driving and therefore the wind farm zonal harbour porpoise densities (Hornsea Zone of 2.22 ind.km^2 and Dogger Bank Zone of 0.71 ind./km^2) are used for both wind farm and seismic estimates.

18.138 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 or disturbed is between 1,003 and 2,937 individuals, equivalent to between 0.30% and 0.87% of the North Sea Management Unit population based on the survey occurring in an area of average harbour porpoise density (Table 93). If the seismic survey occurs in areas of higher than average harbour porpoise density, there is potential for up to 4,032 harbour porpoise to be displaced or disturbed, equivalent to 1.2% of the Management Unit population.

Table 93: 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	Two Wind farms alone		Two Wind farms + Seismic in-combination		
	Combined Area of impact (km²)	No. of ind. displaced	Area of impact (km²)	No. of ind. displaced (Ave. density)	No. of ind. displaced (Zonal density)
Hornsea Two + Creyke Beck A	3,585	2,329	4,352	2,937	4,032
Creyke Beck A + East Anglia Three	3,243	458	4,010	1,003	1,002
Creyke Beck A + Creyke Beck B	2,288	586	3,055	1,131	1,130
Teesside B + Creyke Beck A	2,404	627	3,171	1,172	1,171
Teesside A + Teesside B	3,417	876	4,184	1,421	1,420
Teesside B + East Anglia Three	4,294	709	5,061	1,254	1,253
Creyke Beck A + Creyke Beck B + Teesside B	3,436	914	4,203	1,459	1,458

See Table 81 for combined area of impact from wind farms and estimated number of porpoise displaced by the wind farms.

Estimated area of impact from seismic survey (at any one time) = 767 km^2.

'Ave. density' assumes that a seismic survey could be undertaken anywhere within the SAC and therefore the estimated number of harbour porpoise impacted by the seismic survey is calculated based on the average density of harbour porpoise across SAC as a whole of 0.71 ind.km^2.

'Zonal density' assumes that a seismic survey is being undertaken within the same wind farm zone as the one undertaking pile-driving and therefore the wind farm zonal harbour porpoise densities are used for both wind farm and seismic estimates.

Effective Deterrent Range

18.139 The EDR for seismic surveys is 12 km (JNCC, NE and DAERA 2020a). However, previous assessments have been based on either an EDR of 5 km or 10 km (e.g. MMO 2017a, EAOWL 2017).

18.140 The worst-case scenario is based on the area impacted from the seismic survey being wholly within either the 'summer' or 'winter' area. However, recent applications for seismic surveys in the Southern North Sea have shown that a significant proportion of a seismic survey may occur outwith the SAC and therefore the impacts beyond 12 km of the site boundary would not be included using the threshold approach (BEIS 2019).

18.141 A seismic survey vessel travelling at 4.5 knots (8.3 km/h) could, in theory, survey a total of 199 km of survey line in a single 24 hr period and therefore impact an area of 4,294 km^2 (Figure 66). If this were to occur up to 15.9% of the 'summer' area and 33.8% of the 'winter' area could be impacted. However, this does not take into account the time when the airguns are not firing each day. Airguns are required to be switched off at the end of every survey line during which the vessel is turning and this typically, takes between two to three hours with usually one or more line turns per day. Other technical reasons or weather related delays further reduce the amount of time surveys are undertaken each day. A review of six seismic surveys indicated that, on average, airguns operate for 52% of the time (See Para. 6.14).

18.142 The extent of impact per day within the SAC is based on the worst-case scenario of a seismic vessel travelling at 4.5 knots and there being no breaks in the use of airguns during the 24 hr period and the whole of the survey occurring within the SAC. Under this scenario the vessel may travel 199 km/day and impact an area of 5,228 km^2 and impact 19.3% of the SAC 'summer' area and 41.2% of the 'winter' area.

18.143 This is an unrealistic worst-case scenario as it is very unlikely that a survey would be undertaken along a single transect line of 199 km in a single day, wholly within the SAC. Shorter survey lines will require the vessel to undertake line turns each lasting approximately three hours, during which time the airguns will be switched off, thus reducing the length of line surveyed in a day.

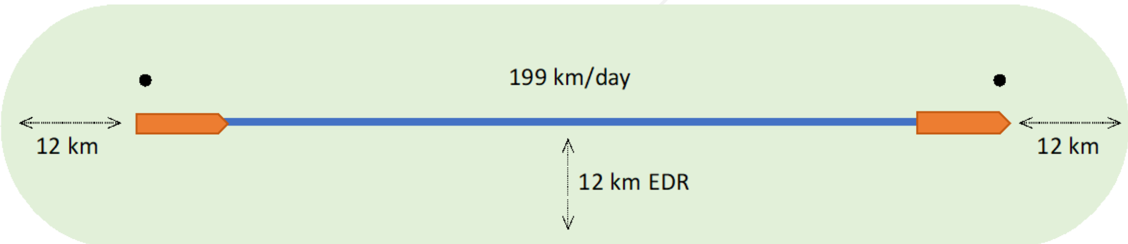


Figure 66: Maximum worst-case theoretical area of impact over a single day from a seismic survey travelling at 4.5 knots using 10 km EDR.

18.144 The average seasonal footprint is based on a single seismic survey lasting for 42 days, which is the median duration for a 3D seismic survey in the 'summer' area during the summer period and up to 19 days in the winter period (Table 12 and Table 13).

18.145 The results of the in-combination assessment for each of the consented wind farm developments for while pile-driving has still to be undertaken are presented in Table 94.

Table 94: Daily and average seasonal footprint in-combination with pile-driving and a seismic survey.

Wind farm construction scenario	Wind farm		One wind farm + 42 day seismic survey in-combination	
	Area of SAC impacted (km^2)	Daily % of area	Daily % of area	Average seasonal footprint (%)
Hornsea Two				
Single pile-driving	1,976	7.3	26.7	6.4
Concurrent pile-driving	2,874	10.6	30.0	7.2
Creyke Beck A				
Single pile-driving	2,124	7.9	27.2	6.5
Concurrent pile-driving	3,569	13.2	32.5	7.8
Creyke Beck B				
Single pile-driving	2,124	7.9	27.2	6.5
Concurrent pile-driving	3,577	13.2	32.6	7.8
Teesside A				
Single pile-driving	23	0.1	19.4	4.7
Teesside B				
Single-pile-driving	1,509	5.6	24.9	6.0
Concurrent pile-driving	2,080	7.7	27.0	6.5

The area of SAC impacted is the area impacted by pile-driving.

The maximum theoretical daily area of impact from a seismic survey is 5,228 km^2, equivalent to 19.3% of the 'summer' area.

The duration of in-combination impact is 44 days (The median duration of seismic surveys in the Southern North Sea of 42 days plus two days recovery period).

18.146 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 SAC.

18.147 Under all but one of the in-combination scenarios the proportion of the 'summer' area impacted during a single day could be greater than 20%. The maximum area of potential combined impact arises in the event that either Creyke Beck A or Creyke Beck B undertake concurrent pile-driving at the same time as a seismic survey. If this arises there is potential for up to 32.5% of the SAC 'summer' area to be impacted during any single day and a seasonal impact of up to 7.8%.

18.148 In order to ensure that the draft daily thresholds are not exceeded in the event a seismic survey is undertaken at the same time as one wind farm is pile-driving, under the worst-case scenario no more than 117 km of seismic survey line may be undertaken in a single day within the 'summer' area and none can be undertaken in the 'winter' area when pile-driving is being undertaken. Similarly, if a seismic survey is being undertaken during in the summer area no more 189 km^2 of the SAC may be impacted by pile-driving noise and none during the winter period (Table 95).

Table 95: Predicted extent of worst-case impact from pile-driving and seismic surveys within the SAC not exceeding the draft daily thresholds in 'summer' and 'winter' areas of the Southern North Sea SAC.

Wind farm construction scenario	Summer		Winter	
	Impact in SAC	Daily % of area	Impact in SAC	Daily % of area
Pile-driving				
Pile-driving (maximum area of impact)	2,124 km^2	7.9	2,124 km^2	16.7
In-combination seismic (length of survey line)	117 km	12.0	0 km	3.3
Seismic				
Seismic (maximum length of survey line)	199 km	19.3	86.9 km	20
In-combination pile-driving (area of impact)	189 km^2	0.7	0 km^2	0

18.149 There is also potential for two wind farms to be undertaking construction and a seismic survey simultaneously and causing an in-combination impact. In the event that this occurs there is potential for the daily threshold to be exceeded under all scenarios. The seasonal threshold is not exceeded under any scenario (Table 96).

18.150 There is a theoretical possibility that concurrent pile-driving is undertaken at one or two wind farms and a seismic survey is undertaken at the same time and is wholly within the SAC. In this event the daily and seasonal impacts will be greater than those assessed here. All future application will require an assessment that considers the potential of all in-combination impacts based on the information available at the time of application.

Table 96: Daily and average seasonal footprints in-combination with pile-driving at two separate wind farm projects and a seismic survey.

Wind Farm (planned - single pile-driving)		Daily Threshold (Pile-driving)	Daily Threshold (Pile-driving and Seismic)	Average seasonal footprint
Hornsea Two	Creyke Beck A	15.17	34.51	8.30
	Creyke Beck B	15.17	34.51	8.30
	Teesside A	7.40	26.74	0.58
	Teesside B	12.89	32.24	7.75
Creyke Beck A	Hornsea Two	15.17	34.51	8.30
	Creyke Beck B	15.71	35.06	8.43
	Teesside A	7.94	27.28	0.60
	Teesside B	13.44	32.78	7.88
	East Anglia Three	15.71	35.06	8.43
Creyke Beck B	Hornsea Two	15.17	34.51	8.30
	Creyke Beck A	15.71	35.06	8.43
	Teesside A	7.94	27.28	0.60
	Teesside B	13.44	32.78	7.88
	East Anglia Three	15.71	35.06	8.43
Teesside A	Hornsea Two	7.40	26.74	0.58
	East Anglia Three	7.94	27.28	0.60
	Teesside B	5.67	25.01	0.55
	Creyke Beck A	7.94	27.28	0.60
	Creyke Beck B	7.94	27.28	0.60
Teesside B	Hornsea Two	12.89	32.24	7.75
	Teesside A	5.67	25.01	0.55
	Creyke Beck A	13.44	32.78	7.88
	Creyke Beck B	13.44	32.78	7.88
	East Anglia Three	13.44	32.78	7.88

The duration of in-combination impact is 44 days (The median duration of seismic surveys in the Southern North Sea of 42 days plus two days recovery period).

