Thanet Offshore Wind Farm

Annual Monitoring Report 2013

Version 3

23 October 2013

A company of Royal Haskoning

A COMPANY OF

ROYAL HASKONING

HASKONING UK LTD.
INDUSTRY & ENERGY

Rightwell House
Bretton
Peterborough PE3 8DW
United Kingdom

+44 1733 334455	Telephone
	Fax
info@peterborough.royalhaskoning.com	E-mail
www.royalhaskoning.com	Internet

Document title	Thanet Offshore Wind Farm
Document short title	Annual Monitoring Report 2013
Status	Version 3
Date	23 October 2013
Project name	Thanet Offshore Wind Farm
Project number	9X1738
Client	Thanet Offshore Wind Limited
Reference	9W4969/R/PBor

Royal HaskoningDHV
Enhancing Society Together

EXECUTIVE SUMMARY

The Thanet Offshore Wind Farm is located in the Thames Estuary, 11.3km from Foreness Point in Kent. The export cables come ashore at Pegwell Bay and run for 2.2km to the existing substation site at Richborough where connection to the National Grid distribution network is made. The wind farm consists of 100 turbines which have a maximum output of 300MW.

Construction of the Thanet Offshore Wind Farm commenced in March 2009 and was completed at the end of December 2011. The wind farm became fully operational in December 2012.

Environmental monitoring surveys have been carried out in and around the Thanet Offshore Wind Farm site during the pre, during and post-construction stages of the development. This has been a requirement of the licences issued under the Marine and Coastal Access Act (Marine Licence); formally the Food and Environmental Protection Act (FEPA) licence. This document represents a summary of the post-construction monitoring that has been undertaken since the wind farm became operational.

Surveys of the wind farm site and export cable route for construction debris were undertaken using bottom and side scan sonar techniques and no construction debris was found. Surveys also indicated that the cables have predominantly been buried to a depth of 1m along their length. When 1m depth has not been achieved, rock dumping has taken place to ensure adequate cable protection.

Scour surveys have been conducted on a six monthly basis around four wind turbine generators and four cable crossings and will continue will continue for another year as part of the three year campaign. Scour has been recorded with a diameter around the foundations of 3.5 metres to 4.5 metres. At the cable crossing points, scour was observed and have demonstrated moderate amounts of scour that may require scour protection methods in future. The 2013 surveys have not yet been reported on and therefore information for 2013 has not been included in the scour assessment. These will be provided to the MMO as soon as they become available.

The morphology of the wind farm site has changed slightly with a variance in the distribution of sand waves across the site since before construction was undertaken along with a slight variation in the sediment boundaries. The general appearance of the site has remained the same as pre-construction and any changes are not considered significant.

Ornithological monitoring has been conducted with data collected from the wind farm and a reference area during boat-based surveys. Surveys undertaken to date indicate that the wind farm has not resulted in significant collision risk. Some minor displacement of species was observed during construction and there is evidence of displacement of divers, gannets, guillemots and razorbills during operation. For all species, the displacement observed was not considered to be significant.

Sabellaria spinulosa was mapped in 2012 and compared to pre-construction maps. It was found over a large proportion of the wind farm site and the 2012 data illustrated a wider distribution with less signs of damage; possibly due to a reduction in bottom fishing in the wind farm area.

The benthic invertebrate fauna within the wind farm site and along the export cable route have been sampled before and after the main construction period and on an annual basis. The monitoring detected only natural variations in the seabed habitat and associated invertebrate communities. No evidence of change attributable to the construction of the Thanet Offshore Wind Farm has been recorded.
Seasonal trawl surveys of fish have been completed during the pre and post construction periods. The abundance and diversity of the elasmobranch species in the wind farm site and cable corridor has not significantly altered after the construction of the wind farm. The adult fish surveys indicate that the offshore wind farm has not affected the diversity or abundance of species and there is little effect on the juvenile population in relation to habitat disturbance.

A desk based subsea noise assessment was undertaken and an assumption was made of the operational noise levels at the site. It was not considered likely that the wind farm would contribute to injury or behaviour changes in the marine fauna.

Whilst saltmarsh monitoring was not a requirement of the licences, in agreement with Natural England, monitoring was undertaken following the cable installation. The surveys have indicated that the cable corridor has predominantly been recolonised and become analogous with the surrounding area.

In summary, it can be concluded that the environmental monitoring completed at the Thanet Offshore Wind Farm has met the requirements of the FEPA and Marine Licences and has revealed minimal environmental impact arising from the construction phase which is in line with the predictions made.

CONTENTS

1 INTRODUCTION

1.1 Project Overview

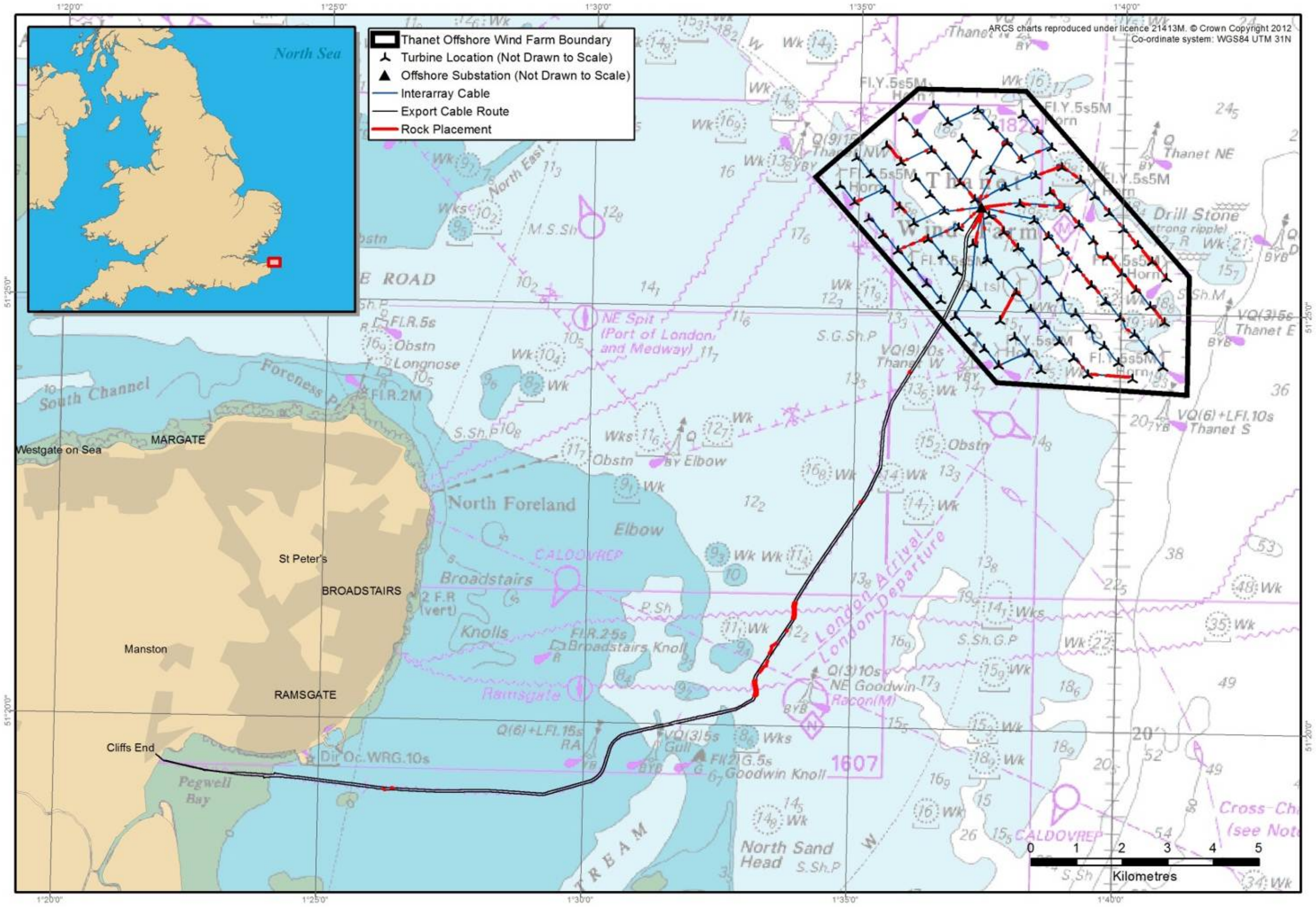
The Thanet Offshore Wind Farm (Thanet Project) is located 11.3km offshore from Foreness Point, the eastern most part of the Kent coastline (see **Figure 1.1**). The wind farm consists of 100 wind turbine generators (WTG), which have a maximum output of 300MW.

