Vattenfall Wind Power Ltd
Thanet Extension Offshore Wind Farm

Environmental Statement Volume 2
Chapter 6: Fish and Shellfish Ecology

June 2018, Revision A

Document Reference: 6.2.6

Pursuant to: APFP Reg. 5(2)(a)

Vattenfall Wind Power Ltd

Thanet Extension Offshore Wind Farm

Volume 2

Chapter 6: Fish and Shellfish Ecology

June 2018

Drafted By:	GoBe Consultants Ltd
Approved By:	Helen Jameson
Date of Approval	June 2018
Revision	A

Vattenfall Wind Power Ltd
First Floor
1 Tudor Street
London
EC4Y 0AH
T +44 207 451 1150

www.vattenfall.co.uk

Table of Contents

6 FISH AND SHELLFISH ECOLOGY

6.1 Introduction

6.1.1 This chapter of the Environmental Statement (ES) has been prepared by GoBe Consultants Ltd. and assesses the effects on fish and shellfish ecology receptors associated with the Thanet Extension Offshore Wind Farm (Thanet Extension). The chapter should be read in conjunction with the project description in Volume 2, Chapter 1: Project Description Offshore (Document Ref: 6.2.1). The following sections of the chapter include:

- A summary of relevant legislation and planning policy;
- A description of the methodology for the assessment, including details of the study area and the approach to the assessment of effects;
- A summary of consultation with stakeholders;
- A review of the baseline (existing) conditions;
- Details of the measures proposed as part of the project to avoid or reduce environmental effects, including mitigation and design measures proposed as part of the project (embedded mitigation);
- An assessment of the likely effects for the construction, Operations and Maintenance (O&M) and decommissioning phases of the project, taking into account the measures proposed;
- Identification of any further mitigation measures or monitoring required in relation to likely significant effects; and
- Assessment of any cumulative effects with other proposed developments.

6.1.2 This chapter presents an assessment of the potential impacts upon fish (both pelagic and demersal, including elasmobranch species) and shellfish (molluscs and crustaceans) ecology arising from the construction, O&M and decommissioning of the offshore components of Thanet Extension development. This chapter does not include an assessment of impacts to commercial fisheries as this is covered separately in Volume 2, Chapter 9: Commercial Fisheries (Document Ref: 6.2.9).

6.1.3 The assessment is based upon a combination of an understanding of the proposed development in terms of the potential for impact and the resultant effects on receptors, as defined by the characterisation work presented in the Fish and Shellfish Technical Reports (Document Ref: 6.4.6.1 and 6.4.6.2). The technical reports provide a detailed characterisation of the fish and shellfish study area based on existing literature sources (e.g. for the original Thanet Offshore Wind Farm (TOWF)) and site-specific surveys carried out for Thanet Extension, and includes information on fish and shellfish species of ecological importance and conservation value.

6.1.4 Information on the Scoping process for the proposed development is detailed in the scoping report (VWPL, 2016) that was submitted to the Planning Inspectorate (PINS) on 13th December 2016 and in the formal Scoping Opinion (PINS, 2017) received from PINS.

6.2 Statutory and policy context

6.2.1 This section identifies legislation and national and local policy of particular relevance to fish and shellfish ecology. The Planning Act (2008), the Infrastructure Planning (Environmental Impact Assessment (EIA) Regulations (2017) and The Environment Act (1995) are considered along with the legislation relevant to fish and shellfish.

6.2.2 In undertaking the assessment, the following additional legislation has been considered:

- Common Fisheries Policy;
- UK Salmon and Freshwater Fisheries Act 1975 (as amended);
- The Convention on the Conservation of European Wildlife and Natural Habitats (the Bern Convention);
- EU Council Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna (the 'Habitats Directive');
- Sea Fisheries (Shellfish) Act 1967 (as amended); and
- The Wildlife and Countryside Act 1981 (as amended).

6.2.3 Guidance on the issues to be assessed for offshore renewable energy developments has been obtained through reference to the Overarching National Policy Statement (NPS) for Energy (NPS EN-1; DECC, 2011a) and the National Policy Statement for Renewable Energy Infrastructure (NPS EN-3, DECC, 2011b).

6.2.4 Specifically, the guidance provided within NPS EN-3 was considered. paragraph 2.6.59 identifies that applicants should have regard to impacts on fish and shellfish.

6.2.5 NPS EN-3 (paragraphs 2.6.64 to 2.6.67 and 2.6.74) also includes guidance on what matters are to be included in an applicant's assessment, these being summarised in Table 6.1.

6.2.6 It is noted that NPS EN-3 also includes guidance relating to potential secondary or indirect impacts arising from changes to the physical environment which should also be considered.

Table 6.1: Summary of NPS EN-3 policy relevant to fish and shellfish ecology and consideration of the Thanet Extension assessment

Policy/ legislation	Key provisions	Section where provision addressed
NPS EN-3 Paragraph 2.6.64	Assessment of offshore ecology and biodiversity should be undertaken by the applicant for all stages of the lifespan of the proposed Offshore Wind Farm (OWF) and in accordance with the appropriate policy for OWF EIAs.	This assessment considers effects on fish and shellfish receptors at all stages of the lifespan of the project, including the construction, O&M and maintenance, and decommissioning phases (see Table 6.7 and paragraphs 6.10.16.10.1 *et seq*.).
NPS EN-3 Paragraph 2.6.65	Consultation on the assessment methodologies should be undertaken at early stages with the statutory consultees as appropriate.	Consultation with relevant statutory and non-statutory stakeholders has been carried out from the early stages of Thanet Extension (see Table 6.3: for a summary of consultation with regard to fish and shellfish).
NPS EN-3 Paragraph 2.6.66	Any relevant data that has been collected as part of post-construction ecological monitoring from existing, operational OWFs should be referred to where appropriate.	Relevant data collected as part of post-construction monitoring from other OWF projects has informed the assessment of Thanet Extension (see paragraph 6.7.9 *et seq*.).
NPS EN-3 Paragraph 2.6.67	The assessment should include the potential of the scheme to have both positive and negative effects on marine ecology and biodiversity.	The assessment methodology includes the provision for assessment of both positive and negative effects (see Table 6.6).
NPS EN-3 Paragraph 2.6.74	The applicant should identify fish species that are the most likely receptors of impacts with respect to: • Spawning grounds; • Nursery grounds; • Feeding grounds; • Over-wintering areas for crustaceans; and • Migration routes.	Particular attention has been given to impacts on fish species at key life stages such as during spawning or on known nursery habitats (see paragraph 6.7.23 *et seq*.).

6.2.7 Following the abolition of the Infrastructure Planning Commission (IPC), the planning process for Nationally Significant Infrastructure Projects (NSIPs) is now administered by PINS with the decision on the Development Consent Order (DCO) being taken by the Secretary of State (SoS). NPS EN-3 highlights a number of points relating to the judgement of an application and in relation to mitigation (paragraphs 2.6.68 to 2.6.71 and 2.6.75 to 2.6.77); these are summarised in Table 6.2.

Table 6.2: Summary of NPS EN-3 guidance on decision making with regard to fish and shellfish ecology and consideration in the Thanet Extension assessment

Policy/ legislation	Key provisions	Section where provision addressed
NPS EN-3 Paragraph 2.6.68	The SoS should consider the effects of a proposal on marine ecology and biodiversity taking into account all relevant information made available to it.	This has been described and considered throughout the assessment of Thanet Extension.
NPS EN-3 Paragraph 2.6.69	The designation of an area as Natura 2000 site does not necessarily restrict the construction or operation of OWFs in or near that area (see also Section 4.3 of EN-1).	Natura 2000 sites have been considered during the Thanet Extension assessment (Volume 2, Chapter 8: Designated Sites (Document Ref: 6.2.8)).
NPS EN-3 Paragraph 2.6.70	Mitigation may be possible in the form of careful design of the development itself and the construction techniques employed.	Mitigation has been considered during the design and development of Thanet Extension (see Table 6.8).
NPS EN-3 Paragraph 2.6.71	Ecological monitoring is likely to be appropriate during the construction and operational phases to identify the actual impact itself so that, where appropriate, adverse effects can then be mitigated and to enable further useful information to be published relevant to future projects.	Where appropriate, and through reference to the MMO's review of post-construction monitoring (MMO, 2011) monitoring has been considered during the assessment of potential effects associated with Thanet Extension.
NPS EN-3 Paragraph 2.6.75	Where it is proposed that mitigation measures of the type set out in paragraph 2.6.76 below are applied to offshore export cables to reduce Electromagnetic Fields (EMF) the residual effects of EMF on sensitive species from cable infrastructure during operation are not likely to be significant. Once installed, operational EMF impacts are unlikely to be of sufficient range or strength to create a barrier to fish movement.	EMF effects are considered within the Thanet Extension assessment (see paragraphs 6.11.33 *et seq*.).
NPS EN-3 Paragraph 2.6.76	EMF during operation may be mitigated by use of armoured cable for inter-array and export cables which should be buried at a sufficient depth. Some research has shown that where cables are buried at depths greater than 1.5 m below the seabed impacts are likely to be negligible. However, sufficient depth to mitigate impacts will depend on the geology of the seabed.	Mitigation of EMF through cable burial (and cable armouring, where appropriate) is considered within the Thanet Extension EIA (see Table 6.8 Table 6.7).
NPS EN-3 Paragraph 2.6.77	During construction, 24 hour working practices may be employed so that the overall construction programme and the potential for impacts to fish communities is reduced in overall time.	The duration of the proposed works is given due weight within the Thanet Extension assessment process (see Table 6.7).

6.2.8 The geographical extent of Thanet Extension lies within the south east inshore marine plan area. This marine plan remains under development but aims to provide a clear approach to managing activities within the area. Through policy requirements, it will inform and guide regulation, management and use of the area.

6.2.9 The principal guidance documents and information used to inform the assessment of potential impacts on fish and shellfish ecology are as follows:

- Centre for Environment, Fisheries and Aquaculture Science (Cefas) Guidance note for Environmental Impact Assessment in respect of Food and Environment Protection Act (FEPA) and Coast Protection Act (CPA) requirements. Version 2 – June 2004; and
- Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects (Judd, 2012).

6.2.10 Further advice in relation specifically to the proposed development has been sought through consultation with the statutory authorities, through the Thanet Extension Evidence Plan (Marine Ecology Technical Review Panel), and from Scoping Opinions issued by PINS.

6.3 Consultation and scoping

6.3.1 The fish and shellfish ecology of the area within which the proposed development is located has been the subject of detailed discussion between regulators and VWPL.

6.3.2 As part of the Environmental Impact Assessment (EIA) process, a number of consultations have been undertaken with various statutory and non-statutory authorities, under the auspices of the Thanet Extension Evidence Plan (Marine Ecology Technical Review Panel). A formal Scoping Opinion was sought from PINS following submission of the Scoping report (VWPL, 2016). Ongoing consultation post-scoping has been important in the evolution of the project and the parameters for assessment.

6.3.3 In response to the Thanet Extension Scoping Report (VWPL, 2016), PINS issued a Scoping Opinion (PINS, 2017). The SoS identified a number of issues that could not be scoped out of the assessment at this stage, based on a review of the Scoping Report. The issues relating to fish and shellfish ecology are summarised in Table 6.3.

Table 6.3: Summary of the consultation relating to fish and shellfish ecology

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
Scoping Opinion	The SoS welcomes reference to monitoring studies that have been conducted in respect of the existing TOWF zone both pre- and post-construction and understands the Applicant's [VWPL] broad position that there is lack of evidence to suggest gross changes to the fish and shellfish community. Table 2.9 [of the Scoping Report] identifies a significant number of available fish datasets including site specific surveys for the Proposed Development offshore export cable area. The Applicant should ensure that the need for or absence of further survey effort in support of the assessment is justified in the context of these existing datasets.	The characterisation surveys having been agreed with the relevant stakeholders (MMO scoping response letter dated 2nd February 2017) the characterisation of the receiving environment is presented in paragraphs 6.7.1 *et seq*.
Scoping Opinion	Table 2.5 of the Scoping Report scopes in an assessment of water quality effects during construction, and Table 2.27 cites the potential interrelationship between water quality and fish and shellfish topic areas. The SoS therefore does not agree with Paragraph 321 and Table 2.11 that changes to water quality in respect of fish and shellfish impacts can be scoped out of the assessment in terms of construction and decommissioning. Paragraph 321 of the Scoping Report also implies that the Applicant [VWPL] will need to consult further with relevant consultees prior to making a decision on scoping out this topic.	The consideration of the potential effects associated with changes in water quality are considered at paragraphs 6.10.27 *et seq.*, the detail of the assessment having been considered in consultation with the Thanet Extension Evidence Plan (Document Ref: 8.5), and specifically with regards the Water Framework Directive Quality Elements of relevance to fish and shellfish.
Scoping Opinion	The SoS considers the approach outlined in Paragraph 320 in respect of suspended sediments and smothering during construction is appropriate, and notes the importance and reliance on the physical processes assessment to inform the assessment on physical, migratory and spawning patterns of sensitive fish and shellfish species (which should be specifically defined).	The approach to physical processes modelling of the potential effects associated with increased suspended sediment concentrations and deposition has been agreed under the Thanet Extension Evidence Plan. The assessment of the potential effects are presented in paragraphs 6.10.12 *et seq*.
Scoping Opinion	In terms of EMF effects on fish and shellfish during operation, the Applicant is seeking to scope this out due to the lack of evidence to suggest there is potential for an impact. The SoS is aware of other OWF projects that have acknowledged potential EMF impacts on fish within a few metres proximity of offshore cables. Given this and the potential proximity to the existing TOWF zone export cable (and therefore the combined effect of the Proposed Development with the existing TOWF zone EMF baseline conditions), the SoS does not agree that this can be scoped out of the assessment at this time.	The potential effects associated with EMF are considered in paragraphs 6.11.33 *et seq*.
Scoping Opinion	Loss of habitat during construction and decommissioning is proposed to be scoped out of the EIA on the basis that the effects would be small in a regional context. The SoS does not consider that sufficient evidence is	The consideration of potential effects associated with the loss of habitat during the construction and operational phases of the

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
	provided in order to agree to this being scoped out at this stage.	project is presented in paragraphs 6.10.3 *et seq*. and paragraphs 6.11.3 *et seq*. respectively.
Scoping Opinion	Section 2.6.3 of the Scoping Report states that it is considered unlikely that mitigation for fish and shellfish ecological effects will be required. The SoS expects that this will be kept under review as the assessment progresses and draws the Applicant's attention to the distinction between embedded mitigation and additional mitigation (as defined at Section 1.6.4.5 of the Scoping Report) as Section 2.6.2 appears to describe mitigation in respect of fish and shellfish ecological impacts.	Mitigation measures deemed appropriate to avoid significant effects on fish and shellfish receptors are presented in Table 6.8. It should be noted that due to the absence of any significant effects associated with the project there are no mitigation measures deemed necessary.
MMO Response 5.6	If onsite dredge and disposal activities are to be undertaken, the MMO would expect the potential effects of dredging and disposal to be included. Increased suspended sediment could potentially have an impact on fish eggs, larvae, juvenile and adult fish. This should therefore be considered in the EIA.	Potential effects of increased SSC and sediment deposition are discussed in paragraphs 6.10.12 *et seq.*
MMO Response 5.8	MMO recommend that the EIA considers seabass in the context of the current special measures in place. Seabass have also been placed under special protection measures to drastically reduce catches of this species. The new protection measures include waters in and around Sussex, Kent and Essex.	Seabass are considered as a part of the existing environment in Section 6.7 (paragraph 6.7.6) in the context of the special protection measures in place. Additional text about this has been included 6.11.75.
MMO Response 5.14	[Underwater noise] The noise could therefore extend to both the Thames substock, (spring-spawning February to April) and Southern North Sea substock (spawns end November to January). We therefore recommend that underwater noise considers the potential effects on these two herring stocks.	Potential effects from underwater noise in the context of herring spawning are addressed in paragraph 6.10.34 *et seq.*
MMO Response 5.16	The MMO encourages early engagement with the MMO to ensure the modelling is appropriate.	Potential effects from underwater noise including results from underwater noise modelling are addressed in paragraph 6.10.34 *et seq*.
MMO Response 5.17	Should cable burial be limited due to the local seabed geology (or other receptors in the area) then it is recommended that the possible effects of EMF on electro-sensitive fish remain scoped in.	Potential EMF effects are discussed in paragraphs 6.11.33 *et seq.*
MMO response 5.18	The commercial shellfish species, *Homarus gammarus, Pecten maximus, Cancer pagurus, Buccinum undatum* and *Ostrea edulis* are all listed as being of commercial importance locally; including in the proposed cable corridor at Pegwell Bay and should be included in the EIA.	Commercial shellfish species are considered alongside other fish and shellfish receptors within the assessment. Commercial shellfish species are further considered in Volume 2, Chapter 9: Commercial Fisheries (Document Ref: 6.2.9).
S42 Consultation Natural England January 2018	Quantitative assessment in tabulation form: In general, the documents read well, are well structured and include a large quantity of supporting evidence provided within the documents. The main chapter would benefit from additional tables summarising the quantitative impacts both at a project and cumulative level, i.e. a summary table of each anticipated impact and the quantitative assessment in relation to the relevant receptors. The recent Norfolk Vanguard PEIR chapters provided good examples of tables where all the relevant assessment information	Where relevant and appropriate, summary tables have been added to the assessment sections.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
	is summarised in one place. It is currently difficult to draw out individual figures without picking through the individual sections.	
S42 Consultation Natural England January 2018	Operations and Maintenance works: Further detail should be provided within the assessment with relation to the anticipated operations and maintenance activities throughout the lifetime of the project. Natural England point the TEOW team towards the Vattenfall O&M assessment recently provided for the Norfolk Vanguard OWF. Anticipated justified quantities are required in order for a realistic assessment to consider the extent of the impacts.	Additional detail on the O&M activities has been provided in Table 6.7, and subsequently included within the assessments.
S42 Consultation Natural England January 2018	Concerns regarding impacts to herring and sandeel spawning and nursery grounds from SSC's and loss of habitat: We query whether mitigation options could be considered out of best practice to avoid impacts to herring and sandeel spawning/nursery grounds (see point 5 below for full details).	Additional study on the potential spawning grounds has been undertaken, which is described in the baseline environment section (paragraph 6.7.29 *et seq.*) as well as in the impact assessment. Additional mitigation options are not deemed necessary.
S42 Consultation Natural England January 2018	The cumulative assessment: We have several outstanding concerns with regards to the cumulative assessment undertaken including why only three tiers have been applied (this also applies to Volume 2, Chapter 9: Commercial Fisheries (Document Ref: 6.2.9)); the request for a map depicting the plans/projects considered in the cumulative assessment and whether oil and gas pipelines have been considered within the assessment.	The approach to the cumulative assessment was agreed in the Evidence Plan (EP) process that has been ongoing throughout the EIA. Figure 6-15 has been added, depicting the projects screened in for the cumulative assessment. No oil and gas interests were identified for consideration in the cumulative assessment.
S42 Consultation Natural England January 2018	Referral to previous tables: Throughout the chapter previous tables are referred to with no further text. For example, in paragraph 6.15.1 it is stated that embedded mitigation is identified in table 6.8. In such instances it would be helpful to include a statement summarising the information as well as cross referencing to the appropriate table as it becomes difficult to read. i.e. a sentence in brackets (soft start approach; pollution contingency plan etc). This is also true throughout the cumulative assessment section.	Where relevant and appropriate, short descriptions have been added to provide context alongside table/ figure cross-references. Cross references have been checked for circularity or long-windedness.
S42 Consultation Natural England January 2018	"Herring and sandeel spawning/nursery areas: Natural England acknowledge that the herring spawning areas appears to have migrated south (according to the IHLS data) and that only a small portion of the lower intensity habitat will be impacted by direct disturbance. Natural England also note that overall there is only a minor significant impact in terms of EIA, however we query whether there would be scope under best practice to avoid cable installation between 15 Aug and 15 Oct. This would be in line with the current ICES advice which details a precautionary approach in relation to disturbance of herring noting that the project boundaries fall within the herring spawning area (albeit the lower intensity parts). Sandeels are anticipated to be present in large numbers within the project area. Due to their high site fidelity and limited ability to recolonise they are at risk of being adversely affected. As a result, the potential to microsite/ avoid these prime areas could be a potential method of mitigation under best practice. Further data collection to provide PSA to inform where areas of preferred	Additional mitigation such as a seasonal restriction is not deemed necessary (as discussed in the Evidence Plan). Additional study has been undertaken in relation to potential herring and sandeel spawning habitat (described in paragraph 6.7.29 *et seq.*). This was based on freely available as well as site-specific sediment data collected for the project.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
	sandeel habitat may be present would be helpful." (Paragraph 6.7.28)	
S42 Consultation Natural England January 2018	Map depicting sediment types: A map depicting the sediment types would be helpful in order to make a comparison between potential suitable substrate and the estimated spawning/nursery grounds of herring and sandeel. (Table 6.7)	Figure 6-8 and Figure 6-9 have been inserted which show the sediment types according to the EU Sea Map (2016) data and site-specific data (Fugro, 2016). Figure 6-10 also shows the sediment data collected for the NEMO interconnector project.
S42 Consultation Natural England January 2018	"Maximum design scenario: We have several outstanding concerns with regards to the WCS considered. 1- Impacts through disturbance from site preparation works has not been included. 2- Habitat disturbance from cable reburial, repairs and replacements has not been included within O&M. 3- Impacts of operational noise in relation to the potential effects this is having on fish behaviour, in relation to disturbance of communication should also be considered. 4- Decommissioning: The permanent effects of leaving cables and therefore cable protection *in situ* need to be considered. Particularly if these locations occurred within the herring and sandeel spawning/nursery grounds and also the Sandwich Bay SPA where indirect impacts to prey resource could be witnessed." (Table 6.7)	Seabed preparation has been clarified in the maximum design scenario (Table 6.7). Disturbance from cable repair and reburial has been included within the O&M assessment section (paragraph 6.11.46 *et seq.* and paragraph 6.11.53 *et seq.*). Literature has been reviewed and added with regard to O&M noise (paragraph 6.11.23 *et seq.*). Additional project design information has been incorporated within the assessments where relevant. Decommissioning effects have been clarified in paragraph 6.12.2. If infrastructure is left *in situ*, then impacts will be similar

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
		to those in the O&M phase in terms of long-term/ permanent habitat loss.
S42 Consultation Natural England January 2018	Embedded mitigation: We advise that an initial draft PEMP should be provided at time of submission of the application. (Table 6.8)	As discussed with the Evidence Plan, a draft Project Environmental Management Plan will not be included with the application as it relates to environmental management practices that will be determined post-consent in the detailed design phase.
S42 Consultation Natural England January 2018	Consideration of egg and larval stages of fish: It should be made clear that the sessile eggs and less mobile larvae are at risk of direct damage. (Section 6.10)	Clarification has been added regarding the sensitivity of sessile eggs and less mobile larvae in the relevant assessment sections.
S42 Consultation Natural England January 2018	Herring and sandeel spawning/nursery areas: As above at point 5 we query whether mitigation options could be considered out of best practice to avoid impacts to these vulnerable species and their habitats of importance. (Section 6.10)	Additional study has been undertaken regarding potential herring and sandeel spawning habitat. Additional mitigation measures are not deemed necessary.
S42 Consultation Natural England January 2018	Auditory impacts to fish: We welcome the level of assessment regarding the auditory impacts to fish. However, we query the conclusion that there is no overlap between herring spawning grounds, Figure 6-14 depicts an overlap between the Coull et al spawning grounds and with the IHLS data lower and moderate density areas of larval abundance. Can Vattenfall provide further clarification regarding this statement. (Section 6.10)	Further clarification has been added in paragraph 6.10.51 *et seq.* as regards auditory impacts and overlap with spawning grounds for herring.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
S42 Consultation Natural England January 2018	Habitat loss: There seems some discrepancy between the terms long-term habitat loss and permanent habitat loss. The term "long-term duration, continuous and irreversible (during the lifetime of the project" is used and both long-term and permanent are referred to intermittently in this section. Natural England would consider long-term habitat loss to occur within the lifetime of the OWF project. Permanent habitat loss should consider the situation where infrastructure will not be removed at the time of decommissioning, i.e. in the case that foundations and cable protection are left *in situ*. These differences and the anticipated effects should be made clearer within the assessment. Reference should be made to vulnerable species such as herring and sandeel which would be more greatly impacted from a permanent loss or change in habitat, particularly at a cumulative level. (Section 6.11)	The terms have been clarified throughout the assessment. 'Long-term' refers to effects that are experienced throughout the O&M phase. Clarification is provided in paragraph 6.12.2 as to 'permanent' effects which are longer lasting than the 30-year lifetime of the project.
S42 Consultation Natural England January 2018	Impacts from underwater noise: Disturbance and avoidance is considered impacts from underwater noise during operation, however there is no mention of less direct impacts such as disturbance to communication or disturbance/displacement to prey. (Section 6.11)	Additional documentation has been referenced in paragraph 6.11.23 *et seq.*as regards operational noise impacts to fish communication and disturbance/ displacement to prey.
S42 Consultation Natural England January 2018	Operations and maintenance works: As above at point 4, further detail should be provided within the assessment with relation to the anticipated operations and maintenance activities throughout the lifetime of the project. Natural England point the TEOW team towards the Vattenfall O&M assessment recently provided for the Norfolk Vanguard OWF. Anticipated justified quantities are required in order for a realistic assessment to consider the extent of the impacts. In particularly the impacts of SSCs from sediment disturbance and the introduction of additional cable protection is relevant to the impacts to fish and shellfish. As recently advised for other OWFs in relation to operation and maintenance works we advise that a regulatory review (such as the 5 yearly reviews within the Aggregates industry) should be implemented in order to ensure that the monitoring evidence will be used to inform further works (see advice to the MMO in relation to the Race Bank OWF "1429 227964 Race Bank OWF Operations & Maintenance - Transmission Assets NE 081117". (Section 6.11)	Additional information has been added to the assessment in relation to O&M activities (Table 6.7). specifically, areas of temporary habitat loss and disturbance due to O&M activities have been added, and the impact of increases SSCs and associated sediment deposition has been included.
S42 Consultation Natural England January 2018	Cumulative assessment: We have several outstanding concerns with regards to the cumulative assessment undertaken. 1- We query why only the three tiers are described. It has been standard practice to consider a number of tiers for the last few years, we again point TEOW towards table 1.1 in chapter 10.4 of the Norfolk Vanguard PEIR for reference where the standard six tiers are considered (in addition to this we would suggest that a further tier is included between tier 4 and 5 to consider those projects that are at the stage of submitting a PEIR). (Section 6.13)	Noted. The three-tiered approach was agreed in the Evidence Plan process. Additional justification for this approach has been referenced in Volume 1, Chapter 3: EIA Methodology (Document Ref: 6.1.3).
S42 Consultation Natural England January 2018	We also query whether oil and gas pipelines have been considered? (Section 6.13)	No oil or gas interests were located within the study area. The projects considered for the cumulative assessment are described in Table 6.14 and illustrated in Figure 6-15.
S42 Consultation	We acknowledge that the projects screened into the cumulative assessments are within Table 6.15However, it would be helpful to list	Noted. Projects have been listed, where relevant, and an additional figure (Figure

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
Natural England January 2018	them within the text rather than redirecting the reader to Table 6.15(which then redirects to Table 6.14) at every section.	6-15) has been included illustrating the projects screened in for cumulative assessment.
S42 Consultation Natural England January 2018	"Cumulative impacts of SSC's and sediment disturbance: A greater level of detail is required within this section to tabulate and justify the conclusions. There is currently not enough detail within the quantitative assessments in order to conclude minor adverse. We note that the Nemo Interconnector will result in a volume of 94,308m3 of displaced material. We acknowledge that the Nemo cable is scheduled for 2017/18 and TEOW not until 2019 but welcome the consideration of the cumulative impacts in the case that timeframes were to slip. We query what the actual duration of construction is proposed to be for the NEMO interconnector, as the difference in construction scenarios may only be a couple of months apart. The Thanet replacement cable is mentioned very briefly. We advise that more detail is provided where possible acknowledging that the licence application is yet to be provided in the public domain. Further details for the final application would help to define the assessment as the cumulative assessment is currently unclear. This is particularly important given the importance of the herring and sandeel spawning and nursery grounds."	The approach to the Nemo Interconnector was agreed in the Evidence Plan. Additional information on volumes of displaced material has been incorporated into the cumulative assessment. The Thanet 132 kV Cable Replacement project has been cancelled since the publishing of the Thanet Extension PEIR, and so is not included in the cumulative assessment.
S42 Consultation Natural England January 2018	Cumulative habitat loss: We refer to our comments above at point 12 regarding the consideration of long-term versus permanent impacts. In line with our comments above at point 16 we advise that a greater level of detail is required within this section to tabulate and justify the conclusions. There is currently not	Clarification has been provided in relation to 'long-term' vs. 'permanent' habitat loss.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
	enough detail within the quantitative assessments in order to conclude minor adverse.	
S42 Consultation Natural England January 2018	Mitigation: Given the lack of detail regarding proposed O&M activities and the lack of a quantitative cumulative assessment we are unable to agree that no specific mitigation is necessary, in particular in relation to the impacts from SSCs and changes in habitat type to spawning and nursery grounds for herring and sandeel. Further detail is required in summarising the quantitative information. (Section 6.15)	Additional information has been included regarding O&M activities in Table 6.7 and has subsequently been incorporated into the assessments.
S42 Consultation Natural England January 2018	Mantis shrimp: We note that the mantis shrimp was also recorded at sampling location BT02 was which is scarce around the UK and has only been recorded a small number of times off the east coast of the British Isles.	Noted. This has been described in the baseline environment section (paragraph 6.7.4*et seq.*).
S42 Consultation MMO January 2018	The MMO considers that the surveys carried out follow best practice to provide a general description of species in the windfarm area. The points below should be considered in the EIA process and the MMO would welcome the outcome of our suggestions in the subsequent ES.	Noted.
S42 Consultation MMO January 2018	Within Volume 2 Chapter 6: Fish and Shellfish Ecology para 6.4.6 (Document Ref: 6.2.6) and Figure 6-2, it is noted that in the fish characterisation strategy there are 5 sites proposed along the cable route, but only four have been detailed in the PEIR (the site closest to shore has been lost). Also, there are no reference sample sites outside the extension area. These are required to check that if there are any changes (occurring during/post construction) and if these are occurring within	Paragraph 2.2.2 of the Autumn Fish Characterisation Survey Report (Document Ref: 6.2.6.1) states that four otter trawls and four beam trawls would be carried out along the OECC. It was deemed that reference sites were not required.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
	the windfarm region only or if the pattern is being observed over a wider area.	
S42 Consultation MMO January 2018	Volume 2 Chapter 6: Fish and Shellfish Ecology, para 6.7.8 and 6.7.9 (Document Ref: 6.2.6) summarise the spring and autumn surveys and the fish species found especially in abundance. However, these surveys are only a snapshot in time and the MMO recommends the results of the surveys should therefore be used with caution. For example, the surveys were undertaken outside the herring spawning periods: the spring survey was undertaken in May and the Thames substock spawns February to April; the autumn survey was undertaken in early November and the Southern North Sea substock spawns end of November to January.	As above. Additional study regarding potential herring and sandeel spawning grounds has been undertaken in paragraph 6.7.29 *et seq*.
S42 Consultation MMO January 2018	Volume 2 Chapter 6: Fish and Shellfish Ecology, para 6.7.23 (Document Ref: 6.2.6), the proposed development is in proximity to nursery grounds for seabass. Fishing regulations have now been implemented to protect juvenile stocks of seabass (Kent and Essex IFCA, 2014). Seabass has also been placed under special protection measures. The new protection measures include the waters in and around Sussex, Kent and Essex (MMO, 2016) therefore this should be considered in the ES. The MMO would expect that the EIA considers seabass in the context of the current special measures in place.	Additional information regarding seabass in the context of the special protection measures in place has been added in paragraph 6.7.6 *et seq*. This has also been incorporated into the assessment of changes to fishing pressure (paragraph 6.11.74 *et seq.*).
S42 Consultation MMO January 2018	Volume 2 Chapter 6: Fish and Shellfish Ecology, para 6.10.34 (Document Ref: 6.2.6) states that 'Construction activities, particularly the pile-driving of foundations for offshore structures, will result in high levels of underwater noise that will be audible to fish over tens of kilometres around Thanet Extension'.	The description of the study areas and search areas has been amended to reflect the ranges and extents of the various impacts, including underwater noise (paragraph 6.4.1 *et seq*.).
	Therefore, the MMO would expect the study area to be increased to the extent of the modelling. See also comment 6.9 below.	
S42 Consultation MMO January 2018	Regarding Volume 1 Chapter 3: EIA Methodology, Table 3.2 (Document Ref: 6.1.3), whilst search areas are a useful starting point to focus the assessment, these search areas should be extended where assessments show potential impacts beyond this search area.	As above.
S42 Consultation MMO January 2018	In Volume 2 Chapter 1, Para 1.4.29, the MMO welcome the proposal to use soft start procedures and recommend the soft-start duration should be a period of not less than 20 minutes. Should piling cease for a period greater than 10 minutes, then the soft start procedure must be repeated in line with JNCC (2009) guidance.	Noted. Though not specifically relevant to fish, this has been clarified in the draft Marine Mammal Mitigation Protocol (Document Ref: 8.11).
S42 Consultation MMO January 2018	Within Volume 2 Chapter 6: Fish and Shellfish Ecology, para 6.4.3 (Document Ref: 6.2.6), the PEIR states that the study area for fish and shellfish was based on expert judgement. The MMO would expect the study area to have also been informed by modelling of underwater noise and physical processes to ensure all potential impacts and receptors have been considered (see also point 6.5)	As previous.
S42 Consultation MMO January 2018	Volume 2 Chapter 6: Fish and Shellfish Ecology, para 6.7.4 (Document Ref: 6.2.6) provides a list of fish species found within the area using the surveys and references to date however, as per MMO scoping advice, the proposed development is in proximity to nursery grounds for mackerel and sandeel (Coull et al, 1998; Ellis et al, 2012). The MMO seek clarification as to why these species have not been included.	Nursery grounds for mackerel and sandeel are included in Figure 6-6 and Figure 6-5, respectively. They have also been added to the baseline environment description in paragraph 6.7.1 *et seq*.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
S42 Consultation MMO January 2018	Within Volume 2 Chapter 6: Fish and Shellfish Ecology, para 6.10.24 (Document Ref: 6.2.6), whilst noting that Sandeel eggs are subject to some turbulence and must therefore have a certain level of tolerance to sediment movement, there is little information on how much sediment deposition is acceptable. Therefore, if the sediment deposition is to be higher than normal around spawning time, there is the potential for an adverse effect.	Noted. Text has been amended in paragraph 6.10.24 to reflect this.
S42 Consultation MMO January 2018	Volume 2 Chapter 6: Fish and Shellfish Ecology, para 6.10.24 (Document Ref: 6.2.6), states 'High intensity spawning sites for sandeel do not occur within the Thanet Extension study area and the main area of spawning is to the North, and so effects on sandeel spawning are not expected'. It is unclear how this conclusion was reached. Coull et al 1998 and Ellis 2012 indicate the area is used for spawning, although note that this is towards the western edge of the windfarm. Sandeels spawn close to their substrate habitat, and one of the common species of sandeel (Ammodytes. marinus) spawns November to February; the MMO notes that this timing coincides with the sandeel 'dormancy' period, when they emerge just to spawn during this time.	Figure 6-5 indicates that Thanet Extension overlaps with low intensity spawning areas for sandeel, rather than high intensity spawning sites. Additional study has been carried out on the preferred spawning habitat for herring and sandeel in paragraph 6.7.29 *et seq*.
S42 Consultation MMO January 2018	In order to assess how much preferred sandeel habitat lies in and around the windfarm, a short specialised sandeel survey is recommended, and to carry out the Marine Space assessment procedure, using sediment samples to inform the sediment type (Latto, 2013).	As described previously for the Natural England responses, a specialised sandeel survey has not been carried out. Instead, a description of the potential sandeel spawning habitat based on sediment data collected for the project as well as existing data has been included in paragraph 6.7.29 *et seq.*