The maximum daily area of impact from a seismic survey is 5,228 km^2, equivalent to 19.3% of the 'summer' area.

18.151 The assessment based on noise modelling outputs and reported densities of harbour porpoises within the SAC indicates that there is potential for more than 1% of the North Sea Management Unit harbour porpoise population to be disturbed in the event that pile-driving is undertaken at Hornsea Two at the same time as either Creyke Beck A or East Anglia Three and when a seismic survey is being undertaken wholly within the 'summer' area of the SAC and over an area of relatively higher harbour porpoise density. However, it is below 1.7% of the population which is currently considered to be the level at which population level effects are predicted to arise. Under all other scenarios the results from the noise modelling indicate that less than 1% of the population will be affected.

18.152 The assessment based on the threshold approach indicates that the there is potential for the daily threshold to be exceeded under all but one in-combination scenario (Table 94 and Table 96). Under no scenarios are the thresholds for the average seasonal footprint exceeded.

18.153 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).

18.154 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. Studies undertaken in the Danish sector of the Central North Sea reported disturbance out to 12 km from a 3,570 cu. in. airgun, although the duration of the disturbance is not reported (Sarnocińska *et al*. 2020).

18.155 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). Seismic surveys have been regularly undertaken within the SAC since the 1950's with 65 separate surveys between 2005 and 2014 (Para. 6.10). Since the first SCANS survey was undertaken in 1994 there has been a change in the harbour porpoise distribution with increasing numbers within the Southern North Sea, including the SAC and there has been no decline in the harbour porpoise population. Consequently, although there have been regular seismic surveys in the region over the same period there has been no population level effect.

18.156 There is a high degree of certainty that harbour porpoise will be disturbed and displaced by pile-driving and 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.

18.157 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 and NE 2019). Consequently, the historical widespread impact of seismic surveys has not resulted in a significant adverse effect on the harbour porpoise population within the SAC.

In-combination offshore wind farm pile-driving and seismic surveys: Conclusions

18.158 It is concluded that, based on the results from the noise modelling and known behaviour of harbour porpoise to noise impacts, 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 SAC. However, under the worst-case scenarios the draft daily thresholds would be exceeded but not the seasonal thresholds.

18.159 A pre-construction licence condition requiring a SIP will ensure that the spatio-temporal impacts developed and secured in a SIP will ensure that thresholds are not exceeded.

In-combination Assessment: Wind Farm Pile-driving and Sub-bottom profilers

18.160 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.

18.161 The historical use of sub-bottom profilers by the oil and gas industry within the SAC 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 a sub-bottom profiler being used 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.

18.162 The results from the noise modelling indicate that the area of potential impact from PTS is within 23 m of the airgun array (Table 54) 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

18.163 Noise modelling indicates that disturbance could extend to 2.5 km from the sub-bottom profilers and impact over an area estimated to be 18.3 km^2 (Table 55). This is equivalent to 0.04% of the SAC, 0.07% of the 'summer' area and 0.14% of the 'winter' area.

18.164 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.

18.165 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 undertaken 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 97). This is equivalent to between 0.07% and 0.63% of the North Sea Management Unit population.

18.166 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 98).

18.167 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 278 and 2,301 individuals, equivalent to between 0.08% and 0.69% of the North Sea Management Unit population (Table 99).

18.168 The worst-case scenario of concurrent pile-driving at Hornsea two and a sub-bottom profiler operating within the Hornsea Zone could affect 0.83% of the North Sea Management Unit population.

Table 97: 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 + Wind farm		
	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 SAC 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 Dogger Bank Zone of 0.71 ind./km^2 (for sub-bottom profiler impacts only).

Table 98: 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 + Wind farm		
	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 SAC 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 Dogger Bank Zone of 0.71 ind./km^2 (for sub-bottom profiler impacts only).

Table 99: Estimated area of impact and number of porpoises disturbed from two wind farms pile-driving in-combination with a sub-bottom profiler.

Wind farm	Two wind farms		Sub-bottom profiler in-combination		
	Area of impact (km^2)	No. of ind. displaced	Area of impact (km^2)	No. of ind. displaced (Ave. SAC density)	No. of ind. displaced (Zonal density)
Hornsea Two + Creyke Beck A	3,585	1,825	3,603	1,838	1,865
Hornsea Two + East Anglia Three	5,246	2,261	5,264	2,274	2,301
Creyke Beck A + Triton Knoll	1,725	265	1,743	278	278
Creyke Beck A + East Anglia Three	3,243	458	3,261	471	471
Creyke Beck A + Creyke Beck B	2,289	586	2,307	596	596
Teesside B + Creyke Beck A	2,404	627	2,422	640	640
Teesside A + Teesside B	3,417	876	3,435	889	889
Teesside B + East Anglia Three	4,294	709	4,307	722	722
Creyke Beck A + Creyke Beck B + Teesside B	3,436	914	3,454	927	927

See Table 81 for combined area of impact from wind farms and number of porpoise displaced.

Estimated area of impact from sub-bottom profiler (worst-case) = 18.3 km^2.

'Ave. SAC density' is the estimated average density of harbour porpoise across SAC as a whole of 0.71 ind.km^2 (for sub-bottom profiler impacts only).

Zonal density - The Number of individuals displaced by a Sub-bottom profiler and the construction of two wind farms is estimated based on the number of individuals displaced from the two wind farms (column three) and the seismic survey being undertaken in the wind farm zone with the higher of the two porpoise densities, i.e. either the Hornsea Zone or Dogger Bank Zone depending on the scenario and is therefore a worst-case.

Effective Disturbance Range

18.169 The EDR for geophysical survey equipment is 5 km (JNCC, NE and DAERA 2020a). However, previous assessments have been based on either an EDR of 5 km or 10 km (e.g. MMO 2017a, EAOWL 2017).

18.170 The EDR for geophysical equipment is 5 km (JNCC, NE and DAERA 2020). Consequently, at any one point in time a total area of 78.54 km^2 could be impacted, equivalent to 0.29% of the 'summer' area and 0.6% of the 'winter' area. If, in the unlikely event that a sub-bottom profiler is used continuously over a period of 24 hrs with a vessel speed of 4 knots (7.4 km/h) a total area of 256.1 km^2 per day could be affected, equivalent to 0.9% of the 'summer' area and 2% of the 'winter' area.

18.171 The estimated impacts based the threshold approach for a single pile-driving and 14 days of sub-bottom profiler are presented in Table 100 and two wind farms in-combination in Table 101. Neither the daily nor seasonal thresholds are exceeded under any of the in-combination scenarios.

Table 100: Daily and average seasonal footprint in-combination with pile-driving and a 14 day geophysical survey.

Wind farm construction scenario	Wind farm		One wind farm + 14 day geophysical survey in-combination	
	Area of SAC impacted (km^2)	Daily % of area	Daily % of area	Average seasonal footprint (%)
Hornsea Two				
Single pile-driving	1,976	7.3	8.3	0.7
Concurrent pile-driving	2,874	10.6	11.6	1.0
Creyke Beck A				
Single pile-driving	2,124	7.9	8.8	0.8
Concurrent pile-driving	3,569	13.2	14.2	1.2
Creyke Beck B				
Single pile-driving	2,124	7.9	8.8	0.8
Concurrent pile-driving	3,577	13.2	14.2	1.2
Teesside A				
Single pile-driving	23	0.1	1.0	0.1
Teesside B				
Single-pile-driving	1,509	5.6	6.5	0.6
Concurrent pile-driving	2,080	7.7	8.6	0.8

The area of SAC impacted is the area impacted by pile-driving.

The maximum theoretical daily area of impact from a sub-bottom profiler is 256 km^2, equivalent to 0.95% of the 'summer' area.

The duration of in-combination impact for the purposes of this assessment is 16 days (14 days of geophysical survey using a sub-bottom profiler plus two days recovery period).

Table 101: Daily and average seasonal footprints in-combination with pile-driving at two separate wind farm projects and a geophysical survey.

Wind Farm (planned - single pile-driving)		Daily Threshold (Pile-driving)	Daily Threshold (Pile-driving and Seismic)	Average seasonal footprint
Hornsea Two	Creyke Beck A	15.17	16.12	1.41
	Creyke Beck B	15.17	16.12	1.41
	Teesside A	7.40	8.34	0.18
	Teesside B	12.89	13.84	1.21
Creyke Beck A	Hornsea Two	15.17	16.12	1.41
	Creyke Beck B	15.71	16.66	1.46
	Teesside A	7.94	8.89	0.19
	Teesside B	13.44	14.39	1.26
	East Anglia Three	15.71	16.66	1.46
Creyke Beck B	Hornsea Two	15.17	16.12	1.41
	Creyke Beck A	15.71	16.66	1.46
	Teesside A	7.94	8.89	0.19
	Teesside B	13.44	14.39	1.26
	East Anglia Three	15.71	16.66	1.46
Teesside A	Hornsea Two	7.40	8.34	0.18
	East Anglia Three	7.94	8.89	0.19
	Teesside B	5.67	6.61	0.14
	Creyke Beck A	7.94	8.89	0.19
	Creyke Beck B	7.94	8.89	0.19
Teesside B	Hornsea Two	12.89	13.84	1.21
	Teesside A	5.67	6.61	0.14
	Creyke Beck A	13.44	14.39	1.26
	Creyke Beck B	13.44	14.39	1.26
	East Anglia Three	13.44	14.38	1.26

The duration of in-combination impact is 16 days (The median duration of seismic surveys in the Southern North Sea of 14 days plus two days recovery period).

The duration of in-combination impact for the purposes of this assessment is 16 days (14 days of geophysical survey using a sub-bottom profiler plus two days recovery period).

18.172 The use of a 5 km EDR is likely to be precautionary and noise modelling indicates a relatively localised area of no more than 2.5 km in extent within which disturbance is predicted to occur.

18.173 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 53 harbour porpoises. Based on the threshold approach the daily and seasonal thresholds are not exceeded. 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

18.174 It is concluded that, based on the results from the noise modelling and the threshold approach, 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 SAC.