Thanet Offshore Wind Farm Limited (TOWL) submitted the consents application and associated Environmental Statement (ES) for the Thanet project to the Department of Trade and Industry (DTI), which is now known as the Department of Energy and Climate Change (DECC) in November 2005, and the project was fully consented on 18th December 2006.

The maximum height of the WTGs is approximately 115m from mean sea level (MSL) to the blade tip in the vertically up position. The minimum clearance between the blade tip in the vertically down position to mean high water springs (MHWS) level is 22m. The spacing between WTGs is approximately 450m within rows and 675m between rows. The WTGs are interconnected by an offshore 33 kilovolt (kV) inter array cable network and connected to an offshore substation platform where the voltage is then stepped up to 132kV. Electricity is transferred to shore via two export cables, which have been laid and routed to a landfall point in Pegwell Bay. The subsea cables have been buried to provide adequate protection against abrasion, anchors and fishing gear. The electrical connection for the wind farm is located at the existing substation at the site of the now demolished power station at Richborough.

The construction of the Thanet Project commenced on the 20th March 2009 and all construction activities and commissioning was completed by the end of December 2011. The wind farm became fully operational in December 2012 when the temporary navigational marking was removed.

Figure 1.1 Location of the Thanet Offshore Wind Farm



1.2 Purpose of monitoring report

This report provides a collated summary of the marine environmental monitoring that has been completed at the Thanet Project before, during and after the construction phase, in accordance with the requirements of the Marine and Coastal Access Act Licences ("Marine Licence") formally Food & Environmental Protection Act (FEPA) Licence (see **Table 1.1** for licence numbers and details).

Part 4 of The Marine and Coastal Access Act (MCAA) 2009 provides a framework for the marine licensing system for works below the level of MHWS tides. The current marine licensing system has been in force since the 6th of April 2011 and consolidates and replaces previous statutory controls, including:

- Licences under Part 2 of the Food and Environment Protection Act (FEPA) 1985;
- Consents under Section 34 of the Coast Protection Act 1949 (CPA);
- Consents under Paragraph 11 of Schedule 2 to the Telecommunications Act 1984; and
- Licences under the Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) Regulations 2007.

Table 1.1 Licences applicable to the Thanet Offshore Wind farm

Licence	Component	Licence number	Case Ref
FEPA Licence	Deposits in the sea connected with marine construction works	33119/10/1	N/A
Marine Licence	Export cable replacement	L/2011/00321/4	MLA/2011/00304/4
	Inter array cable protection	L/2012/00423/1	MLA/2012/00378/1
	Intertidal joint	L/2011/00232/2	MLA/2011/00159/2
	Midline joint and cable crossing protection	L/2011/00077	MLA/35123/110328

The monitoring detailed in this report makes reference to the various conditions of the licences, based on the most recently amended versions (a copy of the most recent licence is available to download from:
(http://www.marinemanagement.org.uk/licensing/public_register.htm).

This report includes an overview of the construction of the Thanet Project, with a focus on those aspects of most relevance to the Marine Licence conditions (i.e. the offshore components). The report then goes on to provide a summary of all the monitoring undertaken at the site.

All pre- and post-construction monitoring has been agreed with the Licensing Authority, Natural England and the Centre for Environment, Fisheries and Aquaculture Science (Cefas) in the '*Pre-Construction Environmental Monitoring Plan*' (Royal Haskoning, 2008) and the '*Post-Construction Environmental Monitoring Plan: Version Five*' (Royal Haskoning, 2012).

2 CONSTRUCTION OF THE THANET OFFSHORE WIND FARM

2.1 Introduction

The following sections describe the offshore (and onshore) construction of the Thanet Project.

Construction of the project was undertaken between the 20th March 2009 and the end of December 2011, including installation of the main offshore and onshore components, testing and commissioning.