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
S42 Consultation MMO January 2018	The MMO considers that the PEIR and associated documents are well written and thorough. The report accurately reflects that in the proposed development area, potting for crab, lobster and whelk, and dredging for cockles and mussels take place.	Noted.
S42 Consultation MMO January 2018	The MMO previously advised that a cockle survey of Pegwell Bay be undertaken in the absence of any more recent available data (post 2014) from the Kent and Essex Inshore Fishing and Conservation Authority (IFCA) to ensure an up to date characterisation of the Pegwell Bay cockle population. In the current report, Haywood et al., (2016) is cited (K&E IFCA) as evidence that Maplin and Foulness Sands, along the Essex coast, are the principle cockle grounds, which are considerable distances from the proposed development. The MMO considers this sufficient to address our previous comments.	Noted. No additional survey undertaken.
S42 Consultation MMO January 2018	Volume 2 Chapter 6: Fish and Shellfish Ecology para 6.11.58 (Document Ref: 6.2.6) states that: 'During the operational phase of Thanet Extension, the intensity of fishing activities (including trawling and potting) may be reduced inside the array area. This has the potential to enhance fish and shellfish populations by providing refuge from fishing activities for certain species targeted by commercial fisheries. Conversely, this also has the potential to increase the intensity of fishing activity outside of the array area as fishing activity is displaced, to the detriment of fish populations there.' The MMO considers enhanced shellfish populations within the proposed area would not be noticeable in the short-term, except for a potential brief-period around the construction phase. If shellfish abundances are then enhanced due to lack of	Noted. This is reflected in paragraph 6.11.68 *et seq.* of the assessment.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
	fishing effort, it is likely that an abundance of predator species would then also follow, assuming prey items are in sufficient abundances for the shellfish species to be sustained.	
S42 Consultation MMO January 2018	As has been noted by the MMO within Item 1.11, consideration must be given to all relevant in-combination effects on the marine environment including the proposed 132kV cable replacement project for the existing Thanet OWF.	Noted. Since the submission of the Thanet Extension PEIR, the TCR 132 kV project has been cancelled and is therefore not included in the cumulative assessment.
S42 Consultation MMO January 2018	Regarding Volume 2, Chapter 6: Fish and Shellfish (Document Ref: 6.2.6), the MMO supports that underwater noise during both the construction and operation of the project has been considered.	Noted.
S42 Consultation MMO January 2018	For the construction phase, the assessment focuses on underwater noise from pile-driving for the installation of foundations for offshore structures. The report states that 'while other activities such as cable laying, dredging and vessel movements will result in underwater noise, these have the potential to affect a relatively small area in the immediate vicinity of activities and are therefore insignificant in the context of the underwater noise from piling operations'. The MMO seeks further clarification as to why the potential effects of these other activities on marine mammals have been considered in more detail, but not for fish/shellfish.	Further information has been added, with references to literature regarding the effects of noise from other activities on fish and shellfish in paragraph 6.10.62 *et seq.*
S42 Consultation Kent Wildlife Trust January 2018	Species that are likely to be vulnerable to smothering by suspended sediments during the construction phase should be specifically defined and easy to reference (the only mention of smothering to specific species is regarding herring eggs)	Additional clarification has been added in paragraph 6.10.22 *et seq.* regarding species likely to be affected by smothering.
S42 Consultation Kent Wildlife Trust January 2018	Loss of habitat during construction and decommissioning should not be scoped out of the EIA at this stage just because it is considered to be a small area affected.	The impact of loss of habitat has been included within the assessment (paragraph 6.10.3 *et seq*. The effect during decommissioning is considered to be of no greater significance than in the construction phase.
S42 Consultation Kent Wildlife Trust January 2018	The potential impacts of EMF on fish and shellfish should not be scoped out of the EIA at this stage.	The effects of EMF on fish and shellfish have been included within the assessment (paragraph 6.11.33 *et seq*.).
S42 Consultation Kent Wildlife Trust January 2018	Given that "the greatest abundances of individuals were recorded in soft and mixed sediment habitats in the north and western extent of the wind farm footprint‟, positioning of the WTGs in areas of high abundance should be avoided to minimise disturbance to these species. The fact that the high abundances „were often heavily skewed by one or two species (e.g. the queen scallop Aequipecten opercularis) present in extremely high numbers‟ suggests that this region is of ecological importance for these species and this must be given due consideration, for instance, in terms of micro-siting and layout of WTGs.	Further mitigation is not deemed to be required.
S42 Consultation Kent Wildlife Trust January 2018	The exclusively female population of small-spotted catsharks (Scyliorhinus canicula) recorded at inshore locations along one of the proposed Offshore Export Cable Corridor (OECC) routes suggests that this area is important for females of this species. Given that female catsharks lay their eggs during spring and early summer in near shore nursery grounds and that the surveys were carried out	Further mitigation is not deemed to be required as there are no significant impacts predicted on these species. Further information can be found in Section 6.10.

Date and consultation phase/ type	Consultation and key issues raised	Section where provision addressed
	in May and November, suggests that this area is important to female populations year-round, but specifically in spring and summer months. We would like to re-iterate the point that the timing of disruptive construction activities should be carefully planned so as to reduce the impact on the breeding and population of this species, including the laying females, laid eggs and small juveniles. Careful timing of construction and cable-laying activities will minimise the risk of smothering to juveniles in nursery areas, not only for the small-spotted catshark, but also for the ecologically and commercially important species that are supported by the foraging, spawning and nursery grounds in this area, such as herring, cod, plaice, and sole.	
S42 Consultation Kent Wildlife Trust January 2018	Further information should be provided about the effects of vibrations in the sediment on sandeels, in particular on their fitness and survivability during winter hibernation and the consequent potential need for avoidance of pile driving during this time of year. Given the high vulnerability of sandeels to OWF developments and their regional importance (including economically and to the survival of many other species), we seek assurance that impact assessments on sandeels will be undertaken.	Further study has been undertaken on the potential spawning habitats of sandeels (paragraph 6.7.29 *et seq.*). The effects of vibration on sandeels marine fauna, including sandeels, are discussed in paragraph 6.10.54 *et seq*.
S42 Consultation Kent Wildlife Trust January 2018	We question, and request further justification for, the conclusion of a low magnitude outcome in Section 6.11.6, given that long-term, continuous and irreversible impact is predicted for fish and shellfish within the development area for the lifetime of the project.	Within the context of the wider habitat available, the conclusion of low magnitude is deemed appropriate (see paragraph 6.11.3 *et seq.*).

6.4 Scope and methodology

6.4.1 The assessment considered the potential interaction between Thanet Extension, as described by the project details set out in Volume 2, Chapter 1: Project Description Onshore (Document Ref: 6.2.1), and fish and shellfish ecology receptors within the offshore study area for the proposed development.

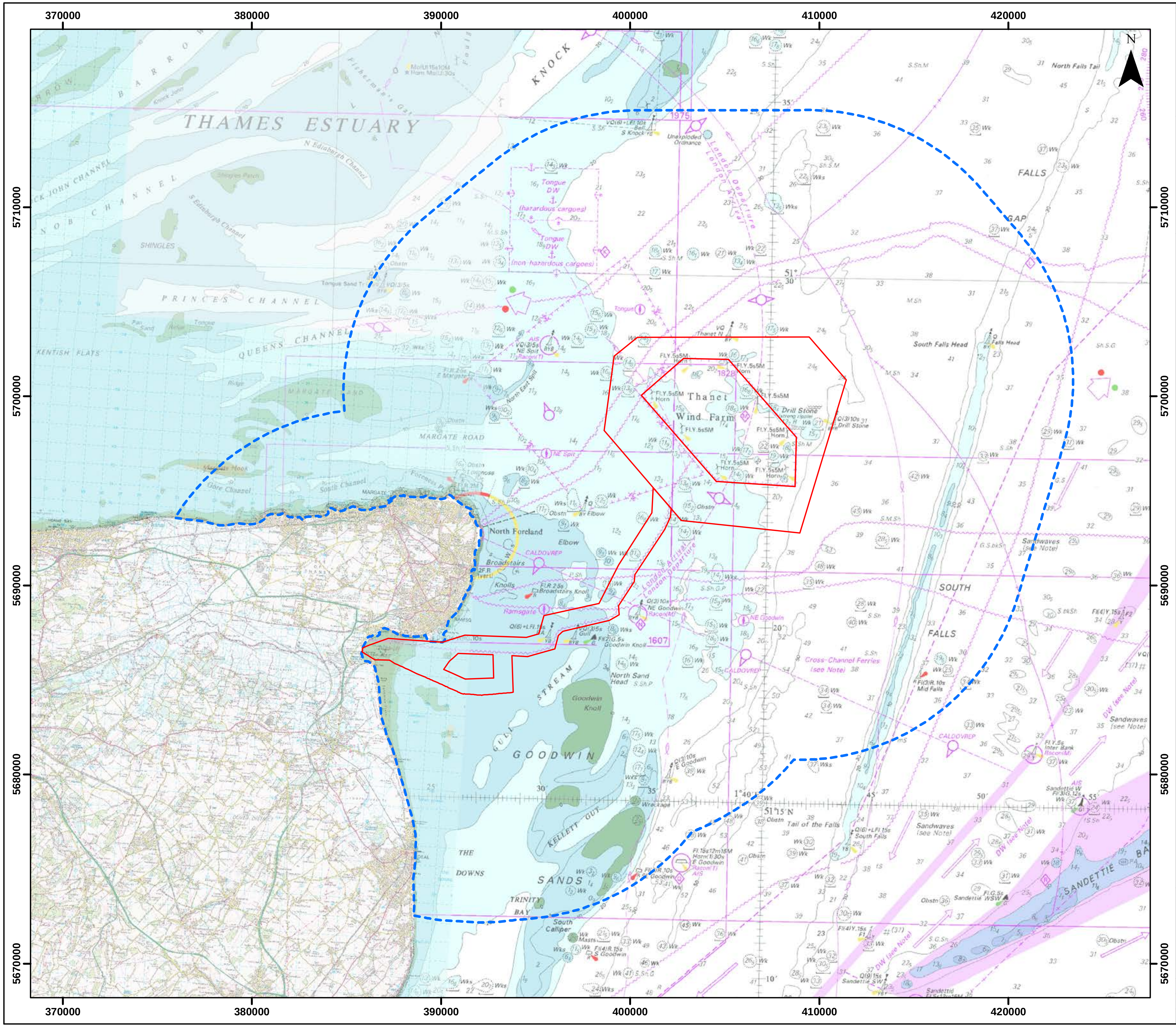
6.4.2 Baseline characterisation data on fish and shellfish resources were gathered through a desktop study combining the site-specific Thanet Extension survey data with other regional datasets.

Study area

6.4.3 The 'study area' for fish and shellfish ecology is dynamic, in that it varies according to the nature of the impact being studied. The study areas have been derived according to expert judgement and include primarily (for direct impacts) the proposed wind farm array area and the more linear Offshore Export Cable Corridor (OECC), beyond the array boundary, up to and including the intertidal zone at Pegwell Bay, up to Mean High Water Springs (MHWS).

6.4.4 For those impacts that can extend to receptors beyond the direct footprint of the proposed development, for example increased Suspended Sediment Concentrations (SSCs), a wider study area is used incorporating a 12 km buffer around the proposed site, based on the range of one tidal excursion (see Volume 2, Chapter 2: Marine Geology, Oceanography and Physical Processes). This study area is considered to be representative of the typical habitats found within the southern North Sea. This study area is illustrated in Figure 6-1.

6.4.5 For impacts whose effects extend beyond this wider study area, such as underwater noise, the study area is defined by the extent of those relevant effects. Where the study area for a particular impact is greater than the study area defined in Figure 6-1, this is stated within the relevant assessment section.



GoBe VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 6.1

Fish and Shellfish Study Area

Legend

Offshore Red Line Boundary

Fish and Shellfish Ecology Study

Datum: ETRS 1989
Projection: UTM31N

1:200,000 0 2 4 km 0 1 2 nm

Drg No	Fig6.1_StudyArea			Figure 6.1
Rev	0.1	Date	25/05/2018	
By	RM	Layout	N/A	

Site-specific Thanet Extension Surveys

6.4.6 Site-specific geophysical and geotechnical surveys have also been completed (Fugro surveys) of the array and OECC, including sediment Particle Size Analysis (PSA) and contaminant analysis using the grab samples. These data have been reviewed to consider the presence of source-receptor pathways when assessing the potential for water quality to be negatively impacted.

6.4.7 Surveys commissioned by VWPL for Thanet Extension included the following:

- Autumn 2016 survey (Ocean Ecology, 2016; Volume 4, Annex 6-1 (Document Ref: 6.4.6.1)) – This survey was the first of two fish and shellfish characterisation surveys undertaken for Thanet Extension. The survey was undertaken between 14th and 18th November 2016. 16 target otter trawl and beam trawl locations were surveyed (12 in the array area and four in the OECC). With the exception of two locations, all target locations were sampled successfully, and generally within 50 m of the target location;
- Spring 2017 survey (Ocean Ecology, 2017; Volume 4, Annex 6-2 (Document Ref: 6.4.6.2)) – This survey was the second of the two site characterisation surveys for fish and epifaunal communities across the Thanet Extension site. The survey was undertaken between 6th and 12th May 2017. All 16 target otter trawl and beam trawl locations were sampled successfully, and generally within 50 m accuracy of target positions.

6.4.8 The sample locations for the above Ocean Ecology site characterisation surveys are shown in Figure 6-2.

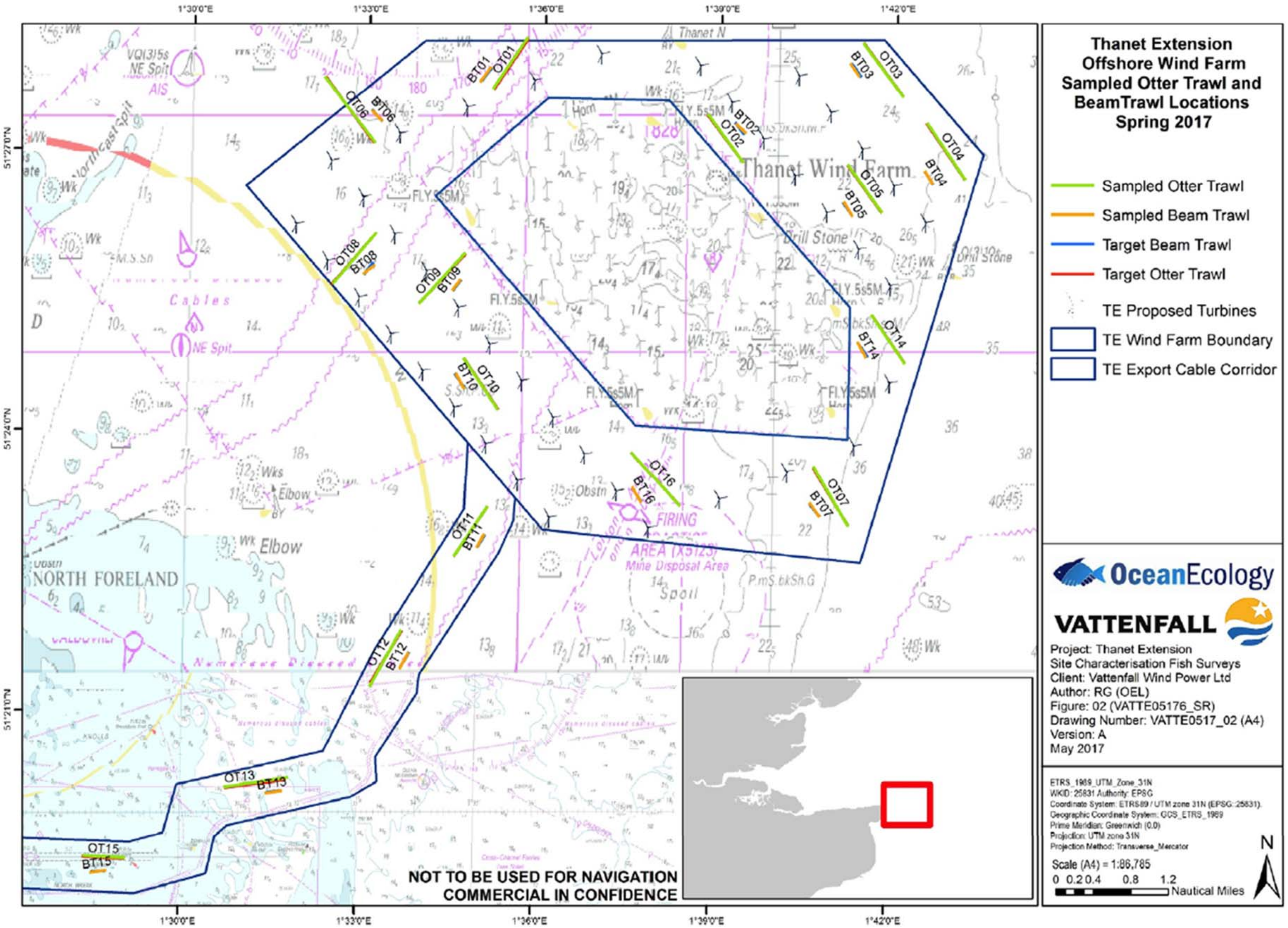


Figure 6-2: Target trawl locations during the fish surveys at the Thanet Extension array area (Ocean Ecology 2016; 2017).

6.4.9 This assessment has also been informed by the Environmental Statement (ES) for the existing TOWF. TOWF Site specific surveys were undertaken for TOWF including adult fish surveys, juvenile fish surveys, and eight observer trips on six vessels from the local Ramsgate fleet.

6.4.10 Other studies undertaken as part of the Thanet Extension EIA, specifically Volume 2, Chapter 2: Marine Geology, Oceanography and Physical Processes (Document Ref: 6.2.2), Volume 2, Chapter 5: Benthic and Intertidal Ecology (Document Ref: 6.2.5), and Volume 2, Chapter 9: Commercial Fisheries (Document Ref: 6.2.9), have also informed the assessment of impacts upon fish and shellfish ecology. Reference is made to these specific studies, and the associated inter-relationships, where relevant in the impact assessment below.

Additional sources of information

6.4.11 Additional sources of information used in this report also include:

- Distribution of Spawning and Nursery Grounds as defined in Coull *et al*. (1998) (Fisheries Sensitivity Maps in British Waters) and in Ellis *et al*. (2012) (Spawning and Nursery Grounds of Selected Fish Species in UK waters);
- The International Herring Larval Survey (IHLS) data (from ICES);
- Rogers, S.I., Millner, R.S., and Mead, T.A. (1998). The distribution and abundance of young fish on the east and south coast of England (1981 to 1997). Cefas Science Series Technical Report Number 108; and
- Rogers, S. and Stocks, R. (2001). Strategic Environmental Assessment – SEA2 Technical Report 003 – Fish and Fisheries.

6.5 Assessment criteria and assignment of significance

6.5.1 This assessment considers the potential impacts associated with the construction, O&M and decommissioning of Thanet Extension and the subsequent effects upon fish and shellfish ecology. This assessment is based on publicly available data and detailed consultation with identified stakeholders. This is summarised in the consultation section of this chapter (Table 6.3:).

6.5.2 The assessment method used in the fish and shellfish ecology impact assessment has drawn on the most recent Chartered Institute for Ecological and Environmental Management (CIEEM) guidelines (CIEEM, 2016). Guidance on the EIA process was also sought from the following resources:

- Guidelines for ecological impact assessment in the UK and Ireland. Terrestrial, Freshwater and Coastal (CIEEM, 2016);
- Guidance note for Environmental Impact Assessment in Respect of Food and Environmental Protection Act (FEPA) and Coast Protection Act (CPA) Requirements (Cefas *et al.,* 2004).
- Guidelines for Data Acquisition to Support Marine Environmental Assessments of Offshore Renewable Energy Projects (Judd, 2012); and
- Guidance on Environmental Considerations for Offshore Wind Farm Development (OSPAR, 2008).

6.5.3 In addition, the EIA follows the legislative framework as defined by the Offshore Marine Conservation (Natural Habitats, & c.) Regulations 2017; the Conservation of Habitats and Species Regulations 2017; the Wildlife and Countryside Act 1981 (as amended); and the Marine and Coastal Access Act 2009 (as amended). The full EIA methodology is presented in Volume 1, Chapter 3: EIA Methodology (Document Ref: 6.1.3).

6.5.4 Information about the project and the project activities for all stages of the project life cycle (construction, O&M and decommissioning) have been combined with information about the environmental baseline to identify the potential interactions between the project and the environment. These potential interactions are known as potential impacts, the potential impacts are then assessed to give a level of significance of effect upon the receiving environment/ receptors.

6.5.5 The outcome of the assessment is to determine the significance of these effects against predetermined criteria.

6.5.6 The sensitivities of fish and shellfish receptors are defined by both their potential vulnerability to an impact from the proposed development, their recoverability, and the value or importance of the receptor. The definitions of terms relating to the sensitivity of fish and shellfish ecology chapters are detailed in Table 6.4.

Table 6.4: Sensitivity/ importance of the environment

Receptor sensitivity/ importance	Description/ reason
High	Nationally and internationally important receptors with high vulnerability and no ability for recovery.
Medium	Regionally important receptors with high vulnerability and no ability for recovery. Nationally and internationally important receptors with medium to high vulnerability and low to medium recoverability.
Low	Locally important receptors with medium to high vulnerability and low recoverability. Regionally important receptors with low vulnerability and medium recoverability. Nationally and internationally important receptors with low vulnerability and medium to high recoverability.
Negligible	Receptor is not vulnerable to impacts regardless of value/ importance. Locally important receptors with low vulnerability and medium to high recoverability.

6.5.7 The magnitude of potential impacts is defined by a series of factors including the spatial extent of any interaction, the likelihood, duration, frequency and reversibility of a potential impact. The definitions of the levels of magnitude used in the assessment as shown in Table 6.5 below.

Table 6.5: Magnitude of impact

Magnitude	Definition
High	The proposal would affect the conservation status of the site or feature, with loss of ecological functionality. Major shift away from baseline conditions.
Medium	The feature's conservation status would not be affected, but the impact is likely to be significant in terms of ecological objectives or populations. Fundamental shift away from baseline conditions.
Low	Minor change from the baseline condition but the impact is of limited temporal or physical extent.
Negligible	No change from the baseline conditions.

6.5.8 The matrix used for the assessment of significance is shown in Table 6.6. The magnitude of the impact is correlated against the sensitivity of the receptor to provide a level of significance.

6.5.9 For the purposes of this assessment any effect that is **Moderate** or **Major**, and shaded in in the table below, is considered to be significant in EIA terms. Any effect that is minor or below, is not significant in respect to the EIA.

Table 6.6: 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 respect of the EIA

6.6 Uncertainty and technical difficulties encountered

6.6.1 The description of spawning and nursery grounds is primarily based on the information presented in Ellis *et al*. (2012) and Coull *et al*. (1998). The limitations of these sources of information should, however, be recognised. These publications provide an indication of the general location of spawning and nursery grounds, particularly in the context of the relatively small footprint of Thanet Extension. Similarly, the spawning times given in these publications represent the maximum duration of spawning on a species/ stock basis. In some cases, the duration of spawning may be much more contracted, on a site-specific basis, than reported in Ellis *et al*. (2012) and Coull *et al*. (1998). An industry led review of impacts on fish from piling at offshore wind farms was conducted by the Offshore Renewables Joint Industry Programme (ORJIP, 2018) specifically in relation to herring spawning. The report highlighted that the exact locations of herring spawning (spawning beds) was a key uncertainty when considering them in assessments. Therefore, where available, additional research publications have also been reviewed to provide site specific information.

6.6.2 Mobile species, such as fish, exhibit varying spatial and temporal patterns. All of the wind farm project site specific surveys were undertaken to provide a semi-seasonal description of the fish and shellfish. It should be noted, however, that the data collected during these surveys represent snapshots of the fish and shellfish assemblage at the time of sampling and whilst the surveys were conducted in the autumn and spring to account for seasonal variation the fish and shellfish assemblages may vary both seasonally and annually. The description of the existing environment also draws upon the data collected for the TOWF ES and monitoring of TOWF. With this in mind, the surveys conducted are considered sufficient and follow best practice.

6.7 Existing environment

Overview

6.7.1 The description of the existing environment draws on the existing TOWF ES, as well as site specific surveys for the array area, and site-specific surveys for the OECC.

6.7.2 The array area of the proposed wind farm is situated in an area of water varying in depth from 13 - 33 m with the shallowest areas recorded in the inshore, western edge of the array, and deeper areas extending offshore to the east of the site. Geophysical data indicates that the seabed appears complex with areas of finer sand and muds in deeper waters to the north, north-west and east of the site, mixed sediments within the central region, and isolated patches of sands and muddy sands in places. The seabed along the OECC also appears relatively heterogeneous with mixed and coarse sediments located in the central and offshore end with rocky substrate identified along the inshore end.

6.7.3 Similar fish and shellfish communities exist within the array area and OECC (Ocean Ecology 2016; 2017), however there were differences in community composition and distribution between the array and OECC. The site-specific surveys indicated that communities within the wind farm footprint were typical of soft sediment or mixed sediment habitats whilst those in the OECC were more typical of hard substrate communities, most notably towards the inshore end of the corridor. Fish communities reflected this gradient in seabed type with species such as pouting (*Trisopterus luscus*) and the small-spotted catshark (*Scyliorhinus canicula*) dominating areas of coarser ground and hard substrate in the east of the wind farm site and along the OECC and the thornback ray (*Raja clavata*) and Dover sole (*Solea solea*) dominating communities in soft sediment locations. The greatest abundances of individuals were recorded in soft and mixed sediment habitats in the north and western extent of the wind farm footprint. These abundances however were often heavily skewed by one or two species (e.g. *Aequipecten opercularis*) present in extremely high numbers.

6.7.4 A number of species are potentially present within the proposed development area and surrounding areas as informed by a review undertaken as part of the characterisation survey strategy (CMACS, 2016), monitoring undertaken at the existing TOWF (Royal Haskoning 2013), the site-specific surveys, and through discussion with the Thanet Fisherman's Association (TFA).

Fish

- Dover sole (*S. solea*);
- Cod (*Gadus morhua*);
- Whiting (*Merlangius merlangus*);
- Pouting (*T. luscus*);
- Plaice (*Pleuronectes platessa*);
- Dab (*Limanda limanda*);
- Seabass (*Dicentrarchus labrax*);
- Flounder (*Platichthys flesus*);
- Lemon sole (*Microstomus kitt*);
- Herring (*Clupea harengus*);
- Sandeel (*Ammodytidae*);
- Mackerel (*Scomber scombrus*);
- Gobies (Gobidae);
- Thornback ray (*R. clavata*);
- Small-spotted catshark (*S. canicula*);
- Starry smoothound (*Mustelus asterias*);
- Spurdog (*Squalus acanthias*);
- Tope (*Galeorhinus galeus*);
- Allis shad (*Alosa alosa*);
- Twaite shad (*Alosa fallax*);
- Atlantic salmon (*Salmo salar*);
- Sea trout (*Salmo trutta*); and
- Smelt (*Osmerus eperlanus*).

Shellfish

- Common whelk (*Buccinum undatum*);
- Edible crab (*Cancer pagurus*);
- Lobster (*Homarus gammarus*);
- Blue mussel (*Mytilus edulis*);
- Brown shrimp (*Crangon crangon*);
- Mantis Shrimp (*Rissoides desmaresti*);
- King scallop (*Pecten maximus*); and
- Queen scallop (*A. opercularis*).

Other species of interest

6.7.5 The following species were identified as being likely to occur or known to occur in the baseline review with the exception of the invasive slipper limpet, *Crepidula fornicata*, originally found on the east coast of America but now present along the southern coasts of Britain. Most of the species listed are considered to be incidental catches with only a very small number of sporadic records across the site. Both the common whelk and the common prawn (*Palaemon serratus*) were regularly sampled across the site in beam trawls. The tub gurnard (*Chelidonchthys lucerna*) was present across the site in relatively low but consistent numbers whilst the edible crab (*C. pagurus*) was recorded in similar numbers but across fewer trawl locations. The abundance of gobies, an important prey item for many commercially important fish species, was recorded in relatively low numbers at eight of the 16 beam trawl locations sampled.

6.7.6 Since 2015, due to declining seabass stocks, the species has been placed under special protection measures limiting recreational and commercial catches, and fish size restrictions to allow females to reach spawning age. This involved:

- A ban on pelagic trawling for seabass during the 2015 spawning season;
- A limit on recreational anglers of 3 fish per day per angler;
- A maximum catch per month by gear type, limiting the targeting of the vulnerable stock; and
- An increased minimum landing size (from 36 to 45 cm).

6.7.7 The species of commercial and/ or conservation interest are listed below.

- Cod (*G. morhua*);
- Seabass (*D. labrax*);
- Lemon sole (*M. kitt*);
- Flounder (*P. flesus*);
- Red mullet (*Mullus barbatus*);
- Tub gurnard (*C. lucerna*);
- Gobies (Gobidae);
- Lobster (*Homarus gammarus*);

- Edible crab (*C. pagurus*);
- Spiny spider crab (*Maja squinado*);
- Common prawn (*P. serratus*);
- Common whelk (*B. undatum*);
- Cockle (*Cerastoderma edule*);
- European Oyster (*Ostrea edulis*); and
- Slipper limpet (*C. fornicata*).

Array area

TOWF survey results

6.7.8 Information on the fish and shellfish communities in the area around the proposed development has been compiled for the existing TOWF. This included data obtained both from desk-based searches and from baseline surveys. The baseline description of the array area will draw on this existing information, as well as on site-specific surveys undertaken for Thanet Extension. This information adds to the extensive knowledge of the area based on other developments in the region, such as other OWFs.

6.7.9 Fish monitoring undertaken at the existing TOWF recorded numerous flatfish; particularly dab (*L. limanda*), plaice (*P. platessa*), Dover sole (*S. solea*), and to a lesser extent, flounder (*P. flesus*) and lemon sole (*M. kitt*). Round fish included whiting (*M. merlangus*), pouting (*T. luscus*), gobies (Gobidae), and Clupeidae (the family that herring belong to). Generally, hauls were low in abundance of individuals and often of low diversity dominated by a few key species that were sampled at the majority of trawl locations. The abundance of commercial fish was found to be slightly elevated at cable route locations, seemingly driven by the elevated numbers of pouting (*T. luscus*) at these locations rather than increased diversity of species. A total of 11 species of fish and four species of shellfish were recorded with the most abundant fish species being pouting and the most abundant shellfish species being the common whelk (*B. undatum*). The TOWF ES assessed the significance of effects on fish and shellfish receptors and deemed them to be negligible.

Thanet Extension survey results

6.7.10 A full interpretation in the Fish and Shellfish Technical Report was produced following completion of the two fish and shellfish characterisation studies, the specifications of which were agreed with the relevant stakeholders, and the characterisation reports (Volume 4, Annex 6-1 and 6-2 (Document Ref: 6.4.6.1 and 6.4.6.2)) (Ocean Ecology 2016; 2017) submitted to the Thanet Extension Evidence Plan Technical Review Panel for approval.

6.7.11 Generally, hauls were low in abundance of individuals and often of low diversity, dominated by a few key species that were sampled at the majority of trawl locations. The abundance of commercial fish was found to be slightly elevated at cable route locations, seemingly driven by the elevated numbers of pouting (*T. luscus*) at these locations rather than increased diversity of species. A total of 11 species of fish and four species of shellfish were recorded with the most abundant fish species being pouting and the most abundant shellfish species being the common whelk (*B. undatum*), reflecting similar results when comparing with the surveys carried out for the existing TOWF.

6.7.12 The commercial fish community in this area was dominated by pouting and whiting with moderate abundances of Dover sole and plaice. Other fish and shellfish were present only sporadically and in comparatively low numbers. Pouting was the most abundant and one of the most widespread fish species sampled from the Thanet Extension development area but showing greater abundance in the OECC. Whiting showed no obvious spatial distribution and was widespread whereas Dover sole and plaice showed an opposite trend to pouting, being the most abundant in areas further offshore in the wind farm footprint.

6.7.13 There were only two species of elasmobranch recorded across the survey area, the small-spotted catshark and the thornback ray. Combined abundances of elasmobranch species were greatest in the array areas due largely in part to the restricted abundance of thornback ray on soft sediment areas away from the OECC.

6.7.14 The small-spotted catshark was the more abundant of the two elasmobranch species sampled from the survey area and was widespread, recorded across a range of habitat types. Abundances were generally lower in the northern area of the wind farm where sediments consist of sands and muddy sands and notable abundances were associated with the hard substrate area at the inshore end of the OECC and an area of *Sabellaria spinulosa* sampled in the north-east area of the development site (Volume 2, Chapter 4: Benthic Subtidal and Intertidal Ecology (Document Ref: 6.2.4)). Also apparent was a distinct spatial separation between male and female catshark with males in offshore areas and females at inshore locations along the OECC. In contrast, thornback ray exhibited a much reduced spatial distribution and abundances were generally higher in the northern area of the array area. There was no apparent trend in distribution of male and female thornback ray nor did either sex predominate over the other in terms of abundance.

6.7.15 The beam trawl sampling undertaken across the survey area revealed a diverse fish and epifaunal assemblage with a total of 69 taxa recorded. A total of 20 species of fish and 49 species of macroinvertebrate were recorded with the most abundant invertebrate species being the brittlestar, (*Ophiuroidea)*, and the most abundant fish species group being the Dover sole.

6.7.16 Juvenile fish and epifaunal invertebrate communities showed a clear trend between soft sediment habitats and hard substrates with species such as the Dover sole, thornback ray and the small-spotted catshark dominating communities in soft sediment locations. Dominant invertebrates were the brittlestar *O. albida* the common starfish (*A. rubens*) and hermit crabs (Paguridae).

6.7.17 There was evidence of *S. spinulosa* reef recorded at three of the 16 tow locations sampled, in the north and north-eastern areas of the Thanet Extension wind farm footprint. A substantial quantity of *S. spinulosa* was sampled at epibenthic beam trawl location BT02 immediately adjacent to the existing TOWF where *S. spinulosa* has previously been recorded (Ocean Ecology, 2016). A diverse assemblage of fish and invertebrates was associated with this sample including juvenile and adult fish (Dover sole, small-spotted catshark, thornback ray, and solenette, *Buglossidium luteum*) and various invertebrates including the commercially important edible crab, common prawn and pink shrimp (*Pandalus borealis*).

The offshore export cable corridor

Thanet Extension survey results

6.7.18 The description of the offshore cable corridor baseline will draw on site specific data collected in November 2016 (Ocean Ecology, 2016) and April 2017 (Ocean Ecology, 2017).

6.7.19 Generally, samples were of low abundance of individuals and often of low diversity, as with the array area. The most abundant fish species was pouting and the most abundant shellfish species was the common whelk. Despite a relatively uniform number of taxa per haul, there was a noticeable difference in community composition across the site which correlated well with the range in seabed types, particularly between offshore locations within the wind farm footprint and the inshore cable route locations.