In-combination Assessment: Wind Farm Vessels and Commercial Shipping

18.175 The noise arising from vessels, or their physical presence, can cause the displacement of harbour porpoise from an area. Approximately 4% of SAC 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 SAC in 2015, an average of 737 vessel movements per day (MMO 2017b).

18.176 If displacement occurs out to 400 m from each vessel (See Para. 16.26), the total area within the SAC 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 SAC at any one time. Based on an average density of harbour porpoise across the SAC of 0.71 ind./km^2 an estimated 262 harbour porpoise may be temporarily displaced by existing levels of shipping; this is equivalent to 0.08% of the North Sea Management Unit population.

18.177 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 SAC per year (Table 60). Should all the consented offshore wind farms be constructed an estimated 18,740 additional vessel movements per year could occur within the SAC. Therefore, there is the potential for an in-combination impact with existing shipping and other offshore activities within the SAC.

18.178 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 SAC of 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 construction vessel movements within the SAC 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 SAC and once construction is completed there will be no in-combination impacts from construction vessels.

18.179 During the operating period an estimated 52 vessels per day associated with offshore wind farm operations may occur within the SAC (Table 60) and therefore increase the daily average number of vessels within the SAC 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 SAC compared with current levels of shipping within the SAC (See Para. 18.176).

18.180 The additional vessel movements associated with operation of consented offshore wind farms will not contribute significantly to the existing levels of shipping across the SAC and any potential displacement effects to harbour porpoise will be temporary and localised to within approximately 400 m of a transiting vessel (Akkaya Bas *et al.* 2017, Polacheck 1990, Hermannsen *et al*. 2014, Wisniewska *et al*. 2018b).

18.181 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 impact on harbour porpoise.

In-combination offshore wind farm and commercial shipping: Conclusions.

18.182 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 SAC, the 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 SAC.

In-combination Assessment: Wind Farm Pile-driving and UXO Detonation

18.183 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). However, prolonged UXO clearance campaigns in a localised area could cause displacement if there are frequent detonations.

18.184 UXO clearance could be undertaken at the same time as pile-driving at an offshore wind farm is being undertaken and 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).

18.185 There is potential for UXO clearance to be undertaken from 2020 onwards. Neither the exact location of the UXO nor the number of items required to be detonated are known. 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 an EPS 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.

18.186 Table 102 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 53. 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 77 and for pile-driving is the worst-case scenario based on maximum hammer energies presented in Section 17. It is presumed that there is no overlap in the areas potentially impacted.

Table 102: Estimated number of harbour porpoise at risk from the onset of PTS in-combination with UXO detonation and a single 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	131	234	366	667	1,053	1,666
	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	698	1,084	1,697
	East Anglia Three	79	124	227	359	660	1,046	1,659
Creyke Beck A	Hornsea Two	43	57	90	132	228	352	548
	Creyke Beck B	35	49	82	124	220	344	540
	Teesside A	65	79	112	154	250	374	570
	Teesside B	65	79	112	154	250	374	570
	East Anglia Three	27	41	74	116	212	336	532
Creyke Beck B	Hornsea Two	43	57	90	132	228	352	548
	Creyke Beck A	34	48	81	123	219	343	539
	Teesside A	65	79	112	154	250	374	570
	Teesside B	65	79	112	154	250	374	570
	East Anglia Three	27	41	74	116	212	336	532
Teesside A	Hornsea Two	43	57	90	132	228	352	548
	East Anglia Three	27	41	74	116	212	336	532
	Teesside B	65	79	112	154	250	374	570
	Creyke Beck A	34	48	81	123	219	343	539
	Creyke Beck B	35	49	82	124	220	344	540
Teesside B	Hornsea Two	43	57	90	132	228	352	548
	Teesside A	65	79	112	154	250	374	570
	Creyke Beck A	34	48	81	123	219	343	539
	Creyke Beck B	35	49	82	124	220	344	540
	East Anglia Three	27	41	74	116	212	336	532

18.187 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.

18.188 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 17.160, mitigation measures to reduce the level of impact from UXO detonation is an EPS and Marine Licence condition and therefore significantly reduces the potential in-combination impact to a level below which there will not be an adverse effect.

18.189 The area of the SAC within which harbour porpoise may be deterred by UXO clearance based on a 26 km EDR is presented in Table 78. Between 7.9% and 15.7% of the 'summer' area may be impacted depending on the number of UXO detonations undertaken per day. Table 103 presents the daily and seasonal spatial impact within the SAC in the event that up to two items of UXO are detonated per day at the same time as either single or concurrent pile-driving is undertaken. The daily threshold could be exceeded in the event that single items of UXO are cleared per day and concurrent pile-driving is undertaken at either Creyke Beck A or Creyke Beck B. In the event that two items of UXO are cleared each day the daily threshold could be exceeded under all scenarios with the exception of pile-driving at Teesside A.

18.190 Table 104 presents the daily and average seasonal footprints in the event that pile-driving is undertaken at two wind farms and a single item of UXO is cleared per day. Under this scenario the daily threshold could be exceeded under most circumstances with the exception for in-combination impacts involving Teesside A. The seasonal overlap is always below the seasonal threshold.

Table 103: Daily and average seasonal footprint in-combination with pile-driving and up to two UXO detonation per day.

Wind farm construction scenario	Pile-driving only	Pile-driving + single UXO clearance per day		Pile-driving + two UXO clearances per day	
	Daily % of area	Daily % of area	Average seasonal footprint (%)	Daily % of area	Average seasonal footprint (%)
Hornsea Project Two					
Single pile-driving	7.3	15.2	3.16	23.0	2.51
Concurrent pile-driving	10.6	18.5	2.03	26.3	2.88
Creyke Beck A					
Single pile-driving	7.9	15.8	3.27	23.6	2.57
Concurrent pile-driving	13.2	21.1	2.31	28.9	3.16
Creyke Beck B					
Single pile-driving	7.9	15.8	3.27	23.6	2.57
Concurrent pile-driving	13.2	21.1	2.31	28.9	3.16
Teesside A					
Single pile-driving	0.1	8.0	1.66	15.8	1.73
Teesside B					
Single-pile-driving	5.6	13.5	2.80	21.3	2.33
Concurrent pile-driving	7.7	15.6	1.70	23.4	2.56

The duration of in-combination impacts for single UXO clearance is 38 days (The maximum reported number of UXO required to be cleared within the SAC to-date plus two days recovery period) and 20 days for two UXO cleared per day.

Single item of UXO detonation impacts on 7.9% of the SAC and two items of UXO clearance impacts on 15.7%. Assuming no overlapping EDR.

The relatively low average seasonal footprint for Teesside A is due to the low number of days that impacts from Teesside A are predicted to occur within the SAC.

Table 104: Daily and average seasonal footprint in-combination with pile-driving at two wind farms and the clearance of a single item of UXO per day.

Wind farm		Daily threshold (Pile-driving)	Daily threshold (Pile-driving + UXO)	Average seasonal footprint
Pile-driving + UXO	Pile-driving only			
Hornsea Two	Creyke Beck A	15.2	23.07	5.4
	Creyke Beck B	15.2	23.07	5.4
	Teesside A	7.4	15.30	3.6
	Teesside B	12.9	20.79	4.8
Creyke Beck A	Hornsea Two	15.2	23.07	5.4
	Creyke Beck B	15.7	23.61	5.5
	Teesside A	7.9	15.84	3.7
	Teesside B	13.4	21.34	5.0
	East Anglia Three	15.7	23.61	5.5
Creyke Beck B	Hornsea Two	15.2	23.07	5.4
	Creyke Beck A	15.7	23.61	5.5
	Teesside A	7.9	15.84	3.7
	Teesside B	13.4	21.34	5.0
	East Anglia Three	15.7	23.61	5.5
Teesside A	Hornsea Two	7.4	15.30	3.6
	East Anglia Three	7.9	15.84	3.7
	Teesside B	5.7	13.57	3.2
	Creyke Beck A	7.9	15.84	3.7
	Creyke Beck B	7.9	15.84	3.7
Teesside B	Hornsea Two	12.9	20.79	4.8
	Teesside A	5.7	13.57	3.2
	Creyke Beck A	13.4	21.34	5.0
	Creyke Beck B	13.4	21.34	5.0
	East Anglia Three	13.4	21.34	5.0

The duration of in-combination impacts for single UXO clearance is 38 days (The maximum reported number of UXO required to be cleared within the SAC to-date plus two days recovery period).

UXO clearance impacts on 7.9% of the SAC per day

The relatively low average seasonal threshold arising from projects in-combination with Teesside A is due to the low number of days that impacts from Teesside A are predicted to occur within the SAC.

In-combination offshore wind farm pile-driving and UXO detonation: Conclusions.

18.191 It is concluded that conditions secured through the Marine Licence or European Protected Species Licence 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. Management of the spatio-temporal impacts will also be managed through the licensing process. 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 SAC.

In-combination assessment: offshore wind farm UXO detonation and seismic surveys

18.192 Within the SAC there is potential for the detonation of UXO associated with the consented wind farms and a seismic survey to occur simultaneously resulting in an in-combination impact.

18.193 Data on the recent historical seismic survey activities within the SAC 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 34.7% 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 10 year period and an average of 3.7 days per year (2.3% of the season) impacted during the winter period (Table 13). Consequently, there is a relatively high likelihood of an in-combination impact occurring 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.

18.194 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 UXO clearance campaign to be undertaken at the same time as a single seismic survey and this has been assessed.

18.195 The results from the noise modelling indicate that the area of potential impact from PTS is within 500 m of the airgun array (Table 52) 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 2017c). 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.

18.196 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 2017c). 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, with 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 permanent auditory 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 from PTS between UXO detonation and seismic surveys.

18.197 There is potential for a level of disturbance to arise with repeated UXO detonations undertaken over a period of time. The area of the SAC within which harbour porpoise may be deterred by UXO clearance is presented in Table 78. Between 7.9% and 15.7% of the 'summer' area may be impacted depending on whether one or two UXO detonations are undertaken per day.

18.198 The area within which there is potential for harbour porpoise to be deterred by a seismic survey is presented in paragraph 18.142 and Figure 66. Based on the threshold approach the maximum daily area impacted by a seismic survey is 19.3% of the 'summer' area.

18.199 Table 105 presents the maximum daily and average seasonal footprints within the SAC in the event that one or two items of UXO are detonated per day at the same time as a seismic survey is being undertaken within the SAC. The daily threshold is exceeded under both scenarios and the average seasonal footprint is not.