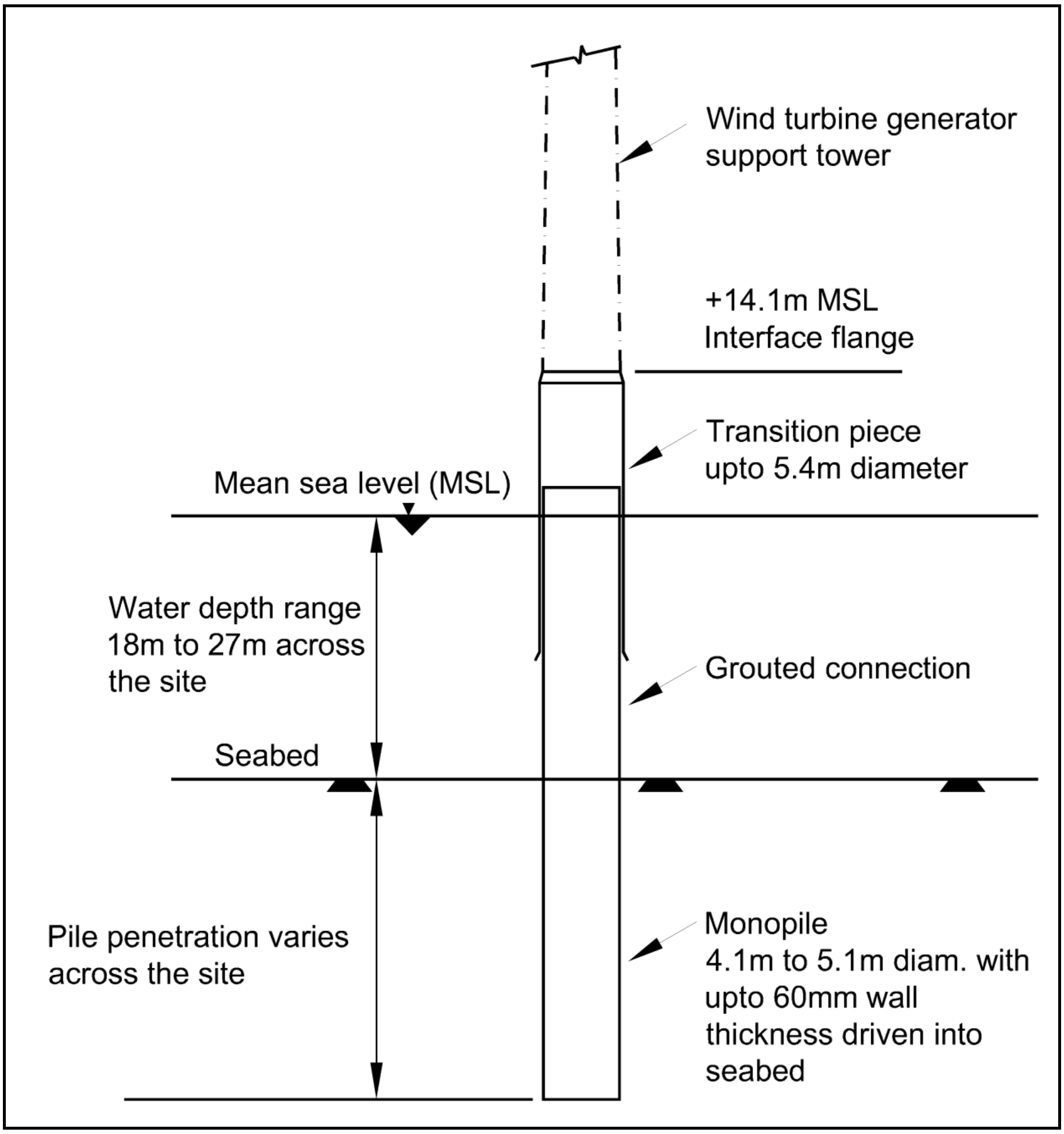
2.2 Main construction activities

The main offshore construction works included the following components:

- Installation of 100 monopile foundations;
- Installation of tower transition pieces;
- Installation of 100 turbine towers and WTGs;
- Installation of a jacket foundation for the offshore substation; and
- Installation and burial of connecting inter-turbine and export cables to landfall (with onshore cabling to an onshore substation connection).

Figure 2.1 shows the indicative component parts of a WTG.

Figure 2.1 **Schematic showing the indicative component parts of a Wind Turbine Generator**



2.2.1 Monopile foundation installation

The monopile foundations provide the support for each of the 100 WTGs and consist of a welded steel tube of between 45 and 65 metres in length and ~4.5m in diameter. The steel tubes were driven into the seabed, with penetration of between 18 to 40 metres below seabed level (depending on the nature of the geology at each turbine location).

Piles were driven into the seabed by pile-driving using a hydraulic hammer (**Figure 2.2**).

Figure 2.2 **Installation of monopile foundation**

2.2.2 The Transition Piece

Following the completion of the piling operations a transition piece was mounted onto the top of each of the monopiles (see **Figure 2.3**). This steel structure was grouted to the monopile using specialist cement adhesive and provided for levelling as well as having necessary equipment such as boarding ladders, cathodic protection, cable ducts for the submarine cables and appropriate navigational lighting. The transition piece thereby provided for safe access to the foundation for the WTG installation as well as during the operational phase.

Figure 2.3 Installation of the transition piece

2.2.3 Turbine Tower & Generator Installation

Pre-assembly of the WTG components was completed at the nearby Port of Felixstowe on the Suffolk coast. Components were transported to Dunkirk from the various fabrication plants around Europe and included tower sections, nacelles (blades), hubs and cables etc.

Pre-assembly involved the preparation of the tower sections including fitting of cables, switchgear, ground controller and man-lift installation. The turbine nacelle was also prepared and two of the WTG blades attached (the “bunny-ears” configuration) ready for transport (see **Figure 2.4**). All of the components for two complete WTG installations were subsequently loaded onto the specialist installation vessel, the MV Resolution.

Figure 2.4 Installation of the towers

For each WTG installation, three lifts were completed in order to install each of the Vestas V90 3MW WTGs. Firstly, the tower sections were lifted into place and bolted onto the transition piece. Secondly, the nacelle (with bunny ears) was lifted and bolted onto the top of the tower section. Finally, the third blade was lifted and bolted onto the nacelle rotor hub.

On average, the installation of each WTG required about 24 hours, including loading, transport from Dunkirk (six to eight hours), positioning and the three lifts. Installation continued around the clock with no limitation (8hrs/WTG was the best case scenario but this was installation time with the MPI Resolution fully loaded and on site, at the end of the project three WTG's were being installed in 24hrs). Following the installation of the main WTG components, engineers were then transported to each WTG by small vessel from the local port of Ramsgate and began the commissioning process. Commissioning took an average of three days to complete but these were not consecutive days. Commissioning was completed in two stages. 'Cold' commissioning was completed with no High Voltage power to the WTG. Once completed, the team returned once the WTG was powered up to complete the 'hot' commissioning.

2.2.4 Offshore substation

The offshore substation jacket was installed in a single lift, weighing approximately 600 tonnes. The jacket structure allows the J-tubes, which contain the electrical cables, including the export cables and inter array cables to the WTG arrays, to be 'shielded' and hence less vulnerable from any vessel impact throughout the lifetime of the wind farm.

The jacket was fixed to the seabed using out-rigging piles at each of the four jacket leg positions. The piles were approximately 1.83m in diameter.

The topside was also designed and manufactured as a single unit, which was loaded and transported out to the Thanet site using the same heavy lift vessel and a similar procedure to that outlined above for the jacket structure. Once the topside was lifted into position, site welding and mechanical hook-up for items such as walkways, J tubes etc. were completed (see **Figure 2.5**).

Figure 2.5 Installation of the offshore substation

2.2.5 Offshore Cable Installation

Inter array cables

The inter array cables connect the WTGs into arrays and then connect the various arrays to the offshore substation. The 100 WTGs were connected in seven strings; each string has between 11 and 17 WTGs. The cables between adjacent WTGs are in the range of 750m to 1.1km. The inter array cables are 33kV, 3-core copper conductors, insulation/conductor screening and steel wire armoured. All cables contain optical fibres embedded between the cores.