6.7.20 The fish community was similar to that of the array area. Pouting was the most abundant commercial fish species and exhibited a clear trend in its distribution with abundances focused along the export cable corridor and within the eastern extent of the array footprint. Whiting was also widespread and Dover sole and plaice were present, though to a lesser extent than the array area.

6.7.21 The elasmobranch community in the OECC was similar to that of the array area, consisting of the small-spotted catshark and the thornback ray. The small-spotted catshark was the more abundant of the two elasmobranch species, with a notable abundance associated with the hard substrate area at the inshore end of the OECC. There was also a distinct spatial separation of male and female small-spotted catshark, with males in offshore areas and females at inshore areas along the OECC in both the autumn and spring surveys.

6.7.22 Juvenile fish and epifaunal invertebrate communities showed a clear trend between soft sediment habitats and hard substrates with species such as the butterfish (*Pholis gunnellus*), the common sea snail (*B. undatum*), common dragonet, (*Callionymus lyra*) and the pogge (*Agonus cataphractus*) dominating hard substrate locations along the OECC.

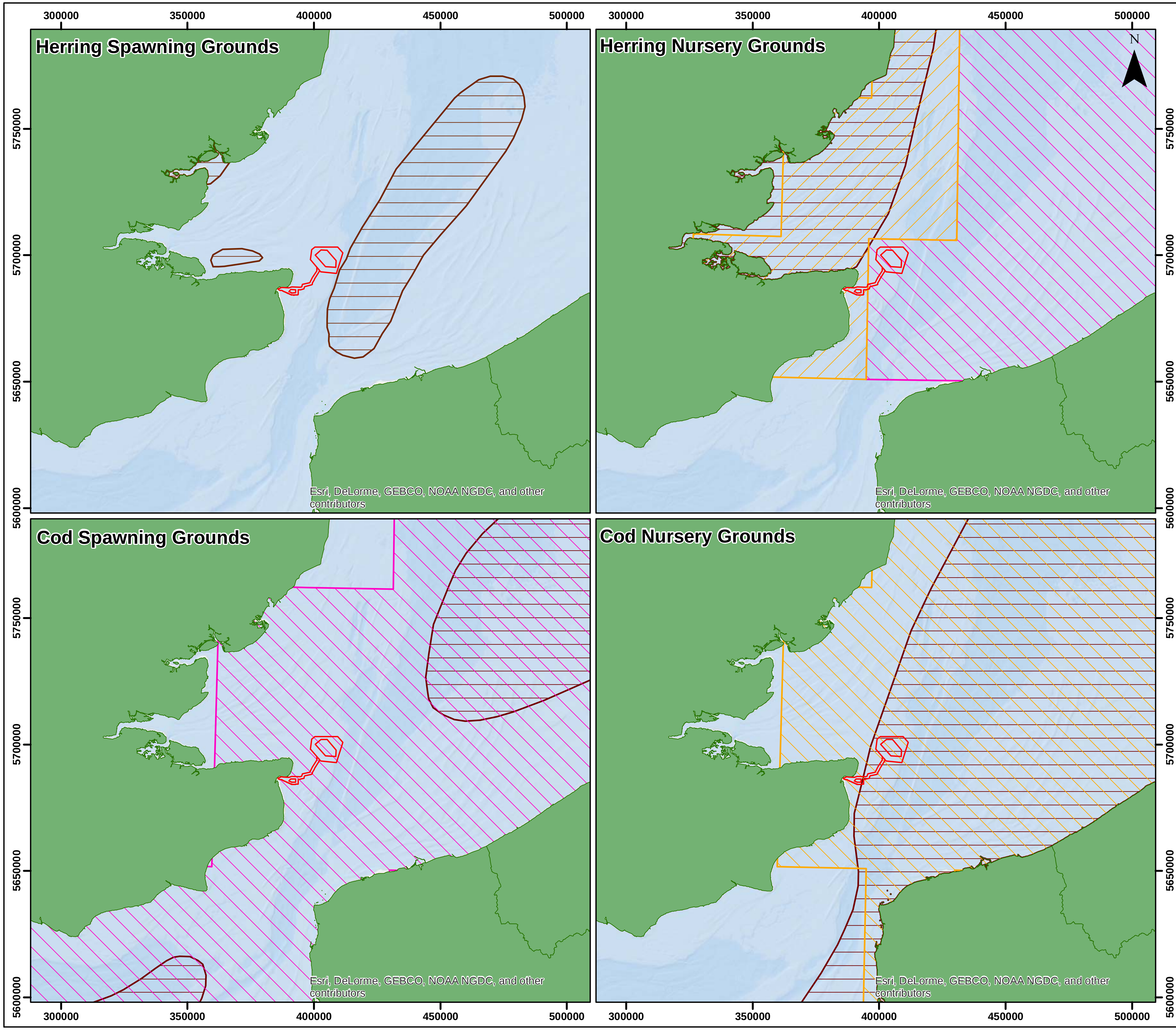
Spawning and nursery areas

6.7.23 Many species of fish and shellfish are known to either spawn or have nursery areas in relatively close proximity to, or potentially overlapping with Thanet Extension (Coull *et al.,* 1998; Ellis *et al.,* 2012). Detailed information on spawning and nursery areas for fish species within the array was also considered in the TOWF ES through reference to data available at that time. This section describes fish species which have spawning and nursery areas that overlap, or are in close proximity to, the Thanet Extension array area or OECC.

6.7.24 Spawning and nursery areas are categorised by Ellis *et al*. (2012) as either high or low intensity dependent on the level of spawning activity or abundance of juveniles recorded in these habitats. Coull *et al*. (1998) does not always provide this level of detail.

6.7.25 Spawning activity is summarised below (see Figure 6-3 to Figure 6-7Figure 6-7: C):

- The only species with high intensity spawning grounds that overlap with the site are sole and plaice;
- Low intensity spawning areas overlap the site for cod, sandeel (Ammodytidae) (though it should be noted that when considered alongside the site-specific sediment data the habitat is considered to be less than optimal (i.e. mixed and fine sediment), and lemon sole (undetermined intensity);
- For fish nursery grounds, the only species with high intensity grounds according to Coull *et al* (1998) is herring (OECC only). Further reference is however made to the International Herring Larval Survey data (IHLS) (2005 - 2015) which suggest that there has been a shift since the Coull *et al*. paper was drafted to a population in the East English Channel; and
- Species with low intensity nursery grounds are herring (array area), thornback ray, cod, whiting, sandeel, mackerel (*Scomber scombrus*) plaice and sole.



GoBe VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 6.3

Spawning and Nursery Grounds for Herring and Cod

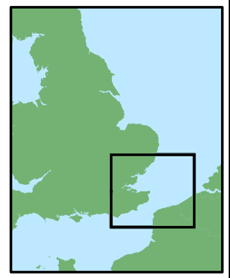
Legend

- Offshore Red Line Boundary

Spawning/Nursery Ground Data

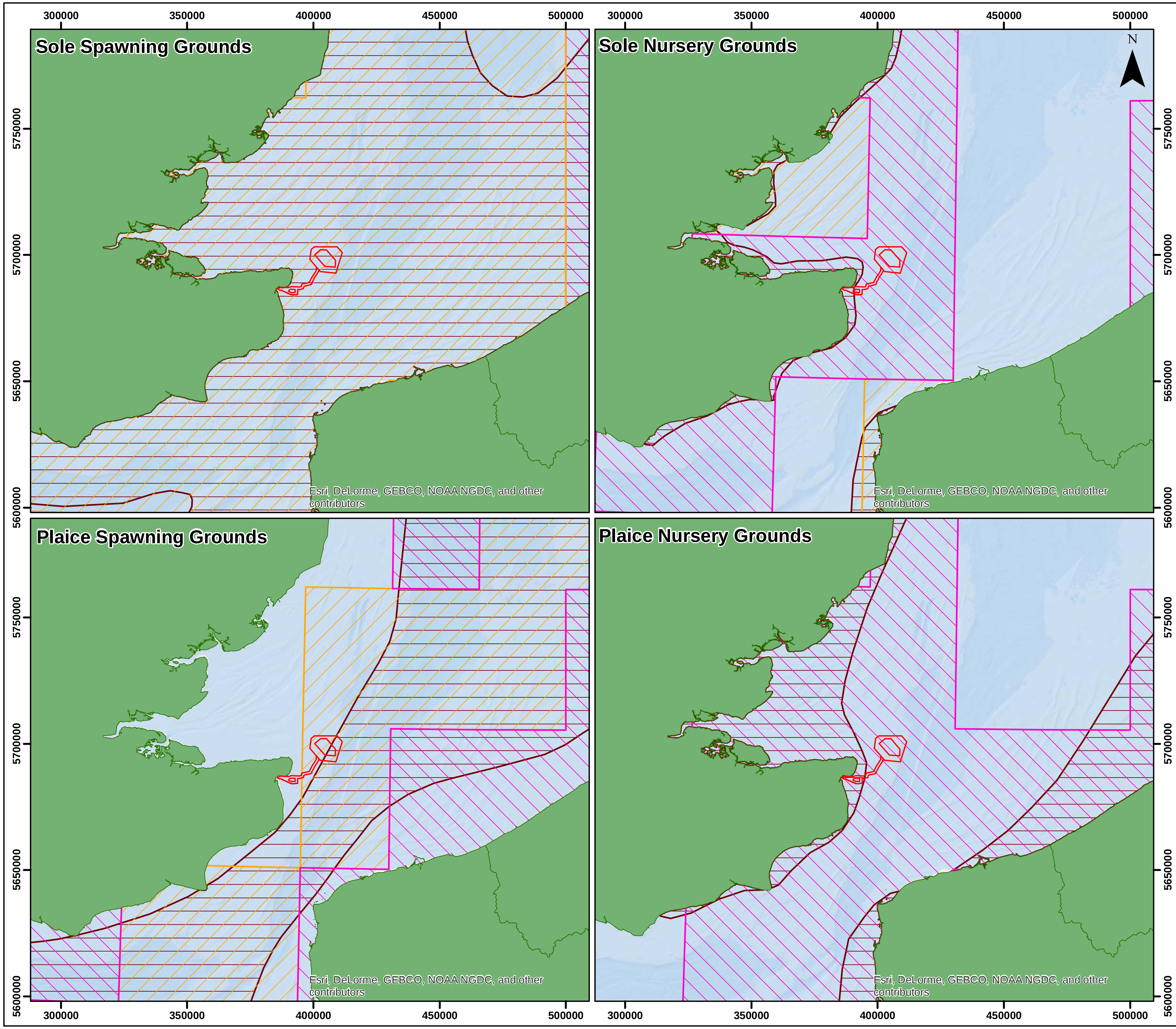
- High Intensity (Ellis et al., 2012)
- Low Intensity (Ellis et al., 2012)
- Coull et al., 1998

Datum: ETRS 1989
Projection: UTM31N



1:1,500,000 — 0 10 20 km — 0 8.5 17 nm

Drg No	Fig6.3_HerrCod			Figure 6.3
Rev	0.1	Date	25/05/2018	
By	RM	Layout	N/A	



GoBe VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 6.4

Spawning and Nursery Grounds for Sole and Plaice

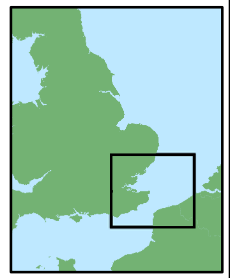
Legend

- Offshore Red Line Boundary

Spawning/Nursery Ground Data

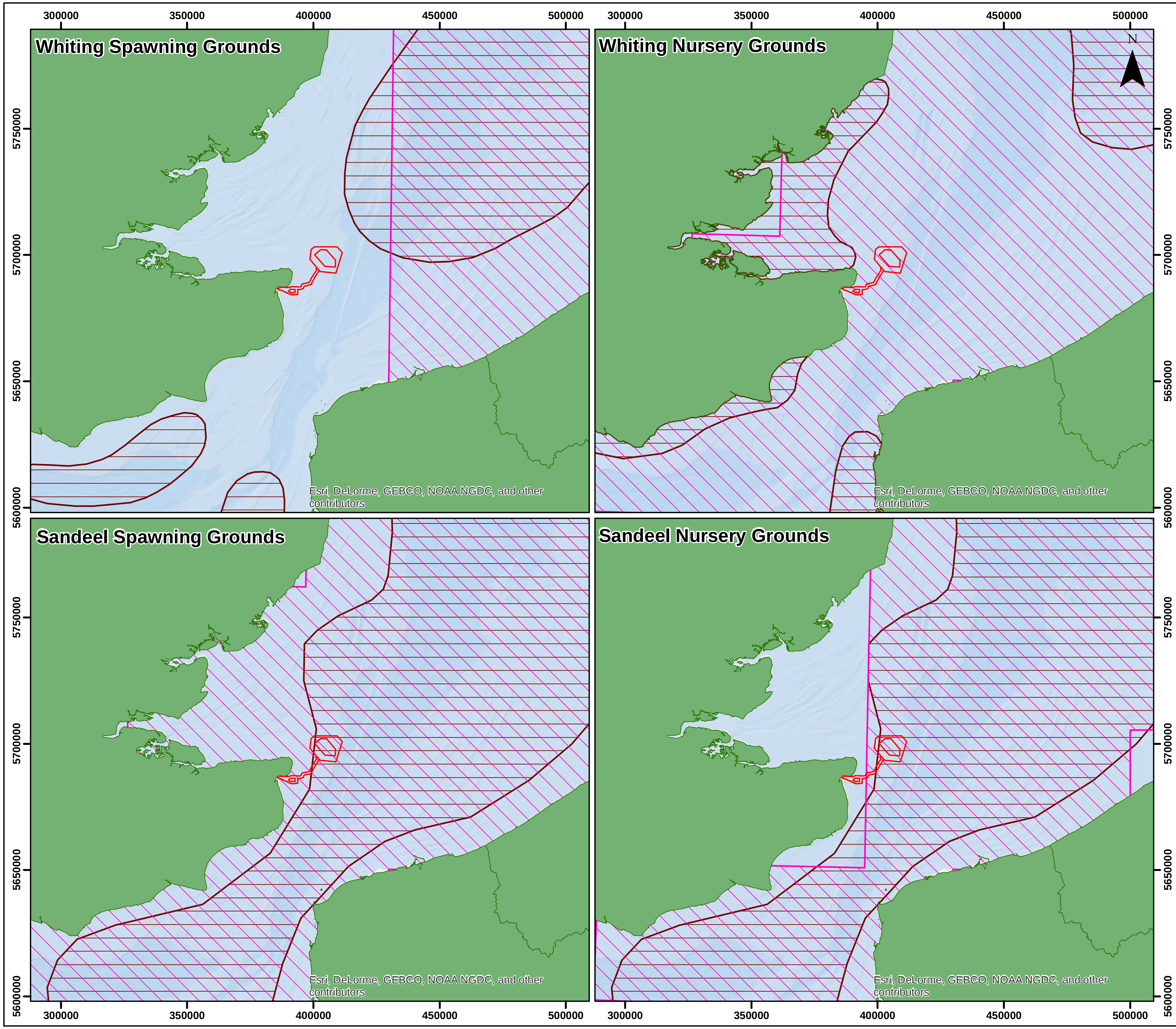
- High Intensity (Ellis et al., 2012)
- Low Intensity (Ellis et al., 2012)
- Coull et al., 1998

Datum: ETRS 1989
Projection: UTM31N



1:1,500,000 0 10 20 km 0 8.5 17 nm

Drg No	Fig6.4_SolePlaice			Figure 6.4
Rev	0.1	Date	25/05/2018	
By	RM	Layout	N/A	



GoBe VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 6.5

Spawning and Nursery Grounds for Whiting and Sandeel

Legend

Offshore Red Line Boundary

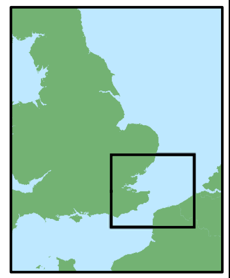
Spawning/Nursery Ground Data

High Intensity (Ellis et al., 2012)

Low Intensity (Ellis et al., 2012)

Coull et al., 1998

Datum: ETRS 1989
Projection: UTM31N

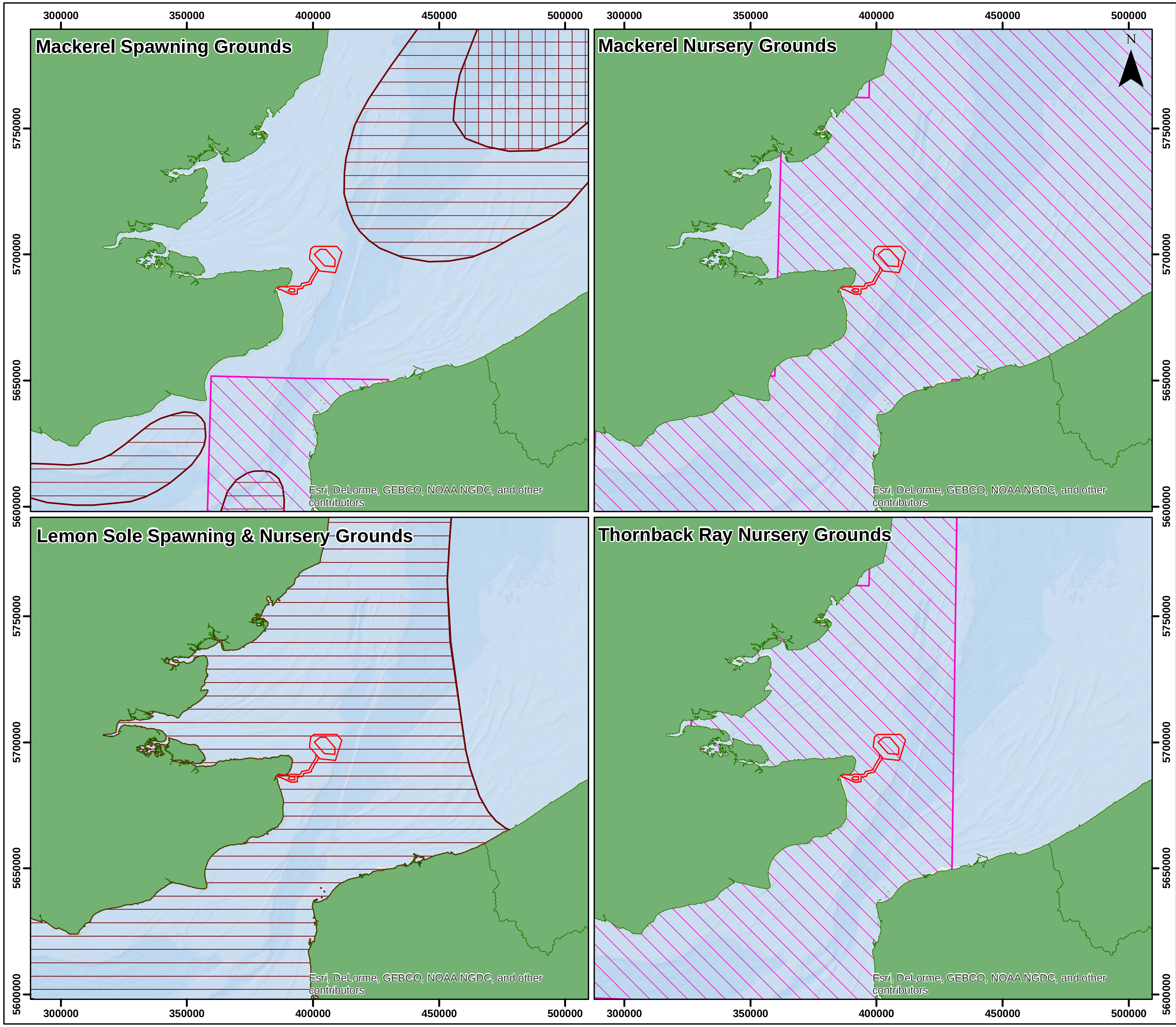


1:1,500,000

0 10 20 km

0 8.5 17 nm

Drg No	Fig6.5_WhitSand			Figure 6.5
Rev	0.1	Date	25/05/2018	
By	RM	Layout	N/A	



GoBe VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 6.6

Spawning and Nursery Grounds for Mackerel, Lemon Sole and Thornback Ray

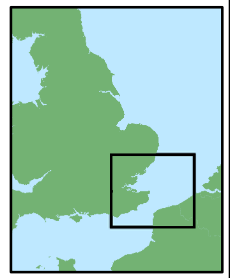
Legend

- Offshore Red Line Boundary

Spawning/Nursery Ground Data

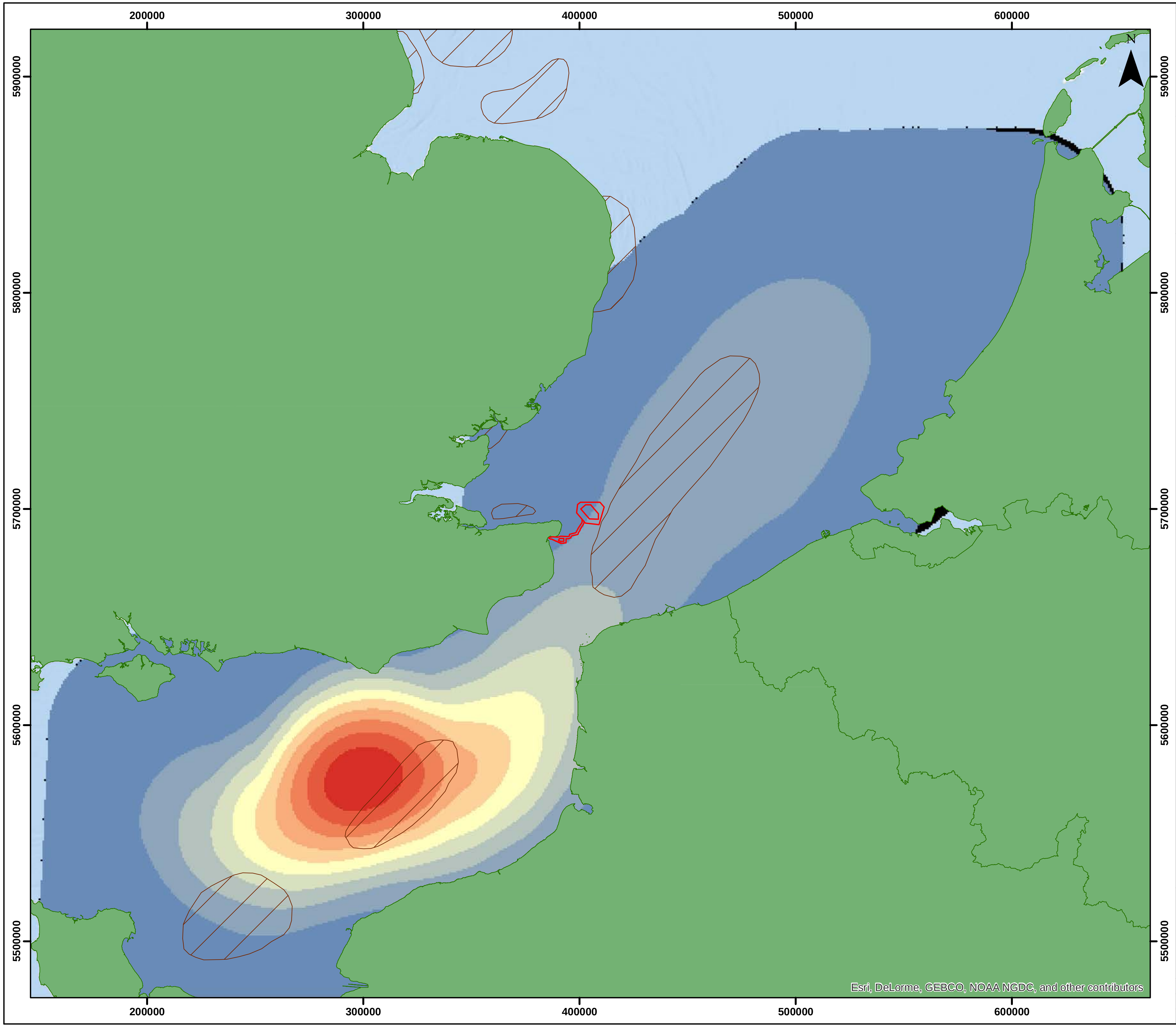
- High Intensity (Ellis et al., 2012)
- Low Intensity (Ellis et al., 2012)
- Undetermined Intensity (Coull et al., 1998)
- Low Intensity (Coull et al., 1998)

Datum: ETRS 1989
Projection: UTM31N



1:1,500,000 — 0 10 20 km — 0 8.5 17 nm

Drg No	Fig6.6_MackLemThor			Figure 6.6
Rev	0.1	Date	25/05/2018	
By	RM	Layout	N/A	



GoBe VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 6.7

Herring Spawning Grounds: IHLS Comparison

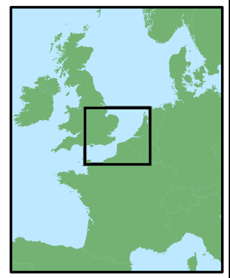
Legend

- Offshore Red Line Boundary
- Herring Spawning Grounds (Coull *et al*., 1998)

IHLS 2007/2008-2016/17 Downs Data - Total Larval Abundance Per m^2

- 0
- 0.1 - 9,400
- 9,400.1 - 27,700
- 27,700.1 - 50,100
- 50,100.1 - 76,200
- 76,200.1 - 106,100
- 106,100.1 - 139,500
- 139,500.1 - 177,900
- 177,900.1 - 221,100
- 221,100.1 - 266,700
- 266,700.1 - 314,600

Datum: ETRS 1989
Projection: UTM31N



1:1,750,000 0 10 20 km 0 10 20 nm

Drg No	Fig6.7_IHLS			Figure 6.7
Rev	0.1	Date	25/05/2018	
By	RM	Layout	N/A	

Herring and sandeel spawning

6.7.26 Herring and sandeel are of particular relevance when considering impacts to spawning areas as they are demersal spawners. Sandeel, as their name suggests, spawn in coarse sands to gravelly sands, whilst herring prefer to spawn in coarser sediments comprising sandy gravels to gravel.

6.7.27 Data from Coull *et al*. (1998) suggests that Thanet Extension lies in close proximity to herring spawning grounds. However, data from the International Herring Larval Survey (IHLS) shows that the main important area for herring spawning is located to the south in the English Channel (the Downs stock) Figure 6-7). This herring stock has its peak spawning season from the end of November to January. There is also a herring sub-stock in the Thames Estuary (the Thames sub-stock, for which spawning peaks in February to April.

6.7.28 Low intensity sandeel spawning and nursery areas overlap with both the array area and OECC. Spawning areas for sandeel off the east coast are large, extending from northern England down to the English Channel. It is also important to note that sediment type is considered an important determinant in the distribution of sandeel spawning habitat.

Potential herring and sandeel spawning habitat

6.7.29 As demersal spawners, herring and sandeel lay demersal eggs. As such, they have specific requirements in terms of spawning grounds, with seabed sediment being the primary determinant (Maravelias *et al.*, 2000).

6.7.30 The preferred sediment habitat for herring spawning is gravel, with some tolerance of more sandy sediments, although these are primarily on the edge of any spawning grounds (Stratoudakis *et al.* 1998). Atlantic herring spawning beds are typically small localised features. Actual spawning habitat, or habitat that could be used for spawning activity, likely comprises relatively small seabed features, with discrete spatial extents, although these may be spread across wide area of suitable seabed spawning habitat at a regional scale (e.g. spawning grounds (MarineSpace *et al*., 2013)). Eggs are laid on the seabed, usually in water 10-80 m deep, in areas of gravel, or similar coarse habitats (e.g. coarse sand, shell and maerl), with well oxygenated waters (Ellis *et al.*, 2012; Bowers, 1980; de Groot, 1980; Rakine, 1986, Aneer, 1989; Stratoudakis *et al*., 1998).

6.7.31 In a report published by ORJIP (2018), it was noted that while herring demonstrate a preference to spawn on gravel (or gravelly sands), predictive sediment habitat mapping has a high chance of being significantly conservative when used to predict spawning areas. This is demonstrated using larval abundance heatmapping (such as that illustrated in Figure 6-7), when compared to potential herring spawning areas, which extend across the majority of the North Sea basin. It is also noted that spawning grounds are subject to change over time.

6.7.32 Sandeel also spawn in coarse sediments, though as their name suggests, their preferred spawning habitats are sandier than those of herring. Sandeel prefer habitats composed of sand to gravelly sand but will tolerate sandy gravels as a marginal spawning habitat.

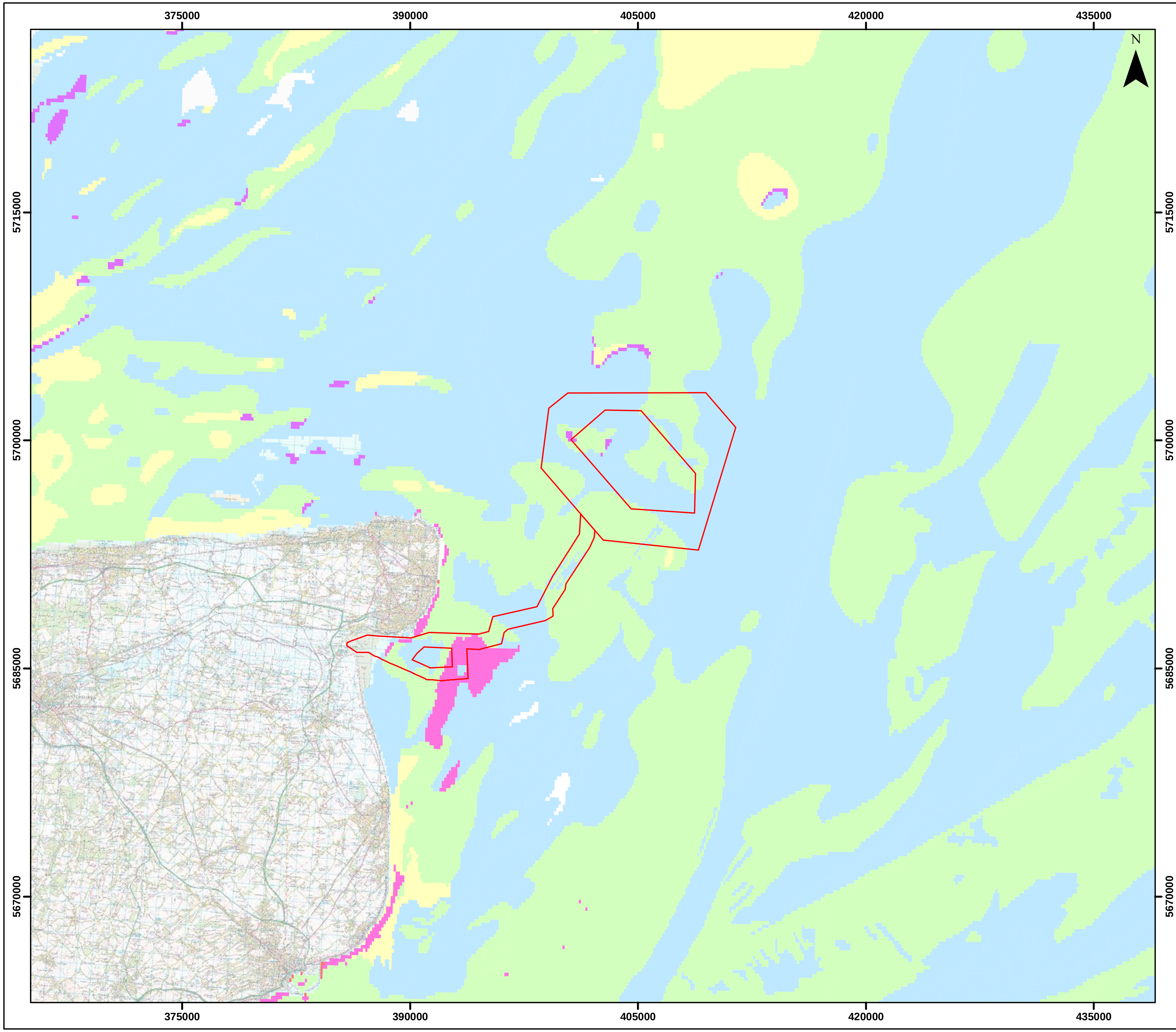
6.7.33 EU Sea Map (2016) data, as illustrated in Figure 6-8, shows that the array and OECC are dominated by sand and coarse sediments, with patches of rock or other hard substrata, primarily in the mid and nearshore section of the OECC.

6.7.34 Sediment and habitat data collected for the Nemo Interconnector project is illustrated in Figure 6-10. This data identifies that in the areas that overlap with the Thanet Extension OECC, the habitats are generally made up of a mixture of infralittoral mixed sediments, fine sand and muddy sand, with finer sediments being found closer to shore within Pegwell Bay. Sediments are classified as ranging from gravel to sand, with smaller pockets of sand and gravel.

6.7.35 A site-specific geotechnical survey was undertaken in 2016 in the proposed Thanet Extension array area and OECC. The particle size analysis and main characteristics of the surficial seabed sediments are described in Volume 2, Chapter 2: Marine Geology, Oceanography and Physical Processes (Document ref: 6.2.2). The sediments throughout the array and wider study area are generally highly heterogenous, although the site-specific surveys showed that sediments in the south-west are relatively coarser, with finer, sandier sediments being found further offshore. Sediments throughout the OECC were generally heterogenous, with a slight pattern in distribution of sediments being generally coarser offshore and finer closer to shore. The sediment characterisation from the site-specific surveys are illustrated in Figure 6-9.

6.7.36 It is apparent that preferred herring spawning habitat (gravelly sand/ sandy gravel) can be found throughout the array and OECC, mainly in the south-western part of the array and north-eastern section of the OECC (Figure 6-9). However, Figure 6-8 would also indicate that this habitat is also widespread throughout the study area and wider region.

6.7.37 Preferred spawning habitat for sandeel (coarse sediments, sand, etc.) can be found throughout the array and OECC. As with potential herring spawning areas, this habitat is widespread throughout the wider study area and region. To the south-west of the array and north-eastern OECC, sediments are largely marginal spawning habitat (sandy gravel). Preferred, marginal and unsuitable sandeel spawning habitat from site-specific data (Fugro, 2016) are illustrated in Figure 6-11.