Table 105: Daily and average seasonal footprint in-combination with UXO clearance and a seismic survey.

UXO clearance scenario	UXO Detonation	Seismic survey	UXO + Seismic survey	
	Daily % of area	Maximum daily % of area	Daily % of area	Average seasonal footprint (%)
One UXO per day	7.9	19.3	27.2	6.4
Two UXO per day	15.7	19.3	35.0	4.3

The duration of in-combination impacts for single UXO clearance is 38 days (The maximum reported number of UXO required to be cleared within the SAC to-date plus two days recovery period) and 20 days for two UXO cleared per day.

In-combination offshore wind farm UXO detonation and seismic surveys: Conclusions.

18.200 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. There is potential for wider areas of disturbance to arise. The daily thresholds for disturbance may be exceeded based on the maximum possible areas of impact. However, the impacts from both activities are temporary and harbour porpoise will be able to return to the area once either the UXO has been detonated or the seismic survey is completed. Therefore, any displacement or disturbance impacts will be temporary and evidence from surveys have shown that there has been no population level effect from long-term seismic survey activity within the SAC. Management of the spatio-temporal impacts will also be managed through the licensing processes. 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 SAC.

In-combination Assessment: Wind Farm Pile-driving and Commercial Fisheries

18.201 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.

18.202 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.

18.203 Commercial fishing has occurred within the SAC for many years and has had, and will continue to have, direct and indirect impacts on harbour porpoise, their habitat and prey within the SAC. As the conservation status of harbour porpoise in UK waters and the SAC is considered favourable (JNCC 2017a, JNCC and NE 2019) current and historical levels of fishing in the SAC are not considered to have affected the conservation status of the species.

18.204 There are no known plans to suggest that the level of fishing within the SAC 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 SAC will not increase.

In-combination offshore wind farm pile-driving and commercial fisheries: Conclusions.

18.205 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 SAC, 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 SAC.

19 CONCLUSIONS

19.1 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 SAC.

19.2 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.

19.3 The Secretary of State has undertaken a robust assessment using all of the information available to him.

19.4 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. 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, either alone or in-combination with other plans or projects.

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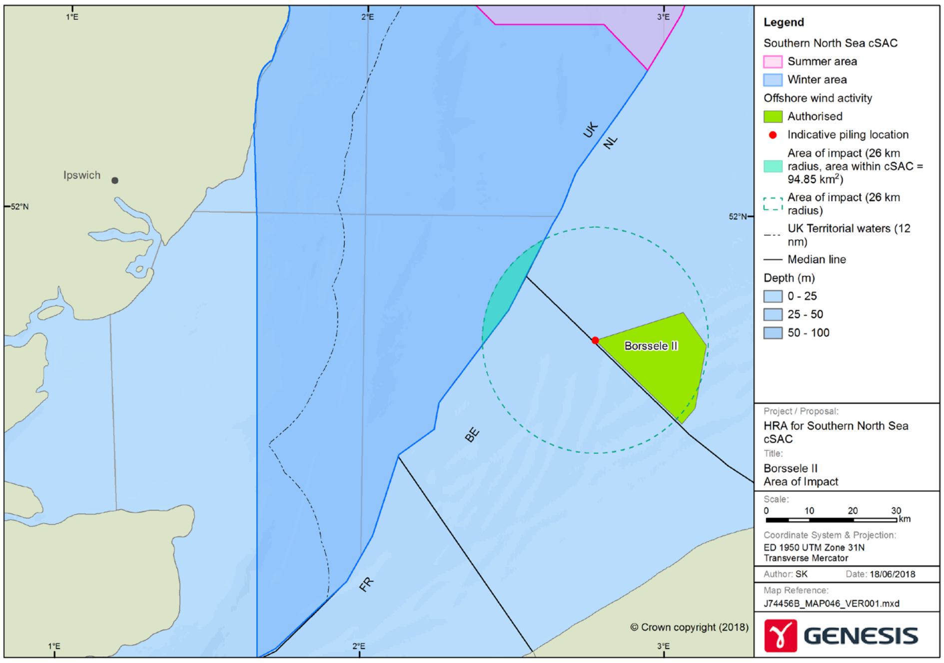
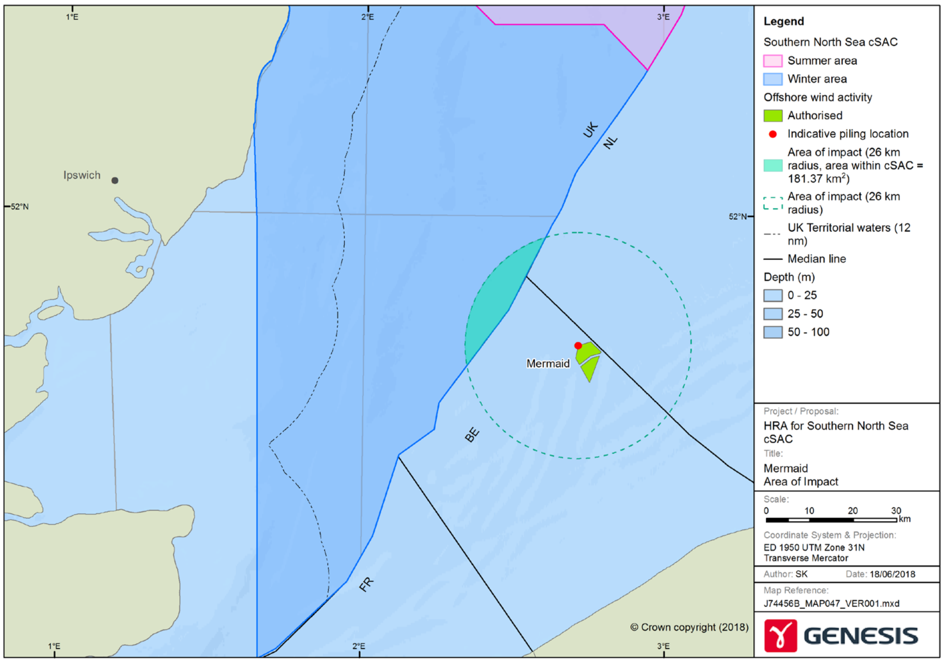
APPENDIX A: EFFECTIVE DETERRENT RANGE FOR BORSSELE II AND MERMAID OFFSHORE WIND FARMS



Appendix A. Figure 1: The maximum area of SAC overlapping within 26 km of the Borssele II offshore wind farm.



Appendix A. Figure 2: The maximum area of SAC overlapping within 26 km of the Mermaid offshore wind farm.

APPENDIX B: EAST ANGLIA THREE NOISE MODELLING RESULTS AND HABITAT IMPACTS.

20.1 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.

20.2 The East Anglia Three offshore wind farm lies wholly within the SAC. 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.

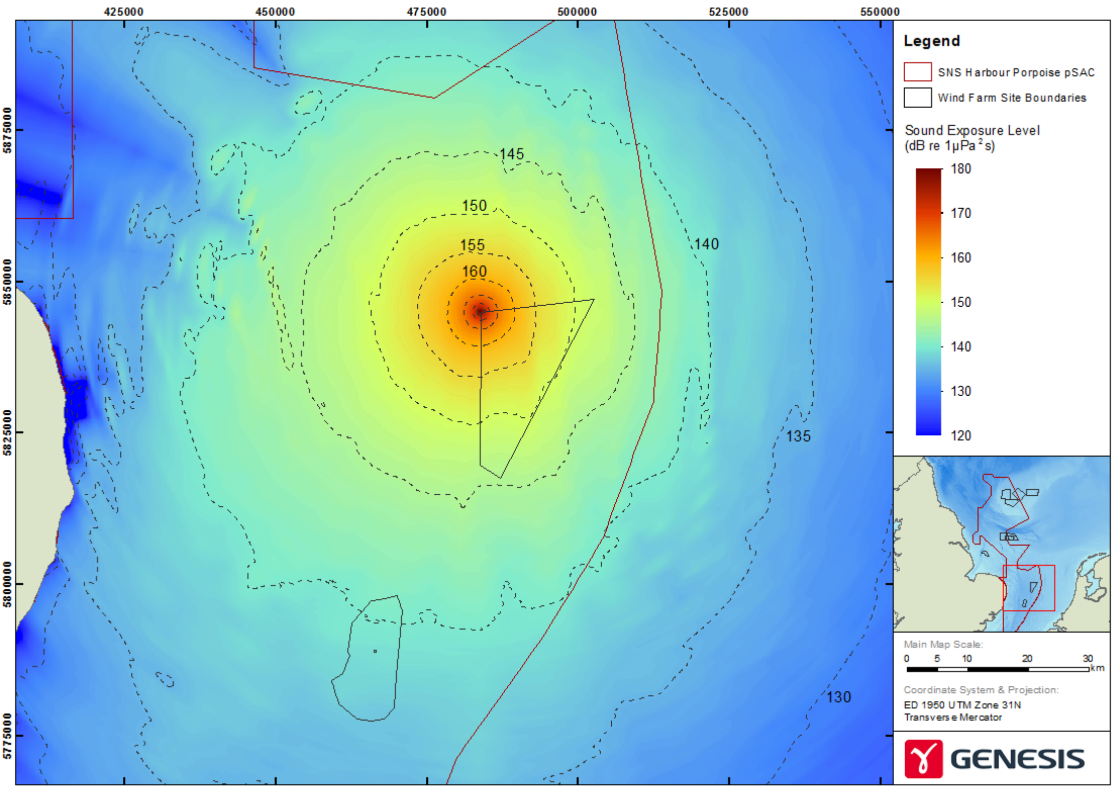
Physical Injury

20.3 Results from the noise 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 49).

20.4 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

20.5 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 SAC 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).