The intra-array cables were surface laid, and then buried using a subsea remotely operated vehicle (ROV) which used water jetting technology (see **Figure 2.6**).

In most cases, target burial of >1m was achieved, except adjacent to each WTG where the cables approach the surface of the seabed before being fed through the J-tube on the foundation. Cables were pulled through the J-tube and jointed to the cabling within the tower sections (once installed).

Cables were tested following the installation process and in each case, cable installation was completed prior to installation of the WTGs.

Figure 2.6 **Installation of the offshore cables**

Export cables

From the WTG array, two main export cables were laid in a south west direction outwards to the cable landfall point at Pegwell bay, a distance of 26km. Each of these two export cables were installed using a cable plough (see **Figure 2.7**).

The cable landfall area in Pegwell Bay was constrained by a large intertidal zone with shallow water close to the shore. In order to overcome this constraint, it was decided that both export cables were installed in two lengths. The inshore section of cable from the cable landfall position out to the extreme of the intertidal zone, approximately 2.2km long. Cable joints were installed in both export cables at this point, and the remainder of offshore sections of both export cables were laid for approximately 24.3km out to the offshore substation.

Figure 2.7 **Example of plough used to install offshore cables**

Installation was achieved using a specialist cable installation barge. Burial of the export cables achieved the target burial depth of at least one metre in the offshore environment and at least two metres closer inshore, in the intertidal.

The offshore cables at the Thanet Project are operated at 132kV and hold the three main phases for high-voltage transmission of power from the generators, and also vital fibre optic cables for remote communication.

The landfall for the export cables is at a location that is adjacent to a now decommissioned service station along the A256. The export cables were installed into a transition pit which was excavated to house the joint between the offshore and onshore cables.

Export cable crossings

A number of telecommunications cables to the southwest of the Thanet Project presented an obstacle that required crossing by the export cables, namely:

- UK to Belgium 5 (out-of-service);
- Pan European Crossing (PEC); and
- Tangerine.

The procedure for the out-of-service cable required a section of cable to be located and a length removed to provide an adequate corridor for the crossing export cables. This procedure was undertaken in accordance with guidelines set out by the International Cable Protection Committee (ICPC).

For the in-service cables, concrete mattresses were laid across the telecommunications cables by a bespoke vessel, and divers were deployed to ensure accurate placement. The mattresses weighed approximately 10 tonnes and measured 5m x 3m x 300mm thickness. The export cables were laid over the mattresses. The top protection mattresses were then laid.

2.2.6 Cable protection

Cable protection was used on both the inter array cables and the export cables. Discrete sections of the inter array cables were protected through the placement of rock material. This rock material originated from a quarry in Norway and was transported to the Thanet Project. A dynamic positioning (DP) vessel using a fall pipe was used to place the material. The design specification of the structure allowed for fishing gear to pass over the top of the structure and for the structure to maintain its integrity in a high current velocity environment.

Where the export cable crossed the two telecommunications cables, concrete mattresses were used (as described in **Section 2.2.5**). The mattresses were laid over the communications cables and subsequently over the export cables. In areas where the export cable could not be buried to the target depth, rock protection was used. **Figure 1.1** shows the discrete areas of rock protection.

2.2.7 Onshore Cable Installation

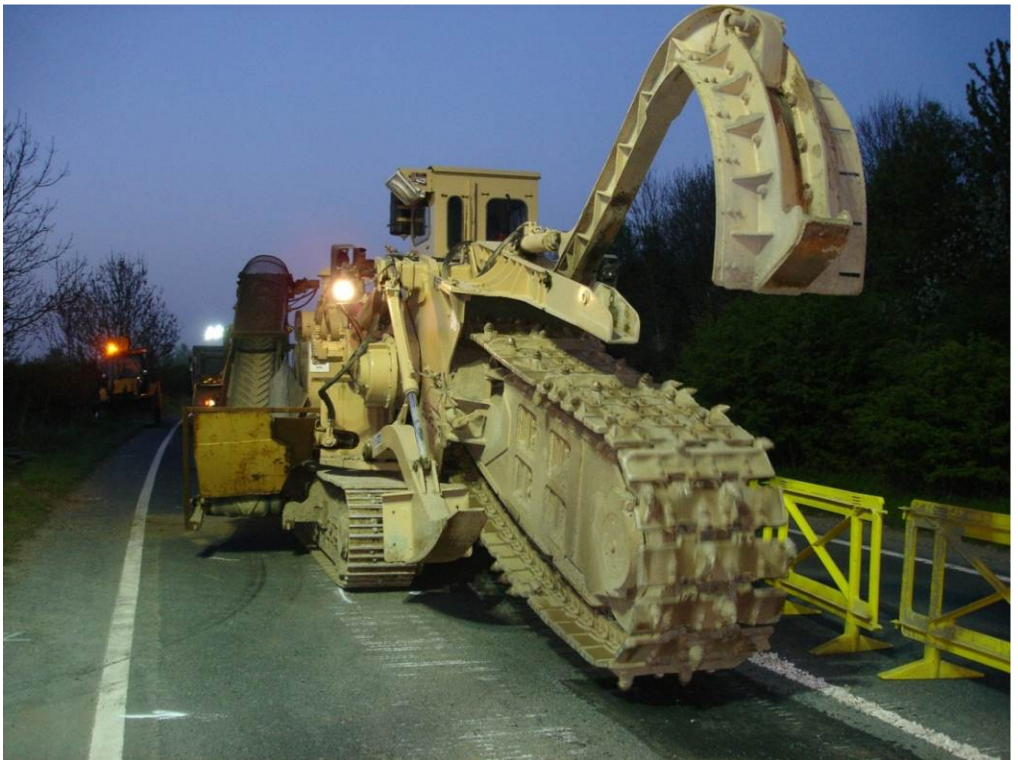
The onshore cables run from the landfall to the onshore substation at the site of the demolished Richborough Power Station. The onshore cables consist of:

- Two groups of three single-core 132kV power cables. Each group forming a single 3-phase connection, and connect to one of the subsea export cables; and
- Two optical fibre cables for communications.

The onshore cables run from the transition pit along the A256 Sandwich Road and along the carriageway to the existing EDF Energy substation. The total length of the onshore cable route is approximately 2.2km.

PVC ducts of 150mm diameter were laid in a trench that was constructed using an excavator (**Figure 2.8**), to accommodate each of the single core 132kV cables. Each group of ducts were arranged in trefoil formation, except for specific sections (e.g. Minster Stream crossing) where the reduced burial depth dictated a flat formation.

Figure 2.8 **Installation of the onshore cables**



2.2.8 Navigational Safety Measures

A number of navigational safety measures were installed on the Thanet WTGs in accordance with the requirements of the various consents issued for the project. These include:

- Navigational lighting to a specification agreed with Trinity House, installed on eight of the WTGs at the height of the boarding platform;
- Fog horns to a specification agreed with Trinity House, installed on four of the WTGs at the height of the boarding platform;
- The WTGs are painted a high-visibility yellow colour to just above the height of the boarding platform to improve visibility to surface shipping;
- Red fixed medium intensity aeronautical obstruction lights installed on eight of the WTGs at nacelle height to Civil Aviation Authority (CAA) specifications; and
- Identification markers around each WTG at platform level and also on top of each nacelle.