GoBe VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 6.8

Seabed Habitats around Thanet Extension (EU Sea Map, 2016)

Legend

Offshore Red Line Boundary

Substrate (EU Sea Map, 2016)

- Coarse sediment
- Mixed sediment
- Rock or other hard substrata
- Sand
- Sandy mud to muddy sand
- Seabed

Datum: ETRS 1989
Projection: UTM31N

1:250,000 0 2.5 5 km 0 1.5 3 nm

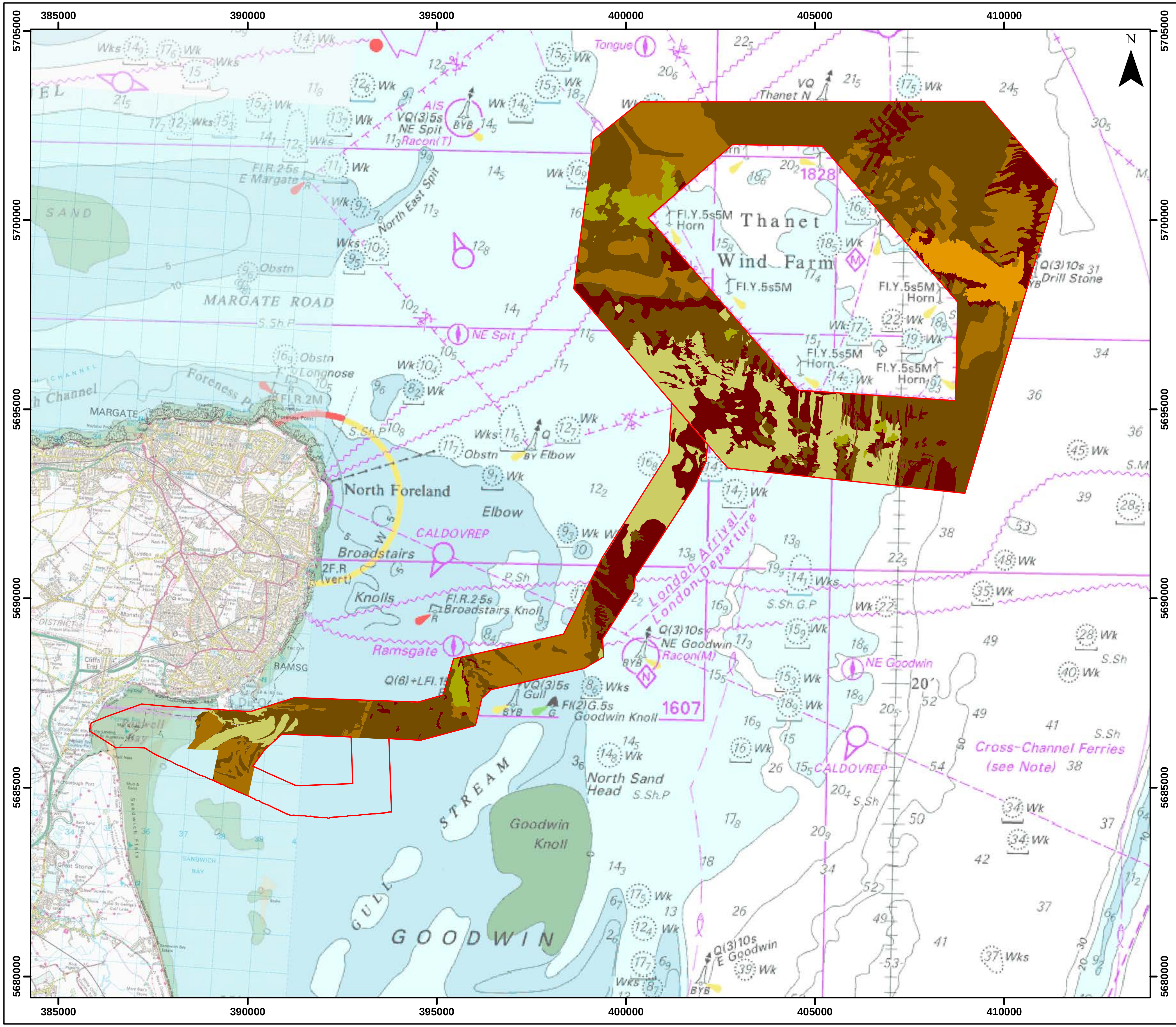
Drg No	Fig6.8_EUSeaMap			Figure 6.8
Rev	0.1	Date	25/05/2018	
By	RM	Layout	N/A	

GoBe VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 6.9

Seabed Habitats around Thanet Extension (Fugro, 2016)



Legend

- Offshore Red Line Boundary

Sediment Classification

- Clayey Sand
- Fine to Coarse Sand
- Gravelly Sand
- Sandy Gravel
- Outcrop
- 'Drill Stone' reef

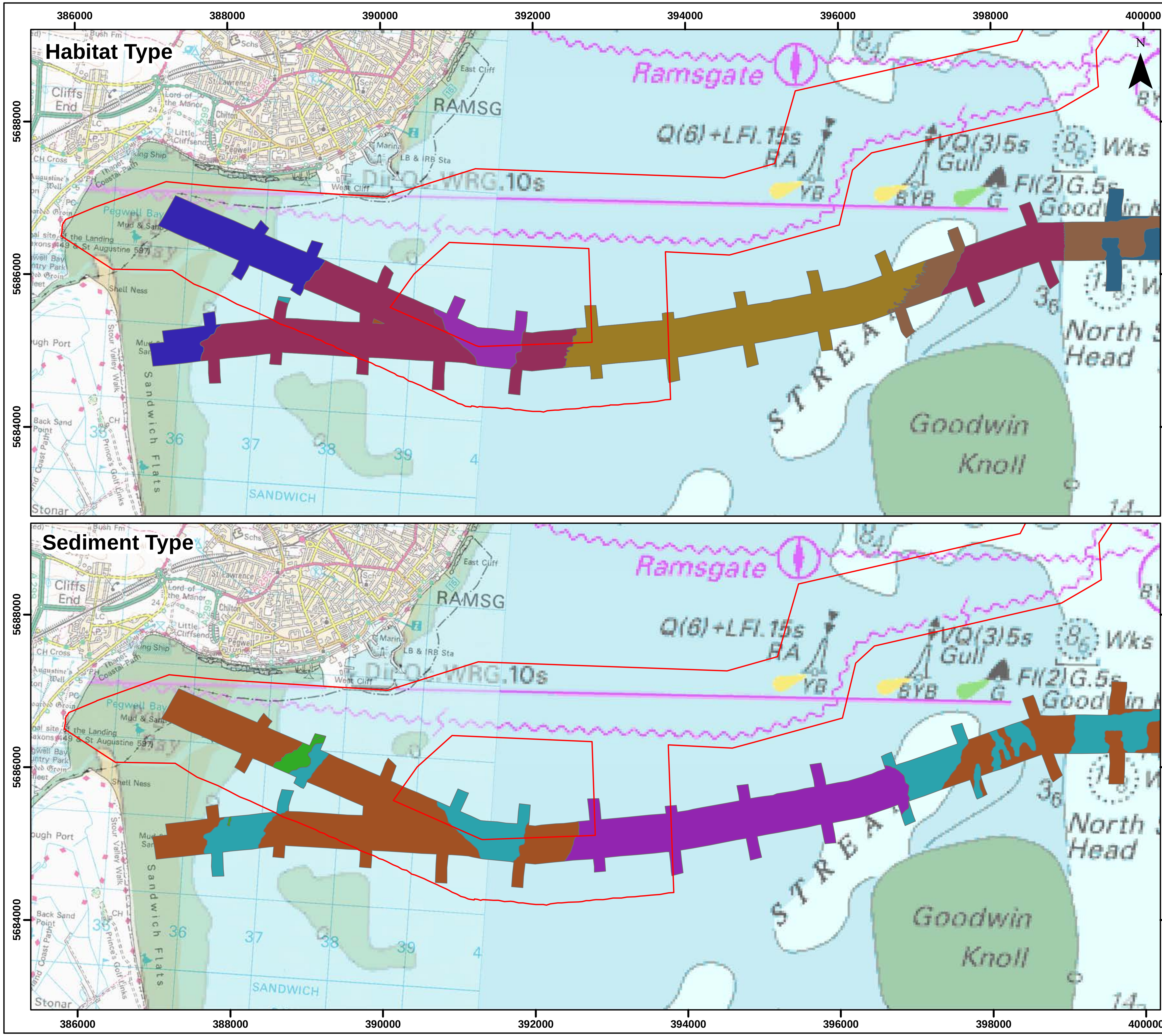
Datum: ETRS 1989
Projection: UTM31N

Notes
[1] Data from the Thanet Extension Geophysical Survey conducted by Fugro Emu Ltd, July to September 2016

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

Drg No	Fig6.9_FugroData		
Rev	0.1	Date	25/05/2018
By	RM	Layout	N/A

Figure 6.9



GoBe VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 6.10

Seabed Habitats in the vicinity of Thanet Extension (Nemo Interconnector, 2016)

Legend

- Offshore Red Line Boundary

Habitat Type (Nemo Interconnector, 2016)

- Circalittoral fine sand
- Infralittoral fine sand
- Infralittoral mixed sediments
- Infralittoral mobile clean sand with sparse fauna
- Infralittoral muddy sand
- Pomatoceros triqueter with barnacles and bryozoan crusts on unstable circalittoral cobbles and pebbles

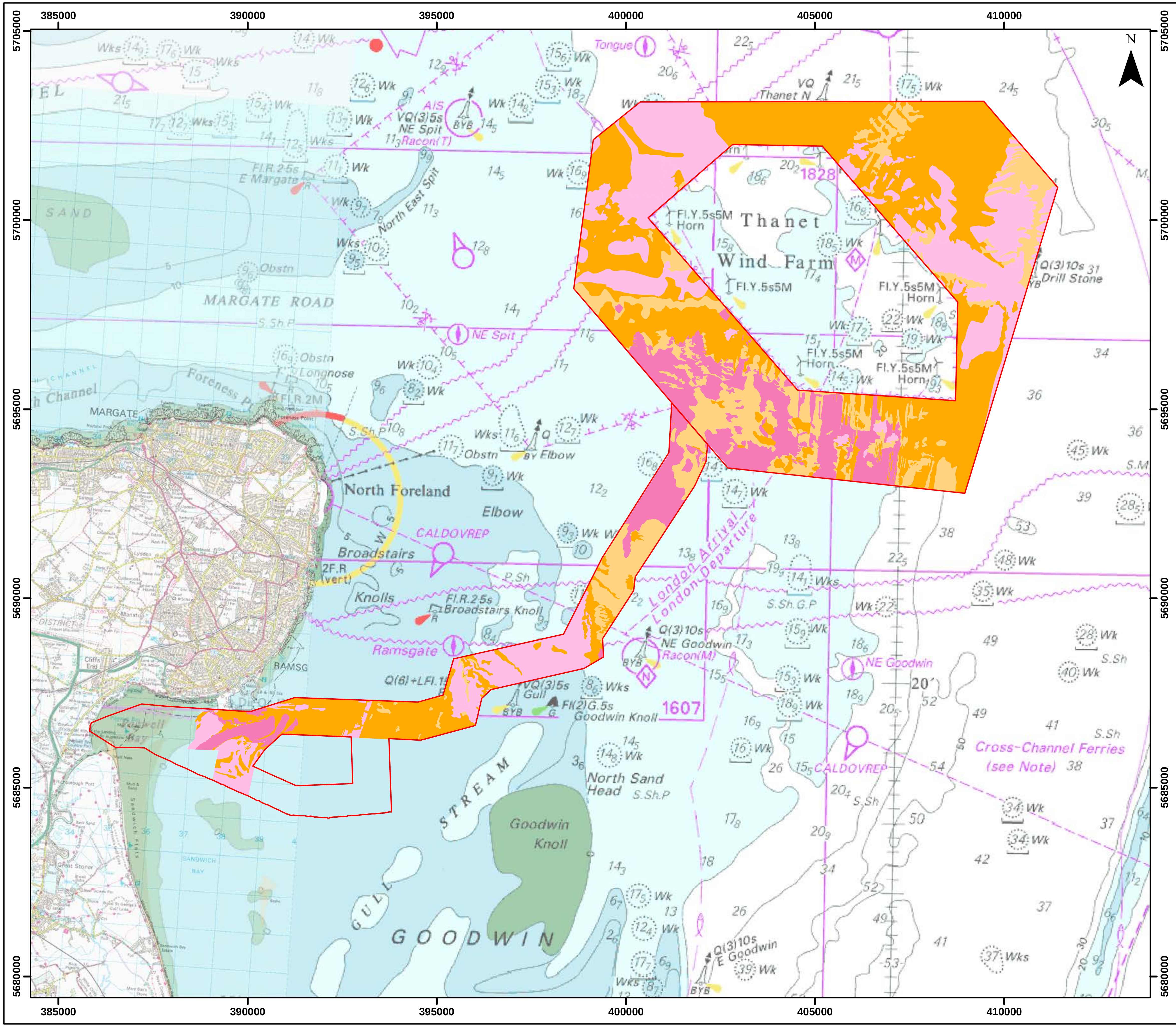
Sediment Type (Nemo Interconnector, 2016)

- Clay Silt
- Gravel
- Sand
- Sand and Gravel

Datum: ETRS 1989
Projection: UTM31N

1:50,000 — 0 0.5 1 km — 0 0.25 0.5 nm

Drg No	Fig6.10_NemoData			Figure 6.10
Rev	0.1	Date	29/05/2018	
By	RM	Layout	N/A	



GoBe

VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 6.11

Preferred and Marginal Sandeel Spawning Habitat According to Site-Specific Data (Fugro, 2016)

Legend

- Offshore Red Line Boundary

Preferred and Marginal Sandeel Spawning Habitat

- Gravelly Sand (Preferred)
- Fine to Coarse Sand (Preferred)
- Sandy Gravel (Marginal)
- Unsuitable

Datum: ETRS 1989
Projection: UTM31N

Notes
[1] Data from the Thanet Extension Geophysical Survey conducted by Fugro Emu Ltd, July to September 2016

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

Drg No	Fig6.11_SandeelPreferred		
Rev	0.1	Date	08/06/2018
By	RM	Layout	N/A

Figure 6.11

6.8 Key parameters for assessment

6.8.1 The offshore project description for Thanet Extension is described in Volume 2, Chapter 1: Project Description (Offshore) (Document Ref: 6.2.1) of this ES. A maximum development envelope based on the Rochdale envelope principle has been developed for the project EIA.

6.8.2 The maximum design scenarios identified in Table 6.7 have been selected as those having the potential to result in the greatest effect on an identified receptor or receptor group. These scenarios have been selected from the details provided in the project description (Volume 2, Chapter 1: Project Description (Offshore) (Document Ref: 6.2.1)). Effects of greater adverse significance are not predicted to arise should any other development scenario (based on details within the project description envelope) to that assessed here be taken forward in the final design scheme.

6.8.3 It is noted that only variations in those design parameters detailed under each specific impact in Table 6.7 have the potential to influence the significance of the effect described. Therefore, if a particular design parameter is not discussed, then any change to that parameter is not considered to have a material bearing on the outcome of the assessment.

Design envelope assessed

6.8.4 The Thanet Extension application is for the construction, O&M and decommissioning of an OWF with a capacity of up to 340 MW, comprising of up to 34 WTGs with individual capacities ranging from 8 MW to >12 MW (see paragraph 6.8.5). The assessment scenarios identified have been selected as those having the potential to represent the greatest effect on an identified receptor. These scenarios have been selected based on details provided in Volume 2, Chapter 1: Project Description (Offshore) (Document Ref: 6.2.1) as representing the worst-case scenario.

6.8.5 Subject to final design it is possible that an alternative, larger capacity, WTG (i.e. >12 MW) type may be selected. In this scenario, the number of turbines would be reduced, but the overall project capacity will not exceed 340 MW. This scenario also hereby referred to as 12 MW. The maximum adverse effects scenarios set out in Table 6.7 consider both direct and indirect impacts as required.

Table 6.7: Maximum design scenario assessed

Potential effect	Maximum design scenario assessed	Justification
Construction		
Direct damage (e.g. crushing) and disturbance to mobile demersal and pelagic fish and shellfish species arising from construction activities	**Jack-up vessel footprints:** 33,930 m^2 for up to 34 turbines, one Offshore Substation (OSS) and one met-mast (assuming six 'legs' per vessel and two jack-up operations per foundation). **Anchor footprints:** 69,810 m^2 from anchor placement ((150 m^2 per foundation x 36 (5,400 m^2 total) +150 m^2 for OSS topside+ 34,560 m^2 for export cable installation + 29,700 m^2 for inter-array cable installation) **Inter-array cable installation:** 640,000 m^2 from burial of 64 km of inter-array cables, by ploughing/ trenching/ jetting/ surface laying with or without post-burial (10 m disturbance corridor from ploughing). **Export cable installation:** 1,440,000 m^2 from burial of 120 km of export cables (four x 12 m disturbance corridor width from ploughing of 30 km length) 480,000 m^2 from pre-sweeping assuming that this will be required along 20% of the cable route and a 20 m wide disturbance corridor. Up to 2,400,000 m^2 from a 20 m wide pre-lay grapnel run along the entirety of the cable route. **Total:** Temporary direct damage of up to 5,063,740m^2 (5.05 km^2) of seabed.	The maximum adverse scenario associated with HVAC transmission is the 34 turbine (8 MW or 10 MW) scenario as this provides up to 36 foundations, resulting in the highest number of jack-up vessel operations. The maximum adverse scenario for cable installation is that installation of four cables. It is important to note that for export cable installation, the total area is the sum of the area disturbed by pre-lay grapnel suns, route pre-sweeping and cable installation, which will overlap. Therefore, this total number should be viewed with caution.
Temporary localised increases in suspended sediment concentrations and smothering	**Foundations:** Seabed preparation for 30 quadropod suction caisson foundations (28 turbine foundations, one OSS and one met-mast (9,600 m^3 each)), resulting in 288,000 m^3 of sediment being dredged and re-deposited. **Cable installation:** Installation of 64 km of inter-array cable by jetting, to a maximum depth of 3 m resulting in 96,000 m^3 of sediment being displaced (v-shaped trench width of 1 m and 50% of sediment in the trench being liquidised); Installation of 120 km of export cable by jetting, to a depth of 3 m resulting in 180,000 m^3 of sediment being displaced (v-shaped trench, width of 1 m and 50% of sediment being liquidised); and Pre-sweeping, assuming 20% of the export cable route requires pre-sweeping and 60 m^3 of sediment is swept per metre, resulting in 1,440,000 m^3 of sediment being dredged and re-deposited. **Total:** Maximum volume of displaced sediment of up to 1,944,400 m^2 of sediment.	The maximum adverse scenario for foundation installation is jacket foundations for 12 MW turbines which would comprise 20 m suction-caissons (compared to 15 m caissons for the 8 or 10 MW turbines). The increased diameter of the suction caissons would result in the largest spoil volume compared to the smaller volume by more numerous smaller caissons. Of the methods proposed for cable installation, jetting results in the greatest volume of sediment dispersed as it is assumed that 100% of the sediment is liquidised, whereas for any other method, less sediment would be suspended. Predicted increases in suspended sediment and sediment deposition assumes the greatest number and length of cables and the greatest cable depth.
Direct and indirect seabed disturbances leading to the	Seabed disturbance arising from installation of foundations and cables as described above for localised increases in suspended sediment concentrations and smothering.	This scenario represents the maximum design scenario for Thanet Extension and therefore the

Potential effect	Maximum design scenario assessed	Justification
release of sediment contaminants		maximum amount of contaminated sediment that may be released into the water column during construction activities.
Mortality, injury, behavioural changes and auditory masking arising from noise and vibration	**Maximum spatial design scenario** Piling of up to 36 monopile foundations of 10 m monopile foundations (34 turbines, one OSS and one met-mast). Maximum hammer energy of 5,000 kJ, which is considered highly conservative with significantly lower hammer energies used for the majority of the time. Maximum piling time of 6 hours per monopile (although average duration is likely to be 3 hours per monopile). 24-hour piling is considered. Maximum total piling duration 216 hours (6 hours x 36 monopiles). Piling is likely to occur over a 6-month period (allowing for breaks between piling events and weather downtime). Concurrent piling using more than one vessel is not considered. **Maximum temporal design scenario** Piling of up to 30 jacket foundations using 4 m pin-piles (28 turbines, one OSS and one met-mast). Maximum hammer energy of 2,700 kJ which is considered conservative. Maximum duration of 10 hours per jacket foundation (12 MW) (although average piling time of 5 hours per foundation). 24-hour piling considered. Maximum total active piling duration of 300 hours (10 hours x 30 jacket foundations). Piling is likely to occur over a 6-month period (allowing for breaks between piling events and weather downtime). Concurrent piling using more than one vessel is not considered. **Maximum design scenario – Unexploded Ordnance (UXO)** Up to 30 controlled explosions across the proposed site, of charge weights between 0.05 and 130 kg. UXO clearance would be undertaken in 2020, with up to 8 controlled explosions on any single day.	**Maximum spatial design scenario** The maximum spatial design scenario equates to the greatest effect from subsea noise at any one time during piling. Piling of fewer (29) 10 m monopiles represents a greater spatial impact than a greater number (35) 9 m monopiles. **Maximum temporal design scenario** The maximum temporal design scenario represents the longest duration of effects from subsea noise. This scenario assumes piled foundations again but this time using pin-piled jackets as this could result in a longer duration of piling per foundation. **UXO** Experience from other projects within the southern North Sea suggest that, on average, 20 *in situ* detonations may be expected, however a precautionary assumption is being made here. Locations of UXO have not yet been identified, and the final locations will influence the potential for disturbance.
O&M		
Long-term loss of seabed habitat due to the presence of turbine foundations, scour protection and cable protection	**Foundations and associated scour protection:** The maximum design scenario for long-term habitat loss from foundations and associated scour protection results from the use of piled quadropods. The worst-case is a loss of 8,901.2 m^2 per foundation, leading to a total of 267,036 m^2 for 28 12+ MW turbines, one OSS and one met-mast. **Cable protection:** The worst-case for cable protection assumes that 25% of the total length of both export cables and inter-array cables require additional cable protection. The assumptions are that inter-array cables would require a 5 m wide rock berm, and export cables would require a 7 m wide rock berm. This would result in 80,000 m^2 (16 km x 5 m) of seabed habitat loss for inter-array cables, and 210,000 m^2 for export cables (30 km x 7 m). **Cable crossings:** The inter-array cables will be required to make 12 crossings across existing assets, and the export cables will require up to 80 crossings in total. Each crossing will be 100 m long by 10 m wide, resulting in a total loss of habitat of up to 92,000 m^2. **Total:** 649,036 m^2 (0.65 km^2)	The maximum adverse scenario is associated with the use of quadropod suction bucket foundations for 12 MW turbines (each bucket has a 4 m diameter and consequently, the area of seabed affected is greater even though this only includes 28 turbines) and HVAC transmission as this includes the construction of an OSS. This also considers that scour protection is required for all foundations. The maximum adverse scenario for long-term habitat loss also includes the use of cable protection (i.e. rock placement or concrete mattresses) along 25% of the inter array cables and 25% of the export cable.

Potential effect	Maximum design scenario assessed	Justification
Increased hard substrate and structural complexity as a result of the introduction of turbine foundations, scour protection and cable protection	The total area of new habitat introduced would be equal to the total amount of habitat lost as above (0.65 km^2).	Maximum surface area created by foundations, OSS, scour protection and cable protection. This assumes that 25% of inter-array cables and 25% of export cables require cable protection and that all foundations require scour protection. It also assumes that no cable protection is required in the intertidal area.
Underwater noise as a result of operational turbines	Underwater noise over the design lifetime of the project (30 years) from up to 34 operational turbines.	The maximum adverse scenario is underwater noise from the maximum number of operational turbines.
Electromagnetic fields (EMF) effects arising from cables	Up to 64 km of inter-array cable connecting 34 turbines operating at up to 66 kilovolts (kV) and up to 120 km of export cable (4 cables of approximately 30 km length each) operating at up to 220 kV buried less than 1.2 m below the surface (assuming shallowest cables to be underneath protection measures.	The maximum adverse scenario is associated with the use of 34 turbines as this results in the greatest length of inter-array cable and four export cables as this results in the longest total length of export cable.
Direct disturbance resulting from maintenance during operation	Maximum of 10 jack-up operations per turbine (340 jack-up operations total), with up to four legs per vessel. The individual footprint area is 28.27 m^2 (113.10 m^2 combined) resulting in a maximum disturbance area for turbines of 38,453 m^2. Maximum of 13 jack-up operations throughout the O&M phase for the OSS (assumptions as above), resulting in up to 1,470 m^2 of seabed habitat being disturbed. The replacement of up to 7 (assumed) inter-array cables during the lifetime of the wind farm (the longest of which is 2 km long), with a width of disturbance from installation of 10 m, resulting in a maximum area of 140,000 m^2. The repair/ reburial of up to 64 km of inter-array cables every 5 years (6 times in the 30 year O&M period), with a width of disturbance of 10 m, resulting in a total disturbance area of 3,840,000 m^2. The assumption of one export cable failure every 5 years (24 throughout the 30 year O&M period), requiring the repair/ reburial of up to 300 m of export cable per failure, with a disturbance width of 10 m, resulting in a maximum disturbance area of 72,000 m^2. **Total disturbance:** 4,111,801 m^2 (4.11 km^2).	The maximum adverse scenario is based on 10 jack-up vessel visits per turbine, using the maximum number of turbines (34).
Increases in SSC from O&M activities.	The maximum volume of sediment that could be re-suspended during the O&M phase would result from cable maintenance, reburial or replacement. The maximum design scenario is assumed to be the replacement of up to 7 inter-array cables (maximum length 2 km), as well as the repair or reburial of up to 64 km of inter-array cables every 5 years (6 times during the 30-year O&M phase). For the export cables, the maximum design scenario would be the repair/ reburial of up to 300 m of cable every 5 years throughout the O&M period. Each cable would be re-buried in a trench of up to 3 m deep, by 1 m wide, where 50% of the disturbed sediment is liquidised. This would result in a maximum re-suspended volume of 576,000 m^3 for inter-array cables and 2,700 m^3 for export cables. **Total:** Volume of sediment re-suspended is 596,700 m^3.	Of the methods proposed for cable repair/ reburial, jetting results in the greatest volume of sediment dispersed as it is assumed that 100% of the sediment is liquidised, whereas for any other method, less sediment would be suspended. Predicted increases in suspended sediment and sediment deposition assumes the greatest number and length of cables and the greatest cable depth.

Potential effect	Maximum design scenario assessed	Justification
Indirect disturbance resulting from the accidental release of pollutants	Synthetic compound, heavy metal and hydrocarbon contamination resulting from up to 34 turbines and one OSS. Accidental pollution may also result from up to 307 round-trips to port by O&M vessels (including crew supply vessels and jack-up vessels) per year over the 30-year design lifetime*. A typical 12 MW turbine is expected to contain approximately 2,000 litres of grease, 2,000 litres of synthetic or hydraulic oil, 200 litres of liquid nitrogen, 2,000 kg of silicone oil and 100 kg SF6 gas. The OSS is expected to contain approximately 200,000 litres of diesel, 1,000 litres of grey water, 1,000 litres of black water, 600,000 litres of transformer coolant water, 10 litres of UPS batteries, 20,000 litres of fire suppressant material, 1,500 kg of SF6, 5 m^3 of engine oil and 5 m^3 of HVAC coolant (glycol).	These parameters are considered to represent the maximum adverse scenario with regards to vessel movement during the operational period, and the maximum volumes of potentially hazardous materials contained within operational infrastructure.
Potentially reduced fishing pressure within the Thanet Extension array area and increased fishing pressure outside of the array area due to displacement	Design life of the project is 30 years (following the start of operation). Up to 34 turbines with suction bucket jacket foundations, 64 km of inter-array cable (of which 25% is protected by cable protection), 120 km of export cable (of which 25% is protected by cable protection), one OSS and one met-mast, with all infrastructure situated within the proposed boundary, with associated closest foundation spacing of 480 m). Operational safety zones of 500 m around the OSS. 500 m safety zones during all major maintenance activities. No safety zones around turbines, however a 50 m safe working distance from turbines is assumed. 500 m safety zones during all major maintenance activities. Buried cables will be installed to a minimum depth of 1 m below stable seabed (except where cables are surface laid and protected), subject to a cable burial risk assessment for all buried cables. Total affected seabed area is 1,052,035 m^2 assuming a 500 m safety zone around the OSS and a 50 m safe working distance from turbines. 500 m advisory safety zone around 'construction type' maintenance activities for all subsea cables, centred on the cable maintenance vessel, but not for regular maintenance.	Assessment assumes that fisheries will not be excluded from the Thanet Extension proposed development area, however, due to logistical constraints, fishing pressure may be reduced.
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.		
Cumulative effects		
Cumulative effects are assessed in section 6.13.		

*The operational life is expected to be around 30 years.

6.9 Embedded mitigation

6.9.1 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 fish and shellfish are listed in Table 6.8.

6.9.2 General mitigation measures, which would apply to all parts of the development, are set out first. Thereafter mitigation measures that would apply specifically to fish and shellfish issues associated with the development, are described separately.

6.9.3 In the event further mitigation is to be proposed which cannot be embedded into the project, this has been included as proposed additional mitigation. The residual significance of effect is then assessed.

Table 6.8: Embedded mitigation relating to fish and shellfish

Parameter	Mitigation measures embedded into the project design
General	
Definition of development boundaries	The development boundary selection was made following a series of constraints analyses, with the array area and cable corridor route selected to ensure the impacts on the environment and other marine users are minimised.
Construction	
Pollution prevention	A Project Environmental Management Plan (PEMP) will be produced and followed to cover the construction and O&M phases. The PEMP will 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.
	Typical measures will include: only using chemicals approved by CEFAS under the Offshore Chemical Regulations 2002; storage of all chemicals in secure designated areas with impermeable bunding (generally to 110% of the volume); and double skinning of pipes and tanks containing hazardous materials. The purpose of these measures is to 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.
Underwater noise	During piling operations, soft starts with lower hammer energies (10%) will be used at the beginning of the piling sequence before increasing energies to the higher levels.
Operation	
EMF	Inter-array and export cables will be buried to a minimum target depth of 1 m, subject to a cable burial risk assessment. Where it is not possible to bury the cables sufficiently, cable protection will be used. While this does not decrease the strength of EMF at source, it does increase the distance between cables and benthic receptors, thereby reducing the received EMF (attenuation) and potentially reducing the effect on those receptors.
Decommissioning	
Embedded mitigation measures implemented in the Decommissioning Phase are likely to be similar to those implemented during the Construction Phase, 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*. A Decommissioning Plan will be developed to cover the Decommissioning Phase.	

6.10 Environmental assessment: construction phase

6.10.1 The impacts of the construction of Thanet Extension have been assessed on fish and shellfish ecology in the study area. The effects arising from the construction of Thanet Extension are listed in Table 6.7 along with the design envelope parameters against which each construction phase impact has been assessed.

6.10.2 A description of the significance of effects upon fish and shellfish receptors caused by each identified impact is given below.

Direct damage (e.g. crushing) and disturbance to mobile demersal and pelagic fish and shellfish species arising from construction activities

6.10.3 Direct damage to fish and shellfish has the potential to occur during construction activities, such as from seabed preparation, foundation installation, jack-up vessel spud cans, and cable installation. In particular, demersal spawning fish have the greatest potential to be affected, as their escape response may be limited at this time.

6.10.4 A maximum of 5.05 km^2 of seabed is predicted to be directly impacted during the construction of Thanet Extension, with the potential for direct damage to mobile demersal and pelagic fish and shellfish within this footprint. The impact is predicted to be of local spatial extent, of short-term duration, intermittent and reversible. It is predicted that the impact will affect fish and shellfish receptors directly. The magnitude is therefore considered to be Low.

6.10.5 In general, mobile fish species are able to avoid temporary disturbance (EMU, 2004). The most vulnerable species are likely to be shellfish which are much less mobile than fish. The fish species in the fish and shellfish study area which are likely to be most sensitive to temporary habitat loss are those species which spawn on or near the seabed sediment (e.g. herring, sandeel and elasmobranchs). Fish eggs and less mobile larvae are also at risk as they are unable to avoid the area affected.

6.10.6 Sandeel and herring are known to have spawning habitats within, or in close proximity to, the Thanet Extension study area, although this is predicted to be of low intensity. High intensity (i.e. more important) spawning habitat for sandeel is located to the North, outside the area affected by the Thanet Extension construction activities, with the heterogeneous sediments present within the development area being considered generally less than optimal (paragraph 6.7.29 *et seq.*). The proportion of sandeel spawning habitat potentially affected is also small in the context of the available spawning habitat available in the wider region, as demonstrated in Figure 6-8.

6.10.7 Sandeel are considered most vulnerable during their winter hibernation period when they are less mobile. Recovery of sandeel populations would be expected following construction operations. Effects of OWF construction (Jensen *et al*., 2004) and operation (van Deurs *et al*., 2012) on sandeel populations have been examined through short-term and long-term monitoring studies at the Horns Rev OWF. These monitoring studies have shown that wind farm construction and operation has not led to significant negative effects on sandeel populations. Further information on recovery can also be inferred from a study by Jensen *et al*. (2010), which examined mixing of adult sandeel populations at different fishing grounds within the entire North Sea. This study showed evidence of mixing populations to distances of 28 km for within fishing grounds. This suggests that some recovery of adult populations would be predicted to occur following construction operations, with adults re-colonising suitable sandy substrates from adjacent unimpacted habitats (for example the high intensity spawning habitats to the north). Recovery may also occur through larval recolonization of suitable sandy sediments (which was not investigated in the Jensen *et al*., 2010 study) with sandeel larvae likely to be distributed throughout the southern North Sea (Ellis *et al*., 2010).

6.10.8 Although Figure 6-3 suggests that the Thanet Extension array area is in close proximity to herring spawning habitat, Figure 6-7, which incorporates the IHLS data presented as a heat map, shows that, using larval density as a proxy for herring spawning, the main area of spawning is further south. In relation to potential herring spawning habitat, Figure 6-9 shows that there is potential for spawning habitat (as discussed within paragraph 6.7.29 *et seq*.) within the array area and OECC, but that much of this is less than optimal, or marginal, rather than the preferred gravel habitats of herring. Furthermore, there is evidence to suggest that suitable habitat is not the only parameter that indicates potential spawning habitat. Other environmental parameters such as oxygenation, siltation, overlap with range of spawning populations, micro-scale seabed morphological features (e.g. ripples and ridges) all contribute to the suitability of seabed habitat to be used as spawning beds (Aneer, 1989; Vattenfall, 2009; Nordhein *et al*. 2018). It should be noted that while herring demonstrate a clear preference to spawn on gravel (or gravelly sands), predictive sediment habitat mapping has a high chance of being significantly conservative when used to predict spawning areas (ORJIP, 2018). Habitat loss/ disturbance will only affect a small proportion of herring spawning habitat which is widespread throughout the region, and the area affected is of relatively low intensity. Therefore, the magnitude of the impact is considered to be Low.

6.10.9 Most fish and shellfish receptors in the study area are deemed to be of low vulnerability, medium recoverability and of local to international importance. The sensitivity of these receptors is therefore considered to be Low.

6.10.10 Sandeel and herring are deemed to be of high vulnerability, medium recoverability and of regional importance. The sensitivity of these receptors is therefore considered to be Medium.

6.10.11 The effect of direct damage to all mobile demersal and pelagic fish and shellfish species within the total installation footprint will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Temporary localised increases in suspended sediment concentrations and smothering

6.10.12 The installation scenario that represents the worst-case for increases in Suspended Sediment Concentration (SSC) is the use of jetting tools which is assumed to result in 100% of the material within the trench being liquidised and dispersed in the lower water column, as well as seabed preparation for 28 turbine foundations, one OSS foundation and one met-mast foundation on quadropod suction caissons.

6.10.13 The resulting initial SSC is dependent on the rate of release and the height at which the displaced sediment is initially dispersed. Some of these details are not presently available for Thanet Extension and some details can only be assumed in any case. Typically, the initial SSC at the point of release will be very high (in the order of hundreds of thousands of mg/l) for all sediment types (Volume 2, Chapter 2: Marine Geology, Oceanography and Physical Processes (Document Ref: 6.2.2)). The initial plume will act under gravity to sink down through the water column (dynamic phase). Coarser sediments in the plume will settle relatively quickly (0.05 to 0.5 m/s) and so may return to the seabed within a matter of seconds to minutes after being suspended. The downstream extent of the plume is therefore limited to the distance that the plume can be advected by ambient current speeds in that short time. In the passive plume phase, finer sediments may persist in the water column for longer (hours to days) and so can be advected over greater distances by ambient currents. SSC will reduce to near background levels with time due to natural dispersion and deposition. The maximum extent of this plume will initially be limited to the tidal excursion distance, although low level effects can be advected further by longer-term residual currents, although SSC is likely to be below background levels by this point.