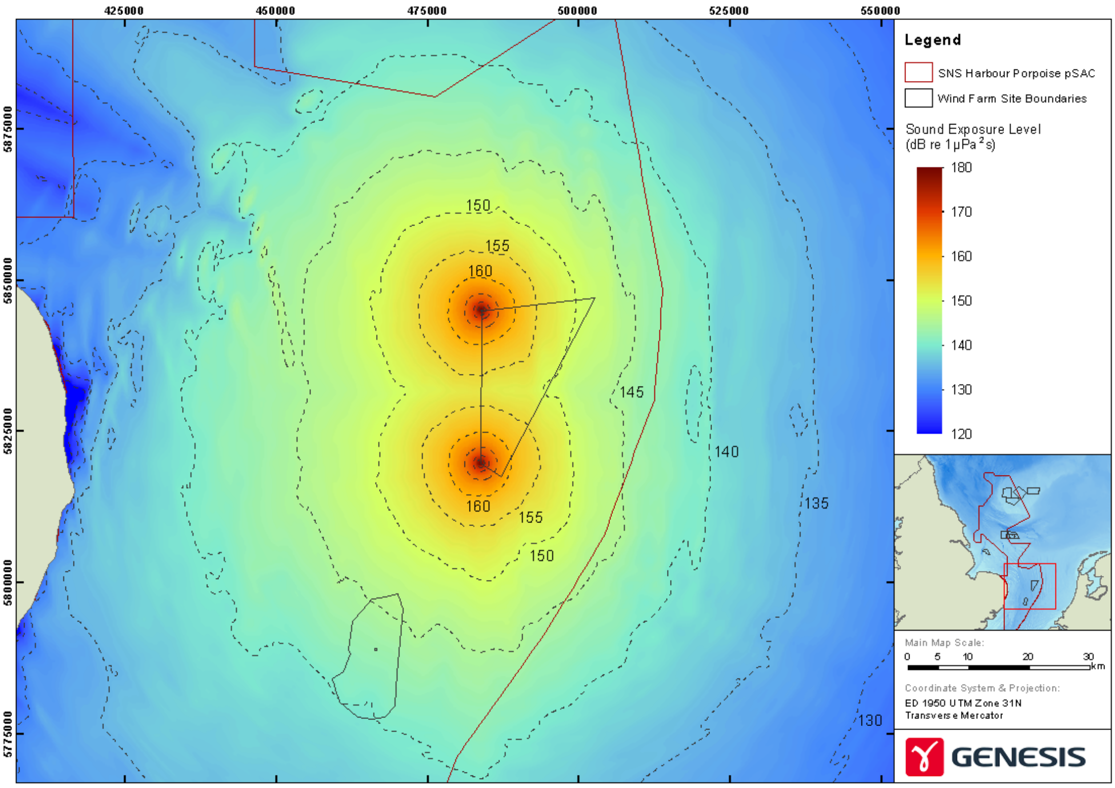
Appendix B. Table 1: Estimated number of harbour porpoise predicted to be displaced by pile-driving from East Anglia Three offshore wind farm in total and within the SAC.

Location	East Anglia Three							
	2,400 kJ				3,000 kJ			
	Area (km^2)	No. of Ind.	Area within SAC (km^2)	No. of Ind. Within SAC	Area (km^2)	No. of Ind.	Area within SAC (km^2)	No. of Ind. Within SAC
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

20.6 In the event concurrent pile-driving is undertaken at two locations within the SAC (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 SAC no more than 394 harbour porpoise are predicted to be impacted from concurrent pile-driving.

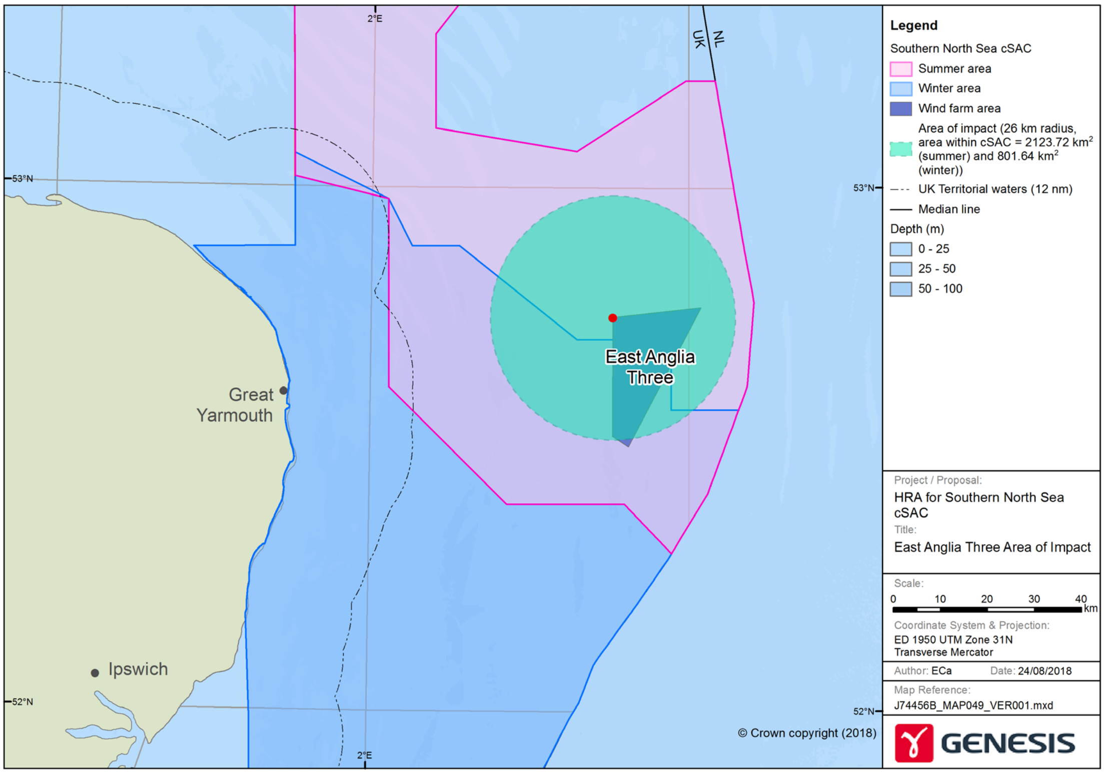


Appendix B. Figure 2: East Anglia Three concurrent pile-driving (unweighted SEL for pile-driving 3,000 kJ).

Effective Deterrent Range

20.7 The East Anglia Three offshore wind farm lies wholly within the SAC and, under the worst-case scenario, the whole of a 26 km EDR will be within the ‘summer’ area of the SAC 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 SAC. Consequently, the assessment based on all turbines impacting the maximum EDR is worst-case.

20.8 As a worst-case, noise from pile-driving at East Anglia Three may cause displacement over 5.7% of the SAC 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 SAC from pile-driving at East Anglia Three.

20.9 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.

20.10 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 footprint during the summer is also 7.5% and during the winter 6.0% (Appendix B. Table 2).

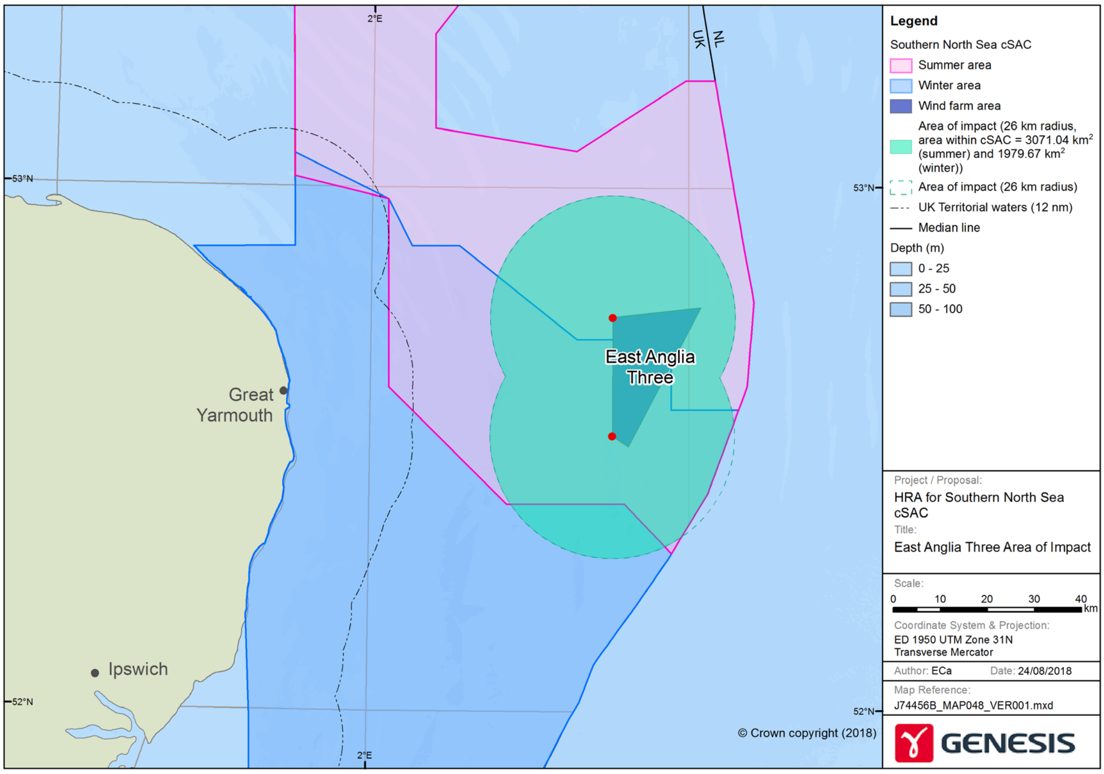
Appendix B. Table 2: Average seasonal footprint for East Anglia Three offshore wind farm within the SAC.

SAC area	Maximum area of SAC impacted (km²)	% of area	No. of turbines	Estimated duration of impact (days)	Average seasonal footprint (%)
Single pile-driving					
'summer'	2,124	7.9	172	174	7.5
'winter'	802	6.3	172	174	6.0
Concurrent pile-driving (worst-case)					
'summer'	3,071	11.4	172	88	5.4
'winter'	1,980	15.6	172	88	7.5

-

20.11 In the event concurrent pile-driving occurs there is potential for a larger area of the SAC to be impacted over a shorter period of time. The maximum area within the SAC 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 km² and in the winter 1,979.7 km².

20.12 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 footprint is 5.4%. Similarly, in the winter area the maximum area impacted is equivalent to 15.6% of the winter area and a average seasonal footprint of 7.5%.



Appendix B. Figure 4: Area of effective deterrence within the Southern North Sea SAC from concurrent pile-driving at East Anglia Three.

Physical impact to the seabed

20.13 East Anglia Three offshore wind farm area lies wholly within the SAC. An estimated 0.44 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 0.77 km^2 of cable protection may be required (Table 89). Consequently, an estimated 0.002% of the SAC habitat could be physically impacted.