2.2.9 Operation & Maintenance

The Thanet WTGs have been operational since 2010 with the few remaining construction activities completed in 2012. During the operational phase maintenance of the offshore WTGs has been undertaken by Vestas personnel based at the purpose built maintenance facility at Ramsgate Harbour. A total of 16 employees are employed full time on the routine maintenance of the WTGs. Purpose built maintenance vessels operate from Ramsgate Harbour which are used for crew transfers (**Figure 2.9**).

Figure 2.9 Crew vessel

Normal, planned maintenance during the operational phase includes:

- A one off mechanical service of WTGs after the first three months of operation;
- Annual full WTG servicing;
- Mandatory HV equipment inspections;
- Six monthly safety inspections of climbing PPE;
- Annual statutory inspections i.e. lift, anchor points, ladders etc., under an agreed inspection scheme; and
- Annual offshore safety rescue exercise in cooperation with the Coast Guard.

Routine management and monitoring of the Thanet Project is achieved through a Supervisory Control and Data Acquisition system (SCADA) which is able to monitor the performance and status of each of the WTGs, sending and receiving data through the fibre optic cables. The SCADA system can be accessed remotely through the internet from any location.

3 THANET OFFSHORE WIND FARM MONITORING

3.1 Introduction

The following sections provide an overview of the key findings arising from the environmental monitoring completed at the Thanet Project as required by the provision of the Marine and FEPA licence conditions. The results of all the monitoring conducted during the post-construction periods of the development process are summarised, specifically in relation to the following monitoring studies:

- Construction debris survey;
- Scour survey;
- Bathymetric;
- Benthic ecology monitoring;
- Fish surveys;
- Operational underwater noise;
- Ornithological monitoring; and
- Saltmarsh re-colonisation survey.

The majority of the post construction surveys were completed in 2012. However, a number of reports were submitted individually when they became available, namely; ornithological survey report for 2010/11 submitted to the Marine Management Organisation (MMO) in 2011 and the operational underwater noise report in 2012. As-built information relating to the cable burial and cable protection were supplied upon completion of the works.

The relationship between the different variables subject to monitoring is also explored (e.g. scour effects and benthos; fish monitoring and birds etc.) as required by the licence conditions. In addition, where it is applicable, results of the pre-construction monitoring studies are discussed.

Particular reference is also made to the findings of the original Thanet ES (2005) in relation to the predicted environmental effects of the project. It is pertinent in interpreting the results of the monitoring that many of the monitoring requirements have been put in place specifically to confirm that the predictions made in the ES have accurately described the environmental effects arising from the development.

3.2 Environmental Monitoring Specifications and Timing

Table 3.1 summarises the environmental monitoring program set out by the licences for each of the main monitoring studies (greater detail on precise timing and scope of each survey is given under the summary of each of the studies in the following sections).

Table 3.1 Summary of key FEPA and Marine Licence monitoring studies

Parameter	Survey requirement	Pre-construction	Post-construction	FEPA 33119/10/1 Licence Condition	Marine Licence
Hydrodynamics and geomorphology	Swath bathymetric survey		✓	FEPA 9.28	L/2012/00423/1 Inter array cable protection Section 3.3.3 L2011/00077 Midline Joint and Cable Crossing Protection Section 3.3.1
	High resolution swath bathymetric survey	✓		FEPA 9.31	
			✓	FEPA 9.31	L/2012/00423/1 Inter array cable protection Section 3.3.3 L2011/00077 Midline Joint and Cable Crossing Protection Section 3.3.1
	Bottom and side-scan sonar survey	✓		FEPA 9.41	
			✓	FEPA 9.41	L/2012/00423/1 Inter array cable protection Section 3.3.3 L2011/00077 Midline Joint and Cable Crossing Protection Section 3.3.1
	Cable burial depth		✓	FEPA 9.33	L/2011/00321/4 Export Cable Replacement Section 3.3.4
	Removal of construction		✓	FEPA 9.40	L/2011/00321/4 (Export Cable

Parameter	Survey requirement	Pre-construction	Post-construction	FEPA 33119/10/1 Licence Condition	Marine Licence
	debris				Replacement Section 3.3.4)
	Additional scour surveys following large wave events		✓	FEPA 9.29	
Ornithology	Ornithology survey		✓	FEPA 9.4, 9.12, 9.13, Annex II Commitment made in ES	
Marine Ecology	*Sabellaria spinulosa*	✓		FEPA 9.5, Annex 1 Paragraph 3	
			✓	FEPA 9.6 and 9.28 Commitment made in the ES	L/2012/00423/1 (Inter array cable protection) Section 3.3.2
	Sub-tidal benthic ecology	✓		Commitment made through consultation process	
			✓	FEPA 9.4, Annex I Paragraph 3	
	Monopile colonisation		✓	FEPA Annex I Paragraph 3	
Fish resources	Elasmobranch survey	✓		FEPA Annex 1 Paragraph 4 & 5	
			✓	FEPA Annex I Paragraph 4	
	Herring spawning	✓		Commitment made through consultation process	
			✓	FEPA Annex I, Paragraph 4	
	Adult & juvenile fish survey		✓	FEPA 9.10	
Marine mammals	Marine mammal monitoring		✓	FEPA Annex I Paragraph 6	
Noise and vibration	Subsea noise		✓	FEPA 9.9 &	

Parameter	Survey requirement	Pre-construction	Post-construction	FEPA 33119/10/1 Licence Condition	Marine Licence
	monitoring			Annex I Paragraph 7	
Additional requirements	Reporting		✓	FEPA 9.3	
	Saltmarsh recolonisation survey		✓		

All pre-construction monitoring was completed prior to the start of the main offshore construction works which was underway by 2009. Post-construction monitoring started following the completion of the installation of the main foundation installation works which were completed by 2010. The timing of surveys is displayed in **Tables 3.2** – **3.7** below.