6.10.14 Across much of the array area and OECC, the seabed sediment comprises coarse sand and gravel (Volume 2, Chapter 2: Marine Geology, Oceanography and Physical Processes (Document Ref:6.2.2)). As such, dredging/ trenching/ jetting of this material is not expected to create persistent plumes as the coarse material would quickly settle to the seabed (0.05 to 0.5 m/s). However, the disturbance of the finer grained sediments has the potential to give rise to more persistent plumes that settle out of suspension over a wider area than for coarse grained sediments. Monthly averaged satellite imagery of surface suspended particulate matter suggests that, levels are generally greater than 10 mg/l, increasing through the winter period to 30 – 80 mg/l and occasionally reaching up to 100 mg/l. At the seabed, localised increases of up to several hundred mg/l are anticipated during storm events.

6.10.15 It has been predicted for drilling operations for monopile foundations (Volume 2, Chapter 2, Marine Geology, Oceanography and Physical Processes (Document Ref: 6.2.2)) that sand sized material could remain in suspension for approximately 15 minutes and therefore may be transported up to approximately 0.5 km, with increases in SSC in excess of natural ranges over a short timescale. Away from release locations (i.e. order of hundreds of metres to a few kilometres), elevations of SSC above background levels are expected to be very low (less than ~20 mg/l) and are within the range of natural variability. After approximately 24 hours, sufficiently fine sediment may become diluted to very low concentrations (<5 mg/l), indistinguishable from background levels. Assuming that 50% of turbine locations require drilling, as well as one monopile OSS, the maximum total volume that could theoretically be released from drilling is 20,527 m^3, resulting in an average bed elevation of 0.3 mm (which is well within the natural variation in bed level change for the area) over the array area (equivalent to an average increase of 5 cm over an area equal to 0.6% of the array area). In practice, this change would comprise a series of discrete deposits (smaller overlapping and non-overlapping deposits), distributed throughout parts of the array area. Individual deposits are likely to be relatively thicker on average than the example value of 5 cm, with a correspondingly smaller area of effect.

6.10.16 For suction caisson foundations, some seabed preparation may be required prior to their installation. Assuming 28 turbines, one OSS and one met-mast, the maximum total dredge spoil could be up to 2,912,400 m^3, resulting in a seabed elevation of 5 cm over approximately 0.2% of the array area. As above, in practice, this would result in a series of discrete deposits distributed at locations around the array area, that are thicker than the example of 5 cm, but covering a smaller area.

6.10.17 The impact of cable installation operations mainly relates to a localised and temporary re-suspension and settling of sediments. The exact nature of the disturbance will be determined by the sediment conditions, the length of installed cable, burial depth and burial method. The maximum adverse scenario for cable installation involves jetting into a V-shaped trench measuring 3 m wide and 3 m deep (although this may be up to 5 m in very localised areas where soft sediment is present). Due to the expected low height of release/ injection, the effect of coarser sands and gravels on SSC and deposition will be spatially limited to up to approximately 20 m for gravels and up to a few hundred metres for sands. Finer material may be advected over a few thousand metres, but to near background concentrations (tens of mg/l). The volumes of material being displaced and deposited locally are relatively limited (up to 7.5 m^3 per metre of cable assuming a maximum depth of 5 m in soft sediments, although this is likely to be much less where cable burial is limited to 3 m). The distance to which this volume of material may be spread to an increase in bed level of 5 cm is 150 m from the cable. However, it is expected that the extent (and so area) of deposition will be smaller for sands and gravels (leading to a greater thickness of tens of centimetres to a few metres), and that fine material will be distributed more widely, becoming so dispersed that it is unlikely to settle in a measurable thickness.

6.10.18 The magnitude of the maximum potential increase in SSC resulting from construction activities is within the natural range of SSC within the region and the impact will be short-term, intermittent, of localised extent and reversible. The magnitude of the impact is therefore considered to be Low.

6.10.19 Construction activities may increase levels of suspended sediments and reduce light levels within the water column. Reduction in light levels within the water column can create a number of adverse effects particularly upon species reliant on their visual acuity to detect and locate prey (BERR, 2008).

6.10.20 Adult fish would normally be able to detect significantly elevated levels of suspended sediment and avoid the affected area (ABP Research, 1999; EMU, 2004). Juvenile fish, including those likely to occur in nursery habitats in the vicinity of the Thanet Extension fish and shellfish study area, are generally considered to be more sensitive to suspended sediment plumes than adults (Wilber and Clarke, 2001). This may arise as a consequence of their reduced mobility compared to adults and increased biological susceptibility (i.e. smaller gill surface areas (ABP Research, 1999)). The Thanet Extension fish and shellfish study area was identified as supporting both foraging and nursery grounds for a number of commercially and ecologically important species. These species are expected to be resilient to any increases to SSC at a juvenile stage due to the high background suspended sediment concentration in the southern North Sea. Additionally, winter storm events in their natural environment cause temporary increases in suspended sediment concentration of a similar magnitude to that which will be produced by the construction operations.

6.10.21 More sedentary species (such as shellfish) are likely to be more vulnerable to increases in SSCs, which may result in reduced growth or increased mortality, particularly when spatfall occurs (ABP Research, 2007). With the exception of gravid females, edible crabs have a high tolerance to suspended sediment and are reported to be insensitive to increases in turbidity, however they are likely to avoid areas of increased SSC as they rely on visual acuity during predation (Neal and Wilson, 2008). Berried crustaceans (e.g. edible crab, European lobster and *Nephrops*) are likely to be more vulnerable to increased SSC as the eggs carried by these species require more regular aeration and as they are considered to have limited mobility, remaining sedentary while egg bearing. Increased SSCs will only affect a small area at any one time and will be temporary in nature.

6.10.22 The species likely to be affected by sediment deposition are those which feed or spawn on or near the seabed, as well as more sedentary and slow-moving species such as shellfish. The majority of species which have known spawning grounds in close proximity to Thanet Extension are herring and sandeel. Sandeel eggs are likely to be tolerant to sediment deposition due to the nature of resuspension and deposition within their natural high energy environment. High intensity spawning sites for sandeel do not occur within the Thanet Extension study area and the main area of spawning is to the North, and so effects on sandeel spawning are not expected. As shown in Figure 6-7, the main area of herring spawning is located to the south of Thanet Extension (paragraph 6.7.29 *et seq.*), and therefore effects on spawning herring populations will be limited. Furthermore, it has been shown that herring eggs are tolerant of very high levels of SSC (Mesieh *et al*., 1981; Kiorboe *et al*., 1981). Detrimental effects may be seen if smothering occurs (Griffin *et al.,* 2009) and the deposited sediment is not removed by currents (Birklund and Wijsman, 2005), however this would be expected to occur quickly with the small amount of sediment deposition forecast. The level of sediment deposition outside of a few meters within the construction footprint would not be expected to significantly affect slow-moving and sedentary species such as shellfish, and as such they are not expected to be significantly affected.

6.10.23 Based on the increase in sensitivity of herring eggs to the smothering effects of increased sediment deposition, herring is deemed to be of medium vulnerability, high recoverability and of regional importance, and therefore the sensitivity of the receptor is considered to be Medium. As described in paragraph 6.7.29 *et seq.*, potential herring spawning habitat exists within the array and OECC, although this is less than optimal in most areas, and is small in the context of the spawning habitat available in the wider region.

6.10.24 Sandeel eggs are likely to be tolerant to sediment deposition due to the nature or resuspension and deposition within their natural high energy environment. However, little information is available on the level of sediment deposition that is acceptable and therefore if sediment deposition is to be higher than normal in the spawning season, there is the potential for an adverse effect. High intensity spawning sites for sandeel do not occur within the Thanet Extension study area and the main area of spawning is to the North and potential spawning habitat is similarly likely to be of low intensity, and so effects on sandeel spawning are not expected to be significant.

6.10.25 All other fish and shellfish receptors (including sandeel) within the study area are deemed to be of low vulnerability, high recoverability and of local to international importance. The sensitivity of the receptor is therefore considered to be Low.

6.10.26 Increases in SSC and associated sediment deposition will represent a temporary and short-term intermittent impact, affecting a relatively small portion of the fish and shellfish habitats in the study area. Most receptors are predicted to have some tolerance to this impact. Overall, the magnitude of the impact has been assessed as Low, with the sensitivity of receptors being Low to Medium. The significance of effect therefore is deemed **Minor** adverse, which is not significant in EIA terms.

Direct and indirect seabed disturbances leading to the release of sediment contaminants

6.10.27 As identified in Table 6.7 and assessed in the above section, construction activities will re-suspend sediments. While in suspension, there is the potential for sediment bound contaminants, such as metals, hydrocarbons and organic pollutants, to be released into the water column and lead to an effect on fish and shellfish receptors.

6.10.28 An assessment of subtidal sediment contamination was undertaken in Volume 2, Chapter 5: Benthic Subtidal and Intertidal Ecology (Document Ref: 6.2.5). Contaminant analysis was undertaken by Fugro EMU (Fugro, 2017; Document Ref: 6.4.5.1). The results of the metals analysis showed that metal concentrations in sediment samples were below the marine sediment quality guidelines for most of the metals included in the analysis. The only exception was arsenic, concentrations of which was below the CSEMP (2012) Effects Range Medium (ERM), but above the Effects Range Low (ERL), and between Cefas Alert Level 1 and 2 (AL1; AL2). Natural sources of arsenic in the marine environment include (but are not limited to) remobilisation and erosion of arsenic-rich rocks (Research Council of Norway, 2012), which vary naturally according to local geology. Anthropogenic sources include mining and smelting (Research Council of Norway, 2012) as well as the burning of fossil fuels (ICES, 2004). Due to the high natural occurrence of this metal, it is often difficultto precisely discern between natural and anthropogenic sources of this metal (OSPAR, 2005). However, high arsenic concentrations in the outer Thames Estuary, as well as the south-west Dogger Bank and Norfolk may be associated with a history of arsenical waste disposal in the Thames estuary (Whalley *et al*., 1999). The arsenic concentrations in the Fugro study (Fugro, 2017) were within the range reported for the southern North Sea: < 0.5 mg kg^{-1} to 135 mg kg^{-1} of dry weight arsenic (Whalley *et al*., 1999). Quantifiable, but below the standards, concentrations of cadmium and mercury at station WF47 (Document Ref: 6.4.5.1), within the north-western end of the development site, may be associated with the high mud content at this station, as finer sediment offers a larger surface area to volume ratio for metals to adsorb (and conversely, to desorb) (Davies, 2004). Cadmium and mercury in the marine environment are predominantly of anthropogenic origin (UNEP, 1990), with rivers being the dominant sources compared to direct discharge (OSPAR, 2005). Sediment hydrocarbon concentrations were below the limit of detection in samples from three out of the seven stations investigated and, where quantifiable, concentrations were below the Canadian marine sediment quality guidelines and are therefore unlikely to pose a threat to the marine environment. Polychlorinated bisphenyls and organotins levels were considerably below the limit of detection in all samples.

6.10.29 The total area that is likely to be disturbed by construction activities, and therefore the potential volume of material disturbed, resulting in the potential release of sediment bound contaminants is small and localised in extent. In addition, the nature of the subtidal sediments is predominantly coarse, typically with low levels of fines adhering to them. Following disturbance as a result of construction activities, the majority of re-suspended sediments are expected to be deposited in the immediate vicinity of the works (see paragraphs 6.10.12 *et seq*.). The release of contaminants such as arsenic and Polycyclic Aromatic Hydrocarbons (PAHs) from the small proportion of fine sediments is likely to be rapidly dispersed with the tide and/ or currents and therefore increased bio-availability resulting in adverse eco-toxicological effects are not expected. The levels found are all comparable to the wider regional background and not considered to be of a low quality that may result in a significant effect-receptor pathway if made bioavailable.

6.10.30 The impacts to fish and shellfish receptors as a result of the release of sediment-bound contaminants are therefore considered to be of Negligible magnitude.

6.10.31 The sensitivity of fish and shellfish receptors will vary depending on a range of factors including species and life stage. Due to their increased mobility, adult fish are less likely to be affected by marine pollution. Fish eggs and larvae are likely to be particularly sensitive, with potentially toxic effects of pollutants on fish eggs and larvae (Westerhagen, 1988). Effects of resuspension of sediment bound contaminants (e.g. heavy metals and hydrocarbon pollution) on fish eggs and larvae are likely to include abnormal development, delayed hatching and reduced hatching success (Bunn *et al*., 2000). Any such events therefore will have varying levels of effect dependent on the species present and pollutants involved. As sediment bound contaminants would be expected to be dispersed quickly in the subtidal environment, the level of effect is predicted to be small.

6.10.32 The fish and shellfish receptors are deemed to be of low to medium vulnerability, high recoverability and of local to international importance. The sensitivity of the receptors is therefore considered to be Low to Medium.

6.10.33 The resuspension of contaminants as a result of sediment disturbance is predicted to occur on a small scale, with contaminants predicted to be rapidly dispersed by the tide. Overall, the magnitude of the impact is deemed to be Negligible, and the sensitivity of receptors is considered to be Low to Medium. The effect on fish and shellfish receptors will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Mortality, injury, behavioural changes and auditory masking arising from noise and vibration

6.10.34 Construction activities, particularly the pile-driving of foundations for offshore structures, will result in high levels of underwater noise that will be audible to fish over tens of kilometres around Thanet Extension (Table 6.10:). At the highest levels of noise, sub-lethal and lethal effects may occur, resulting in injury and in extreme cases, the death of exposed fish. The assessment focuses on underwater noise from pile-driving for the installation of foundations for offshore structures. While other activities such as cable laying, dredging and vessel movements will result in underwater noise, these have the potential to affect a relatively small area in the immediate vicinity of activities and are therefore insignificant in the context of the underwater noise from piling operations.

6.10.35 Piling operations will take place intermittently within Thanet Extension during the construction phase, with piling operations taking place over a period of 6 months.

6.10.36 As outlined in Table 6.7, the maximum design scenario considered with respect to underwater noise from piling in terms of the spatial extent of the impact is 30, 10 m monopiles (28 12+ MW turbines, one OSS and one met-mast), being driven with a 5,000 kJ hammer energy. It should be noted that this maximum hammer energy is considered highly conservative. Although the absolute maximum hammer energy identified within the design envelope is 5,000 kJ, hammer energies will be considerably lower for the majority of the time. The hammer energy will only be raised to 5,000 kJ when absolutely necessary. To minimise fatigue loading on the piles, hammer energies are continuous, set at the minimum required, which also reduces likelihood of breakdown of the equipment. Hammer energies will therefore typically start at low levels (10% soft start) and gradually increase to the maximum required installation energy during the piling of the final few metres, which is typically significantly less than the maximum consented hammer energy.

6.10.37 The temporal maximum design scenario represents the longest duration of effects from subsea noise and assumes a scenario whereby piled jacket foundations are used for all offshore structures. The temporal scenario includes a maximum hammer energy of 2,700 kJ for pin-pile installation, which is also considered conservative with many of the assumptions discussed in the paragraph above also expected to be relevant to this maximum hammer energy.

6.10.38 With respect to the duration of piling activities, the maximum design scenarios detailed in Table 6.7 also make conservative assumptions. The maximum duration of piling is assumed to be 10 hours per foundation (4 pin-piles), with the temporal maximum design scenario assuming a maximum total duration of piling of 292 hours, based on this maximum per pile duration. The duration would be considerably less in the event of fewer foundations or different foundation types (monopiles).

6.10.39 In order to quantify the spatial extent of any potential noise impacts on fish and shellfish populations, predictive subsea noise modelling was undertaken using the maximum design hammer energy (5,000 kJ for monopiles and 2,700 kJ for pin-piles) at two representative locations: one at the East of the site boundary (the deepest location furthest from shore), and one at the south-west of the site boundary (the shallowest location closest to shore). The following sensitivity assessment provides a summary of the key results of this modelling in the context of the impact assessment on fish and shellfish receptors, with full details of the underwater noise modelling presented in Volume 4, Annex 6-3: Underwater Noise Technical Report (Document Ref: 6.4.6.3).

6.10.40 As detailed in Table 6.7, as part of the site preparation activities for Thanet Extension, UXO clearance may have to be completed within the array area and OECC, prior to construction works. A conservative assumption of up to 30 contacts has been made based on experience from other projects in the area. The maximum design scenario assumes that each of these will be detonated, noting that some may be left *in situ* and microsited around.The maximum design scenario also assumes a maximum charge weight of 130 kg. Detonation of a UXO represents a short-term increase in underwater noise and whilst noise levels will be elevated to levels which may result in injury or behavioural effects on fish and shellfish species, these effects would be considerably less than those associated with piling operations.

6.10.41 Underwater noise can potentially have a negative impact on fish species ranging from physical injury/ mortality to behavioural effects. In general, biological damage as a result of sound energy is either related to a large pressure change (barotrauma) or to the total quantity of sound energy received by a receptor. Barotrauma injury can result from exposure to a high intensity sound even if the sound is of short duration. However, when considering injury due to the energy of an exposure, the time of the exposure becomes important. For example, a continuous source operating at a given sound pressure level has a higher total energy and is therefore more damaging than an intermittent source reaching the same Sound Pressure Level (SPL).

6.10.42 Recent papers on the effects of underwater noise on fish and shellfish species have highlighted the lack of clear evidence to support setting thresholds for impacts on fish and shellfish receptors (Hawkins and Popper, 2016; Popper *et al*., 2014). These have highlighted some of the shortcomings of impact assessments, including the use of broad criteria for injury and behavioural effects based on limited studies. One of the key data gaps with respect to impacts on fish and shellfish populations relates to the effects of the particle motion element of underwater noise, which is considered to be more important for many fish species, and particularly invertebrates, than sound pressure which has been the main consideration in noise impact assessments to date.

6.10.43 Recent peer reviewed guidelines have been published by the Acoustical Society of America (ASA) and provide directions and recommendations for setting criteria (including injury and behavioural criteria) for fish. For the purposes of this assessment, these Sound Exposure Guidelines for Fishes and Sea Turtles (Popper *et al*., 2014) were considered to be most relevant for impacts of underwater noise on fish species. The Popper *et al*. (2014) guidelines broadly group fish into the following categories based on their anatomy and the available information on hearing of other fish species with comparable anatomies:

- Group 1: Fishes lacking swim bladders that are sensitive only to sound particle motion and show sensitivity to a narrow band of frequencies (includes flatfishes and elasmobranchs);
- Group 2: Fishes with a swim bladder where the organ does not appear to play a role in hearing. These fish are sensitive only to particle motion and show sensitivity to a narrow band of frequencies (including salmonids and some tuna);
- Group 3: Fishes with swim bladders that are close, but not intimately connected to the ear. These fishes are sensitive to both particle motion and sound pressure and show a more extended frequency range than groups 1 and 2, extending to about 500 Hz (includes gadoids and eels); and
- Group 4: Fishes that have special structures mechanically linking the swim bladder to the ear. These fishes are sensitive primarily to sound pressure, although they also detect particle motion. These species have a wider frequency range. Extending to several kHz and generally show higher sensitivity to sound pressure than fishes in Groups 1, 2 and 3 (includes clupeids such as herring, sprat and shads).

6.10.44 There have been a few studies on the ability of aquatic invertebrates to respond to noise (e.g. Wale *et al*., 2013; Roberts *et al*., 2016), although these are insufficient to make firm conclusions about sensitivity. It is highly likely that aquatic invertebrates can detect particle motion (including seabed vibration); what evidence there is indicates those species are primarily sensitive to particle motion at frequencies well below 1 kHz (Hawkins and Popper, 2016).

Injury criteria

6.10.45 There is a lack of accepted injury criteria for fish species and recent reviews (e.g. Popper and Hastings, 2009; Popper et al, 2014; Hawkins et al, 2014) on the effects of anthropogenic sound on fishes concluded that there are substantial gaps in the knowledge that need to be filled before meaningful noise exposure criteria can be developed. The recent ASA guidelines (Popper et al., 2014) have provided recommendations for setting injury criteria for fish from a range of noise sources. Table 6.9: summarises the fish injury criteria recommended for pile-driving. For the purposes of the assessment, the underwater noise technical report has modelled a range of noise levels, with modelling results in Table 6.10:. The modelling results for cumulative sound exposure level (SELcum) assume a fleeing animal, with the receptor fleeing from the source at a constant rate of 1.5 m/s.

Table 6.9: Criteria for onset of injury in fish due to piling operations (Popper et al., 2014)

Receptor	Mortality and potentially mortal injury		Recoverable injury		TTS (Temporary Threshold Shift) SEL_{cum} (Weighted dB re 1 µPa² s)
	SPL_{peak} (Unweighted dB re 1 µPa)	SEL_{cum} (Weighted dB re 1 µPa² s)	SPL_{peak} (Unweighted dB re 1 µPa)	SEL_{cum} (Weighted dB re 1 µPa² s)	
Group 1 Fish: no swim bladder (particle motion detection)	> 213	> 219	> 213	> 216	>> 186
Group 2 Fish: swim bladder is not involved in hearing (particle motion detection)	> 207	210	> 207	203	> 186
Group 3 and 4 fish: swim bladder involved in hearing (pressure and particle motion detection)	> 207	> 207	> 207	203	186
Eggs and larvae	> 207	> 210	N: Moderate I: Low F: Low	N: Moderate I: Low F: Low	N: Moderate I: Low F: Low

NB: For eggs and larvae, relative risk (high, moderate low) is given for animals at three distances from the source in relative terms as near field (N: 10s of metres), intermediate (I: 100s of metres), and far field (F: 1000s of metres); (Popper *et al*., 2014). (>> (much greater than))

6.10.46 The results of the modelling for injury ranges for fish species are presented in Volume 4, Annex 6-3: Underwater Noise Technical Report (Document Ref: 6.4.6.3), and the outputs are presented in Figure 6-12 and Figure 6-13. These show that for the 5,000 kJ hammer energy (monopile foundations) within the Thanet Extension array area, mortality, potentially mortal injury and recoverable injury effects may be expected to occur within a mean range of 140 m for group 1 fish, and within 330 m for fish with swim bladders, based on SPL_{peak}. Mortality and potentially mortal injury may be expected within a mean range of <10 m, and recoverable injury may be expected within 10 m for group 1 fish, and within 40 m for other fish groups based on SEL_{cum} (assuming a fleeing animal at 1.5 m/s).

6.10.47 Underwater noise modelling has not been undertaken for underwater noise associated with UXO detonation, however, Popper *et al*. 2014 indicates that the noise levels at which potential injury effects in fish species may occur are higher for explosions than for piling activities.

6.10.48 Recoverable injury is a survivable injury with full recovery occurring after exposure, although decreased fitness during this recovery period may result in increased susceptibility to predation or disease (Popper *et al*., 2014). Although the impact ranges for recoverable and mortality/ potentially mortal injury are more or less the same due to the thresholds used, the potential for mortality or mortal injury is likely to only occur in extreme proximity to the pile. Though not a measure put in place for fish, the risk of this occurring will be reduced by proxy through the use of soft start techniques in place to mitigate against effects on marine mammals at the start of the piling sequence. This means that fish in close proximity to piling operations will move outside of the impact range, before noise levels reach a level likely to cause irreversible injury.

Table 6.10: Mean noise impact ranges for fish at the modelled locations and noise levels for monopile installation (5,000 kJ hammer energy). Where the maximum/minimum range differs from the mean, these values are indicated in brackets

Receptor	Criteria	Noise level (dB re 1 µPa SPL/ dB re 1 μPa^2 s SEL)	Distance from east monopile location (m)	Distance from south-west monopile location (m)
Mortality and potentially mortal injury				
Group 1 fish	SPL_{peak}	213	140	130
	SEL_{cum}	219	< 10	< 10
Group 2 fish	SPL_{peak}	207	330	290
	SEL_{cum}	210	< 10	< 10
Group 3 and 4 fish	SPL_{peak}	207	330	290
	SEL_{cum}	207	< 10	< 10
Eggs and larvae	SPL_{peak}	207	330	290
	SEL_{cum}	210	< 10	< 10
Recoverable injury				
Group 1 fish	SPL_{peak}	213	140	130
	SEL_{cum}	216	< 10	< 10
Group 2 fish	SPL_{peak}	207	330	290
	SEL_{cum}	203	40	30 (20 – 30)
Group 3 and 4 fish	SPL_{peak}	207	330	290
	SEL_{cum}	203	40	30 (20 – 30)
TTS				
Group 1 fish	SEL_{cum}	186	7,050 (4,660 –	3,090 (2,150 – 4,080)
Group 2 fish	SEL_{cum}	186	7,050 (4,660 –	3,090 (2,150 – 4,080)
Group 3 and 4 fish	SEL_{cum}	186	7,050 (4,660 –	3,090 (2,150 – 4,080)

6.10.49 For the 2,700 kJ hammer energy (pin-piles), mortality, potentially mortal injury and recoverable injury effects may be expected within a more restricted area, with a mean range of 96 m for group 1 fish, and within 220 m for fish with swim bladders, based on SPL_{peak}, and <10 m, based on SEL_{cum} assuming a fleeing animal at 1.5 m/s. The effect ranges are summarised in Table 6.11.

Table 6.11: Mean noise impact ranges for fish at the modelled locations and noise levels for pin-pile installation (2,700 kJ hammer energy). Where the maximum/ minimum range differs from the mean, these values are given in brackets

Receptor	Criteria	Noise level (dB re 1 µPa SPL/ dB re 1 µPa^2 s SEL)	Distance from east pin-pile location (m)	Distance from south-west pin-pile location (m)
Mortality and potentially mortal injury				
Group 1 fish	SPL_{peak}	213	96 (95 – 96)	23 (22 - 23)
	SEL_{cum}	219	< 10	<10
Group 2 fish	SPL_{peak}	207	220	200
	SEL_{cum}	210	< 10	<10
Group 3 and 4 fish	SPL_{peak}	207	220	200
	SEL_{cum}	207	< 10	< 10
Eggs and larvae	SPL_{peak}	207	220	200
	SEL_{cum}	210	2	< 10
Recoverable injury				
Group 1 fish	SPL_{peak}	213	96 (95 - 96)	23 (22 - 23)
	SEL_{cum}	216	< 10	< 10
Group 2 fish	SPL_{peak}	207	220	200
	SEL_{cum}	203	10	<10
Group 3 and 4 fish	SPL_{peak}	207	220	200
	SEL_{cum}	203	10	<10
TTS				
Group 1 fish	SEL_{cum}	186	4,500 (3,170 – 5,860)	1,800 (2,280 – 1,330)
Group 2 fish	SEL_{cum}	186	4,500 (3,170 – 5,860)	1,393 (860 – 2,100)
Group 3 and 4 fish	SEL_{cum}	186	4,500 (3,170 – 5,860)	1,393 (860 – 2,100)

6.10.50 Although there is currently a lack of understanding on the effects of piling noise on fish eggs and larvae, a study by the Institute for Marine Resources and Ecosystem Studies (IMARES) (Bolle *et al*., 2011; 2012) which exposed common sole larvae to piling noise, observed no statistically significant effect on their survival rates for a piling sequence which resulted in a SEL dose of 206 dB re 1 µPa^{2}s. For fish larvae, the risk of mortality due to prolonged noise exposure would be significantly reduced by any drift of larvae due to water currents (see Volume 2, Chapter 2: Marine Geology, Oceanography and Physical Processes (Document Ref: 6.2.2)) and would substantially reduce the risk of mortality to an insignificant level based on recent work by Bolle *et al*. (2011; 2012). Effects on fish larvae may therefore occur within ranges smaller than those summarised above, noting that the ranges for these are based on the most precautionary criteria for fish injury. It is, however, not possible to establish if mortality might occur or indeed at what range from the pile, as the work by Bolle *et al*. (2011; 2012) was unable to induce a statistically significant change in survival rates of fish larvae, following a prolonged exposure with a substantial cumulative SEL dose.

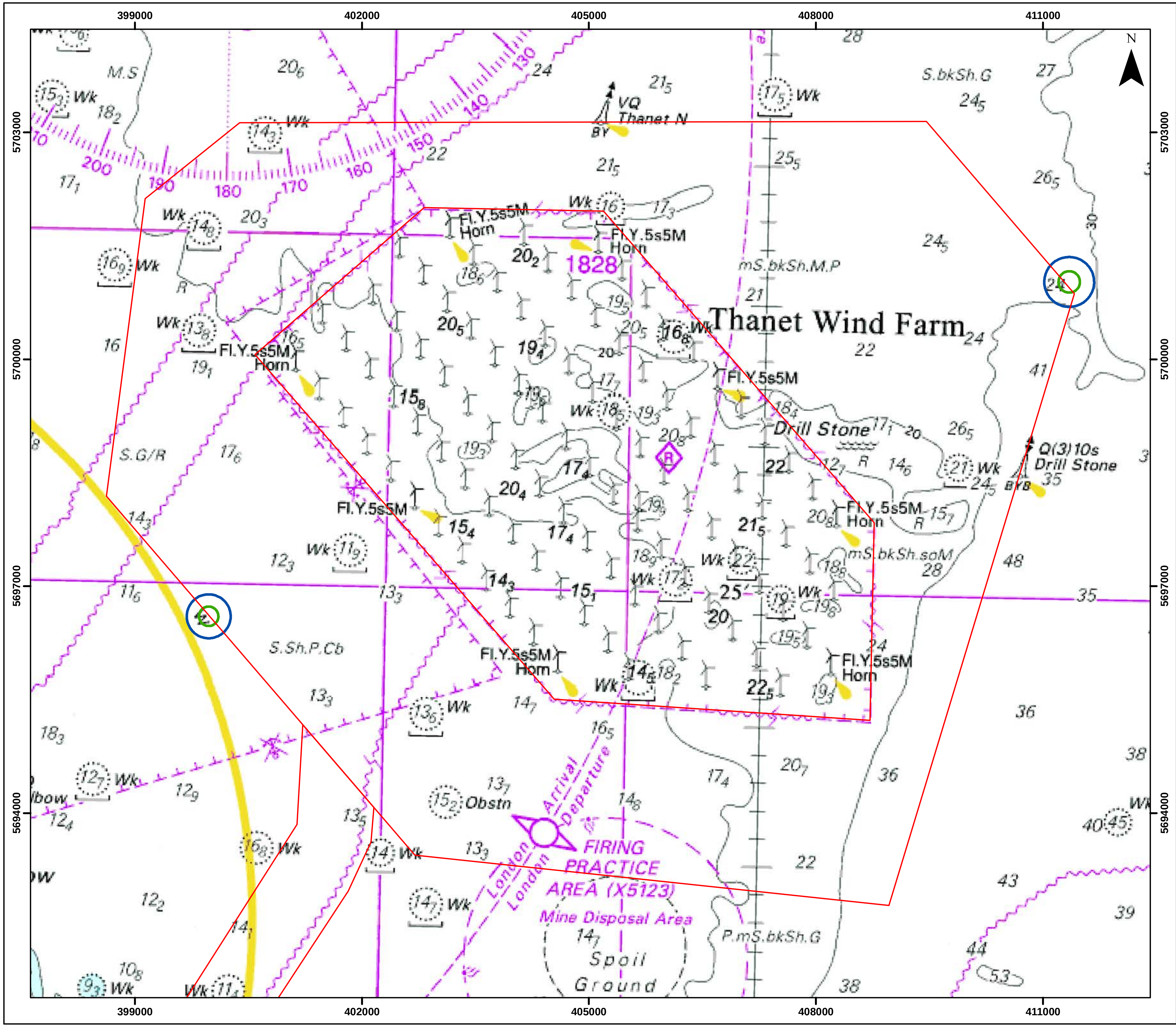
6.10.51 Figure 6-12 shows the noise contours for the peak sound pressure levels (SPL_{peak}) of 207 and 213 dB re 1 µPa, and Figure 6-13 shows the cumulative Sound Exposure Level (SEL_{cum}) of 186 dB re 1 µPa2 sfor Temporary Threshold Shift (TTS). The smaller ranges for the other noise levels identified in Table 6.10: are not shown. Figure 6-14 shows an overlay of 186 dB re 1 µPa^{2}s SEL_{cum} (TTS) noise contours along with herring spawning areas. This figure demonstrates that there is overlap between the TTS range and herring spawning grounds, however this area of overlap is small in the context of the wider habitat available. As discussed in paragraph 6.7.29 *et seq*., the main area of herring spawning appears to be further south, and potential herring spawning areas within the vicinity of the array are less than optimal. Piling for Thanet Extension will have limited to no interaction with the Thames herring sub-stock in terms of TTS (further to the limited interaction with the Downs Stock as identified in Figure 6-7).