20.14 An estimated 15.46 km^2 of seabed may be temporarily impacted by the inter array cables and the export cable route within the SAC. 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.

20.15 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.

20.16 The Triton Knoll offshore wind farm lies wholly outwith the SAC. Offshore construction started in 2020.

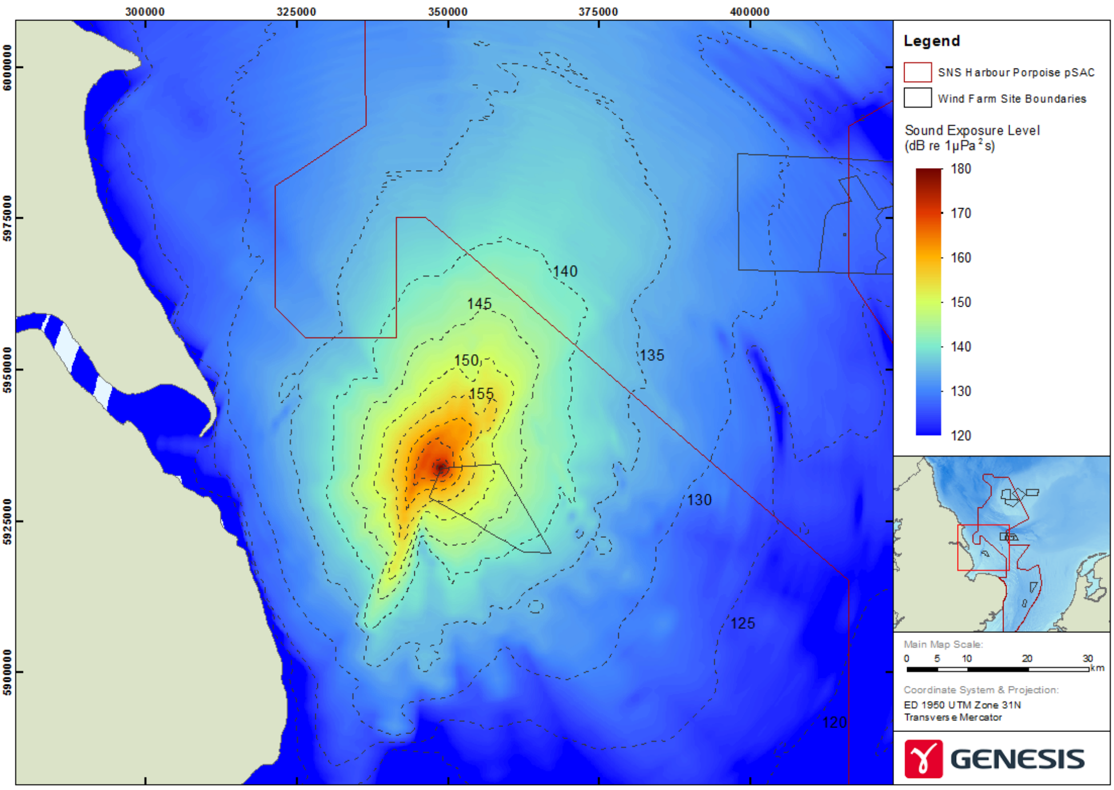
Physical Injury

20.17 Results from the noise 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 45).

20.18 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

20.19 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 SAC 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).

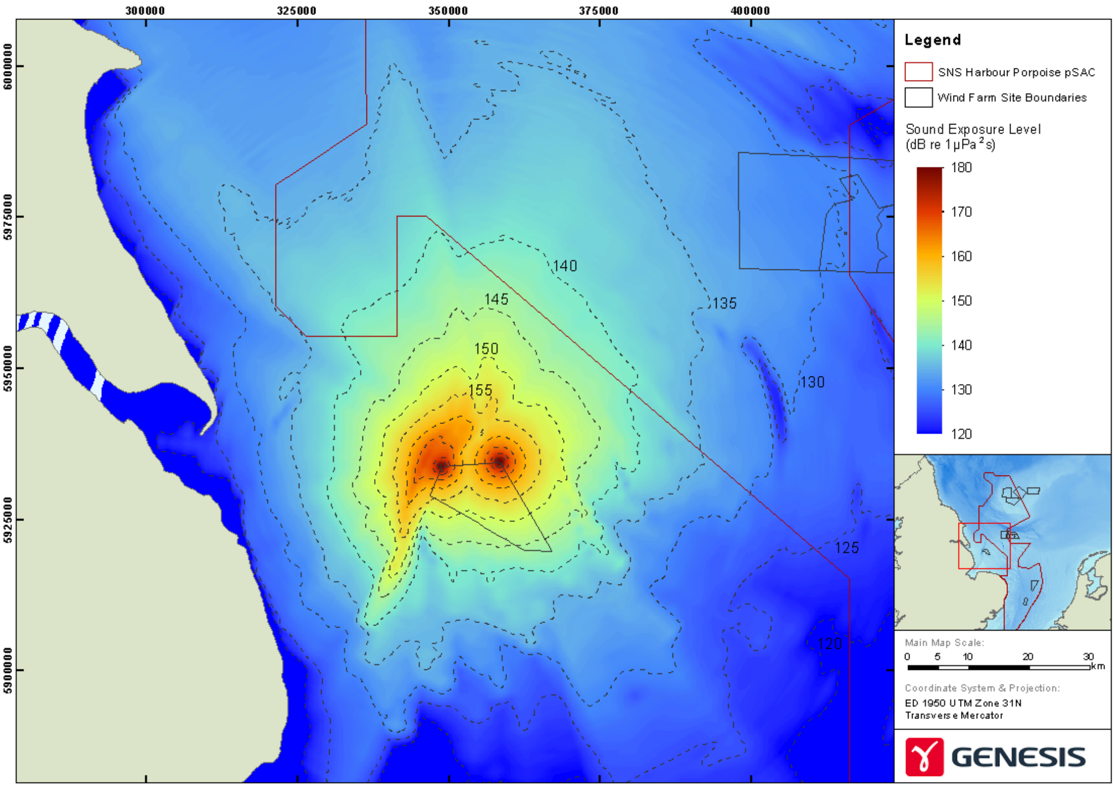
Appendix C. Table 1: Estimated number of harbour porpoise predicted to be displaced by pile-driving from Triton Knoll offshore wind farm in total and within the SAC.

Location	Triton Knoll							
	2,700 kJ				4,000 kJ			
	Area (km^2)	No. of Ind.	Area within SAC (km^2)	No. of Ind. Within SAC	Area (km^2)	No. of Ind.	Area within SAC (km^2)	No. of Ind. Within SAC
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

20.20 In the event concurrent pile-driving is undertaken at two locations within the SAC (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 SAC no harbour porpoise are predicted to be impacted from concurrent pile-driving.



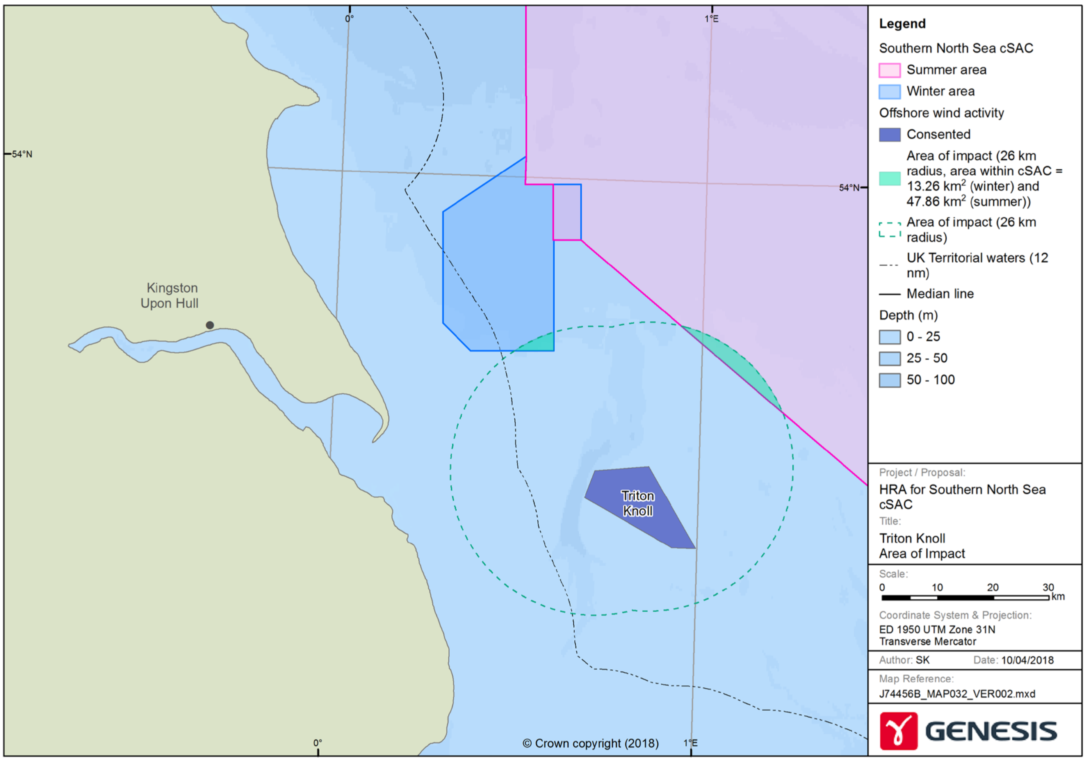
Appendix C. Figure 2: Triton Knoll concurrent pile-driving (unweighted SEL for pile-driving 3,000 kJ).

Effective Deterrent Range

20.21 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 SAC (TKOWFL 2018a).

20.22 The 26 km EDR overlaps a total area of 61.12 km^2 of the SAC, 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.

20.23 As a worst-case, noise from pile-driving may cause displacement over 0.16% of the SAC 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 SAC.



Appendix C. Figure 3: Area of effective deterrence within the Southern North Sea SAC from pile-driving at Triton Knoll offshore wind farm.

20.24 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 SAC 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 2018a).

20.25 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 2018a). 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.

20.26 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 average seasonal footprint 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 average seasonal footprint is 0.02% (Appendix C. Table 2).

