Vattenfall Wind Power Ltd
Thanet Extension Offshore Wind Farm

Environmental Statement Volume 2
Chapter 7: Marine Mammals

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Vattenfall Wind Power Ltd

Thanet Extension Offshore Wind Farm

Volume 2

Chapter 7: Marine Mammals

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7 MARINE MAMMALS

7.1 Introduction

7.1.1 This chapter of the Environmental Statement (ES) describes the marine mammals present at Thanet Extension Offshore Wind Farm (Thanet Extension) site and assesses the potential impacts on these species that may arise from the construction, Operations & Maintenance (O&M) and decommissioning phases of the offshore elements of Thanet Extension.

7.1.2 This chapter summarises the information contained within three technical reports, which are included as Annexes. Volume 4, Annex 7-1: Marine Mammal Technical Baseline (Document Ref: 6.4.7.1) provides a detailed account of the marine mammal ecology at the Thanet Extension site and surrounding area based on existing literature, regional strategic surveys and site specific surveys. Volume 4, Annex 6-3: Technical Noise Modelling (Document Ref: 6.4.6.3), provides a detailed description of the noise modelling undertaken to inform the assessment of the impact of underwater noise from the construction of Thanet Extension. This chapter provides a detailed description of the quantitative impact analyses carried out to assess the potential magnitude of the impact of underwater noise on marine mammals.

7.2 Statutory and policy context

7.2.1 This section outlines the legislation, policy and guidance that is relevant to the assessment of the potential impacts on marine mammals associated with the construction, O&M and decommissioning of Thanet Extension. In addition, other national, regional and local policies are considered within this assessment where they are judged to be relevant. A summary of relevant legislation and policy most relevant to this assessment is outlined in Table 7.1 and described in the following paragraphs.

7.2.2 All cetaceans in Northern European waters are listed under Annex IV of the EU Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora (the Habitats Directive) as European Protected Species (EPS) of Community Interest and in need of strict protection. The harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncatus*), harbour seal (*Phoca vitulina*) and grey seal (*Halichoerus grypus*) have protection under Annex II as species of Community Interest whose conservation requires the designation of Special Areas of Conservation (SACs).

7.2.3 The Habitats Directive is transposed through the Conservation of Habitats and Species Regulations 2017 (in relation to reserved matters) and the 1994 Regulations. The Conservation (Natural Habitats, &c.) Regulations 2017 implement the Habitats Directives in territorial waters out to 12 nautical miles (nm). The Offshore Marine Conservation (Natural Habitats &c.) Regulations 2017) (the Offshore Marine Regulations) transpose the provisions of the Habitats Directive in offshore waters, beyond 12 nm. The Habitat Regulations provide protection for designated sites, known as Natura 2000 sites which include SACs and Special Protection Areas.

European Protected Species

7.2.4 The Habitats Regulations and the Offshore Marine Regulations make it an offence to injure or disturb any EPS. Any incidence of disturbance would be considered an offence if the disturbance is likely to have an ecologically significant adverse effect on a significant number of animals (note: for the purpose of simplification, in this guidance, references to 'adversely affect(ed)' should be taken to mean 'significantly affect the ability to survive, breed, or rear or nurture their young'). The second element is that the disturbance must be likely to significantly affect the local distribution or abundance of the species. A disturbance offence would be committed if either of these elements occurred.

7.2.5 The Joint Nature Conservation Committee (JNCC) has published guidance which defines deliberate disturbance and the circumstances in which an EPS licence is required (JNCC 2008). This document provides guidance on how to determine what constitutes a 'deliberate disturbance', a 'significant' effect on the ability of the species to survive, breed, or rear/ nurture their young, what is a 'significant' group of animals and what are considered to be 'significant' effects on the distribution and abundance of a species.

7.2.6 What constitutes a significant number of animals depends on the species, its population size, local abundance, its Favourable Conservation Status (FCS), the behaviour of the species and the circumstances in which the disturbance might take place (i.e. time of year, and the spatial and temporal range of the impact). For a significant effect on the local distribution or abundance of a species to occur, disturbance would need to produce more than a transient effect and result in a detrimental change from the natural variability in the spatial-temporal distribution and abundance of the species and its populations within their natural range. This would occur, for example, if a significant group of animals of a population were to become displaced, either from an area which they are known to persistently use or from a fraction of their natural range, for long periods of time; particularly if animals are displaced from essential habitats to less suitable ones.

7.2.7 If the risk of injury or significant disturbance cannot be reduced to negligible levels with mitigation, then an EPS licence is required. In England, offshore EPS licencing is managed by the MMO. Licenses are granted if:

- 1) the reason for the license relates to one of the specified purposes listed in Regulation 53(2)(e) of the Conservation (Natural Habitats) Regulations 2010;
- 2) there is no satisfactory alternative way to reduce injury or disturbance risk (Regulation 53(9)(a)); and
- 3) the action authorised must not be detrimental to the maintenance of the population of the species concerned at a FCS in their natural range (Regulation 53(9)(b)).

Special Areas of Conservation

7.2.8 In order to conserve biodiversity, by maintaining or restoring Annex II species to a FCS, the Habitats Directive requires the designation of SACs for harbour porpoise, bottlenose dolphins, harbour seals and grey seals.

Harbour Porpoise

7.2.9 In 2016 five possible SACs (pSACs) for harbour porpoise were proposed in England, Northern Ireland and Wales, which following consultation were then submitted by the UK Government to the European Commission for formal designation. At this stage these sites are known as candidate SACs (cSACs). One of these five sites, the Southern North Sea (SNS) cSAC is relevant to Thanet Extension. The Southern North Sea cSAC has been divided into two areas based on the apparent seasonality of harbour porpoise density: the northern summer area where harbour porpoise densities are highest in the summer months (April to September inclusive), and the southern winter area where porpoise densities are higher in the winter months (October to March inclusive). The Thanet Extension Offshore Wind Farm overlaps with the 'winter' portion of the cSAC.

7.2.10 Full consideration of the potential impact on the draft conservation objectives of the cSAC will be presented as part of the Report to Inform Appropriate Assessment (RIAA).

Harabour Seal

7.2.11 The closest harbour seal SAC to Thanet Extension is The Wash and North Norfolk Coast SAC where harbour seals are listed as the primary reason for site selection. The Wash and North Norfolk Coast SAC supports the largest breeding colony of harbour seals in the UK. The boundary of The Wash and North Norfolk Coast SAC is approximately 190 km from the boundary of Thanet Extension.

7.2.12 Full consideration of the potential impact on the conservation objectives of the cSAC will be presented as part of the RIAA.

Grey Seals

7.2.13 The closest grey seal SAC to Thanet Extension is the Humber Estuary SAC where grey seals are listed as a qualifying feature but not the primary reason for site selection. The Humber Estuary SAC is approximately 265 km from the boundary of Thanet Extension. To the north of that is the Berwickshire and North Northumberland Coast SAC where grey seals are listed as the primary reason for site selection. The boundary of the Berwickshire and North Northumberland Coast SAC is approximately 500 km from the boundary of Thanet Extension.

7.2.14 Full consideration of the potential impact on the conservation objectives of the cSAC will be presented as part of the RIAA.

Bonn Convention

7.2.15 The Convention on the Conservation of Migratory Species of Wild Animals (the Bonn Convention) requires members to conserve migratory species and their habitats by providing strict protection for endangered migratory species (Appendix I of the Convention), and lists migratory species which would benefit from multilateral Agreements for conservation and management (Appendix II). There are 16 cetacean species listed under Appendix I of the Bonn Convention.

7.2.16 The UK ratified the Convention in 1985. The legal requirement for the strict protection of Appendix I species is provided by the Wildlife and Countryside Act (1981 as amended). The UK has entered into legally binding Agreements under the Convention, including the Agreement on the Conservation of Small Cetaceans in the Baltic, North-East Atlantic, Irish and North Seas (ASCOBANS).

ASCOBANS

7.2.17 ASCOBANS came into force in 1994. The aim of the Agreement is for member parties to cooperate to achieve and maintain a FCS for small cetaceans. ASCOBANS is applied in all UK waters in accordance with existing statutory protection for cetacean species.

Berne Convention

7.2.18 The Convention on the Conservation of European Wildlife and Natural Habitats (the Berne Convention) aims to ensure conservation and protection of wild plant and animal species and their natural habitats (listed in Appendices I and II of the Convention). There are 19 species of cetacean listed under Annex II of the Berne Convention (strictly protected fauna), including harbour porpoise, bottlenose dolphins, common dolphins, Risso's dolphins, white-beaked dolphins and minke whales. All other cetacean species as well as both grey and harbour seals are listed under Annex III of the Berne Convention (protected fauna). The obligations of the Convention are transposed into national law by means of the Wildlife and Countryside Act (1981 as amended).

Wildlife and Countryside Act, 1981

7.2.19 The Wildlife and Countryside Act, 1981 makes it an offence to intentionally (or recklessly) kill, injure or take any wild animal listed on Schedule 5 of the Act, and prohibits interference with places used for shelter or protection, or intentionally disturbing animals occupying such places. All cetacean species are protected within the 12 nm territorial waters under Schedule 5 of the Wildlife and Countryside Act.

Conservation of Seals Act, 1970

7.2.20 Both grey and harbour seal species are protected under the Conservation of Seals Act (1970) which provides closed seasons during which it is an offence to take or kill any seal except under licence.

7.2.21 Following the Phocine Distemper Virus (PDV) outbreak in 1999, an Order was issued under the Conservation of Seals Act providing year round protection to both grey and harbour seals on the east and south-east coast of England, from Berwick to Newhaven (under the Conservation of Seals (England) Order 1999).

National Policy Statements

7.2.22 The Overarching National Policy Statement (NPS) for Energy (‘EN-1’), in-conjunction with the NPS for Renewable Energy Infrastructure (‘EN-3’), provide the primary policy framework within which the project will be considered during the application process for Development Consent.

7.2.23 NPS EN-3 paragraphs 2.6.90 - 2.6.99 provide guidance on the elements to include in the assessment of the effects of impacts on marine mammals. Including: details of likely feeding areas, birthing areas, nursery areas and haul-out sites; known migration or commuting routes; duration of the potentially disturbing activity including cumulative/ in-combination effects with other plans or projects; baseline noise levels; predicted noise levels in relation to mortality, Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS); soft start noise levels according to proposed hammer and pile design; and operational noise. All of these elements will be considered in the baseline environment description and the impact assessment.

Table 7.1: Legislation and policy context

Policy/ legislation	Key provisions	Section where provision addressed
Habitats Directive	All cetaceans in Northern European waters are listed under Annex IV of the EU Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora (the Habitats Directive) as EPS of Community Interest and in need of strict protection. The harbour porpoise, bottlenose dolphin, harbour seal and grey seal have protection under Annex II as species of Community Interest whose conservation requires the designation of SACs. The Habitats Directive was transposed into UK law under the Conservation (Natural Habitats, &c) Regulations 1994. The Conservation of Habitats and Species Regulations 2010 consolidate the various amendments to the 1994 Regulations in respect of England and Wales.	The potential impact to harbour porpoise as an EPS (risk of injury or disturbance) is assessed in Sections 7.11, 7.12, 7.13 and 7.14. The potential effect on marine mammal SACs is fully assessed in a separate RIAA.
ASCOBANS	ASCOBANS came into force in 1994. The aim of the Agreement is for member parties to cooperate to achieve and maintain a FCS for small cetaceans. ASCOBANS is applied in all UK waters in accordance with existing statutory protection for cetacean species.	The effect of all potential impacts on the conservation status the harbour porpoise (the only relevant species of small cetacean) are assessed in Sections 7.11, 7.12, 7.13 and 7.14.

Policy/ legislation	Key provisions	Section where provision addressed
Marine Strategy Framework Directive (MFSD)	The overarching goal of the MSFD is to achieve 'Good Environmental Status' (GES) by 2020 across Europe's marine environment. To this end, Annex I of the Directive identifies 11 high level qualitative descriptors for determining GES. Those descriptors particularly relevant to the marine mammal assessment for Thanet Extension are Descriptors 4) Elements of marine food webs, 6) Sea floor integrity, 8) Contaminants, 11) Energy including underwater noise.	The effects of the project on the abundance and distribution of marine mammals within the Thanet Extension site and wider regional area have been described and considered within the assessment for Thanet Extension alone and in the Cumulative Effects Assessment (CEA) (see sections 7.11 to 7.13 and 7.14, respectively). The effect on marine mammal prey species as a result of impacts on the sea floor have been described and considered within the assessment for Thanet Extension alone and in the CEA. The effects of contaminants on marine mammal receptors were scoped out as agreed by Planning Inspectorate (PINS) in the scoping opinion (PINS, February 2017). The effects of underwater noise from piling of Wind Turbine Generators (WTG) and substation foundations, other construction activities (e.g. cable installation) and vessel noise have been considered within the assessment for Thanet Extension alone (Section 7.11) and in the CEA (see Section 7.14).
NPS EN-3	Paragraph 2.6.92 of EN-3 advises that the assessment of the effects on marine mammals should include details of: likely feeding areas; known birthing areas/ haul-out sites; nursery grounds; known migration or commuting routes; duration of disturbing activity including cumulative/ in-combination effects; baseline noise levels; predicted noise levels in relation to mortality, PTS and TTS; soft-start noise levels; and operational noise.	All of the specified marine mammal ecology details are included in this chapter. This assessment also considers the cumulative impacts of Thanet Extension and other relevant plans or projects (Section 7.14).
NPS EN-3	Paragraph 2.6.93 of EN-3 advises that the Applicant should discuss any proposed piling activities with the relevant body. Where assessment shows that noise from offshore piling may reach noise levels likely to lead to an offence, the Applicant should look at possible alternatives or appropriate mitigation before applying for an EPS licence.	In discussion with the Offshore Ecology Technical Expert Panel, the marine mammal assessment has considered the environmental impact of piling noise over a range of hammer energies and foundation types. The results of this assessment are detailed in paragraphs 7.11.74 to 7.11.112. Mitigation adopted as part of Thanet Extension is outlined in Section 7.10.

7.3 Consultation and scoping

7.3.1 Table 7.2 provides a summary of the key issues raised during the consultation process to date, in relation to marine mammals, together with details of how they have been considered in the production of the PEIR chapter.

7.3.2 Advice on the marine mammal assessment has been sought through the Evidence Plan process, the report of which will be included within the final Thanet Extension application documentation.

7.3.3 As part of the Evidence Plan process for Thanet Extension, an Offshore Ecology Expert Panel was established with representatives from the regulatory bodies, SNCBs and other stakeholders, including the Marine Management organisation (MMO), NE, The Centre for Environment, Fisheries and Aquaculture Science (Cefas), the Environment Agency (EA), Whale and Dolphin Conservation (WDC), Dover District Council (DDC), Agence Francaise pour la Biodiversite Annex (AFB) and the Kent Wildlife Trust (KWT). A number of meetings have been held since February 2017 and the topics under discussion for marine mammals have been: the key issues raised in the Scoping Opinion, the baseline characterisation including the adequacy of data and the scope of the assessment and the methodology to be used in the impact assessment, with discussion primarily focussing on the underwater noise piling impact assessment. A summary of these discussions is outlined in Table 7.2.

Table 7.2: Summary of consultation relating to marine mammals

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
February 2017 PINS Scoping Opinion	The Secretary of State (SoS) expects the Applicant to make efforts to agree with the statutory nature conservation bodies the appropriate approach to the assessment.	Addressed with Expert Panel as part of Evidence Plan process. The approach to the assessment was outlined in a briefing note circulated to the Expert Panel – proposed methodology was approved at the meeting held on 12 July (Offshore Ecology Evidence Panel meeting minutes 12/7/2017)
February 2017 PINS Scoping Opinion	The SoS endorses the comments of NE at Appendix 3 of this Opinion who suggest that Small Cetaceans in the European Atlantic and North Sea III (SCANS III) data should be used (where possible) to inform the assessment.	The use of the SCANS III data to inform the assessment was agreed by the Expert Panel (Offshore Ecology Evidence Panel meeting minutes 12/7/2017). This is detailed in Table 7.13
February 2017 PINS Scoping Opinion	The SNS cSAC should be specifically addressed as part of the Environmental Statement (ES) and cross referred to in considering potential risks to EPS and any need for EPS licences for example, for harbour porpoises and grey seal.	The SNS cSAC is discussed in Sections 7.11, 7.12, 7.13 and 7.14 assess impacts to harbour porpoise as an EPS. The potential effect on marine mammal SACs is fully assessed in a separate RIAA. Thanet Extension will complete an EPS licence application post-consent, if appropriate, once there is more certainty on the project design envelope and updated assessment of impacts and mitigation requirements. Harbour seal and grey seal are not EPS.
February 2017 PINS Scoping Opinion	Seal haul-out sites will be given further consideration in light of the landfall locations. There is also a known presence of harbour seals at a haul-out point on the River Stour Estuary and Goodwin sands.	This was further discussed and agreed with the Expert Panel at Evidence Plan meeting 26 May 2017. Information on these seal haul-outs is presented in paragraphs 7.7.57 to 7.7.66. The potential impact of landfall activities on seal haul-outs is assessed in 7.11.123 to 7.11.134.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
February 2017 PINS Scoping Opinion	The Applicant's attention is drawn to the Defra Marine Noise Registry which could inform the baseline noise environment and may provide a useful reference in preparing the assessment. Similarly, the SoS draws the attention of the Applicant to the comments of NE at Appendix 3 of this Opinion that the National Oceanic and Atmospheric Administration (NOAA) thresholds for injury and disturbance to marine mammals should be considered as part of the assessment of underwater noise impacts.	NOAA thresholds for injury and disturbance to marine mammals have been considered as part of the assessment of underwater noise impacts – see paragraphs 7.11.55-7.11.56.
February 2017 PINS Scoping Opinion	SoS agrees that, on the basis of literature references provided at Paragraphs 366 and 367 of the Scoping Report, operational effects on marine mammals in terms of physical barriers and Electro-Magnetic Fields (EMF) can be scoped out of the Environmental Impact Assessment (EIA).	The effects of EMF and physical barriers during the operational phase have been scoped out of the assessment.
February 2017 PINS Scoping Opinion	The SoS does not agree impacts on marine mammals relating to changes in water quality during construction and decommissioning can be scoped out of the EIA. However, the SoS does agree to scope the impacts out in relation to the operational phase.	Impacts on marine mammals relating to changes in water quality during construction and water quality are assessed in paragraphs 7.11.141 to 7.11.147. Impacts on marine mammals relating to changes in water quality during the operational phase have not been assessed.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
February 2017 PINS Scoping Opinion	SoS does not agree that physical barrier effects during construction can be scoped out and expects that the pertinent aspects of physical barrier effects during construction should be picked up as part of vessel and other construction infrastructure interaction effects.	The full range of potential impacts as a result of construction (including vessel and construction infrastructure interaction effects are assessed in Section 7.11.
February 2017 PINS Scoping Opinion	SoS does not agree that operational impacts of the Proposed Development in terms of underwater noise can be scoped out and echoes the comments of NE in this respect.	Operational noise impacts are assessed in Section 7.12
February 2017 PINS Scoping Opinion	SoS does not agree that operational effects in terms of marine mammal prey impacts can be scoped out of the EIA. Paragraph 379 of the Scoping Report also highlights the need to further consider potential impacts on marine mammals and their prey.	The full range of potential impacts as a result of construction (including vessel and construction infrastructure interaction effects) are assessed in paragraphs 7.12.15 to 7.12.18.
February 2017 PINS Scoping Opinion	The SoS welcomes the proposal for both soft-start piling and the preparation of a Marine Mammal Mitigation Plan (MMMP) in consultation with key stakeholders. The ES should clearly state how these measures are to be secured as part of the Development Consent Order (DCO) and/ or any Deemed Marine License (DML).	Thanet Extension has committed to the development of a marine mammal mitigation protocol (MMMP) post consent to mitigate an injury offence to harbour porpoise from pile-driving noise.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
February 2017 PINS Scoping Opinion	The SoS agrees that the initiation of Unexploded Ordnance (UXO) during all phases of the development can be scoped out of further assessment and detailed geophysical survey and investigations would identify abandoned UXO and this is a health and safety risk that will be carefully mitigated rather than being a specific environmental impact. However, the SoS advises that the mitigation proposed in the event that UXO is found should take into account environmental impacts (e.g. on species and habitats) and that geophysical survey and mitigation is secured by a suitably drafted condition within any DML. The comments of NE at Appendix 3 of the opinion are noted here and the SoS agrees that some assumptions based on experience should be made as to an assessment of noise impacts from UXO on marine mammals.	The risk to marine mammals from UXO will be fully addressed post-consent once detailed geophysical survey data is available. There was no record of any UXO from the Thanet construction so there is no further information at this stage on which to base an assessment. An assessment has been made based on a number of assumptions but the risk to marine mammals from UXO will be refined once detailed geophysical survey data is available. Once the risk has been identified and quantified, post consent, a separate Marine Licence application will be made if necessary and MMMP drafted and agreed with statutory consultees.
February 2017 MMO Response to Scoping	The MMO notes that piling noise is of the greatest concern, although it will also be appropriate to consider other sources of noise such as vessel noise, seabed preparation, rock dumping and cable installation.	The potential impacts of other sources of underwater noise are assessed in paragraphs 7.11.5 to 7.11.13.
February 2017 MMO Response to Scoping	The MMO suggests that operational noise should remain scoped in as insufficient evidence is presented in the scoping document as to why these impacts should be scoped out.	Operational noise is assessed in Section 7.12.
February 2017 MMO Response to Scoping	The potential acoustic impact on marine species can be mitigated by reducing the amount of noise emitted at the source. For pile-driving there are noise reduction technologies available such as big bubble curtains and acoustic barriers that are integrated into the piling rig (e.g. IHC Noise Mitigation System). Such source mitigation should be considered as primary means of reducing the potential acoustic impact of pile-driving operations.	The exact details of the mitigation proposed as part of the MMMP will be determined post-consent, once the final construction details are known and a final assessment of impact carried out. Consideration of the need, feasibility, and cost-effectiveness of all possible mitigation techniques, including noise reduction technologies will be made at that point.
February 2017 Natural England Response to Scoping	SCANS III data should be used if the timeline allows.	Abundance and density estimates for harbour porpoise in the North Sea and in individual survey blocks from the SCANS III surveys have been used in the assessment as detailed in Table 7.13

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
February 2017 Natural England Response to Scoping	NE recommended that detonation of UXO should be included in the EIA. Some assumptions based on experience should be made in terms of the assessment of noise impacts to marine mammals.	See previous comment – there is currently limited data to inform the requirement for UXO clearance on the Thanet Extension site. An assessment has been made based on a number of assumptions but the risk to marine mammals from UXO will be refined once detailed geophysical survey data is available. Once the risk has been identified and quantified, post consent, a separate Marine Licence application will be made if necessary and MMMP drafted and agreed with statutory consultees.
February 2017 Natural England Response to Scoping	NE note that the project lies, in part, in the SNS pSAC for harbour porpoises. It is located in the portion of the pSAC with a higher density of harbour porpoise during the winter season. However, NE is of the opinion that with appropriate mitigation in place, impacts to the winter portion of the site may be reduced to acceptable levels and as such should be thoroughly assessed in the EIA and HRA.	Impacts on the North Sea Harbour porpoise population are addressed in paragraphs 7.11.74 to 7.11.95 . Impacts on the integrity of the cSAC will be specifically assessed in a separate RIAA.
February 2017 Natural England Response to Scoping	NE suggest that the new NOAA thresholds for injury and disturbance to marine mammals are also considered in any assessment of underwater noise impacts to marine mammals. Whilst the SNCBs have yet to fully digest the new thresholds, NE would expect the SNCBs to have formed a judgement on the NOAA thresholds by the time the EIA is undertaken.	The new NOAA thresholds represent an update of the previously widely accepted Southall *et al*. (2007) thresholds for auditory injury in marine mammals as a result of exposure to noise. The thresholds are based on all the available data on noise exposure related hearing damage in marine mammals and has been thoroughly consulted on and peer reviewed. The underwater noise impact assessment detailed below presents results using these thresholds while also presenting the results from the previously standard approaches for comparison. This approach was agreed through the Evidence Plan process (Offshore Ecology Evidence Panel meeting minutes 12/7/2017).
Evidence Plan meeting – Offshore Ecology Expert Panel 12th July 2017	Agreement was reached with Natural England on: • The species to be included in the impact assessment are harbour porpoise, harbour seals and grey seals. • The appropriate Management Units (MUs) and reference populations for the marine mammal impact assessment. • The methodology for the impact assessment.	Agreed through the Evidence Plan process (Offshore Ecology Evidence Panel meeting minutes 12/7/2017).

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
PEIR s42 comments	DDC, KWT and NE requested further details on the impacts on seal haul-out sites at the landfall and in relation to the pile driving.	The landfall impact assessment has been expanded to include the three final landfall options and their potential impact on seal haul-outs in Pegwell Bay (7.11.123 to 7.11.135). The potential for pile driving to affect haul-outs and present a barrier to movement has been presented in 7.11.113, 7.11.114 and Figure 7.24.
PEIR s42 comments	AFB requested additional information be provided on the connectivity with French seal haul-out sites.	Grey seal connectivity with the Wadden Sea and French haul-out sites is outlined in 7.7.82 to 7.7.84.
PEIR s42 comments	AFB requested that the Dieppe-Le Tréport OWF be scoped into the cumulative impact assessment.	Included in Table 7.36, Table 7.38 and in Teir 3 of the cumulative assessment.
PEIR s42 comments	AFB recommended changing the PTS sensitivity score for porpoise and seal species.	Small edits to the definitions of PTS sensitivity have been made and sensitivity scores have been adjusted to ensure consistency with the other current OWF projects.
PEIR s42 comments	AFB highlighted that it is necessary to take into account non-UK SACs/SPAs and their functional areas in an Appropriate Assessment to ensure sustaining Good Environmental Status and the integrity of the Natura 2000 network and its features.	Noted. Chapter doesn't list all screened in non UK SAC sites. Cross reference is made to RIAA.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
PEIR s42 comments	NE requested further details on turbidity information for the greater Thames Estuary to provide confidence in the assumption that all porpoise in the top two meters of data are available for detection.	Information from APEM and from previous turbidity surveys in the area have been presented in sections 7.7.30 to 7.7.34
PEIR s42 comments	NE requested clarification be provided as to why out of 198 sightings, 163 sightings (82%) were of insufficient quality to identify to species level.	The definition of a "definite" porpoise, the large number of submerged animals in images and the strict scoring system has been described in section 7.7.23.
PEIR s42 comments	NE requests that the JCP III data is presented.	JCP III data have also been presented in 7.7.38.
PEIR s42 comments	MMO and NE questioned the use of SELss instantaneous PTS.	This had been included in the PEIR as a comparison to other projects that have used the SELss metric in this way (as had been agreed through EP process). This has now been removed from the ES.
PEIR s42 comments	MMO welcomes the assessment of non-piling noise during the construction phase. MMO welcomes the assessment of operational noise during the construction phase and note this has been assessed as negligible.	Noted.
PEIR s42 comments	MMO highlighted that the potential for UXO clearance has not been assessed within the PEIR; the MMO notes that a full assessment will be carried out and presented in the ES.	UXO clearance has been assessed in section 7.11.19 to 7.11.44 and Table 7.16 to Table 7.20.

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Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
PEIR s42 comments	KWT/NE requested that the impact of increased shipping movement should be considered in more detail against the Heinänen and Skov (2015) report. This is of particular importance for the cumulative assessment, of which existing vessel movements should be taken into account as part of the assessment.	Level of predicted increase in vessel movement has been expressed relative to the Heinanen & Skov (2015) threshold value.
PEIR s42 comments	KWT highlighted that it is important that a site based approach is undertaken to the Southern North Sea cSAC HRA assessment. Since the designation of Southern North Sea cSAC, more monitoring on the impacts of offshore wind farm on harbour porpoise is required.	Noted but no action required for ES chapter.
PEIR s42 comments	KWT noted that only offshore wind farms have been considered in the cumulative impact assessment. To capture the true nature of cumulative impacts, a broad range of activities must be considered such as UXO clearance, geophysical surveys, aggregate extraction and dredging, navigation and shipping operations (presence/numbers and collision risk), commercial fishing, cables and pipelines and coastal developments e.g. ports and harbours.	UXO clearance, Oil and gas seismic surveys and harbour construction projects, are included in the CIA in the ES chapter. Aggregate extraction, dredging, shipping and fishing are included in the baseline as ongoing activities that were ongoing at the time of baseline characterisation - no change in levels of these activities nor construction periods for any other projects overlapped with Thanet Extension (as per cumulative screening).
PEIR s42 comments	KWT would like to begin discussions with Vattenfall on how we can develop our relationship post-consent with regards to the development of marine mammal mitigation. We would like to reflect the best practice we have been developing with other wind farm developers.	Noted.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
PEIR s42 comments	KWT: After reviewing the marine mammal sensitivity assessment criteria used across a range of offshore wind farms, we have concerns regarding inconsistencies in approaches.	Small edits to the definitions of magnitude and sensitivity have been made to ensure consistency with the other current OWF projects.
PEIR s42 comments	KWT highlighted that caution is required when comparing disturbance and displacement population impacts against the iPCoD (Interim Population Consequences of Disturbance).	Amended to highlight the uncertainties, but note the report referred to represents our current best estimate of the effects of piling noise resulting from UK offshore wind farm construction on the North Sea harbour porpoise population.
PEIR s42 comments	KWT & NE noted that for the cumulative assessment the conclusion on harbour porpoise is moderate. Therefore, no matter the size of the contribution of Thanet Extension, mitigation must be considered.	No amount of project specific mitigation at Thanet Extension will be able to reduce the cumulative assessment significance level.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
PEIR s42 comments	KWT do not agree that dolphins should be scoped out of the impact assessment at this stage.	Dolphin species were scoped out of the assessment in agreement with the Evidence Working Group due to the low numbers sighted in the area and therefore the low potential for impact to these species. While not assessed as part of the impact assessment, dolphin species will be included in the mitigation plans in so far as the standard JNCC mitigation measures will apply to all cetacean species. No specific action for the ES chapter.
PEIR s42 comments	NE & MMO would welcome further work to be undertaken to monitoring the operational noise of larger turbines to update the evidence in this area and our understanding of it.	Noted.
PEIR s42 comments	NE questioned why the grey seal MUs to be assessed includes the Scottish east coast MU. Other wind farms further north are not using this MU in their assessments.	Grey seal MU has been amended.
PEIR s42 comments	NE requested clarification on why the dose response curves include behavioural reactions down to 120 dB SELss when other studies have used 145 dB SEL (after Lucke, 2009).	The 145 dB SEL is a fixed threshold (assumes 100% response within and 0 response outwith). Whereas the data behind the dose response curve does suggest very small responses in harbour porpoise out to 120 dB. The response range is between 120-180 because the Subacoustech report stated that noise levels were usually above 120 and a maximum of 135.
PEIR s42 comments	NE asks whether there is a reason for the soft start for the OSS to start at 20 blows per minute, compared to 15 blows per minute for the WTGs?	This difference has been confirmed by the engineers.
PEIR s42 comments	Natural England highlighted areas for minor amendments to clarify text.	Required amendments/ clarifications have been addressed where relevant.
PEIR s42 comments	NE highlighted that sub bottom profiler surveys are voluntary notifications only, therefore there may be more surveys that recorded on the Marine Noise Registry.	Text amended
Evidence Plan meeting – Offshore Ecology Expert Panel 26th January 2018	Agreement was reached with NE and Cefas that the ES should present the NOAA NMFS (2016) PTS thresholds and not the old Southall *et al*. (2007) thresholds.	Southall *et al* metrics have been removed from the ES chapter.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
Evidence Plan meeting – Offshore Ecology Expert Panel 26th January 2018	The seal dose response curves have been re-analysed since the PEIR to create a new dose curve. NE confirmed that the approach used to calculate the revised seal-dose response curve was reasonable.	Revised curve and associated assessment is presented in paragraphs 7.11.67 and paragraphs 7.11.108 to 7.11.114.
Post Evidence Plan meeting – Offshore Ecology Expert Panel 26th January 2018	NE and Cefas confirmed the requirement for TTS to be included in the ES. CEFAS have since provided a position statement regarding TTS (dated 13/02/2018).	The NOAA TTS ranges have been presented for UXOs in paragraphs 7.11.86, 7.11.37, 7.11.39, Table 7.18. Piling impacts on porpoise in paragraphs 7.11.84 to 7.11.86 and Table 7.27 and for piling impacts on seals in paragraphs 7.11.106, 7.11.107 and Table 7.34. SMRU Consulting provided a response to the CEFAS position statement (dated March 2018). CEFAS and Natural England have yet to comment on SMRU Consulting's response.
Post Evidence Plan meeting – Offshore Ecology Expert Panel 26th January 2018	NE and Cefas confirmed that the use of the 171 dB TTS/fleeing threshold for seal disturbance could be removed from the ES given that the PTS, TTS and dose-response curve assessment is included and the uncertainty regarding fixed behavioural thresholds.	The Southall TTS/fleeing threshold for behavioural disturbance for seal species has been removed from the ES and the reasoning outlined in paragraph 7.11.66.

7.4 Scope and methodology

7.4.1 The marine mammal study area varies depending on the species, considering individual species ecology and behaviour. For all species, the area covers the operational Thanet Offshore Wind Farm (TOWF) area, the proposed Thanet Extension array area and export cable corridor route up to the mean high water spring (MHWS) and is extended over an appropriate area considering the scale of movement and population structure for each species. For each species, the area considered in the assessment is largely defined by the appropriate species MU as defined by the UK Inter Agency Marine Mammal Working Group (IAMMWG). For harbour porpoise, the study area includes the whole of the North Sea (IAMMWG 2015). For harbour seals, the study area includes the extent of the South-east England MU (IAMMWG 2013) and for grey seals the study area includes the South-east England, North-east England and Scottish east coast MUs (IAMMWG 2013). The appropriateness of these study areas has been agreed with the Thanet Extension Offshore Ecology Technical Review Panel.

7.4.2 Baseline information was gathered by a combination of desk based study of existing sources and site specific survey data. The existing sources reviewed and the surveys carried out are described in detail in Section 7.7.

7.5 Assessment criteria and assignment of significance

7.5.1 The terms negligible, minor, moderate or major have been used in this chapter, and have been defined in Volume 1, Chapter 3: Approach to EIA (Document Ref: 6.1.3), to describe the significance of predicted impacts. Any impacts that are assessed as moderate or major are deemed to be significant in terms of the EIA Regulations.

7.5.2 The terms short-, medium- or long-term have been used in this chapter, and have been defined in Volume 1, Chapter 3: Approach to EIA (Document Ref: 6.1.3) to describe the duration of the predicted effects. Effects have also been described as either temporary or permanent.

7.5.3 The Sensitivity of the receptors is defined in Table 7.3.

Table 7.3: Sensitivity of marine mammals

Receptor sensitivity	Description/ reason
High	• No ability to adapt behaviour so that survival and reproduction rates are affected. • No tolerance – Effect will cause a change in both reproduction and survival rates. Limited ability for the animal to recover from the effect.
Medium	• Limited ability to adapt behaviour so that survival and reproduction rates may be affected. • Limited tolerance – Effect may cause a change in both reproduction and survival rates. • Some ability for the animal to recover from the effect.
Low	• Ability to adapt behaviour so that survival and reproduction rates are unlikely to be affected. • Some tolerance – Effect unlikely to cause a change in both reproduction and survival rates. Unlikely to cause a change in the population demographics. • Ability for the animal to recover from the effect.
Negligible	• Receptor is able to tolerate the effect without any impact on reproduction and survival rates. • Receptor is able to return to previous behavioural states/ activities almost immediately.

7.5.4 Magnitude of impact is defined in Table 7.4.

Table 7.4: Magnitude of Impact

Magnitude	Definition
High	The impact would affect the behaviour and distribution of sufficient numbers of individuals, with sufficient severity, to affect the conservation status and/ or the long-term viability of the population.
Medium	Temporary changes in behaviour and/ or distribution of individuals at a scale that would result in potential reductions to lifetime reproductive success to some individuals although not enough to affect the population trajectory over a generational scale. Permanent effects on individuals that may influence individual survival but not at a level that would alter population trajectory over a generational scale.
Low	Short-term, temporary changes in behaviour and/ or distribution of a limited number of individuals. Survival and reproductive rates unlikely to be impacted and population trajectory unlikely to be altered.
Negligible	Very short-term and temporary effect in a small number of individuals. Survival and reproductive rates very unlikely to be impacted and therefore the population trajectory is not altered.

7.5.5 Assessment of the significance of potential effects is described in Table 7.5.

Table 7.5: Significance of potential effects

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

Note: Shaded cells are defined as significant effects in EIA terms

7.6 Uncertainty and technical difficulties encountered

7.6.1 There are a number of uncertainties inherent in the marine mammal assessment. This section provides an overview of the main assumptions and limitations of the available data and approach.

7.6.2 The noise impact assessment is based on the temporal and spatial worst-case design scenarios, and are therefore very precautionary. At this stage in the project design there is not sufficient information available to inform a full pile drivability assessment across the site. Therefore, proposed hammer energies and piling durations are absolute maximums. For example, the noise modelling assumes a soft-start involving a ramp-up to full hammer energy (5,000 kJ for monopiles and 2,700 kJ for pin piles). This modelling assumes that after the soft-start, all piling is conducted at maximum hammer energy. The modelling also assumes that piling duration is a maximum of six hours. These are both unlikely assumptions as, in reality, it is likely that only a small proportion of the piling time would require full hammer energy, and it is likely that some piles will not require the full hammer energy at all (depending on the substrate type). Furthermore, piling durations are likely to be much shorter on most foundations, with only a minority, if any, requiring the maximum amount of time. Therefore, the impact ranges and number of animals presented in the noise assessment are highly precautionary and will over-estimate the effect for the overall piling sequence.

7.6.3 There are uncertainties relating to the ability to predict the exposure of animals to underwater noise. These uncertainties relate to a number of factors: the ability to predict the level of noise that animals are exposed to, particularly over long periods of time; the ability to predict the numbers of animals affected, and the ability to predict the individual and ultimately population consequences of exposure to noise. These are explored in further detail in the paragraphs below.

7.6.4 There are uncertainties related to the baseline data used to inform the assessment. The numbers of animals predicted to be impacted by the project is highly dependent on the density data used in the calculation. It is difficult to obtain representative fine scale temporal and spatial data on the density and distribution of marine mammals. For example, the SCANS III density data are not considered to be fine scale at either the temporal or spatial scale as the surveys are conducted in one month over a large area every 11 years; it is therefore not possible to obtain any information on seasonal changes in density and distribution from this dataset. The APEM UK Ltd. (APEM) survey data for harbour porpoise present a better temporal and spatial scale as they are based on data collected during one survey per month over 12 months, however, having only one year of data available means the ability to characterise annual variability in distribution and abundance is constrained. Since marine mammals are highly mobile species, surveys conducted on one day per month are snapshots of the marine mammal density and distribution at the site and it should be recognised that abundance can vary considerably on both spatial and temporal scales. Therefore, while the available density data provide an indication of how many animals could be present in the area during piling, it means that the number of animals estimated to experience impacts are indicative, rather than absolute predictions of the numbers that will experience impact.

7.6.5 It should also be noted that the APEM surveys for harbour porpoise were restricted to the 4 km buffer survey area surrounding the Thanet Extension site. Therefore, where impact ranges extend beyond this survey area (such as the fixed and dose-response behavioural response ranges), when using these data to inform predictions, it is assumed that the densities at these larger ranges were the same as at the Thanet Extension study site.

7.6.6 There are uncertainties relating to the ability to predict the exposure of animals to underwater noise – the propagation of underwater noise is relatively well understood and modelled using standard methods (see Volume 4, Annex 6-3: Subsea Noise Technical Report (Document Ref: 6.4.6.3)). However, there are uncertainties regarding how the pulse characteristics change with range from the source which are not currently accounted for in the assessment. There are also uncertainties regarding the position of receptors in relation to received levels of noise, particularly over time and understanding how position in the water column may affect received level. Noise monitoring is not always carried out at ranges relevant to the ranges predicted for effects on marine mammals so effects at far ranges remain unvalidated in terms of actual received levels. The extent to which ambient noise and other anthropogenic sources of noise may mask signals from the offshore wind farm is not specifically addressed. The dose-response curves for porpoise and seals include behavioural responses at noise levels down to 120 dB SEL_{ss}. A report produced by Subacoustech for VWPL on the baseline background noise levels at the Thanet site reported that background noise levels were usually above 120 dB and maximum background noise levels of 135 dB were recorded (Volume 4, Annex 6-3: Subsea Noise Technical Report (Document Ref: 6.4.6.3)). This means that a behavioural response is likely to be overestimated if the piling noise is not detectable above the background noise levels.

7.6.7 There are also uncertainties relating to the ability to predict the responses of animals to underwater noise. There is limited empirical data available to confidently predict the extent to which animals may experience auditory damage or display responses to noise. It also should be noted that the dose-response curves were not created from data at the Thanet Extension site, and differences in bathymetry, noise propagation and animal motivation at different sites may affect the dose-response curve. There is particularly a lack of information on how observed effects (e.g. short-term displacement around pile-driving activities) manifest themselves in terms of effects on individual fitness, and ultimately population dynamics. For example, it could be assumed that the displacement of an animal from a foraging area could result in increased energy expenditure to move away in addition to decreased foraging opportunities if the animal is displaced to an area that is of lower quality for foraging. This could ultimately result in a reduction in energy gain which has the potential to lead to reductions in survival and fecundity. However, the amount of disturbance and displacement that is required to impact an animal's fitness is unknown. In this assessment it is assumed that displacement away from the area will result in an impact to that individual, over the period over which it is displaced. Animals are expected to recover quickly and will return to the area after piling stops.

7.6.8 Studies at Horns Rev 2 demonstrated that porpoises returned to the area between 1 and 3 days (Brandt *et al*. 2011) and monitoring at the Dan Tysk wind farm as part of the DEPONS project found return times of around 12 hours (cited in van Beest *et al*. 2015). Two studies at Alpha ventus demonstrated using aerial surveys that the return of porpoises was about 18 hours after piling (Dähne *et al*. 2013). The available data for return times for seals suggests much shorter recovery period with harbour seals returning to site around two hours after piling at the Lincs wind farm in the Wash (Russell *et al*. 2016). The worst-case assumption is that displaced animals may experience reduced foraging opportunities which may lead to effects on breeding success in the year they have experienced displacement. This means that for the Thanet Extension construction period, animals that are predicted to experience disturbance may be at risk of these effects for over a maximum of two breeding seasons. However, it is likely that the majority of animals will find suitable alternative foraging areas and impacts on breeding success will be small.

7.6.9 There are no empirical data on the threshold for PTS onset for either porpoise or seals, as to test this would be inhumane. Therefore, PTS onset thresholds are estimated based on extrapolating from TTS onset thresholds. For pulsed noise, such as piling, PTS onset is expected to occur following exposure to a sound that is 15 dB SEL (M-weighted) above the TTS-onset threshold, and it is arbitrarily assumed that the difference between TTS- and PTS-onset is 6 dB Sound Pressure Level (SPL) re 1 µPa (peak) (flat) (Southall *et al*. 2007). The use of PTS-onset thresholds does not mean that all animals will experience PTS. Rather the thresholds are precautionary and indicate the levels below which no PTS will occur. PTS-onset is therefore indicative of the numbers of animals at risk of PTS, rather than those predicted to develop PTS. TTS dose response curves derived from data from Finneran *et al*. (2005) suggest that at the onset thresholds, the probability of an individual developing TTS is around 16%. Furthermore, one would have to extrapolate this curve well beyond the range of measured data (and 11 dB above the TTS-onset level) to reach the point where 50% of the population were predicted to experience TTS.

7.6.10 In addition to this, the consequences of PTS for individuals are unknown. It is likely that the consequences will depend on the frequency band which has experienced PTS, and whether or not this frequency band is in the critical hearing sensitivity band for that species. For example, it is possible that PTS at frequencies outside of the critical hearing frequencies for a species will result in little effect. However, a PTS at frequencies that are required for critical activities such as echolocation, foraging and communication could have more severe impacts on individuals, potentially leading to changes in fitness and vital rates. Most piling noise is relatively low frequency, and therefore the effect of PTS at low frequencies, on a high frequency specialist species, such as the harbour porpoise, may be minimal.

7.6.11 Despite these limitations and uncertainties, this assessment has been carried out according to best practice and using the best available scientific information, adopting precautionary assumptions where there is uncertainty. The information provided is therefore considered to be sufficient to carry out an adequate assessment.

7.7 Existing Environment

7.7.1 Characterisation of the baseline environment to understand the spatial and temporal diversity, abundance and density of marine mammals that could potentially be impacted by Thanet Extension has been produced through a combination of a literature reviews and site-specific surveys. A detailed account of this characterisation can be found in Volume 2, Annex 7-1: Marine Mammal Technical Baseline (Document Ref: 6.4.7.1), which has been submitted to, and approved by, the Offshore Ecology Technical Review Panel (25 July 2017), however the main features are presented below.

7.7.2 The 'Study area' examined to characterise the baseline environment was defined largely by the extent of the MU for each of the populations of interest. Although regional and site specific datasets where available were also examined at the scale of the likely individual site impact footprints.

Data Sources

Thanet Extension Baseline Surveys

7.7.3 Site-specific surveys have been undertaken to characterise the marine mammal baseline environment at the Thanet Extension site. Vattenfall commissioned an initial three months of vessel surveys to collect baseline data on birds and marine mammals. These surveys were conducted between January and March 2016. The survey consisted of nine transects, spaced approximately three km apart.

7.7.4 Following this, it was advised by SNCBs that aerial surveys were conducted instead of vessel surveys (for details of this consultation see Volume 2, Chapter 4: Offshore Ornithology (Document Ref: 6.4.6.4)). Therefore, APEM were contracted to conduct aerial surveys of Thanet Extension and a 4 km buffer around it. The data available from these 24 surveys is between March 2016 and February 2018. The survey methodology was designed for both bird and marine mammal species using a grid-based survey design at 2 cm resolution to achieve a minimum of ten percent coverage. The data collected were high-resolution digital still images using a GPS-linked bespoke flight management system to ensure the tracks were flown with a high degree of accuracy. The aerial surveys were conducted along either 22 or 37 transects with nodes spaced 868 m or 500 m apart, respectively (depending on the camera system used). All photographs from the surveys were processed and where possible, marine mammals were identified to species level. An internal QA of the photographs was undertaken to ensure that no animals were missed and to ensure correct species identification before being sent for external QA by SMRU Consulting. A strict probability score of species identification is assigned to each photograph. An animal in a photograph is only categorised as "definite" if the reviewer is 100% certain of the species identification. However, due to the number of animals that were submerged in the photographs a probability score of definite is difficult, leading to many of the photographs being categorised as "probable" for the species ID. Further details can be found in Volume 4, Annex 4-1: Offshore Ornithology Baseline Technical Report (Document Ref: 6.4.4.1).

TOWF Ornithological Surveys

7.7.5 There have been a series of pre-, during and post-construction surveys at the TOWF, which were conducted primarily to survey birds. Pre-construction surveys for birds were conducted by vessel between November 2004 - October 2005, and by aerial survey between November 2004 - March 2005 (Royal Haskoning 2005). Construction vessel based surveys for birds were conducted between February - March 2009 and again between October 2009 - March 2010 (Royal Haskoning 2010). Post-construction vessel based surveys have been conducted between October 2010 - March 2011, then between October 2011 - March 2012 and again between October 2012 - January 2013 (TOWFL 2012a, b, 2013b). The pre-construction surveys covered the wind farm site plus a one km buffer (total 67 km^2) and a control area to the South (33 km^2). This survey area was extended in 2009 to cover the wind farm site plus a 22 km buffer (total 111 km^2) and a control area to the South (38 km^2).

7.7.6 The surveys were conducted following the JNCC Seabirds at Sea recommendations by experienced ornithologists that had also been trained as Marine Mammal Observers. As such sightings of marine mammals were recorded during the surveys, but no dedicated surveys for marine mammals were conducted.

Other Offshore Wind Farm Projects Survey Data

7.7.7 There are also five Offshore Wind Farms (OWFs) in the vicinity of Thanet Extension that have conducted site specific surveys and presented marine mammal sightings; these are Galloper OWF, Greater Gabbard OWF, Kentish Flats OWF, Kentish Flats Extension OWF and London Array 1 OWF.