GoBe VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 6.12

Predicted Impact Ranges at Specified Noise Levels (SPL_{peak})



Legend

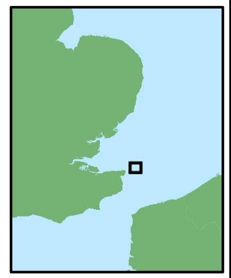
Offshore Red Line Boundary

Noise Level (SPL_{peak} (dB re 1

207 dB re 1 μPa

213 dB re 1 μPa

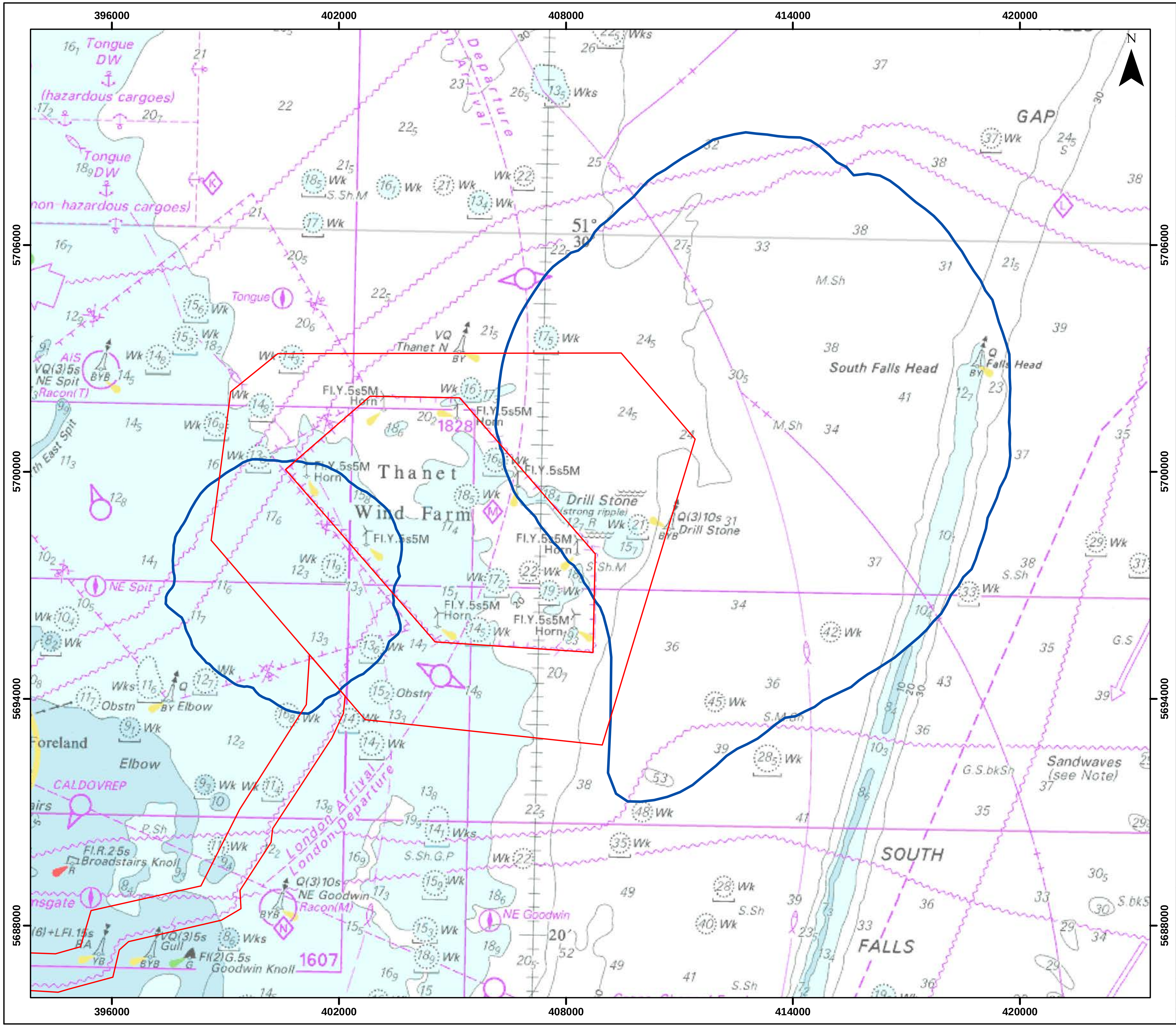
Datum: ETRS 1989
Projection: UTM31N



1:50,000 — 0 0.5 1 km — 0 0.25 0.5 nm

Drg No	Fig6.12_SPL		
Rev	0.1	Date	08/06/2018
By	RM	Layout	N/A

Figure 6.12



GoBe VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 6.13

Predicted Impact Ranges at Specified Noise Levels (SEL_{cum})

Legend

Offshore Red Line Boundary

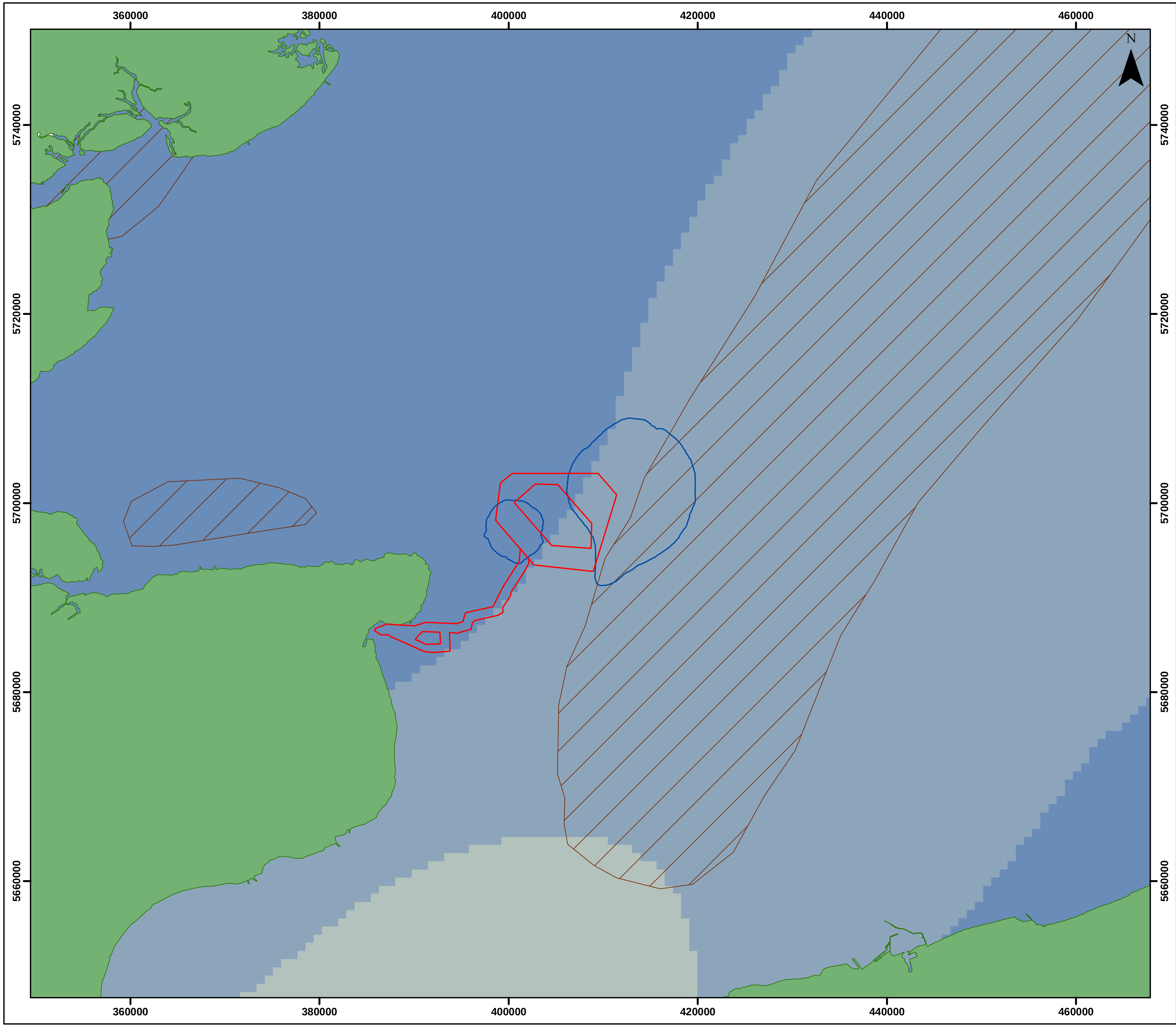
Noise Level (SEL_{cum} (dB re 1 µPa^2)

186 dB re 1 µPa^{2}s

Datum: ETRS 1989
Projection: UTM31N

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

Drg No	Fig6.13_SEL			Figure 6.13
Rev	0.1	Date	08/06/2018	
By	RM	Layout	N/A	



GoBe VATTENFALL

THANET EXTENSION OFFSHORE WIND FARM

Figure 6.14

Comparison of SEL_{cum} Noise Contours with Herring Spawning Grounds

Legend

Offshore Red Line Boundary

Noise Level (SEL_{cum})

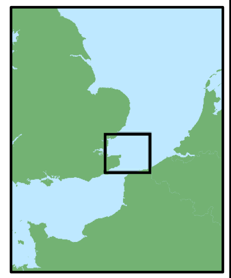
186 dB re 1 µPa^{2}s

Herring Spawning Grounds (Coull et al., 1998)

IHLS 2007/2008-2016/17 Downs Data - Total Larval Abundance Per m^2

- 0
- 0.1 - 9,400
- 9,400.1 - 27,700
- 27,700.1 - 50,100
- 50,100.1 - 76,200
- 76,200.1 - 106,100
- 106,100.1 - 139,500
- 139,500.1 - 177,900
- 177,900.1 - 221,100
- 221,100.1 - 266,700
- 266,700.1 - 314,600

Datum: ETRS 1989
Projection: UTM31N



1:400,000 — 0, 4.5, 9 km; 0, 2, 4 nm

Drg No	Fig6.14_NoiseHerrSpawn			Figure 6.14
Rev	0.1	Date	08/06/2018	
By	RM	Layout	N/A	

Behavioural impacts

6.10.52 Different fish and shellfish have varying sensitivities to piling noise, depending on how these species perceive sound in the environment. Behavioural effects in response to construction related underwater noise include a wide variety of responses including startle responses (C-turn), strong avoidance behaviour, changes in swimming or schooling behaviour, or changes of position in the water column. Depending on the strength of the response and the duration of the impact, there is the potential for some of these responses to lead to significant effects at an individual level (e.g. reduced fitness, increased susceptibility to predation) or at a population level (e.g. avoidance or delayed migration to key spawning grounds), although these may also result in short-term, intermittent changes in behaviour that have no wider effect, particularly once acclimatisation to the noise source is taken into account. The recent ASA guidelines (Popper *et al*., 2014) provide qualitative behavioural criteria for fish from a range of sources. These categorise the risks of effects in relative terms as 'high, moderate or low' at three distances from the source: near (10s of metres), intermediate (100s of metres), and far (1000s of metres), respectively. Table 6.12: summarises these behavioural criteria for the four fish groupings identified.

Table 6.12: Criteria for onset of behavioural effects in fish from piling operations (Popper *et al*., 2014). (N: near field; I: intermediate field; F: far field)

Receptor	Auditory masking	Behavioural effect
Group 1 Fish: no swim bladder (particle motion detection)	N: Moderate I: Low F: Low	N: High I: Moderate F: Low
Group 2 Fish: swim bladder is not involved in hearing (particle motion detection)	N: Moderate I: Low F: Low	N: High I: Moderate F: Low
Group 3 and 4 fish: swim bladder involved in hearing (pressure and particle motion detection)	N: High I: High F: Moderate	N: High I: High F: Moderate
Eggs and larvae	N: Moderate I: Low F: Low	N: Moderate I: Low F: Low

6.10.53 Group 1 Fish (e.g. flatfish and elasmobranchs), Group 2 Fish (e.g. salmonids) and shellfish are considered to be less sensitive to sound pressure, with these species detecting sound in the environment through particle motion. Fish sensitivity to the acoustic particle velocity component of the sound field has been noted by a number of researchers (Hawkins, 2006; Nedwell *et al*., 2007; Popper and Hastings, 2009) and the potential for marine piling to generate the type of sound fields that may contain substantial acoustic particle velocity components has been noted in the literature (Hawkins, 2009). Sensitivity to particle motion in fish is also more likely to be important for behavioural responses rather than injury (Hawkins, 2009; Mueller-Blenkle *et al*., 2010; Hawkins *et al*., 2014).

6.10.54 Information on the impact of underwater noise on marine invertebrates is scarce, and no attempt has been made to set exposure criteria (Hawkins *et al*., 2014b). Studies on marine invertebrates have shown sensitivity of marine invertebrates to substrate borne vibration (Roberts *et al*., 2016). Aquatic decapod crustaceans are equipped with a number of receptor types potentially capable of responding to the particle motion component of underwater noise (e.g. the vibration of the water molecules which results in the pressure wave) and ground borne vibration (Popper *et al*., 2001). It is generally their hairs which provide the sensitivity, although these animals also have other sensor systems which could be capable of detecting vibration. It has also been reported that slow, rolling interface waves that move out from a source like a pile driver can produce large particle motion amplitudes travelling considerable distances (Hawkins and Popper, 2016), with implications for demersal and sediment dwelling fish (e.g. sandeel) and shellfish (e.g. *Nephrops*) in close proximity to piling operations. Sandeel may be particularly affected by vibration through the seabed during winter hibernation when sandeel remain buried in sandy sediments.

6.10.55 When considering particle motion, it should be noted that little to no data exists on the effect on demersal fish or shellfish species or on the levels generated during marine impact piling (Hawkins and Popper, 2016). However, as indicated by the risk criteria outlined for Groups 1 and 2 in Table 6.12:, particle motion generated from piling would be expected to attenuate more rapidly than the acoustic pressure component in the water, with a low risk of behavioural effects in the far field (i.e. kilometres from the source). Behavioural effects on fish and shellfish receptors in the Thanet Extension study area are likely to be spatially limited to within kilometres of piling operations. Although spawning and nursery habitats are present within the Thanet Extension array area, these extend over a wide area, and the relative proportion of these habitats affected by piling operations at any one time will therefore be small in the context of the wider habitat available.

6.10.56 Group 3 and 4 Fish are more sensitive to the sound pressure components of underwater noise and therefore the risks of behavioural effects in the intermediate and far fields are greater for these species. A number of studies have examined the behavioural effects of the sound pressure component of impulsive noise (including piling operations and seismic airgun surveys) on fish species, including gadoids. Mueller-Blenkle *et al*. (2010) measured behavioural responses of cod (and sole) to sounds representative of those produced during marine piling, with considerable variation across subjects (i.e. depending on the age, sex, condition etc. of the fish, as well as the possible effects of confinement in cages on the overall stress levels in the fish). This study concluded that it was not possible to find an obvious relationship between the level of exposure and the extent of the behavioural response, although an observable behavioural response was reported at 140 to 161 dB re 1 µPa SPL_{peak} for cod and 144 to 156 dB re 1 µPa SPL_{peak} for sole. However, these thresholds should not be interpreted as the level at which an avoidance reaction will be elicited, as the study was not able to show this.

6.10.57 A study by Pearson *et al*. (1992) on the effects of geophysical survey noise on caged rockfish *Sebastes* spp. observed a startle (C-turn) response at peak pressure levels beginning around 200 dB re 1 µPa although this was less common with the larger fish. Studies by Curtin University in Australia for the oil and gas industry by McCauley *et al*. (2000) exposed various fish species in large cages to seismic airgun noise and assessed behaviour, physiological and pathological changes. The study made the following observations:

- A general fish behaviour response to move to the bottom of the cage during periods of high level exposure (greater than root mean square (RMS) levels of around 156 – 161 dB re 1 µPa, approximately equivalent to SPL_{peak} levels of around 168 - 173 dB re 1 µPa;
- A greater startle response by small fish to the above levels;
- A return to normal behavioural patterns between 14 - 30 minutes after airgun operations ceased;
- No significant physiological stress increases attributed to air gun exposure; and
- Some preliminary evidence of damage to the hair cells when exposed to the highest levels, although it was determined that such damage to the hair cells would only likely occur at short ranges from the source.

Table 6.13 Behavioural noise response criteria (McCauley *et al*. (2000); Pearson *et al*. (1992))

Potential response	Behavioural response criteria for generic fish species (SPL_{peak} (dB re 1 µPa)
Possible moderate to strong avoidance (McCauley *et al*., 2000)	168 – 173
Startle response or C-turn reaction (Pearson *et al*., 1992)	200

6.10.58 The authors did point out that any potential seismic effects on fish may not necessarily translate to population scale effects or disruption to fisheries and McCauley *et al*. (2000) showed that caged fish experiments can lead to variable results. While these studies are informative to some degree, these, and other similar studies, do not provide an evidence base that is sufficiently robust to propose quantitative criteria (Table 6.13) for behavioural effects (Hawkins and Popper, 2016; Popper *et al*., 2014) and as such the qualitative criteria outlined in Table 6.12: are proposed.

6.10.59 It should be noted that fish and shellfish behavioural responses to underwater noise are highly dependent on factors such as the type of fish/ shellfish, sex, age and condition, as well as other stressors to which the fish is or has been exposed. For example, it would be expected that smaller fish might show behavioural responses at lower levels. In addition to this, the response of the fish will depend on the reasons and drivers for the fish being in the area. Foraging or spawning, for example, may increase the desire for the fish to remain in the area despite the elevated noise level (see Peña *et al*., 2013).

6.10.60 As detailed above, up to 30 UXO with charge weights between 0.05 and 130 kgmay be detonated across the Thanet Extension array and OECC during site preparation activities (noting that this number is precautionary). These will result in elevated noise levels with consequent effects on fish and shellfish behaviour, potentially over the same extent expected for piling operations (i.e. at a range of kilometres to tens of kilometres). However, these detonations will occur over very short durations (i.e. seconds) and therefore will have a considerably shorter overall duration than piling.

6.10.61 Behavioural effects on cod, whiting and herring would therefore be expected to occur over the range of tens of kilometres, although as detailed above, this may not necessarily result in a strong avoidance reaction. Spawning and nursery habitats for these species coincide with Thanet Extension and effects on these habitats would be expected to occur. The proportion of these habitats that are likely to be affected by underwater noise from piling operations within Thanet Extension would be expected to be small in the context of the widespread nature of these habitats.

6.10.62 When considering lower levels of construction noise, such as that from vessels, cable installation, and other methodologies that do not involve percussive piling, the predicted noise levels are expected to be far lower. As such, the extent to which this noise may cause a behavioural response will be far lower. Effects from lower level noise may include disturbance to predation behaviour and auditory masking of communication (Mueller-Blenkle *et al.*, 2010; Thomsen *et al.,* 2006).

6.10.63 This lower level noise will however be generated more constantly compared to piling noise, which is more intermittent, however the lower level of noise generated will be short-term in the context of the relatively short construction phase and will not affect the same spatial extent over the entire construction phase. Considering the high levels of vessel traffic in the region, as well as various cable installations and other offshore wind farms in the region, it is likely that fish are at least in part habituated to high levels of background noise. It is therefore considered highly unlikely that such noise would have a significant impact on fish species.

6.10.64 The impact of construction related underwater noise is predicted to be of local to regional spatial extent, short duration (6 months maximum), intermittent and reversible (for non-injurious effects). It is predicted that the impact will directly affect fish and shellfish receptors. The magnitude of the impact is therefore considered to be Low.

6.10.65 Herring, cod and whiting are considered to be of medium vulnerability, high recoverability and of regional to national importance. Habitat displacement is interpreted as fish not reaching key habitats that are required as part of their life-cycle (including spawning grounds) due to sound pressure levels affecting their normal behaviour. With reference to Figure 6-14, it can be seen that there is overlap of the noise contours with the Coull *et al.* herring spawning ground data. This area is considered to be small in the context of the habitat available in the wider region. Furthermore, Figure 6-7 indicates that the main area for herring spawning according to IHLS data appears to be further to the south. As discussed in paragraph 6.7.29, potential spawning habitat for herring exists throughout the proposed development boundary, though this area is small in the context of the wider habitat available, and there is some uncertainty as to how likely this potential spawning habitat is to be utilised. The sensitivity of these receptors is therefore considered to be Medium.

6.10.66 All other fish and shellfish receptors within the study area are deemed to be of low vulnerability, high recoverability and of local to international importance. The sensitivity of these receptors is therefore considered to be Low.

6.10.67 Construction related underwater noise will represent a temporary, short- to medium-term duration and intermittent impact, affecting only a relatively small portion of the habitats in the fish and shellfish study area. Overall, it is predicted that the sensitivity of fish and shellfish receptors is considered to be Low to Medium and the magnitude of impact is deemed to be Low. The effect therefore, will be of **Minor** adverse significance, which is not significant in EIA terms.

6.11 Environmental assessment: operational phase

6.11.1 The impacts of the O&M phase of Thanet Extension have been assessed on fish and shellfish ecology in the study area. The effects arising from the operation of Thanet Extension are listed in Table 6.7 along with the design envelope parameters against which each O&M phase impact has been assessed.

6.11.2 A description of the significance of effects upon fish and shellfish receptors caused by each identified impact is given below.

Long-term loss of habitat due to the presence of turbine foundations, scour protection and cable protection

6.11.3 The presence of infrastructure such as foundations and cable protection at crossings have the potential to impact on fish and shellfish ecology by the removal of essential habitats for survival (e.g. spawning, nursery and feeding habitats).

6.11.4 The introduction of foundations and scour protection would result in a permanent loss of seabed habitat. Fish and shellfish that are reliant on the presence of suitable sediment/ habitat for their survival are considered to be more vulnerable to change depending on the availability of habitat within the wider geographical region. The Thanet Extension fish and shellfish study area coincides with known and potential fish spawning and nursery habitats including herring and sandeel.

6.11.5 The long-term habitat loss due to the presence of foundations, scour protection and cable protection is expected to be up to a maximum of 617,350 m^2, which represents 0.62% of the area within the Thanet Extension proposed Order Limits, and a much smaller proportion of the wider study area. Comparable habitats are present and widespread within the wider area.

6.11.6 The impact is predicted to be of local spatial extent (i.e. within the Thanet Extension development boundary), long-term duration, continuous and irreversible (within the lifetime of the project). It is predicted that the impact will affect fish and shellfish receptors directly. The magnitude is therefore considered to be Low.

6.11.7 Fish and shellfish species that are reliant upon the presence of suitable sediment/ habitat for their survival are considered to be more vulnerable to change depending on the availability of habitat within the wider region. Thanet Extension coincides with spawning and nursery areas for herring, cod, plaice, sole, whiting, sandeel and thornback ray (see section 6.7). The fish species most vulnerable to habitat loss include herring and sandeel (demersal spawners) as these have specific habitat requirements for spawning. Thanet Extension is located outside of the main herring spawning grounds (Figure 6-7) and therefore they will not be affected by long-term habitat loss. Thanet Extension overlaps with low intensity spawning and nursery habitat for sandeel. As well as laying demersal eggs, sandeel also have specific habitat requirements throughout their juvenile and adult life history and loss of this specific habitat could impact this species. Effects of OWF construction (Jensen *et al*., 2004) and O&M (van Deurs *et al*. 2012) on sandeel populations have been examined through short-term and long-term monitoring studies at the Horns Rev OWF. These monitoring studies have shown that OWF construction and O&M have not led to significant negative effects on sandeel populations. The proportion of habitat affected within Thanet Extension is small and this area is smaller still in the context of known wider sandeel habitats.

6.11.8 Most fish and shellfish receptors in the study area are deemed to be of low vulnerability and of local to international importance (recoverability is not applicable for this impact due to the impact occurring over the lifetime of the project). Given the widespread nature of spawning and nursery habitat in the wider area, the sensitivity of these receptors is considered to be Low.

6.11.9 Sandeel and herring are deemed to be of high vulnerability and of regional importance. Due to the specific habitat requirement of these species, the sensitivity of these receptors is considered to be Medium.

6.11.10 Long-term habitat loss will represent a long-term and continuous impact throughout the lifetime of the project. However only a relatively small proportion of the fish and shellfish habitats within the development boundary and wider study area are likely to be affected. Overall, it is predicted that the sensitivity of fish and shellfish is considered to be Low to Medium and the magnitude is deemed to be Low. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Increased hard substrate and structural complexity as a result of the introduction of turbine foundations, scour protection and cable protection

6.11.11 Any introduction of infrastructure such as foundations and scour protection would result in the introduction of hard substrate to the currently predominantly soft seabed habitat of the Thanet Extension site. This would result in an increase in the heterogeneity of the seabed habitat and a change of the composition of the benthic community. As a result, an increase in the biodiversity if the benthic community in the vicinity of the area where hard substrate is introduced is expected to occur (Wilhelmsson and Malm, 2008).

6.11.12 This increase in diversity and productivity of the seabed communities expected may have a positive impact on fish and shellfish receptors, resulting in either attraction or increased productivity (Hoffman *et al*., 2000). The potential for marine structures, whether man-made or natural, to attract and concentrate fish is well documented (Sayer *et al*., 2005; Bohnsack, 1989; Bohnsack and Sutherland, 1985; Jorgensen *et al*., 2002). However, whether these structures act only to attract and aggregate fish or actually increase biomass is currently unclear.

6.11.13 Up to 617,350 m^2 of new hard substrate is likely to be created in Thanet Extension as a result of foundation installation, scour protection and cable protection. The impact is predicted to be of local spatial extent (within Thanet Extension), long-term duration, continuous and irreversible (during the lifetime of the project). It is predicted that the impact has the potential to affect fish and shellfish receptors both directly and indirectly. The magnitude is therefore considered to be Low.

6.11.14 Hard substrate created by the introduction of turbine foundations and scour/ cable protection are likely to be primarily colonised within hours or days after construction by demersal and semi-pelagic fish species (Andersson, 2011). Continued colonisation has been seen for a number of years after the initial construction, until a stratified re-colonised population is formed (Krone *et al*., 2013). Fish aggregate from the surrounding areas, attracted by feeding opportunities or the prospect of encountering other individuals which may increase the carrying capacity of the area (Andersson and Öhman, 2010; Bohnsack, 1989).

6.11.15 The dominant natural substrate character of the construction area (e.g. soft sediment or hard rocky seabed) will determine the number of new species found on the introduced vertical hard surface and associated scour protection. When placed on an area of seabed which is already characterised by rocky substrates, few species will be added to the area, but the increase in total hard substrate could sustain higher abundance (Andersson and Öhman, 2010). Conversely, when placed on a soft seabed, most of the colonising fish will be normally associated with rocky (or other hard bottom) habitats, thus the overall diversity of the area may increase (Andersson *et al*., 2009). A new baseline species assemblage will be formed via re-colonisation and the original soft-bottom population will be displaced (Desprez, 2000). This was observed in studies by Leonhard *et al*. (Danish Energy Agency, 2012) at the Horns Rev OWF, and Bergström *et al*. (2013) at the Lillgrund OWF, where an increase in fish species associated with reefs, such as goldsinny wrasse *Ctenolabrus rupestris*, lumpsucker *Cyclopterus lumpus* and eelpout *Zoarces viviparus*, and a decrease in the original sandy-bottom fish population, were reported.

6.11.16 The longest monitoring programme conducted to date at the Lillgrund OWF in the Öresund Strait in southern Sweden, showed no overall increase in fish numbers, although redistribution towards the foundations within the OWF area was noticed for some species (i.e. cod, European eel (*Anguilla anguilla*) and eelpout; Andersson, 2011). More species were recorded after construction than before, which is consistent with the hypothesis that localised increases in biodiversity may occur following the introduction of hard substrates in a soft sediment environment. Overall, results from earlier studies reported in the scientific literature did not provide robust data (e.g. some were visual observations with no quantitative data) that could be generalised to the effects of artificial structures on fish abundance in OWF areas (Wilhelmsson *et al*., 2010). More recent papers are, however, beginning to assess population changes and observations of re-colonisation in a more quantitative manner (Krone *et al*., 2013).

6.11.17 Post-construction fisheries surveys conducted in line with the FEPA licence requirements for the Barrow and North Hoyle OWFs, found no evidence of fish abundance across these sites being affected, either positively or negatively, by the presence of the OWFs (Cefas, 2009; BOWind, 2008) therefore suggesting that any effects, if seen, are likely to be highly localised.

6.11.18 It is likely that the greatest potential for positive effects exists for crustacean species, such as crab and lobster, due to expansion of their natural habitats (Linley *et al*., 2007) and the creation of additional refuge areas. Where foundations and scour protection are placed within areas of sandy and coarse sediments, this will represent novel habitat and new potential sources of food in these areas and could potentially extend the habitat range of some shellfish species. Post-construction monitoring surveys at the Horns Rev OWF noted that the hard substrates were used as a hatchery or nursery grounds for several species, and was particularly successful for edible crab. They concluded that larvae and juveniles rapidly invade the hard substrates from the breeding areas (BioConsult, 2006). As both crab and lobster are commercially exploited within the Thanet Extension fish and shellfish study area, particularly along nearshore sections of the Thanet Extension offshore cable corridor, there is potential for benefits to the fisheries, depending on the materials used in construction of the OWF.

6.11.19 Other shellfish species, such as the blue mussel, have the potential for great expansion of their normal habitat due to increased hard substrate in areas of sandy habitat. Krone *et al*., (2013) coined the term 'mytilusation' to describe this mass biofouling process recorded at a platform in the German Bight, North Sea. It was found that over a three-year period, almost the entire vertical surface area of the platform piles had been colonised by three key species: blue mussel, the amphipod *Jassa* spp. and anthozoans (mainly *Metridium senile*). These three species were observed to occur in depth-dependant bands, attracting pelagic fish species such as horse mackerel *Trachurus trachurus* and demersal pouting in great numbers. Layers of shell detritus were visible at the base of the foundations due to the mussel populations above and both velvet swimming crab (*Necora puber*) and edible crabs were recorded here. These species were not typical of baseline species assemblage, providing further evidence of localised changes in fish and shellfish assemblages in the vicinity of foundation structures.

6.11.20 The colonisation of new habitats may potentially lead to the introduction of non-indigenous and invasive species. With respect to fish and shellfish populations, this may have indirect adverse effects on shellfish populations as a result of competition. There is little evidence of adverse effects resulting from colonisation of other OWFs by non-indigenous species; the post-construction monitoring report for the Barrow OWF demonstrated no evidence of invasive or alien species on or around the monopiles (EMU, 2008a), and a similar study of the Kentish Flats monopiles only identified slipper limpet *Crepidula fornicata* (EMU, 2008b), which were identified as already being present in the Thanet Extension study area (Ocean Ecology, 2017).

6.11.21 Fish and shellfish receptors in the study area are deemed to be of low vulnerability and local to international importance (recoverability is not relevant to this impact). The sensitivity is therefore considered to be Low.

6.11.22 There is some uncertainty associated with the likely effects of introduction of hard substrates into the marine environment on fish and shellfish receptors. Fish populations are unlikely to show noticeable benefits as a result of this impact, though there is evidence that shellfish populations (particularly edible crab and lobster) would benefit from the introduction of hard substrates. Overall, it is predicted that the sensitivity of fish and shellfish receptors is Low and the magnitude is predicted to be Low. The effect therefore, will be of **Minor** adverse significance, which is not significant in EIA terms.

Underwater noise as a result of operational turbines

6.11.23 Underwater noise is predicted to occur as a result of the O&M of up to 34 turbines within the Thanet Extension array area, although at considerably lower levels compared to those of the construction phase. Underwater noise from operational turbines mainly originates from the gearbox and the generator and has tonal characteristics (Madsen *et al*., 2005; Tougaard *et al*., 2009). The radiated levels are low and the spatial extent of the potential impact of the operational wind farm noise on marine receptors is generally estimated to be small and therefore unlikely to result in any injury to fish (Wahlberg and Westerberg, 2005). Besides the sound source level, the potential for impact will also depend on the propagation environment, the receptors hearing ability and the ambient sound levels.

6.11.24 Marine animals may perceive the radiated tonal components where these exist above the ambient noise levels, which may result in a behavioural response of the receptor or lead to a reduced detection of other sounds due to masking. Operational noise may also result in effects such as disturbance to communication or disturbance/ displacement of prey. Previous studies have shown that behavioural responses of fish are only likely at close ranges from the turbine (i.e. a few metres; Wahlberg and Westerberg, 2005). Although effects on fish are difficult to establish given the lack of information available in the scientific literature, there is indicative evidence that fish would be unlikely to show significant avoidance to the noise levels radiating from the turbine.

6.11.25 Studies of very low frequency sound have indicated that consistent deterrence from the source is only likely to occur at particle accelerations equivalent to a free-field SPL of 160 dB re 1 µPa (RMS) (Sand *et al*., 2001). Particle acceleration resulting from an operational wind turbine has also been measured by Sigray *et al*. (2011) with the resultant levels being considered too low to be of concern for behavioural reactions from fish. Furthermore, the particle acceleration levels measured at 10 m from the turbine were comparable with hearing thresholds. Whilst limited, the available data provides an indicator that operational wind turbines are unlikely to result in disturbance of fish except within very close proximity of the turbine structure, as postulated by Wahlberg and Westerberg (2004). Any potential avoidance reactions (should they occur) would be limited to a short distance from the operational turbine with the potential for acclimatisation occurring over the lifetime of the project.

6.11.26 Research (e.g. Marmo *et al.*, 2013) suggests that fish are certainly able to detect underwater noise from operational turbines, though there is a general lack of research in this field. The detectability of operational noise is highly dependent on foundation type, with fish being more sensitive to the low-frequency noise transmitted through monopiles rather than jackets or gravity bases. The level to which operational noise causes communication or auditory masking effects is uncertain. Considering the high levels of background noise already in the region, it is not expected that effects would be significant.

6.11.27 The impact is predicted to be of a highly localised spatial extent (in the immediate vicinity of the operational turbines), long-term duration, continuous and irreversible (during the lifetime of the project). It is predicted that the impact will affect the fish and shellfish receptors indirectly. Due to the extremely localised spatial extent, the magnitude is considered to be Negligible.

6.11.28 Given the low noise levels associated with operational turbines, any risk of significant behavioural disturbance to fish and shellfish would be limited to the area immediately surrounding the turbine, which represents a very small proportion of the total Thanet Extension array area. A major contributor to the ambient noise is sea-state, which would be expected to increase as the turbine rotational speed increases with wind speed. Increased ambient noise may exceed the turbine noise, as has been observed by Tougaard *et al*. (2009) at three OWFs (Middelgrund and Vindeby in Denmark, and Bockstigen-Valar in Sweden). Investigations at all three of these OWFs resulted in no response by fish and shellfish receptors. Sensitivities of fish and shellfish receptors to underwater noise are discussed in paragraphs 6.10.34 *et seq*.

6.11.29 Given the high level of background noise present within the vicinity of Thanet Extension from vessels and other operations, it is likely that fish are at least in part habituated to these background noise levels. There is a general lack of literature surrounding the effects of operational wind farm noise on fish in terms of disturbance to communication and effects on prey-species. A review by Thomsen *et al.,* 2006 highlighted that masking of auditory fish communication within the zone of audibility is possible, however the effects of this are unlikely to be significant, especially considering the high noise levels in the area.

6.11.30 Herring, cod and whiting are considered to be of medium vulnerability, high recoverability and of regional to international importance, however the sensitivity to the type and levels of noise associated with operational OWFs and fish monitoring for these species in proximity to OWFs suggests a lower overall sensitivity to operational noise. The sensitivity of these receptors is therefore considered to be Low.

6.11.31 All other fish and shellfish receptors in the study area are deemed to be of low vulnerability, high recoverability and of local to international importance. The sensitivity of these receptors is therefore considered to be Negligible.

6.11.32 Subsea noise resulting from turbine operation will represent a long-term and continuous impact throughout the lifetime of the project. However, any risk of significant behavioural disturbance for fish and shellfish would be limited to the area immediately around the turbine. Overall, it is predicted that the sensitivity of fish and shellfish receptors is Low to Negligible and the magnitude is predicted to be Negligible. The effect will therefore be of **Negligible** adverse significance, which is not significant in EIA terms.

Electromagnetic fields (EMF) effects arising from cables

6.11.33 EMF will result from the operation of up to 64 km of HVAC inter-array and 120 km of HVAC export cables. The transport of electricity through cables has the potential to emit a localised EMF which could potentially affect the sensory mechanisms of some species of fish and shellfish, particularly electro-sensitive species (including elasmobranchs) and migratory fish species (CMACS, 2003). EMF comprise both the electric (E) fields, measured in volts per metre (Vm^{-1}) and the magnetic (B) fields, measured in Teslas (T).

6.11.34 Molluscs, crustaceans and fish (particularly elasmobranchs) are able to detect applied or modified magnetic fields. Species for which there is evidence of a response to E and B fields include elasmobranchs (sharks, skates and rays), river lamprey, sea lamprey, cod (E field only), European eel, plaice and Atlantic salmon (Gill *et al*., 2005). Data on the use that marine species make of these capabilities is limited, although it can be inferred that the life functions supported by an electric sense may include detection of prey, predators or conspecifics to assist with feeding, predator avoidance, and or social or reproductive behaviours. Life functions supported by a magnetic sense may include orientation, homing, and navigation to assist with long or short-range migrations or movements (Gill *et al*., 2005; Normandeau *et al*., 2011). Therefore, the EMF emitted by subsea cables may interfere with these functions in areas where cable EMF levels are detectable by the organism, causing expenditure of energy moving to areas which may not be suitable for finding either prey species or members of the same species, or expenditure of energy to moving away from areas where predators are mistakenly located.

6.11.35 Crustacea, including lobster and crabs, have been shown to demonstrate a response to B fields, with the spiny lobster (*Palinurus argus*) shown to use a magnetic map for navigation (Boles and Lohmann, 2003). However, it is uncertain if other crustaceans including commercially important edible crab and European lobster are able to respond to magnetic fields in this way. Limited research undertaken with the European lobster found no neurological response to magnetic field strengths considerably higher than those expected directly over an average buried power cable (Normandeau *et al*., 2011; Ueno *et al*., 1986). Indirect evidence from post-construction monitoring programmes undertaken in operational wind farms do not suggest that the distribution of potentially magnetically sensitive species of crustaceans or molluscs have been affected by the presence or absence of submarine power cables and associated magnetic fields.