20.27 The final project design envelope is smaller than the consented project and the number of wind turbines within the area that could affect the SAC is reduced to no more than 14 turbines (TKOWFL 2018a). 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 average seasonal footprint within the 'summer' area is 0.02% and 0.009% of the 'winter' area (Appendix C. Table 2).

Appendix C. Table 2: Average seasonal footprint for Triton Knoll offshore wind farm within the SAC.

SAC area	Maximum area of SAC impacted (km^2)	% of area	No. of turbines	Estimated duration of impact (days)	Average seasonal footprint (%)
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

20.28 The Triton Knoll offshore wind farm lies outwith the boundaries of the SAC and there will be no physical impacts to the site.

APPENDIX D: WIND FARM PARAMETERS USED FOR HRA.

20.29 This appendix presents the data used regarding the wind farm parameters used to inform the HRA. The data were obtained from information provided in the relevant applications and associated documents.

Appendix D: Table 1: Wind turbine parameters used in HRA.

Wind farm	Number of turbines	Size of trubines (MW)	Foundation type	Pile diameter (m)	Footprint per turbine (m^2)	Area of seabed impacted (Scour Protection)	Total Turbines and Scour (km^2)
Galloper	56	6.3	Monopile	7.5	44	1,700	0.098
Greater Gabbard	140	3.6	Monopile	n/a	33.2	796	0.116
Hornsea One	174	7	Monopile	7	57	1,362	0.247
Hornsea Two	165	8.5	Monopile	n/a	79	1,885	0.324
East Anglia One	102	6	Jacket	35 m x 35 m	1,225	0	0.125
East Anglia Three	172	12	Jacket	43.5 m x 43.5 m	1,893	0	0.326
Creyke Beck A	95	10	Monopile	10	962	3,777	0.450
Creyke Beck B	95	10	Monopile	10	962	3,777	0.450
Teesside A	120	10	Monopile	10	0	0	0.000
Teesside B	100	10	Monopile	10	962	4,713	0.568

Appendix D: Table 2: Wind farm infrastructure parameters used in HRA.

Wind farm	Infrastructure	No. of each installation type	Area per platform including scour (m^2)	Area of seabed impacted by infrastructure (m^2)	Area of seabed impacted by infrastructure (km^2)
Galloper	Offshore substation	1	2,262	2,262	0.002
Greater Gabbard	Offshore substation	2	2,300	4,600	0.005
Hornsea One	HVAC Collector	3	12,723	38,169	0.038
	HVAC Reactor substation	1	6,362	6,362	0.006
	Accommodation	1	6,362	6,362	0.006
Hornsea Two (consented)	HVAC Collector	6	12,723	76,338	0.076
	HVAC Reactor substation	2	6,362	12,724	0.013
	HVDC Converter	2	50,894	101,788	0.102
	Accommodation	2	6,362	12,724	0.013
Hornsea two (planned)	HVAC Collector	3	12,723	38,169	0.038
	HVAC Reactor substation	2	6,362	12,724	0.013
	Accommodation	2	6,362	12,724	0.013
East Anglia One	HVAC Collector	1	29,000	29,000	0.029
	Met mast	1	900	900	0.001
East Anglia Three	HVAC Collector	4	15,855	63,420	0.063
	HVDC Converter	2	15,855	31,710	0.032
	Accommodation	1	15,855	15,855	0.016
	Met mast	2	900	1,800	0.002
Creyke Beck A	HVAC Collector	4	14,367	57,468	0.057
	HVDC Converter	1	21,242	21,242	0.021
	Accommodation	2	21,242	42,484	0.042
	Met Masts	5	4,350	21,750	0.022
Creyke Beck A (planned)	HVDC Converter	1	21,242	21,242	0.021
Creyke Beck B	HVAC Collector	4	14,367	57,468	0.057
	HVDC Converter	1	21,242	21,242	0.021
	Accommodation	2	21,242	42,484	0.042
	Met Mast	5	4,350	21,750	0.022
Creyke Beck B (planned)	HVDC Converter	1	21,242	21,242	0.021
Teesside A	None	0	0	0	0.000
Teesside B	HVAC Collector	4	9,025	36,100	0.036
	HVDC Converter	1	17,400	17,400	0.017
	Accommodation	2	17,400	34,800	0.035
	Met Mast	5	4,657	23,285	0.023

Appendix D: Table 3: Cable parameters used in HRA.

Wind farm	Length of cable in SAC (from GIS)	Export cables			Inter array / Platform cables		
		No. of cable trenches	Area of seabed impacted by cable trenching (km^2)	Cable protection (km^2)	Length of inter array and inter installation cable within SAC (km)	Area of seabed impacted (km^2)	Cable protection (km^2)
Galloper	45	2	0.9	0.05	300	3.0	0.15
Greater Gabbard	42	3	1.26	0.06	173	1.73	0.09
Hornsea One	44.98	4	1.80	0.09	530	5.3	0.27
Hornsea Two	35.86	8	2.87	0.14	975	9.75	0.49
East Anglia One	55.87	2	1.12	0.06	620	6.20	0.31
East Anglia Three	166	4	6.64	0.33	882	8.82	0.44
Creyke Beck A	101.4	2	2.03	0.10	1,270	12.7	0.64
Creyke Beck B	97.18	2	1.94	0.10	1,270	12.7	0.64
Teesside A	76.51	2	1.53	0.08	0	0.0	0
Teesside B	83.36	2	1.67	0.08	1,270	12.7	0.64

As figures for the extent of cable protection required within the SAC were not available within the applications for most projects the area of cable protection required is estimated based on 10% of cable length requiring protection and a 5 m wide corridor of seabed being impacted.

APPENDIX E: WIND FARM PARAMETERS USED FOR NOISE MODELLING.

20.30 This Appendix presents the data used to undertake the noise modelling for the pile-driving at each of the relevant wind farms. The data were obtained from developers during Scoping.

Appendix E. Table 1: Hornsea One parameters used for noise modelling.

HORNSEA ONE								
Longitude	Latitude	Maximum Hammer Energy (kJ)	Pile-driving duration (hrs)	% of maximum hammer energy	Duration (mins)	Hammer Strike Rate (Blows/minute)	Hammer strike rate Interval (s)	Number of pile strikes
1.65108	53.83556	2,300	4.0	20	8	10	6	75
1.69783	53.97237	3,000		40	8	10	6	75
2.19493	53.82152			60	8	15	4	113
				80	8	15	4	113
				100	210	35	2	7,350
1.65108	53.83556	2,300	7.0	20	8	10	6	75
1.69783	53.97237	3,000		40	8	10	6	75
2.19493	53.82152			60	8	15	4	113
				80	8	15	4	113
				100	390	35	2	13,650

Appendix E. Table 2: Hornsea Two parameters used for noise modelling.

HORNSEA TWO								
Longitude	Latitude	Maximum Hammer Energy (kJ)	Pile-driving duration (hrs)	% of maximum hammer energy	Duration (mins)	Hammer Strike Rate (Blows/minute)	Hammer strike rate Interval (s)	Number of pile strikes
1.45143	53.83611	2,300	4.0	20	30	38	2	1,140
1.44033	54.00955	3,000		40	30	38	1.6	1,140
				60	15	32	1.9	480
				80	60	32	1.9	1,920
				100	105	32	1.9	3,360
1.45143	53.83611	2,300	9.0	20	30	38	1.6	1,140
1.44033	54.00955	3,000		40	30	38	1.6	1,140
				60	15	32	1.9	480
				80	60	32	1.9	1,920
				100	405	32	1.9	12,960

Appendix E. Table 3: East Anglia One parameters used for noise modelling.

EAST ANGLIA ONE								
Longitude	Latitude	Maximum Hammer Energy (kJ)	Pile-driving duration (hrs)	% of maximum hammer energy	Duration (mins)	Hammer Strike Rate (Blows/minute)	Hammer strike rate Interval (s)	Number of pile strikes
2.40257	52.20422	900	3.5	20	7.5	10	6	75
2.55935	52.33131	1,200		40	7.5	10	6	75
2.50739	52.24935	1,800		60	7.5	15	4	112
		2,400		80	7.5	15	4	113
				100	180	35	2	6,300
2.40257	52.20422	900	4.0	20	7.5	10	6	75
2.55935	52.33131	1,200		40	7.5	10	6	75
2.50739	52.24935	1,800		60	7.5	15	4	112
		2,400		80	7.5	15	4	113
				100	210	35	2	7,350
2.40257	52.20422	900	5.5	20	7.5	10	6	75
2.55935	52.33131	1,200		40	7.5	10	6	75
2.50739	52.24935	1,800		60	7.5	15	4	112
		2,400		80	7.5	15	4	113
				100	300	35	2	10,500

Appendix E. Table 4: East Anglia Three parameters used for noise modelling.

EAST ANGLIA THREE								
Longitude	Latitude	Maximum Hammer Energy (kJ)	Pile-driving duration (hrs)	% of maximum hammer energy	Duration (mins)	Hammer Strike Rate (Blows/minute)	Hammer strike rate Interval (s)	Number of pile strikes
2.76081	52.7537	1,200	3.5	20	7.5	10	6	75
2.76027	52.52639	1,800		40	7.5	10	6	75
		2,400		60	7.5	15	4	112
		3,000		80	7.5	15	4	113
				100	180	35	2	6,300
2.76081	52.7537	1,200	4.0	20	7.5	10	6	75
2.76027	52.52639	1,800		40	7.5	10	6	75
		2,400		60	7.5	15	4	112
		3,000		80	7.5	15	4	113
				100	210	35	2	7,350
2.76081	52.7537	1,200	5.5	20	7.5	10	6	75
2.76027	52.52639	1,800		40	7.5	10	6	75
		2,400		60	7.5	15	4	112
		3,000		80	7.5	15	4	113
				100	300	35	2	10,500

Appendix E. Table 5: Creyke Beck A and B parameters used for noise modelling.

CREYKE BECK A								
Longitude	Latitude	Maximum Hammer Energy (kJ)	Pile-driving duration (hrs)	% of maximum hammer energy	Duration (mins)	Hammer Strike Rate (Blows/minute)	Hammer strike rate Interval (s)	Number of pile strikes
1.63438	54.74244	3,000	3.5	10	30	20	3	600
1.87960	54.8003			100	180	40	1.5	7,200
1.97839	54.66004							
1.63438	54.74244	3,000	5.5	10	30	20	3	600
1.87960	54.8003			100	300	40	1.5	12,000
1.97839	54.66004							
CREYKE BECK B								
1.47537	54.8717	3,000	3.5	10	30	20	3	600
1.50699	55.07523			100	180	40	1.5	7,200
1.47537	54.8717	3,000	5.5	10	30	20	3	600
1.50699	55.07523			100	300	40	1.5	12,000

Appendix E. Table 6: Teesside A and B parameters used for noise modelling.