SCANS surveys

7.7.8 The SCANS III surveys were completed in July 2016 and comprised of a combination of vessel and aerial surveys. The main objective of these surveys was to estimate small cetacean abundance and density in the North Sea and European Atlantic continental shelf waters. The aerial surveys involved a single aircraft method using circle-backs (or race-track) methods (Hammond *et al*. 2006). Thanet Extension is located in SCANS III survey block L which was surveyed by aircraft covering a total surface area of 31,404 km^2 of which 1,949.3 km was surveyed as the primary search effort on transect (Hammond *et al*. 2017).

7.7.9 While the SCANS surveys provide sightings, density and abundance estimates for marine mammals present in the North Sea and European Atlantic continental shelf waters, the surveys are conducted during one month, every 11 years and so do not provide fine scale temporal or spatial information on species abundance and distribution. These data are however considered to be appropriate for the purposes of undertaking impact assessment and have been requested by stakeholders (PINS Scoping Opinion – see Table 7.2).

Joint Cetacean Protocol (JCP) Phase III Analysis

7.7.10 The JCP Phase III analysis included datasets from 38 sources, totalling over 1.05 million km of survey effort between 1994 and 2010 from a variety of platforms (Paxton *et al*., 2016). The JCP Phase III analysis was conducted to combine these data sources to estimate spatial and temporal patterns of abundance for seven species of cetaceans: harbour porpoise, minke whale, bottlenose dolphin, short-beaked common dolphin, Risso's dolphin, white-beaked dolphin and Atlantic white-sided dolphin (*Lagenorhynchus acutus*). In 2017, JNCC released R code that can be used to extract the cetacean abundance estimates for summer 2007-2010 (average) for a user specified area. This code was originally created by Charles Paxton at CREEM, and was modified by JNCC to include abundance estimates that are scaled to the SCANS III results. The user specified area used to extract these abundance estimates is shown in Figure 7.1 in green and consists of a total area of 13,229.7 km^2.

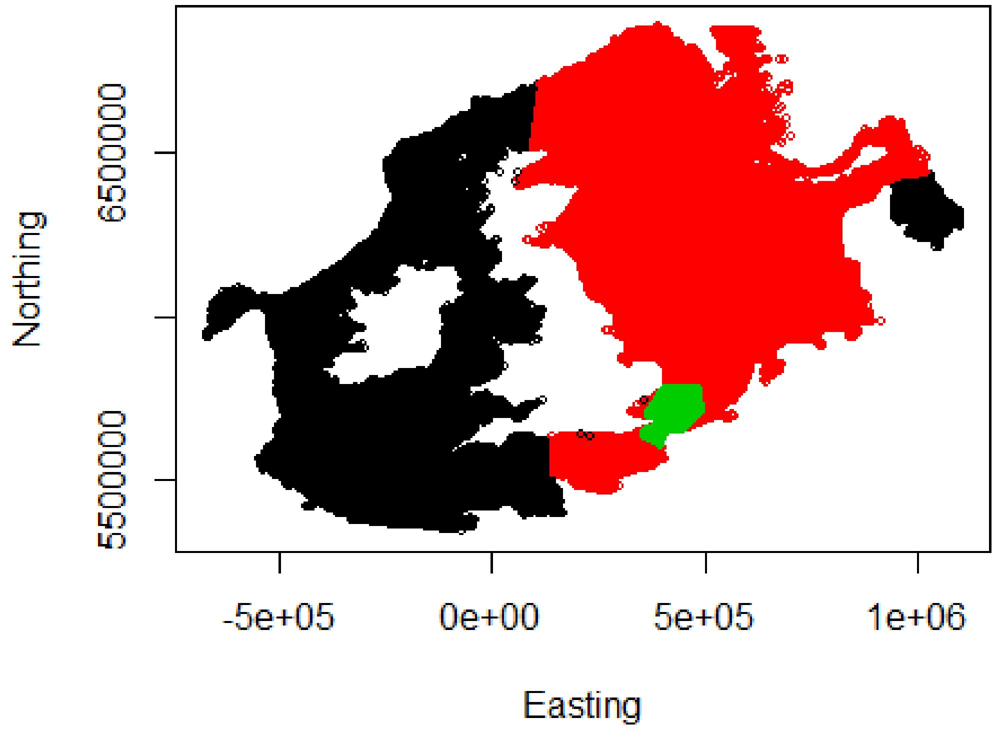

Figure 7.1: The user specified area used to extract cetacean abundance and density estimates from the JCP III R code. The map shows the whole area under consideration (black + red + green), the harbour porpoise North Sea MU (red) and the specific area of interest (green).

JNCC Report 544: Harbour Porpoise Density

7.7.11 Heinänen and Skov (2015) conducted a detailed analysis of 18 years of Joint Cetacean Protocol (JCP) harbour porpoise distribution survey data (1994 - 2011 inclusive) around the UK. The goal of this analysis was to try to identify "discrete and persistent areas" that might be considered important for harbour porpoise with the ultimate goal of determining SACs for the species. Their approach involved constructing predictive models using corrected sightings rates analysed with respect to topographic, hydrodynamic and anthropogenic covariates and then generating predicted distribution maps of density estimates for the waters around the UK. The analysis grouped data into three subsets: 1994 - 1999, 2000 - 2005 and 2006 - 2011 to account for patchy survey effort, and analysed summer (April - September) and winter (October - March) data separately to explore whether distribution patterns were different between seasons. The authors note that "*due to the uneven survey effort over the modelled period, the uncertainty in modelled distributions vary to a large extent*" and that "*model uncertainties are particularly high during winter*". The areas identified as containing persistently high predicted harbour porpoise densities were formed of high confidence data, and were used as part of the assessment conducted by JNCC and NE to designate five cSACs for harbour porpoise in England, Wales and Northern Ireland.

SMRU Seal Haul-out Surveys

7.7.12 The Sea Mammal Research Unit (SMRU) carries out surveys of harbour and grey seals in Scotland and on the east coast of England to contribute to the Natural Environment Research Councils (NERC's) statutory obligation under the Conservation of Seals Act 1970 'to provide the (UK government) with scientific advice on matters related to the management of seal populations'. These SMRU surveys are funded by NERC, Scottish Natural Heritage (SNH) and NE and form the routine, statutory monitoring of seal populations around the UK.

7.7.13 Surveys of harbour seals are carried out during the summer months. The main population surveys are carried out when harbour seals are moulting, during the first three weeks of August. To maximise the numbers of seals on shore and to reduce the effects of environmental variables on counts, surveys are restricted to within two hours either side of afternoon low tides on days with no rain. Grey seals are also counted on all harbour seal surveys, although this data does not necessarily provide a reliable index of population size. The counts obtained represent the number of seals that were on shore at the time of the survey and are an estimate of the minimum size of the population. They do not represent the total size of the local population since a number of seals would have been at sea at the time of the survey. It is noted that these data refer to the numbers of seals found within the surveyed areas only at the time of the survey; numbers and distribution may differ at other times of the year.

7.7.14 Grey seals aggregate in the autumn to breed at traditional colonies. Their distribution during the breeding season is very different to their distribution at other times of the year. SMRU's main surveys of grey seals are designed to estimate the numbers of pups born at the main breeding colonies around and the wider UK. Breeding grey seals are surveyed annually between mid-September and late-November using large-format vertical photography from a fixed-wing aircraft. Over 60 colonies are surveyed annually between three and seven times, at ten to 12 day intervals, through the breeding season. Total pup production for each colony is derived from the series of counts obtained. Approximately 40 additional colonies are surveyed less regularly.

7.7.15 While grey seals are counted during the August harbour seal moult surveys, SMRU does not conduct regular targeted grey seal haul-out surveys in England. A complete survey of grey seal August counts in the Northeast England MU was last conducted in 2008. In addition to this, helicopter surveys with thermal imagers from the Farne Islands to the Scottish boarder were conducted most recently in 2015.

Zoological Society of London Seal Counts

7.7.16 The Zoological Society of London (ZSL) has conducted surveys of both harbour and grey seals in the Greater Thames Estuary annually during the August harbour seal moult since 2013. These data combine three aerial, two boat, and two land-based transects to make a comprehensive count of harbour seals in the region. The counts are conducted within two hours either side of low tide, when the greatest number of seals are likely to be hauled out.

SMRU Seal Telemetry

7.7.17 SMRU has deployed telemetry tags on grey seals and harbour seals in the UK since 1988 and 2001, respectively. Telemetry data are particularly useful as they provide information on seal movement patterns away from their haul-out sites, provide data on the foraging behaviour of seals at sea and demonstrate connectivity between areas.

Seal At-Sea Usage Maps

7.7.18 The seal at-sea usage maps were created in order to predict the at-sea density of seals in order to inform impact assessments and marine spatial planning. The original SMRU seal density maps were produced as a deliverable of Scottish Government Marine Mammal Scientific Support Research Programme (MMSS/001/01) and were published in Jones *et al*. (2015). These have since been revised to include new seal telemetry and haul-out count data and modifications have been made to the modelling process (Russell *et al*. 2017). The analysis uses telemetry data from 270 grey seals and 330 harbour seals tagged in the UK only between 1991 – 2015, and haul-out count data from 1996 - 2015 to produce UK-wide maps of estimated at-sea density with associated uncertainty. The combined at-sea usage and haul-out data were scaled to the population size estimate from 2015.

Harbour Porpoise Baseline

7.7.19 Harbour porpoise are the smallest and most abundant cetacean species in UK waters (Reid *et al*. 2003). They are typically sighted in small groups between one and three individuals. Animals are frequently sighted throughout coastal habitats with studies suggesting they are highly mobile and cover large distances (Nabe-Nielsen *et al*. 2011). Harbour porpoise in the UK are considered to have a FCS (JNCC 2013). Thanet Extension is located within the North Sea MU for harbour porpoise (IAMMWG 2015), which is estimated to have an abundance of 227,298 porpoise (95% CI: 176,360 – 292,948) based on estimates from Hammond *et al*. (2013). The modelling conducted on the SCANS II data have since been revised using a point independence model which is less likely to result in a negatively biased abundance estimate. The revised harbour porpoise abundance for the North Sea using the SCANS III data was 355,000 (CV 0.22) (Hammond *et al*. 2017) which suggests that the IAMMWG (2015) MU abundance data should therefore be considered out of date and not applicable.

7.7.20 Based on the SCANS III data (Hammond *et al*. 2017), the estimated abundance of harbour porpoise in the ICES North Sea Assessment Unit is 345,373 (95% CI: 246,526 – 495,752) with an estimated density of 0.52 porpoise/km^2. The trend analysis conducted on estimates in the North Sea and the Skagerrak/Kattegat/Belt Seas shows no support for changes in harbour porpoise abundance since 1994 (Hammond *et al*. 2017).

7.7.21 The following sections describe the available data on harbour porpoise within the North Sea MU and, specifically, in relation to Thanet Extension, in order to determine their spatial and temporal patterns of abundance and density.

Thanet Extension– Vessel Surveys

7.7.22 During the three months of vessel line transect surveys conducted across the Thanet Extension area a total of 33 harbour porpoise were sighted with a maximum sightings rate of 0.187 porpoise/km in February 2016 (Table 7.6). The sightings were all primarily located on the eastern side of the survey area (Figure 7.3).

Table 7.6: Harbour porpoise counts during the 3 months of vessel surveys covering the Thanet Extension survey area

	TOWF	Thanet Extension	Thanet Extension 4km buffer	Total Count	Distance Surveyed (km)	Sightings Rate (#/km)
Jan-16	3	2	6	**11**	84.4	0.130
Feb-16	1	1	22	**24**	128.5	0.187
Mar-16	0	0	5	**5**	122.8	0.041
Total Count	**4**	**3**	**33**			

Thanet Extension– Aerial surveys

7.7.23 During the 24 months of aerial surveys conducted across the Thanet Extension survey area, a total of 47 harbour porpoise have been identified from the still images collected by APEM (Table 7.7). A further 235 sightings of small cetaceans of insufficient quality to identify to species were also recorded during these surveys (Table 7.7). The reason behind the high number of “unidentified small cetacean” sightings (83% of the cetacean sightings) is due to the strict probability scoring of the photographs for species identification. A large number of the photographs were of submerged animals where the reviewers found it difficult to be 100% confident in their species identification and therefore were unable to categorise the species identification as “definite”. Many of these “unidentified small cetacean” sightings are likely to be “probable” harbour porpoise; therefore, for the purpose of analysis the two datasets (definite harbour porpoise and unidentified small cetacean) were combined and treated as all harbour porpoise. When these two datasets are combined then there is an apparent seasonal pattern to the sightings data, where sightings are highest in late winter/ early spring. Although it is important to note that the effects of variable sighting conditions have not been considered in this analysis and care must be taken not to confound seasonal patterns with differences in detectability. While sightings were highest in February and March 2017, the survey in February 2017 was one of only two surveys to be conducted in sea state one (ripples in water). Harbour porpoise are notoriously difficult to detect during visual surveys due to their small size and inconspicuous surfacing behaviours. The detection probabilities for cryptic species, such as the harbour porpoise, are estimated to decrease with increasing sea state leading to most harbour porpoise visual studies to be restricted to sea conditions up to a maximum of sea state two (small wavelets that do not break). Although most studies of the effect of sea state on harbour porpoise detectability have been carried out in relation to boat-based visual surveys, it is also likely that sea conditions may affect harbour porpoise detectability during aerial surveys, although perhaps to a lesser extent when sighting conditions allow the detection of non-surfacing animals.

7.7.24 There is a spatial pattern in the sightings of combined harbour porpoise and unidentified small cetaceans. The sightings in the summer months were loosely clustered in the north-east part of the survey area, while in the winter months there is a concentration of sightings in the south-eastern part of the survey area (Figure 7.3).

Table 7.7: Combined counts of porpoise and unidentified small cetacean sightings during the 24 months of aerial surveys covering the Thanet Extension survey area

	Porpoise	Unidentified small cetacean	Total	Sea State
Mar-16	0	9	9	**2**
Apr-16	4	9	13	**2**
May-16	0	0	0	**2**
Jun-16	1	2	3	**1-3**
Jul-16	5	0	5	**2**
Aug-16	3	1	4	**1-3**
Sep-16	1	0	1	**2-3**
Oct-16	0	1	1	**3**
Nov-16	0	6	6	**3-4**
Dec-16	2	2	4	**3**
Jan-17	0	4	4	**3**
Feb-17	15	56	71	**1**
Mar-17	11	61	72	**1-4**
Apr-17	1	4	5	**1-2**
May-17	0	1	1	**1**
Jun-17	2	8	10	**2-3**
Jul-17	0	0	0	**3-4**
Aug-17	2	5	7	**2-3**
Sep-17	0	1	1	**2-3**
Oct-17	0	4	4	**3-4**
Nov-17	0	3	3	**2-3**
Dec-17	0	1	1	**3**
Jan-18	0	31	31	
Feb-18	0	26	26	
Total Count	**47**	**235**	**282**	

7.7.25 Porpoise abundance was estimated by dividing the raw counts by the number of images taken to provide a mean number of porpoise per image. This was then multiplied by the total number of images required for the survey area. The resulting abundance and density estimates are provided in Table 7.7.

7.7.26 A report produced by APEM (Voet *et al*. 2017) provides a correction factor to account for availability bias in aerial digital still surveys. This correction factor assumes that the top 2 m of water are visible in the digital still images and uses animal-borne telemetry data from Teilmann *et al*. (2007) and Teilmann *et al*. (2013) on the proportion of time that harbour porpoise spend in the top two meters of the water column. The abundance estimate is then adjusted by this correction factor to account for animals below two meters water depth that are not available for detection at the time of the survey.

7.7.27 The telemetry data presented in Teilmann *et al.* (2007) and Teilmann *et al.* (2013) demonstrated significant variation in the depth distribution of porpoise with season. Therefore, a seasonal correction factor was applied where the mean total time harbour porpoises spent at zero to two meters was 47.2% in winter, 57.1% in spring, 54.7% in summer and 45.5% in autumn. The corrected abundance and density data are presented in Table 7.8. The existing data available in the literature and from site-specific surveys at nearby OWF (as outlined below) show that no species of dolphin is common in the greater Thames Estuary area; therefore, it is unlikely that these unidentified small cetacean sightings are dolphin species. Therefore, the same correction factor was applied to the unidentified small cetacean sightings, densities were calculated based on a survey area of 345 km^2 and combined with the harbour porpoise data (Table 7.8). These data present corrected densities of up to 4.11 combined porpoise/dolphins per km^2 in February 2017 and 3.21 combined porpoise/dolphin per km^2 in March 2017, with much lower densities throughout the rest of the year (mean of 0.61 combined porpoise/dolphins per km^2, Table 7.8 and Figure 7.2.

7.7.28). Interestingly the estimated peak in density in March 2017 is not reflected in the March 2016 data (0.43 in March 2016 and 3.21 in March 2017). Likewise, the estimated peak density in February 2017 (4.11 combined porpoise/dolphins per km2) was not reflected in the February 2018 data where the estimated density was much lower (1.45 combined porpoise/dolphins per km2).

7.7.29 This correction factor is based on the assumption that the digital still images provide full visibility of the top two meters of the water column and so it is assumed that any porpoise present between zero to two meters depth will be available for detection (and equally as important, that porpoises below two meters are undetected). This assumption has not been tested and therefore it is important to note that the effect of variable sighting conditions affecting the depth of the water visible during surveys has not been accounted for in these estimates. It would be expected that the visible depth is likely to vary between surveys. Such variation could have the effect of either underestimating (if the portion visible was less than two meters) or overestimating (if the portion visible is more than two meters) harbour porpoise abundance.

7.7.30 Although APEM did not collect site and survey specific turbidity data, they have stated that “our aerial digital surveys over the Thanet Extension Survey Area did not suffer from heavy loads of turbidity” and that they “have confidence in being able to detect down to two metres below the sea surface” (pers. com. Sean Sweeney, APEM Ltd.).

7.7.31 While site and survey specific measures of visibility in the water column are not available, alternative sources of data on turbidity and sediment concentration data can allow us to make an estimate as to whether or not this assumption may be valid at this site. A common method used to estimate visibility in the water column is to use a Secchi disk which is a black and white disk that is lowered into the water; the depth at which the disc ceases to be visible from the surface is called the “Secchi depth”. For example, Capuzzo *et al*. (2015) have presented the results of Secchi depth measurements taken in the Southern and Central North Sea during the 20th century. Their results showed that for the East Anglia Plume area (within which the Thanet Extension is located), the mean Secchi depth measurements post 1950 were 5.52 m in the summer (n=45, SD=1.06) and 1.1 m in the spring/autumn (n=43, SD=0.82). While the exact depths are not listed for all 88 measurements, the mean of 5.52 and 1.1 is 3.31 m. If these measurements are representative of the visibility at the Thanet Extension site, then the correction factor assuming a 2 m visible depth may be underestimating the visible depth in the summer (and therefore overestimating the number of porpoise) and overestimating the visible depth in the spring/autumn (and therefore underestimating the number of porpoise). If the average of 3.31 m is true then the 2 m correction factor will underestimate the visible depth and therefore overestimate the number of porpoise predicted to be present, which makes the resulting estimate precautionary.

7.7.32 In another study, Aarup (2002) presents Secchi depth measurements from across the North Sea and the Baltic Sea. The raw data were available from this study and there were a total of 76 Secchi depth readings from within a 10 km buffer around the Thanet Extension study area. These data are from 1994 and 1997 and for the months May – November. The Secchi depth readings varied considerably from 0 to 7 m, with an average across all 76 measurements of 2.3 m. While these data are not recent, they are within the Thanet Extension area and show that, while there is a high level of variability in the data, the average of 2.3 m visible depth would support the assumption that on average a 2 m depth visibility is possible at this site and that the correction factor applied to the data is suitable.

7.7.33 As detailed in Volume 2 Chapter 2: Marine Geology, Oceanography and Physical Processes (Document Ref: 6.2.2), monthly averaged satellite imagery of surface suspended particulate matter within the Thanet Extension array area is generally >10 mg/l, with higher concentrations in the winter months (30 – 80 mg/l) occasionally reaching up to 100 mg/l. By applying a general rule of thumb of <100 mg/l SPM = Kd 0.97 (pers. com. Mike Best, Environment Agency) and S=1.4/Kd where S= Secchi depth and Kd= light attenuation (Kirk 1994) then the levels of suspended particulate matter within the Thanet Extension array area of <100 mg/l would result in an estimated Secchi depth visibility of 1.44 m. However, it should be noted that this is a very rough and ready rule of thumb that surface reflection can result in significant errors when measuring Secchi depths and that this rule of thumb estimate is less reliable for more turbid transitional water bodies. If it is assumed that the average visible depth during the surveys was 1.5 m and that animals distribute themselves uniformly between 0 and 2 m depth, then the correction factor can be adjusted by multiplying it by 0.75. This results in an average corrected density of 0.81 combined porpoise/dolphins per km^2 across the 24 survey months.

7.7.34 Given that no survey and site specific data are available, the assumption of visibility to 2 m depth has been taken forward based on APEMs confidence in their ability to see animals to this depth at this site. Given the effects of variable detectability (both from variable sea state and from visibility into the water column), there remains some uncertainty in the extent of these remaining potential biases, and therefore in the extent that these estimates can be considered robust absolute density estimates. However, this approach represents a step forward in correcting survey biases in marine mammal aerial survey data and correlates closely with estimated densities from other methods. The mean density estimated from the Thanet Extension aerial surveys (0.610 combined porpoise/dolphins per km^2) is fractionally higher than the SCANS III Block L estimate of 0.607 porpoise/km^2, however, the SCANS III density estimates have 95% confidence intervals while the APEM data do not. Therefore, the resulting mean site specific survey estimates (plus minimum and maximum density) will be used in the marine mammal impact assessment alongside mean density estimates from the SCANS III survey (plus 95% Confidence Intervals). This has been agreed with the Offshore Ecology Technical Expert Panel.

Table 7.8: Abundance and density estimates for the sightings of "harbour porpoise" combined with the additional "dolphin/porpoise" sightings before and after correcting for availability bias with the correction factor (Voet *et al*. 2017)

	Abundance	Density (#/km^2)	Correction Factor	Corrected Abundance	Corrected Density (#/km^2)	Sea State
	Combined Porpoise and Dolphin/Porpoise					
Mar-16	85	0.25	0.571	149	0.43	2
Apr-16	123	0.36	0.571	215	0.62	2
May-16	0	0.00	0.571	0	0.00	2
Jun-16	25	0.07	0.547	46	0.13	1-3
Jul-16	43	0.12	0.547	79	0.23	2
Aug-16	33	0.10	0.547	60	0.17	1-3
Sep-16	9	0.03	0.455	20	0.06	2-3
Oct-16	8	0.02	0.455	18	0.05	3
Nov-16	53	0.15	0.455	116	0.34	3-4
Dec-16	36	0.10	0.472	76	0.22	3
Jan-17	34	0.10	0.472	72	0.21	3
Feb-17	671	1.94	0.472	1422	4.11	1
Mar-17	633	1.83	0.571	1109	3.21	1-4
Apr-17	47	0.14	0.571	82	0.24	1-2
May-17	9	0.03	0.571	16	0.05	1
Jun-17	94	0.27	0.547	172	0.50	2-3
Jul-17	0	0.00	0.547	0	0.00	3-4
Aug-17	66	0.19	0.547	121	0.35	2-3
Sep-17	9	0.03	0.455	20	0.06	2-3
Oct-17	38	0.11	0.455	84	0.24	3-4
Nov-17	28	0.08	0.455	62	0.18	2-3
Dec-17	9	0.03	0.472	19	0.06	3
Jan-18	285	0.82	0.472	604	1.75	
Feb-18	236	0.68	0.472	500	1.45	
			Min	**0**	**0.00**	
			Mean	**211**	**0.61**	
			Max	**1,422**	**4.11**	

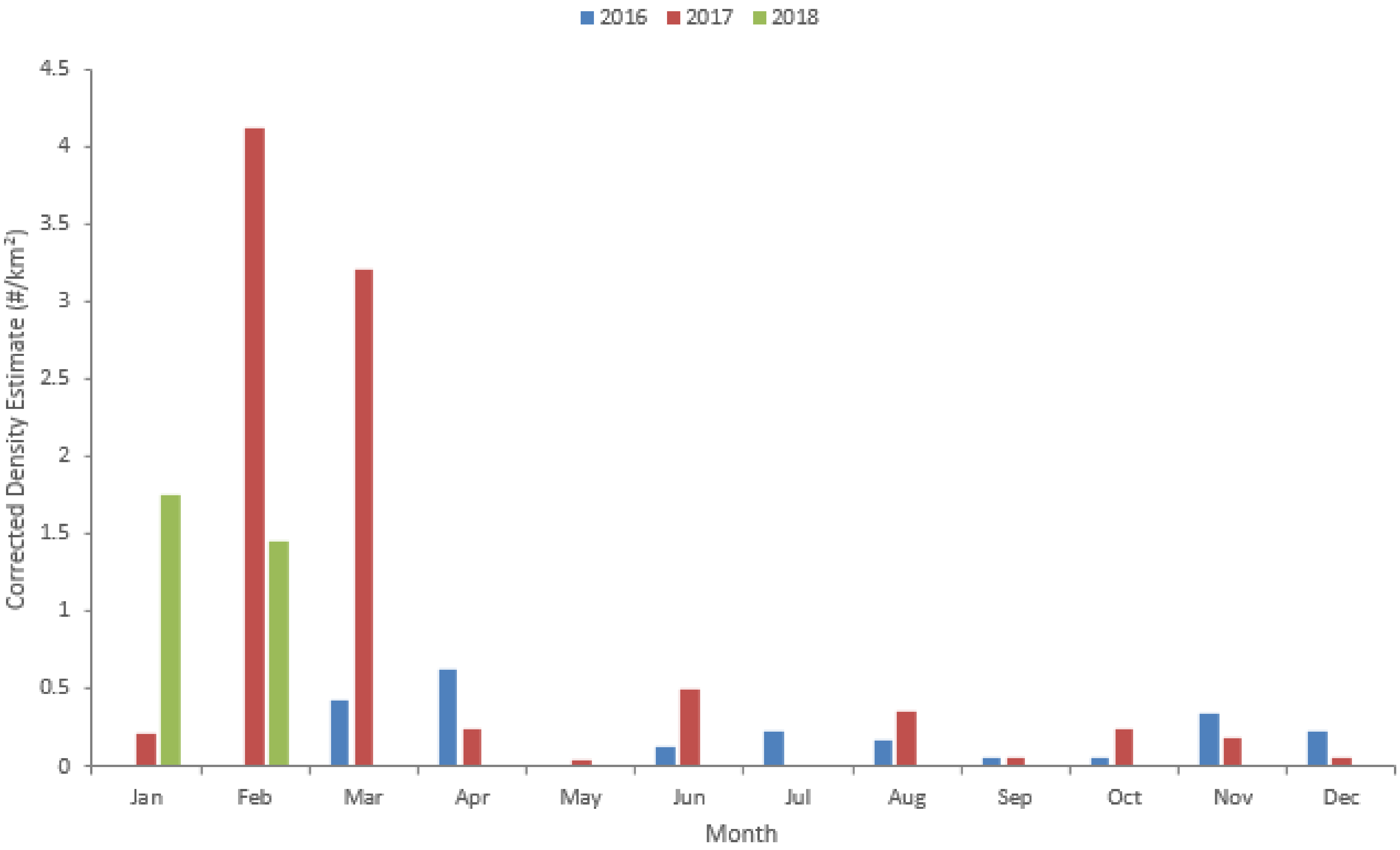

Figure 7.2: Corrected density estimates for combined "harbour porpoise" and "dolphin/porpoise" by survey month between March 2016 and February 2018.

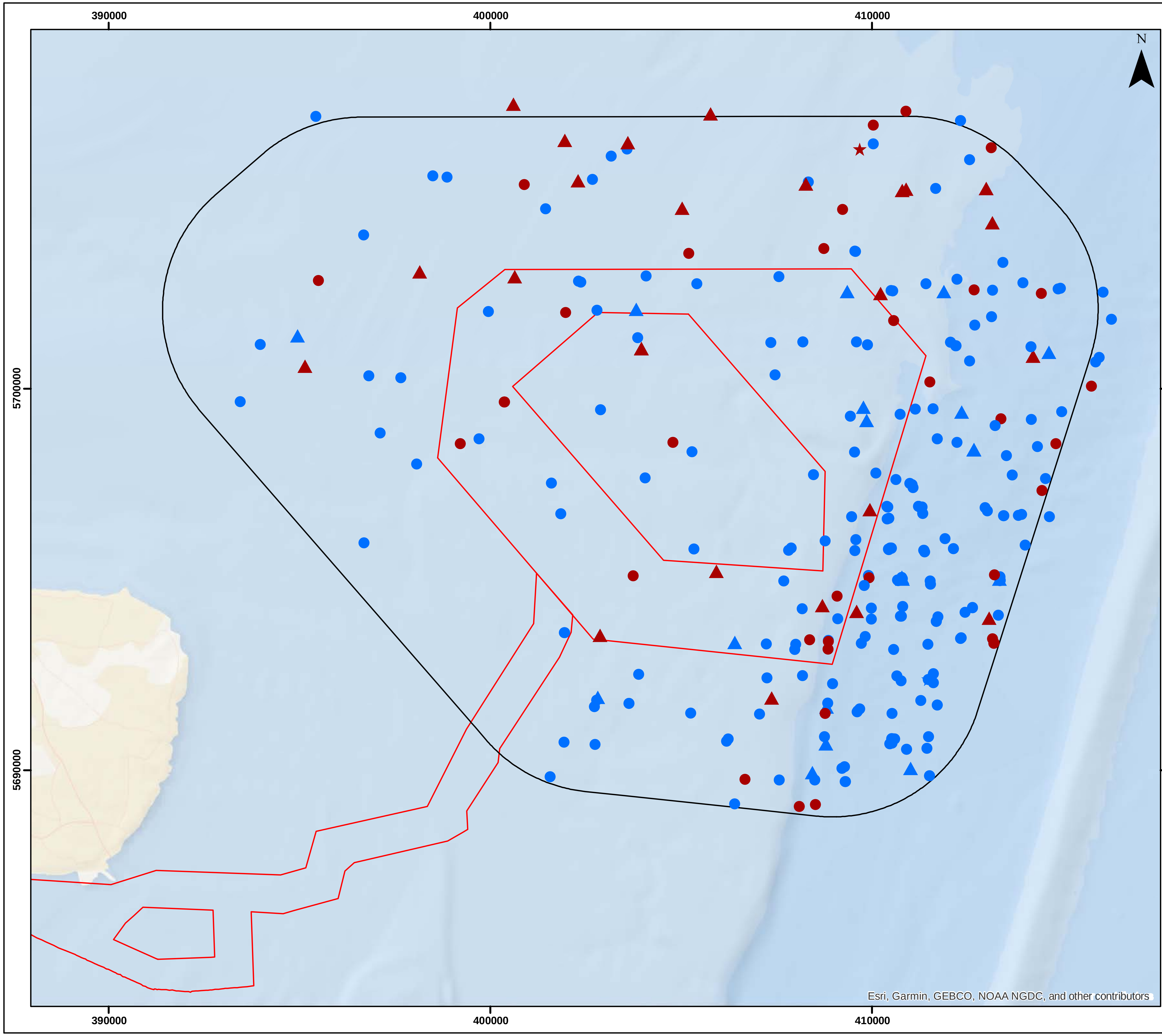

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Figure 7.3

Marine Mammal Sightings During 24 Months APEM Aerial Surveys

Legend

- Offshore Red Line Boundary
- Environmental Surveys

Summer Sightings

- Harbour Porpoise
- Dolphin/Porpoise
- Dolphin Species

Winter Sightings

- Harbour Porpoise
- Dolphin/Porpoise
- Dolphin Species

Datum: ETRS 1989
Projection: UTM31N

1:100,000 — 0, 1, 2 km — 0, 0.55, 1.1 nm

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Figure 7.3

TOWF Ornithological Surveys

7.7.35 Harbour porpoise were the main cetacean species sighted during the pre-, during and post-construction TOWF ornithological vessel based surveys. The survey data collected were analysed to determine if there was evidence of a change in harbour porpoise numbers during the construction phase. The results of this analysis identified a statistically significant decline in porpoise incidental sightings within the TOWF site during the construction phase compared to the pre-construction baseline, with no statistical evidence of a decline outside of the TOWF site or beyond the end of the construction period (TOWFL 2013a). The fact that porpoises were sighted during construction surveys indicates that they were not completely excluded during construction. These data also indicate that the construction of TOWF only resulted in small-scale and temporary disturbance of harbour porpoises. However, it should be noted that these are only incidental sightings and not dedicated marine mammal surveys. Therefore, any quantification of this effect relies on a constant detection probability over time for marine mammals – an assumption that remains untested in these analyses.

7.7.36 The post-construction monitoring data show that harbour porpoise were incidentally sighted in all surveyed months (October - March) across all post-construction survey years, with increasing numbers of incidental sightings between January - March compared to October - December. The locations of the incidental sightings made during the post-construction surveys between 2010 - 2013 show a change in sightings locations from being primarily located in the south-east corner of the TOWF site and buffer in 2010 - 2011 to the sightings being located in the north and eastern areas of the TOWF site and buffer in 2012 - 2013. The temporal pattern is similar to that seen in the aerial surveys, with a higher number of sightings in the winter months. However, as highlighted above, since potential differences in detection probability are not accounted for, similar caveats remain.

SCANS Surveys

7.7.37 The aerial survey data collected in survey block L for SCANS III produced an estimated harbour porpoise abundance of 19,064 (95% CI: 6,933 – 65,703) and a density of 0.607 porpoise/km^2. These SCANS III density values are taken forward for Thanet Extension impact assessment as they are: a) the most recent of the SCANS survey density estimates and are therefore most likely to represent the current porpoise densities in the area; and b) the density is estimated for a smaller survey block than in previous SCANS surveys which makes it more applicable to the Thanet Extension area than previous survey blocks which estimated the density over a much wider area. However, it should be noted that the SCANS III data are for a single summer time point estimate and may not be representative of harbour porpoise abundance and density at other times of the year. Therefore, the SCANS III data will be presented in the impact assessment alongside the results of the APEM Thanet Extension site specific survey to provide a range of estimates.

Joint Cetacean Protocol (JCP) Phase III Analysis

7.7.38 The R code provided by JNCC was used to determine the number of harbour porpoise within the area defined in Figure 7.1. This resulted in a harbour porpoise abundance estimate for the area averaged for summer 2007-2010 of 15,355 (95% CI 8,679 – 22,699) which equates to a density estimate of 1.16 porpoise/km^2 (95% CI 0.66 – 1.72). This is higher than the SCANS III summer 2016 density estimate for block L, however, it is within the range of density estimates obtained from the Thanet Extension surveys where densities ranged between 0.00 and 4.11 porpoise/km^2.

JNCC Report 544: Harbour Porpoise Density

7.7.39 The Heinänen and Skov (2015) analysis predicted higher harbour porpoise densities in the winter than the summer, in the southern part of the North Sea MU, with predicted density estimates for the Thanet Extension area of up to >3 porpoise/km^2 in the winter of 1997 and up to 3 porpoise/km^2 in the winter of 2009 (Figure 7.4); though it is important to note that the authors stated that "*model uncertainties are particularly high during winter*". It is also worth highlighting that the analysis presented in Heinänen and Skov (2015) relies on extensive extrapolation of survey data over space and time. Any such extrapolation is sensitive to the covariates used in models, as opposed to predictions within the support of the data. Subjective decisions in the retention of covariates in Heinänen and Skov (2015) calls into question the validity of such extrapolation. The survey effort on which the analysis is based was particularly patchy in time in the southern North Sea which may limit the degree of confidence that can be placed in the model predictions. Despite the noted uncertainties in the data, the areas that were subsequently identified as cSACs for harbour porpoise had relatively high survey effort associated with them. It is also important to note that harbour porpoise density varies significantly in space and time as evidenced by the site specific densities obtained from the Thanet Extension surveys where densities ranged between 0.00 and 4.11 porpoise/km^2.

7.7.40 Thanet Extension is located within the persistent high-density area identified and selected in the southern North Sea MU during the winter; which has since been put forward as a cSAC as a result of these data and the analyses presented in Heinänen and Skov (2015).

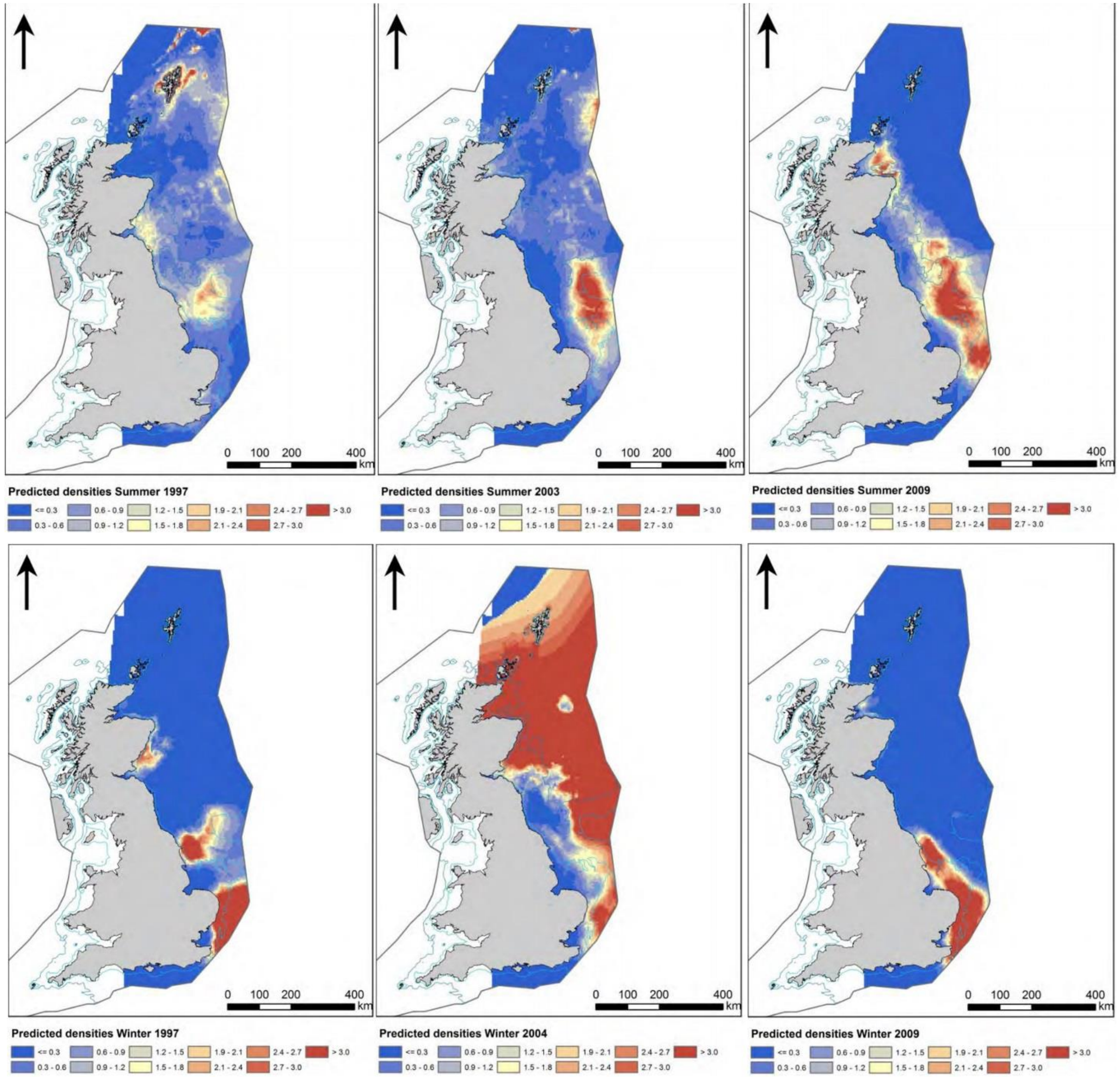

Figure 7.4: Predicted densities (number/km^2) during summer (top) and winter (bottom) in the North Sea MU for three different years in each model period (Heinänen and Skov 2015).

Nearby OWF Data

7.7.41 Harbour porpoise were the main species incidentally sighted during the site-specific surveys conducted at Greater Gabbard (Royal Haskoning 2011), Galloper (Royal Haskoning 2011), London Array (RPS 2005), Kentish Flats (VWPL 2011) and Kentish Flats Extension OWFs (VWPL 2011). These data highlight that harbour porpoise are present year round, with the highest incidental sightings rate recorded between February - May. Unfortunately, the site-specific surveys conducted for these wind farms were primarily ornithological surveys, therefore the data were obtained from incidental sightings of marine mammals, from which it is not possible to calculate a reliable density estimate.

Harbour Porpoise Baseline Conclusion

7.7.42 All data sources examined have confirmed that harbour porpoise are present in the southern North Sea, within the Greater Thames Estuary area and the Thanet Extension area. There is strong evidence of harbour porpoise density and sightings rates being seasonal in this area although different sources suggest different patterns. The Heinänen and Skov (2015) modelling of the JCP data showed that predicted porpoise densities in the southern North Sea were higher in the winter (October - March) than the summer (April - September). However, the site specific data from the Thanet site and data collected at nearby OWFs, shows that higher numbers of porpoises are generally only seen over the late winter/ early spring period (February - May), with low numbers the rest of the year. From these data it is possible to conclude that harbour porpoise densities in the Thanet Extension area may be higher in the late winter and early spring months in comparison to the rest of the year.

7.7.43 Currently, the only sources of data on the density of harbour porpoise in the Thanet Extension area are from SCANS III (Hammond *et al*. 2017), the JNCC report on areas of persistent porpoise densities, modelled using the JCP data (Heinänen and Skov 2015) and the density estimates obtained from the APEM aerial surveys of the Thanet Extension survey area (Voet *et al*. 2017).

7.7.44 The Heinänen and Skov (2015) analysis produced predicted density estimates for the Thanet Extension area of over three porpoise/km^2 in the winter of 1997 and up to three porpoise/km^2 in the winter of 2009. Though it is important to recognise the limitations of the data used and the method of analysis conducted which limits degree of confidence for these density predictions.

7.7.45 The porpoise density estimates presented in Voet *et al*. (2017) using the APEM aerial survey data for the Thanet Extension survey area, corrected for 'availability' provide a mean density of 0.610 porpoise/km^2 and a maximum density of 4.1 per km^2 for combined harbour porpoise and unidentified small cetacean sightings. However, as previously stated, sightings rates and therefore abundance and density estimates are subject to unquantified biases due to different sea states and sightings conditions between surveys. Therefore, there are limitations to the extent to which the corrected densities can be taken as an accurate reflection of absolute abundance. However, the similarity between the APEM derived estimate and the SCANS III estimate (0.607 porpoise/km^2) provides some confidence that the digital aerial survey derived estimate is representative of porpoise presence at the site. Although it is important to bear in mind the differences in spatial and temporal coverage between these two data sources.

7.7.46 The SCANS III surveys estimated a block-wide density of 0.607 porpoise/km^2 (Hammond *et al*. 2017). The results of the quantitative impact assessment are presented below for both the SCANS III density estimate and the APEM density estimate.

Harbour Seal Baseline

7.7.47 Harbour seals are the smaller of the two species of seal resident in UK waters. They forage at sea and haul-out on land to rest, moult and breed. Harbour seals normally feed within 40 - 50 km around their haul-out sites and take a wide variety of prey including sandeels, gadoids, herring and sprat, flatfish, octopus and squid (SCOS 2016). Harbour seals come ashore in sheltered waters, typically on sand banks and in estuaries, but also in rocky areas. They give birth to their pups in June and July and moult in August. At these, as well as other times of the year, harbour seals haul-out on land regularly in a pattern that is often related to the tidal cycle.

7.7.48 Approximately 30% of European harbour seals are found in the UK; this proportion has declined from approximately 40% in 2002 due to the declines in harbour seal numbers in parts of Scotland and large increases in the Wadden Sea. Harbour seals are widespread around the west coast of Scotland and throughout the Hebrides and Northern Isles. On the east coast, their distribution is more restricted with concentrations in the major estuaries of the Thames, The Wash, Firth of Tay and the Moray Firth.

7.7.49 In the UK, harbour seals are considered to have an Unfavourable Inadequate Conservation Status (JNCC 2013) which means that "*a change in management or policy is required to return the habitat type or species to favourable status but there is no danger of extinction in the foreseeable future*" (ETC/BD 2014).

7.7.50 The most recent UK wide harbour seal count presented in SCOS (2016) combines data collected between 2011 - 2015. This produced a total UK count of 31,200 seals, which, scaled to account for the proportion of animals at sea at the time of the count, gives an estimated UK population size of 43,300 (95% CI: 35,500 – 59,000) (SCOS 2016). Thanet Extension is located within the South-east England seal MU. The most recent count presented in SCOS (2017) for the South-east England MU was 5,061 in 2016, which scales to a population estimate of 7,029 harbour seals in the MU (95% CI 5,751 – 9,972), which accounts for 16% of the total UK population. The counts within the South-east England MU are concentrated mainly in The Wash SAC.

7.7.51 The following sections describe the available data on harbour seals in the South-east England seal MU and, specifically, in relation to Thanet Extension, in order to determine their spatial and temporal patterns of abundance and density.

Thanet Extension Surveys

7.7.52 During the 3 months of vessel line transect surveys of the Thanet Extension survey area between January - March 2016 there was only one sighting of an unknown seal species, which could have been either a harbour or a grey seal.

7.7.53 During the 22 months of aerial surveys conducted across the Thanet Extension survey area, a total of nine seals have been identified from the still images collected by APEM. These seals could not be identified to species level.

At-Sea Usage Maps

7.7.54 The seal usage maps (Russell *et al*. 2017) predict harbour seal at-sea densities of up to 3.20 seals/cell within grid cells that overlap the Thanet Extension site (CI: 1.30 – 5.09), up to 4.35 seals/cell within grid cells that overlap the survey area (CI: 0.20 – 8.49) and up to 17.52 seals/cell within grid cells that overlap the export cable corridor route (CI: 4.26 – 30.78) (Figure 7.5).

7.7.55 Assuming seals are evenly distributed within each 5x5 km grid cell, the density estimate can be scaled to provide a density per one km^2. This gives at-sea harbour seal densities of up to 0.13 seals/km^2 within grid cells that overlap the Thanet Extension site, up to 0.17 seals/km^2 within grid cells that overlap the survey area and up to 0.70 seals/km^2 within grid cells that overlap the export cable corridor route.

Telemetry Data

7.7.56 Between 2003 and 2012, SMRU have tagged a total of 66 aged 1+ harbour seals in the South East England MU. Of these, 47 were tagged in The Wash and 19 were tagged in the Thames (Figure 7.6 inset). A total of 11 of these tagged harbour seals had telemetry tracks that crossed into Thanet Extension or export cable corridor route, all of which were tagged in the Thames (Figure 7.6); none of the 47 seals tagged in The Wash had telemetry tracks that crossed into Thanet Extension or export cable corridor route. Two of the 11 harbour seals that had telemetry tracks that overlapped with Thanet Extension or export cable corridor route also showed telemetry tracks within The Wash SAC. Therefore, while none of the seals tagged at The Wash crossed into the Thanet Extension area, the data collected from the Thames seals show that there is a degree of connectivity between The Wash SAC, the Thames tagging sites and the Thanet Extension and export cable corridor route.