6.11.36 Elasmobranchs (sharks, skates and rays) are known to be the most electro-receptive of all fish. They possess specialised electro-receptors which enable them to detect very weak voltage gradients (down to 0.5 $\mu V\ m^{-1}$) in the environment naturally emitted from their prey (Gill *et al*., 2005). Both attraction and repulsion reactions to E fields have been observed in elasmobranch species. A COWRIE-sponsored mesocosm study demonstrated that the lesser spotted dogfish and thornback ray were able to respond to EMF of the type and intensity associated with subsea cables; the responses of some ray individuals suggested a greater searching effort when the cables were switched on. However, the responses were not predictable and did not always occur (Gill, *et al*., 2009).

6.11.37 Elasmobranch species in the study area are deemed to be of medium vulnerability and local importance. The sensitivity of these receptors is therefore considered to be Low.

6.11.38 Another concern with EMF is the potential for interference with the navigation of sensitive migratory species. Species such as Atlantic salmon and European eel have both been found to possess magnetic material of a size suitable for magnetoreception, and these species can use the Earth's magnetic field for orientation and direction finding during migration (Gill and Bartlett, 2010). Mark and recapture experiments undertaken at the operational Nysted OWF showed that eel did cross the export cable (Hvidt *et al.*, 2003) but studies on European eel have highlighted some limited effects of subsea cables. The swimming speed during migration was shown to change during the short-term (tens of minutes) with exposure at AC electric subsea cables, even though the overall direction remained unaffected (Westerberg and Langenfelt, 2008). The authors concluded that any delaying effect (i.e. on average 40 minutes) would not be likely to influence fitness in a 7,000 km migration. The review by Gill and Bartlett (2010) highlights the mixed results from the few studies that have been reported and that there is no clear evidence as to what, if any, the overall effect of EMFs on migration and movement behaviour of these species is likely to be. It concludes that EMFs from subsea cables may interact with migratory eel (and perhaps salmonids) if their migration route takes them over the cables, particularly in shallow waters. Therefore, limited effects may be expected in fish migration, should indeed the cable route be used by migratory species, although such effects are likely to be short-lived affecting only a small area of habitat within metres of the buried cable. All other fish and shellfish receptors are deemed to be of low vulnerability and are of local to regional importance. The sensitivity of these receptors is therefore considered to be Low.

6.11.39 Background measurements of magnetic fields are approximately 50 µT in the North Sea and the naturally occurring electric field in the North Sea is approximately 25 μVm^{-1} (Tasker *et al*., 2010). The naturally occurring fields are static (DC), meaning their direction and magnitude are constant. The magnetic and induced electric fields produced by AC change in direction and magnitude over time as the current flow alternates. It is common practice to block the direct electric field (E) using conductive sheathing, meaning that the EMFs that are emitted into the marine environment are the magnetic field (B) and the resulting induced electric field (iE). A key misconception in the understanding of the effects of EMF has been the assertion that cable burial will work to mitigate iE and B field effects and that there will be no externally detectable electric fields generated by industry standard subsea power cables. The conclusion of the Collaborative Offshore Wind Research into the Environment (COWRIE) EMF study (Gill *et al*., 2005) and subsequent clarification in the Phase 2 COWRIE EMF report (Gill *et al*., 2009) highlights the fact that it is impractical to assume that cables can be buried at depths that will reduce the magnitude of the B field, and hence the sediment-sea water interface induced E field, below that at which they could be detected by certain marine organisms.

6.11.40 A series of investigations have taken place at the Nysted Wind Farm at Rødsand, in Denmark, on the effects of EMF on fish. Due to difficulties and high complexity within the sampling and analysis phase, only the post-construction monitoring data from 2003 and 2004 were used in the final analysis (Hvidt *et al*., 2004). While the voltage of the export (and inter-link) cables are not the same (132 kV at Nysted and maximum 220 kV at Thanet Extension), this difference is not considered to be significant in terms of the EMF fields produced, as the strength of EMF fields depends on the electrical power (amperes) of the current rather than the voltage. When the Nysted farm is at full production (600 A), the magnetic field does not exceed 5 µT (micro Tesla's) at 1 m from the cable. In all cases, the predicted magnetic field is less than the Earth's magnetic field (~50 µT). The Nysted studies, using pound nets to collect data on the directional movement of individual species around the cables, were able to determine that there was no change in the overall distribution of any species outside of natural variation that could be attributed to the presence of the cables. In support of the conclusions for the Nysted studies, and in a more recent comparable study, post-construction monitoring at Burbo Bank OWF, which has the same cable voltage as Thanet Extension (220 kV), has shown that there has been no change in any electro-sensitive species during the first three years of operation (with the cables buried at 1 m depth).

6.11.41 Induced electric fields emitted from AC and DC cables are not directly comparable, though modelling studies have shown average iE fields from submarine DC cables of 194 µV m^{-1} at 0 m horizontal distance from the cable (assuming cable burial to 1 m below seabed and a 5 knot current), with field strength decreasing with horizontal and vertical distance from the cable. As fish and other mobile marine organisms also cause movement of electrical charges even in still water, the movement of a fish at five knots would also experience a similar electrical field. The modelling of induced electrical fields for AC cables requires consideration of the size of an organism and its distance from the cable. Modelling of induced electrical fields in a small shark of 150 cm length, swimming 0.6 m above and parallel to a 60 Hz AC cable buried to 1 m produced a maximum iE field strength of 765 µV m-1 (Normandeau *et al*., 2011). Other orientations will result in lower values of induced electric fields. Ultimately, the effects would depend on site and project specific factors related to both the magnitude of EMFs and the ecology of local populations including spatial and temporal patterns of habitat use.

6.11.42 The strength of the magnetic field (and consequently, induced electrical fields) decreases rapidly horizontally and vertically with distance from source. Modelling studies have indicated that the range of the field is in the order of 10 m each side of the cable (assuming 1 m burial) (Normandeau *et al*., 2011).

6.11.43 A recent study (Love *et al*., 2016) investigated the effects of EMF from energised cables (35 kV) on marine biological receptors, including fish, by comparing ecological data from cables, pipes and natural habitats. No significant differences were observed in the fish communities living around energised and un-energised cables, and natural habitats. Although fish at un-energised cables were marginally larger than those at energised ones, this result was very slight, and likely biologically insignificant. Species diversity, as well as the density of the most important fish species, was higher at cables when compared to natural habitats, although this was likely as a result of greater heterogeneity of habitat afforded by the cables than the soft sediment natural habitats. Despite observing very few electro-sensitive species such as elasmobranchs (sharks, skates and rays) at any location, no compelling evidence was found to suggest EMF produced by the energised cables were either attracting or repelling such species. It was also found that measured EMFs produced by the cables diminished to background levels at about 1 m from the cable. Given the rapidity with which the EMF produced by the cable diminished with distance from the cable, and the lack of response to EMF by marine biological receptors, it was concluded that cable burial (at a sufficient depth) is an adequate tool to prevent EMF from being present at the seafloor. However, as described in paragraph 6.11.39, it cannot be assumed that this is the case. For Thanet Extension, cables will be buried at depths between 1 and 3 m for the majority of the route. The final burial depth will be decided when a detailed study has been completed to assess the relevant factors for each part of the cable route.

6.11.44 The impact is therefore predicted to be highly localised, of long-term duration (i.e. over the lifetime of the project), continuous and irreversible (over the lifetime of the project). It is predicted that the impact will affect fish and shellfish receptors directly. Due to the localised spatial extent, the magnitude is considered to be Low.

6.11.45 Based on the low magnitude and low sensitivity of receptors, the effects of EMF from cables will be of **Minor** adverse significance, which is not significant in EIA terms.

Direct disturbance resulting from maintenance during operation

6.11.46 Temporary habitat loss/ disturbance is likely to occur during the operational phase of Thanet Extension as a result of spud-can impacts from jack-up vessels and also cable re-burial works (where necessary). The impacts associated with these operations are likely to be similar (at least in nature) to those associated with the construction phase.

6.11.47 Direct impacts to the seabed arising from jack-up vessels and cable maintenance (10 visits per foundation over a 30-year period, plus cable maintenance including re-burial and replacement) will affect a maximum footprint of 4,111,801 m^2. These impacts will be localised and temporary, as for construction, but to a much smaller extent.

6.11.48 Given that the habitats affected are common and widespread throughout the region, this impact represents a small footprint compared to their overall extent. The impacts will be temporary and limited at each location, and there will likely be sufficient time between events for recovery. Therefore, the magnitude is assessed as Negligible.

6.11.49 Sensitivity of receptors to temporary habitat loss/ disturbance is discussed in detail in paragraphs 6.10.3 *et seq*. The receptors affected by this impact during the operational phase would be largely restricted to those within the Thanet Extension array area and OECC. The species most likely to be affected are demersal fish species whose life strategies are strongly connected to the use of the seabed for shelter or for reproduction (e.g. the demersal spawners, herring and sandeel).

6.11.50 Most fish and shellfish receptors in the study area are deemed to be of low vulnerability, high recoverability and of local to international importance. The sensitivity of these receptors is therefore considered to be Low.

6.11.51 Sandeel and herring are deemed to be of high vulnerability, medium recoverability and of regional importance. The sensitivity of these receptors is therefore considered to be Medium.

6.11.52 Temporary habitat loss as a result of maintenance during the operational lifetime of Thanet Extension is predicted to affect a very small proportion of fish and shellfish habitats within the study area, with limited effects on fish and shellfish receptors. Overall, it is predicted that the sensitivity of fish and shellfish is considered to be Low to Medium and the magnitude is deemed to be Negligible. The effect therefore, will be of **Negligible** adverse significance, which is not significant in EIA terms.

Increases in SSC and associated sediment deposition from O&M activities

6.11.53 Increases in SSC and sediment deposition are possible from cable repair and re-burial activities. The worst-case scenario for this is described in Table 6.7. As described in paragraph 6.10.12 *et seq.*, the resulting SSC is dependent on the rate of release and the height at which the displaced sediment is initially released. Due to the low release level from cable maintenance works (at or near the seabed level), it is anticipated that sediments will settle to the seabed relatively quickly, and that the extent of any sediment plume will be limited to one tidal excursion, to below background levels beyond this.

6.11.54 In paragraph 6.10.18 *et seq.*, the magnitude of the impact of increased SSCs and sediment deposition would be Low. As the potential impact in the O&M phase will be more limited, less frequent, intermittent and localised, they will fall within the envelope assessed for the construction phase and are therefore also considered to be Low.

6.11.55 In the construction phase assessment, fish and shellfish receptors were deemed to be of Low sensitivity, with the exception of herring, which were considered to be of Medium sensitivity (paragraph 6.10.32 *et seq*.).

6.11.56 Increases in SSC and associated sediment deposition will represent an intermittent impact, affecting a relatively small portion of the fish and shellfish habitats within the wider region. In addition, most receptors are predicted to have some tolerance to this impact. Overall, the magnitude of the impact has been assessed as low, and the sensitivity of the receptors as Low to Medium. The significance of this effect therefore is deemed to be **Minor** adverse, which is not significant in EIA terms.

Indirect disturbance resulting from the accidental release of pollutants

6.11.57 Accidental spillage of chemicals and substances from the operational turbines may impact on fish and shellfish receptors, resulting in behavioural effects such as displacement from affected areas and prevention of spawning. Chemical spills may also have sub-lethal to lethal effects dependent on the life stage of the organism, exposure level and the level of toxicity.

6.11.58 The magnitude of impact is entirely dependent on the nature of the pollution incident but it is recognised that the potential for accidental loss is limited due to the small inventories contained on the installation (DECC, 2011c). Any spill or leak within Thanet Extension would be subject to immediate dilution and rapid dispersal.

6.11.59 Turbines will require lubricants and hydraulic oils in order to operate (see Table 6.7). However, the nacelle, tower and hub of the turbine will be designed to retain any leaks should any occur. With respect to leachate from anodes, dissolved zinc from anodes is toxic to marine life at low concentrations; the Environmental Quality Standard (EQS) is 40 µg/l (annual mean value), but no such EQS currently exists for aluminium. The concentrations of zinc and aluminium released into the marine environment from sacrificial anodes are likely to be minimal and well below the EQS for zinc.

6.11.60 Any impact on fish and shellfish receptors would only be realised if an incident occurs where the fuel is accidentally released. Given the embedded mitigation (Table 6.8) which is proposed for the O&M phase, it is considered that the likelihood of accidental release is extremely low. Any impact is predicted to be of local to regional spatial extent, short-term duration, intermittent and reversible. It is predicted that the impact would affect the receptor both directly and indirectly. Though the risk of a spill is small, the magnitude is considered to be Low.

6.11.61 The sensitivity of the receptors will vary depending on a range of factors including species and life stage, with adult fish less likely to be affected by marine pollution due to their increased mobility compared to fish eggs, larvae, juveniles and shellfish species. Any such pollution events will therefore have varying levels of effect depending on the species present and pollutants involved. However, as fuel and oil spills are likely to be dispersed on the surface, effects on fish and shellfish receptors are likely to be limited.

6.11.62 The fish and shellfish receptors within the study area are considered to be of low to medium vulnerability, high recoverability and local to international importance. The sensitivity of the receptor is therefore considered to be Low to Medium.

6.11.63 Overall, it is predicted that the sensitivity of fish and shellfish receptors is Low to Medium and the magnitude is deemed to be Low, with a low likelihood of a pollution event occurring due to the implementation of the control measures during the operational phase. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Potentially reduced fishing pressure within the Thanet Extension array area and increased fishing pressure outside the array area due to displacement

6.11.64 During the operational phase of Thanet Extension, the intensity of fishing activities (including trawling and potting) may be reduced inside the array area. This has the potential to enhance fish and shellfish populations by providing refuge from fishing activities for certain species targeted by commercial fisheries. Conversely, this also has the potential to increase the intensity of fishing activity outside of the array area as fishing activity is displaced, to the detriment of fish populations there.

Reduced fishing pressure within the Thanet Extension array area

6.11.65 Fishing activity may be reduced within Thanet Extension as a result of a 50 m operational safety zone around all structures and as a result of the physical presence of the infrastructure within the array area.

6.11.66 The impact is predicted to be of a local spatial extent (within the array area), long-term duration, continuous and irreversible (during the lifetime of the project). It is predicted that the impact will affect the fish and shellfish receptors directly. The magnitude is therefore considered to be Low.

6.11.67 A range of species are targeted by commercial fisheries in the area. these species are likely to observe the greatest benefit from a reduction in fishing effort within the Thanet Extension array area, although non-target fish caught as by-catch are also likely to benefit due to a reduction in fishing mortality.

6.11.68 The habitat protected from trawling may also become a refuge for young and spawning fish, thus providing benefits to fish populations beyond the immediate exclusion area (Byrne Ó Cléirigh *et al*., 2000). However, many of the commercially important fish species in the area are highly mobile and therefore may not significantly benefit from a reduction in fishing pressure. Additionally, any enhancements in abundances due to reduction in fishing efforts are likely to be followed by an increase in abundance of predator species.

6.11.69 Trawling can damage the seabed and its marine life (Hart *et al*., 2004). Therefore, the potential reduction in trawl fishing within Thanet Extension may benefit shellfish communities that were historically disturbed by trawling activity.

6.11.70 Fish and shellfish receptors are deemed to be of low vulnerability, high recoverability and of local to international importance within the study area. The sensitivity of these receptors is therefore considered to be Low.

6.11.71 There is considerable uncertainty associated with the potential benefits to fish and shellfish populations as a result of the potential reduction of fishing activities within the Thanet Extension array area due to the mobility of most of the receptors identified. Potential benefits are most likely to be realised by species with limited mobility and specific habitat requirement. Overall, it is predicted that the sensitivity of fish and shellfish receptors to potential reduction in fishing pressure is considered to be Low and the magnitude is deemed to be Negligible beneficial. The effect will therefore be of **Negligible** adverse significance, which is not significant in EIA terms.

Increased fishing pressure outside the array area

6.11.72 Receptors likely to be affected by an increase in fishing pressure outside the Thanet Extension array area include those demersal fish species targeted by commercial fisheries occurring within Thanet Extension (e.g. plaice and sole). It would not be expected that any changes in fishing activities in this area (should these effects occur at all) would lead to changes in populations of these species.

6.11.73 A reduction in fishing pressure within Thanet Extension may mean increased fishing pressure in areas adjacent to Thanet Extension. However, it is expected that any such increase would have a localised effect on fish populations in the wider study area, with any population level effects minimised by fisheries management measures (e.g. quotas, days at sea etc.).

6.11.74 The impact is predicted to be of a local spatial extent (adjacent to the Thanet Extension array area), long-term duration, continuous and irreversible (within the lifetime of the project). It is predicted that the impact will affect fish and shellfish receptors directly. The magnitude is therefore considered to be Negligible adverse.

6.11.75 With respect to the special protection measures in place upon seabass (paragraph 6.7.6), it is expected that any increase in fishing pressure on this species outside of the array area would similarly be Negligible adverse.

6.11.76 Fish and shellfish receptors in the study area are deemed to be insensitive to this impact and of local to international importance. The sensitivity of these receptors is therefore considered to be Negligible.

6.11.77 Limited displacement of fishing activity within the Thanet Extension array area may lead to increases in fishing activity outside the array area. The extent to which commercial fisheries will be displaced will have a limited effect on fish and shellfish populations in the study area, with fish and shellfish receptors not likely to be sensitive to this change in fishing activity. Overall, it is predicted that the sensitivity of fish and shellfish receptors to displacement of fishing activity from the Thanet Extension array area is considered to be Negligible and the magnitude is deemed to be Negligible. The effect therefore will be of **Negligible** adverse significance, which is not significant in EIA terms.

6.12 Environmental assessment: decommissioning phase

6.12.1 Impacts from decommissioning are expected to be similar to those listed for construction, if project infrastructure is removed from the seabed at the end of the development's operational life. The nature and scale of impacts arising from decommissioning are expected to be of similar, or reduced magnitude to those generated during the construction; certain activities such as piling would not be required.

6.12.2 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. In this case, materials such as cable and scour protection would represent a permanent loss of habitat/ introduction of new habitat greater than that assessed for the 30-year O&M period. However, by this point, introduced habitat would represent a 'new baseline' environment, the removal or disturbance of which may incur a greater environmental effect than leaving *in situ*. If certain parts of the development were left *in situ*, effects dependent on the operation of the wind farm such as operational noise and EMF effects would not occur.

6.12.3 To date, no large OWF has been decommissioned in UK waters. It is anticipated that any future programme of decommissioning would be developed in close consultation with the relevant statutory marine and nature conservation bodies. This would enable the guidance and best practice at the time to be applied to minimise any potential impacts.

6.13 Environmental assessment: cumulative effects

6.13.1 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.

6.13.2 The approach to cumulative assessment for Thanet Extension takes into account the Cumulative Impact Assessment Guidelines issued by RenewableUK in June 2013, together with comments made in response to other renewable energy developments within the Southern North Sea, and PINS 'Advice Note 9: Rochdale Approach'. The renewable energy developments that have informed this approach have been agreed within the Scoping Opinion (PINS, 2017), the suggested tiers, and the Cumulative Impact Assessment conducted for Thanet Extension.

6.13.3 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. There is thus a need to build in some 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.

6.13.4 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).

6.13.5 The projects and plans selected as relevant to the assessment of impacts to fish and shellfish receptors are based upon an initial screening exercise undertaken on a long list. Each project, plan or activity has been considered and scoped in or out on the basis of effect–receptor pathway, data confidence and the temporal and spatial scales involved.

6.13.6 For most potential effects, proposed and planned projects were screened into the cumulative effects assessment within a 12 km buffer of Thanet Extension provided there was a potential effect-receptor pathway. The 12 km buffer was used as this area was considered representative of the wider fish and shellfish habitats in the southern North Sea. Based on tidal ellipses, this is also the maximum range that effects such as increased SSC and associated sediment deposition are likely to occur (Volume 2, Chapter 2: Marine Geology, Oceanography and Physical Processes (Document Ref: 6.2.2)). For the impact of underwater noise, a larger search area was used (100 km), as noise is predicted to have a greater area of effect than the other effects identified (see Table 6.15).

6.13.7 For the purposes of assessing the impact of Thanet Extension on fish and shellfish in the region the cumulative impact assessment technical note submitted with the Scoping Report and forming Volume 1, Annex 3-1: CIA Annex (Document Ref: 6.1.3.1) screens in the following projects and activities presented in Table 6.14, which are illustrated in Figure 6-15. Since the submission of the Thanet Extension PEIR, the Thanet 132 kV Cable Replacement project has been cancelled and has therefore been excluded from the cumulative effects assessment.

6.13.8 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

6.13.9 Thanet Extension considered alongside other projects/ plans currently under construction and/ or those consented but not yet implemented, and/ or those submitted but not yet determined where data confidence for the projects falling within this category is high.

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

Tier 2

6.13.11 All projects included in Tier 1 plus other projects/ plans consented but not yet implemented and/ or submitted applications not yet determined where data confidence for the projects falling into this category is medium.

Tier 3

6.13.12 The above plus projects on relevant plans and programmes (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. This includes, projects for which Scoping Reports have been submitted and data availability is limited and/ or data confidence is low.

6.13.13 The specific projects scoped into this cumulative impact assessment, and the tiers into which they have been allocated are presented in Table 6.14 below. The operational projects included within the table are included due to their completion/ commission subsequent to the data collection process for Thanet Extension and as such not included within the baseline characterisation.

6.13.14 The cumulative Rochdale Envelope will be described in the following table with a column for impact, a column for the scenario (e.g. aggregates sites plus OWFs) and then a scenario for justification/ notes/ assumptions (i.e. fishing can continue in OWFs).

6.13.15 The cumulative Rochdale Envelope is described in Table 6.15.

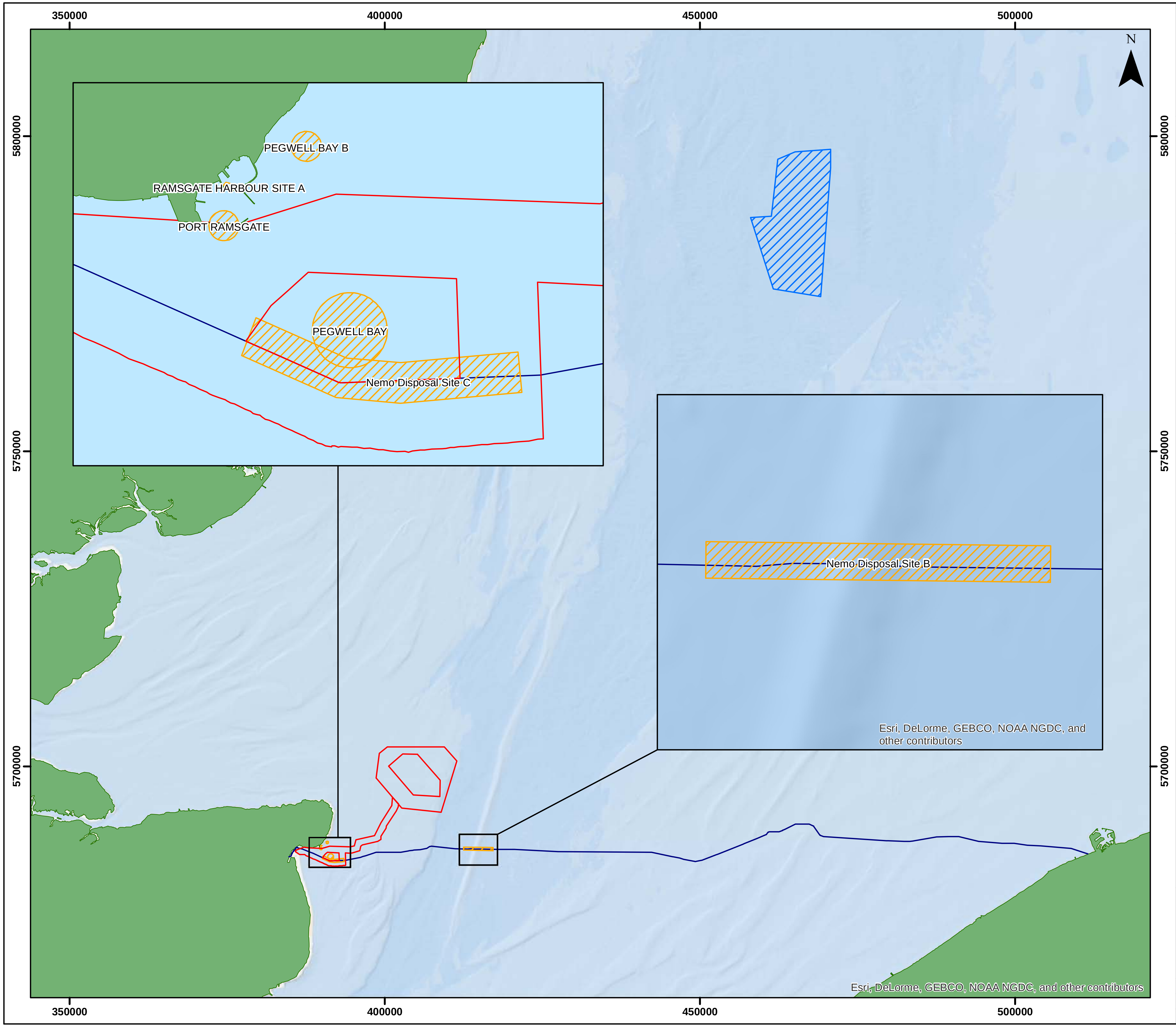
Table 6.14: Projects for cumulative assessment

Development type	Project	Status	Data confidence assessment/ phase	Tier
OWF	East Anglia ONE	Consented	High – Third party project details published in the public domain and confirmed as being 'accurate' by the developer.	Tier 1
Cable installation	Nemo interconnector cable	Under construction	High – Third party project details published in the public domain and confirmed as being 'accurate' by the developer.	Tier 1
Disposal area	Nemo disposal site B	Open	Medium – Third party project details published in the public domain but not confirmed as being 'accurate'.	Tier 1
Disposal area	Nemo disposal site C	Open	Medium – Third party project details published in the public domain but not confirmed as being 'accurate'.	Tier 1
Disposal area	Pegwell Bay	Open	Medium – Third party project details published in the public domain but not confirmed as being 'accurate'.	Tier 2
Disposal area	Pegwell Bay B	Open	Medium – Third party project details published in the public domain but not confirmed as being 'accurate'.	Tier 2
Disposal site	Ramsgate Harbour Site A	Open	Medium – Third party project details published in the public domain but not confirmed as being 'accurate'.	Tier 2
Disposal site	Ramsgate Harbour Site B	Open	Medium – Third party project details published in the public domain but not confirmed as being 'accurate'.	Tier 2

THANET EXTENSION OFFSHORE WIND FARM

Figure 6.15

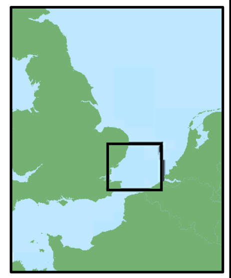
Projects Screened into the Cumulative Assessment



Legend

- Offshore Red Line Boundary
- East Anglia ONE Offshore Wind Farm
- Disposal Sites
- Nemo Cable

Datum: ETRS 1989
Projection: UTM31N



1:600,000 — 0, 6.5, 13 km — 0, 3.5, 7 nm

Drg No	Fig6.15_CumulativeProjects		
Rev	0.1	Date	08/06/2018
By	RM	Layout	N/A

Figure 6.15

Table 6.15: Cumulative Rochdale Envelope

Impact	Scenario	Justification
Cumulative temporary habitat loss as a result of construction activities	*Construction phase* Tier 1: Nemo Interconnector Cable Tier 2 No other projects to consider	Maximum additive temporary habitat loss is calculated within a representative 12 km buffer of Thanet Extension as this area is considered to be a fair representation of fish and shellfish habitats within the wider southern North Sea area. The Nemo Interconnector cable will result in temporary habitat loss of up to 340,000 m^2 in UK waters (within 12 km of Thanet Extension).
Cumulative increases in SSC and associated sediment deposition	*Construction phase* Tier 1: Nemo Interconnector Cable Nemo Disposal Site B Nemo Disposal Site C Tier 2: All projects within Tier 2	The Nemo Interconnector cable has permission to use three disposal sites, with the two sites screened into this cumulative effects assessment having a total permitted disposal volume of 94,308 m^3. The use of the Pegwell Bay and Ramsgate Harbour disposal sites is primarily for the dumping of sediment removed during maintenance dredging. The use of these sites is intermittent and the volumes disposed of are unknown in advance and therefore it is not possible to determine if the use of the sites will overlap with the construction of Thanet Extension. However, while the volumes are likely to be greater, the impacts are likely to be smaller than those predicted for the deposition of drill arisings for Thanet Extension.
Cumulative effects of noise and vibration	*Construction phase* Tier 1: East Anglia ONE Tier 2: No other projects to consider	Maximum potential for interactive effects from underwater noise associated with OWF piling activities is considered within a representative 100 km buffer of the Thanet Extension array area. This larger buffer was used for this impact assessment as effects of underwater noise are expected to occur over a wider area than other impacts. The area within this representative 100 km buffer is considered to be a fair representation of fish and shellfish habitats within the wider southern North Sea area. Although the construction period of East Anglia ONE overlaps with the construction period of Thanet Extension, piling at EA ONE is currently anticipated to take place between April and September 2018, and is therefore outside the construction period for Thanet Extension.
Cumulative long-term habitat loss/ change as a result of the presence of foundations and scour/ cable protection	*O&M phase* Tier 1: Nemo Interconnector Cable Tier 2: No other projects to consider	Maximum additive long-term habitat loss is calculated within a representative 12 km buffer of Thanet Extension as this is considered to be a fair representation of fish and shellfish habitats within the wider southern North Sea area. If cable protection is used, the significance of effect of long-term habitat loss from the Nemo Interconnector has been assessed as minor in UK waters.
Cumulative effects of electromagnetic fields (EMF) from subsea cables	*O&M phase* Tier 1: Nemo Interconnector Cable Tier 2: No other projects to consider	Maximum cumulative effects of EMF from subsea electrical cables within a 12 km buffer of Thanet Extension on fish and shellfish species in this region of the southern North Sea.

Cumulative temporary habitat loss as a result of construction activities

Tier 1

6.13.16 There is potential for cumulative temporary habitat loss as a result of construction activities associated with Thanet Extension and other projects (Table 6.15). For the purposes of this ES, this additive impact has been assessed within a 12 km buffer of Thanet Extension, which is considered to be representative of the habitats of the wider southern North Sea area. The only project identified was the Nemo Interconnector. No Tier 2 or 3 projects have been identified.

6.13.17 The Nemo Interconnector will result in temporary habitat loss of 340,000 m^2 within 12 km of Thanet Extension. Cumulatively with Thanet Extension, this will result in temporary habitat loss of 1,864,187 m^2, although this will not be concurrent; the Nemo Interconnector is scheduled for installation in 2017/ 2018. Construction of Thanet Extension is not proposed until 2019, and there will therefore be no temporal overlap of the construction of Thanet Extension with this project. However, the baseline surveys for Thanet Extension have been undertaken and do not include the effects from this project and therefore cumulative effects of the projects need to be considered.

6.13.18 The cumulative impact of temporary habitat loss is predicted to be of local spatial extent, medium-term duration, intermittent and reversible with a very small proportion of the total loss occurring at any one time. It is predicted that the impact will affect fish and shellfish receptors directly. It is therefore predicted that the impact will be of Low magnitude.

6.13.19 Full discussion of the sensitivity of fish and shellfish to temporary habitat loss is discussed in paragraphs 6.10.3 *et seq*., which conclude that most species have relatively low vulnerability to temporary habitat loss and disturbance. Those species which have specific requirements, such as sandeel and herring, are considered to have greater sensitivity.

6.13.20 Most fish and shellfish receptors in the study area are deemed to be of low vulnerability, high recoverability and of local to international importance. The sensitivity of these receptors is therefore considered to be Low.

6.13.21 Sandeel and herring are deemed to be of high vulnerability, medium recoverability and of regional importance. The sensitivity of these receptors is therefore considered to be Medium.

6.13.22 The maximum sensitivity of receptors in the area is Medium and the magnitude has been assessed as Low. Therefore, the significance of effect from the temporary habitat loss from the installation of Thanet Extension cumulatively with the Nemo Interconnector is **Minor** adverse, which is not significant in EIA terms.

Cumulative increases in SSC and associated sediment deposition

Tier 1

6.13.23 There is potential for cumulative increases in SSC and associated sediment deposition to occur during the construction of Thanet Extension within one tidal excursion (see Volume 2, Chapter 2: Marine Geology, Oceanography and Physical Processes (Document Ref: 6.2.2)). The Tier 1 projects identified are shown in Table 6.15, the projects being the Nemo Interconnector and its B and C disposal sites..

6.13.24 The sediments identified along the Nemo Interconnector route are similar to those identified for Thanet Extension (Nemo Link, 2013) and therefore, sediment disturbed by the installation of this development can be expected to behave in a similar manner to those described for Thanet Extension.

6.13.25 The maximum volume of material displaced from the Nemo Interconnector will be 94,308 m^3 across the two disposal sites screened into this assessment. Cumulatively with Thanet Extension, this may result in the disturbance and deposition of up to 1,358,203 m^3 of sediment. As discussed in paragraphs 6.10.12 *et seq*., this will not happen concurrently; the Nemo Interconnector is scheduled for installation in 2017/ 2018. Construction of Thanet Extension is not proposed until 2021, and there will therefore be no temporal overlap of the construction of Thanet Extension with this project and so it is not expected that there will be any overlap between sediment plumes. Separation distances between the projects will be at least 50 m, except for at any cable crossings, and therefore there will be limited interaction between the sediment deposition from the different projects and it is unlikely that cumulative sediment deposition will exceed 5 cm cumulatively from Thanet Extension and the Nemo Interconnector.

6.13.26 Cumulative effects can also be considered in terms of duration of exposure from multiple projects which do not overlap but happen consecutively. However, as the effects from the projects will be short-lived, there are likely to be significant temporal gaps between the discrete construction events, which will have localised effects. Due to the lack of significant effects identified in section 6.10.12, and the tolerance of fish and shellfish receptors to increases in SSC and sediment deposition, cumulative effects in terms of duration of exposure are not expected.

6.13.27 The magnitude of the cumulative impact from increased SSC and sediment deposition for Tier 1 projects is considered to be Low, due to the limited interaction between the impacts of the projects.

6.13.28 The sensitivity of fish and shellfish to increases in SSC and associated sediment deposition is fully discussed in paragraphs 6.10.12 *et seq*. Most fish and shellfish receptors in the wider southern North Sea area are deemed to be of low vulnerability, high recoverability and of local to international importance. The sensitivity of most receptors is therefore considered to be Low.

6.13.29 Based on the increase in sensitivity of herring eggs to the smothering effects of increased sediment deposition, herring is deemed to be of medium vulnerability, high recoverability and of regional importance, and therefore the sensitivity of the receptor is considered to be Medium.

6.13.30 Overall, it is predicted that the sensitivity of fish and shellfish receptors to cumulative increases in SSC and associated sediment deposition is considered to be Low to Medium, and the magnitude is deemed to be Low. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Tier 2

6.13.31 The Tier 2 projects screened into the cumulative effects assessment are shown in Table 6.15.

6.13.32 It is not known what volumes of sediment, if any, will be deposited at the identified disposal sites, however, as the disposal events are discrete and the disposal areas are wide, it is considered unlikely that the increases in SSC and sediment deposition resulting from the use of the disposal sites combined with the other identified projects will cumulatively exceed the natural variation or the 5 cm smothering baseline to be considered 'light' smothering for the sensitivity assessments. As the use of these sites is intermittent, it is not possible to determine if the use of these sites will overlap with sediment deposition from Thanet Extension.