Table 3.2 2011 Post-construction survey windows

Surveys	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Comments
Ornithology survey													Completed
Subsea noise survey													
Saltmarsh vegetation survey													Completed

Table 3.3 2012 Post-construction survey windows

Surveys	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Comments
Scour survey													Completed
High resolution swath													Completed
Debris survey													Completed
Ornithology survey													Completed
Multibeam *S. spinulosa*†													Completed
Drop-down *S. spinulosa**													Completed
Subtidal benthic survey													Completed
Monopile colonisation survey													Postponed 2013
Elasmobranch survey													Completed
Adult fish survey													Completed
Juvenile fish survey													Completed
Subsea noise survey													Completed desk top study
Saltmarsh vegetation survey													Completed

† To be undertaken as part of the high resolution swath bathymetry survey and the scour survey (see **Sections 3.2.1, 3.2.2** and **6.2.1**)

* Drop down camera to be undertaken to ground truth known and potential aggregations of *Sabellaria spinulosa*, to be undertaken following analysis of data obtained during the high resolution swath survey

Table 3.4 2013 Post-construction survey windows

Surveys	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Comments
Scour survey													April Completed
Ornithology survey													Completed
Monopile colonisation survey													Postponed to 2014

Table 3.5 2014 post-construction survey windows

Surveys	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Comments
Scour survey													
Monopile colonisation survey													

Table 3.6 2017 post-construction survey windows

Surveys	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Comments
Subtidal benthic survey													

Table 3.7 2022 post-construction survey windows

Surveys	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Comments
Subtidal benthic survey													

The post-construction monitoring schedule varied for each of the studies but for the longest running (ornithology) was for a period of three years following the end of construction and, therefore, finished in March 2013. The monopile colonisation survey was postponed to 2014 due to the lack of suitable weather and tidal conditions in 2012/3. The majority of the remaining surveys were completed for the first year of post construction monitoring, at the end of 2012.

In all cases, the scope of each of the monitoring studies was agreed with the relevant regulatory bodies and their advisors (principally Cefas and Natural England) prior to any monitoring being undertaken.

This report is a summary of the technical reports produced for Thanet Offshore Wind farm prepared in support of the requirement of FEPA Condition 9.3 to provide the reporting aspect of the monitoring programme. The technical reports can be found at the end of this report in **Appendices 4A** – **10A**.

4 HYDRODYNAMICS AND GEOMORPHOLOGY

4.1 Objective

The objective of the geomorphological surveys was to assess if any impacts on the bed form morphology (such as scouring or effects on sand waves) have occurred as a result of the presence of the monopile foundations and other ancillary infrastructure, in addition to monitoring any on-going effects during the operational phase. The survey objectives are based upon the requirements to meet the FEPA and Marine licence conditions outlined below.

The specific commitments in relation to the *Sabellaria spinulosa* reef (Condition 9.28) and Marine Licence L/2012/00423/1 (Inter array cable protection) Section 3.3.3 commitments in relation to invasive species are both covered in the Marine Ecology section of this report (**Section 6**).

In April 2012, Titan Environmental Surveys Limited were commissioned by Gardline Geosurvey Limited on behalf of TOWL, to conduct a post-construction geophysical survey of the export cable route, and initial scour surveys of a selected number of WTGs. The surveys were completed at four WTGs (E01, E02, F01 and F02) and along the North and South cable crossings. Both cable crossings are in water depths ranging from 12m to 14m below chart datum. The southern crossing is the Dumpton Gap to Oostende, Tangerine Telecom Cable and the northern crossing is the Dumpton Gap to Bredene Pan European Crossing Telecom Cable). Surveys will be repeated at six monthly intervals for three years around these structures to allow for a survey in the late winter period and the other in the late summer period each year in order to capture possible scour pit evolution after winter storms and infilling after calmer, summer weather. To date, a morphology survey (including scour assessment) has been undertaken in April 2012 and a scour survey in October 2012. These are discussed below, with further details available in **Appendix 4A**. **Appendix 4A** also contains the as-built information for the cable protection and the cable burial assessment.

4.2 Scour survey

4.2.1 Scope of survey

The purpose of the April and October surveys was to provide an assessment of the foundations of at least four WTGs and four cable crossings with the use of swathe bathymetry and high resolution side scan sonar. The identified occurrence of *Sabellaria spinulosa* in the scour pits was required to be cross-referenced with previous survey data.

4.2.2 Monitoring undertaken

Swathe bathymetry and high resolution side scan sonar was used in both the April and October 2012 surveys. Data were generally of good quality although swathe performance varied considerably due to sea conditions and underlying seabed conditions during data collection. Full coverage swathe bathymetry was achieved across the whole survey site.

The 2013 surveys have not yet been reported on and therefore information for 2013 has not been included in the scour assessment. These will be provided to the MMO as soon as they become available.

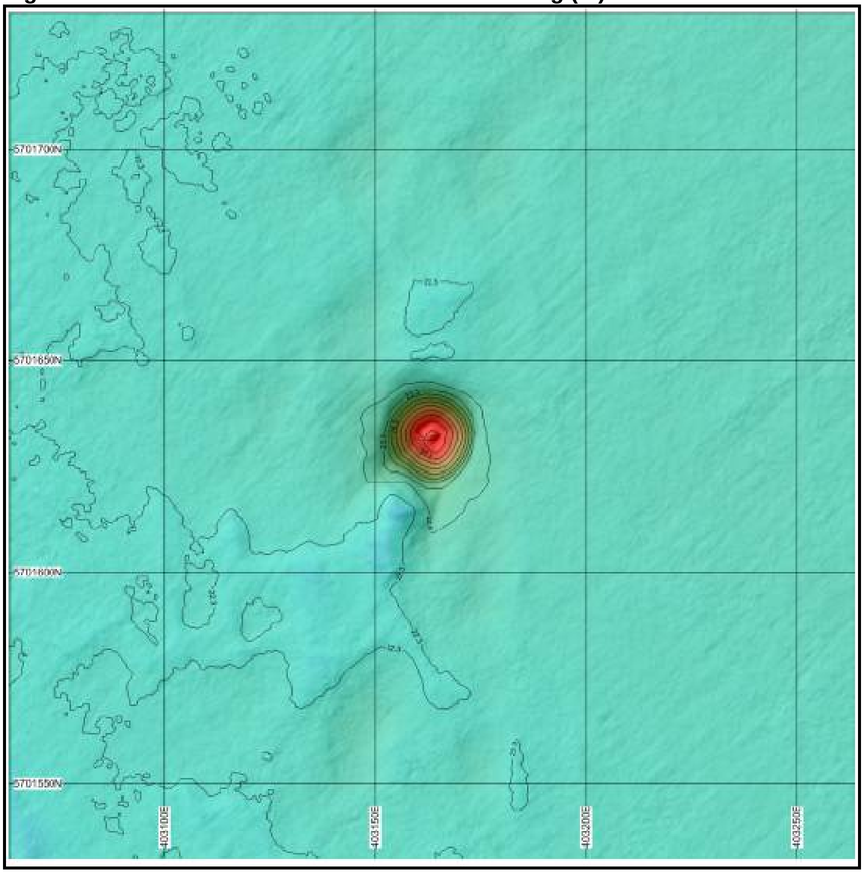
The identified occurrence of *Sabellaria spinulosa* in the scour pits was cross-referenced with previous survey data and is discussed fully in Section 6: Marine Ecology.

4.2.3 Overview of results

<u>Wind turbines</u>

The selected WTGs that have been surveyed are situated in water depths of 20m below chart datum and all show signs of scouring around the base of the monopiles. The scour ranges between 3.5m to 4.5m diameter in a circular shape around the base of the monopile. The circular shape of scour is evident in **Figure 4.1** below, suggesting a non-distinctive direction of tide current in the area of the Thanet Project site.