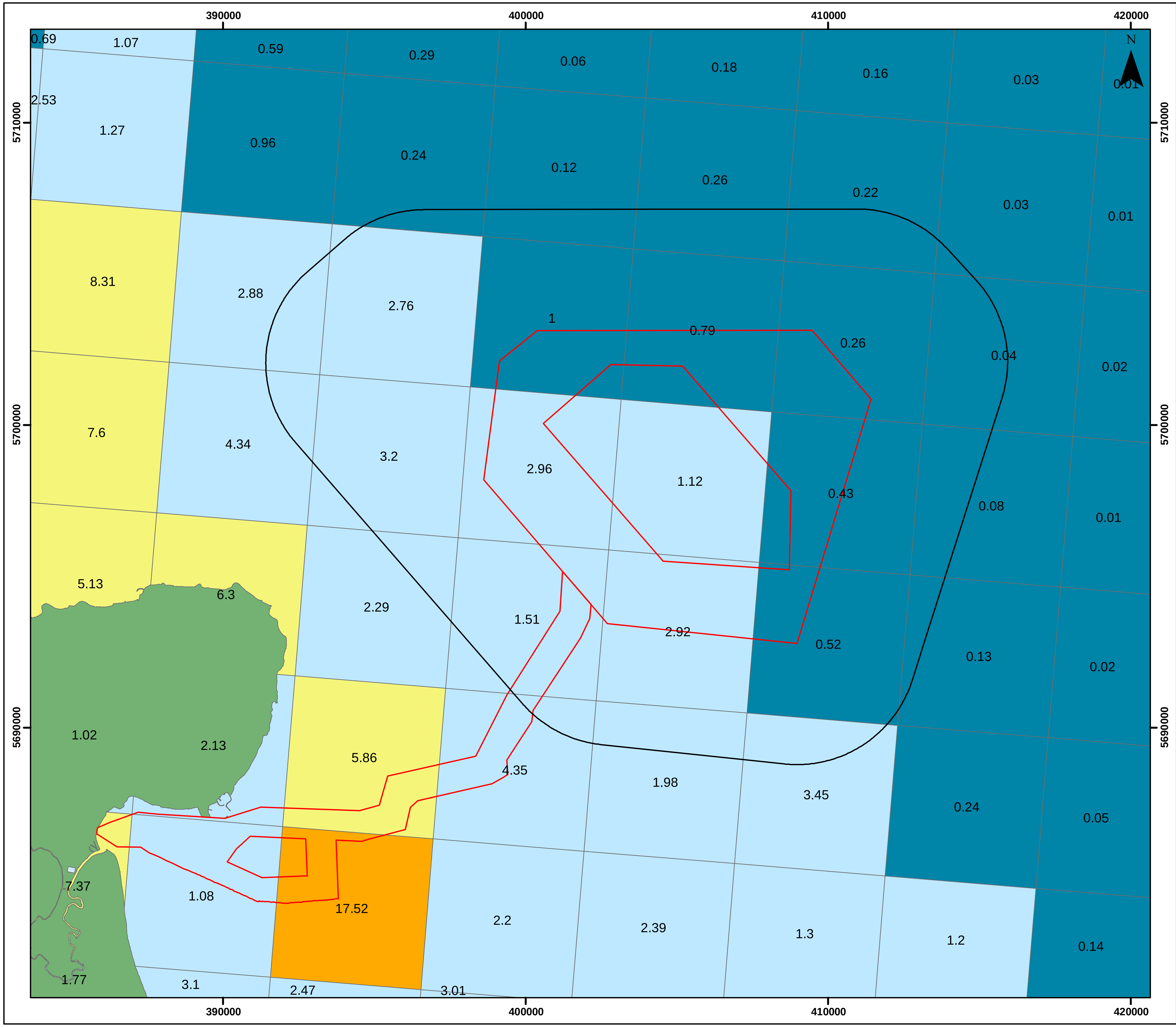

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Figure 7.5

Estimated Harbour Seal At-sea Usage (#/cell)

Legend

- Offshore Red Line Boundary
- Environmental Surveys

Harbour Seal Usage

- 0<1
- 1<5
- 5<10
- 10<50
- 50<100
- >100

Datum: ETRS 1989
Projection: UTM31N

Seal density data from Russell et al. (2017)

1:125,000 0 1 2 km 0 0.7 1.4 nm

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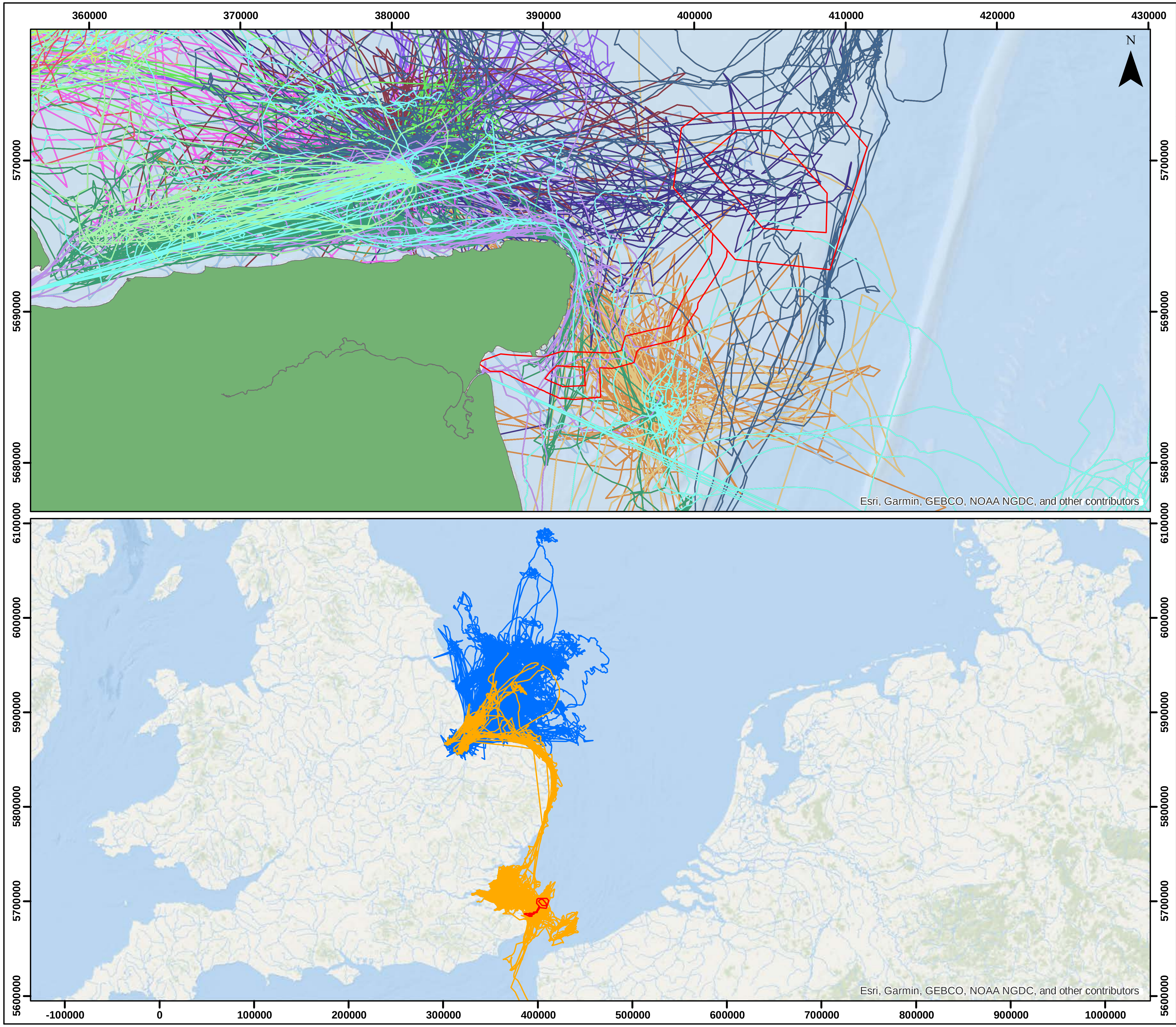

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Figure 7.6
Harbour Seal Telemetry Tracks

Legend
- Offshore Red Line Boundary
- Harbour seals tagged at the Thames
- Colours respresent individual seals
- All harbour seals tagged at the Wash
- All harbour seals tagged at the Thames

Datum: ETRS 1989
Projection: UTM31N

Telemetry data provided by SMRU

1:250,000 — 0 2.5 5 km — 0 1.5 3 nm

Drg No	ES Vol 2 Chpt 7 Fig 7.6			Figure 7.6
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By	RP	Layout	N/A	

Seal Counts – The Wash

7.7.57 Breeding surveys of harbour seals at The Wash have shown a large increase in pup production from 548 pups counted in 2001 to 1,586 pup counted in 2016, with a maximum count in 2014 of 1,802 pups. This provides a 7.5% annual increase in the pup counts at The Wash between 2001 - 2016 (Thompson *et al*. 2017). Since 2006, the moult count has increased from 1,695 animals to 3,086 animals in 2014, with an average annual increase of nine percent between 2006 - 2014. These count data show that the population of harbour seals at the closest SMRU monitored breeding site to Thanet Extension is a healthy, increasing population, which is reflected in both the annual breeding and moult counts.

Seal Counts – Greater Thames Estuary

7.7.58 Moult counts of harbour seals have been conducted in the Greater Thames Estuary between 2003 - 2016. From the August moult count data, a population estimate can be calculated by scaling the counts under the assumption that 72% of harbour seals are likely to be hauled out during the moult period (Lonergan *et al*. 2013). The harbour seal population estimate for the Greater Thames Estuary based on ZSL count data between 2013 - 2016 ranges between 626 - 964 harbour seals, with an average of 734 harbour seals (Table 7.9) (Barker and Obregon 2015).

Table 7.9: Harbour seal counts and resulting population estimates for the Greater Thames Estuary from the SMRU and ZSL surveys

Year	Source	# Haul-outs	Total Count	Population Estimate
2003	SMRU	10	180	250
2008	SMRU	18	319	443
2010	SMRU	18	379	526
2013	ZSL	50	482	669
2014	ZSL	43	489	679
2015	ZSL	53	451	626
2016	ZSL	52	694	964

7.7.59 Harbour seals are not evenly distributed within the Greater Thames Estuary; however, the same general areas appear to be used across years. Haul-outs are located throughout the Greater Thames Estuary but with the largest haul-out being located on coastal sandbanks, which includes the areas adjacent to Thanet Extension and the export cable corridor route and landfall (Figure 7.8). Combining the counts across the Stour Estuary/Pegwell Bay area in 2016 gives a total of 63 harbour seals (Table 7.10, Figure 7.9).

7.7.60 There is also a cluster of haul-out sites immediately south of the proposed export cable corridor route referred to generally as “Goodwin” which consists of haul-outs at: Goodwin Sands, Goodwin Knoll, South Goodwin Sand, South Kellet Gut, Gull Stream and North Trinity Bay (Table 7.10, Figure 7.9). The distance between these haul-out sites and the export cable corridor route ranges between 1.5 km (Gull Stream) and 13 km (Goodwin Knoll).

7.7.61 The Goodwin haul-out area is divided into two main clusters of haul-outs. The northern cluster contains the haul-outs named Goodwin 1, Goodwin 2, Goodwin Knoll, Goodwin Sands (Goodwin Knoll) and Gull Stream. The closest of these haul-outs to the offshore export cable corridor route is 1.5 km, the furthest is 4.3 km and main group of haul-outs (including the haul-out with the largest count) is ~2.2 km from the export cable corridor route.

7.7.62 The southern cluster contains the haul-outs called Goodwin 3, Goodwin 4, Goodwin Sands, Goodwin Sands (S Kellett Gut) and South Goodwin Sand. The closest of these haul-outs to the offshore export cable corridor route is 8.7 km and the furthest is 11.7 km.

7.7.63 In 2016 a total of 150 harbour seals were counted at the six haul-out sites in the Goodwin area (minimum distance 2.3 km from the export cable corridor route).

7.7.64 The counts of harbour seals at both Pegwell Bay and the Goodwin area have increased from 79 in 2003 to 296 in 2016. The harbour seals counted in Pegwell Bay and the Goodwin area during the 2016 moult survey represents 31% of the total population estimate for the Greater Thames Estuary (Figure 7.7).

Table 7.10: Harbour seal haul-out counts closest to the export cable corridor route (as depicted in Figure 7.9)

Year	Source	Location	# Haul-outs	Total Count
2003	SMRU	Goodwin	4	79
2008	SMRU	Goodwin	1	97
2010	SMRU	Goodwin	2	59
2013	ZSL	Outer Stour	1	40
		Inner Stour	1	1
		North Trinity Bay	1	2
		Goodwin Sands	2	40
		Goodwin Knoll	2	48
2014	ZSL	Pegwell Bay	1	16
		Goodwin Sands (S Kellett Gut)	2	59
		Goodwin Knoll	4	51
		Gull Stream	1	1
2015	ZSL	Pegwell Bay (inc. Inner & Outer Stour)	3	52
		South Goodwin Sand	3	62
		Goodwin Knoll	3	54
2016	ZSL	Pegwell Bay	1	63
		Goodwins	6	150

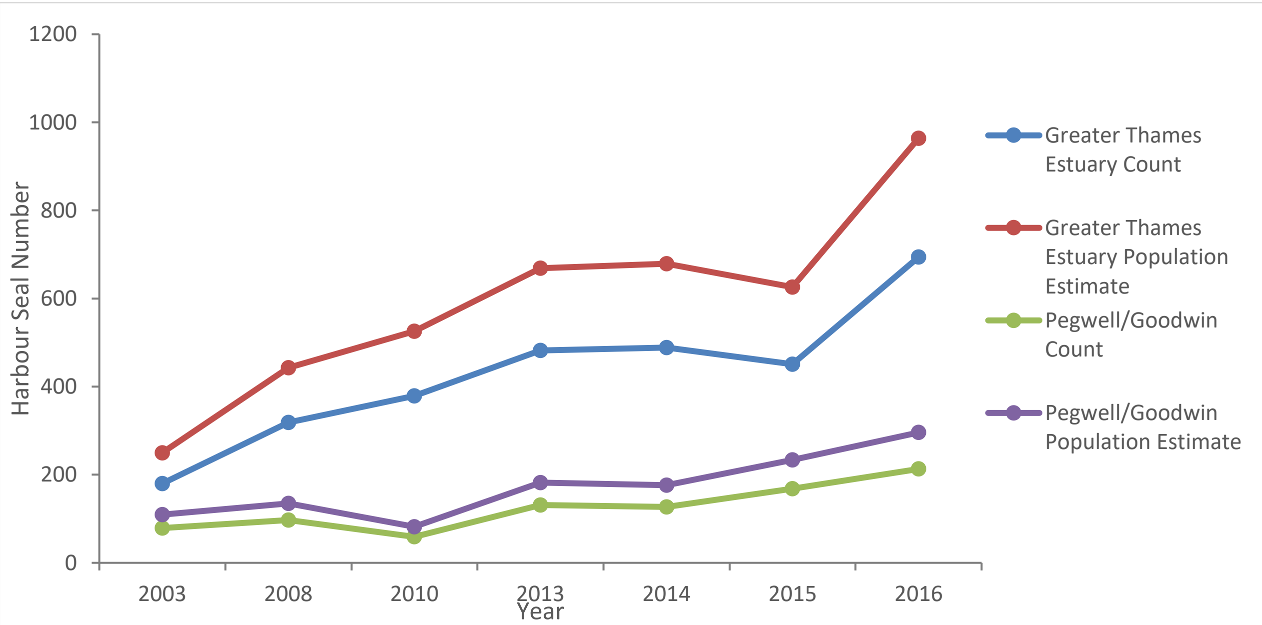

Figure 7.7: Harbour seal moult counts and population estimates for the Greater Thames Estuary and the Pegwell Bay and Goodwin areas. Population estimates are scaled from moult counts using a multiplier to account for the proportion of seals at sea (see text for details).

Seal Counts – Wadden Sea

7.7.65 The latest moult count for harbour seals in the Wadden Sea is 15,900 in Germany, 7,700 in the Netherlands and 2,800 in Denmark which results in a total Wadden Sea count of 26,400 harbour seals. When the count is scaled to account for the number of animals at sea at the time of the survey, this results in a total Wadden Sea population of 36,667 seals (95% CI 30,000 – 48,889).

Harbour Seal Baseline Conclusion

7.7.66 The SMRU breeding and moult harbour seal haul-out count data show that the population of harbour seals at The Wash (the closest monitored breeding site to Thanet Extension) is a healthy, increasing population. In addition to this, the ZSL moult counts in the Greater Thames Estuary show a stable population size. The harbour seal telemetry data show that there is some degree of connectivity between The Wash SAC, the Thames haul-out sites and Thanet Extension and export cable corridor route.

7.7.67 Of key importance for the Thanet Extension impact assessment is that there is a small harbour seal haul-out site in Pegwell Bay (63 animals counted in August 2016) which is where the Thanet Extension export cable landfall location is proposed. In addition to this, there are haul-out sites on Gull Stream, Goodwin Sands, South Goodwin Sand, Goodwin Knoll and South Kellett Gut, all of which are in close proximity to the Thanet Extension site and export cable corridor route (distance to export cable corridor route 1.5 - 11.7 km).

7.7.68 The only density estimates available for harbour seals in the Thanet Extension area are obtained from the Russell *et al*. (2017) seal usage maps. These give at-sea harbour seal densities of up to 0.70 seals/km^2 within the Thanet Extension survey area and export cable corridor route.

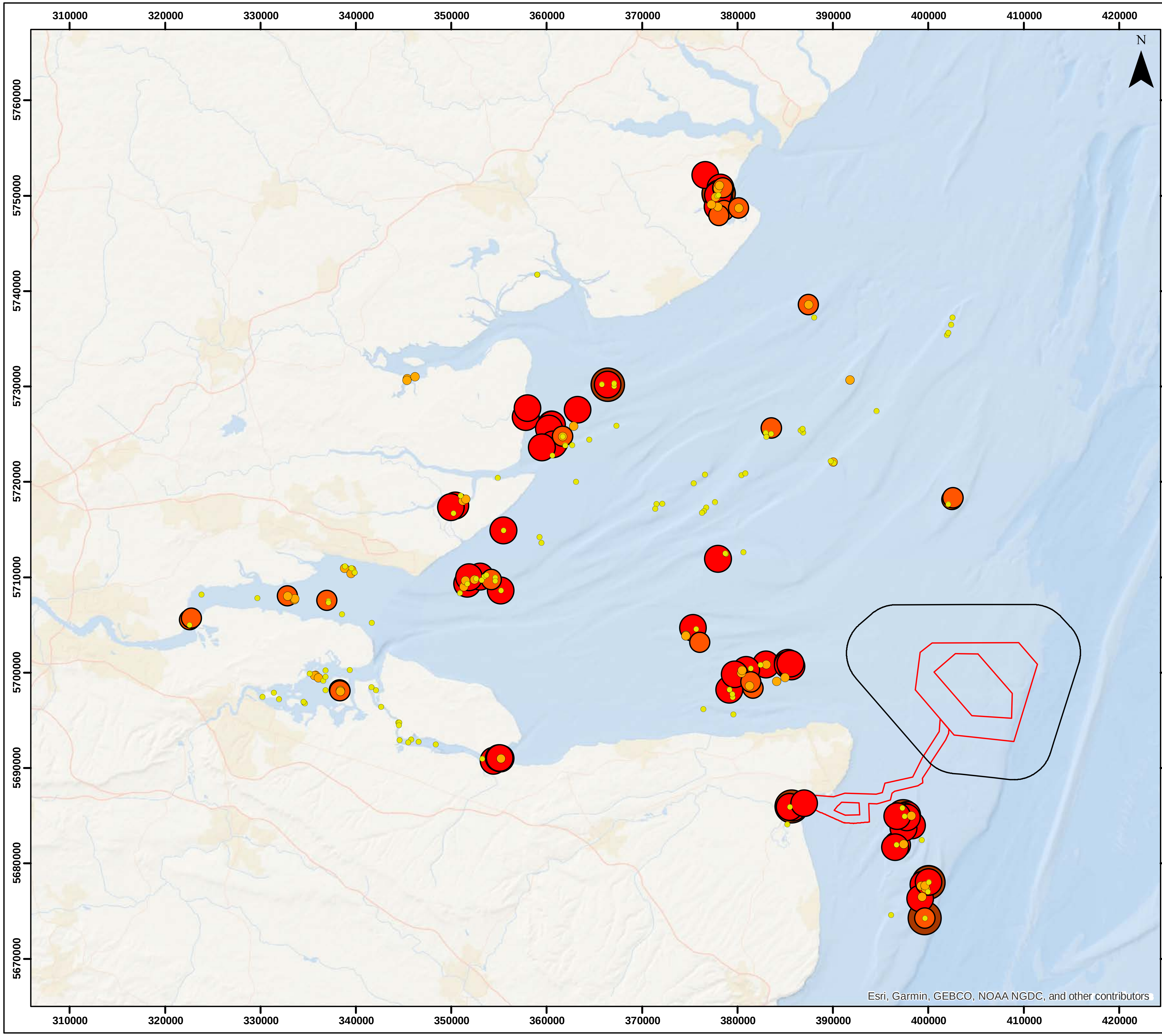

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Figure 7.8

Harbour Seal August Haul-out Counts 2003 - 2016

Legend

Offshore Red Line Boundary

Environmental Surveys

Harbour Seal Count

- 1-5
- 6-10
- 11-15
- 16-50
- 51-100
- >100

Datum: ETRS 1989
Projection: UTM31N

Haul-out count data provided by SMRU and ZSL

1:400,000 0 4.5 9 km 0 2 4 nm

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Figure 7.8

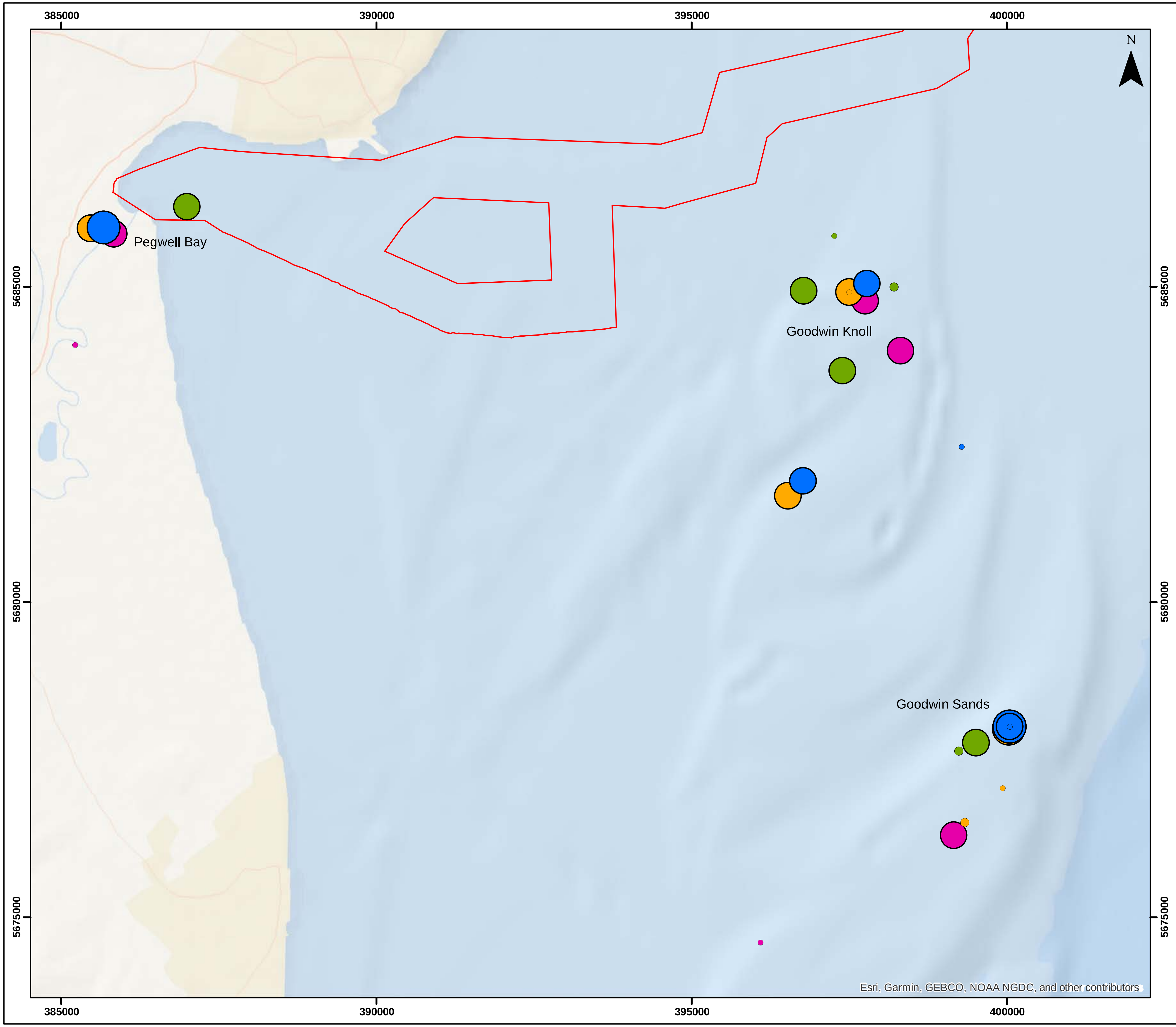

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Figure 7.9

Harbour Seal 2013-2016 August Haul-out Counts Pegwell Bay & Goodwin

Legend

Offshore Red Line Boundary

Harbour Seal Count

- 1-5
- 6-10
- 11-15
- 16-50
- 51-100
- >100

2016 = blue
2015 = orange
2014 = green
2013 = pink

Datum: ETRS 1989
Projection: UTM31N

Haul-out count data provided by SMRU and ZSL

1:60,000 — 0 0.65 1.3 km — 0 0.35 0.7 nm

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Figure 7.9

Grey Seal Baseline

7.7.69 Grey seals are the larger of the two species of seal resident in UK waters. They haul-out on land to rest, moult and breed and forage at sea where they range widely, frequently travelling for up to 30 days with over 100 km between haul-out sites (SCOS 2016). Approximately 38% of the world's grey seal population breeds in the UK with 88% of these breeding in Scotland with other breeding colonies in Shetland, on the north and east coasts of mainland Britain and in SW England and Wales. Grey seal population data are assessed using pup counts during the autumn breeding season when females haul-out to give birth. The number of pups throughout Britain has grown steadily since the 1960s but there is clear evidence that the population growth is levelling off in all areas except the central and southern North Sea where growth rates remain high.

7.7.70 In the UK, grey seals typically breed on remote uninhabited islands or coasts and in small numbers in caves. Preferred breeding locations allow females with young pups to move inland away from busy beaches and storm surges. Seals breeding on exposed, cliff-backed beaches and in caves may have limited opportunity to avoid storm surges and may experience higher levels of pup mortality as a result. UK grey seals breed in the autumn, but there is a clockwise cline in the mean birth date around the UK. The majority of pups in SW Britain are born between August and September, in north and west Scotland pupping occurs mainly between September and late November and eastern England pupping occurs mainly between early November to mid-December.

7.7.71 The grey seal is considered to have a FCS in the UK (JNCC 2013). The most recent UK wide grey seal pup production count was in 2014, which produced a total UK pup production estimate of 60,500 (95% CI: 53,900 – 66,900), which, modelled to estimate the non-pup portion of the population, gives an estimate of 141,000 aged 1+ grey seals in the UK (95% CI: 117,500 – 168,500) (SCOS 2016, 2017).

7.7.72 The most recent August haul-out count of grey seals for the Southeast England MU is 6,085 and for the Northeast England MU is 6,948 (SCOS 2017). Combined this gives a count of 13,033 which, scaled to account for the proportion at-sea at the time of the survey gives an estimated population size of 37,237 grey seals for the Southeast and Northeast England MUs combined.

7.7.73 The following sections describe the available data on grey seals in relation to Thanet Extension, in order to determine their spatial and temporal patterns of abundance and density.

Thanet Extension Baseline Surveys

7.7.74 During the three months of vessel transect surveys of the Thanet Extension survey area a total of three grey seals were sighted in addition to the one unknown seal species sighting.

7.7.75 During the 22 months of aerial surveys conducted across the Thanet Extension survey area, a total of nine seals have been identified from the still images collected by APEM. These seals could not be identified to species level.

Pup Production

7.7.76 Thanet Extension is not located in any of the five key breeding regions for grey seals in the UK. The nearest key breeding region for grey seals to Thanet Extension is the Donna Nook and East Anglia area of the North Sea region which encompasses the breeding colonies at Donna Nook, Blakeney Point and Horsey. In the Donna Nook and East Anglia area (Blakeney and Horsey) a total of 5,919 pups were counted in 2016 (data provided by SMRU). The 2016 pup count for the Donna Nook and East Anglia area increased from 2,566 in 2010 which is an average annual increase of 15% between 2010 - 2016.

7.7.77 The 2016 data show a large increase in pup production at Blakeney Point from 1,560 in 2013 to 2,404 in 2016 (a 54% increase), which made Blakeney Point the largest grey seal breeding colony in England. There was also a large increase in pup production at Horsey between 2014 – 2016, where the pup production count increased from 803 - 1,526 (a 90% increase). Therefore, these breeding colonies and associated populations can be considered to be healthy and increasing.

7.7.78 The grey seal pup production estimate for England (Donna Nook, East Anglia and the Farne Islands) in 2014 was 6,627 (SCOS 2017) which, using the same scaler to estimate the non-pup portion of the population, results in an English population size of 15,445 aged 1+ grey seals in 2016.

At-Sea Usage Maps

7.7.79 The seal usage maps (Russell *et al*. 2017) predict grey seal at-sea densities of up to 0.92 seals/cell within grid cells that overlap the Thanet Extension site (CI: 0.55-1.29), up to 1.43 seals/cell within grid cells that overlap the survey area (CI: 0.83-2.03) and up to 0.84 seals/cell within grid cells that overlap the export cable corridor route (CI: 0.651-1.17) (Figure 7.13).

7.7.80 Assuming seals are evenly distributed within each 5x5 km grid cell, the density estimate can be scaled to provide a density per one km^2. This gives at-sea grey seal densities of up to 0.04 seals/km^2 within grid cells that overlap the Thanet Extension site, up to 0.06 seals/km^2 within grid cells that overlap the survey area and up to 0.03 seals/km^2 within grid cells that overlap the export cable corridor route.

Telemetry Data

7.7.81 Between 1988 - 2015 SMRU have tagged a total of 32 aged 1+ grey seals in the South East England Management Area. Of these, ten were tagged at Blakeney in Norfolk and 22 were tagged at Donna Nook. Only one of these tagged grey seals had telemetry tracks that crossed into the Thanet Extension export cable corridor route. This one seal (ID hg48-009-15) was tagged at Blakeney and also showed telemetry tracks within the Berwickshire and North Northumberland Coast SAC which indicates that there is at least a small degree of connectivity between this SAC and Thanet Extension.

Wadden Sea Data

7.7.82 Telemetry data from grey seals tagged in the Netherlands have shown some connectivity between the Wadden Sea Natura 2000 site in the Netherlands and haul-out sites and the coastal waters of the UK, including the Greater Thames Estuary area and areas around Thanet Extension (Brasseur *et al*. 2015, IMARES 2015) (Figure 7.10). There is an increasing population of grey seals in the Wadden Sea, and the latest aerial breeding surveys recorded a peak pup count of 1,113 in December 2015 (Brasseur *et al*. 2016). The increase in pup counts between 2014 (peak count 829) and 2015 was higher than expected which indicates either: a) this population is increasing; and/ or b) the Wadden Sea is experiencing an influx of breeding female grey seals from the UK.

7.7.83 In the Wadden Sea, the most recent pup count is available for the winter of 2016-2017 where the highest count was in mid-December of 1,279 pups (Duck and Morris 2015, TSEG 2017). The maximum number of grey seals in the Wadden Sea is obtained from moult counts in the spring. The 2017 spring moult count resulted in a total count of 5,445 grey seals (TSEG 2017). Unfortunately, there is no data on the proportion of time grey seals spend at sea during their moult period, and so these raw count data cannot be scaled to obtain a population estimate for the Wadden Sea.

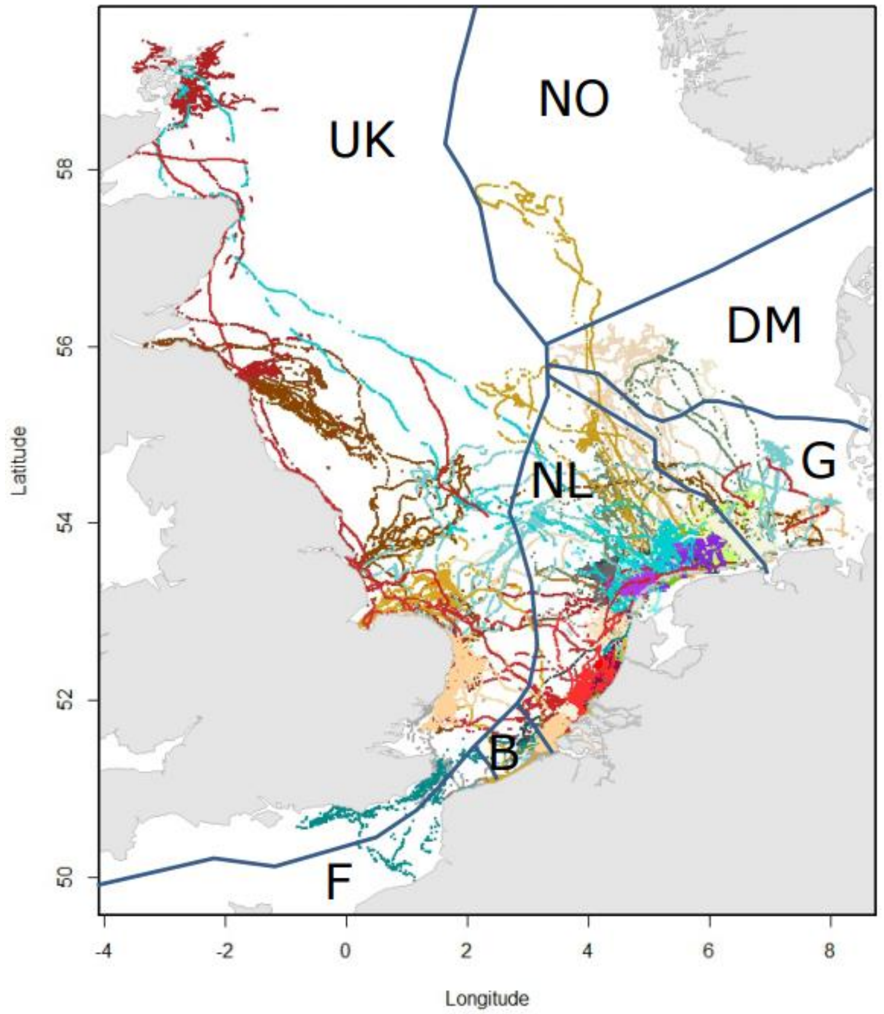

Figure 7.10: Locations of grey seals tracked from sites in the Netherlands up to 2014 - colours indicate individual seals (n = 75) (Brasseur *et al*. 2015).

7.7.84 Telemetry data from grey seals tagged in France also show than grey seals that haul-out in Molene archipelago (MOL), Sept Iles archipelago (SEP) and baie de Somme have telemetry tracks that overlap with the Goodwin Sands area (Figure 7.11) (Vincent *et al*. 2017). There is also an increasing grey seal population along the French coast, with grey seal haul-out counts showing annual increases of +6% pa at MOL and +8% pa at SEP.

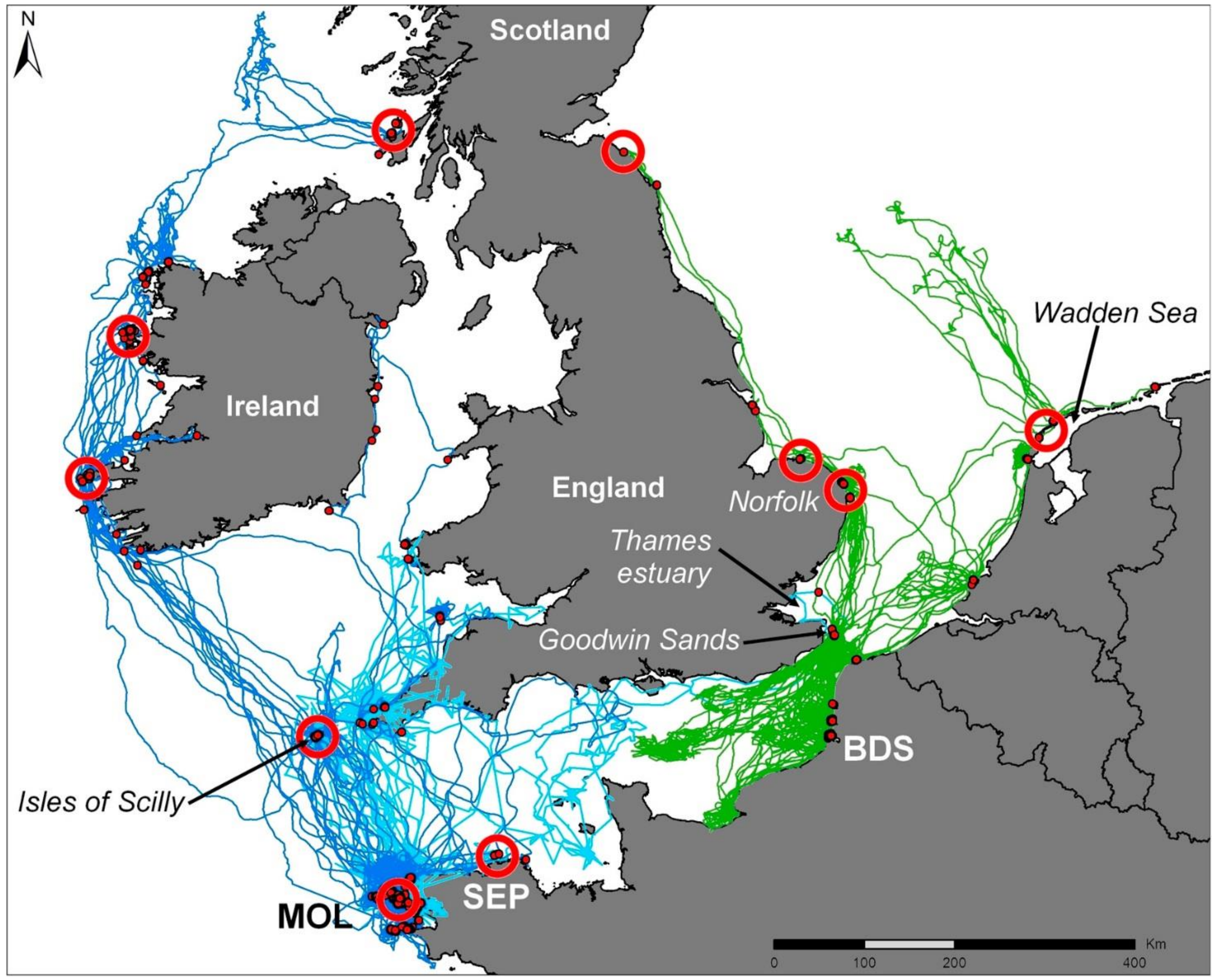

Figure 7.11: Grey seal temelemetry tracks from MOL (Molene archipelago, light blue n=15 tagged between 1999-2003, dark blue n=19 tagged between 2010-2013) and BDS (baie de Somme, green n=11 tagged in 2012) (Vincent *et al*. 2017).

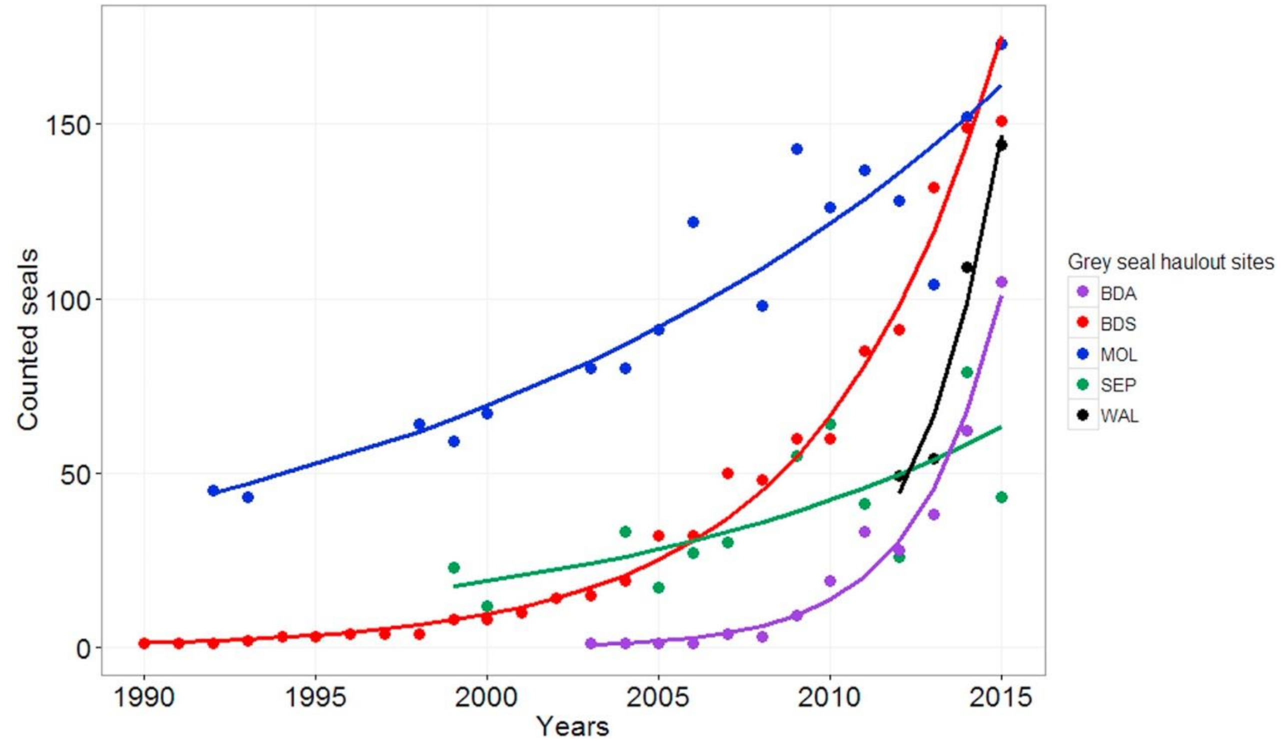

Figure 7.12: Grey seal maximum yearly counts at the main French study sites (BDA = baie d'Authie, BDS =, MOL = Molene archipelago, SEP = Sept iles archipelago and WAL = Walde) (Vincent *et al*. 2017).

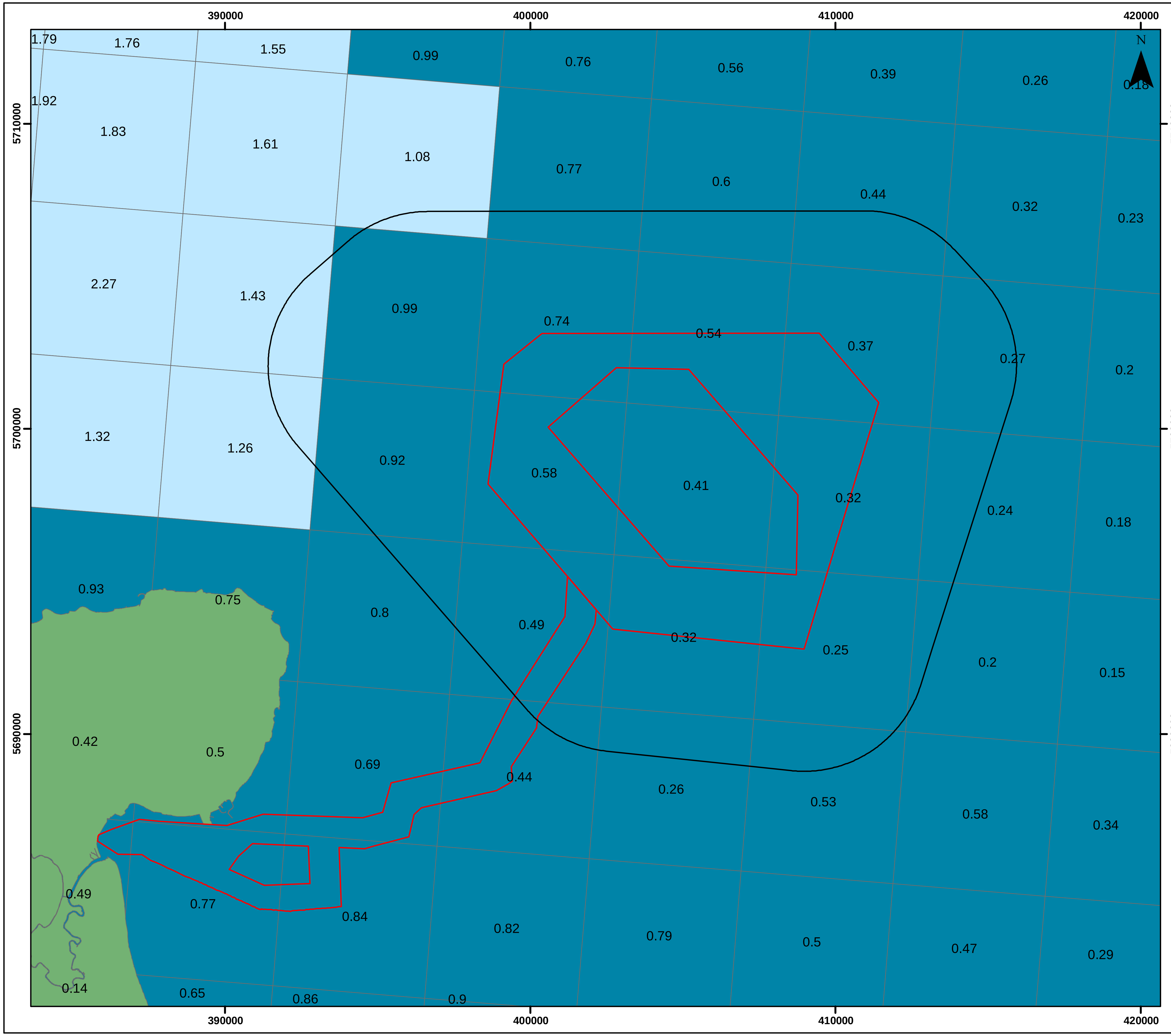

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Figure 7.13

Estimated Grey Seal At-sea Usage (#/cell)

Legend

- Environmental Surveys
- Offshore Red Line Boundary

Grey Seal Usage

- 0<1
- 1<5
- 5<10
- 10<50
- 50<100
- >100

Datum: ETRS 1989
Projection: UTM31N

Seal density data from Russell et al. (2017)

1:125,000 — 0 1 2 km — 0 0.7 1.4 nm

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Figure 7.13

Seal Counts - Greater Thames Estuary

7.7.85 Grey seals are not evenly distributed within the Greater Thames Estuary; however, the same haul-out sites appear to be used across years. Haul-outs are located throughout the Greater Thames Estuary but with the largest haul-out being located on coastal sand banks, which includes the areas adjacent to Thanet Extension and the export cable corridor route and landfall (Figure 7.14). There is a cluster of haul-out sites immediately south of the proposed export cable corridor route referred to generally as "Goodwin" which consists of haul-outs at: Goodwin Sands, Goodwin Knoll, South Goodwin Sand and South Kellet Gut (Table 7.12). The distance between these haul-out sites and the export cable corridor route ranges between two km (Goodwin Knoll) and 13 km (Goodwin). In 2016 a total of 344 grey seals were counted in the Goodwin area (Goodwin Sands, and Goodwin Knoll).

Table 7.11: Grey seal counts for the Greater Thames Estuary from the SMRU & ZSL surveys

Year	Source	# Haul-outs	Total Count
2003	SMRU	2	96
2008	SMRU	7	160
2010	SMRU	8	376
2013	ZSL	16	203
2014	ZSL	15	449
2015	ZSL	15	454
2016	ZSL	15	481

Table 7.12: Grey seal haul-out counts closest to the export cable corridor route (as depicted in Figure 7.14)

Year	Source	Haul-out Location	# Haul-outs	Total Count
2003	SMRU	Goodwin	1	92
2008	SMRU	Goodwin	1	125
2010	SMRU	Goodwin	2	311
2013	ZSL	Goodwin Sands	2	134
		Goodwin Knoll	3	9
2014	ZSL	Goodwin Sands (S Kellett Gut)	3	308
		Goodwin Knoll	2	19
2015	ZSL	South Goodwin Sand	2	327
		Goodwin Knoll	1	13
2016	ZSL	Goodwins	5	344

Grey Seal Baseline Conclusion

7.7.86 Thanet Extension is not located in any of the five key breeding regions for grey seals in the UK. The nearest key breeding region for grey seals to Thanet Extension is the Donna Nook and East Anglia area of the North Sea region. Donna Nook has shown a relatively stable pup production count over the last five years while both the Blakeney Point and Horsey breeding colonies have shown large increases in pup production over the last five years; therefore, these breeding colonies can be considered to be healthy and increasing. From the telemetry data there is evidence of connectivity between the Berwickshire and North Northumberland Coast SAC and Thanet Extension as well as connectivity between the Wadden Sea Natura 2000 site in the Netherlands and the coastal waters in the Greater Thames Estuary area, including areas around Thanet Extension. Of importance for the Thanet Extension impact assessment is that there are grey seal haul-outs in the Goodwin area where in 2016 344 grey seals were counted. The distance between these haul-out sites and the export cable corridor route ranges between two km (Goodwin Knoll) and 13 km (Goodwin).

7.7.87 The only density estimates available for grey seals in the Thanet Extension area are obtained from the Russell *et al*. (2017) seal usage maps. These give at-sea grey seal densities of up to 0.06 seals/km^2 within the Thanet Extension survey area and export cable corridor route.