TEESSIDE A								
Longitude	Latitude	Maximum Hammer Energy (kJ)	Pile-driving duration (hrs)	% of maximum hammer energy	Duration (mins)	Hammer Strike Rate (Blows/minute)	Hammer strike rate Interval (s)	Number of pile strikes
2.57835	54.96083	1,900	3.5	10	30	20	3	600
2.57669	55.11861	2,300		100	180	40	1.5	7,200
		3,000						
2.57835	54.96083	1,900	5.5	10	30	20	3	600
2.57669	55.11861	2,300		100	300	40	1.5	12,000
		3,000						
TEESSIDE B								
1.95600	55.01183	1,900	3.5	10	30	20	3	600
2.26400	54.8398	2,300		100	180	40	1.5	7,200
		3,000						
1.95600	55.01183	1,900	5.5	10	30	20	3	600
2.26400	54.8398	2,300		100	300	40	1.5	12,000
		3,000						

APPENDIX F: ADDITIONAL IN-COMBINATION PILE-DRIVING SCENARIOS.

20.31 Following comments received from consultation on the draft HRA undertaken in December 2018 additional in-combination scenarios have been calculated using the threshold approach for single pile-driving being undertaken at two wind farms simultaneously (Appendix F - Table 1); concurrent pile-driving is undertaken at one wind farm location Appendix F - Table 2 and concurrent pile-driving at both wind farms Appendix F - Table 3.

20.32 Many of these scenarios will be unlikely to occur due to differences in project construction schedules. However, they are presented here for information and demonstrate that there is potential for either the draft daily or seasonal thresholds to be exceeded. However, they are worst-case scenarios as they presume that all impacts occur over the maximum possible area of the SAC through each day and over the course of a single season. This will not occur but the information on the piling programmes for each wind farm required to refine the assessments are not available.

Appendix F - Table 1: Wind farm pile-driving in-combination daily and seasonal thresholds (single pile-driving at each location) based on planned build-out scenarios.

Wind farms		Area (Km^2)	Daily % of SAC	Estimated duration of impact (days)	Average seasonal footprint (%)
Single pile-driving	Single pile-driving				
Hornsea Two	Creyke Beck A	4,100	15.2	97	8.0
	Creyke Beck B	4,100	15.2	97	8.0
	Teesside A	1,999	7.4	4	0.2
	Teesside B	3,485	12.9	102	7.2
	East Anglia Three	4,099	15.2	167	**13.9**
Creyke Beck A	Hornsea Two	4,100	15.2	97	8.0
	Creyke Beck B	4,248	15.7	97	8.3
	Teesside A	2,147	8.0	4	0.2
	Teesside B	3,314	12.3	97	6.5
	East Anglia Three	4,247	15.7	97	8.3
Creyke Beck B	Hornsea Two	4,100	15.2	97	8.0
	Creyke Beck A	4,248	15.7	97	8.3
	Teesside A	2,147	8.0	4	0.2
	Teesside B	3,633	13.5	97	7.1
	East Anglia Three	4,247	15.7	97	8.3
Teesside A	Hornsea Two	1,999	7.4	4	0.2
	East Anglia Three	2,146	7.9	4	0.2
	Teesside B	1,518	5.6	4	0.1
	Creyke Beck A	2,147	8.0	4	0.2
	Creyke Beck B	2,147	8.0	4	0.2
Teesside B	Hornsea Two	3,485	12.9	102	7.2
	Teesside A	1,518	5.6	4	0.1
	Creyke Beck A	3,314	12.3	97	7.1
	Creyke Beck B	4,248	15.7	97	7,1
	East Anglia Three	3,632	13.5	102	7.5

Numbers highlighted in bold exceed the threshold

Based on the planned build-out scenarios the daily threshold is not exceeded under any of the potential in-combination scenarios. The seasonal threshold could be exceeded in the event that Hornsea two and East Anglia Three offshore wind farm undertake construction within the SAC over the same period.

Appendix F - Table 2: Wind farm pile-driving in-combination daily and seasonal thresholds (concurrent pile-driving at one wind farm and single pile-driving at the other), based on planned build out scenarios.

Wind farms		Area (Km^2)	Daily % of SAC	Estimated duration of impact (days)	Average seasonal footprint (%)
Concurrent pile-driving	Single pile-driving				
Hornsea Two	Creyke Beck A	4,998	18.5	85	8.5
	Creyke Beck B	4,998	18.5	85	8.5
	Teesside A	2,897	10.7	4	0.2
	Teesside B	4,383	16.2	85	7.5
	East Anglia Three	4,997	18.5	85	8.5
Creyke Beck A	Hornsea Two	5,545	**20.5**	50	5.5
	Creyke Beck B	5,693	**21.1**	50	5.7
	Teesside A	3,592	13.3	4	0.3
	Teesside B	5,078	18.8	50	5.1
	East Anglia Three	5,692	**21.1**	50	5.7
Creyke Beck B	Hornsea Two	5,553	**20.5**	50	5.6
	Creyke Beck A	5,700	**21.1**	50	5.7
	Teesside A	3,599	13.3	4	0.3
	Teesside B	5,085	18.8	50	5.1
	East Anglia Three	5,700	**21.1**	50	5.7
Teesside A	Hornsea Two	1,999	7.4	4	0.2
	East Anglia Three	2,146	7.9	4	0.2
	Teesside B	1,532	5.7	4	0.1
	Creyke Beck A	2,147	7.9	4	0.2
	Creyke Beck B	2,147	7.9	4	0.2
Teesside B	Hornsea Two	4,056	15.0	52	4.3
	Teesside A	2,103	7.8	4	0.2
	Creyke Beck A	4,203	15.6	52	4.4
	Creyke Beck B	4,203	15.6	52	4.4
	East Anglia Three	4,203	15.5	52	4.4

Numbers highlighted in bold exceed the threshold

Under the majority of scenarios the daily thresholds will not be exceeded in the event concurrent pile-driving occurs at one of the wind farms in-combination with single pile-driving at another site. The seasonal thresholds will not be exceeded.

Appendix F - Table 3: Wind farm pile-driving in-combination daily and seasonal thresholds (concurrent pile-driving at two wind farms) based on planned build out scenarios.

Wind farms		Area (Km^2)	Daily % of SAC	Estimated duration of impact (days)	Average seasonal footprint (%)
Concurrent pile-driving	Concurrent pile-driving				
Hornsea Two	Creyke Beck A	6,443	**23.8**	50	6.4
	Creyke Beck B	6,451	**23.9**	50	6.5
	Teesside A	2,897	10.7	4	0.2
	Teesside B	4,954	18.3	52	5.2
	East Anglia Three	5,945	**22.0**	85	**10.2**
Creyke Beck A	Hornsea Two	6,443	**23.8**	50	6.4
	Creyke Beck B	7,145	**26.4**	50	7.2
	Teesside A	3,592	13.3	4	0.3
	Teesside B	5,649	**20.9**	50	5.7
	East Anglia Three	6,640	**24.6**	50	6.6
Creyke Beck B	Hornsea Two	6,451	**23.9**	50	6.5
	Creyke Beck A	7,145	**26.4**	50	7.2
	Teesside A	3,599	13.3	4	0.3
	Teesside B	5,656	**20.9**	50	5.7
	East Anglia Three	6,648	**24.6**	50	6.7
Teesside A	Hornsea Two	2,897	10.7	4	0.2
	East Anglia Three	3,094	11.4	4	0.3
	Teesside B	2,103	7.8	4	0.2
	Creyke Beck A	3,592	13.3	4	0.3
	Creyke Beck B	3,599	13.3	4	0.3
Teesside B	Hornsea Two	4,954	18.3	52	5.2
	Teesside A	2,103	7.8	4	0.2
	Creyke Beck A	5,649	**20.9**	50	5.7
	Creyke Beck B	5,656	**20.9**	50	5.7
	East Anglia Three	5,151	19.1	52	5.4

Numbers highlighted in bold exceed the draft SNCB thresholds.

In the event that two wind farms undertake concurrent pile-driving over the same period the daily threshold is likely to be exceeded in the majority of scenarios with the exception of Teesside A. The seasonal threshold could be exceeded under only the one scenario if Hornsea Two is concurrently pile-driving as East Anglia Three.

APPENDIX G: SITE INTEGRITY PLAN MARINE LICENCE CONDITION.

Prior to the commencement of any activities which produce underwater noise authorised under this licence on or after 28 September 2020 a Site Integrity Plan (SIP) must be submitted to, and approved in writing, by the MMO in consultation with the relevant statutory nature conservation body.

The SIP submitted for approval must contain a description of the conservation objectives for the Southern North Sea Special Area of Conservation (SNS SAC) as well as any agreed Management Measures and it must set out the key Statutory Nature Conservation Body (SNCB) Advice on Activities within the SNS SAC which could reasonably be expected to impact upon site integrity as a result of the Project, as are set out in the SNCB guidance published in June 2020: Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs Joint Nature Conservation Committee (JNCC) Report no.654, May 2020 ("the Guidance").

The MMO will approve the SIP where it is satisfied that the Project, either alone or in-combination with other plans or projects, will not exceed the noise thresholds assessed within the Special Area of Conservation Review of Consents Habitats Regulations Assessment ("the HRA"), which are based on the Guidance.

Where the MMO cannot be satisfied that the Project, either alone or in-combination with other plans or projects, will not exceed the thresholds set out in the HRA then the MMO will not approve the SIP.

The SIP must be submitted to the MMO for approval no later than 6 months prior to the start of construction unless otherwise agreed with the MMO.
In spite of anything to the contrary in any licence or consent, the Project must be carried out in accordance with the approved SIP.

The approved SIP may be amended with the prior written approval of the MMO, in consultation with the relevant statutory nature conservation body, where the MMO remains satisfied that the Project, either alone or in-combination with other plans or projects, will not exceed the thresholds set out in the HRA.

This report was prepared by Phil Bloor, Alex Thompson and David Still

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