Figure 4.1 Turbine E01 with circular scouring (m)

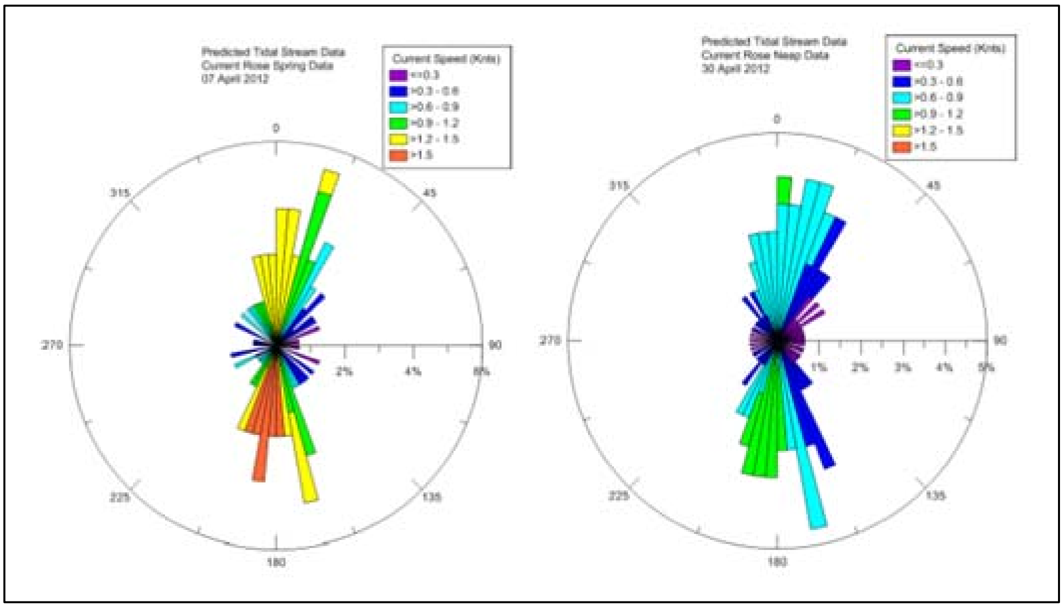


The data from the tidal diamond (51°26.03'N 1°38.90'E) in **Table 4.1** below suggests that the tidal flow has a clockwise rotational component and is not linear, with the dominant current direction being NE-SW. **Figure 4.2** shows the current roses for the average Spring and Neap for the Thanet Project site and clearly shows that there is no period of slack water in either spring or neap tides.

Table 4.1 Tidal Diamond data for 51°26.03'N 1°38.90'E at the Thanet Project

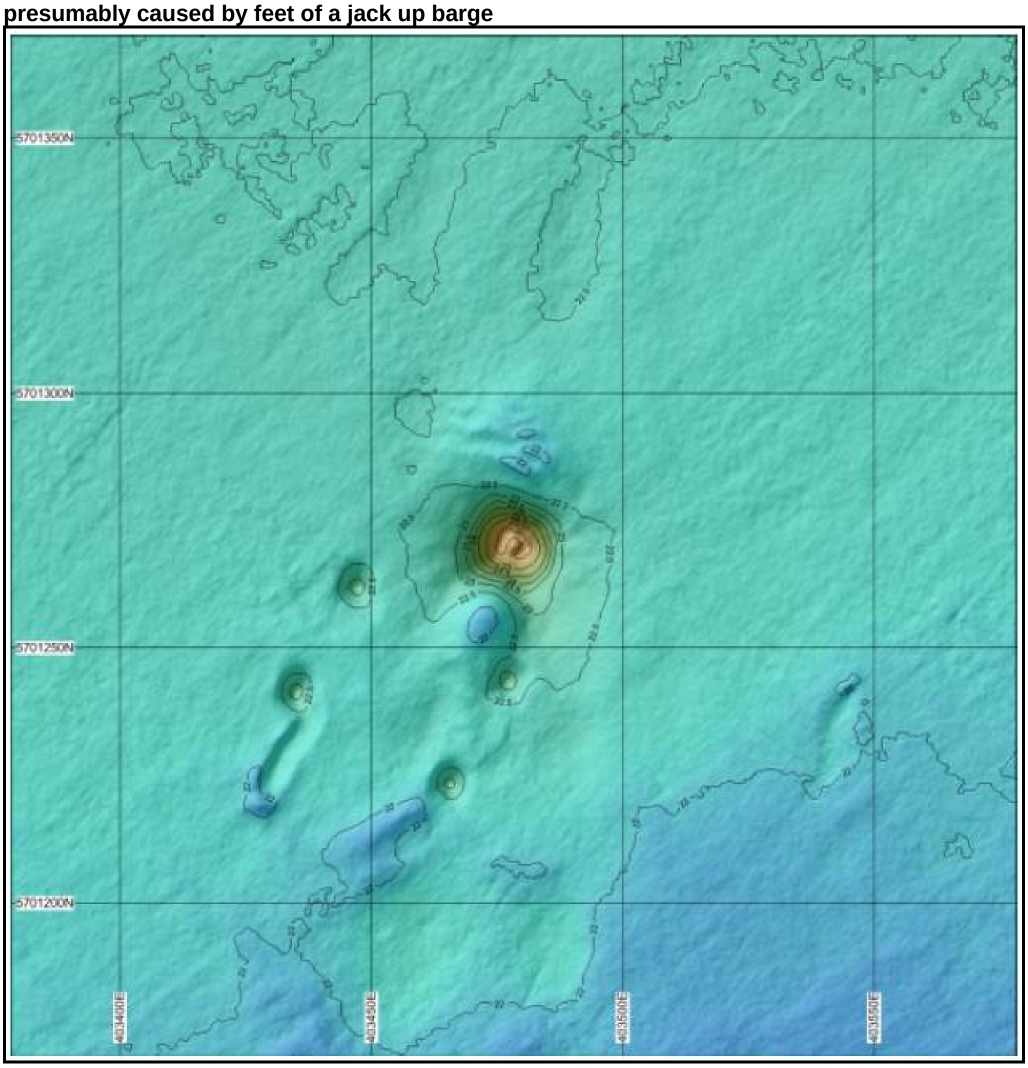
Time	Direction (oT)	Spring (Knts)	Neap (Knts)
HW-6h	161	1	0.5
HW-5h	171	1.5	0.8
HW-4h	186	2	1.1
HW-3h	198	1.6	0.9
HW-2h	229	0.8	0.4
HW-1h	320	0.8	0.5
HW	349	1.4	0.8
HW+1h	002	1.6	0.9
HW+2h	014	1.4	0.8
HW+3h	024	1	0.6
HW+4h	040	0.6	0.3
HW+5h	090	0.3	0.2
HW+6h	153	0.7	0.4

Figure 4.2 Current roses for the average Spring and Neap tides at Thanet Project



The total scour net gain will incorporate new scouring features identified on the seabed since April 2012 within the 200m grid around the WTG, for example where additional scour activity has occurred since the pre-construction surveys were conducted, such as from indentations caused by the feet of a jack-up barge. As a result this may give an unrealistic scour net gain specifically around the WTG foundation. An example of this can be seen at WTG E02 in **Figure 4.3**. Previously unrecorded seabed indentations are present south west of the WTG, presumably from a jack up barge, have caused a small amount of scour to appear on the seabed.