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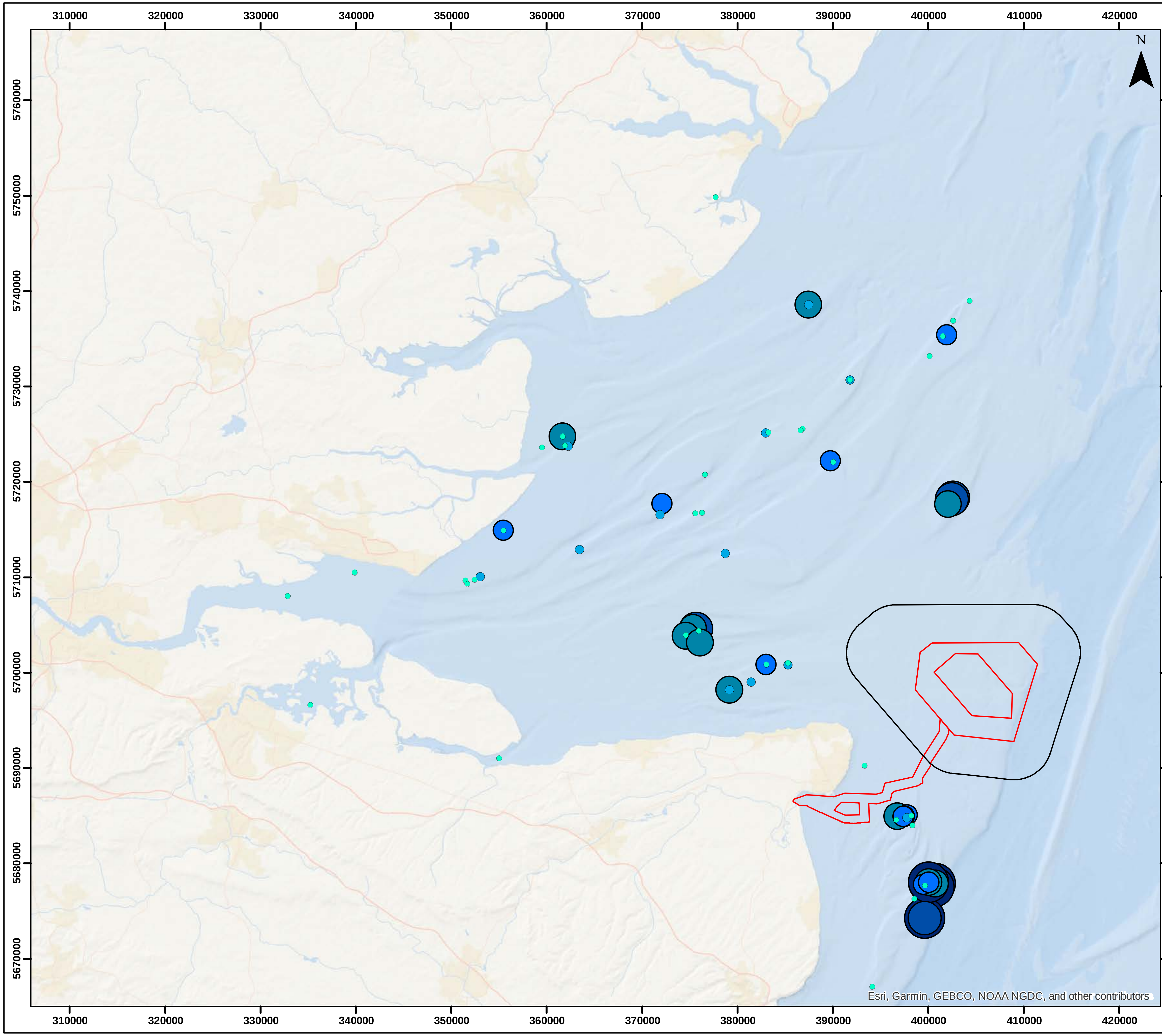
Figure 7.14

Grey Seal August Haul-out Counts 2003 - 2016



Legend

- Offshore Red Line Boundary
- Environmental Surveys

Grey Seal Count

- 1-5
- 6-10
- 11-15
- 16-50
- 51-100
- >100

Datum: ETRS 1989
Projection: UTM31N

Haul-out count data provided by SMRU and ZSL

1:400,000 0 4.5 9 km 0 2 4 nm

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Figure 7.14

Dolphin Species Baseline

7.7.88 There is little evidence that any species of dolphin are common in the Thanet Extension area. There were only four sightings of confirmed dolphin species during the APEM aerial surveys of the Thanet Extension site. There have also been sightings of four bottlenose dolphins during the London Array aerial surveys, four white-beaked dolphins in the Galloper OWF study area and four Risso's dolphins sighted in the Greater Gabbard OWF study area. Other than these, there have been sightings of unidentified small cetaceans during the APEM aerial surveys at the Thanet Extension site, where the images collected were of insufficient quality to determine whether the animals photographed were a dolphin species or a harbour porpoise. Given the seasonal pattern of these sightings and the frequency of porpoise sightings, it is probable that the majority of these sightings are of porpoise. Dolphin species have therefore been scoped out of the impact assessment for Thanet Extension. This has been agreed with the Offshore Ecology Technical Expert Panel.

Minke Whale Baseline

7.7.89 The SCANS III surveys did not record any minke whales in survey block L (Hammond *et al*. 2017). No minke whales were sighted during the 22 months of Thanet Extension APEM aerial surveys, nor were they sighted during the Thanet, Kentish Flats, London Array, Greater Gabbard or Galloper site-specific surveys. Minke whales have therefore been scoped out of the impact assessment for Thanet Extension. This has been agreed with the Offshore Ecology Technical Expert Panel.

Baseline Conclusions

7.7.90 Based on the data obtained from the baseline characterisation desk based study and the site-specific surveys conducted for Thanet Extension, the abundance and density values for each marine mammal species presented in Table 7.13 have been identified as the most robust values to take forward for the impact assessment.

Table 7.13: MU and density estimates taken forward for impact assessment for each species of marine mammal. Values in brackets show 95% confidence intervals

Species	MU	Abundance	Density (#/km^2)	Density Source
Harbour porpoise	North Sea	345,373 (246,526 – 495,752)	SCANS III: 0.607 APEM: 0.610	SCANS III (Hammond *et al*. 2017)
Harbour seal	South-east England	7,029	5x5 km grid cell specific densities	At-Sea Usage Maps (Russell *et al*. 2017)
	Wadden Sea	36,667	na	na
Grey seal	South-east and North-east England	37,237	5x5 km grid cell specific densities	At-Sea Usage Maps (Russell *et al*. 2017)
	Wadden Sea	5,445*	na	na

** This is the raw grey seal count during the spring moult in 2017. There is no data on the proportion of grey seals at sea during this moult period and so the raw counts cannot be reliably scaled to obtain a population estimate. Using the raw counts alone makes the assessment of impact highly precautionary.*

7.8 Key parameters for assessment

7.8.1 The maximum design envelope scenarios have been selected as those having the potential to have the greatest effect on marine mammals. These are shown in Table 7.14 and are based on the details provided in Volume 2, Chapter 1: Project Description (Offshore) (Document Ref: 6.2.1).

Table 7.14: Design envelope scenario assessed

Potential effect	Maximum design scenario assessed	Justification
Construction		
Construction activities: Underwater Noise	**<u>WTG:</u>** Maximum site capacity 340 MW Maximum one piling operation at any one time (single vessel piling only) Maximum piling period expected to be six working months in total, phased over a 28 month period <u>Worst case (spatial extent, largest impact footprint):</u> Pile-driving of 28 monopile foundations (12 MW WTG) • Max pile diameter 10 m; • Maximum hammer driving energy 5,000 kJ; • Soft start starting hammer energy 250 kJ; • Soft start duration one hour; • Soft start 15 blows per minute; • Maximum 30 blows per minute; • Average 20 blows per minute; • Maximum 8,000 blows per foundation; • Maximum piling time per foundation (assuming issues such as low blow rate, refusal, etc) six hours; and • Maximum piling time for WTG foundations = 168 hours. <u>Worst-case (temporal extent, longest duration of piling):</u> Pile-driving of 28 quadropod/jacket foundations (12 MW WTG) • Four piles per foundation; • Maximum pile diameter four meters; • Maximum hammer driving energy 2,700 kJ; • Soft start starting hammer energy 270 kJ; • Soft start duration one hour; • Soft start 15 blows per minute; • Maximum 30 blows per minute; • Average 30 blows per minute; • Maximum 8,400 blows per foundation; • Maximum piling time per foundation (assuming issues such as low blow rate, refusal, etc) ten hours; and • Maximum piling time for WTG foundations = 280 hours.	The installation of monopiles with the highest maximum hammer energy will result in the highest overall levels of underwater noise, resulting in the largest impact footprint for each piling operation. The longest duration of underwater noise from piling operations will occur with the installation of quadropod jacket foundations, requiring four pin piles per foundation. Modelling locations were selected for each species separately that would result in noise effects over the areas of highest density to ensure a precautionary approach was adopted. Locations were chosen for noise modelling for each species to reflect a maximum design scenario in terms of highest numbers potentially affected for each species and the maximum sound propagation conditions. Maximum design scenario from the installation method requiring the highest maximum hammer energy.

Potential effect	Maximum design scenario assessed	Justification
	Offshore Substation (OSS): • Maximum one OSS; • Monopile, tripod or quadropod foundation; • Maximum pile diameter ten meters for monopile, three meters for tripod or quadropod; • Maximum hammer driving energy 2,700 kJ; • Soft start starting hammer energy 270 kJ; • Soft start duration 0.33 hours; • Soft start (assumed) 20 blows per minute; • Maximum 30 blows per min; and • Maximum piling time per foundation (assuming issues such as low blow rate, refusal, etc) six hours. **Met Mast** Pile-driving of one monopile foundations (equivalent to 12 MW WTG) • Max pile diameter 10 m; • Maximum hammer driving energy 5,000 kJ; • Soft start starting hammer energy 250 kJ; • Soft start duration one hour; • Soft start 15 blows per minute; • Maximum 30 blows per minute; • Average 20 blows per minute; • Maximum 8,000 blows per foundation; and • Maximum piling time per foundation (assuming issues such as low blow rate, refusal, etc) six hours. **Cable installation (export and array cables)** • Cable will be buried using ploughing, trenching, jetting, cutting, mass flow excavation or pre-sweeping (or combination); • 25% of cable route may require additional protection (e.g. rock dumping or mattressing); and • At closest point, export cable corridor route is 1.5 km from known seal haul-out locations in Goodwin Sands. There are potential seal haul-out areas within the export cable corridor route and landfall in Pegwell Bay.	Worst-case scenario is expected to be underwater noise generated by trenching (noise levels predicted at 171-172 dB re 1 µPa @ 1m (RMS)). Vessels required for cable laying covered in section below.
UXO clearance	The following has been assumed: • 30 UXOs; • Clearance dates: 2020; • Number UXO clearances/day: 8; and • Charge weights: between 0.05 and 130 kg.	The characterisation surveys undertaken as part of the EIA process do not include surveys for detecting UXO and therefore the final number of UXO that may need to be cleared prior to the start of construction for Thanet Extension is not currently known and a risk based approach has been undertaken by UXO contractors. Further, detailed

Potential effect	Maximum design scenario assessed	Justification
		geophysical survey work will be undertaken post consent to determine the potential number of UXO that will require detonation and if required, an updated assessment of this risk will be carried out at that time. For the purposes of this assessment a number of assumptions were made based on data from surveys carried out to inform other projects within the study area, and using expert judgement.
Vessel Interactions: Disturbance and collision risk	Worst-case: A maximum of total of 48 vessels may be in operation onsite during the construction phase for construction (although it is highly unlikely that all will be onsite at the same time): • Three seabed preparation vessels; • One foundation spread (with five vessels); • Two transition piece installation vessels; • Six scour installation vessels; • Five vessels engaged in foundations; • Six WTG installation vessels; • Seven commissioning vessels; • One accommodation vessel; • Four IA cable vessels; • Six export cable vessels; • Two landfall cable installation vessels; • Three substation/collector IV; and • Three other vessels. 1,160 round trips to port for 340 MW project over three years.	Although the worst-case scenario is that all vessels are onsite at one time, this is highly unlikely as construction activities will be staggered.
Disturbance at seal haul-outs from cable landfall activities	Two landfall cable installation vessels (vessels covered in above section) Maximum duration of the landfall works (including transition joint bays (TJBs)) is five months. Three options for landfall**:** Option 1: Use of Horizontal Directional Drilling from the Pegwell Bay Country Park to the Intertidal mudflats • Four HHD pits located ~0.75 km from the closest haul-out; and • HDD rig (105 dB LwA) and can run on a 24 hour working day. Option 2: A seaward extension of the existing sea wall to allow the export cables to interface from burial within the intertidal mudflat and saltmarsh to a surface laid berm within the Pegwell Bay Country Park • Installation works will require the temporary installation of a cofferdam, the extension of the sea wall, open trenching from the intertidal zone to the sea wall before being laid in a surface laid bund up to the interface with the surface laid TJBs, followed by the removal of the cofferdam; • Sea wall extension will be a maximum of 155 m in length with a seaward extension of the permanent sea wall of 18.5 m;	The primary means by which seals could be impacted by cable landfall activities is by disturbance at nearby haul-out sites as a result of construction activities, with duration, proximity to haul-out sites and noise levels being the likely most important parameters. In terms of the maximum adverse design scenario, it is likely that the activities generating the loudest noise levels and with the longest duration would represent the worst-case impacts on hauled out seals. In this respect it is likely that Option 2 or 3 will represent the maximum design scenario with no difference between them.

Potential effect	Maximum design scenario assessed	Justification
	• Cofferdam will be a maximum of 25 m seaward and 165 m wide; • 33 days of (on land) piling between 0700 and 1900 7 days a week; • Cofferdam piling rig will reach levels of 132 dB equivalent continuous sound pressure level (LAeq) at 10 m; • Cofferdam piling (including installation and removal) will take up to 33 days; and • Cofferdam located ~1 km from the closest seal haul-out. Option 3: Open trenching through the existing sea wall and Pegwell Bay Country Park • Installation works will require the temporary installation of a cofferdam, the temporary removal of the sea wall, open trenching from the intertidal zone through the cofferdam to the TJBs followed by the re-installation of the sea wall and the removal of the cofferdam; • Cofferdam will be a maximum of 25 m seaward and 165 m wide; • Cofferdam piling rig will reach levels of 132 dB equivalent continuous sound pressure level (LAeq) at 10 m; • Cofferdam piling (including installation and removal) will take up to 33 days; and • Cofferdam located ~1 km from the closest haul-out.	
Changes in water quality: Increased suspended sediments arising from construction activities with the potential to affect the foraging ability of marine mammals	<u>Dredging for seabed preparation prior to foundation installation:</u> <u>Greatest Volume of Sediment Disturbed and Released from a Single Foundation Location</u> • Largest WTG quadropod suction caisson foundation (12 MW) spoil volume from seabed preparation per foundation 9,600 m^3; • Disposal of material on the seabed within the array area; • Dredging carried out using a representative trailer suction hopper dredger (11,000 m^3 hopper capacity with split bottom for spoil disposal); • Material to be deposited 'close' to the installation works; • Dredging carried out using a representative trailer suction hopper dredger (11,000 m^3 hopper capacity with split bottom for spoil disposal); and • Construction phase lasting up to 28 months (but anticipated to be around 12 working months spread over a minimum of two summer seasons). <u>Drilling operations for foundation installation:</u> <u>Greatest Volume of Sediment Disturbed and Released from a Single Foundation Location</u> • Largest WTG monopile foundations (12+ MW), associated drill diameter 7.5 m, drilling to 30 m penetration depth, spoil volume per foundation 1,325 m^3; • Up to two foundations may be simultaneously drilled, minimum spacing 1,000 m; and • Disposal of drill arisings at or above water surface. <u>Greatest Volume of Sediment Disturbed and Released across the Entire Array Area</u>	Seabed preparation works would only be required prior to installation of quadropod suction caisson foundations (if at all). Two maximum adverse scenarios are identified, corresponding to the greatest volume of sediment disturbance locally (from a single foundation) and across the entire array (from all foundations). The greatest sediment disturbance from a single quadropod suction caisson foundation location is associated with the largest diameter caisson cans whereas the greatest volume of sediment release for the entire array area is associated with a layout comprising a smaller number of large (12+ MW) WTG foundations. Although the volumes of material released via drilling are less than for seabed preparation via dredging, drilling has the potential to release larger volumes of relatively finer sediment. Two maximum adverse scenarios are identified, corresponding to the greatest volume of sediment disturbance locally (from a single foundation) and across the entire array (from all foundations).

Potential effect	Maximum design scenario assessed	Justification
	• Project comprising 34 (ten MW) monopile foundations, associated drill diameter 7 m, drilling to 30 m penetration depth, spoil volume for entire array area 19,627 m^3, up to 50% of foundations may be drilled; • One OSS monopile foundation, associated drill diameter 6 m, drilling to 30 m penetration depth, total spoil volume 900 m^3; • Disposal of drill arisings at or above water surface; and • Construction phase lasting up to 28 months. Inter-array cable installation • Installation method: jetting; • Total length: 64 km; • Maximum burial depth: three meters; • Indicative trench width: one meter; • Width of disturbance from jetting: five meters; and • Area of disturbance from jetting: 0.3 km^2. HVAC export cable installation • Maximum four HVAC cables; • Maximum length of HVAC export cable within WTG site boundary: 120 km; • Length of cables from project boundary to landfall: 28 km per cable; • Indicative total cable length from OSS to landfall: 30 km per cable; • Indicative duration of installation: 30 days per cable; • Spacing between cables: 50 m within pair, 120 m between pairs, maximum 250 m between adjacent cables; • Installation method: ploughing; • Maximum burial depth: three meters; • Indicative with of disturbance: 12 meters; and • Indicative area of disturbance: 1.4 km^2	The greatest volume of drill arisings from a single foundation location is associated with the largest diameter monopile foundation whereas the greatest volume of drill arisings for the entire array area is associated with a layout comprising a smaller number of large (12+ MW) quadropod foundations. Jetting (by mass flow excavation) will most energetically disturb the greatest volume of sediment in the trench profile and as such is considered to be the maximum adverse scenario for sediment dispersion.
Loss of prey resources from changes in benthic habitats and/or changes in the fish and shellfish community from impacts during construction	The maximum adverse design scenario for the fish and shellfish ecology assessment is presented in Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6). The maximum adverse design scenario for the Benthic habitats is presented in Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5).	Any impacts to marine mammals are dependent on the significance of impacts on fish and shellfish ecology and benthic habitats, therefore the maximum adverse scenarios for those receptors are those considered for prey related impacts on marine mammals
Operation		
Vessel Interactions: disturbance and collision risk	• Two O&M vessels; • One lift vessel; • One cable maintenance vessel; and	Maximum numbers of vessels and vessel movements expected during the operational period.

Potential effect	Maximum design scenario assessed	Justification
	• One auxiliary vessels. Total of 307 vessel round trips to port per year (mostly small O&M vessels)	
Subsea Operational noise	Up to 34 x ten MW WTG operating over a lifetime of 30 years.	The maximum design scenario is based on the largest number of WTG over the maximum lifetime of the project.
Change in prey resources resulting from changes in benthic habitats and/or changes in the fish and shellfish community from impacts during operation	The maximum adverse design scenario for the fish and shellfish ecology assessment is presented in Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6). The maximum adverse design scenario for the Benthic habitats is presented in Volume 2, Chapter 5: Benthic Ecology (Document 6.2.5).	Any impacts to marine mammals are dependent on the significance of impacts on fish and shellfish ecology and benthic habitats, therefore the maximum adverse scenarios for those receptors are those considered for prey related impacts on marine mammals.
Decommissioning		
Impacts from decommissioning are expected to be similar to those listed above for construction, if project infrastructure is removed from the seabed at the end of the development's operational life. If it is deemed closer to the time of decommissioning that removal of certain parts of the development (e.g. cables) would have a greater environmental impact than leaving in-situ, it may be preferable to leave those parts in-situ. In this case, the impacts would be similar to those described for the operational phase.		

7.10 Embedded Mitigation

7.10.1 Mitigation measures that were identified and adopted as part of the evolution of the project design (embedded into the project design) and that are relevant to marine mammals are listed in Table 7.15).

Table 7.15: Embedded mitigation relating to marine mammals

Parameter	Mitigation measures embedded into the project design
General	
Vessels	A vessel operator code of conduct will be developed as part of the Project Environmental Management Plan (PEMP) including advice to operators to not deliberately approach marine mammals, to travel on predictable routes as far as is possible and to avoid abrupt changes in course or speed should marine mammals approach the vessel to bow-ride.
Construction	
Pile-driving WTG	Monopiles: A one hour soft-start will be used for all piling activities. Piling will commence at a maximum of 200 kJ (eight and ten MW WTG) or 250 kJ (12+ MW WTG) hammer energy. Hammer energy will ramp up to full hammer energy of 4,000 kJ (eight and ten MW WTG) or 5,000 kJ (12+ MW WTG). The strike rate will increase from 15 blows per minute during the soft start to a maximum of 30 blows per minute during full piling. Quadropod/jacket: A one hour soft-start will be used for all piling activities. Piling will commence at a maximum of 270 kJ. Hammer energy will ramp up to full hammer energy of 2,700 kJ. The strike rate will increase from 15 blows per minute during the soft start to a maximum of 30 blows per minute during full piling.
UXO clearance	The exact details of the mitigation required during UXO detonation will be agreed at such time as detailed information is available on the location, number and size of the detonations required. However, the MMMP will include visual monitoring and the deployment of Acoustic Deterrent Devices (ADDs) prior to the detonation of any UXO. Where practicable and safe to do so after a specific dynamic Risk Assessment, a 'soft-start approach' may be conducted before detonation of any UXO 130 kg or over, which involves the detonation of three small charges of 50 g, 100 g and 150 g spaced at five minute intervals with a further five minutes before the main UXO is detonated.
Pile-driving OSS	A one hour soft-start will be used for all piling activities. Piling will commence at a maximum of 270 kJ hammer energy. Hammer energy will ramp up to full hammer energy of 2,700 kJ. The strike rate will increase from 20 blows per minute during the soft start to a maximum of 30 blows per minute during full piling. This is the same irrespective of the foundation type (monopile, tripod or quadropod).
All Pile-driving	Following JNCC (2010) guidelines, a Marine Mammal Mitigation Plan will be produced and followed to cover the construction phase. This will outline the soft-start procedure, monitoring, and any other agreed mitigation options deemed necessary, to reduce to negligible levels the potential risk of injury or death to marine mammals in close proximity to piling operations.
Pollution prevention	A Project Environmental Management and Monitoring Plan (PEMMP) will be produced and followed to cover the construction and O&M phases. This will also incorporate plans to cover accidental spills, potential contaminant release and include key emergency contact details (e.g. MMO, Maritime and Coastguard Agency (MCA) and the project site co-ordinator). A decommissioning programme will be developed to cover the decommissioning phase. The purpose of the measures to be implemented ensure that potential for contaminant release is strictly controlled and therefore provides protection to marine life across all phases of the life of the project.
Operation	
EMF	Cable burial to a minimum target depth of one meter (where possible and subject to risk assessment) will increase the distance between cables and benthic receptors, thereby reducing the strength of the received EMF.
Decommissioning	
Embedded mitigation measures implemented in the Decommissioning Phase are likely to be similar to those implemented during the Construction Phase.	

7.11 Environmental assessment: construction phase

7.11.1 This section details the assessment of the impacts of underwater noise generated during construction activities. These activities include clearance of unexploded ordinance (UXO) prior to construction, pile-driving during the installation of WTG foundations, vessel activity, seabed preparation for both WTG and cable installation (e.g. dredging) and other activities in relation to cable installation (such as rock dumping and trenching).

7.11.2 Marine mammals use sound for a variety of reasons (foraging, orientation and navigation, communication, detection and predator avoidance) and are therefore potentially susceptible to elevated levels of anthropogenic noise. Extremely high levels of noise can cause physical damage as a result of barotrauma due to high intensity of noise within a short period of time. Elevated anthropogenic noise can cause physical damage to the hearing systems of marine mammals, in addition to disrupting normal behaviour and masking auditory cues used for foraging, navigation and communication.

7.11.3 The underwater noise modelling that was undertaken to support this assessment is detailed in Volume 4, Annex 6-3: Technical Noise Modelling (Document Ref: 6.4.6.3). Due to the greater potential for noise from underwater piling to impact marine mammals, this assessment is separated into non-piling noise and piling noise. A more detailed description of the quantitative impact assessment for piling noise on marine mammals is detailed in paragraphs 7.11.45 *et seq.*

Non Piling construction noise

7.11.4 Increased vessel traffic during construction has the potential to result in disturbance of marine mammals. Disturbance from vessel noise is only likely to occur where increased noise from vessel movements associated with the construction of Thanet Extension is greater than the background ambient noise. The outer Thames Estuary is a busy shipping area; therefore, background noise levels are likely to be high. The current maximum design scenario assumes a total of 48 vessels on site at the same time and a total of 1,220 round trips to port over a three year period. This absolute worst-case scenario assumes a very compressed programme where multiple different activities are taking place at once, such as ground preparation, foundation installation, WTG installation and WTG commissioning. However, the likelihood that all these activities will overlap is very low so the number of vessels present on site at any one time during construction is realistically expected to be much lower.

7.11.5 Comparative analysis undertaken by Subacoustech Ltd of potential noise sources during construction ranked noise from construction vessels as least noisy when compared to other construction activities. During the period of piling operations, it is therefore considered unlikely that vessel noise will impact marine mammal receptors at anything other than immediate proximity, should animals be in the area. Individuals have more potential to be impacted by increased vessel movements during periods when piling is not taking place.

7.11.6 The magnitude and characteristics of vessel noise varies depending on ship type, ship size, mode of propulsion, operational factors and speed. Vessels of varying size produce different frequencies, generally becoming lower frequency with increasing size. The predominant sound frequencies associated with large vessels are below several hundred Hz. Thomsen *et al*. (2006) used species hearing detection thresholds to conclude that ship noise from larger vessels around 0.25 kHz will be detected by harbour porpoise at distances of approximately one km, and ship noise from smaller vessels around two kHz will be detected at around three km. Harbour and grey seals are expected to detect two kHz ship noise at approximately three km and 0.25 kHz at ranges of 20 km. These frequencies were chosen as because most noise from construction/ maintenance vessels is exhibited at these ranges (Richardson 1995). The distance at which animals may react is difficult to predict. Behavioural responses can vary a great deal depending on context and data specific to harbour porpoises and seals are sparse. According to Thomsen *et al*. (2006), both porpoises and seals might be expected to respond to vessels of this type at approximately 400 m.

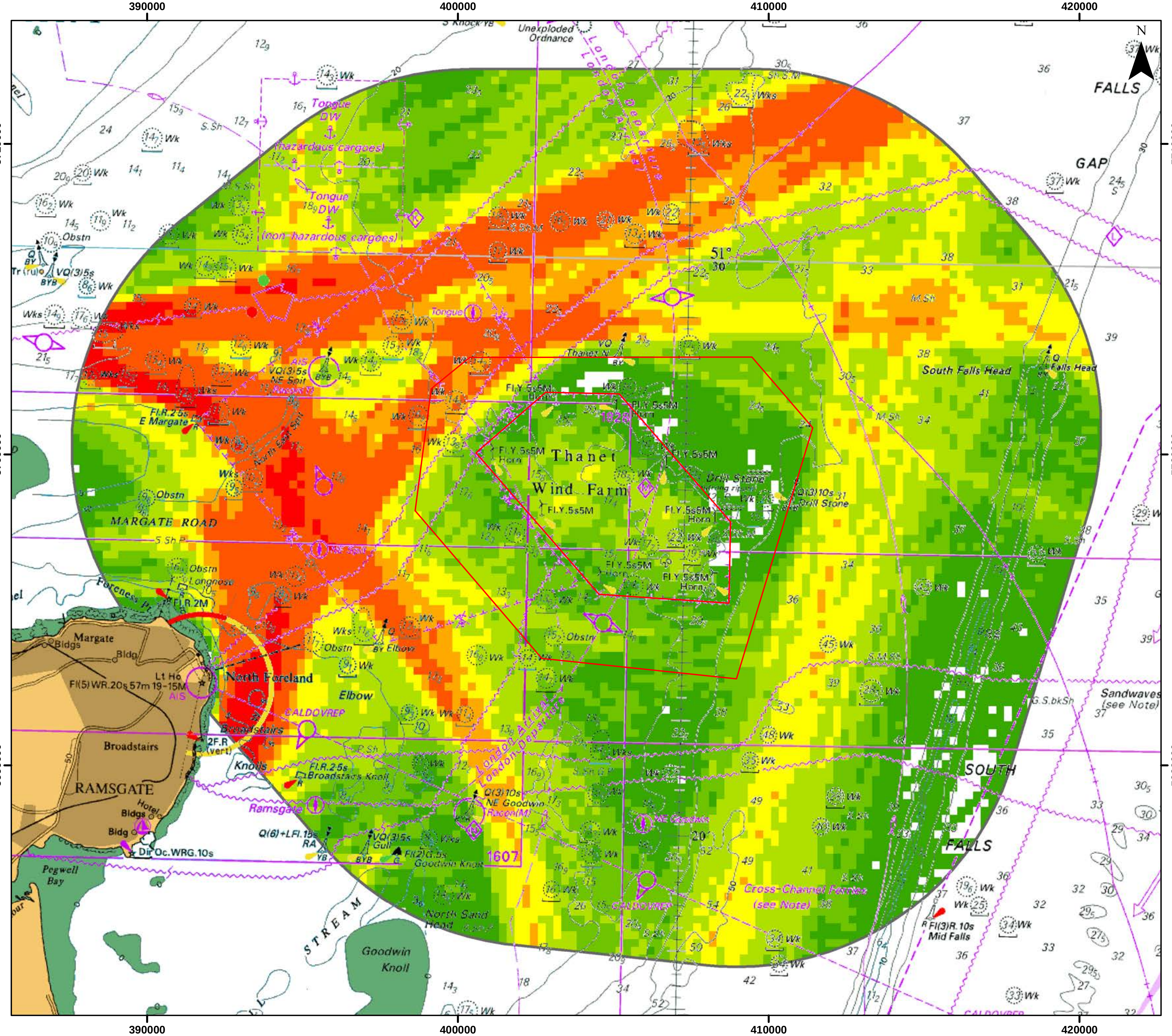
7.11.7 Given their high-frequency hearing range, it has been suggested that porpoise are more likely to be sensitive to vessels that produce medium to high frequency noise components (e.g. Hermannsen *et al*. 2014). Harbour porpoise are known to avoid vessels and strong behavioural responses have been shown in porpoise exposed to vessel noise that contains low levels of high-frequency components (e.g. Dyndo *et al*. 2015). Therefore, the sensitivity of porpoise to vessel noise will likely depend on the frequency of the noise components produced by the vessel.

7.11.8 There is a possibility that responses to vessels are not related to noise *per se* and that the simple presence of vessels may result in a response. Pirotta *et al*. (2015) demonstrated that the response of bottlenose dolphins in the Moray Firth was related to the number of boats present but did not vary significantly with the levels of overall noise. While this result does provide evidence that a perception of risk can be related to the presence of boats, silent and stationary boats did not elicit a response. It is therefore difficult to disentangle the effect of presence of boats with the noise they emit, although it is expected that observed responses are at least in part due to noise disturbance and in part due to perceived risks of collision.

7.11.9 There is very little published information on the responses of seals at sea to vessels. Jones *et al*. (2017) presents an analysis of the predicted co-occurrence of ships and seals at sea which demonstrates that UK wide there is a large degree of predicted co-occurrence between ships and seals at sea, particularly within 50 km of the coast close to seal haul-outs. There is no evidence relating decreasing seal populations with high levels of co-occurrence between ships and animals and areas where seal populations are increasing (e.g. south east England) and where ship co-occurrences are highest, are experiencing the highest levels of growth (Jones *et al*. 2017).

7.11.10 Detailed information on the baseline levels of vessel activity in the vicinity of Thanet Extension is provided in Volume 2, Chapter 10: Shipping and Navigation (Document Ref: 6.2.10). Commercial shipping traffic lanes are located within 5 nm of the site (Figure 7.15) with traffic through the boundaries of the Thanet Extension area boundary occurring at a rate of approximately 328 commercial vessel passages per month. With many hundreds more occurring around the site boundaries. A gate analysis presented in Volume 2, Chapter 10: Shipping and Navigation (Document Ref: 6.2.10), assessed the frequency and distribution of traffic flow within nearby shipping routes. Transit rates were up to between 25 and 30 transits per day. These shipping routes are mainly occupied by large commercial cargo vessels, fishing vessels and tankers. As a result, any marine mammals in the vicinity of the site are likely to be habituated to a large volume of ship traffic.

7.11.11 The maximum total number of additional transits during the construction period is expected to be a maximum of five additional transits per day. These will total 1,220 over a three year period, equating to an average of 34 additional transits per month. This is not considered to be a significant increase in total vessel movements. Based on the baseline transit levels presented above, the transit rates will potentially be increased to a maximum of 35 vessel transits per day. This level is below the threshold value of 80 ships per day suggested by the analysis of Heinanen and Skov (2015) as being associated with significantly lower harbour porpoise densities. Existing commercial shipping traffic lanes will likely be rerouted to outside of the Thanet Extension boundary, therefore numbers of vessel movements within the boundary of the site will actually decrease as a result of construction and operation resulting in a reduced amount of exposure to vessel noise within the site boundaries.



THANET EXTENSION OFFSHORE WIND FARM

Figure 7.15
Vessel Traffic Density (Winter and Summer Surveys)

Legend:

Offshore Array Red Line Boundary

Transits Per Day

- 0.03 - 0.25
- 0.26 - 0.50
- 0.51 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
- 2.01 - 5.00
- 5.01 - 10.00

Datum: ETRS 1989
Projection: UTM31N

1:125,000 0 1 2 km 0 0.7 1.4 nm

Drg No	16UK1255_ES_10_3_v1		
Rev	0.1	Date	5/25/2018
By	AR	Layout	N/A

Figure 7.15

7.11.12 The impact of disturbance from vessels during construction (both from underwater noise generated and the presence of vessels) is predicted to be of local spatial extent, short-term duration and reversible. The magnitude of impact is therefore considered to be Low for all marine mammal species. Given the proximity of shipping channels and the use of the site by other vessels, it is likely that marine mammals using this area are habituated to ship noise and will tolerate vessel presence. The sensitivity for all marine mammal species is determined as Low. The effect will therefore be of **Minor** adverse significance which is not significant in EIA terms.

7.11.13 Other, non-piling underwater noise sources include cable laying techniques (such as ploughing, trenching, rock dumping and jetting), dredging of the seabed prior to foundation installation and drilling for foundation installation. Information on the sound produced by the specific vessels and construction activities for this project are not available, however, parallels can be drawn from similar projects and vessels. Previously, Subacoustech have provided estimated noise levels for cable laying, rock placing and trenching which are considerably lower than that produced by pile driving, therefore, during the period of piling operations it is therefore considered unlikely that these activities will impact marine mammals receptors at anything other than immediate proximity. Individuals have more potential to be impacted by these activities during periods when piling is not taking place.

7.11.14 In another example, Xodus Group Ltd (2015) conducted noise modelling for a cable laying vessel, similar to the type which will be used for the construction of this project. This modelling concluded that the radius of potential injury from cable laying vessels was 25 m for Low Frequency (LF) cetaceans, 15 m for Mid Frequency (MF) cetaceans, 12 m for High Frequency (HF) cetaceans and 50 m for pinnipeds – assuming continuous exposure within that radius over a 24 hour period. These values mean that animals would have to stay within these very small ranges for 24 hours before they experienced injury, which is an extremely unlikely scenario as it is far more likely that any marine mammal within the injury zone would move away from the vicinity of the vessel.

7.11.15 The potential effects of cabling techniques used in the offshore wind farm industry was reviewed in a report by BERR in association with DEFRA (BERR and DEFRA 2008). The report reviewed various cable types and installation methods including burial ploughs, machines, ROVs and sleds and the burial methods themselves including jetting, rock ripping, and dredging. The review concluded that it would be "*highly unlikely that cable installation would produce noise at a level that would cause a behavioural reaction in marine mammals*".

7.11.16 Subacoustech estimated noise levels for dredging as 186 dB re 1µPa @ 1m (RMS). However, most of the noise emitted is broadband with frequencies below 1 kHz, it is unlikely to cause any auditory injury, and is more likely to cause masking and behavioural impacts for lower frequency cetacean species (Todd *et al*. 2015) which are not of concern at Thanet Extension.

7.11.17 There is evidence that dolphins avoid areas when high levels of dredging activity occur, however this effect was only temporary (Pirotta *et al*. 2013). Given that dolphins are not present at Thanet Extension, and that Thanet Extension has not been identified as an important foraging area for any marine mammal species, any potential temporary displacement as a result of dredging activities is unlikely to significantly affect any marine mammal species.

7.11.18 The behavioural impacts of non-piling underwater construction noise have been previously assessed for a number of other projects. Results have been previously expressed based on the dBht level, where 90 dB_{ht} is a "strong avoidance in virtually all individuals" and 75 dB_{ht} is a "mild behavioural reaction" (Nedwell *et al*. 2007). The estimated behavioural impact ranges were higher for harbour porpoise compared to harbour seals, and extended furthest for trenching and rock dumping activities with "mild behavioural reactions" predicted out to 640 m from trenching. While these impact ranges are indicative, due to the generic nature of the activities assessed, effects are likely to be small scale and temporary, therefore disturbance as a result of non-piling construction noise is assessed as being Low magnitude and Low sensitivity for all marine mammal species, resulting in an overall **Minor** adverse significance which is not significant in EIA terms.

UXO Clearance

7.11.19 There is the potential requirement for underwater UXO clearance prior to construction. The preference would be to avoid UXO wherever possible or remove them from the seabed for disposal to a designated area. However, in some cases, this may be considered unsafe and therefore to is necessary to consider the requirement for underwater UXO detonation. UXO clearance for the purposes of this assessment is considered to involve the detonation of the UXO *in situ* to make it safe to undertake construction works in the surrounding area. UXO detonations underwater are performed for those UXO that are considered unsafe for removal to be disposed of onshore.

7.11.20 A risk review has therefore been undertaken by UXO specialists to identify a realistic worst-case for UXO clearance. Experience suggests that the number of targets encountered can be significant, but that the number which prove positive and actually require detonation is limited. Experience from other offshore wind projects within the southern North Sea suggests that, on average, around 20 *in situ* detonations may be expected – however, a precautionary assumption of a maximum of 30 UXOs, up to a charge weight of 130 kg, is being made here. UXO clearance is expected to occur during daylight hours only, with the potential for multiple clearances to occur within a day, thus limiting the overall duration of the work. It is anticipated that up to 8 detonations could occur within a single 24 hour period, with approximately 7.5 days of work in total (based on an average of four clearances per day).

7.11.21 The potential for impact would therefore be expected to relate to a series of up to 30 controlled explosions across the project area and OECC, resulting in a series of discrete, single sources of underwater noise. The location(s) of any such UXO have yet to be identified; the final location of any UXO requiring clearance will influence the potential for disturbance.

7.11.22 Surveys have indicated the potential for UXOs to be present across the Thanet Extension site and cable corridor (Unexploded Ordnance (UXO) Hazard and Risk Assessment with Risk Mitigation Strategy by Ordtek (Report reference JM5384_RA-RMS_V2.0)). An assessment has been made based on assumptions about the size and number of UXO based on this information. It is important to note that a robust detailed assessment of the requirements for UXO clearance at the Thanet Extension site and cable route will not be possible until high resolution magnetometer surveys are carried out. These are only valid for UXO purposes for a limited period of time and therefore will not be carried out until post-consent. Therefore, there remains some uncertainty about the extent of UXO clearance required, although the assumptions have been made on the basis of current best available information.

7.11.23 There is expected be a variety of explosive types, which will have been subject to varying degrees of degradation and burying over time. Two otherwise identical explosive devices are likely to produce different blasts where one has spent an extended period on the sea bed. Therefore, a selection of explosive sizes has been considered in the estimation of the underwater noise levels produced by detonation of UXO. The potential impact has been estimated using up to date impact criteria in respect of marine mammals that could be present in the area. A selection of 'scare' charges have also been included.

7.11.24 The specific locations, numbers and sizes of UXO that will require detonation will be determined post-consent and therefore it is not possible to accurately characterise the nature of the UXO that may require detonation or define the appropriate mitigation measures at this stage. Consequently, Thanet Extension are not seeking to consent the detonation of UXO as part of this DCO application. However, Thanet Extension recognises that there is a possibility that UXO clearance may be required prior to commencement of construction of the project and that in-situ detonations of UXO are another source of noise in the marine environment and hence some consideration of the additional impact from this activity is appropriate. Therefore, an assessment has been provided for UXO clearance charges of up to 130 kg.

7.11.25 Explosive detonations, some of the loudest anthropogenic underwater noises, can result in source levels of 272-287 dB SPL_{peak} re 1µPa@1 m with a frequency spectrum of 2 – 1,000 Hz and the highest energies between 6 - 21 Hz over very rapid durations of 1 – 10 ms (Gotz *et al*. 2009, Richardson *et al*. 1995). The low frequency energy has the potential to travel considerable distances (Parvin *et al*., 2007) and this level of sound can cause injury or even cause death to marine mammals, with the injuries from both the high peak pressures and the initial shock wave that is generated (Genesis, 2011, von Benda-Beckman *et al*., 2017). The main potential effects from UXO detonations to individual animals are: physical injury (from the shock wave); auditory injury (from the acoustic wave) resulting in permanent threshold shift (PTS); and behaviour changes such as disturbance to feeding, mating, resting and breeding. As described in Section 7.10, the project will have a UXO specific marine mammal mitigation plan (MMMP), including mitigation measures such as the use of marine mammal observers (MMOs) and acoustic deterrent devices (ADDs).

7.11.26 Current advice from the statutory nature conservation bodies (SNCBs) is that the NOAA injury thresholds (NMFS, 2016) should be used for assessing the impacts from UXO detonation on marine mammals. However, the suitability of the NOAA criteria for UXO is currently under discussion due to the lack of empirical evidence from UXO detonations using the NOAA metrics, in particular the range dependent characteristics of the peak sounds, and whether current propagation models can accurately predict the range at which these thresholds are reached. Current models have not been validated at ranges relevant to the predictions and there is a possibility that models significantly overestimate ranges for large charge masses (>25 kg; von Benda-Beckman *et al.,* (2015)).

Magnitude of impact

7.11.27 The magnitude of the impact from UXO detonations is related to the source level of the noise generated, which may be affected by a range of factors including: design; composition; age; state of deterioration; orientation; whether it is covered by sediment; and the charge weight of the explosive (von Benda-Beckman *et al*., 2015). Ultimately, only the charge weight of the explosive can be factored into noise modelling and has the greatest influence on the noise modelling source levels.

7.11.28 UXO clearance it is proposed, will be subject to a dedicated deemed Marine Licence and EPS Licence. It is standard practice for a condition to be attached to any such licences requiring an appropriate MMMP to be in place as part of the required mitigation, to ensure that the risk of lethal and injurious effects is kept as low as feasible, with the works meeting the required EPS tests[1]. Furthermore, it should be noted that in the JNCC guidance for minimising the risk of injury to marine mammals from explosives[2], that mitigation measures implemented through a UXO-MMMP are focused on the prevention of injury rather than disturbance. For activities that make use of explosions for a relatively short period of time (such as clearance of UXO), the JNCC guidance notes that there is a low likelihood of disturbance occurring that could be sufficient to lead to an offence. From this, it can be seen that the UXO-MMMP that would be required (and agreed with SNCBs) would provide mitigation to ensure that the risk of injury is as low as possible.

UXO Clearance - PTS

7.11.29 Subacoustech have conducted noise modelling assuming the worst-case scenario, where it has been assumed that the UXO to be detonated is not buried. Other UXO parameters such as design, composition, age, position and orientation are unknown, therefore the exact source levels and sound propagation parameters are unknown. Further details are presented in Mason (2017).

7.11.30 Since the locations of UXOs are not known, the tables below present the quantification of impact assuming the UXO is located at the East model location for porpoise and the South-west model location for seals.

7.11.31 PTS onset ranges were predicted using the dual criteria approach and thresholds provided in NMFS, (2016), whereby both unweighted (SPL, dB re 1 µPa) and weighted according to hearing curves (SEL dB re 1 µPa2s) should be applied and the largest range used to inform the impact assessment . The largest impact ranges for UXO clearance were from the unweighted SPL thresholds.

7.11.32 The maximum PTS onset range predicted for harbour porpoise is 6.99 km for a 130 kg charge using the NOAA unweighted threshold of 202 dB re 1 µPa (Table 7.16). The number of porpoises expected to be within this range is 93 using the SCANS III density estimate (Table 7.17) before the application of any mitigation. This equates to 0.03 % of the harbour porpoise reference population.

7.11.33 The maximum PTS onset range predicted for seal species is 1.53 km for a 130 kg charge using the NOAA unweighted threshold of 218 dB re 1 µPa (Table 7.16). This equates to <1 harbour seal and <1 grey seal using the at-sea usage densities (Table 7.17).

7.11.34 As discussed in paragraph 7.11.28, an appropriate UXO-MMMP will be implemented to reduce the risk of auditory injury to marine mammals. The details of this will be agreed once further geophysical survey has been carried out and all potential UXOs have been identified and characterised. However, it is likely that this mitigation will involve a pre-detonation watch by marine mammal observers prior to the detonation of any charges to ensure that no sightings of marine mammals occur in the monitored zone prior to detonations. Acoustic Deterrent Devices (ADDs) and scare charges will also likely be deployed to ensure that any animals that are present outwith the monitored zone are triggered to start moving away before the largest charges are detonated. Previous studies have shown that the Lofitech ADD reduced the rate of detection of harbour porpoises by approximately 88% over an area with a maximum distance of 15 km to the ADD (Brandt *et al.,* 2012). Applying a similar effectiveness to the Thanet Extension site would reduce the number of porpoises potentially at risk of PTS to 11 individuals. CPOD data from the work of Brandt *et al*., also demonstrated significant decrease in acoustic detections, at 7.5 km from the piling source, the measured reduction was from 3.1 porpoise positive minutes per day (PPM) to 0.1 PPM. This may indicate a reduction in abundance of 97% which if also occurred at the Thanet Extension would reduce the number of porpoises potentially at risk to only three. Eleven individuals would be equivalent to less than 0.01 % of the reference population and three individuals would be equivalent to less than 0.001% of the reference population. Both of these levels of impacts would be considered negligible magnitude. The use of additional, intermittent smaller 'scare' charges prior to UXO charge detonation may also provide additional mitigation and help move animals out of the impact area.

7.11.35 Given the uncertainty in the ability of current models to predict the extent of impact ranges, particularly in relation to peak thresholds, this is likely to be an overestimate. von Benda-Beckman concluded that models for the prediction of PTS ranges for charge weights above 25 kg required further validation. Furthermore, von Benda-Beckman *et al*., (2015) reported that PTS as a result of exposure to a 263 kg charge weight explosion (using an upper limit for the onset of PTS based on observations by Ketten (2004)), could occur out to 1.8 km from the source.

[1] http://publications.naturalengland.org.uk/file/8499055

[2] http://jncc.defra.gov.uk/pdf/JNCC_Guidelines_Explosives%20Guidelines_August%202010.pdf

7.11.36 Given the low number of individuals and percentages of the reference populations predicted to be affected, even in light of the likely overestimation of impact ranges, the magnitude of PTS from UXO clearance is considered Negligible for all marine mammal species. The sensitivity to PTS is considered High for porpoise and Medium for seals. The significance of the impact is therefore considered of **Minor** adverse significance for harbour porpoise and both seal species.

UXO Clearance – TTS

7.11.37 The maximum TTS onset range predicted for harbour porpoise is 11.7 km for a 130 kg charge using the NOAA unweighted threshold of 196 dB re 1 µPa (Table 7.18).

7.11.38 The maximum TTS onset range predicted for seal species is 2.8 km for a 130 kg charge using the NOAA unweighted threshold of 212 dB re 1 µPa (Table 7.18).

7.11.39 These TTS onset ranges do not represent an impact which is considered to be of biological significance across the whole area indicated by these ranges, but are intended to indicate the level of noise exposure which could induce any measureable threshold shift. TTS within these ranges could range from a small (~6 dB) reduction in hearing sensitivity that would recover in less than hour, to more significant reductions in hearing sensitivity that may last for a number of days. Reductions in hearing sensitivity may affect an animal's ability to forage, avoid predation and communicate but the TTS onset ranges alone do not allow assessment of the magnitude or significance of the likely consequences for individuals and ultimately populations of the predicted extent over which any TTS might occur. Mitigation in place to reduce the risk of PTS to marine mammals will also reduce the risk of TTS below the ranges presented here.