6.13.33 Cumulative impacts of increased SSC and sediment deposition from the identified Tier 2 sites is expected to be of local spatial extent, short-term duration, intermittent and reversible. The magnitude of impacts from the Tier 2 sites identified is therefore considered to be Low.

6.13.34 The sensitivities of fish and shellfish receptors are as described in paragraphs 6.10.12 *et seq*. and are deemed to be Low to Medium.

6.13.35 Overall, it is predicted that the sensitivity of fish and shellfish receptors to cumulative increases in SSC and associated sediment deposition is considered to be Low to Medium, and the magnitude is deemed to be Low. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Cumulative effects from construction noise and vibration

Tier 1

6.13.36 There is potential for cumulative effects from construction (piling) noise to occur during the construction of Thanet Extension. The only Tier 1 project identified within the 100 km buffer that will be under construction at the same time as Thanet Extension is East Anglia ONE (Table 6.15), although piling at East Anglia ONE is currently anticipated to take place between April and September 2018, and is therefore outside the construction period for Thanet Extension (2021 – 2023). However, the baseline assessment for Thanet Extension has not considered effects from East Anglia ONE, and therefore there is the need for the consideration of cumulative effects. No Tier 2 or 3 projects have been identified.

6.13.37 The greatest risk of cumulative impacts of underwater noise on fish and shellfish species has been identified as being that produced by impact piling during the construction phase at other OWF sites in the wider study area. Injury or mortality of fish from piling noise would not be expected to occur cumulatively due to the small range within which potential injury effects would be expected (i.e. predicted to occur within a few hundred metres of piling activity within each of the OWF projects) and the large distances between Thanet Extension and East Anglia ONE. Cumulative effects of underwater noise are therefore discussed in the context of behavioural effects, particularly on spawning or nursery habitats.

6.13.38 The impacts of underwater noise from piling during the construction of Thanet Extension are discussed in paragraphs 6.10.34 *et seq*. Similarly, for East Anglia ONE, mortality of fish would be unlikely to occur except in very close proximity to piling. Fish may be expected to avoid an area around the foundation of 4 – 9 km for fish in the mid-water column, and 2 – 4 km for fish at the seabed (ERM, 2012).

6.13.39 Due to the lack of temporal overlap (piling at East Anglia ONE is expected to take place in 2018, and piling at Thanet Extension will not take place until 2021), there is not considered to be a cumulative impact of these two projects on fish and shellfish receptors. As evidenced by McCauley *et al*. (2000), it is expected that fish will resume to normal behaviour and distribution well within this time period, and as such, significant effects are not expected to occur in terms of cumulative duration of exposure. The cumulative impact of underwater noise on fish and shellfish receptors is predicted to be of regional spatial extent, short-term duration, intermittent and reversible. It is predicted that the impact will affect the receptor directly. The magnitude of the cumulative impact is therefore considered to be Low.

6.13.40 The sensitivities of fish and shellfish receptors to underwater noise are discussed in paragraphs 6.10.34 *et seq*. Fish injury as a result of piling noise would only be expected within the immediate vicinity of piling operations, and the area within which effects on fish eggs and larvae would be expected is similarly small.

6.13.41 Behavioural effects on fish species as a result of piling noise are predicted to be dependent on the nature of the receptors. The predicted behavioural response may be sufficient to result in temporary avoidance by some species, with some temporary redistribution of fish in the wider area between the affected areas. Between piling events, fish may resume normal behaviour and distribution (McCauley *et al*. (2000). However, there are some uncertainties over the response of fish to intermittent piling over a prolonged period of time and the extent that behavioural reactions will cause a negative effect in individuals (Mueller-Blenke *et al*., 2010).

6.13.42 As discussed in paragraphs 6.10.34 *et seq*., the proportions of fish spawning and nursery habitats predicted to be affected by underwater noise from piling operations are expected to be small, particularly in the context of available spawning and nursery habitats in the wider area (particularly for pelagic spawning species).

6.13.43 Herring, cod and whiting are considered to be of medium vulnerability, high recoverability and of regional to international importance. The sensitivity of these receptors is therefore considered to be Medium.

6.13.44 All other fish and shellfish receptors are considered to be of low vulnerability, high recoverability and of local to international importance. The sensitivity of these receptors is therefore considered to be Low.

6.13.45 Overall, it is predicted that the sensitivity of fish and shellfish receptors is Low to Medium and the magnitude is deemed to be Low. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Cumulative long-term habitat loss/change as a result of the presence of foundations and scour/cable protection

Tier 1

6.13.46 Cumulative long-term habitat loss is predicted to occur as a result of the presence of Thanet Extension infrastructure and cable installation projects identified in Table 6.15 (Nemo Interconnector only). Long-term habitat loss may result from the physical presence of foundations, scour protection and cable protection (see paragraphs 6.11.3 *et seq*.). Conversely, the introduction of hard substrate into areas of predominantly soft sediment has the potential to alter fish and shellfish community composition including potentially acting as fish aggregation devices (see paragraphs 6.11.13 *et seq.*). No Tier 2 or 3 projects have been identified.

6.13.47 If cable protection is used for the Nemo Interconnector, the significance of effect of habitat loss/ change from the Nemo Interconnector has been assessed as being not significant. While the impact is permanent and irreversible (during the lifetime of the project), the area affected is highly localised and small compared to the wider region, and is small relative to the habitat loss/ change associated with Thanet Extension. The impact will therefore be of Negligible magnitude.

6.13.48 The sensitivity of fish and shellfish receptors is discussed in paragraphs 6.11.3 *et seq*. The sensitivity of most fish and shellfish receptors is deemed to be Low, while the sensitivity of species with specific habitat requirements (i.e. herring and sandeel) is considered to be Medium.

6.13.49 Cumulative long-term habitat loss will represent a long-term and continuous impact throughout the lifetime of the projects. However, only a relatively small proportion of the fish and shellfish habitats in the wider area are likely to be affected. Overall, it is predicted that the sensitivity of fish and shellfish receptors is considered to be Low to Medium, and the magnitude is deemed to be Negligible. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

Cumulative effects of electromagnetic fields (EMF) from subsea cables

Tier 1

6.13.50 The cumulative effect assessment considers the effects of EMF emitted by subsea cables from Thanet Extension and other subsea electrical cables as identified in Table 6.15 (Nemo Interconnector only). No Tier 2 or 3 projects have been identified.

6.13.51 EMF, comprising magnetic (B) and induced electrical (iE) fields, have the potential to affect fish and shellfish receptors. A variety of design and installation factors have the potential to affect EMF levels in the vicinity of electrical cables, including current flow, distance between cables, cable orientation relative to the Earth's magnetic field (DC only), cable insulation, number of conductors, configuration of the cable and burial depth as well as well as whether the subsea cabling systems are AC or DC. It has not been possible to determine the exact specifications of the electrical cables for each of the projects predicted to have a cumulative effect on fish and shellfish receptors, though predictions have been made for the cumulative length of electrical cables associated with the projects identified in Table 6.15. The maximum length of cables predicted within a 12 km buffer of Thanet Extension is 35 km from the Nemo Interconnector, resulting in a cumulative length (including Thanet Extension) of up to 215 km.

6.13.52 The strength of the magnetic field (and consequently the induced electrical fields) decreases rapidly horizontally and vertically with distance from the source (i.e. in the order of 10 m each side of the cable, assuming burial to depths of 1 m (Normandeau *et al*., 2011). As such, any effects of EMF on fish and shellfish receptors are predicted to be extremely limited in extent, only affecting a relatively small proportion of the fish and shellfish habitat available in the southern North Sea.

6.13.53 The impact is predicted to be of highly localised extent, long-term duration, continuous and irreversible (within the lifetime of the project). The magnitude of the impact is therefore considered to be Low.

6.13.54 The effects of EMF on fish and shellfish are discussed in paragraphs 6.11.33 *et seq*., with particular focus on the sensitivity of elasmobranchs. Any EMF from electrical cabling is likely to attenuate rapidly with distance from the cable, resulting in a localised effect in the order of a few metres, if any effects occur at all.

6.13.55 Elasmobranch species in the study area are deemed to be of medium vulnerability and local importance. The sensitivity of these receptors is therefore considered to be Low.

6.13.56 All other fish and shellfish receptors are deemed to be of low vulnerability and are of local to regional importance. The sensitivity of these receptors is therefore considered to be Low.

6.13.57 Although there is potential for cumulative effects of EMF as a result of electrical cables from other projects, cumulative effects on fish behaviour are not expected to be greater than those assessed for Thanet Extension, due to the limited extent over which any behavioural effects would be expected (i.e. within metres of the cable). Overall, it is predicted that the sensitivity of fish and shellfish receptors is considered to be Low and the magnitude is considered to be Low. The effect will therefore be of **Minor** adverse significance, which is not significant in EIA terms.

6.14 Inter-relationships

6.14.1 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 turbines, vessels and decommissioning).
- 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 fish and shellfish – direct habitat loss or disturbance, sediment plumes, underwater noise and EMF 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.

6.14.2 Volume 2, Chapter 14: Inter-relationships (Document Ref: 6.2.14) provides a description of the likely inter-related effects arising from Thanet Extension on fish and shellfish ecology. Potential inter-relationships exist between fish and shellfish ecology and:

- Marine Geology, Oceanography and Physical Processes;
- Benthic Subtidal and Intertidal Ecology;
- Commercial fisheries;
- Marine Mammal Ecology; and
- Offshore Ornithology.

6.15 Mitigation

6.15.1 Given the generally low level of significance ascribed to the predicted impacts on fish and shellfish ecology as a result of the construction, O&M and decommissioning of Thanet Extension, it is concluded that no specific mitigation is required. Embedded mitigation is identified in Table 6.8.

6.15.2 It should be noted that for effects of construction noise and vibration on fish and shellfish receptors, mitigation that is already being applied for marine mammals (such as soft-start piling), will also act to mitigate against potential effects to fish and shellfish.

6.16 Transboundary statement

6.16.1 No transboundary effects are predicted to result from the construction, O&M and decommissioning of Thanet Extension.

6.17 Summary of effects

6.17.1 This chapter has investigated the potential effects on fish and shellfish ecology receptors arising from Thanet Extension. The range of potential impacts and associated effects considered has been informed by Scoping responses, as well as reference to existing policy and guidance. The impacts considered include those brought about directly (e.g. by the presence of infrastructure at the seabed), as well as indirectly (e.g. through electromagnetic fields). Potential impacts considered in this chapter are listed below in Table 6.16.

6.17.2 Cumulative impacts were also considered and an assessment was carried out looking at the potential for interaction of direct and indirect impacts as a result of the combined activities of the construction of Thanet Extension and other industrial activities in the study area. These include aggregate extraction operations, construction of OWFs as well as dredge disposal activities.

6.17.3 These potential impacts have been investigated using a combination of methods including analytical techniques, the existing evidence base and numerical modelling. In accordance with the requirements of the Rochdale Envelope approach to EIA, the worst-case characteristics of the proposed development have been considered thereby providing a highly conservative assessment.

6.17.4 Even adopting the conservative assessment approach described above, it has been found that for all of the fish and shellfish ecology receptors included in this assessment, the level of effect significance is Minor or Negligible (Table 6.16). The potential effects to fish and shellfish ecology receptors are therefore Not Significant in terms of the EIA Regulations (Volume 1, Chapter 3: EIA Methodology (Document Ref: 6.1.3)).

6.17.5 Table 6.16 presents a summary of the effects of the proposed development during the construction, O&M and decommissioning phases on fish and shellfish ecology at the Thanet Extension site.

Table 6.16: Summary of predicted impacts of Thanet Extension

Description of impact	Impact	Possible mitigation measures	Residual impact
Construction			
Direct damage (e.g. crushing) and disturbance to mobile demersal and pelagic fish and shellfish species arising from construction activities.	**Minor** adverse	N/A	**Minor** adverse
Temporary localised increases in suspended sediment concentrations and smothering.	**Minor** adverse	N/A	**Minor** adverse
Direct and indirect seabed disturbances leading to the release of sediment contaminants.	**Minor** adverse	N/A	**Minor** adverse
Mortality, injury, behavioural changes and auditory masking arising from noise and vibration.	**Minor** adverse	N/A	**Minor** adverse
O&M			
Long-term loss of habitat due to the presence of turbine foundations, scour protection and cable protection.	**Minor** adverse	N/A	**Minor** adverse
Increased hard substrate and structural complexity as a result of the introduction of turbine foundations, scour protection and cable protection.	**Minor** adverse	N/A	**Minor** adverse
Underwater noise as a result of operational turbines.	**Negligible** adverse	N/A	**Negligible** adverse
Electromagnetic fields (EMF) effects arising from cables.	**Minor** adverse	N/A	**Minor** adverse
Direct disturbance resulting from maintenance during operation.	**Negligible** adverse	N/A	**Negligible** adverse
Increases in SSCs and associated sediment deposition as a result of O&M activities.	**Minor** adverse	N/A	**Minor** adverse
Indirect disturbance resulting from the accidental release of pollutants.	**Minor** adverse	N/A	**Minor** adverse
Potentially reduced fishing pressure within the Thanet Extension array area and increases fishing pressure outside the array area due to displacement.	**Negligible** adverse	N/A	**Negligible** adverse
Decommissioning			
Impacts from decommissioning are expected to be similar to those listed 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 for decommissioning would be similar to those described for the operational phase, except where effects are dependent on the operation of the wind farm (e.g. operational noise and EMF from operational cables).			
Cumulative effects			
Cumulative temporary habitat loss as a result of construction activities.	**Minor** adverse	N/A	**Minor** adverse

Description of impact	Impact	Possible mitigation measures	Residual impact
Cumulative increases in SSC and associated sediment deposition.	**Minor** adverse	N/A	**Minor** adverse
Cumulative effects from construction noise and vibration.	**Minor** adverse	N/A	**Minor** adverse
Cumulative long-term habitat loss/ change as a result of the presence of foundations and scour/ cable protection.	**Minor** adverse	N/A	**Minor** adverse
Cumulative effects of electromagnetic fields (EMF) from subsea cables.	**Minor** adverse	N/A	**Minor** adverse

6.18 References

- ABP Research (1999). Good Practice Guidelines for Ports and Harbours Operating within or near UK European Marine Sites. English Nature, UK Marine SACs Project. pp 120.
- ABP Research (2007). MEPF 04/04: Predictive Modelling- Coupling Physical and Ecological Models: Final Report, MEPF 04/04, R/3482/1, DEFRA.
- Andersson, M. and Öhman, M. (2010) Fish and sessile assemblages associated with wind-turbine constructions in the Baltic Sea. Marine and Freshwater Research 61, 642-650.
- Andersson, M. H. (2011). Offshore Wind Farms - Ecological Effects of Noise and Habitat Alteration on Fish. PhD Thesis, Department of Zoology, Stockholm University. http://su.diva-portal.org/smash/record.jsf?pid=diva2:391860 [Accessed: 12/2011].
- Aneer, G. (1989). Herring (*Clupea harengus* L.) spawning and spawning ground characteristics in the Baltic Sea. Fisheries Research 8(2), pp.169-195.
- Bergström, L., Sundqvist, F., Bergström, U. (2013). Effects of an offshore wind farm on temporal and spatial patterns in the demersal fish community. Marine Ecology Progress Series 485, 11pp.
- BERR (2008). Review of Cabling Techniques and Environmental Effects Applicable to the Offshore Wind Farm Industry – Technical Report. http://webarchive.nationalarchives.gov.uk/+/http:/www.berr.gov.uk/files/file43527.pdf [Accessed: 07/2017].
- Birklund, J. and Wijsman, J. W. M. (2005). Aggregate Extraction: A Review on the Effects on Ecological Functions. Report Z3297/10 SAWDPIT Fith Framework Project no EVK3-CT-2001-00056. http://www.fws.gov/filedownloads/ftp_gis/R4/Louisiana_ES/Walther/Dredge%20holes/sandpitecology.pdf [Accessed: 07/2017].
- Bohnsack, J.A. and Sutherland, D.L. (1985). Artificial reef research: a review with recommendations for future priorities. *Bulletin of marine science*, *37*(1), pp.11-39.
- Bohnsack, J. A. (1989). Are High Densities of Fishes at Artificial Reefs the Result of Habitat Limitation or Behavioural Preference? B. Mar. Sci., 44(2), pp. 631-645.
- Boles, L.C. and Lohmann, K.J. (2003). True Navigation and Magnetic Maps in Spiny Lobsters. Nature 421: 60-63.
- Bolle, L. J., de Jong, C. A. F., Bierman, S., de Hann, D., Huijer, T., Kaptein, D., Lohman, M., Tribuhl, S., van Beek, P., van Damme, C. J. G., van den Berg, F., van der Heul, J., van Keeken, O., Wessels, P. and Winter, E. (2011) Effect of Piling Noise on the Survival of Fish Larvae (Pilot Study). IMARES Report number CO92/11.
- Bolle, L. J., de Jong, C. A. F., Bierman, S., van Beek, P., van Keeken, O., Wessels, P., van Damme, C. J. G., Winter, E., de Hann, D. and Dekeling, R. P. A. (2012) Common Sole Larvae Survive High Levels of Pile-Driving Sound in Controlled Exposure Experiments. PLoS ONE, 7(3), pp.e33052 doi:10.1371/journal.pone.0033052.
- Bunn, N.A., Fox, C.J. and Webb, T. (2000) A Literature Review of Studies on Fish Egg Mortality: Implications for the Estimation of Spawning Stock Biomass by the Annual Egg Production Method. Cefas Science Series Technical Report No 111, pp 37.
- Byrne Ó Cléirigh Ltd, Ecological Consultancy Services Ltd (EcoServe) and School of Ocean and Earth Sciences, University of Southampton (2000) Assessment of Impact of Offshore Wind Energy Structures on the Marine Environment. Prepared for the Marine Institute.
- Cefas (2004). Offshore Wind Farms: Guidance note for Environmental Impact Assessment in respect of FEPA and CPA requirements. Version 2.
- Chartered Institute for Ecology and Environmental Management (CIEEM) (2010). Guidelines for Ecological Impact Assessment in Britain and Ireland, Marine and Coastal.
- CIEEM (2016) Guidelines for Ecological Impact Assessment in the UK and Ireland. Terrestrial, Freshwater and Coastal. Chartered Institute of Ecology and Environmental Management. Second Edition. January 2016.
- CMACS (Centre for Marine and coastal studies). (2003) A Baseline Assessment of Electromagnetic fields Generated by Offshore Wind farm Cables. Report No. COWRIE EMF-01-2002, 66. Centre for Marine and Coastal Studies, Birkenhead, UK.
- CMACS (2016) Thanet Extension Offshore Wind Farm. Fish ecology characterisation strategy. Prepared by Centre for Marine and Coastal Studies Ltd for Vattenfall. 25pp.
- CLEAN SEAS ENVIRONMENT MONITORING PROGRAMME (CSEMP), 2012a. CSEMP Assessment Criteria for Metals in Sediment. Marine Environment Monitoring and Assessment National database (MERMAN). https://www.bodc.ac.uk/projects/data_management/uk/merman/assessments_and_data_access/csemp/ [Accessed: 07/2017].
- Coull, K.A., Johnstone, R. and Rogers, S.I. (1998). Fisheries Sensitivity Maps in British Waters Published and distributed by UKOOA Ltd., Aberdeen, 63 pp.
- Davies, I.M., 2004. Background/reference Concentrations (BRCs) for the UK, Fisheries Research Services Contract Report No 05/04. http://www.scotland.gov.uk/Uploads/Documents/0504CollCon.pdf [Accessed: 11/2014].
- DECC (Department for Energy and Climate Change) (2011a). Overarching National Policy Statement for Energy (EN-1). Presented to Parliament pursuant to Section 5(9) of The Planning Act 2008. July 2011. London: The Stationery Office.
- DECC (Department for Energy and Climate Change) (2011b). National Policy Statement for Renewable Energy Infrastructure (EN-3). Presented to Parliament pursuant to Section 5(9) of The Planning Act 2008. July 2011. London: The Stationery Office.

- DECC (2011c) Overarching National Policy Statement for Electricity Networks Infrastructure (NPS EN-5). Department of Energy and Climate Change. July 2011. 32pp.
- Desprez, M. (2000) Physical and biological impact of marine aggregate extraction along the French coast of the eastern English Channel: short and long-term post-dredging restoration. ICES Journal of Marine Science 57, 1428-1438.
- Ellis, J.R., Milligan, S.P., Readdy, L., Taylor, N. and Brown, M.J. (2012). Spawning and nursery grounds of selected fish species in UK waters. Cefas Scientific Series Technical Report 147.
- EMU (2004). Subsea Cable Decommissioning – A Limited Environmental Appraisal. Report commissioned by British Telecommunications plc, Cable and Wireless and AT&T, Report no. 04/J/01/06/0648/0415, available from UKCPC.
- EMU (2008a) Barrow Offshore Wind Farm Monopile Ecological Survey. Report No 08/J/1/03/1321/0825. Report prepared on behalf of Narrow Offshore Wind Ltd. December 2008.
- EMU (2008b) Kentish Flats Offshore Wind Farm Turbine Foundation Faunal Colonisation Diving Survey. Report No 08/J/1/03/1034/0839. Prepared on behalf of Kentish Flats Ltd. November 2008.
- Environmental Resource Management (2012). East Anglia ONE Offshore Wind Farm Environmental Statement.
- Fugro Group (2017). Environmental Investigation Report Thanet Extension Offshore Wind Farm Benthic Characterisation Report. UK Continental Shelf, North Sea. Report No. GE051-R3.
- Gill, A. B., Gloyne-Phillips, I., Neal, K. J. and Kimber, J. A. (2005) The Potential Effects of Electromagnetic Fields Generated by Sub-Sea Power Cables Associated with Offshore Wind Farm Developments on Electrically and Magnetically Sensitive Marine Organisms – A Review. COWRIE 1.5 Electromagnetic Fields Review.
- Gill, A.B., Huang, Y., Gloyne-Philips, I., Metcalfe, J., Quayle, V., Spencer, J. and Wearmouth, V. (2009) COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2: EMF-Sensitive Fish Response to EM Emissions from Sub-Sea Electricity Cables of the Type used by the Offshore Renewable Energy Industry. COWRIE-EMF-1-06.
- Gill, A.B., and Bartlett, M. (2010) Literature Review on the Potential Effects of Electromagnetic Fields and Subsea Noise from Marine Renewable Energy Developments on Atlantic Salmon, Sea Trout and European Eel. Scottish Natural Heritage, Commissioned Report No. 401. (Sutton and Boyd, 2009).
- Griffin, F.J., Smith, H.S., Vines, C.A., Cherr, G.N. (2009) Impacts of suspended sediments on fertilization embryonic development, and early life stages of the Pacific Herring, *Clupea pallasi*. The Biological Bulletin, 216, pp. 175-187.
- Hawkins, A. (2006) Effects on fish of pile driving, wind turbines, and other sources. J. Acoust. Soc. Am., 119, pp. 3283.
- Hawkins, A. (2009) The impact of pile driving upon fish. Proc. Inst. Acoustics, vol.31. pt.1, pp. 72-79.
- Hawkins, A. D., Roberts L., and S. Cheesman (2014a) Responses of free-living coastal pelagic fish to impulsive sounds, J. Acoust. Soc. Am., 135, PP3101-3116
- Hawkins, A. D., Pembroke, A. E., and Popper A., N. (2014b) Information gaps in understanding the effects of noise on fishes and invertebrates, Rev. Fish Biol. Fisheries, http://dx.doi.org/10.1007/s11160-014-9369-3, Springer International Publishing.
- Hawkins, A. D. and Popper, A. N. (2016) A sound approach to assessing the impact of underwater noise on marine fishes and invertebrates. ICES Journal of Marine Science, 74 (3): 635-651.
- Hvidt, C. B., Bech, M., & Klaustrup, M. (2004). Monitoring programme-status report 2003. Fish at the cable trace. Nysted offshore wind farm at Rødsand. Bioconsult.
- Hvidt, C.B., Bech, M., and Klaustrup, M. (2003). Monitoring programme-status report 2003. Fish at the cable trace. Nysted offshore wind farm at Rodsand, Bioconsult.
- International Council for the Exploration of the Sea (ICES), Copenhagen. International Herring Larval Survey (IHLS) data 2005 – 2015. http://eggsandlarvae.ices.dk/Download.aspx [Accessed: 07/2017].
- Jensen, H., Kristensen, P.S., Hoffmann, E. (2004) Sandeels in the wind farm area at Horns Reef. Report to ELSAM, August 2004. Danish Institute for Fisheries Research, Charlottenlund.
- Jensen, H., Rindorf, A., Wright, P.J. and Mosegaard, H. (2010). Inferring the location and scale of mixing between habitat areas of lesser sandeel through information from the fishery. ICES Journal of Marine Science, 68 (1), p42.
- Judd, A. (2012). Guidelines for data acquisition to support marine environmental assessments of offshore renewable energy projects. Cefas contract report: ME5403 – Module 15 submitted to Defra and the MMO.
- Kiorboe, T.E., Frantsen, C., Sorensen, G. (1981). Effects of suspended sediment on development and hatching of herring (Clupea harengus) eggs. Estuarine and Coastal Shelf Science: 13.
- Krone, R. Gutowa, L. Joschko, TJ. Schröder, A. (2013). Epifauna dynamics at an offshore foundation Implications of future wind power farming in the North Sea. Marine Environmental Research, 85, 1-12.

- Love *et al*., (2016). Renewable Energy *in situ* Power Cable Observation. US Department of the Interior, Bureau of Ocean Energy Management (BOEM), Pacific OCS Region, Camarillo, CA. OCS Study 2016-008.
- Madsen, P. T. (2005) Marine Mammals and Noise: Problems with Root Mean Square Sound Pressure for Transients", J. Acoust. Soc. Am., 117, pp. 3952-3956.
- McCauley, R. D., Fewtrell, J., Duncan, A. J., Jenner, C., Jenner, M-N., Penrose, J. D., Prince, R. I. T., Adhitya, A., Murdoch, J. and McCabe, K. (2000) Marine Seismic Surveys – A Study of Environmental Implications. Appea Journal, pp. 692-707.
- Messieh, S.N., Wildish, D.J., Peterson, R.H. (1981). Possible impact from dredging and spoil disposal on the Miramichi Bay herring fishery. Canadian Technical Report on Fisheries and Aquatic Science, 1981. 1008: 33.
- Mueller-Blenkle, C., McGregor, P.K., Gill, A.B., Andersson, M.H., Metcalfe, J., Bendall, V., Sigray, P., Wood, D.T. and Thomsen, F., (2010). Effects of pile-driving noise on the behaviour of marine fish.
- Neal K. and Wilson E. (2008). Cancer pagurus Edible crab. Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme. http://www.marlin.ac.uk/speciesfullreview.php?speciesID=2872 [Accessed: 07/2017].
- Nedwell, J. R., Parvin, S. J., Edwards, B., Workman, R., Brooker, A. G. and Kynoch, J. E. (2007) Measurement and Interpretation of Underwater Noise During Construction and Operation of Wind farms in UK waters, Subacoustech Report No. 544R0738 to COWRIE Ltd. ISBN: 978-0-9554279-5-4.
- Nemo Link UK Environmental Statement (2013). PMSS Document Reference: 29689.
-
- Normandeau (Normandeau Associates, Inc.), Exponent Inc., T. Tricas, T. and Gill, A. (2011). Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Regulation, and Enforcement, Pacific OCS Region, Camarillo, CA.OCS Study BOEMRE 2011-09. https://www.boem.gov/ESPIS/4/5115.pdf [Accessed: 2017].
- Ocean Ecology Limited (2016). Thanet Extension Offshore Wind Farm Site Characterisation Autumn Fish Survey Report. Report No. VATTE1116_SR, 53 pp.
- Ocean Ecology Limited (2017). Thanet Extension Offshore Wind Farm Site Characterisation Spring Fish Survey Report 2017. Report No. VATTE0517_SR, 55 pp.
- Offshore Renewables Joint Industry Programme (ORJIP) (2018). Impacts on fish from piling at offshore wind sites: collating population information, gap analysis and appraisal of mitigation options.
- OSPAR (2005). 2005 Assessment of data collected under the Co-ordinated Environmental Monitoring Programme (CEMP). ISBN 1-904426-77-8. Available from: https://www.ospar.org/documents?v=7017 [Accessed July 2017].
- OSPAR Guidance on Envrionmental Considerations for Offshore Wind Farm Development (2008). Reference No: 2008-3. https://www.ospar.org/documents?d=32631 [Accessed: 07/2017].
- Pearson, W. H., Skalski, J. R. and Malme, C. I. (1992) Effects of Sounds from a Geophysical Survey Device on Behaviour of Captive Rockfish (Sebastes spp.). Can. J. Fish. Aquat. Sci., 49, pp. 1343-1355.
- Peña, H., Handegard, N.O., Ona, E. (2013) Feeding herring schools do not react to seismic air gun surveys. *ICES J Mar Sci* 2013; 70 (6): 1174-1180. doi: 10.1093/icesjms/fst079
- Popper, A. N., Salmon, M. and Horch, K. W. (2001) Acoustic detection and communication by decapod crustaceans. Journal of Comparative Physiology A, 187 (2): 83-89.
- Popper, A. N., Hawkins, A. D., Fay, R. R., Mann, D., Bartol, S., Carlson, Th., Coombs, S., Ellison, W. T., Gentry, R., Hal vorsen, M. B., Lokkeborg, S., Rogers, P., Southall, B. L., Zeddies, D. G. and Tavolga, W. N. (2014) ASA S3/SC1.4 TR-2014 Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI. Springer and ASA Press, Cham, Switzerland.
- Hawkins, A. D., Pembroke, A. E., and Popper A., N. (2014) Information gaps in understanding the effects of noise on fishes and invertebrates, Rev. Fish Biol. Fisheries, http://dx.doi.org/10.1007/s11160-014-9369-3, Springer International Publishing.
- Popper, A. N. and Hastings, M. C. (2009). The Effects of Anthropogenic Sources of Sound on Fishes. Journal of Fish Biology, 75, pp. 455-489.
- Research Council of Norway (2012). *Long-term Effects of Discharges to Sea from Petroleum-Related Activities. The Results of Ten Years of Research.* A sub-programme under the Ocean and Coastal Areas (Havkyst) programme, PROOFNY and the concluded PROOF research programme. ISBN 978-82-12-03027-5.
- Roberts, L., Cheesman, S., Elliott, M., and Breithaupt, T. (2016) Sensitivity of Pagurus bernhardus (L.) to substrate-borne vibration and anthropogenic noise. Journal of Experimental Marine Biology and Ecology, 474: 185–194.
- Rogers, S.I., Millner, R.S., and Mead, T.A. (1998). The distribution and abundance of young fish on the east and south coast of England (1981 to 1997). Cefas Science Series Technical Report Number 108.
- Rogers, S. and Stocks, R. (2001). Strategic Environmental Assessment – SEA2 Technical Report 003 – Fish and Fisheries.

- Royal Haskoning (2013a) Thanet OWF second post-construction fish and epibenthic survey.
- Royal Haskoning (2016) Scoping Report. Thanet Extension Offshore Wind Farm Environmental Impact Assessment Report to Inform Scoping. https://infrastructure.planninginspectorate.gov.uk/projects/south-east/thanet-extension-offshore-wind-farm/
- Sand, O., Enger P. S., Karlsen H. E. and Knudesen, F. R. (2001) Detection of Infrasound in Fish and Behavioural Responses to Intense Infrasound in Juvenile Salmonids and European Silver Eels: A Mini Review, Am. Fish Soc. Symp. 26, pp. 183 - 193.
- Sigray, P. and Andersson, M.H. (2011) Particle Motion Measured at an Operational Wind Turbine in Relation to Hearing Sensitivity in Fish. J. Acoustic Soc. Am., 130(1) pp.200-207.
- Tasker, M. L., Amundin, M., Andre, M., Hawkins, A., Lang, W., and Merck, T. (2010) Marine Strategy Framework Task Group 11 Report and Other Forms of Energy. Underwater noise. Group. doi:10.2788/87079.
- Thanet Offshore Wind Farm Environmental Statement (2005). Thanet Offshore Wind Limited.
- The Planning Inspectorate (2017) Scoping Opinion. Proposed Thanet Extension Offshore Wind Farm. https://infrastructure.planninginspectorate.gov.uk/projects/south-east/thanet-extension-offshore-wind-farm/ [Accessed: 07/2017]
- Tougaard, J. and Henriksen, O. D. (2009) Underwater Noise Form Three Types of Offshore Wind Turbines: Estimation of Impact Zones for Harbor Porpoises and Harbor Seals. J. Acoust. Soc. Am., 125, pp. 3766-3773.
- Ueno, S.P., Lovsund, P. and Ober, P.A. (1986) Effect of Time-Varying Magnetic Fields on the Action Potential in Lobster Giant Axon. Medical and Biological Engineering and Computing 24.
- UNEP (UNITED NATIONS ENVIRONMENTAL PROGRAMME). (1990). *State of the Marine Environment in the ROPME Sea Area*. UNEP Regional Seas Reports and Studies. NO.112 Rev 1.
- van Deurs, M. Grome, T. M. Kaspersen, M. Jensen, H. Stenberg, C. Sørensen, T. K. Støttrup, J. Warnar, T. Mosegaar, H. (2012). Short and Long-term Effects of an Offshore Wind Farm on Three Species of Sandeel and their Sand Habitat. Marine Ecology Progress Series, 458: 169-180.
- Von Nordheim, L., Kotterba, P., Moll, D., Polte, P. (2018). Impact of spawning substrate complexity on egg survival of Atlantic Herring (*Clupea harengus* L.) in the Baltic Sea. Estuaries and Coasts 41(2), pp 549-559.
- Wale, M. A., Simpson, S. D., and Radford, A. N. (2013). Size-dependent physiological responses of shore crabs to single and repeated playback of ship noise. Biology Letters, 9: 20121194.
- Wahlberg, M., & Westerberg, H. (2004). Sovjetiske ubåde eller pruttende sild?. Fisk og Hav, 57, 12-21.
- Wahlberg, M. and Westerberg, H. (2005) Hearing in Fish and their Reactions to Sounds from Offshore Wind Farms. Mar.Ecol. Prog. Ser., 288, pp. 295 – 309.
- Westerhagen, H. V (1988) Sublethal Effects of Pollutants on Fish Eggs and Larvae. In: Fish Physiology. Volume 11, Part A, pp 253-234. Academic Press, New York.
- Westerburg, H., and Langenfelt, I. (2008) Sub-sea power cables and the migration behaviour of the European eel. Fisheries Management and Ecology, 15, 369-375.
- Whalley, C., Rowlatt, S., Bennet, M. & Lavell. D. (1999). Total Arsenic in Sediments from the Western North Sea and the Humber Estuary. *Marine Pollution Bulletin*, 38, (5), pp. 394-400.
- Wilber, D. H., Clarke, D. G. (2001) Biological effects of suspended sediments: A review of suspended sediment impacts on fish and shellfish with relation to dredging activities in estuaries. *North American Journal of Fisheries Management*, 21(4), pp 885 – 875.
- Wilhelmsson, D. and Malm, T. (2008). Fouling assemblages on offshore wind power plants and adjacent substrata. *Estuarine, Coastal and Shelf Science* 79(3) pp 459-466.