UXO Clearance - Disturbance

7.11.40 Behavioural responses to noise are highly variable and are dependent on a variety of internal and external factors. Internal factors include past experience, individual hearing sensitivity, activity patterns, motivational and behavioural state at the time of exposure. Demographic factors such as age, sex and presence of dependent offspring can also have an influence. Environmental factors include the habitat characteristics, presence of food, predators, proximity to shoreline or other features. Responses themselves can also be highly variable, from small changes in behaviour such as longer intervals between surfacing (Richardson 1995) or a cessation in vocalisation (Watkins 1986) to more dramatic escape responses (Götz and Janik 2016).

7.11.41 This variability makes it challenging to predict the likelihood of responses to underwater noise from UXO detonations. There is no empirical data to inform an assessment of potential responses. It is important to note that all any impact assessment can do, is predict the *potential* for behavioural responses, as definitive predictions of likelihood or magnitude are particularly difficult.

7.11.42 Natural England and JNCC advise that a buffer of 26 km around the source location is used to determine the impact area from UXO clearance with respect to disturbance of harbour porpoise in the Southern North Sea cSAC. In the absence of agreed metrics for the use of seal species for disturbance, and given a lack of empirical data on the likelihood of response to explosives, this 26 km area has been applied for seal species as well as harbour porpoise.

7.11.43 Since the locations of UXOs are not known, the tables below present the results assuming the UXO is located at the East location for porpoise and the south-west location for seals (Table 7.19). Assuming a 26 km behavioural disturbance threshold, 1,288 harbour porpoise (0.37% reference population), 200 harbour seals (2.85 % reference population) and 64 grey seals (0.17% reference population) are predicted to be potentially disturbed as a result of UXO clearance.

7.11.44 Each detonation will result in a single pulse of sound and based on data gathered at Thanet, only a small number of UXO, a total of 30, are anticipated to require detonation. Therefore, animals will experience very short lived periods of disturbance on an estimated 30 occasions. Due to this, and the low percentages of the reference populations predicted to be affected, the magnitude of disturbance from UXO clearance is considered Low for all species. Due to the very short-term and temporary nature of the impact, the sensitivity to disturbance from noise from UXO clearance is considered Medium for porpoise and Low for seals. The significance of the impact is therefore considered of **Minor** adverse significance for harbour porpoise and both seal species.

Table 7.16: PTS impact ranges (m) for harbour porpoise and seal species as a result of UXO clearance

	Charge weight	0.05 kg	0.1 kg	0.15 kg	2 kg	25 kg	130 kg
Species	Source level (SPL_{peak})	265 dB	267 dB	268 dB	277 dB	285 dB	290 dB
Unweighted thresholds							
Harbour porpoise	SPL_{peak} 202 dB re 1 µPa	580	725	830	1,920	4,250	6,990
Seal species	SPL_{peak} 218 dB re 1 µPa	115	145	165	390	890	1,530
Weighted thresholds							
Harbour porpoise	$NMFS_{HF}$ SEL 155 dB re 1 µPa^2s	10	10	15	40	140	310
Seal species	$NMFS_{PW}$ SEL 185 dB re 1 µPa^2s	10	10	10	30	85	185

Table 7.17: Estimated number of marine mammals and percentage of reference population potentially at risk of PTS as a result of UXO clearance in the absence of mitigation

	Charge weight	0.05 kg	0.1 kg	0.15 kg	2 kg	25 kg	130 kg
Species	Source level (SPL_{peak})	265 dB	267 dB	268 dB	277 dB	285 dB	290 dB
Unweighted thresholds							
Harbour porpoise	SPL_{peak} 202 dB re 1 µPa	<1 (0.00%)	<1 (0.00%)	<1 (0.00%)	7 (0.00%)	34 (0.01%)	93 (0.03%)
Harbour seal	SPL_{peak} 218 dB re 1 µPa	<1 (0.00%)	<1 (0.00%)	<1 (0.00%)	<1 (0.00%)	<1 (0.00%)	<1 (0.00%)
Grey seal	SPL_{peak} 218 dB re 1 µPa	<1 (0.00%)	<1 (0.00%)	<1 (0.00%)	<1 (0.00%)	<1 (0.00%)	<1 (0.00%)

Table 7.18: TTS impact ranges (m) for harbour porpoise and seal species as a result of UXO clearance

	Charge weight	0.05 kg	0.1 kg	0.15 kg	2 kg	25 kg	130 kg
Species	Source level (SPL_{peak})	265 dB	267 dB	268 dB	277 dB	285 dB	290 dB
Unweighted thresholds							
Harbour porpoise	SPL_{peak} 196 dB re 1 µPa	1,100	1,400	1,600	3,500	7,400	11,700
Seal species	SPL_{peak} 212 dB re 1 µPa	210	270	310	720	1,700	2,800
Weighted thresholds							
Harbour porpoise	$NMFS_{HF}$ SEL 140 dB re 1 μPa^2s	94	140	170	570	1,100	1,300
Seal species	$NMFS_{PW}$ SEL 170 dB re 1 μPa^2s	56	78	95	340	660	730

Table 7.19: Estimated number of marine mammals potentially at risk of disturbance as a result of UXO clearance

Species	Model Location	Disturbance Range	Estimated number in impacted area	% of reference population	Magnitude
Harbour porpoise	East	26 km	1,288	0.37%	Low
Harbour seal	South-west	26 km	200	2.85%	Low
Grey seal	South-west	26 km	64	0.17%	Low

Piling noise

7.11.45 The greatest source of noise impact during construction will be from pile-driving to install WTG foundations. Subacoustech have completed underwater noise modelling based on a range of piling scenarios based on the maximum design parameters presented in Volume 2, Chapter 1: Offshore Project Description (Document Ref: 6.2.1). Volume 4, Annex 6-3: Technical Noise Modelling (Document Ref: 6.4.6.3) describes the propagation modelling methods as well as a background to the acoustic concepts used in the assessment. The details are summarised below.

7.11.46 Noise modelling was carried out at two locations within the Thanet Extension site. These locations were chosen to represent a range of sound propagation conditions in addition to covering locations closest to the highest density areas for each marine mammal receptor. The east location was selected due to its position within the harbour porpoise cSAC combined with the deeper water found along the eastern boundary of the site. The south-west location was selected due to its position closest to seal haul-out sites, as well as it's shallower, more coastal location.

7.11.47 Piling parameters assessed are given in Volume 2, Chapter 1: Offshore Project Description (Document Ref: 6.2.1). In summary, impact ranges were predicted for the first hammer energy in the soft start ramp up and the maximum hammer energy used for the maximum pile diameter for each foundation type (monopile and pin pile).

7.11.48 Monopile scenarios were determined to present the worst-case spatial impact, i.e. would result in the largest overall impact range, whereas the installation of jacket foundations using pin piles would result in the worst-case temporal impact as the total duration of piling will be longer compared to monopile installation.

7.11.49 For monopiles, the maximum hammer energy that was modelled is 5,000 kJ, with a start-up hammer energy of ten percent (500 kJ). For pin pile installation the maximum hammer energy that was modelled was 2,700 kJ with a start-up hammer energy of 270 kJ.

Thresholds - Lethal and Physical Injury

7.11.50 For assessing the potential for lethal injury to occur as a result of close range exposure to the shock waves generated piling, the threshold adopted independent of the species was SPL_{zp} 240 dB re 1 µPa (Parvin *et al*. 2007).

7.11.51 For assessing the potential for non-auditory physical injury the threshold adopted independent of the species was SPL_{zp} 220 dB re 1 µPa (Parvin *et al*. 2007).

Thresholds – Auditory Injury: Permanent Threshold Shift (PTS)

7.11.52 Exposure to loud sounds can lead to a reduction in hearing sensitivity. This reduction (threshold shift) may be temporary (TTS) or permanent (PTS). PTS is considered to result in auditory injury. For determining the number of animals that could potentially experience PTS, thresholds for PTS onset presented in Southall *et al*. (2007) have been adopted in most marine mammal piling noise impact assessments in recent years, following UK SNCB advice (with the adoption of more recently derived PTS thresholds for harbour porpoises from Lucke *et al*. 2009). However, in July 2016, the US NOAA released updated guidance on noise assessment metrics for auditory injury (National Marine Fisheries Service 2016) with revised thresholds for PTS. It was agreed in consultation that the Thanet Extension impact assessment will present only the National Marine Fisheries Service (2016) thresholds for PTS and TTS.

7.11.53 This impact assessment presents PTS and TTS impact ranges using the newer National Marine Fisheries Service (2016) thresholds for all species (Table 7.20).

7.11.54 Only PTS is considered as auditory injury in this assessment. This follows JNCC guidance on the prevention of injury and disturbance to EPS (JNCC, 2010). It is considered that assessment of auditory injury using PTS thresholds is sufficiently precautionary and allows a focus on where the larger risks of hearing damage are and to ensure that these risks are mitigated. In addition, the ranges of TTS overlap with disturbance ranges and many animals will actively avoid hearing damage by moving away or spending more time at or near the surface and that the consequences of any behavioural change are captured in the assessment of disturbance.

Table 7.20: Multiple pulse threshold values for determining PTS and TTS impact ranges for marine mammal impact assessment (NMFS, 2017)

	PTS		TTS	
	$SPL_{z\text{-}p(flat)}$ (dB re 1 µPa)	$SEL_{(HG)}$ (dB re 1 µPa²s)	$SPL_{z\text{-}p(flat)}$ (dB re 1 µPa)	$SEL_{(HG)}$ (dB re 1 µPa²s)
HF Cetacean (harbour porpoise)	202	155	196	140
Pinnipeds (harbour and grey seal)	218	185	212	170

Metrics are unweighted or flat weighted (flat), or weighted according to National Marine Fisheries Service (2016)(HG) with regard to the species' hearing group.

National Marine Fisheries Service (2016) Guidance for assessing auditory injury

7.11.55 Estimates of impact ranges using the latest NOAA guidance for assessing the effects of anthropogenic sound on marine mammal hearing (National Marine Fisheries Service 2016) have also been calculated and presented. To determine the range of auditory injury, National Marine Fisheries Service (2016) sets different threshold values for a set of 'functional hearing groups' adopted from Southall *et al*. (2007). For impulsive sound such as those generated during pile-driving, as in Southall *et al*. (2007) dual metric acoustic thresholds are provided for each hearing group: one unweighted peak SPL_{zp} value for 'instantaneous' PTS, and one weighted SEL_{cum} value for PTS induced by cumulative sound exposure, weighted to take account of species hearing differences. Noise modelling calculated impact ranges for both these instantaneous and cumulative thresholds, as well as impact ranges based on single strike SELs as described above for the Southall thresholds. The thresholds for PTS are given in Table 7.20. The Subacoustech INSPIRE model used in this assessment to model impact ranges is semi-empirical and has been calibrated with data for both SEL and SPL; therefore, it is able to be used to predict SPL.

7.11.56 It is important to consider throughout this assessment that the thresholds in use for auditory injury are thresholds for *the onset* of PTS, rather than being indicative of the level of noise at which all animals will definitely experience PTS. A study looking at the proportion of trials at different SELs that result in TTS in exposed bottlenose dolphins suggests that to induce TTS in 50% of animals it would be necessary to extrapolate well beyond the range of measured SEL levels (Finneran *et al*. 2005). Therefore, only a proportion of animals receiving noise doses at the stated thresholds, will actually develop PTS. The numbers presented in this chapter are therefore indicative of the numbers of animals at risk of PTS, rather than those predicted to develop PTS.

Thresholds – TTS onset

7.11.57 TTS ranges have been modelled and are presented for information but no assessment of magnitude of effect or overall effect significance has been undertaken. This is because basing any impact assessment on the impact ranges for TTS using current TTS-onset thresholds would overestimate the potential for any ecologically significant effect. This is because the species specific TTS-thresholds developed by National Marine Fisheries Service (2016), and those presented by Southall *et al.,* (2007) prior to that, describe those thresholds at which the onset of TTS is observed, which is, per their definition, a 6 dB shift in the hearing threshold, usually measured four minutes after sound exposure, which is considered as "*the minimum threshold shift clearly larger than any day-to-day or session-to-session variation in a subject's normal hearing ability"*, and which "*is typically the minimum amount of threshold shift that can be differentiated in most experimental conditions*." It is necessary to define TTS-onset thresholds, not to indicate any degree of signficant loss of hearing sensitivity, but in order to be able to predict where PTS might occur. Because expermients inducing PTS in animals are considered unethical, our ability to predict where PTS might occur relies on available data from humans and other terrestrial mammals that indicate that a shift in the hearing threshold of 40 dB may lead to the onset of PTS.

7.11.58 TTS is by definition, temporary, and the duration of effect at the threshold for TTS onset is likely to be low, expected to be less than an hour, and therefore unlikely to cause any major consequences for an animal. A large shift in the hearing threshold near to values that may cause PTS may however may require multiple days to recover (Finneran 2015). An impact range which encompasses such a large variation in the predicted effect on individuals is extremely difficult to interpret in terms of the potential consequences for individuals, and therefore assessing the magnitude and significance of effect based on these TTS ranges is impossible to do reliably. It is important to bear in mind that the quantification of the spatial extent over which any impact is predicted to occur in the environmental assessment process, is done so in order to inform an assessment of the potential magnitude and significance of an impact. Because the TTS thresholds are not intended to indicate a level of impact of concern *per se*, but are used to enable the prediction of where PTS might occur, they should not be used for the basis of any assessment of impact significance.

Thresholds - Disturbance

7.11.59 Unlike for thresholds of auditory injury, there are currently no established regulatory guidance documents and few published scientific articles providing clear advice on the appropriate thresholds for behavioural response to pile-driving noise. Southall *et al*. (2007) defined a severity score to categorize the effect of sound on marine mammals, with scores of zero to three used to categorise relatively minor and/ or brief behavioural reactions, scores four to six for behavioural changes that have a higher potential to affect foraging, reproduction or survival, and scores seven to nine for changes that are considered to likely affect vital rates. For the assessment of the behavioural impact of piling, responses with severity scores four to six are likely to require assessment as any responses affecting individual reproduction or survival have the potential to result in population level consequences.

7.11.60 Behavioural responses to noise are highly variable and are dependent on a variety of internal and external factors. Internal factors include past experience, individual hearing sensitivity, activity patterns, motivational and behavioural state at the time of exposure. Demographic factors such as age, sex and presence of dependent offspring can also have an influence. Environmental factors include the habitat characteristics, presence of food, predators, proximity to shoreline or other features. Responses themselves can also be highly variable, from small changes in behaviour such as longer intervals between surfacing (Richardson 1995) or a cessation in vocalisation (Watkins 1986) to more dramatic escape responses (Götz and Janik 2016).

7.11.61 This variability makes it extremely difficult to predict the likelihood of responses to underwater noise from piling. Even where empirical data exist on responses of animals in one particular environment, the context related variability described above makes it difficult to extrapolate from one study to a new situation. It is important to note that all any impact assessment can do, is predict the *potential* for behavioural responses, as definitive predictions of likelihood or magnitude are particularly difficult.

7.11.62 In light of this, this assessment has adopted a two-fold approach: the first approach is to use a fixed threshold to determine the range at which animals might respond, similar to the way in which impact ranges for PTS are calculated. The use of a fixed threshold assumes that all animals within the area of the threshold's calculated impact range display a behavioural reaction, while none of the animals outside this area will react. This is clearly biologically unrealistic. The proportion of animals responding will depend on the received sound level, which will decrease with increasing distance to the sound source. Therefore, a second approach has been adopted, using a dose-response curve. This approach is based on data suggesting that the proportion of animals responding depends on the loudness of the sound, with animals closer to the source, and therefore experiencing louder sounds, more likely to respond than those further away. For this approach, a series of noise contours were modelled and used to calculate the corresponding proportion of animals predicted to respond based on the dose-response curve.

Harbour Porpoise Disturbance (Displacement) Fixed Threshold Assessment

7.11.63 A threshold for harbour porpoise disturbance leading to potential displacement or avoidance can be derived from the study conducted by Lucke *et al*. (2009). The test porpoise showed an aversive behavioural reaction to the stimuli at received peak-peak SPL (SPL_{pp}) above 174 dB re 1 µPa or an SEL of 145 dB re 1 µPa^{2}s, with the SEL being cumulated over one airgun impulse (single strike SEL). Description of the behavioural response in Lucke *et al*. (2009) would appear to be consistent with classification on the Southall *et al*. (2007) severity score of four to six (four = moderate changes in response to trained behaviour, e.g., reluctance to return to station, long inter-trial intervals, six = refusal to initiate trained task), and would therefore be a suitable threshold to indicate a level at which a significant behavioural response would be expected. Although the Lucke *et al*. (2009) study is based on only one animal, field studies of the deterrence effect of pile-driving during wind farm construction estimate the onset of a behavioural reaction at SEL values in the range of 140 – 152 dB re 1 µPa^{2}s (summarised in Brandt *et al*. 2016). Thompson *et al*. (2013b) observed similar avoidance at levels of 145 – 151 dB re 1 µPa^{2}s for a very similar acoustic signal (a seismic airgun). For harbour porpoise, this impact assessment therefore adopted an SEL of 145 dB re 1 µPa^{2}s cumulated over one piling strike (single strike SEL) as fixed threshold for predicting the behavioural impact range.

Harbour Porpoise Disturbance (Displacement): Dose Response Assessment

7.11.64 The dose-response curve that has been be adopted in this assessment was generated from data from a study conducted by Brandt *et al*. (2011) on the response of harbour porpoises to pile-driving activity at the Horns Rev II wind farm. It reflects the proportional decrease in occurrence of harbour porpoises with decreasing range from the piling site, as measured using CPODs. To enable the application of the dose-response curve in this study, the corresponding single strike SEL levels for each point on the curve were determined. This is the same approach as described in Thompson *et al*. (2013c).

7.11.65 The study by Brandt *et al*. (2011) found that at closer distances (2.5 - 4.8 km) there was 100% avoidance, however, this proportion decreased significantly moving away from the pile-driving activity, such that at distances of 10.1 - 17.8 km, avoidance occurred in 32-49% of the population. At 21.2 km, the abundance reduced by just two percent.

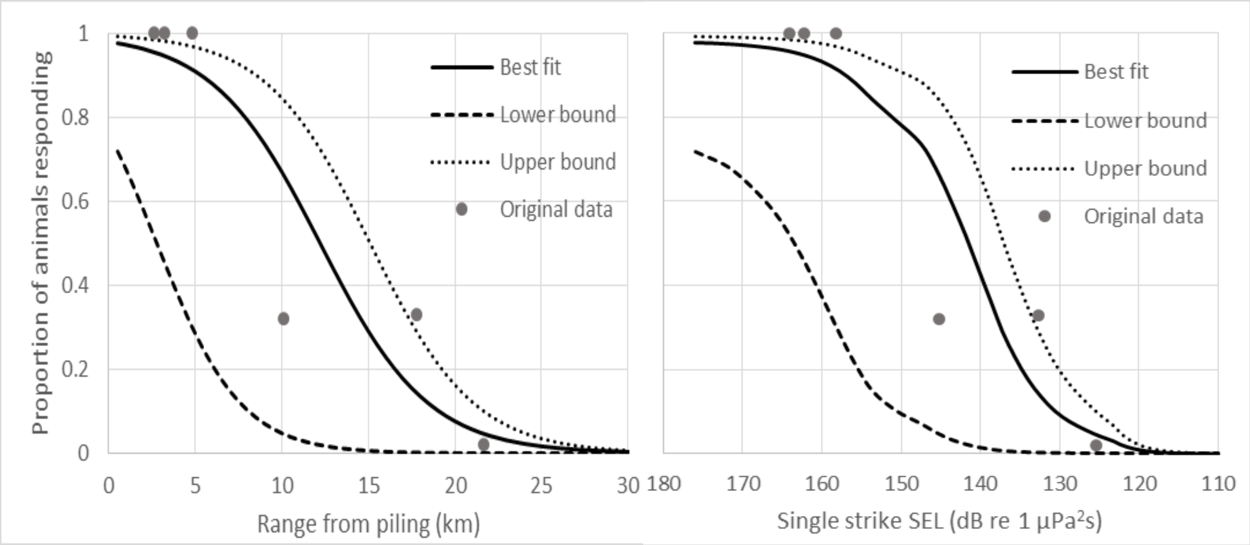


Figure 7.16: Relationship between the proportion of animals responding and distance from the piling site (left graph) and SEL$_{ss}$, respectively (right graph), based on passive acoustic monitoring results obtained by Brandt *et al.* (2011), and the resulting modelled relationship (Thompson *et al*. (2013c).

The best fit relationship is shown as a solid line. Standard errors were used to provide confidence limits around this relationship (upper and lower bounds). The upper bound was weighted to include all data points while the lower bound is based upon the standard anchor of the coefficients. For details see Thompson et al. (2013c).

Seal Disturbance (Displacement) Fixed Threshold Assessment

7.11.66 Until very recently there were no empirical data describing seal behavioural responses to pile-driving noise. For calculating behavioural impact ranges around piling sites for seals, the fixed TTS-onset threshold value given by Southall *et al*. (2007) for seals in water has often previously been adopted. However, TTS/fleeing is not the same thing as behavioural disturbance/displacement and, since both PTS and TTS using the NOAA thresholds are presented here, along with the behavioural dose-response assessment (see below), it was agreed with Natural England and CEFAS that the presentation of the previously used Southall TTS/fleeing fixed threshold for disturbance was not appropriate and so is not presented in this assessment.

Seal Disturbance (Displacement) Dose Response Assessment

7.11.67 A recent study by Russell *et al*. (2016) on the behaviour of 24 tagged harbour seals during pile driving at an offshore wind farm in the Wash, south-east England provides the opportunity to incorporate recent, empirical data on behavioural responses in seals into piling noise assessments. The seal telemetry data collected as part of this study overlapped with the piling of 27 piles which required on average 2887 blows each, a mean of 5.85 hours to install and a blow energy ranging between 100 - 2,000 kJ. The predicted maximum SPL at source at the maximum blow energy was 235 dB re 1 µPa$_{(p-p)}$ @ 1 m. The authors divided the study area in 5x5 km grid cells and predicted the seal density and a corresponding change in density for each cell between periods of piling and periods of non-piling. SEL$_{ss}$ values were modelled and averaged across the installation of all piles to generate a mean received SEL in the pa7.11.108rt of the water column with the lowest (and highest, respectively) predicted level for each of the grid cells. This allowed SEL values to be assigned to the predicted change in seal density. This analysis demonstrated that predicted seal abundance was reduced overall during piling activity across an area with a radius of 25 km from the piling activity, relative to seal abundance when no piling was taking place. It is important to note that during this study displacement was limited to piling activity only and within 2 hours of piling ending, seals were distributed as per during non-piling. Based on the data obtained by Russell *et al*. (2016), a dose-response curve was derived for depth-averaged received levels (mean SEL$_{ss}$) (Figure 7.17) to match those predicted by the noise modelling. See Appendix One for details of how this curve was derived.

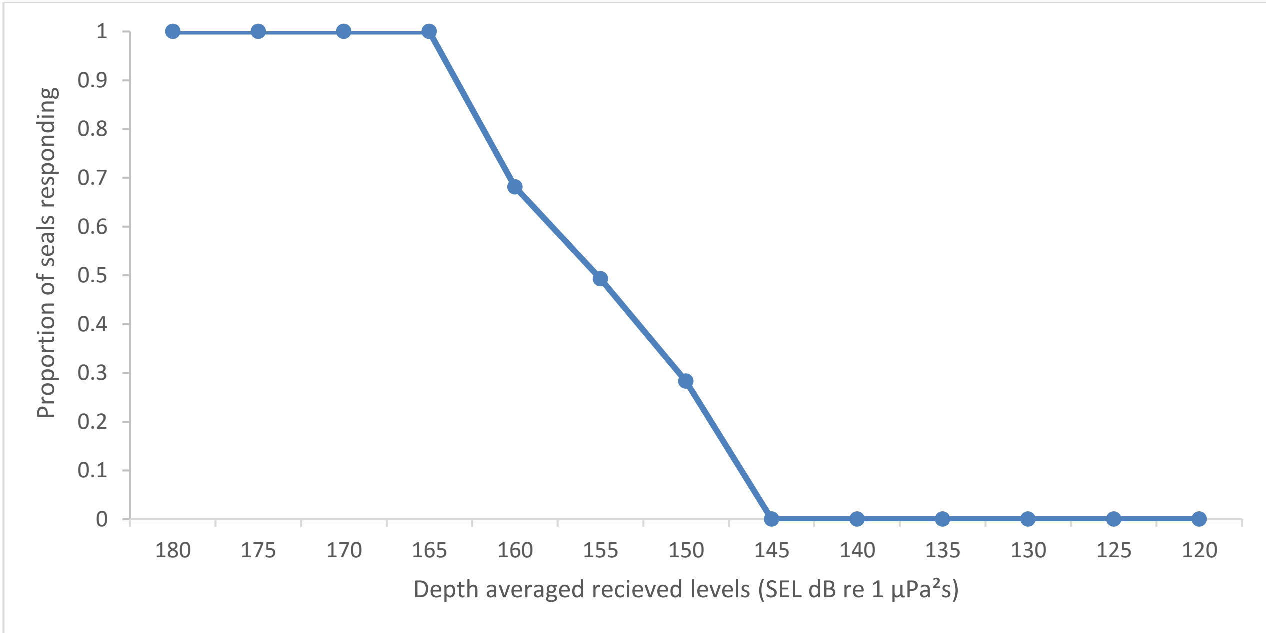


Figure 7.17: The harbour seal dose response curve derived from data presented in Russell *et al.* (2016).

Sensitivity of marine mammals to noise impacts from pile-driving

7.11.68 The ecological consequences of PTS for marine mammals is unknown. As discussed in paragraph 7.6.10 it is likely that the consequences will depend on the frequency band which has experienced PTS, and whether or not this frequency band is in the critical hearing sensitivity band for that species. For example, it is possible that PTS at frequencies outside of the critical hearing frequencies for a species will result in little effect. However, a PTS at frequencies that are required for critical activities such as echolocation, foraging and communication could have more severe impacts on individuals, potentially leading to changes in fitness and vital rates. Most piling noise is relatively low frequency, and therefore the effect of PTS at low frequencies, on a high frequency specialist species, such as the harbour porpoise, may be minimal. However, given how critical sound is for echolocation, foraging and communication in harbour porpoise, they have been assessed as High sensitivity to PTS.

7.11.69 Seals are less dependent on hearing for foraging but may rely on sound for communication and predator avoidance (e.g. Deecke *et al*. 2002). Hastie *et al*. (2015) reported that, based on calculations of SEL of tagged seals during the Lincs OWF construction, at least half of the tagged seals would have received a dose of sound greater than published thresholds for PTS. The data collected during the study covered the installation of 31 monopiles (5.2 m diameter) with a median strike interval of two s and a maximum of 2,000 kJ hammer energy, resulting in a total of 77,968 strikes during the five month study period. Based on the extent of the OWF construction in the Wash over the last ten years and the degree of overlap with the foraging ranges of harbour seals in the region (e.g. see Russell *et al*. 2016), and on the results of Hastie *et al*. (2015), it would not be unreasonable to suggest that a large number of individuals of the Wash population may have experienced levels of sound with the potential to cause hearing loss. The Wash harbour seal population has been increasing over this period which may provide an indication that either: a) seals are not developing PTS despite predictions of exposure that would indicate that they should; or b) that the survival and fitness of individual seals are not affected by PTS. A) could indicate that methods for predicting PTS are unreliable and over precautionary, b) could suggest a lack of sensitivity to the effects of PTS. As a result of the fact that hearing is not a primary sensory modality for foraging and navigation, but also reflecting the uncertainty surrounding consequences of PTS for individuals, the sensitivity of seals to PTS has been given a precautionary assessment of Medium.

7.11.70 Previous studies have shown that harbour porpoise are displaced from the vicinity of piling events. For example, studies at wind farms in the German North Sea have recorded large declines in porpoise detections close to the pile (> 90% decline at noise levels above 170 dB) with decreasing effect with increasing distance from the pile (25% decline at noise levels between 145 and 150 dB) (Brandt *et al*. 2016). The seven windfarms included in the Brandt *et al*. (2016) study were piled between 2010 and 2013 and included monopile, jacket and tripod foundations. The detection rates revealed that porpoise were only displaced from the piling area in the short-term (1 - 3 days) (Brandt *et al*. 2011, Dähne *et al*. 2013, Brandt *et al*. 2016). Harbour porpoise are small cetaceans which makes them vulnerable to heat loss and requires them to maintain a high metabolic rate with little energy remaining for fat storage. This makes them vulnerable to rapid starvation if they are unable to obtain sufficient levels of prey intake. Studies using Digital Acoustic Recording Tags (DTAGs) have shown that porpoise tagged after captured in pound nets foraged on small prey nearly continuously during both the day and the night on their release (Wisniewska *et al*. 2016). Although it can't be ruled out that this was a short-term response to capture in nets this could mean that if the foraging efficiency of harbour porpoise is disturbed or if they are displaced from a high-quality foraging ground, and are unable to find suitable alternative feeding grounds, they could potentially be at risk of changes to their overall fitness and vital rates if they are not able to compensate and obtain sufficient food intake in order to meet their metabolic demands. However, it is important to note that the studies providing evidence for the responsiveness of harbour porpoises to piling noise have not provided any evidence for subsequent individual consequences. It could be that porpoises are quick to respond because they are very mobile and wide ranging and can move quickly to alternative areas to feed if they perceive a risk. Sensitivity may not always equal vulnerability to consequences. However due to observed responsiveness to piling noise harbour porpoises have been assessed as having Medium sensitivity to disturbance and resulting displacement from foraging grounds.

7.11.71 A study of tagged harbour seals in the Wash has shown that they are also displaced from the vicinity of piles during pile-driving activities. Russell *et al*. (2016) showed that seal abundance was significantly reduced during piling activities and the duration of the displacement was only in the short-term as seals returned to non-piling distributions within two hours after the end of a pile-driving event. Unlike harbour porpoise, harbour seals store energy in a thick layer of blubber, which means that they are more tolerant of periods of fasting when hauled out and resting between foraging trips, and when hauled out during the breeding and moulting periods. Therefore, they are unlikely to be particularly sensitive to short-term displacement from foraging grounds during periods of active piling. Juvenile harbour seals may be more sensitive to displacement from foraging grounds due to a smaller body size and higher energetic needs. Therefore, harbour seals have been assessed as having Medium sensitivity to disturbance and resulting displacement from foraging grounds during pile-driving events.

7.11.72 Grey seals are capital breeders and store energy in a thick layer of blubber, which means that they are tolerant of periods of fasting when hauled out and resting between foraging trips, and when hauled out during the breeding and moulting periods. Grey seals are also highly adaptable to a changing environment and are capable of adjusting their metabolic rate and foraging tactics, to compensate for periods of changing energy demand and supply (e.g. Beck *et al*. 2003, Sparling *et al*. 2006). Grey seals are also very wide ranging and are capable of moving very large distances between different haul out and foraging regions (e.g. Russell *et al*. 2013). Therefore, they are unlikely to be sensitive to short-term displacement from foraging grounds during periods of active piling. As such, grey seals seal have been assessed as having Low sensitivity to disturbance and resulting displacement from foraging grounds during pile-driving events.

7.11.73 A summary of the sensitivity of each species to piling noise related effects is provided in Table 7.21.

Table 7.21: Summary of marine mammal sensitivity to each potential pile-driving noise impact

Species	Lethal effect or injury	Permanent threshold shift (PTS)	TTS/ fleeing	Behavioural disturbance/ potential avoidance
Harbour porpoise	High	High	Medium	Medium
Grey seal	High	Medium	Low	Low
Harbour seal	High	Medium	Low	Medium

Lethal and non-auditory injury – all marine mammals

7.11.74 The pile-driving installation is unlikely to result in radiated noise levels sufficient to cause instantaneous mortality in marine mammals beyond a few metres from the pile at the start of piling for either monopiles or pin piles (Table 7.22 and Table 7.19). As a result of the establishment of mitigation zones through the MMMP, as well as the amount of pre-piling vessel activity, there should be no marine mammals within a few metres of the pile. Therefore, there is no potential for any effect.

Table 7.22: Impact ranges (in meters) for lethal and non-auditory injury impacts for monopiles

	100% blow energy 5,000 kJ					
	240 dB SPL_{peak} (Lethal Injury)			**220 dB SPL_{peak} (non-auditory injury)**		
	Max	**Mean**	**Min**	**Max**	**Mean**	**Min**
East Location	4	4	3	53	53	52
South West Location	4	4	3	49	49	48
	10% blow energy 500 kJ					
	240 dB SPL_{peak}			**220 dB SPL_{peak}**		
	Max	**Mean**	**Min**	**Max**	**Mean**	**Min**
East Location	< 1	< 1	< 1	14	14	13
South West Location	< 1	< 1	< 1	13	13	12

Table 7.23: Impact ranges (in meters) for lethal and non-auditory injury impacts for pinpiles

	100% blow energy 5,000 kJ					
	240 dB SPL_{peak}			**220 dB SPL_{peak}**		
	Max	**Mean**	**Min**	**Max**	**Mean**	**Min**
East Location	3	3	2	36	36	35
South West Location	3	3	2	34	34	33
	10% blow energy 500 kJ					
	240 dB SPL_{peak}			**220 dB SPL_{peak}**		
	Max	**Mean**	**Min**	**Max**	**Mean**	**Min**
East Location	< 1	< 1	< 1	10	10	9
South West Location	< 1	< 1	< 1	9	9	8

Results of piling noise assessment for harbour porpoise

'Instantaneous' PTS

7.11.75 The maximum PTS impact range for porpoise is 660 m for the installation of monopiles at Location East. This suggests that a mitigation zone of up to 700 m would be sufficient to mitigate against instantaneous PTS, although the exact distance of the mitigation zone should be determined post-consent, once further information is available, including a full pile drivability assessment and the refinement of the piling profiles and hammer energies likely to be used.

7.11.76 Therefore, with the adoption of an appropriate mitigation zone prior to the onset of piling, and the implementation of a soft start, the risk of instantaneous PTS to any harbour porpoise is extremely low. The magnitude of the impact is therefore Negligible. As the sensitivity of harbour porpoises to PTS is High, this results in an effect of **Minor** adverse significance, and therefore not significant in EIA terms.

7.11.77 Table 7.24 presents the estimated impact ranges for instantaneous PTS at the first soft start hammer energy (ten percent of full hammer energy) at the start of each piling operation for harbour porpoises. All predicted impact ranges are less than 500 m, therefore the establishment of a mitigation zone prior to the onset of piling following current JNCC (2010) guidelines will prevent exposure of individuals to levels of noise which could lead to the instantaneous onset of PTS from pile strikes.

Table 7.24: Estimated impact areas and ranges for harbour porpoise 'instantaneous' PTS at the hammer energy employed during the soft start (10% of full hammer energy)

	East		South west	
	Monopile (500 kJ)	Pin Pile (270 kJ)	Monopile (500 kJ)	Pin Pile (270 kJ)
NOAA (NMFS, 2016)	**Mean range (m)**			
unweighted SPL_{peak} 202 dB re 1µPa	160	110	150	100

Table 7.25: Estimated impact areas and ranges for harbour porpoise 'instantaneous' PTS at full hammer energy

	East				South west			
	Monopile (5,000 kJ)		Pin Pile (2,700 kJ)		Monopile (5,000 kJ)		Pin Pile (2,700 kJ)	
NOAA (NMFS, 2016)	Area (km^2)	Range (km)	Area (km^2)	Range (km)	Area (km^2)	Range (km)	Area (km^2)	Range (km)
unweighted SPL_{peak} 202 dB re 1µPa	1.37	**0.66**	0.63	**0.45**	0.993	**0.56**	0.474	**0.39**

PTS from cumulative exposure (over whole piling event)

7.11.78 The NOAA guidance (National Marine Fisheries Service 2016) proposes a dual criteria whereby impact ranges based on both a peak SPL threshold and a cumulative exposure SEL threshold over the duration of the event, should be calculated and the higher of the two exposure calculations should be adopted for assessment. However, as discussed above this assessment explores the potential for PTS as a result of exposure to piling noise over a 24 hour period separately from instantaneous PTS. This is largely as a result of:

- The need to assess likelihood of 'instantaneous' PTS from exposure to the magnitude of a single pile strike at the onset of piling – before animals are given the chance to move away; and
- The additional uncertainties involved in modelling the exposure of an animal over several hours.

7.11.79 There is likely to be much more uncertainty associated with the cumulative exposure estimate due to the difficulty in predicting the true levels of sound exposure over long periods of time, as a result of uncertainties about animal responsive movement, the position of animals in the water column over such extended periods of time, the extent of TTS recovery between pulses or in breaks in piling and the extent to which pulsed sound loses it's pulse-like characteristics over distance from the source. Pulses increase in duration with distance and therefore subsequent pulses may blend together to form more continuous noise. In addition, the rise time of the pulse increases with distance. Short pulses of high peak pressures and fast rise times are predicted to be important elements of observed responses to pulsed signals, both in terms of physical damage and behavioural responses. Different thresholds are adopted for pulsed noise relative to non-pulsed noise, with pulsed noise predicted to have more of an impact than non-pulsed noise, therefore being associated with lower thresholds. The effect of a change from pulsed to non-pulsed noise over the range over which cumulative exposure is modelled (often tens of kilometres) would result in much smaller impact ranges.

7.11.80 In calculating the received noise level that animals are likely to receive during the whole piling sequence, a soft start was assumed with the first 20 minutes at ten percent of maximum hammer energy, the following 40 minutes ramping up between 10 - 100% with full hammer energy being reached after a total of one hour. Strike rate was assumed to be 30 strikes per minute. All animals were assumed to start moving away at a swim speed of 1.5 ms^{-1} once the piling has started (based on reported sustained swimming speeds for harbour porpoises from Otani *et al*. (2000). The calculated impact ranges therefore represent the minimum starting distances from the piling location for animals to escape and prevent them from receiving a dose higher than the threshold. Harbour porpoises are capable of swimming faster than this, e.g. Otani *et al*. (2000) reports speeds of up to 4.3 ms^{-1}, and it is likely any 'fleeing' response may be, at least initially, higher than 1.5 ms^{-1} and therefore the cumulative SEL modelled here is likely to be an overestimate.

7.11.81 Impact ranges based on NOAA thresholds were calculated and the largest impact ranges (960 m) are for the installation of a pin pile at the east location. The larger impact range for the pin pile despite the fact that it is installed using a lower hammer energy is a result of the weighting applied – the installation of a smaller pin pile generates a larger amount of high frequency noise (compared to a monopile) and therefore less energy is filtered out of the signal, resulting in larger impact ranges. Therefore, there is no difference in the worst-case spatial and temporal scenarios for harbour porpoises for PTS as a result of cumulative exposure – the installation of pin piles represents worst-case for both.

7.11.82 As has been discussed above, and in a number of other previous OWF marine mammal noise impact assessments, there is a great deal of uncertainty associated with these predictions. Therefore, these ranges should be used to acknowledge the risk of PTS as a result of cumulative exposure to piling noise but the ranges themselves should be interpreted with caution. For this reason, no assessment has been made of the significance of PTS resulting from cumulative exposure.

7.11.83 The potential for exposure to noise levels that could cause PTS over the whole piling sequence can be reduced by extending the mitigation zone out to the maximum range (across all species) predicted by the NOAA thresholds of 960 m.

Table 7.26: Estimated impact ranges for PTS as a result of cumulative exposure to noise over a whole piling event

	East				South west			
	Monopile (5,000 kJ)		Pin Pile (2,700 kJ)		Monopile (5,000 kJ)		Pin Pile (2,700 kJ)	
	Area (km^2)	Range (km)	Area (km^2)	Range (km)	Area (km^2)	Range (km)	Area (km^2)	Range (km)
weighted SEL_{cum} 155 dB re 1 $\mu Pa^2 s$ **(NMFS, 2016)**	0.010	**0.060**	3.000	**0.960**	0.004	**0.040**	0.338	**0.330**

TTS Onset

7.11.84 Using the SPL_{peak} threshold, the maximum predicted range of TTS for harbour porpoise was 1.5 km for monopile (5,000 kJ) and 1.0 km for pinpiles (2,700 kJ) at the east location. Ranges were smaller for the south-west location with a maximum of 1.2 km for monopiles (5,000 kJ) and 0.85 km for pinpiles (2,700 kJ) (Table 7.27).

7.11.85 Using the SEL_{cum} threshold, the maximum predicted range of TTS for harbour porpoise was 9.5 km for monopile (5,000 kJ) and 19 km for pinpiles (2,700 kJ) at the east location. Ranges were smaller for the south-west location with a maximum of 3.9 km for monopiles (5,000 kJ) and 9.8 km for pinpiles (2,700 kJ) (Table 7.27).

7.11.86 These TTS onset ranges do not represent an impact which is considered to be of biological significance across the whole area indicated by these ranges, but are intended to indicate the level of noise exposure which could induce any measureable threshold shift. TTS within these ranges could range from a small (~6 dB) reduction in hearing sensitivity that would recover in less than hour, to more significant reductions in hearing sensitivity that may last for a number of days. Reductions in hearing sensitivity may affect an animal's ability to forage, avoid predation and communicate but the TTS onset ranges alone do not allow us to assess the magnitude or significance of the likely consequences for individuals and ultimately populations of the predicted extent over which any TTS might occur. Mitigation in place to reduce the risk of PTS to marine mammals will also reduce the risk of TTS below the ranges presented here.

Table 7.27: Estimated impact ranges for TTS for harbour porpoise

	East						South west					
	Monopile 5,000 kJ			Pinpile 2700 kJ			Monopile 5,000 kJ			Pinpile 2700 kJ		
	Max	Mean	Mix	Max	Mean	Min	Max	Mean	Mix	Max	Mean	Min
NOAA unweighted SPL_{peak} 196 dB re 1 μPa^2												
Range (km)	**1.5**	1.5	1.5	**1.0**	1.0	1.0	**1.2**	1.2	1.2	**0.85**	0.85	0.84
$NOAA_{HF}$ weighted SEL_{cum} 140 dB dB re 1 μPa^2.s												
Range (km)	**9.5**	6.8	4.5	**19**	14	8.6	**3.9**	2.9	2.1	**9.8**	7.1	4.1

Disturbance (Displacement) Fixed Threshold Assessment

7.11.87 Based on a fixed threshold of an SEL of 145 (Lucke *et al*. 2009), the estimated impact ranges for 'possible avoidance' range from 16.8 km for a pin pile installation at the south-west location to a maximum of 28.4 km for the installation of a monopile at the east location (Table 7.28, Figure 7.18 and Figure 7.19).

7.11.88 Similar to the PTS impact ranges presented above, the impact ranges for the east location are larger than the equivalent scenario at the south-west location. This is largely as a result of the deeper water on the eastern boundary of the site which extends eastwards from the site, resulting in more favourable conditions for noise propagation.

7.11.89 Figure 7.18 and Figure 7.19 indicate that there will be no physical barrier to harbour porpoise movement around the Thanet Extension site as a result of the piling. There is sufficient area outwith the impact contour to allow porpoises to move from the North Sea area to other parts of their range, including the channel.

7.11.90 The impact range for possible disturbance is four km smaller for pin piles compared to monopiles at the east location, resulting in a 21% smaller impact area. At the south-west location the equivalent difference was 2.4 km in range and a 25% smaller impact area. However, the installation of pin piles is expected to take up to 40% longer therefore the smaller area of impact is likely to occur over a longer period of time. Which of these scenarios will lead to the overall highest level of impact is hard to determine. There is very little empirical information on how the duration of piling interacts with the size of the impact area and how variation in these parameters affects the total number of animals affected or the severity of the consequences of any effects. The duration of the breaks between piling is another parameter that could affect the total level of impact. With a shorter duration between piling events expected for pin pile installation there may be less opportunity for animals to come back to site between piling events and therefore disturbance may occur over an even longer period of time. At this stage of project design it is very difficult to predict a realistic piling schedule and fully ascertain which scenario represents the realistic worst-case. This assessment assumes that for disturbance and possible avoidance, monopile installation represents a spatial worst-case, and pin pile installation represents a temporal worst-case.

Table 7.28. Estimated impact ranges for 'possible avoidance' for harbour porpoises based on a threshold of 145 dB (re 1 µPa^{2}s) from Lucke *et al.* (2009)

	East				South West			
	Monopile (5,000 kJ)		Pin Pile (2,700 kJ)		Monopile (5,000 kJ)		Pin Pile (2,700 kJ)	
	Area (km^2)	Range (km)	Area (km^2)	Range (km)	Area (km^2)	Range (km)	Area (km^2)	Range (km)
Lucke *et al.* (2009)	**mean**				**mean**			
unweighted SEL_{ss} 145 dB re 1 µPa^{2}s	2,670	28.4	2,100	24.3	1,261	19.2	947	16.8

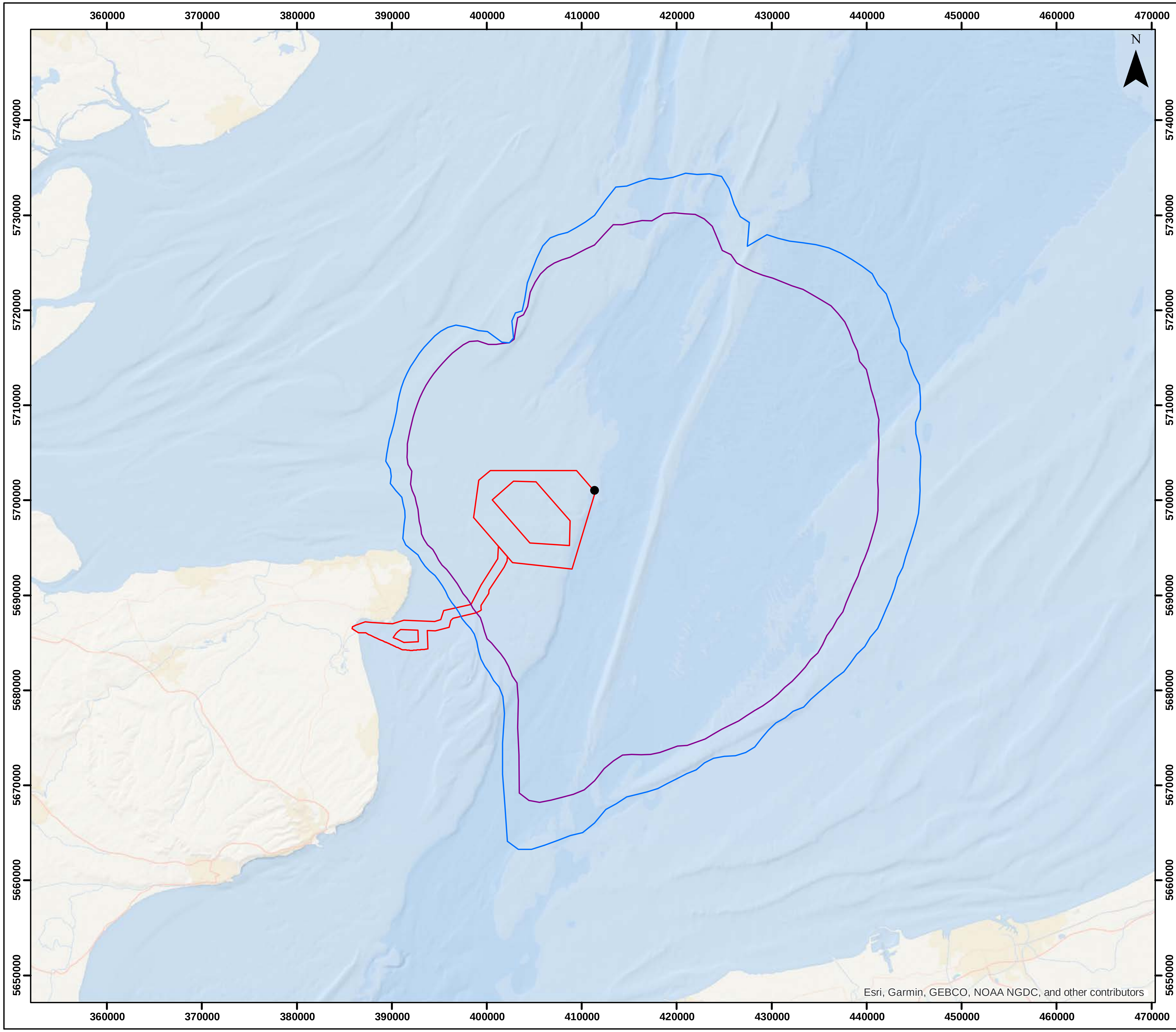


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Figure 7.18

Porpoise Behavioural Response Isopleths Lucke et al. (2009)

Legend

- Offshore Red Line Boundary
- East Model Location

Monopile

- unweighted SELss 145 dB

Pin Pile

- unweighted SELss 145 dB

Datum: ETRS 1989
Projection: UTM31N

1:400,000 — 0, 4.5, 9 km — 0, 2, 4 nm

Drg No	ES Vol 2 Chpt 7 Fig 7.18			Figure 7.18
Rev	0.1	Date	23/05/2018	
By	RP	Layout	N/A	

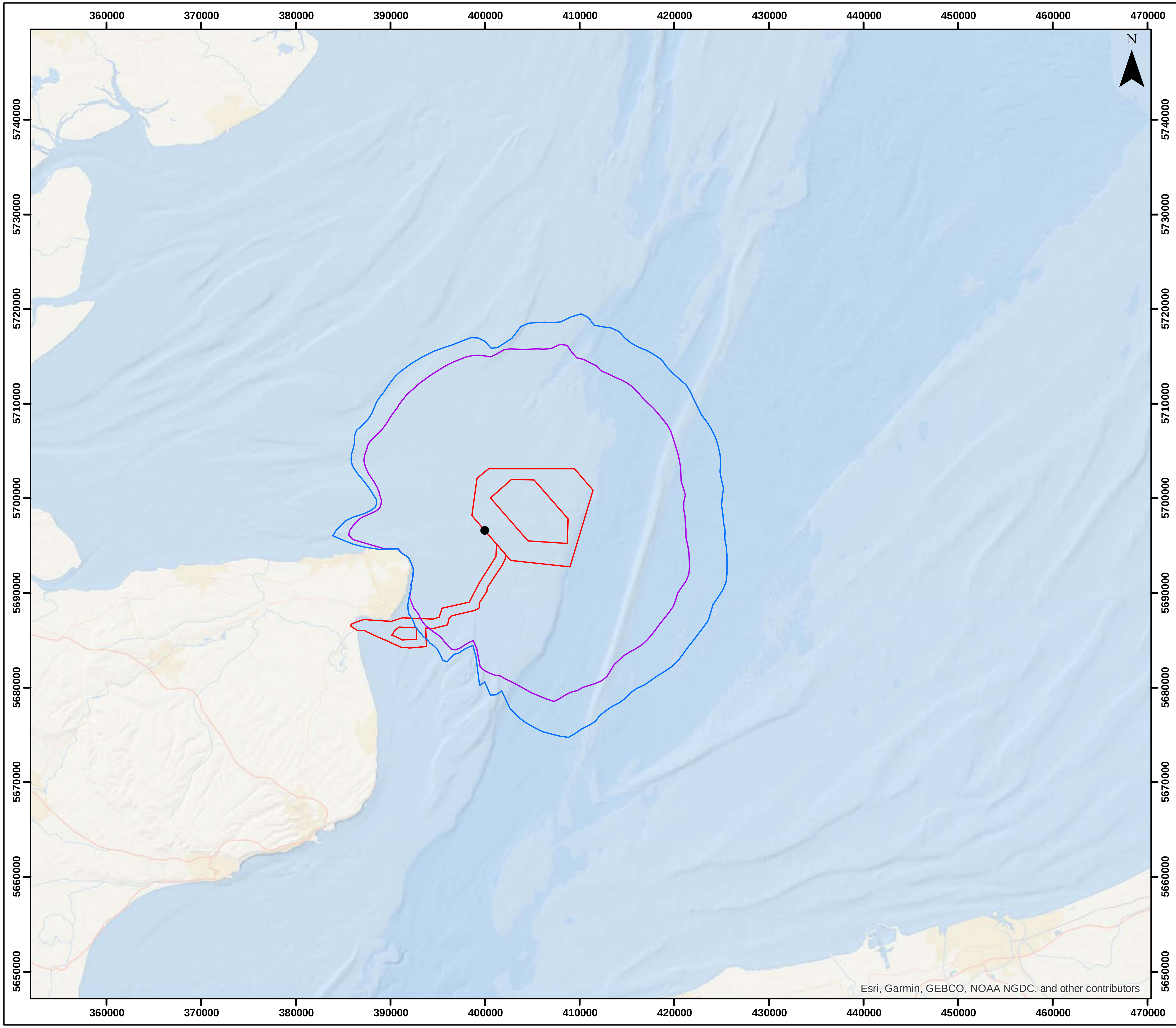

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Figure 7.19

Porpoise Behavioural Response Isopleths Lucke et al. (2009)

Legend

- Offshore Red Line Boundary
- South West Model Location

Monopile

- unweighted SELss 145 dB

Pin Pile

- unweighted SELss 145 dB

Datum: ETRS 1989
Projection: UTM31N

1:400,000 0 4.5 9 km 0 2 4 nm

Drg No	ES Vol 2 Chpt 7 Fig 7.19		
Rev	0.1	Date	23/05/2018
By	RP	Layout	N/A

Figure 7.19

Table 7.29. Number of harbour porpoises within the impact area of the behavioural fixed threshold based on Lucke *et al.* (2009)

	East		South West	
	Monopile (5,000 kJ)	**Pin Pile (2,700 kJ)**	**Monopile (5,000 kJ)**	**Pin Pile (2,700 kJ)**
SCANS III				
Number of animals	**1,621** (589 – 3,036)	**1,275** (464 – 2,388)	**766** (278 – 1,434)	**575** (209 – 1,076)
% of reference population	**0.47%** (0.2 - 0.9)	**0.37%** (0.1 - 0.7)	**0.22%** (0.08 - 0.4)	**0.17%** (0.06 - 0.3)
APEM surveys				
Number of animals	**1,631** (0 – 10,975)	**1,283** (0 – 8,633)	**770** (0 – 5,184)	**578** (0 – 3,890)
% of reference population	**0.47%** (0 – 3.18)	**0.37%** (0 – 2.50)	**0.22%** (0 – 1.50)	**0.17** (0 – 1.13)

The SCANS III numbers are based on the mean density estimate (+/- 95% confidence interval) and are also given as the percentage of the reference population. The APEM numbers are based on the mean density estimate across all surveyed months (minimum and maximum) and are also given as the percentage of the reference population.

7.11.91 In order to calculate the number of individuals that could be exposed to this impact using the fixed threshold, the estimated density for the area has been multiplied by the total area of impact. Using the SCANS III density estimate of 0.607 harbour porpoises per km^2, these impact ranges translate to a prediction of between 575 and 1,621 porpoises potentially experiencing noise levels high enough to elicit a behavioural response. This equates to between 0.17% and 0.47% of the reference population. Using the average site specific APEM density estimate of 0.610 harbour porpoises per km^2, these impact ranges translate to a prediction of between 578 and 1,631 porpoises potentially experiencing noise levels high enough to elicit a behavioural response. This equates to between 0.17% and 0.47% of the reference population.

7.11.92 Figure 7-18 displays the relationship used in the dose response analysis. The dose-response curve adopted in this assessment was developed by Thompson *et al*. (2013c) and was generated from data collected during a study conducted by Brandt *et al*. (2011) on the response of harbour porpoises to pile-driving activity at the Horns Rev II wind farm. It reflects the proportional decrease in occurrence of harbour porpoises with decreasing range from the piling site, as measured using CPODs. The dose-response curve published in Thompson *et al*. (2013c) reveals the relationship between the proportion of animals responding and the distance to the piling site, and the corresponding dB_{ht} level[3], respectively. To enable the application of the dose-response curve in our study, the SEL_{ss} values corresponding to the distance to the piling site were used. These were provided by Subacoustech, who were co-authors on Thompson *et al*. (2013c). From the dose-response curve, the proportion of animals responding to a certain SEL value were used as multipliers to calculate the number of animals responding within each ring. For details of the derived multipliers used to calculate the numbers of animals within each contour, see paragraphs 7.11.64 *et seq* and Figure 7.16.

7.11.93 Figure 7.20, Figure 7.21, Figure 7.22 and Figure 7.23 display the noise contours for the 5 dB incremental levels used in the dose response calculations.

7.11.94 In order to calculate the number of individuals that might be predicted to respond to the piling noise using the dose response approach, the estimated density for each area has been multiplied by the total area within each contour 'ring' and then multiplied by a value that represents the proportion of animals expected to respond within that contour, based on the dose response curve. It could be argued that applying a dose response curve reflecting spatially explicit estimates of sound level, should be combined with spatially explicit estimates of animal density. However, there were no spatially explicit density estimates over the relevant area for harbour porpoise, but using the SCANS III density estimate of 0.607 harbour porpoises per km2, and the dose response curve presented below, these impact ranges translate to a prediction of between 788 and 1,880 porpoises potentially experiencing noise levels high enough to elicit a behavioural response. This equates to between 0.23% and 0.54% of the reference population (Table 7.30). These numbers would be expected to reduce using spatially explicit density estimates because the area of likely highest density of porpoises (north east of Thanet Extension– see Figure 7.4) in the region, is likely to experience the lowest amounts of noise from piling.

[3] The dB_{ht} level is a measure of the loudness of a sound perceived by different species, taking into account different species hearing abilities. See Nedwell *et al*. (2007) for further details.

Table 7.30 Number of harbour porpoises within the impact area of the behavioural dose response method based on Thompson *et al*. (2013c)

	East		South West	
	Monopile (5,000 kJ)	**Pin Pile (2,700 kJ)**	**Monopile (5,000 kJ)**	**Pin Pile (2,700 kJ)**
SCANS III				
Number of animals	**1,880** (265 – 2,558)	**1,546** (188 – 2,157)	**989** (122 – 1,404)	**788** (87 – 1,146)
% of reference population	**0.54%** (0.07 - 0.73)	**0.45%** (0.05 - 0.61)	**0.29%** (0.03 - 0.40)	**0.23%** (0.02 - 0.32)
APEM surveys				
Number of animals	**1,888** (265 – 2,577)	**1,551** (188 – 2,168)	**989** (122 – 1,405)	**788** (87 – 1,146)
% of reference population	**0.55%** (0.08 – 0.75)	**0.45%** (0.05 – 0.63)	**0.29%** (0.04 – 0.41)	**0.23%** (0.03 – 0.33)

The SCANS III numbers are based on the mean density estimate (+/- 95% confidence interval) and are also given as the percentage of the reference population. The APEM numbers are based on the mean density estimate across all surveyed months (lower and upper bound of the dose response curve) and are also given as the percentage of the reference population.

7.11.95 Given these low percentages of the population predicted to be affected across both methods, the fact that the piling will be intermittent over a period of approximately four months, lasting a maximum total amount of active piling of up to 170 hours for monopiles and 230 hours for pin piles, with breaks in between pile installations therefore the effects are considered to be temporary and reversible, affecting only a small proportion of the relevant MUs, and the magnitude of the impact is assessed as Low. Given that harbour porpoises have a Medium sensitivity to the impact of potential avoidance this results in a **Minor** significance, which is not significant in EIA terms.

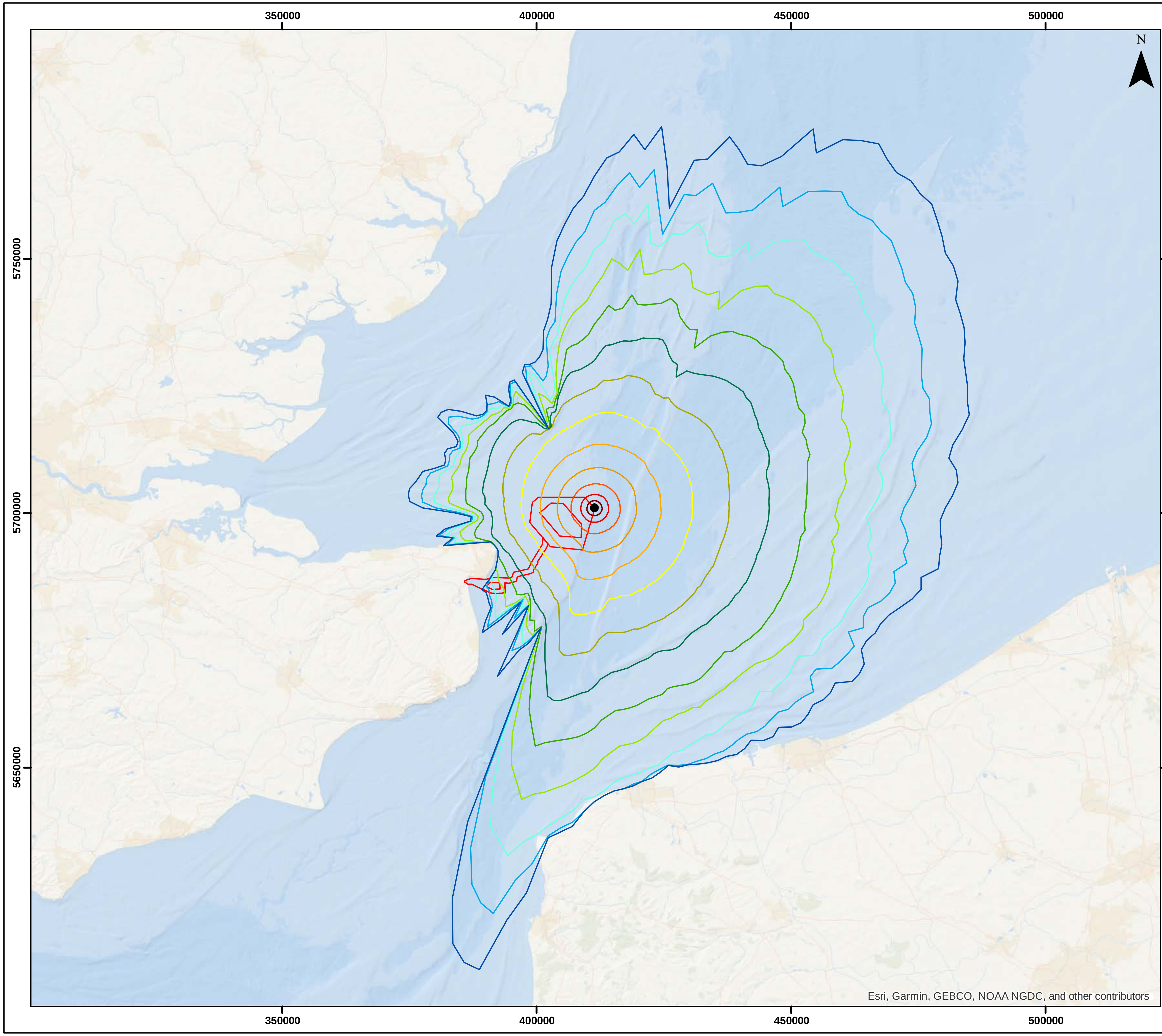

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Figure 7.20

Porpoise & Seal Monopile Behavioural Dose Response Isopleths

Legend

- Offshore Red Line Boundary
- East Model Location

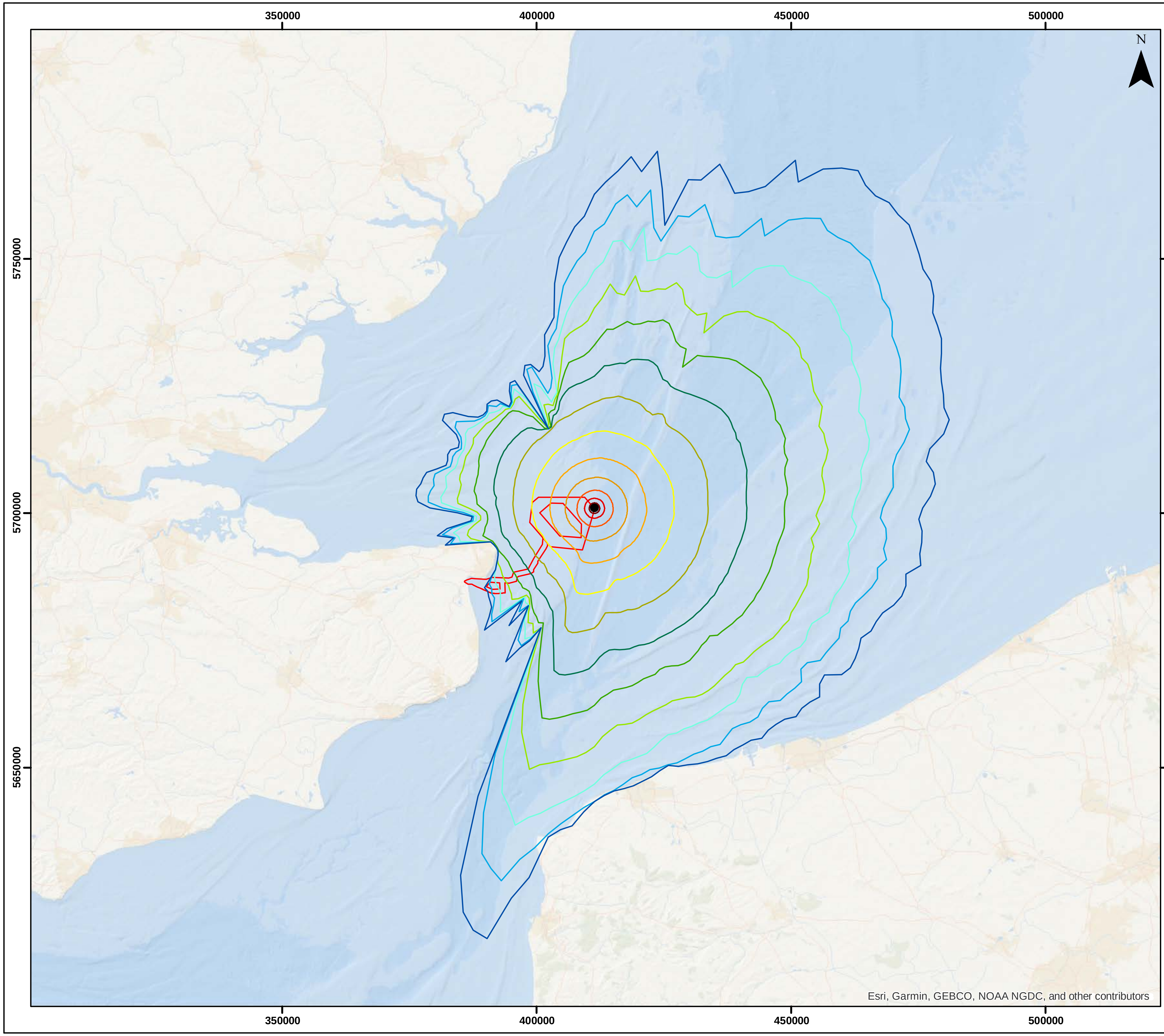
Unweighted SELss isopleths

- 120 dB re 1µPa²s
- 125 dB re 1µPa²s
- 130 dB re 1µPa²s
- 135 dB re 1µPa²s
- 140 dB re 1µPa²s
- 145 dB re 1µPa²s
- 150 dB re 1µPa²s
- 155 dB re 1µPa²s
- 160 dB re 1µPa²s
- 165 dB re 1µPa²s
- 170 dB re 1µPa²s
- 175 dB re 1µPa²s
- 180 dB re 1µPa²s

Datum: ETRS 1989
Projection: UTM31N

1:750,000 0 8 16 km 0 4.5 9 nm

Drg No	ES Vol 2 Chpt 7 Fig 7.20			Figure 7.20
Rev	0.1	Date	23/05/2018	
By	RP	Layout	N/A	



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THANET EXTENSION OFFSHORE WIND FARM

Figure 7.21

Porpoise & Seal Pin Pile Behavioural Dose Response Isopleths

Legend

- Offshore Red Line Boundary
- East Model Location

Unweighted SELss isopleths

- 120 dB re 1µPa²s
- 125 dB re 1µPa²s
- 130 dB re 1µPa²s
- 135 dB re 1µPa²s
- 140 dB re 1µPa²s
- 145 dB re 1µPa²s
- 150 dB re 1µPa²s
- 155 dB re 1µPa²s
- 160 dB re 1µPa²s
- 165 dB re 1µPa²s
- 170 dB re 1µPa²s
- 175 dB re 1µPa²s
- 180 dB re 1µPa²s

Datum: ETRS 1989
Projection: UTM31N

1:750,000 — 0, 8, 16 km; 0, 4.5, 9 nm

Drg No	ES Vol 2 Chpt 7 Fig 7.21			Figure 7.21
Rev	0.1	Date	23/05/2018	
By	RP	Layout	N/A	

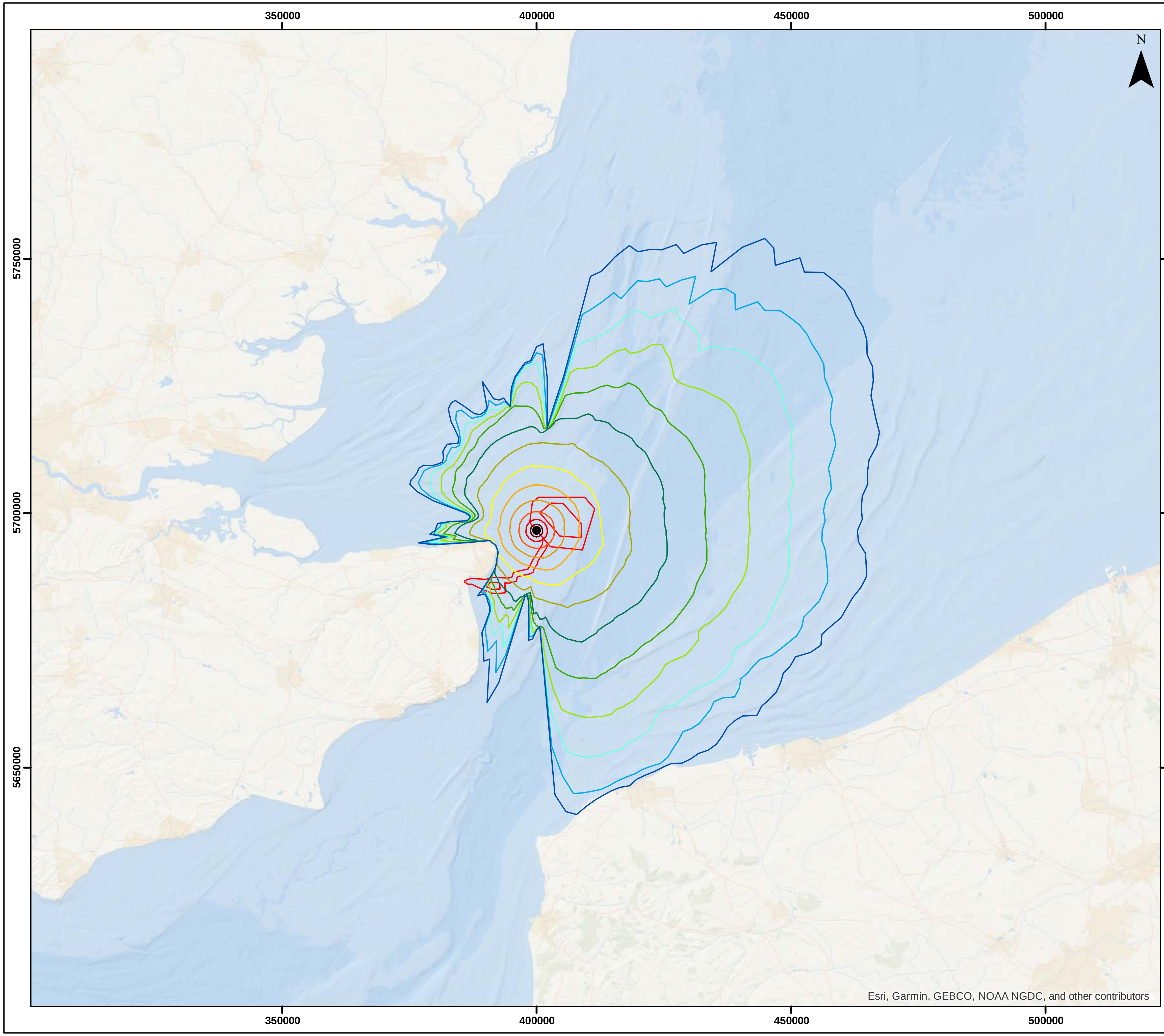

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Figure 7.22

Porpoise & Seal Monopile Behavioural Dose Response Isopleths

Legend

- Offshore Red Line Boundary
- South West Model Location

Unweighted SELss isopleths

- 120 dB re 1µPa²s
- 125 dB re 1µPa²s
- 130 dB re 1µPa²s
- 135 dB re 1µPa²s
- 140 dB re 1µPa²s
- 145 dB re 1µPa²s
- 150 dB re 1µPa²s
- 155 dB re 1µPa²s
- 160 dB re 1µPa²s
- 165 dB re 1µPa²s
- 170 dB re 1µPa²s
- 175 dB re 1µPa²s
- 180 dB re 1µPa²s

Datum: ETRS 1989
Projection: UTM31N

1:750,000 — 0 8 16 km — 0 4.5 9 nm

Drg No	ES Vol 2 Chpt 7 Fig 7.22			Figure 7.22
Rev	0.1	Date	23/05/2018	
By	RP	Layout	N/A	

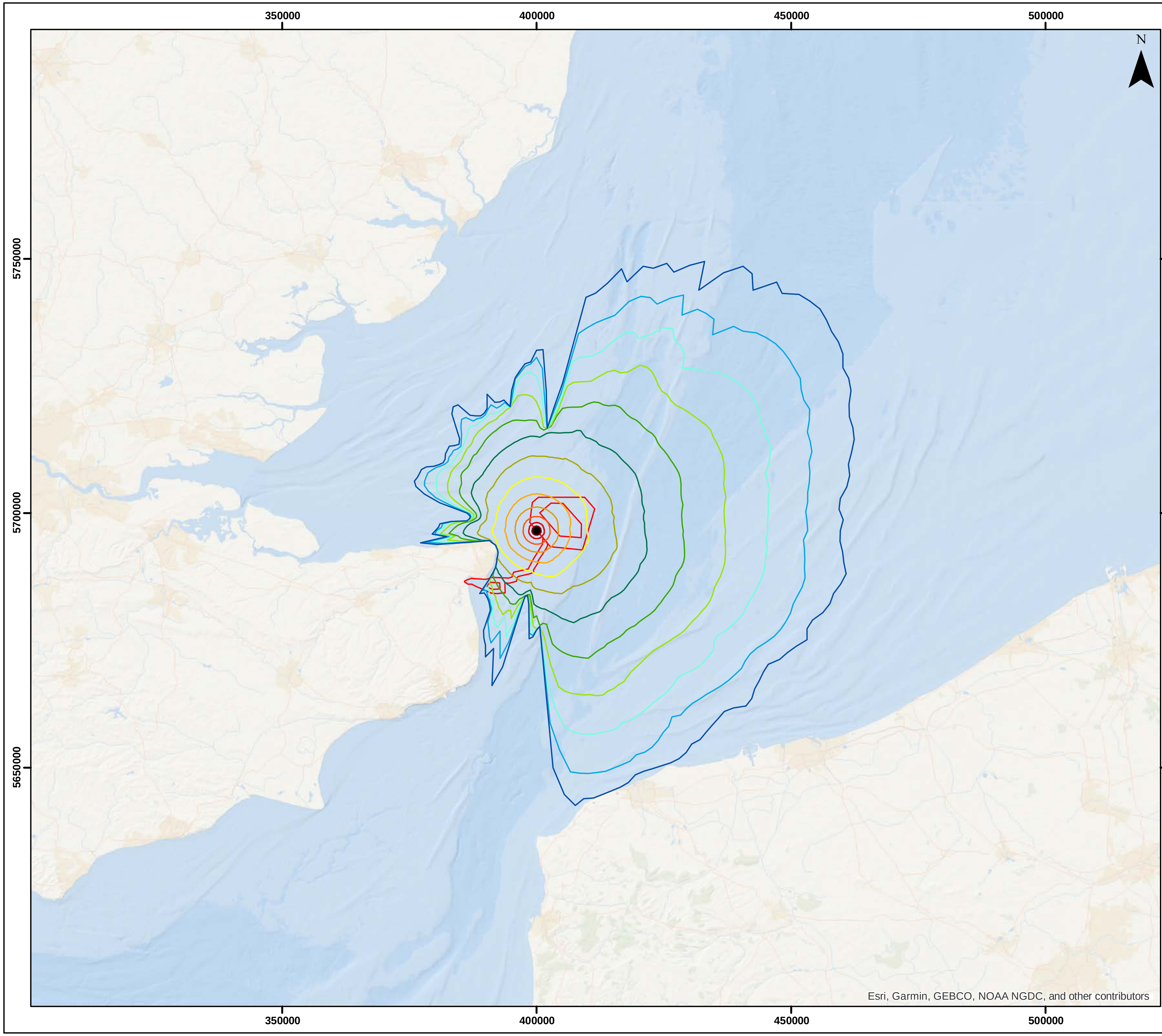

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Figure 7.23

Porpoise & Seal Pin Pile Behavioural Dose Response Isopleths

Legend

- Offshore Red Line Boundary
- South West Model Location

Unweighted SELss isopleths

- 120 dB re 1µPa²s
- 125 dB re 1µPa²s
- 130 dB re 1µPa²s
- 135 dB re 1µPa²s
- 140 dB re 1µPa²s
- 145 dB re 1µPa²s
- 150 dB re 1µPa²s
- 155 dB re 1µPa²s
- 160 dB re 1µPa²s
- 165 dB re 1µPa²s
- 170 dB re 1µPa²s
- 175 dB re 1µPa²s
- 180 dB re 1µPa²s

Datum: ETRS 1989
Projection: UTM31N

1:750,000 — 0, 8, 16 km — 0, 4.5, 9 nm

Drg No	ES Vol 2 Chpt 7 Fig 7.23			Figure 7.23
Rev	0.1	Date	23/05/2018	
By	RP	Layout	N/A	

Results of piling noise assessment for seals

'Instantaneous' PTS

7.11.96 Table 7.31 presents the estimated impact ranges for instantaneous PTS at the first hammer energy at the start of each piling operation for both species of seal. All impact ranges are significantly less than 500 m, therefore the establishment of a mitigation zone prior to the onset of piling following current JNCC (2010) guidelines will prevent exposure of individuals to noise thresholds which could lead to the instantaneous onset of PTS.

7.11.97 As discussed previously, it is expected that animals will start to move away once the piling starts, in response to the soft start. Given a ramp up of one hour before reaching maximum hammer energy and an assumption of a swimming speed of 1.5 ms-1, animals would be expected to be over five km away by the time full hammer energy is reached. The maximum impact range is 70 m, for the unweighted SPLpeak threshold for a monopile installation at the east location. This suggests that a standard mitigation zone (500 m) will be enough to ensure that no seals are at risk from PTS. However, the exact distance of the mitigation zone should be determined post-consent, once further information is available, including a full pile drivability assessment and the refinement of the piling profiles and hammer energies likely to be used.

7.11.98 The instantaneous PTS impact ranges for both soft start and full hammer energy do not overlap with any known seal haul-out sites.

7.11.99 Regardless of the thresholds used, all impact ranges are such that with the adoption of an appropriate mitigation zone prior to the onset of piling, and the implementation of a soft start, the risk of instantaneous PTS to any seals is extremely low. The magnitude of the impact is therefore Negligible. As the sensitivity of both species of seal to PTS is Medium, this results in **Minor** adverse significance, and therefore not significant in EIA terms.

Table 7.31: Estimated impact areas and ranges for 'instantaneous' PTS for seals at the hammer energy employed during the soft start (10% of full hammer energy)

	East		South west	
	Monopile (500 kJ)	Pin Pile (270 kJ)	Monopile (500 kJ)	Pin Pile (270 kJ)
NOAA (NMFS, 2016)	Mean range (m)			
unweighted SPL_{peak} 218 dB re 1 µPa	18	12	17	12

Table 7.32: Estimated impact areas and ranges for 'instantaneous' PTS for seals at full hammer energy

	East				South west			
	Monopile (5,000 kJ)		Pin Pile (2,700 kJ)		Monopile (5,000 kJ)		Pin Pile (2,700 kJ)	
NOAA (NMFS, 2016)	Area (km^2)	Range (km)	Area (km^2)	Range (km)	Area (km^2)	Range (km)	Area (km^2)	Range (km)
unweighted SPL_{peak} 218 dB re 1 µPa	0.015	0.070	0.007	0.048	0.013	0.065	0.006	0.044

PTS from cumulative exposure (over whole piling event)

7.11.100 As discussed in paragraph 7.11.78, the NOAA guidance propose a dual criteria whereby impact ranges based on both a SPLpeak threshold and a cumulative exposure SEL threshold over the duration of the event, should be calculated and the higher of the two exposure calculations should be adopted for assessment. However, as discussed above, this assessment explores the potential for PTS as a result of exposure to piling noise separately from instantaneous PTS. This is largely as a result of: 1) the need to assess likelihood of 'instantaneous' PTS from exposure to the magnitude of a single pile strike at the onset of piling – before animals are given the chance to move away; and 2) the additional uncertainties involved in modelling the exposure of an animal over several hours.

7.11.101 In calculating the received noise level that animals are likely to receive during the whole piling sequence, a soft start was assumed with the first 20 minutes at ten percent of maximum hammer energy, the following 40 minutes ramping up between ten percent and 100%, with full hammer energy being reached after a total of one hour. Strike rate was assumed to be 30 strikes per minute. All animals were assumed to start moving away at a swim speed of 1.5 ms-1 once the piling has started. This speed was selected based on reported sustained swimming speeds for harbour porpoises from Otani *et al*. (2000), and reported swimming speeds and minimum cost of transport speeds for seals (Williams and Kooyman 1985, Gallon *et al*. 2007). The calculated impact ranges therefore represent the minimum starting distances from the piling location for animals to escape and prevent them from receiving a dose higher than the threshold.

Table 7.33: Estimated impact ranges for PTS in seals as a result of cumulative exposure to noise over a whole piling event

	East				South west			
	Monopile (5,000 kJ)		Pin Pile (2,700 kJ)		Monopile (5,000 kJ)		Pin Pile (2,700 kJ)	
NMFS (2016)	**Area (km^2)**	**Range (km)**	**Area (km^2)**	**Range (km)**	**Area (km^2)**	**Range (km)**	**Area (km^2)**	**Range (km)**
NOAA$_{PW}$ weighted SEL$_{cum}$ 185 dB dB re 1 μPa^2.s	0.004	0.03	0.002	0.03	0.002	0.03	0.001	0.01

7.11.102 As with instantaneous PTS, impact ranges based on NOAA thresholds were calculated and the resulting impact ranges were low, with maximum impact ranges for the installation of a monopile at the east location of only 30 m (Table 7.33).

7.11.103 The cumulative SEL PTS impact ranges do not overlap with any known seal haul-out sites.

7.11.104 As has been discussed above, and in a number of other OWF marine mammal noise impact assessments there is a great deal of uncertainty associated with these predictions. Therefore, these ranges should be used to acknowledge the risk of PTS as a result of exposure to piling noise but the ranges themselves should be interpreted with caution.

TTS Onset

7.11.105 Using the SPL$_{peak}$ threshold, the maximum predicted range of TTS for seal species was 160 m for monopile (5,000 kJ) and 110 m for pinpiles (2,700 kJ) at the east location. Ranges were smaller for the south-west location with a maximum of 150 m for monopiles (5,000 kJ) and 100 m for pinpiles (2,700 kJ) (Table 7.34).

7.11.106 Using the SEL$_{cum}$ threshold, the maximum predicted range of TTS was 7.7 km for monopile (5,000 kJ) and 4.6 km for pinpiles (2,700 kJ) at the east location. Ranges were smaller for the south-west location with a maximum of 3.0 km for monopiles (5,000 kJ) and 1.7 km for pinpiles (2,700 kJ) (Table 7.34).The maximum predicted TTS impact ranges for both the east and the south-west model locations do not overlap with any known seal haul-out sites.

7.11.107 These TTS onset ranges do not represent an impact which is considered to be of biological significance across the whole area indicated by these ranges, but are intended to indicate the level of noise exposure which could induce any measureable threshold shift. TTS within these ranges could range from a small (~6 dB) reduction in hearing sensitivity that would recover in less than hour, to more significant reductions in hearing sensitivity that may last for a number of days. Reductions in hearing sensitivity may affect an animal's ability to forage, avoid predation and communicate but the TTS onset ranges alone do not allow us to assess the magnitude or significance of the likely consequences for individuals and ultimately populations of the predicted extent over which any TTS might occur. Mitigation in place to reduce the risk of PTS to marine mammals will also reduce the risk of TTS below the ranges presented here.

Table 7.34: Estimated impact ranges for TTS for seal species

	East						South west					
	Monopile 5,000 kJ			**Pinpile 2700 kJ**			**Monopile 5,000 kJ**			**Pinpile 2700 kJ**		
	Max	**Mean**	**Mix**	**Max**	**Mean**	**Min**	**Max**	**Mean**	**Mix**	**Max**	**Mean**	**Min**
NOAA unweighted SPL$_{peak}$ 212 dB re 1 μPa^2												
Range (m)	**160**	160	160	**110**	110	110	**150**	150	150	**100**	100	99
NOAA$_{PW}$ weighted SEL$_{cum}$ 170 dB dB re 1 μPa^2.s												
Range (km)	**7.7**	5.6	3.7	**4.6**	3.6	2.5	**3.0**	2.3	1.7	**1.7**	1.4	1.0

Disturbance (Displacement) Dose Response Assessment

7.11.108 Figure 7-12 displays the relationship used in the dose response analysis. The dose-response curve adopted in this assessment was generated from data collected during a study conducted by Russell *et al*. (2016) on the response of harbour seals to pile-driving activity at the Lincs wind farm in the Wash. It reflects the proportional decrease in occurrence of harbour seals with decreasing range from the piling site, as measured using a change in usage calculated from telemetry data. From the dose-response curve, the proportion of animals responding to a certain SEL value were used as multipliers to calculate the number of animals responding within each noise contour 'ring'.

7.11.109 Figure 7.20, Figure 7.21, Figure 7.22 and Figure 7.23 display the noise contours for the 5 dB incremental levels used in the dose response calculations (note they are the same as those used for the harbour porpoise dose response analysis since they are absolute predicted noise levels and are not weighted to take account of species hearing).

7.11.110 In order to calculate the number of individuals that might be predicted to respond to the piling noise using the dose response approach, the estimated density for each area has been multiplied by the total area within each contour 'ring' and then multiplied by a value that represents the proportion of animals expected to respond within that contour, based on the dose response curve. This results in a prediction of between 13.9 and 27.0 harbour seals and between 6.1 and 10.3 grey seals potentially experiencing noise levels high enough to elicit a behavioural response. This equates to between 0.20% and 0.38% of the reference population for harbour seals and between 0.02 and 0.03% of the reference population for grey seals (Table 7.35). The equivalent numbers as a proportion of the UK reference population (South East England for harbour seals and North East + South East England for grey seals) plus the Wadden Sea population is 0.03 – 0.06% for harbour seals and 0.01 – 0.02% for grey seals.

7.11.111 Although the impact ranges were larger for the east location, for harbour seals, the total magnitude of impact is higher for harbour seals at the south west location. This is due to the closer proximity of the south west location to areas of higher harbour seal density (see Figure 7.5). At both locations and for both species, the number of animals affected is higher for monopiles compared to pin piles however the overall duration of piling for jacket installation will be approximately 40% longer than for monopiles, leading to an overall larger magnitude of impact.

Table 7.35: Number of harbour and grey seals within the impact area using the behavioural dose response method based on Russell and Hastie (2017). The numbers are based on the mean density estimate (+/- 95% confidence interval) from the Russell *et al*. (2017) at-sea usage maps and are also given as the percentage of the reference population

	East		South West	
	Monopile (5,000 kJ)	**Pin Pile (2,700 kJ)**	**Monopile (5,000 kJ)**	**Pin Pile (2,700 kJ)**
Harbour Seal				
Number of animals	**20.1** (4.3 – 35.9)	**13.9** (3.1 – 24.6)	**27.0** (8.3 – 45.7)	**20.5** (6.4 – 34.6)
% of reference population	**0.29%** (0.06 – 0.51)	**0.20%** (0.04 – 0.35)	**0.38%** (0.12 – 0.65)	**0.29%** (0.09 – 0.49)
Grey Seal				
Number of animals	**10.3** (6.7 – 18.3)	**8.6** (4.6 – 12.5)	**8.8** (5.1 – 12.6)	**6.1** (3.6 – 8.7)
% of reference population	**0.03%** (0.02 – 0.05)	**0.02%** (0.01 – 0.03)	**0.02%** (0.01 – 0.03)	**0.02%** (0.01 – 0.02)

7.11.112 Given the low percentages of the population predicted to be affected across both methods for both species of seal, the fact that the piling will be intermittent over a period of approximately four months, lasting a maximum total amount of active piling of 170 hours for monopiles or 230 hours for pin piles, with breaks in between pile installations of several days (breaks may be longer depending on weather conditions and equipment downtime) therefore the effects are considered to be temporary and reversible, affecting only a small proportion of the relevant MUs, and the magnitude of this impact is assessed as Low. Given that harbour seals have a Medium sensitivity and grey seals have a Low sensitivity to the effect of potential avoidance this results in a **Minor** adverse significance, which is not significant in EIA terms.

7.11.113 The dose response curve for harbour seals only predicts a response out to 150 dB SELss. There are only two harbour seal haul-outs within the 150 dB SELss contour for the installation of a monopile 5,000 kJ foundation at the southwest location (Figure 7.24), however, on average, only 28% of animals within the 150-165 dB SELss contour are expected to show any disturbance responses, and none beyond the 150 dB SELss contour. Therefore, there is only a limited possibility of movement to and from these haul-outs being restricted.

7.11.114 The 155 dB SELss contour for the installation of a monopile at 5,000 kJ at the southwest location does reach the Kent coast (Figure 7.24), therefore there is the potential for some restriction of movement around the coast during piling. However, the majority of seal movements are generally between haul out sites and foraging areas at sea, with a much lesser proportion of movement being around the coast between haul out locations. In addition, only 49% of the animals within this noise contour are predicted to show a disturbance response and, given that the piling activities will be intermittent and that a previous study has shown that harbour seals return within two hours after the end of a piling event (Russell *et al*. 2016), any restriction in movement round the coast at this location will be temporary in nature. The total period over which any effect is expected is minimal when expressed as a proportion of total time. Piling is expected to occur over 6 months, phased over a 28 month period. The total displacement time (installation time plus residual disturbance time) will only be 5% of total time over 6 months, and 1.1% of total time over a 28 month construction period. Therefore, for over >95% of the construction period there will be no restriction to movement around the coast.

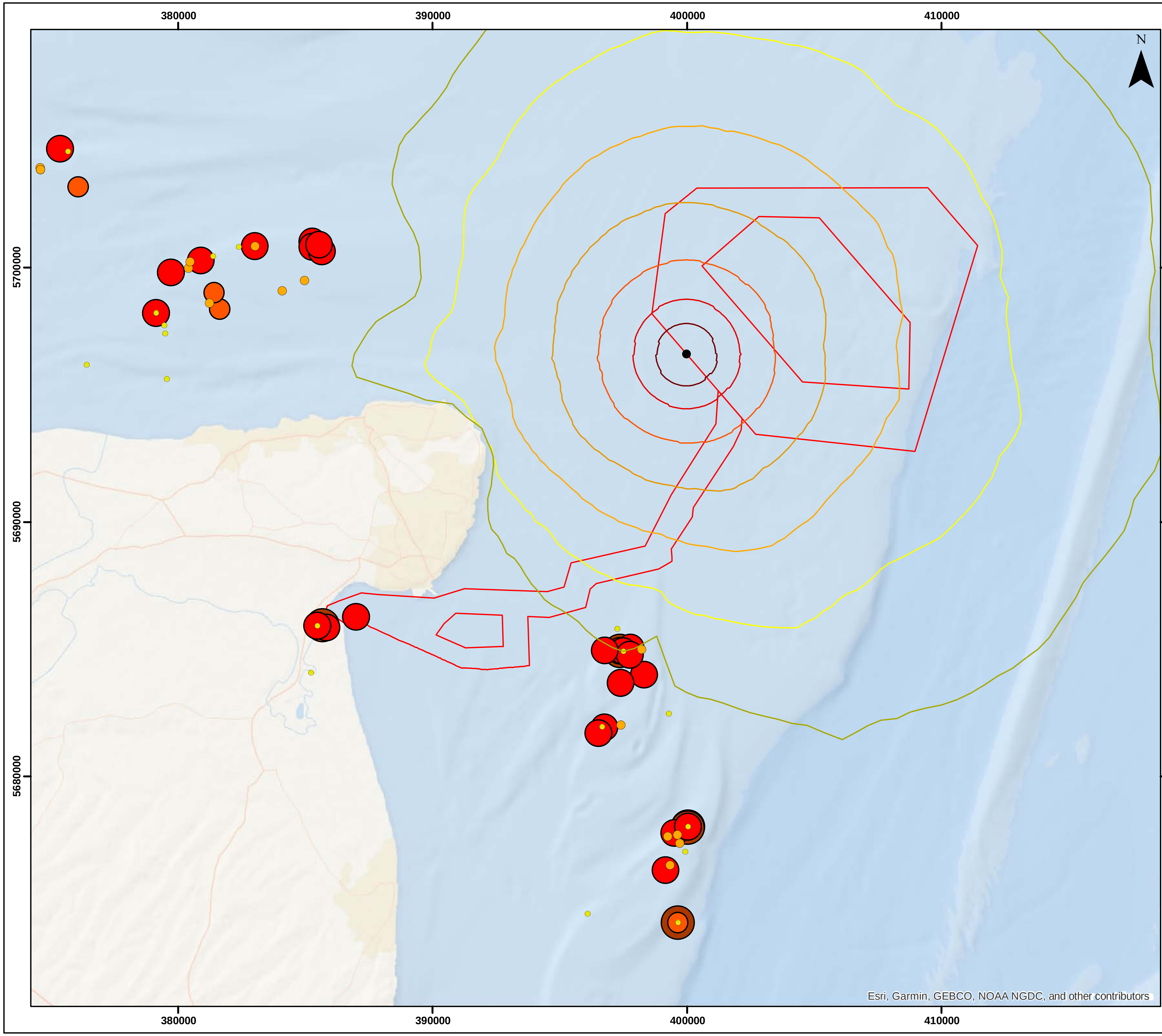

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Figure 7.24

Monopile Behavioural Dose Response Isopleths and Harbour Seal Haul-Outs

Legend

- Offshore Red Line Boundary
- South West Model Location

Harbour Seal Counts

- 1-5
- 6-10
- 11-15
- 16-50
- 51-100
- >100

Unweighted SELss isopleths

- 150 dB re 1µPa²s
- 155 dB re 1µPa²s
- 160 dB re 1µPa²s
- 165 dB re 1µPa²s
- 170 dB re 1µPa²s
- 175 dB re 1µPa²s
- 180 dB re 1µPa²s

Datum: ETRS 1989
Projection: UTM31N

Haul-out count data provided by SMRU and ZSL

1:150,000 0 1.5 3 km 0 0.85 1.7 nm

Drg No	ES Vol 2 Chpt 7 Fig 7.24		
Rev	0.1	Date	23/05/2018
By	RP	Layout	N/A

Figure 7.24

Vessel Interactions - collisions

7.11.115 During construction of the wind farm, another potential source of impact from increased vessel activity is physical trauma from collision with a boat or ship (disturbance as a result of vessel noise has already been assessed – see paragraphs 7.11.4 to 7.11.12). These injuries include blunt trauma to the body or injuries consistent with propeller strikes. The risk of collision of marine mammals with vessels would be directly influenced by the type of vessel and the speed with which it is travelling (Laist *et al*. 2001) and indirectly by ambient noise levels underwater and the behaviour the marine mammal is engaged in. Laist *et al*. (2001) predicted that the most severe injuries from collision with vessels travelling at over 14 knots.

7.11.116 However, there is currently a lack of information on the frequency of occurrence of boat collisions as a source of marine mammal mortality. Non-lethal collision has also been reported by Van Waerebeek *et al*. (2007). Collisions between vessels and marine mammals are therefore not necessarily fatal.

7.11.117 There is little evidence from harbour porpoise stranded in the UK that injury from vessel collisions is an important source of mortality. Of all the post mortems carried out on harbour porpoise strandings in the UK between 2010 and 2014, ship strikes were noted as cause of death for only a very small percentage of deaths (~four percent) over the five year period (CSIP 2015). None of the 53 harbour porpoise post mortem examinations in 2015 identified physical trauma from ship strike as the cause of death (CSIP 2015). Of the 1922 reported harbour porpoise strandings in the UK between 2005 and 2010, 478 were investigated by post mortem and cause of death established for 457 individuals, of these 22 had died from physical trauma of unknown origin, which could include vessel strikes (Deaville and Jepson 2011).

7.11.118 The maximum number of construction vessels on site is 48 vessels at the same time, with an average of 34 vessel transits per month, with a maximum rate of 5 additional transits per day. Any re-routing of existing traffic around the site boundary may lead to an increased risk of collision between marine mammals and ships although the overall increase in ship traffic in the near vicinity that this represents is very small in relation to the high levels of existing baseline vessel activity in this region (up to 30 ship transits per day).

7.11.119 Harbour porpoises and seals are relatively small and highly mobile, and given observed responses to noise (as detailed above), are expected to detect vessels in close proximity and largely avoid collision.

7.11.120 Given the fact that baseline vessel activity in the area is high, it is not expected that the level of increased vessel activity during operation would cause an increase in the risk of mortality from collisions. The adoption of a vessel management plan that includes preferred transit routes and guidance for vessel operation in the vicinity of marine mammals and around seal haul-outs will minimise the potential for any impact. The magnitude of the impact has therefore been assessed as Low. The sensitivity to this impact is assessed as Low for all species given available evidence. The effect is therefore assessed as **Minor adverse** significance for all marine mammal species and therefore not significant in EIA terms.

Seal "corkscrew" injuries

7.11.121 There have been previous concerns that ducted propeller vessels were potentially causing fatal "corkscrew" injuries in both harbour and grey seals, characterised by a single smooth-edged, deep laceration starting at the head and spiralling around the body (Bexton *et al*. 2012, Thompson *et al*. 2013a). In 2015 a SMRU report was released detailing evidence of observed adult male grey seal cannibalism on grey seal pups causing wounds that "clearly resembled" corkscrew wounds (Thompson *et al*., 2015). As such, the previous corkscrew seal cases are likely all due to grey seal predation rather than as a result of interactions with vessel propellers (Brownlow *et al*. 2016, SCOS 2016).

7.11.122 Based on the latest information it is considered very likely that the use of vessels with ducted propellers will not pose any increased risk to seals over and above normal shipping activities and therefore specific mitigation measures and monitoring are not necessary in this regard, although all possible care should be taken in the vicinity of seal breeding and haul-out sites to avoid collisions. The risk of corkscrew seal injuries as a result of ducted propeller vessels is therefore assessed as **Negligible** adverse significance for both species of seal.

Disturbance at haul-out sites

7.11.123 Harbour seals are known to regularly haul-out in Pegwell Bay and in the River Stour Estuary, close to where the proposed export cable landfall is located. The Zoological Society of London annually count the seals during the August moult. The total August moult haul-out count in the Pegwell Bay/ Stour Estuary area was 52 in 2015, 16 in 2014 and 41 in 2013. Given their proximity to the export cable corridor route and landfall (see Table 7.9), it is likely that this haul-out site may experience disturbance from the activities associated with laying the cable and the landfall activities.

7.11.124 Previous studies have demonstrated the disturbance effects on harbour seals at haul-out sites. For example, controlled disturbance vessel trials have shown that harbour seals would reduce the amount of time hauled out around the point of disturbance and they would embark on a foraging trip before hauling out again at the next low-tide cycle (Paterson *et al*. 2015). This was also shown in Andersen *et al*. (2012) where extended inter-haul-out trips occurred directly after a disturbance event. This is particularly important if this disturbance occurs at a time that is critical for harbour seals to be hauled-out, such as during the annual moult or the breeding season.

7.11.125 There is currently no published evidence that harbour seals breed at the Pegwell Bay/ river Stour haul-outs, however, they are known to use these haul-outs during the annual moult and are seen regularly at other times of year. The level of disturbance predicted to be experienced by harbour seals at the Pegwell Bay haul-out will depend on the distance of the haul-outs to the landfall construction activities, the number of vessels involved in the construction activities, the level of sound produced and the previous experience of the seals.

7.11.126 There are three landfall options under consideration for Thanet Extension (see Volume 2, Chapter 1: Project Description (Document Ref: 6.2.1) for further information):

- Option 1: Use of Horizontal Directional Drilling from the Pegwell Bay Country Park to the Intertidal mudflats;
- Option 2: A seaward extension of the existing sea wall: Installation works will require the temporary installation of a cofferdam, the extension of the sea wall, open trenching from the intertidal zone to the sea wall before being laid in a surface laid bund up to the interface with the surface laid TJBs, followed by the removal of the cofferdam; and
- Option 3: Open trenching through the existing sea wall and Pegwell Bay Country Park: Installation works will require the temporary installation of a cofferdam, the temporary removal of the sea wall, open trenching from the intertidal zone through the cofferdam to the TJBs followed by the re-installation of the sea wall and the removal of the cofferdam.

Option 1: HDD

7.11.127 Under this option the TJBs will be located underground within the Country Park and the offshore cables would be installed by Horizontal Directional Drilling from land to sea. The HDD ducts would be installed from the TJB location, out to a punch-out location at least 100 m seaward of the sea wall. A total of four ducts will be installed by HDD from the TJBs, under the sea wall and exiting into four intertidal HHD pits. Following the installation of the HDD ducts, the offshore cables will be pulled through the ducts into the onshore TJBs. The HDD installation will require a HDD rig (105 dB LwA) and can run on a 24 hour working day. The HDD pits are located approximately 0.75 km from the closest recorded harbour seal August moult haul-out location.

Option 2 & 3: Cofferdam

7.11.128 Under Option 2 the TJBs would be located above ground in the Country Park and requires the installation of a temporary cofferdam within the upper intertidal/saltmarsh area before extending the existing sea wall. As with Option 1, the cables would be trenched through the upper intertidal area to the seawall extension. For the purposes of assessment, it is assumed that the temporary cofferdam will be installed using percussive piling and will take a duration of 33 days, assuming active piling for 70% of the 12 hour working day (construction works between 0700 and 1900 six days per week). After construction of the sea wall extension and installation of the cables, the cofferdam would be removed.

7.11.129 Under Option 3 the TJB would be located above ground in the Country Park and requires the installation of a temporary cofferdam before excavating through from the upper intertidal, through the existing sea wall area, which will require the removal then re-installation of the sea wall. The installation of the temporary cofferdam will be of similar duration to Option 2 (piling for up to 33 days, active piling 70% of the 12 hour day, works between 0700 and 1900, six days per week). The offshore cables would be trenched from the intertidal through this cofferdam and seawall area onshore into the TJB area. The cofferdam would be removed, and the sea wall reinstated.

7.11.130 For either Option 2 or Option 3, the cofferdam will be constructed in the upper intertidal area and so will be constructed above the water level. There is a chance of tidal inundation but realistically at this location it would need to be an extreme high spring event and even then, maximum depth of water would be <20 cm across a saltmarsh area. Therefore, it was assumed that the noise produced by the piling of the cofferdam will be transferred through air only and as such, no noise modelling for underwater impacts was conducted. The noise produced by the cofferdam piling rig will reach levels of 132 dB equivalent continuous sound pressure level (LAeq) at 10 m. The location of the cofferdam is approximately 1 km from the closest recorded harbour seal August moult haul-out location in Pegwell Bay.

Impact of landfall

7.11.131 The maximum duration of the landfall works (including TJBs) is five months, likely between Q1 2021 and Q3 2021. It is expected that the cofferdam installation will take up to four - six weeks, and the removal of the cofferdam will take two weeks. There is therefore the potential for disturbance to hauled out seals throughout this period, with the highest potential for disturbance occurring during the cofferdam installation period. The cofferdam installation will take place towards the beginning of this period and therefore is unlikely to overlap with the sensitive breeding or moulting periods in July and August.

7.11.132 There is very little documented evidence on the effects of noise in air on seals at haul-outs. Much of the data available on harbour seal disturbance at haul-out sites is in relation to the presence of vessels close to the haul-outs. There is evidence of onshore vibro-piling construction activity between 10 m and 2 km from harbour seal haul-out sites in Woodard Bay in the southern Puget Sound, USA (Oliver and Calambokidis 2011). In this example, piling was conducted using a vibratory hammer employing a soft start and ensuring that no harbour seals were within 15 m from the activity. The seals were relatively unaffected by the movement of the Barge Crane at distances of greater than 150 metres. The MMO/PSO data collected at this site showed that at distances up to ~300 m seals responded to the noise produced by the vibrating hammer by leaving the haul-out and entering the water.

7.11.133 The worst-case assessment assumes that all seals within approximately 500 m of landfall construction activities will experience disturbance likely to cause them to leave the haul-outs for the duration of the construction activity. Therefore, given the understanding of the locations where seals haul-out from the ZSL surveys disturbance to hauled-out seals may not be expected to occur. However, the year to year variation in haul-out location suggests that the exact locations that seals haul-out may change and therefore there is a possibility that seals may be disturbed from areas of sand bank close to these activities. However, conversely the variation in haul-out locations may also indicate that there are other alternative haul-out sites nearby that seals can move to if they choose to leave the site. Seals can also leave haul-outs voluntarily and embark on foraging trips, returning to the same haul-outs where they experienced disturbance previously (Paterson *et al*. 2015). There is the potential for disturbance to seals at the mouth of the River Stour from construction activities in the Country Park. Using worst-case scenario assumption of cable trenching and landfall activities leading to harbour seals leaving nearby haul-outs, this is likely to affect between approximately ten to 63 seals (based on moult counts, which is when the highest numbers of seals are likely to be ashore). Effects are likely to be temporary and seals are likely to move to alternative haul-outs at Goodwin Sands or Margate sands, resulting in small additional energetic costs. This represents a temporary and reversible impact to 0.9% of the relevant harbour seal MU. The haul-outs for both grey and harbour seals at Goodwin Sands are considered to be sufficiently distant from the landfall so that they will not be affected.

7.11.134 Given the potential for local scale, temporary disturbance to a small number of harbour seals the magnitude of the impact of disturbance at haul-outs as a result of the landfall construction activity is assessed as Low. Harbour seals are assessed as having a Low sensitivity to this magnitude of disturbance and therefore the significance of this effect is assessed as Minor, which is not significant in EIA terms.

7.11.135 Grey seals are not generally observed hauling out in Pegwell Bay or the Stour Estuary, although they do haul-out on sandbanks further offshore at Goodwin Sands. These haul-outs are sufficiently distant from any construction activity that no disturbance is predicted resulting in **no effect** on grey seal haul-outs.

Indirect effects on marine mammals as a result of impacts on prey species

7.11.136 The Benthic ecology assessment (Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5)) did not predict any significant negative impacts to the benthic ecology as a result of any activities associated with the construction of the wind farm. Therefore, **no significant indirect effects** on marine mammals are anticipated due to any changes in prey availability as a result of changes to benthic habitats.

7.11.137 The Fish and Shellfish ecology assessment (Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6)) did not predict any significant negative impacts to any fish populations considered to be an important prey resource for marine mammals as a result of any activities associated with the construction of the wind farm. This leads to the conclusion that no significant indirect effects on marine mammals are anticipated due to any changes in prey availability as a result of changes to fish and shellfish populations.

7.11.138 The Commercial Fisheries assessment (Volume 2, Chapter 9: Commercial Fisheries (Document Ref: 6.2.9)) did not predict any moderate or major significant effects to any commercial fishing practices in the area as a result of any activities associated with the operation of the wind farm. Therefore, no significant indirect effects on marine mammals are anticipated due to any changes in prey availability as a result of changes to commercial fishing activity.

Changes to water quality

7.11.139 Disturbance to the water quality can have both direct and indirect impacts on marine mammals. Indirect impacts would be effects on prey species which were covered in the previous section. Direct impacts include the impairment of visibility and therefore foraging ability which might be expected to reduce foraging success.

7.11.140 The risk of an increase in suspended sediment concentration (SSC) is greatest during drilling operations and from seabed preparation for gravity base foundations (e.g. dredging). For details see Volume 2, Chapter 2: Physical Processes (Document Ref: 6.2.2).

7.11.141 The sediment release from dredging will be quickly dispersed by tidal currents. The highest concentrations of SSC are therefore from the spoil disposal of dredged material. The physical processes assessment concluded that 90% of dredged material will fall straight to the seabed when released from the hopper. SSC levels in the water column will be in excess of natural ranges in the dynamic phase (of the plume from a single full hopper dredge spoil disposal event) but will reduce back to background levels in the order of seconds to minutes. The spatial scale will be in the order of tens of metres (both laterally and vertically). Away from release locations, any elevations in SSC will be very low.

7.11.142 Plumes of elevated SSC will occur as a result of drilling operations which may be required in some locations, depending on geology, in the installation of WTG foundations. These plumes will represent a large increase of SSC above background levels. Although the exact shape, width, length and thickness of such plumes cannot be predicted with certainty, plumes may extend up to a maximum of a tidal excursion distance (~14 km on spring tides and seven km on neap tides) aligned to the tidal stream downstream from the source.

7.11.143 The impact of cable burial operations on SSC concentrations is expected to be a temporary and localised re-suspension and resettling of sediments. Jetting for cable burial is expected to be the worst-case in terms of SSC. Irrespective of sediment type, the volumes of sediment being displaced and deposited locally are relatively limited (up to 7.5 m^3 per metre of cable burial if burial is achieved to a maximum depth of five meters in soft sediments).

7.11.144 As detailed in Volume 2, Chapter 2: Physical Processes (Document Ref: 6.2.2), monthly averaged levels of suspended particulate matter within the Thanet Extension area are relatively high and therefore marine mammals foraging here will have experienced turbid conditions, particularly during winter months and on spring tides. Greatest concentrations are found at the seabed so for benthic foragers such as seals, it is likely they can adapt to such conditions.

7.11.145 Marine mammals are well known to forage in tidal areas where water conditions are turbid and visibility conditions poor. Harbour porpoise and harbour seals in the UK have been documented foraging in areas with high tidal flows (e.g. Pierpoint 2008, Marubini *et al*. 2009, Hastie *et al*. 2016); therefore, low light levels, turbid waters and suspended sediments are unlikely to negatively impact marine mammal foraging success. When the visual sensory systems of marine mammals are compromised, they are able to sense the environment in other ways, for example, seals can detect water movements and hydrodynamic trails with their mystacial vibrissae (whiskers); while porpoise can use echolocation (e.g. Hanke and Dehnhardt 2013) to navigate and find food in darkness. Therefore, the sensitivity to increased SSC is low for seals and harbour porpoises.

7.11.146 Given the other activity associated with drilling and dredging operations (vessels, underwater noise) it is also highly likely that marine mammals will be displaced from the immediate vicinity of these operations and therefore will be outside of the range of the effects described here. Therefore, they are unlikely to be impaired by predicted increased SSC.

7.11.147 The magnitude of any impacts on marine mammals as a result of increased suspended sediment concentrations is assessed as Negligible for all marine mammals. As sensitivity is assessed as Low, this effect is therefore assessed as being of **Negligible** adverse significance and not significant in EIA terms.

7.12 Environmental assessment: operational phase

Vessel Interactions – collision and noise

7.12.1 During the operational phase there would be increased vessel activity for ongoing wind farm O&M activities. It is estimated there will approximately 434 O&M vessel round trips per year associated with the O&M of the wind farm (including large O&M vessels, accommodation O&M vessels, small O&M vessels, lift vessels, cable maintenance vessels and auxiliary vessels). The potential effects of additional vessels include disturbance from vessel noise and physical trauma (including mortality) from collision with a boat or ship.

7.12.2 As discussed above under construction impacts, the risk of collision of marine mammals with vessels would be directly influenced by the type of vessel and the speed with which it is travelling (Laist *et al*. 2001) and indirectly by ambient noise levels underwater and the behaviour the marine mammal is engaged in.

7.12.3 The maximum number of O&M vessels on site is five vessels at the same time, with an average of 157 vessel round trips to port each year which averages at 13 vessel transits per month. Similar to the scenarios assessed for construction vessel activity, this actually represents a decrease from baseline levels (see paragraph 7.11.10 and Volume 2, Chapter 10: Shipping and Navigation (Document Ref: 6.2.10)) where approximately 328 commercial vessel movements occurred within the Thanet Extension site boundary per month and many hundreds more within a few nautical miles. The operational phase of the wind farm will also result in an increase in vessel density outwith the site boundary as a result of the reduction in navigable space. As discussed in the construction impacts section (paragraph 7.11.11), current transit rates have been estimated at a maximum of 25 to 30 vessel transits per day. These levels, even with the additional transits as a result of the operational vessel activity are well below the threshold value of 80 ships per day suggested by the analysis of Heinanen and Skov (2015) as being associated with significantly lower harbour porpoise densities.

7.12.4 Harbour porpoises and seals are relatively small and highly mobile, and given observed responses to noise (as detailed above), are expected to detect vessels in close proximity and largely avoid collision.

7.12.5 Given the fact that baseline vessel activity in the area is high it is not expected that the small increase of vessel activity during operation would cause an increase in the risk of mortality from collisions or result in disturbance to any marine mammals. The adoption of a vessel management plan that includes preferred transit routes and guidance for vessel operation in the vicinity of marine mammals and around seal haul-outs will minimise the potential for any impact. The magnitude of the impact has therefore been assessed as Low. The sensitivity to this impact is assessed as Low for all species given available evidence. The effect is therefore assessed as **Minor** adverse significance for all marine mammal species and therefore not significant in EIA terms.

Operational noise from WTG

7.12.6 Subsea noise is predicted to occur as a result of the operation of up to 34 WTGs within Thanet Extension. Operational noise levels will be much lower than those generated during construction. WTG operation mainly produces a low frequency, low level noise originating from the mechanical vibrations in the drive trains. Mechanical noise can be amplified by structural resonances within the WTG. Operational noise is generally broadband and low levels, with some narrower band, tonal noise produced (Madsen *et al*. 2006, Tougaard *et al*. 2009, Marmo *et al*. 2013). Factors that may affect the nature of the noise emitted are the surface area of the foundation, the material used to construct the foundation and its internal damping and the nature of the connection of the foundation to the sea floor (Marmo *et al.* 2013).

7.12.7 Several underwater acoustic measurements of offshore WTGs have been carried out (Ingemansson Technology 2003, Betke *et al*. 2004, Thomsen *et al*. 2006, Nedwell *et al*. 2011). Differences in design parameters makes direct comparisons difficult; however, noise related to offshore WTGs have common features; specifically, the sound intensity is dominated by pure tones likely to originate from rotating machinery in the nacelle with frequencies mostly below 700 Hz (Marmo *et al*. 2013).

7.12.8 There are currently no measured data available for WTGs with a rated power higher than 3.6 MW. However, it is likely that the overall broadband sound levels may not be significantly higher. The MMO (2014) review of post-consent monitoring at OWFs found that available data on the operational WTG noise, from the UK and abroad, in general showed that noise levels from operational WTGs are low and the spatial extent of the potential impact of the operational WTG noise on marine receptors is generally estimated to be small, with behavioural response only likely at ranges close to the WTG. Although the early measured data were mainly for smaller capacity WTGs ranging from about 0.2 - 2.0 MW, more recently reported measured operational noise data from larger capacity WTGs also had noise levels and characteristics comparable with previous wind farms reported (MMO 2014) .

7.12.9 Marmo *et al*. (2013) modelled the likely operational noise from a generic 6 MW WTG on a variety of foundation types and found some differences in predicted noise fields between foundation types. Generally, the monopile was predicted to produce higher SPL at low frequencies. The jackets may produce less noise at low frequency due to having less surface area in contact with the surrounding environment. At frequencies greater than 500 Hz SPL produced by jackets become high relative to the monopiles and gravity bases, likely due to the resonance of the steel cross bracing elements of the jacket structure amplifying HF vibrations resulting in higher noise emission.

7.12.10 Marmo *et al*. (2013) also predicted behavioural response zones for harbour porpoise and seals. Operational noise was predicted to be audible out to very long ranges (~20 km) but the potential for aversive behavioural responses, predicted using published behavioural thresholds, was not assessed as significant for either foundation type.

7.12.11 This is supported by several published studies which provide evidence that marine mammals are not displaced from operational wind farms. At the Horns Rev and Nysted offshore wind farms in Denmark, long-term monitoring showed that both harbour porpoise and harbour seal were sighted regularly within the operational OWFs, and within two years of operation, the populations had returned to levels that were comparable with the wider area (Diederichs *et al*. 2008). Similarly, a monitoring programme at the Egmond aan Zee OWF in the Netherlands reported that significantly more porpoise activity was recorded within the OWF compared to the reference area during the operational phase (Scheidat *et al*. 2011). Other studies at Dutch and Danish OWFs (e.g. Lindeboom *et al*. 2011) also suggest that harbour porpoise may be attracted to increased foraging opportunities within operating offshore wind farms. In addition, recent tagging work by Russell *et al*. (2014) found that some tagged harbour and grey seals demonstrated grid-like movement patterns as these animals moved between individual WTGs, strongly suggestive of these structures being used for foraging.

7.12.12 In addition, because shipping levels in the area are relatively high (as discussed above), high levels of associated ambient noise will limit the distance over which the noise from operational WTG can be detected.

7.12.13 Despite the potential for long-term effects lasting throughout the operational phase, any behavioural effects are expected to be extremely localised and no barrier effects are anticipated, and the magnitude is considered to be Negligible.

7.12.14 The sensitivity to operational noise is assessed as Low and therefore operational noise effects have been assessed as **Negligible** adverse for all species and therefore not significant in EIA terms.

Impacts on prey species

7.12.15 The Benthic Ecology assessment (Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5)) did not predict any moderate or major significant impacts to the benthic ecology as a result of any activities associated with the operation of the wind farm. Therefore, **no indirect impacts** on marine mammals are anticipated due to any changes in prey availability as a result of changes to benthic habitats.

7.12.16 The Fish and Shellfish Ecology assessment (Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6)) did not predict any moderate or major significant impacts to any fish species as a result of any activities associated with the operation of the wind farm. Therefore, **no indirect impacts** on marine mammals are anticipated due to any changes in prey availability as a result of changes to fish populations.

7.12.17 The Commercial Fisheries assessment (Volume 2, Chapter 9: Commercial Fisheries (Document Ref: 6.2.9)) did not predict any moderate or major significant impacts to any commercial fishing practices in the area as a result of any activities associated with the operation of the wind farm. Therefore, **no indirect impacts** on marine mammals are anticipated due to any changes in prey availability as a result of changes to commercial fishing activity.

7.12.18 It is known that the presence of anthropogenic structures in the marine environment can act as fish aggregating devices and artificial reef systems (Guerin *et al*. 2007, Zawawi *et al*. 2012). There is evidence that both grey and harbour seals can target anthropogenic structures such as subsea pipelines and OWF WTG structures (Russell *et al*. 2014). This telemetry data strongly suggests that the tagged seals were targeting these structures for foraging purposes. Therefore, it is possible that the underwater structures associated with Thanet Extension could provide an ecological benefit by providing new foraging opportunities to marine mammals in the area. Other studies at operational OWFs have also suggested that foraging opportunities may be enhanced, potentially as a result of reduced commercial fishing activity (e.g. Scheidat *et al*. 2012). It is anticipated that there will be **no significant indirect negative impacts** to marine mammals through changes in prey abundance and distribution, and any potential habitat change as a result of fish aggregation or artificial reefs is expected to positively affect marine mammals by providing novel foraging opportunities and is therefore assessed as being of **Minor** beneficial significance to marine mammals.

7.13 Environmental assessment: decommissioning phase

7.13.1 Decommissioning would involve the dismantling of structures and complete removal of all offshore structures above the seabed, in reverse order to the construction sequence. The effects of these activities on marine mammals are considered to be similar to or less (as a result of there being no piling) than those occurring as a result of construction. Therefore, the effects of decommissioning are considered to be no greater than those described for the construction phase. A decommissioning plan in line with standard requirements will be developed in consultation with the relevant advisors.

7.13.2 The effects of decommissioning of Thanet Extension have been assessed on marine mammals. The impacts are expected to be similar to, or less than those predicted as a result of construction and therefore only specific operations have been assessed here.

Underwater Noise - cutting

7.13.3 The decommissioning of the WTGs will involve cutting the structures at one meter below the seabed. The exact cutting method has yet to be defined, so examples of different cutting methods are described below as well as an assessment of their potential impact on marine mammals. There are very few examples of empirical data describing the source level of underwater cutting noise. One study found that sound radiated from a diamond wire cutting operation was not easily discernible above the background noise during cutting operations (Panjerc *et al*. 2016). Other forms of cutting (e.g. abrasive water jet cutting) are considered to be low impact (Brandon *et al*. 2000, Kaiser *et al*. 2005). In the underwater noise technical report submitted in an application for the East Anglia Three wind farm, it was suggested by the National Physics Laboratory that for abrasive cutting the noise level would not be expected to be significantly higher than general surface vessel noise (East Anglia Three Ltd, 2015). Given the data presented in Panjerc *et al*. (2016) it is highly unlikely that the noise generated by cutting to remove structures has the potential to disturb any species of marine mammal. It can be concluded therefore that due to the Low potential for disturbance and the temporary nature of the activities that the use of diamond wire cutting tools will result in a **Negligible** adverse effect on both seals and harbour porpoise.

Vessel Interactions – noise and collision

7.13.4 During the decommissioning of the OWF there would be increased vessel activity. It is estimated that vessel numbers will be similar to those during the construction period and therefore the impacts of collision risk and noise disturbance will be of similar magnitude. The resulting effects were assessed for construction as being of **Minor** adverse significance and therefore not significant in EIA terms and the same assessment applies for decommissioning.

Impacts on prey species

7.13.5 The Benthic ecology assessment (Volume 2, Chapter 5: Benthic Ecology (Document Ref: 6.2.5)) did not predict any moderate or major significant impacts to the benthic ecology as a result of any activities associated with the decommissioning of the wind farm. Therefore, **no indirect impacts** on marine mammals are anticipated due to any changes in prey availability as a result of changes to benthic habitats.

7.13.6 The Fish and Shellfish ecology assessment (Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6)) did not predict any moderate or major significant impacts to any fish populations considered to be an important prey resource for marine mammals as a result of any activities associated with the decommissioning of the wind farm. This leads to the conclusion that **no indirect** effects on marine mammals are anticipated due to any changes in prey availability as a result of changes to fish and shellfish populations.

7.13.7 The Commercial Fisheries assessment (Volume 2, Chapter 9: Commercial Fisheries (Document Ref 6.2.9)) did not predict any moderate or major significant impacts to any commercial fishing practices in the area as a result of any activities associated with the decommissioning of the wind farm. Therefore, **no indirect effects** on marine mammals are anticipated due to any changes in prey availability as a result of changes to commercial fishing activity.

7.14 Environmental assessment: cumulative effects

7.14.1 Cumulative effects refer to effects upon receptors arising from Thanet Extension when considered alongside other proposed developments and activities and any other *reasonably foreseeable project(s)* proposals. In this context the term *projects* is considered to refer to any project with comparable effects and is not limited to offshore wind projects.

7.14.2 The approach to cumulative assessment for Thanet Extension takes into account the Cumulative Impact Assessment Guidelines issued by Renewable UK in June 2013, together with comments made in response to other renewable energy developments within the Southern North Sea, and the Planning Inspectorate (PINS) 'Advice Note 9: Rochdale Approach'.

7.14.3 The projects and plans selected as relevant to the assessment of impacts to marine mammals are based upon an initial screening exercise undertaken on a long list (Volume 1, Annex 3-1: Cumulative Effects Assessment (Document Ref: 6.1.3.1)). The long list included a range of different activity types including marine aggregate extraction, oil and gas extraction, cable installation projects, dredging disposal, pipelines, coastal developments, shipping and commercial fisheries. Screening of this long list for marine mammals depended on the impact pathway and the likelihood for overlap and cumulative effects. The screening for plans and projects in the CEA for marine mammals had a spatial and a temporal element. The spatial extent used to screen projects was the extent of the MU for harbour porpoise (North Sea), harbour seal (south-east England) and grey seal (south-east England, north-east England and east coast Scotland). Marine aggregate projects have been screened out as a potential direct impact on marine mammals as the screening exercise indicated that no new developments are anticipated to become operational within 500 km of Thanet Extension during the construction phase. Existing developments are considered as part of the baseline and any continuing impacts are likely to be localised and small scale. Cable projects have only been included where there is potential for the cable installation periods to overlap with Thanet Extension construction.

7.14.4 For underwater noise as a result of piling operations, OWF and other marine construction projects were included if there was the potential for the construction period to overlap with Thanet Extension, based on the best available information on project schedules.

7.14.5 For constructed projects, the potential for ongoing cumulative effects were considered if the operational period could not be considered part of the baseline environment.

7.14.6 In assessing the potential cumulative impact(s) for Thanet Extension, it is important to bear in mind that for some projects, predominantly those 'proposed' or identified in development plans etc. may or may not actually be taken forward. As a consequence, there is a need to build in consideration of certainty (or uncertainty) with respect to the potential impacts which might arise from such proposals. For example, relevant projects/ plans that are already under construction are likely to contribute to cumulative impact with Thanet Extension (providing effect or spatial pathways exist), whereas projects/ plans not yet approved or not yet submitted are less certain to contribute to such an impact, as some may not achieve approval or may not ultimately be built due to other factors.

7.14.7 For this reason, all relevant projects/ plans considered cumulatively alongside Thanet Extension have been allocated into 'Tiers', reflecting their current stage within the planning and development process. This allows the cumulative impact assessment to present several future development scenarios, each with a differing potential for being ultimately built out. Appropriate weight may therefore be given to each scenario (Tier) in the decision-making process when considering the potential cumulative impact associated with Thanet Extension (e.g., it may be considered that greater weight can be placed on the Tier 1 assessment relative to Tier 2).

7.14.8 The proposed tier structure that is intended to ensure that there is a clear understanding of the level of confidence in the cumulative assessments provided in the Thanet Extension ES is as follows:

Tier 1

7.14.9 Thanet Extension considered alongside other projects/ plans already constructed or currently under construction and/ or those consented but not yet implemented, where data confidence in the project design envelope and timeline for construction is high. This means that these projects have a Contract for Difference (CfD) in place and/or have commenced with the formal submission of discharge plans to the regulators, and therefore there can be confidence as to final scheme design and timing.

7.14.10 Built and operational projects will be included within this tier of the cumulative assessment where they have not been included within the environmental characterisation survey, i.e. they were not operational when baseline surveys were undertaken, and/ or any residual impact may not have yet fed through to and been captured in estimates of 'baseline' conditions.

Tier 2

7.14.11 Thanet Extension considered alongside other projects/ plans which are consented but not yet implemented, and where data confidence in the project design envelope and timeline for construction is medium. For example, the consented envelope may not be what is constructed, or timelines might have changed since the ES was submitted. The project may not yet proceed as a result of financial or other considerations. This Tier includes consented UK projects which have not yet been awarded a CfD.

Tier 3

7.14.12 Thanet Extension considered alongside other projects/ plans which have submitted applications but are not yet consented. The submitted application will have been accompanied by an ES but prior to any hearing or decision, there is the possibility that the design could change, and the project could be withdrawn or refused consent.

Tier 4

7.14.13 The above plus projects on relevant plans and programmes that have been announced by developers and that are listed on the appropriate planning systems (the PINS Programme of Projects and MMO 'Marine Case Management System' being the source most relevant for this assessment). Specifically, all projects where the developer has advised PINS in writing that they intend to submit an application in the future were considered.

7.14.14 Note that this additional tier (Tier 4) has been added into the marine mammal assessment. This is because of the necessity to differentiate the certainty in project envelope and timing for the impact of pile-driving in particular. It is difficult to generate a realistic schedule for the degree to which different projects might overlap in terms of piling periods. Therefore, four tiers were required to ensure that consented projects with more certainty in respect of project plans and timelines (e.g. where CfDs are in place and significant post-consent development and discussions have taken place) could be differentiated from those that have been consented but there is significant uncertainty as to when they will actually go ahead.

7.14.15 This is similar to guidance given for ornithological assessments, where there has been a requirement to resolve the different stages of projects within the project lifecycle at a finer level of detail. The marine mammal assessment has adopted four tiers, rather than the five adopted for birds because operational impacts are generally less of a concern for marine mammals. Projects that have already been constructed are included in Tier 1, rather being assigned a separate tier of their own. The specific projects scoped into this cumulative impact assessment, and the tiers into which they have been allocated are presented in Table 7.36.

Impacts assessed

7.14.16 The following types of impact have been considered in this cumulative assessment:

- Disturbance as a result of increased levels of underwater noise from construction and decommissioning activities – mainly includes the pile-driving phase of offshore wind farm projects but also includes coastal construction projects where noisy construction activities (blasting and piling) are planned;
- PTS and Disturbance from UXO clearance activities for other plans and projects for which there is sufficient information on the timelines, locations and magnitude of activity;
- Disturbance from seismic survey activity in relation to oil and gas projects;
- Disturbance and collision risk as a result of increased vessel traffic arising from the construction, operation and decommissioning of offshore developments;
- Indirect effects on marine mammals as a result of cumulative changes in fish abundance and distribution resulting from the construction, operation and decommissioning of offshore developments.

7.14.17 Table 7.37 presents the maximum design scenarios for each impact.

Table 7.36: Projects scoped into the cumulative assessment for marine mammals

Status of Development	Project/Plan	Type of development	Potential overlap of construction?	Overlap of operation?	Tier
Under construction	Dudgeon	Offshore Wind Farm	No	Yes	1
	Race Bank	Offshore Wind Farm	No	Yes	1
	Nordsee 1	Offshore Wind Farm	No	Yes	1
	Veja Mate	Offshore Wind Farm	No	Yes	1
	Gemini (comprised of Buitengaats and ZeeEnergie)	Offshore Wind Farm	No	Yes	1
	Galloper	Offshore Wind Farm	No	Yes	1
	Beatrice	Offshore Wind Farm	No	Yes	1
	Hornsea Project One	Offshore Wind Farm	No	Yes	1
	East Anglia One	Offshore Wind Farm	No	Yes	1
Consented /Approved	Nemo Link (UK-Belgium Interconnector)	Cable installation	No	Yes	1
	Hornsea Project Two	Offshore Wind Farm	Yes	Yes	1
	MEG Offshore I (now Merkur Offshore Wind Farm)	Offshore Wind Farm	No	Yes	1
	Triton Knoll	Offshore Wind Farm	Yes	Yes	1
	Moray East (previously Moray Offshore Renewables Ltd Eastern Development Area)	Offshore Wind Farm	Yes	Yes	1
	Dogger Bank Creyke Beck A & B	Offshore Wind Farm	Yes	Yes	2
	Dogger Bank Teesside A	Offshore Wind Farm	Yes	Yes	2
	Sofia (formally Dogger bank Teesside B)	Offshore Wind Farm	Yes	Yes	2
	East Anglia Three	Offshore Wind Farm	Yes	Yes	2
	Norther	Offshore Wind Farm	No	Yes	2
	Mermaid	Offshore Wind Farm	Unknown	Unknown	2

Status of Development	Project/Plan	Type of development	Potential overlap of construction?	Overlap of operation?	Tier
	Rentel Area A	Offshore Wind Farm	No	Yes	2
	Seastar	Offshore Wind Farm	Unknown	Unknown	2
	Borkum Riffgrund 2	Offshore Wind Farm	Unknown	Unknown	2
	Borkum Riffgrund West	Offshore Wind Farm	Unknown	Unknown	2
	Demonstrationsprojekt Albatros 1	Offshore Wind Farm	Unknown	Unknown	2
	Deutsche Bucht	Offshore Wind Farm	Unknown	Unknown	2
	EnBW He dreiht	Offshore Wind Farm	Unknown	Unknown	2
	EnBW Hohe See	Offshore Wind Farm	Unknown	Unknown	2
	Gode Wind 3	Offshore Wind Farm	Unknown	Unknown	2
	Gode Wind 4	Offshore Wind Farm	Unknown	Unknown	2
	Kaikas	Offshore Wind Farm	Unknown	Unknown	2
	Nordsee 2	Offshore Wind Farm	Unknown	Unknown	2
	Nordsee 3	Offshore Wind Farm	Unknown	Unknown	2
	OWP Delta Nordsee 1	Offshore Wind Farm	Unknown	Unknown	2
	OWP Delta Nordsee 2	Offshore Wind Farm	Unknown	Unknown	2
	OWP West	Offshore Wind Farm	Unknown	Unknown	2
	Trianel Windpark Borkum Phase 2	Offshore Wind Farm	Unknown	Unknown	2
	Borssele 1 & 2	Offshore Wind Farm	Yes	Yes	2
	Borssele 3 & 4	Offshore Wind Farm	Yes	Yes	1
	Borssele 5	Offshore Wind Farm	Yes	Yes	2
	Horns Rev 3 (Denmark)	Offshore Wind Farm	No	Yes	2
	Fecamp - Seine-Maritime	Offshore Wind Farm	Unknown	Unknown	2

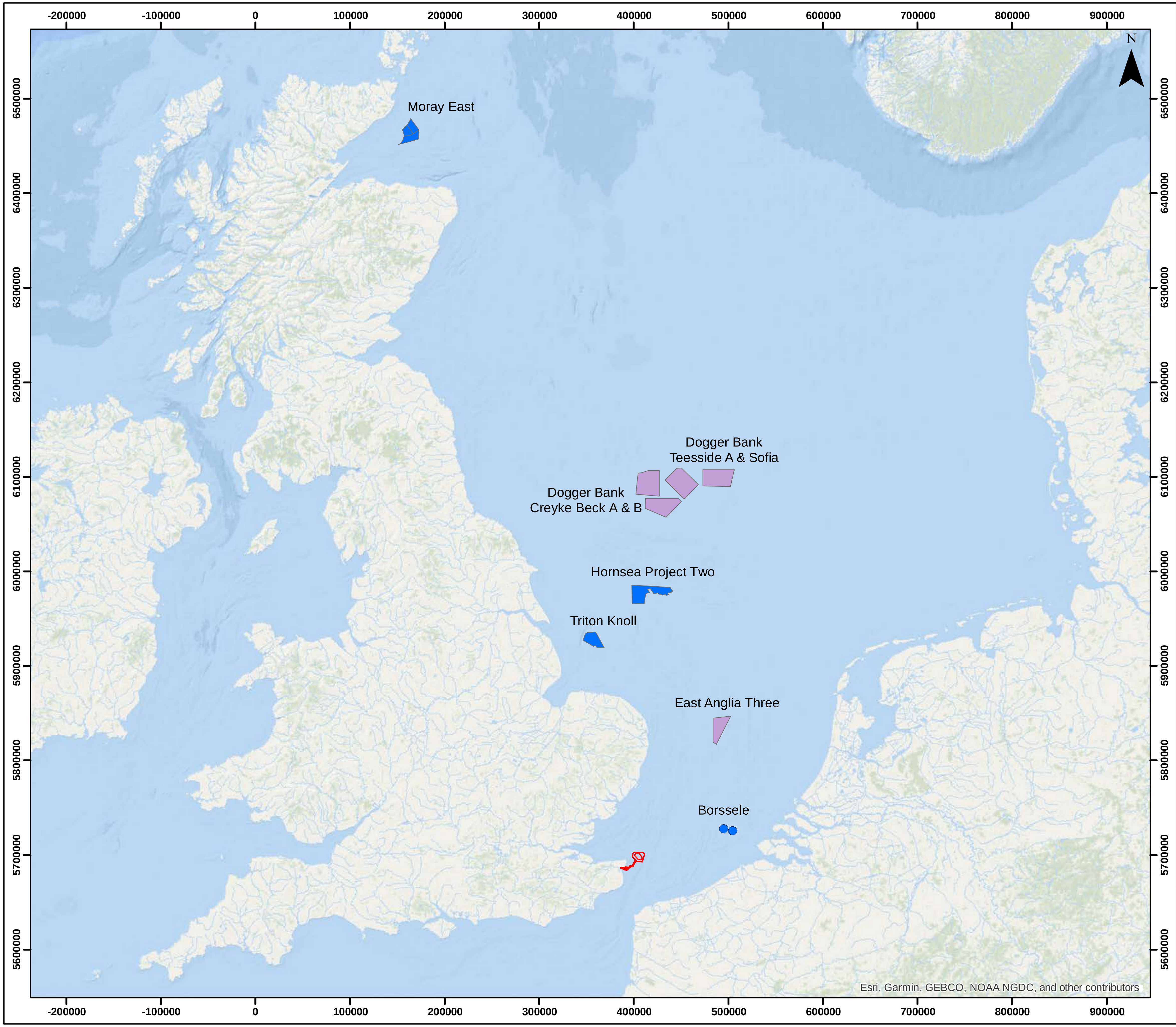
Status of Development	Project/Plan	Type of development	Potential overlap of construction?	Overlap of operation?	Tier
	Parc eolien Courseulles-Sur-Mer	Offshore Wind Farm	Unknown	Unknown	2
	Projet eolien en mer de la Baie de Saint-Brieuc	Offshore Wind Farm	Unknown	Unknown	2
	Borkum West 2	Offshore Wind Farm	Unknown	Unknown	2
	Hollandse Kust noord 1	Offshore Wind Farm	Unknown	Unknown	2
	Hollandse Kust noord 2	Offshore Wind Farm	Unknown	Unknown	2
	Mersea Yacht Club Pontoon Extension	Port Development	Yes	Yes	2
In determination	Hollandse Kust zuid 1 & 2	Offshore Wind Farm	Unknown	Unknown	3
	Hollandse Kust zuid 3 & 4	Offshore Wind Farm	Unknown	Unknown	3
	Dieppe et Le Tréport	Offshore Wind Farm	Yes	Yes	3
	Fécamp	Offshore Wind Farm	Yes	Yes	3
In planning	Hornsea Project Three	Offshore Wind Farm	Yes	Yes	4
	East Anglia Norfolk Vanguard East	Offshore Wind Farm	Yes	Yes	4
	East Anglia Norfolk Vanguard West	Offshore Wind Farm	Yes	Yes	4
	East Anglia Norfolk Boreas	Offshore Wind Farm	No	Yes	4
	East Anglia ONE North	Offshore Wind Farm	Unknown	Unknown	4
	East Anglia TWO	Offshore Wind Farm	Unknown	Unknown	4
	Moray West (Western Development Area of Moray Firth R3 Zone)	Offshore Wind Farm	Unknown	Unknown	4
In planning: resubmission expected of revised design and associated assessment post original consents. Timeline is based on revised applications (information in Scoping reports) .	Neart na Gaoithe	Offshore Wind Farm	Yes	Yes	4
	Inchcape	Offshore Wind Farm	Yes	Yes	4
	SeaGreen Phase 1	Offshore Wind Farm	Yes	Yes	4

Table 7.37: Cumulative Maximum Design Scenarios assessed

Impact	Scenario	Details
Increased levels of underwater noise from construction activities	Construction of other OWF projects with pile-driving activities overlapping with those at Thanet Extension Pile-driving activities associated with ports and harbour developments overlapping with piling activity at Thanet Extension.	Maximum design scenario includes projects whose construction phase overlaps with the construction phase for Thanet Extension. Maximum design scenario considers the longest duration of the piling phase for each of the projects. Where projects do not overlap but run consecutively, it is assumed that piling could occur at any point within the construction phase therefore giving the longest duration of a potential piling phase. Maximum design scenario for ports and harbours assumes an increase in subsea noise arising from projects that involve pile-driving activity or blasting during construction. Projects have been screened out where there is a very short piling duration (less than one month), or very few piles to be installed. Noise impacts arising from aggregate extraction and cable and pipeline installation have been screened out on the basis that these are considered to be highly localised, short-term, and of negligible magnitude. In addition, all oil and gas activities listed in the cumulative screening table are currently operational and therefore were considered to be part of the baseline and screened out for cumulative impacts of subsea noise.
Increased vessel traffic leading to potential disturbance and collision risk	The increase in vessel numbers as a result of the construction of other OWF projects where there is overlap with the Thanet construction period represents the maximum increase in vessel activity, although there is also potential for the increase in vessels as a result of the operational and decommissioning phase of other projects to act cumulatively.	Maximum design scenario includes projects whose construction, O&M and decommissioning phase overlaps with the construction phase for Thanet Extension. The increase in vessel activity during the operation phase of Thanet Extension was assessed as negligible and therefore is scoped out of this cumulative assessment. Maximum design scenario considers the longest duration of the piling phase for each of the projects. Where projects do not overlap but run consecutively, it is assumed that piling could occur at any point within the construction phase therefore giving the longest duration of a potential piling phase.
Underwater noise from seismic survey as a result of oil and gas projects leading to potential disturbance	Seismic surveys in the North Sea Management Unit could overlap with construction at Thanet Extension.	In 2016 JNCC launched the Marine Noise Registry (MNR; JNCC (2016)) which is a database that records the spatial and temporal distribution of impulsive noise generating activities in UK seas. In the absence of detailed information on likely future activity, this assessment has taken the outputs from the noise registry from 2015 as indicative of future levels of activity in the wider management unit.
Underwater noise from UXO clearance	A number of other plans and projects (OWF and Naval exercises) may be undergoing UXO clearance activities at the same time as construction at Thanet Extension.	Impacts have only been assessed where information exists on the likely timing, duration and location of UXO clearance from other projects and activities are likely to overlap with UXO clearance or pile driving at Thanet Extension.
Indirect impacts: changes in prey availability as a result of changes in the fish and shellfish community	The maximum design scenario for Thanet Extension cumulatively with the projects listed in Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6) for each of the impacts screened into the CEA.	The maximum design scenario presented in Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6) will present the worst-case for any cumulative impacts on prey species, which will therefore dictate the potential for an effect on marine mammals.

Table 7.38: OWFs with the potential for overlapping piling periods with Thanet Extension (period over which piling will occur at Thanet Extension is highlighted by red border) for projects for which information is available on the predicted timing of piling activity. Also indicated are the species for which each projects is scoped into the assessment (HP=harbour porpoise; GS=grey seal; HS=harbour seal)

Project	Species	Project Stage	Tier	2018	2019	2020	2021	2022	2023	2024	2025	2026
Triton Knoll	All	Consented	Tier 1									
Moray East	HP		Tier 1									
Hornsea Project Two	All		Tier 1									
Borssele	All		Tier 1									
Dogger Bank Creyke Beck A & B	HP, GS		Tier 2									
Dogger Bank Teesside A	HP, GS		Tier 2									
Sofia (formally Dogger Bank Teesside B)	HP, GS		Tier 2									
East Anglia Three	All		Tier 2									
Dieppe et Le Tréport	HP	Submitted	Tier 3									
Fécamp	HP		Tier 3									
Hornsea Project Three	All	In planning	Tier 4									
East Anglia Norfolk Vanguard East & West	All		Tier 4									
Moray West	HP		Tier 4									



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THANET EXTENSION OFFSHORE WIND FARM

Figure 7.25

Tier 1 and Tier 2 OWF Projects Included in CEA for Piling Noise

Legend

- Offshore Red Line Boundary
- Tier 1
- Tier 2

Datum: ETRS 1989
Projection: UTM31N

1:4,000,000 — 0 40 80 km — 0 20 40 nm

Drg No	ES Vol 2 Chpt 7 Fig 7.25			Figure 7.25
Rev	0.1	Date	23/05/2018	
By	RP	Layout	N/A	

Underwater noise: Offshore wind farm construction activity

7.14.18 Underwater noise from foundation piling and other activities during the construction of Thanet Extension with underwater noise arising during construction of other projects has the potential to cause injury or disturbance to marine mammals.

7.14.19 During the offshore construction of Thanet Extension, the main source of cumulative impacts from underwater noise is likely to be from piling operations from other projects, plans and activities. The projects included in this cumulative impact assessment are detailed in Table 7.36 and Table 7.38 and include OWFs and coastal developments within the wider North Sea where piling is considered likely to occur during construction phases of these projects, and where there is potential for direct overlap of piling phases, or where piling is predicted to occur in the years consecutive to piling at Thanet Extension or is expected to commence within a window of five years from the earliest expected date of piling activity for Thanet Extension (Table 7.38).

7.14.20 Based on the information currently available, within Tier 1, four projects are predicted to potentially have a directly overlapping piling period with Thanet Extension (Triton Knoll, Moray East, Hornsea Project Two and Borssele). In Tier 2, Dogger Bank Creyke Beck A & B, Dogger Bank Teeside A. Sofia (formerly Dogger Bank Teeside B) and East Anglia Three are predicted to potentially have direct overlap of piling phases. In Tier 3, two French projects, Dieppe et Le Tréport and Fécamp are anticipated to potentially overlap. In Tier 4, Hornsea Project Three, East Anglia Norfolk Vanguard and Moray West are predicted to have direct overlapping construction phases with the Thanet Extension piling phase.

7.14.21 The potential for cumulative impacts of pile-driving has been assessed for Thanet Extension based on the maximum scenario of piling at the eastern edge of the boundary using a 5,000 kJ hammer energy. Where a quantitative assessment was possible (information available in ESs) the maximum design scenario has been included in the assessment for associated CEA projects. This is likely to be a highly precautionary approach to assessment as the maximum adverse scenario for each project (e.g. maximum hammer energy, maximum piling duration, maximum construction periods, maximum number of concurrent piling activities etc.) is extremely unlikely to occur the majority of the time, and at every project concurrently.

7.14.22 It should be noted that the cumulative noise assessment has been based on quantitative information and assessments, where available, as presented in the published ESs. Timelines have been assumed based on published information in the public domain. It is important to note that construction timescales are indicative and subject to change and it is considered highly likely that potential overlap of piling phases will vary from those presented above.

7.14.23 Though piling is planned for construction of a number of other OWFs included in Table 7.36, the construction timelines are currently unknown and therefore these projects have not been quantitatively assessed in this CEA.

Tier 1

Permanent Threshold Shift

7.14.24 All UK Tier 1 projects' impact assessments for subsea noise from pile-driving have presented smaller hammer energies therefore the potential ranges for PTS from CEA projects are likely to be smaller than for Thanet Extension. In addition, these projects have all have committed to the implementation of mitigation measures, to reduce the likelihood of PTS to negligible.

7.14.25 As potential impact ranges are small and any risk expected to be reduced to negligible by the adoption of project specific mitigation procedures (including visual and passive acoustic monitoring to ensure the impact zone is free of marine mammals before piling begins, use of acoustic deterrents to move marine mammals out of predicted impact zones and the adoption of piling soft starts), the residual magnitude of impact is predicted to be Negligible across all projects and therefore effects are of **Minor** significance in the cumulative assessment.

Disturbance/displacement (possible avoidance)

7.14.26 The maximum number of harbour porpoises potentially impacted as a result of piling at Thanet Extension was 1,880, which is equivalent to 0.54% of the North Sea MU population. The equivalent numbers for harbour and grey seals were 27 and 10.3 respectively, equivalent to 0.38 and 0.03% of the appropriate MU populations.

7.14.27 For those Tier 1 projects where piling may overlap with the piling phases for Thanet Extension, modelled behavioural impact ranges (likely avoidance and possible disturbance), as presented in published ESs, are presented in Table 7.39 (harbour porpoise) and Table 7.37 (seals) below. Where a total area of potential impact is given for likely avoidance, this has been calculated from the published range of impact provided in the associated ESs. Note that for each species, only those projects within the relevant MU are included. Consequently, a larger range of projects are included in the harbour porpoise assessment than for either species of seal.

7.14.28 Given the degree of uncertainty in the exact timing of piling operations, it is difficult to carry out a confident quantitative cumulative assessment. In addition, there may be significant overlap in predicted impact areas between projects and therefore impact will not be additive. However, if the numbers presented in Table 7.39 below are summed, for the single piling scenario (recognising that concurrent piling across this number of projects is completely unrealistic) and include the Thanet Extension prediction, this provides a total for harbour porpoise displacement of 7159, which is equivalent to 2.1% of the MU population.

7.14.29 The effects are likely to be temporary and any short-term changes in the ability of individual porpoises to reproduce over the period experiencing disturbance, are likely to be reversible, an effect on two percent of the population has been assessed as Low magnitude. Coupled with a Medium sensitivity to disturbance, this results in a **Minor** adverse effect on harbour porpoises.

7.14.30 Booth *et al*. (2017) recently carried out an assessment of the cumulative effects on the North Sea harbour porpoise population as a result of a number of scenarios of OWF construction in eastern English waters. This assessment included many of the projects included in the CEA presented here. This work calculated the "additional risk of a population decline" imposed by various construction scenarios. Worst-case assessed included scenarios with up to 34,000 animals being predicted to experience disturbance from piling noise across a range of OWF projects. This was equivalent to 15% of the total MU population size estimate at the time of assessment.

7.14.31 Based on absolute worst-case assumptions across all input parameters (animal densities, responses, piling scenarios, days of residual disturbance, and the proportion of population vulnerable to impacts) the maximum predicted impact was only a six percent increase in the probability of a one percent or greater population decline. This analysis suggests that a cumulative impact of this magnitude would not have a long-term effect on the North Sea harbour porpoise population. While the iPCoD model is subject to many assumptions and uncertainties relating to the link between impacts and vital rates, the model presents the best available scientific expert opinion at this time. Further information on the assumptions and limitations of this approach can be found in Booth *et al*. (2017).

7.14.32 Following the same procedure for seals and summing the numbers within Table 7.40 provides a total of 118 harbour seals and 102 grey seals. These numbers are equivalent to 1.7 % and 0.27 % of the relevant UK MUs. The equivalent number as a proportion of the UK reference population (South-east England for harbour seals and North-east + South-east England for grey seals) plus the Wadden Sea population is 0.3% for harbour seals and 0.2% for grey seals. This is considered to be Low magnitude. Coupled with a Low sensitivity to disturbance, this results in an assessment of **Minor** adverse significance for both species of seal.

Table 7.39: Modelled behavioural impact ranges for harbour porpoise due to piling at Tier 1 projects predicted to overlap with piling at Thanet Extension

Project	Impact range	Number of animals predicted to be affected		Predicted impact of significance
		Single	Concurrent	
Triton Knoll	16.6 km (90 dBht)	357 (90 dBht)	The magnitude of multiple piling is not predicted to be significantly higher than for individual piling events	**Minor**
Moray East	22 km (75 dBht)	2993	3442	**Major** significance over medium term for individuals during construction phase with M**inor** significance long-term effects on the population.
Hornsea Project Two	62 km (145 SEL, dose response)	3809	6570	**Moderate** (short to medium term) **No significant effect in the long-term**
Borssele	No ranges or numbers predicted – mitigation expected to avoid significant effects: Limiting sound production during pile-driving to a maximum value to be determined between 160 and 172 dB re µPa^{2}s at 750 metres			

Table 7.40: Modelled behavioural impact ranges for seals due to piling at Tier 1 projects with the potential to overlap with piling at Thanet Extension

Project	Species	Number of animals predicted to be affected: Single	Number of animals predicted to be affected: Concurrent	Predicted impact of significance
Triton Knoll	Grey Seal	90 (90 dBht)	The magnitude of multiple piling is not predicted to be significantly higher than for individual piling events	Potentially minor, but in the range minor to moderate
	Harbour Seal			Minor
Hornsea Project TWO	Grey Seal	1.29	1.35	Negligible
	Harbour Seal	0.8	0.8	Negligible
Borselle	No ranges or numbers predicted – mitigation expected to avoid significant effects: Limiting sound production during pile-driving to a maximum value to be determined between 160 and 172 dB re µPa²s at 750 metres			

Tier 1 and Tier 2 combined

PTS

7.14.33 All Tier 2 projects impact assessments for subsea noise from pile-driving have presented smaller hammer energies and are highly likely to follow good practice in implementation of mitigation measures, therefore the potential ranges for PTS are likely to be smaller than for Thanet Extension.

Disturbance/displacement (possible avoidance)

7.14.34 For those projects where piling may overlap with the piling phases at Thanet Extension, modelled behavioural impact ranges (likely avoidance and possible disturbance), as presented in published ESs, are presented in Table 7.41 (harbour porpoise) and Table 7.42 (seals) below. Where a total area of potential impact is given for likely avoidance, this has been calculated from the published range of impact provided in the associated ESs.

Table 7.41: Modelled behavioural impact ranges for harbour porpoise due to piling at Tier 2 projects with piling predicted in the years adjacent to piling at Thanet Extension

Project	Impact range	Number of animals predicted to be affected: Single	Number of animals predicted to be affected: Concurrent	Predicted impact of significance
Dogger Bank Creyke A	19.5-26 km (SEL 145)	1288 (SEL 145)	3119 (SEL 145)	Negligible (single) Minor adverse (concurrent)
Dogger Bank Creyke B	24-43 km (SEL 145)	2276 (SEL 145)	4394 (SEL 145)	Negligible (single) Minor adverse (concurrent)
Dogger Bank Teeside A	22-33.5 km (SEL 145)	1920 (SEL 145)	4302 (SEL 145)	Negligible (single) Minor adverse (concurrent)
Sofia	22-33.5 km (SEL 145)	2035 (SEL 145)	3931 (SEL 145)	Negligible (single) Minor adverse (concurrent)
East Anglia Three	26 km	2869 (EDR)	2869 (EDR)	Spatial worst-case Minor Temporal worst-case Negligible

Disturbance/ displacement (possible avoidance)

7.14.35 As discussed above for PTS, only two Tier 2 projects are expected to have a direct piling overlap with Thanet Extension. However, given the uncertainty in the timing of Tier 2 there is a chance that up to five might overlap.

7.14.36 As discussed above a quantitative assessment is highly uncertain as the numbers affected across these projects will not be additive. For indicative purposes if we sum the numbers presented in Table 7.39 and Table 7.41, and include the Thanet Extension prediction. This provides a total for harbour porpoise displacement of 31,455 across both Tier 1 and 2, which is equivalent to 9 % of the MU population.

7.14.37 As discussed above Booth *et al*. (2017) reported that the cumulative effects on the North Sea harbour porpoise population as a result of offshore wind farm construction in eastern English waters (with an effect magnitude of 15 %) would not present a significant risk of a long-term effect on the North Sea harbour porpoise population. It is therefore considered that a total of 9% effect magnitude would similarly not pose a risk to the long-term health of the North Sea harbour porpoise population.

7.14.38 Even though the effects are likely to be temporary and any short-term changes in the ability of individual porpoises to reproduce over the period experiencing disturbance, are likely to be reversible, an effect on 9 % percent of the population has been assessed as Medium magnitude. Coupled with a Medium sensitivity to disturbance, this results in a **Moderate adverse** effect on harbour porpoises.

7.14.39 It is important to note that this assessment based on the highly implausible scenario of complete overlap between all these construction projects, and multiple piling vessels working concurrently on each site.

7.14.40 It is important to note that despite an overall moderate adverse impact in EIA terms when taking into account overlap with all other potential offshore wind farm projects within the MU, the relative contribution of Thanet Extension is very low. In quantitative terms, predicted displacement from Thanet Extension constitutes only 6 % of the total predicted disturbance. If the impact of Thanet Extension were to be removed from this cumulative assessment, a moderate adverse effect would still be predicted for harbour porpoise based on the levels of impact from the other projects considered. Given this, it would not be possible to reduce this conclusion from a Moderate significance in EIA terms by the application of any mitigation specifically at Thanet Extension. However, mitigation proposed in the HRA (describe mitigation measures proposed in HRA) would have the potential to reduce this to impact to minor.

7.14.41 Following the same procedure for seals and summing the numbers within Table 7.37 and Table 7.42 for both Tier 1 and Tier 2 projects provides a total of 118 harbour seals and 127 grey seals. These numbers are equivalent to 1.68% and 0.34% of the relevant UK MUs. The equivalent number as a proportion of the UK reference population (Southeast England for harbour seals and Northeast + Southeast England for grey seals) plus the Wadden Sea population is 0.3 % for both species of seals. This is considered to be Low magnitude at UK scale. Coupled with a Low sensitivity to disturbance, this effect is assessed as of **Minor** significance for both species of seal.

Table 7.42. Modelled behavioural impact ranges for seals due to piling at Tier 2 projects with piling predicted in the years adjacent to piling at Thanet Extension

Project	Species	impact range (threshold used)	Number of animals predicted to be affected	Predicted impact of significance
Dogger Bank Creyke A	Grey seals	<1.8 km (Mpw 171)	8.5	**Negligible**
Dogger Bank Creyke B	Grey seals	<1.9 km (Mpw 171)	11	**Negligible**
Dogger Bank Teeside A	Grey seals	<1.7 km (Mpw 171)	1.5	**Negligible**
Sofia	Grey seals	<1.7 km (Mpw 171)	4	**Negligible**
East Anglia Three	Grey seals Harbour seals	(Mpw 171)	Not quantified	**Negligible**

Tier 3 and 4

7.14.42 There is very little quantitative information available on the potential magnitude and duration of impact for the additional projects in Tier 3 and 4. The potential for disturbance from these projects is therefore assumed to be similar to the ranges presented for Tier 1 and 2 projects where available. The timing of these projects is much more uncertain and the level of potential impact is currently unknown. It is therefore assumed that the range of effects for the key marine mammal species in this CEA will be the same as described for Tier 1 and 2 projects. The assessment of magnitude, sensitivity and significance is considered to be the same as for Tier 1 and 2 combined, a **Moderate adverse** significant effect for harbour porpoise and a **Minor adverse** effect for seals. As noted above, the overall contribution of Thanet Extension to this overall effect will be low. If the impact of Thanet Extension were to be removed from this cumulative assessment, a moderate adverse effect would still be predicted for harbour porpoise based on the levels of impact from the other projects considered. Given this, it would not be possible to reduce this conclusion from a Moderate significance in EIA terms by the application of any mitigation specifically at Thanet Extension.

Construction ship traffic: disturbance and collision

7.14.43 Increased ship traffic during construction, O&M or decommissioning of Thanet Extension could result in an increased risk of disturbance to, or collisions with marine mammals during construction, operation or decommissioning of other plans and projects.

7.14.44 This cumulative assessment considers the effects of increased vessel noise on, and increased potential for collision with marine mammals, due to the potential increase in vessel movements from the construction, operation and decommissioning of Thanet Extension with other planned or existing projects, plans and activities. These are:

- OWFs where construction and/ or operational phases overlap with the construction and operational phases of Thanet Extension;
- Operational phases of new port and harbour developments where there is a potential for an increase in vessel movements; and
- Cable and pipeline projects that have not yet commenced construction.

7.14.45 Upon examination of data available for offshore wind, pipeline and cable, and coastal developments, it is clear that the greatest potential for cumulative increase in vessel movements arises from the development of other OWF developments.

7.14.46 Two offshore cable projects have been scoped into the CEA. Vessel movements associated with these projects are likely to lead to only a very slight increase in vessel movements, particularly when considered against increased movements associated with OWF developments. Therefore, this can be considered Negligible in relation to potential cumulative increased collision risk or disturbance to marine mammals due to increased vessel movement in the relevant MU.

7.14.47 Table 7.43 summarises the indicative vessel movements predicted to be associated with OWF developments in the North Sea over the lifetime of Thanet Extension, including the construction, O&M, and decommissioning phases. The estimated increase in vessel movements associated with Thanet Extension over the construction period was a total of 1,220 over three years. The estimated increase in vessel movements associated with Thanet Extension over the operational period was a total of 157 return trips per year.

7.14.48 The total numbers presented in Table 7.43 represent a highly unlikely scenario of the maximum design scenarios for all projects. It is likely that vessel movements will occur much less frequently than assumed for maximum design scenarios. The numbers do not reflect that most construction vessels associated with offshore developments will be stationary or slow moving, are likely to follow pre-determined routes to and from ports, and will adhere to best-practice guidance regarding changes of speed, changes in direction and will not approaching marine mammals.

7.14.49 Overall, baseline vessel use within the North Sea MU is considered to be relatively high due to the presence of known shipping routes, ferry routes, and recreational boating areas. Marine mammals are therefore likely to show some degree of tolerance to vessel movements. Given the limited spatial extent of vessel movements from the projects considered in the CEA, with most activity confined to within the project area and transiting via existing routes, it is considered likely that marine mammals will tolerate the additional presence of vessels and the additional noise disturbance due to the increased vessel movements.

7.14.50 The impact is predicted to be long-term but intermittent. The most intense impacts will be seen during overlapping construction periods (see Table 7.38) with a much lower level of vessel activity during the longer term, operational phases. Effects are considered both small scale and reversible (disturbance due to increased vessel noise) and irreversible (collision risk). The magnitude is considered to be Low.

7.14.51 There is a high likelihood of avoidance from both increased vessel noise and collision risk, with both a high potential for recovery for increased noise, and although there is a low potential for recovery for collision risk the likelihood of collision is low. The sensitivity of all marine mammal species is therefore considered to be Low. The significance of this effect is therefore assessed as Minor and therefore insignificant in EIA terms.

Table 7.43: Cumulative effects assessment projects – vessel movements for those projects where quantitative information is available

Project	Construction – number of vessel movements (return trips)	Operation and Maintenance – number of vessel movements (return trips)
Tier 1		
Triton Knoll	3,850 over 3 years	9,220 per year
Moray East	1,355 per construction period (4,065 total)	Not available/assessed as not significant
Hornsea Project Two	6,200 in total over up to 7.5 years	2,817 per year
Borselle	Not available	Not available
Tier 2		
Dogger Bank Creyke A & B	3,460 in total over 3 years	683 per year
Dogger Bank Teeside A & B	5,810 in total over 6 years	730 per year
East Anglia Three	8,000 (two phase approach) over 3.75 years	4,067 per year
Tier 3		
Dieppe et Le Tréport	Not available	Not available
Fécamp	Not available	Not available
Tier 4		
Hornsea Project Three	11,776 over two 2.5 year phases with 6 years apart	2,832 per year
East Anglia Norfolk Vanguard East & West	1,695 in total over 3 years	Assumed to be similar to the construction phase (or less)
Moray West	Not available	Not available
Seagreen	Original consent: 4 vessels on site at any one time for each sub-project = 28 vessels in total at any one time over construction period Revised design: Not available	Original consent: 1,760 per year Revised design: Not available
Inch Cape	Original consent: 3,500 over 1.5 years Revised design: Not available	Original consent: Not available/assessed as not significant Revised design: Not available
Neart na Gaoithe	Original consent: 9,792 over 17 month construction period Revised design: Not available	Original consent: 1,550 per year Revised design: Not available

Underwater noise: Oil & Gas Activities including seismic surveys

7.14.52 Underwater noise is generated by a number of activities related to the oil and gas industry including seismic surveys, drilling and decommissioning. According to The Strategic Environmental Assessment for Offshore Energy (OESEA3) in Regional Seas 1 and 2 (northern central and southern North Sea) the cumulative effects of both seismic survey activity and piling need to be considered. The potential for significant impact from a combination of pile driving at Thanet Extension and oil and gas activities is largely related to the anticipated type, extent and duration of seismic survey. Oil and gas activities are licenced in the UK by the Department for Business, Energy & Industrial Strategy (BEIS) and there is no easily accessible central repository for detailed information on planned or likely future activities over the timescales required for this assessment. In 2016 JNCC launched the Marine Noise Registry (MNR; JNCC (2016)) which is a database that records the spatial and temporal distribution of impulsive noise generating activities in UK seas. In the absence of detailed information on likely future activity, this assessment has taken the outputs from the noise registry from 2015 as indicative of future levels of activity in the wider management unit, although it is unlikely that areas previously subject to detailed seismic survey will be subject to re-survey. It should however, be noted that the sub-bottom profiler surveys are voluntary notifications only and so the number reported to the Marine Noise Registry may be an underestimate of the true number conducted.

7.14.53 Figure 7.27 displays the number of days of impulsive noise in each block and Figure 7.26provides information on the activity types relating to this. Much of the previous seismic survey activity has been concentrated in the central and north North Sea with very little activity in the southern North Sea. Much of this activity relates to the Government funded, Oil and Gas Authority's 'Mid North Sea High' seismic survey. Overall levels of activity have been relatively low – between 2 and 5 days of activity across the whole year, with only a few blocks experiencing higher levels.

7.14.54 Oil and Gas activities in adjacent North Sea waters have also been considered in this assessment. According to TNO (Heinis *et al*. 2015) seismic surveying activity in the years 2016-2022 are not expected to differ from levels prior to 2016 and although year to year variations are expected, in general, ongoing activities can be considered as part of the baseline conditions.

7.14.55 All activities are licenced under EPS regulations therefore current mitigation measures will ensure no cumulative effect of auditory injury related impacts.

7.14.56 There is much uncertainty regarding the potential for cumulative effects of noise disturbance from a combination of pile driving and seismic survey. There is little empirical data on the effect of seismic surveys on marine mammals. One study in the Moray Firth, Scotland, demonstrated that disturbance effects in harbour porpoises occurred over ranges of 5-10 km but that effects were short-lived and animals were typically detected again at affected sites within a few hours (Thompson *et al*. 2013b). This study demonstrated that there was no long-term displacement into sub-optimal or higher risk habitats. A follow up analysis using the same data (Pirotta *et al*. 2014) demonstrated that feeding activity was reduced in the ensonified area (measured by the probability of measuring a porpoise echolocation 'buzz', a behaviour thought to be indicative of foraging attempts) by 15%.

7.14.57 Given the general level of activity recorded in the MNR (a few days per year per block) the cumulative impact of underwater noise from piling at Thanet and seismic surveys in the North Sea region is anticipated to be of Low magnitude. Given the short return times and temporary disturbance effects reported in Thompson *et al*. (2013b) and Pirotta *et al*. (2014) the sensitivity is assessed as Medium. The overall significance of the cumulative effects of disturbance from pile driving noise at Thanet Extension with noise from oil and gas activities is Minor.

Underwater noise: Other construction activities including port and harbour development

7.14.58 Underwater noise is generated by a number of other construction activities related to the development of harbours and ports and by the installation of cables and pipelines. There is the potential for these to affect marine mammals cumulatively with the construction activities at Thanet Extension. No new cable or pipeline installation projects were identified as overlapping with the construction phase of Thanet Extension. The extension of an existing pontoon at West Mersea Yacht Club at West Mersea, Colchester may overlap with construction at Thanet but no underwater noise impacts are anticipated from these activities and therefore no cumulative impacts are anticipated.

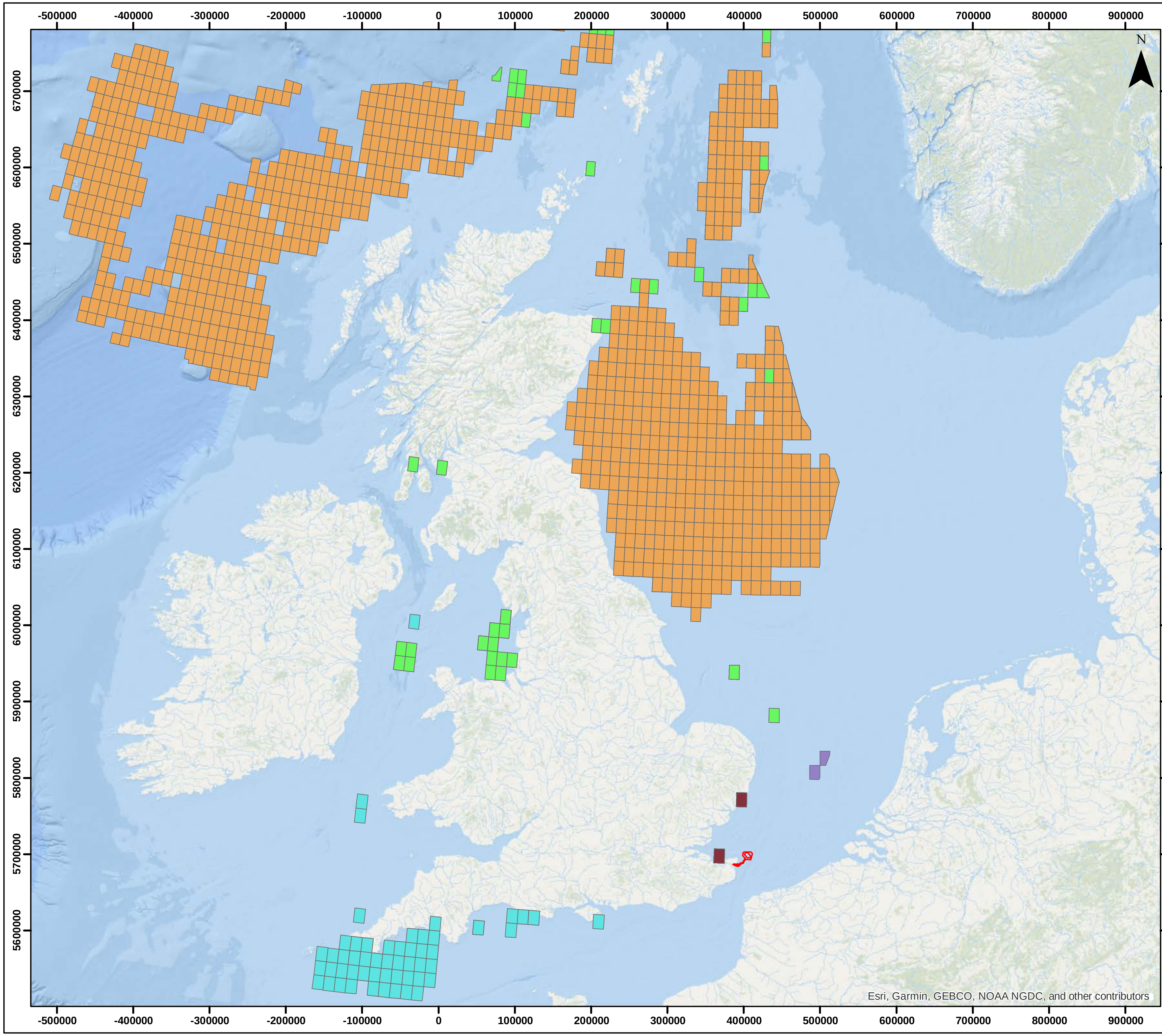
Underwater noise: UXO clearance

7.14.59 There is the potential requirement for explosions for UXO clearance prior to construction of other wind farms across the North Sea management unit with the potential for cumulative impact on the harbour porpoise population. UXO clearance by the Royal Netherlands Navy is also possible (as described in von Benda-Beckman *et al*., (2015)). It is not possible to carry out a reliable quantitative assessment of the extent of UXO clearance related detonations overlapping with UXO clearance or piling at Thanet Extension. However, taking a similar approach to that taken by other projects, an assessment has been based on a number of basic assumptions relating to overlap with UXO clearance operations elsewhere:

- Up to one UXO clearance operation in the UK northern North Sea area;
- Up to one UXO clearance operation in the UK southern North Sea area;
- Up to one UXO clearance operation in the Netherlands / Belgium area of the North Sea; and
- Up to one UXO clearance operation in the German / Denmark area of the North Sea.

7.14.60 No formal guidance has been provided for the deterrence range to be adopted in assessments of the explosion of UXO, although Natural England did reference the 26 km value for UXO clearance in their East Anglia THREE letter of 28th September 2016 and confirmed at the Thanet Extension Steering Group meeting on 2nd October 2017 that the advice has not changed.

7.14.61 Based on the North Sea average density of harbour porpoises from the SCANS III surveys and a deterrence range of 26 km, the number of harbour porpoise that could potentially be disturbed during one UXO clearance operation is 1,105, which is 0.3% of the North Sea MU. During up to four UXO clearance operations, up to 4,420 porpoises could be affected, which is 1 % of the North Sea MU. UXO detonations occur over a very short duration and any disturbance effect is assumed to be temporary. Therefore, the overall magnitude of the cumulative effect of underwater noise from the construction of Thanet Extension with UXO detonations elsewhere in the North Sea is considered to be Low. The sensitivity of harbour porpoise to disturbance is considered Medium. Therefore, the significance of this effect is considered **Minor**, which is not significant in EIA terms.



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THANET EXTENSION OFFSHORE WIND FARM

Figure 7.26

Activity Type Block Contribution Map
Jan - Dec 2015

Legend

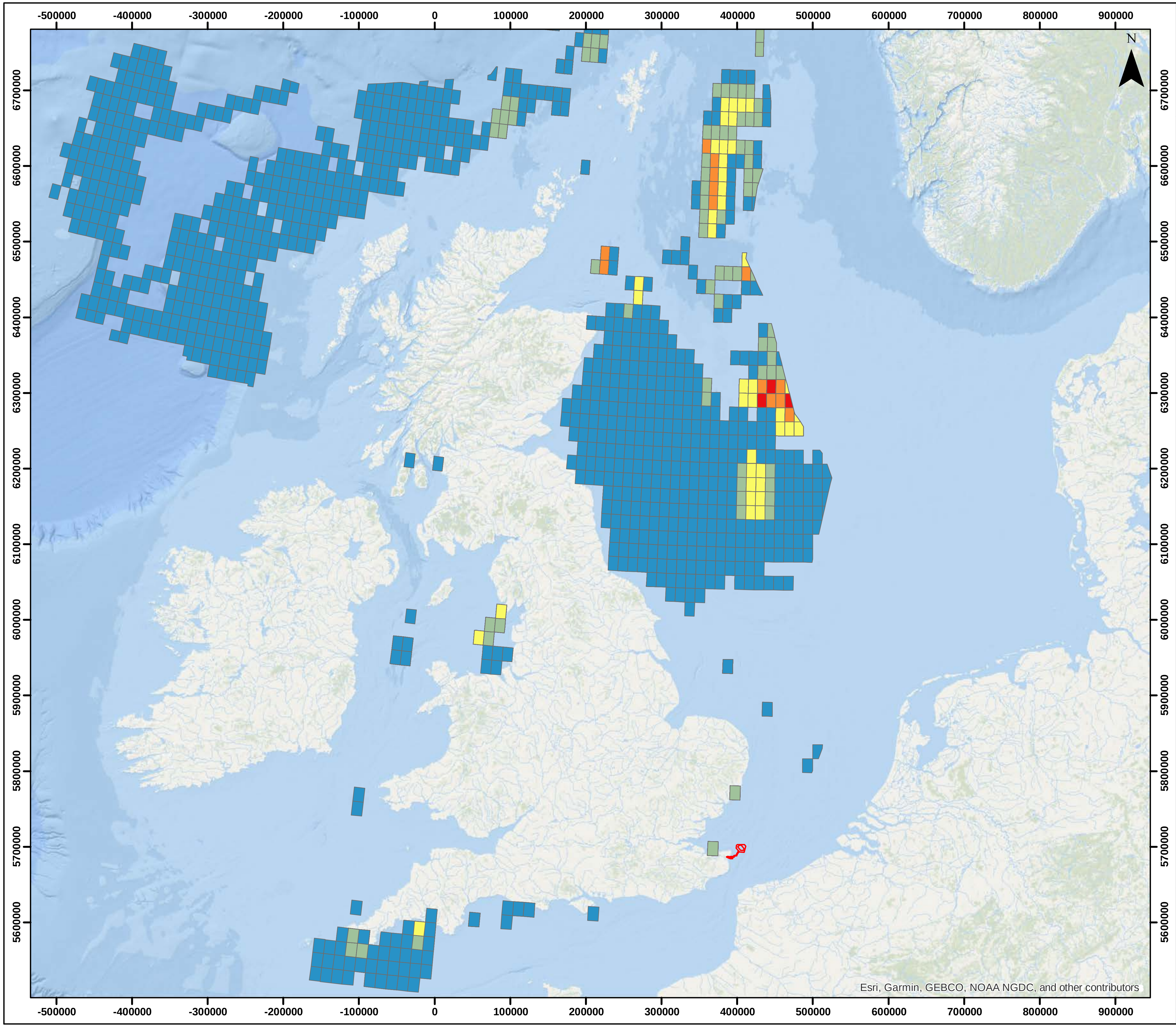
- Offshore Red Line Boundary

Activity Type

- Explosives
- Ministry of Defence
- Piling
- Seismic Survey
- Sub-bottom Profilers

1:5,000,000 0 50 100 km 0 25 50 nm

Drg No	ES Vol 2 Chpt 7 Fig 7.26			Figure 7.26
Rev	0.1	Date	23/05/2018	
By	RP	Layout	N/A	



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THANET EXTENSION OFFSHORE WIND FARM

Figure 7.27

Total Pulse Block Day Map
Jan - Dec 2015

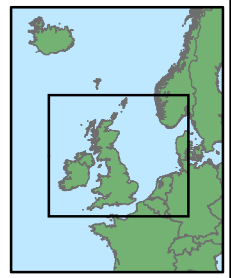
Legend

Offshore Red Line Boundary

Total Pulse Block Day

- 1 - 10
- 11 - 23
- 24 - 42
- 43 - 70
- 71 - 99

Datum: ETRS 1989
Projection: UTM31N



1:5,000,000 0 50 100 km 0 25 50 nm

Drg No	ES Vol 2 Chpt 7 Fig 7.27		
Rev	0.1	Date	23/05/2018
By	RP	Layout	N/A

Figure 7.27

Indirect effects: prey species

7.14.62 Changes in the fish and shellfish community resulting from impacts during construction, O&M or decommissioning of Thanet Extension with the construction, O&M or decommissioning phase of other projects may lead to loss of prey resources for marine mammals.

7.14.63 There is a potential for impacts on marine mammals as a result of the cumulative effects on prey species from the construction activities associated with Thanet Extension and other projects (See Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6)). This could be as a result of: temporary habitat loss as a result of construction activities; cumulative increases in suspended sediment concentration and associated sediment deposition during construction; cumulative effects from construction noise and vibration; electromagnetic fields form subsea cables and long-term habitat loss as a result of the presence of foundations and scour/ cable protection.

7.14.64 Overall all potential cumulative effects on fish and shellfish receptors have been assessed as **Negligible** or **Minor** significance and therefore there is no potential for any cumulative indirect effect for any marine mammal receptors.

7.15 Inter-relationships

7.15.1 Inter-relationships are considered to be the impacts and associated effects of different aspects of the proposal on the same receptor. These are considered to be:

- Project lifetime effects: Assessment of the scope for effects that occur throughout more than one phase of the project (construction, O&M, decommissioning) to interact to potentially create a more significant effect on a receptor than if just assessed in isolation in these three key project phases (e.g. subsea noise effects from piling, operational WTGs, vessels and decommissioning); and
- Receptor led effects: Assessment of the scope for all effects to interact, spatially and temporally, to create inter-related effects on a receptor. As an example, all effects on a given receptor such as marine mammals – injury and disturbance from underwater noise, vessel interactions, indirect effects on prey species etc. may interact to produce a different, or greater effect on this receptor than when the effects are considered in isolation. Receptor led effects might be short-term, temporary or transient effects, or incorporate longer term effects.

7.15.2 Volume 2, Chapter 114 Inter-relationships (Document Ref: 6.2.14) provides a description of the likely inter-related effects arising from Thanet Extension on marine mammals.

7.16 Mitigation

7.16.1 No significant adverse effects have been identified as a result of the Thanet Extension project alone, therefore no additional mitigation, other than that proposed as part of the project in Section 7.10 is required. In terms of the cumulative impact assessment, the potential for disturbance to the harbour porpoise population was assessed as of **Moderate** adverse impact. However, the relative contribution to this from Thanet Extension was predicted to be relatively small – the level of disturbance would be moderate adverse without the consideration of Thanet Extension and therefore any project level mitigation would not reduce this level of significance.

7.16.2 Changes in the fish and shellfish community resulting from impacts during construction, O&M or decommissioning of Thanet Extension with the construction, O&M or decommissioning phase of other projects may lead to loss of prey resources for marine mammals.

7.17 Transboundary statement

7.17.1 A screening of transboundary impacts has been carried out. Given the scale that marine mammal populations exist over, their high levels of mobility and the large extent of the MUs defined by statutory bodies for their management and assessment, there is potential for significant transboundary effects with regard to marine mammals from Thanet Extension upon the interests of other European Economic Area (EEA) States.

7.17.2 Marine mammals range widely over the North Sea from UK coastal waters across to the coast of Europe and into the western Baltic, Skagerrak and Kattegat Seas. Behavioural disturbance could occur over large ranges (tens of kilometres) and therefore there is potential for transboundary effects to occur where subsea noise arising from Thanet Extension could extend into waters of other European states.

7.17.3 The impact assessment presented here takes account of the wider North Sea MU for harbour porpoise and therefore predicted impacts include those on other European States interests in this population. OWFs from other European states were screened into the cumulative impact assessment. For seals, the degree of overlap with east UK seal populations and those from other European countries, particularly the Wadden Sea populations, is explicitly considered in the assessment.

7.17.4 The HRA specifically addresses the potential for a significant effect on other European States Protected Areas for marine mammals.

7.17.5 For all impacts identified for Thanet Extension the assessment has concluded that the effects are very localised and of **Minor** or **Negligible** adverse significance, and therefore these are not considered further in this transboundary effects section.

7.17.6 However, for cumulative effects on the harbour porpoise population, the assessment has concluded that there is the potential for **Moderate** adverse effects. As a result, there is potential for transboundary effects to occur as a result of subsea noise arising cumulatively from all plans and projects assessed in the CEA.

7.18 Summary of effects

7.18.1 Table 7.42 provides a summary of the impact assessment. This impact assessment has not identified any significant effects to harbour porpoise, grey or harbour seals as a result of the construction, operation and decommissioning of Thanet Extension alone. When assessed cumulatively with other plans and projects there is a prediction of an effect of moderate adverse significance on the North Sea harbour porpoise population, however the relative contribution of Thanet Extension project to this overall impact is low.

Table 7.44: Summary of predicted impacts of Thanet Extension

Description of impact	Impact	Possible mitigation measures	Residual impact
Construction			
Underwater Noise (lethal and non-auditory injury)	No potential for any effect	N/A -	No potential for any effect
Underwater Noise (PTS)	Harbour porpoise: **Minor** adverse Seals: **Minor** adverse	N/A	Harbour porpoise: **Minor** adverse Seals: **Minor** adverse
Underwater Noise (TTS)	Not assessed in terms of magnitude/sensitivity	N/A	N/A
Underwater Noise (Disturbance)	**Minor** adverse	N/A	**Minor** adverse
UXO clearance (PTS)	**Minor** adverse	N/A	**Minor** adverse
UXO clearance (Disturbance)	**Minor** adverse	N/A	**Minor** adverse
Vessel Interactions	**Minor** adverse	N/A	**Minor** adverse
Disturbance at Haul-outs	**Minor** adverse	N/A	**Minor** adverse
Prey Species	No indirect impacts	N/A	No indirect impacts
Water Quality	**Negligible** adverse	N/A	**Negligible** adverse
Operation			
Operational Noise	**Minor** adverse	N/A	**Minor** adverse
Vessel Interactions	**Minor** adverse	N/A	**Minor** adverse
Vessel Noise	**Negligible** adverse	N/A	**Negligible** adverse
Indirect impacts: Impacts on Prey Species	**Minor** beneficial	N/A	**Minor** beneficial
Decommissioning			
Underwater Noise	**Negligible** adverse	N/A	**Negligible** adverse
Vessel Interactions	**Minor** adverse	N/A	**Minor** adverse
Water Quality	**Negligible** adverse	N/A	**Negligible** adverse
Indirect impacts: Impacts on Prey Species	No indirect impacts	N/A	No indirect impacts

Description of impact	Impact	Possible mitigation measures	Residual impact
Cumulative effects			
Underwater Noise	Harbour porpoise: Tier 1: **Minor** adverse Tier 1 & 2: **Moderate** adverse but no significant long-term effect on the size or health of the population Seals: **Negligible**-**Minor** adverse	Not possible to apply project specific mitigation that would decrease this below Moderate. If the impact of Thanet Extension were to be removed from this cumulative assessment, a moderate adverse effect would still be predicted for harbour porpoise based on the levels of impact from the other projects considered. Given this, it would not be possible to reduce this conclusion from a Moderate significance in EIA terms by the application of any mitigation specifically at Thanet Extension	Harbour porpoise: **Moderate** adverse but no significant long-term effect on the size or health of the population Seals: **Negligible-Minor** adverse significance
Vessel Interactions	**Minor** adverse	N/A	**Minor** adverse
Indirect impacts: Impacts on Prey Species	No indirect impacts	N/A	No indirect impacts

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7.19 Appendix 1

Associating predictions of change in distribution with predicted received levels during piling

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7.19.1 Russell *et al.* (2016) generated predictions of at-sea distributions of harbour seals during piling and breaks in piling for construction of Lincs wind farm in The Wash (south east England) in 2012. These predictions were based on analyses of location data from 23 harbour seals equipped with GPS telemetry tags. The analyses were restricted to return trips from haul outs within The Wash and comprised a use-availability design within a generalised estimating equation (GEE) framework. Responses to piling, in terms of individual movements were not modelled directly. Rather, the population level at-sea distribution was modelled both during breaks in piling and during piling. The differences in these distributions on a 5 x 5 km resolution (867 cells) were then quantified. Such differences can result from both avoidance (seals not entering an area) and displacement (seals actively moving out of an area) from the vicinity of the windfarm. If displacement occurred, it would take time for harbour seals to redistribute after the onset of piling. The largest apparent change in distribution occurred when the two hours after an event (piling onset or piling cessation) were removed from the data. This suggests that, at least to some extent, the findings of Russell *et al.* (2016) were driven by active redistribution and thus displacement rather than simply avoidance. However, the behavioural mechanism underlying any displacement is currently unknown.

7.19.2 Russell *et al*. (2016) linked the results of the population level analyses, which considered piling as a binary metric, to predicted received levels. To do this, it was necessary to consider predicted received level averaged across piles, at a 5 x 5 km resolution. Acoustic source levels were derived using a combination of the blow energy values and acoustic recordings made using an autonomous underwater recorder (see Hastie *et al.* 2015 for more details). The predicted sound pressure level ($SPL_{(peak-peak)}$) at source, at the maximum blow energy was 235 dB re 1µ$Pa_{(p-p)}$-m and the predicted single pulse sound exposure level ($SEL_{(single\ pulse)}$) was 211 dB re 1 µPa^2 s. A series of range dependent acoustic propagation models were used to estimate transmission loss and received $SELs_{(single\ pulse)}$ at 5 m incremental water depths (Hastie *et al.* 2015). The predictions were made every 1,000 metres along 72 (every 5º) radii from each pile. For each pile, the predicted depth-delineated SELs closest geographically to the centre of each 5 x 5 km cell were assigned to that cell. Predicted minimum and maximum received SELs were then averaged for each cell across the installation of all piles, to generate a mean received SEL in the part of the water column with the lowest and highest predicted level.

7.19.3 For both the non-piling and piling scenario, the seal density (in terms of percentage of the at-sea population) was predicted for each cell (Russell *et al.* 2016). On a cell by cell basis, the predicted percentage change in density during piling was then related to zones of predicted received levels. For both minimum and maximum received levels, zones of increasing size were considered, from a zone encompassing all cells which had a predicted SEL of ≥ 160 dB re 1 µPa^2 s to a one encompassing all cells (SELs of ≥ 80 dB re 1 µPa^2 s). A parametric bootstrap of the GEE model was used to calculate 95% confidence intervals (CIs) for both the predicted usage (percentage of the at-sea population) and predicted change in usage (non-piling to piling) for each zone. As such, Figure 6 in Russell *et al.* (2016) represents the predicted change in usage in zones of received levels (i.e. approximately spherical areas from the wind farm location). For example, the zone represented by an $SEL_{(single\ pulse)}$ of 80 dB re 1 µPa^2s encompasses 100% of the population at-sea during piling and non-piling and thus the percentage change is 0. As the received level increases, the sample size decreases resulting in wider confidence intervals. This cumulative curve was used to contextualise the population level findings from the spatial study with the predicted sound fields from the pile driving and should not be interpreted as a dose-response curve.

7.19.4 For the current study, there was a requirement to link the results of Russell *et al*. (2016) to spatial variation in a single (depth-averaged) received level. To generate a depth averaged received level for the current study, the predicted received levels were converted to pressure (Pa) and averaged across the depths. For each pile, the predicted pressure closest geographically to the centre of each 5 x 5 km cell was assigned to that cell, resulting in a depth averaged pressure value (Pa) for each pile in each cell. The mean distance between the centre of the cell and the geographically closest pile-specific pressure was 2.15 km but was shortest (0.5 km) nearest the wind farm. To generate a single averaged received level for each cell, the pressures were averaged across the piles, and this value was then converted to $SEL_{(single\ pulse)}$ (10 x log (pressure)). Although the maximum estimated source level (211 dB re 1 µPa^2 s) used to predict received levels was assumed to be the same for each pile, the differing pile locations (and to a lesser extent the different distances between predicted pressure level and cell centroid) resulted in substantial variation in predicted received level across piles (mean range 30 dB). The mean range in received levels within a cell was 15 dB within 10 km of the windfarm and 25 dB between 10 and 50 km. This variation is not represented in the relationship between predicted received level and change in usage.

7.19.5 Usage and change in usage was predicted for all cells within 5 dB zones (i.e. annulus areas between predicted received levels). Following Russell *et al*. (2016), a parametric bootstrap of the GEE model was used to calculate 95% confidence intervals (CIs) for each zone (Figure 1, Table 1).

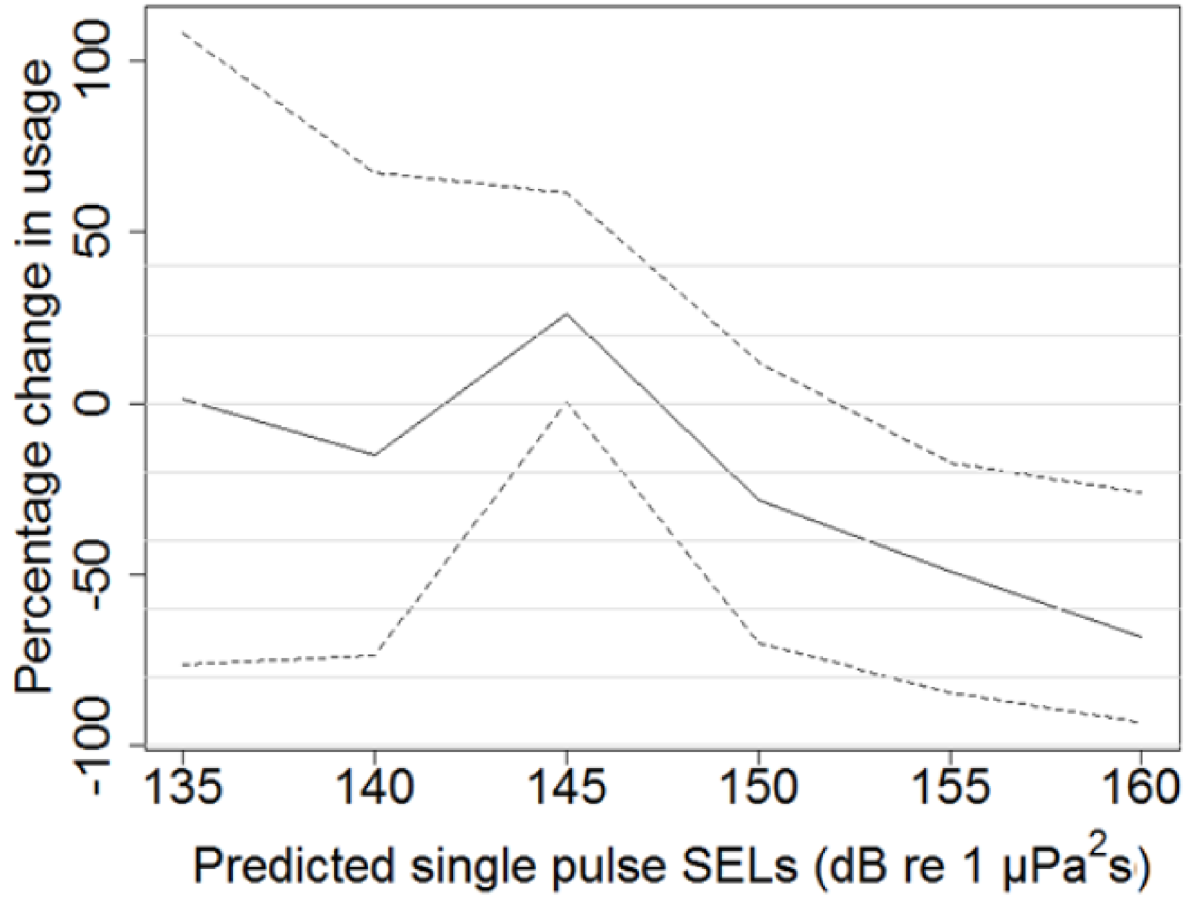

Figure 1. The predicted percentage change in usage at given SELs. Please note each point represents the following 5 dB. E.g. the predicted percentage change in usage value at 135 dB represents the mean for cells with an estimated SEL of 135dB ≤ 140dB.

Table 1. The predicted usage during piling and breaks in piling (and percentage change in usage) in zones of predicted received levels.

zone		Mean density (as percentage of at-sea population)			Percentage change			
SEL (dB)	number of cells	non-piling	piling	difference	mean	median	Lower 95% CI	Upper 95% CI
135 < 140	50	0.51	0.52	0.01	1.4	-7.1	-76.1	108.1
140 < 145	381	10.19	8.63	-1.56	-15.3	-15.9	-73.6	67.4
145 < 150	271	55.94	70.53	14.59	26.1	24.6	0.3	61.5
150 < 155	81	21.37	15.32	-6.05	-28.3	-28.7	-70.2	12.2
155 < 160	24	7.50	3.80	-3.70	-49.3	-54.0	-84.7	-17.5
160 < 165	7	0.88	0.28	-0.60	-68.1	-71.0	-93.0	-26.1