Figure 4.3 **Turbine E02, with new indentations (scour features) in the south west of the WTG, presumably caused by feet of a jack up barge**



The width, depth and gradient of scour around each WTG are summarised in **Table 4.2** below. All scour direction was recorded at 360° around each WTG, with no linearity.

Table 4.2 **Width, depth and gradient of scour around WTGs**

Turbine	Date surveyed	Width (total) including 4.7 m monopole) (metres)	Scour depth (metres)	Max gradient (degrees)
E01	03/04/12	22	4.1	49.5
E01	13/10/12	24	4.7	38.05
E02	03/04/12	18	3.7	47.5
E02	19/10/12	19	3.7	30.02
F01	03/04/12	22	3.5	51
F01	19/10/12	25	3.5	37.98
F02	03/04/12	20	3.2	44

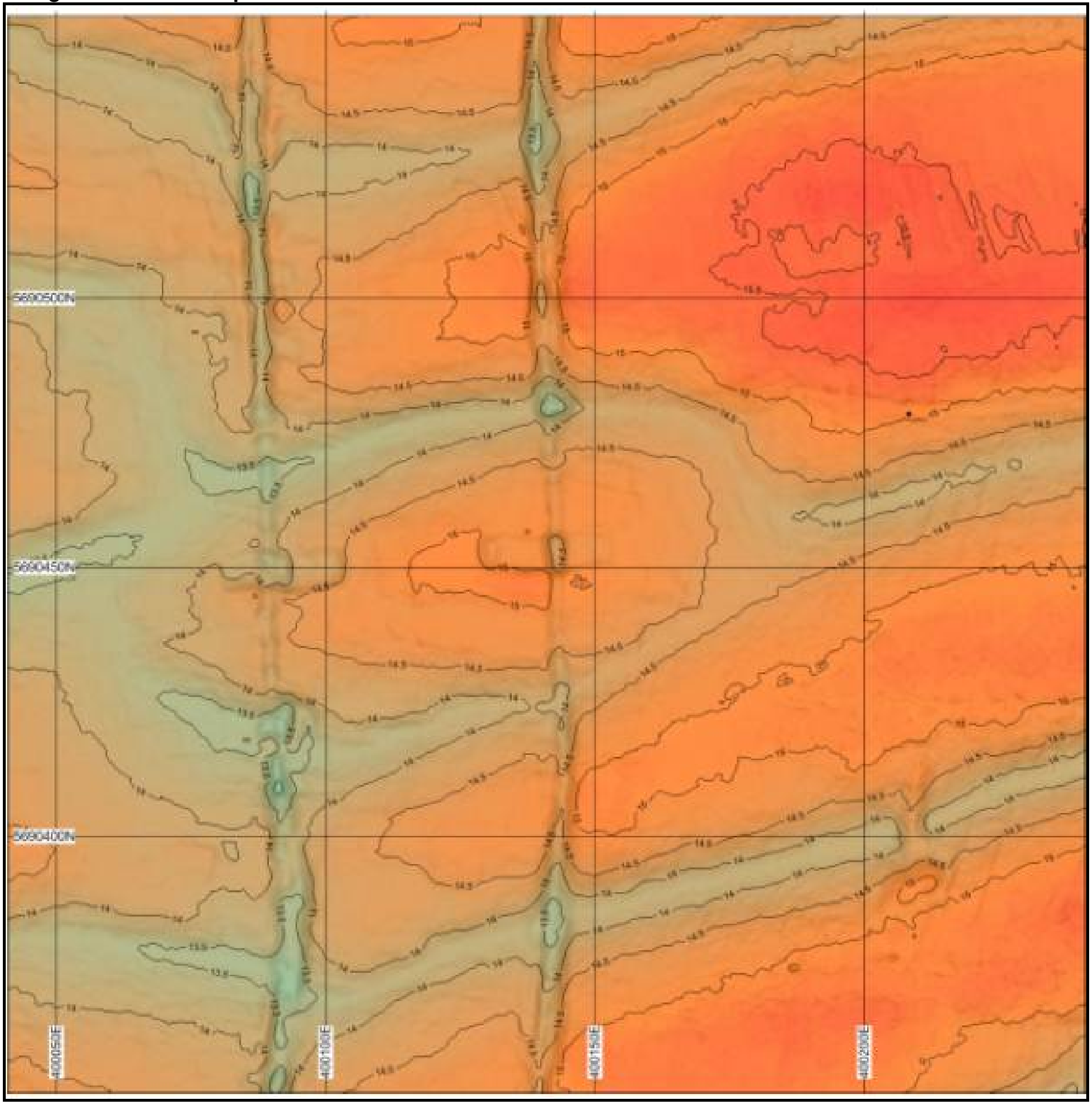
F02	19/10/12	21	3.6	30.44

Cable Crossings

At the locations of both the cable crossings, the sea bed is dominated by sand wave formations and mega ripples. The sand waves at these locations have heights ranging between 1m to 1.5m. The Thanet Project export cables continue to show signs of scour at both the northern and the southern cable crossing locations.

One of the Thanet Project export cables is clearly present above the sea bed in sections, with the concrete matressing also visible. **Figure 4.4** below shows the northern export cable crossing point and highlights the export cable and concrete matting which are visible. Depth profiles included on the charts suggest that slight back filling has continued around the concrete matting as profiles do not show obvious protrusion of the sea bed. Generally the profiles show a thin layer of erosion across all of the crossing locations.

Figure 4.4 North East Cable Crossing with concrete matting, with depth profiles showing back filling and no obvious protrusion of the sea bed



4.2.4 Conclusions

Scour Comparisons

The most significant scour at the Thanet Project site has been localised, and continues to occur around the foundations of the WTGs. Very little deposition of sediment has occurred around the WTG locations apart from WTG F01. There has been some erosion, with the main amount occurring in a non-distinctive direction around the base of the WTG. Furthermore, there has been erosion potentially caused by a jack up barge at WTG locations E02 and F02. WTG's E01 and E02 continue to be impacted by further scouring resulting in deeper erosion around the base of the monopile. Whilst the scouring around the monopile of WTG F01 and F02 is wider in diameter, the erosion has not changed considerably since the 2007 survey.

The results and the profiles from the scour survey completed in 2012 suggest that all four cable crossing locations have had a thin layer of erosion take place across the survey locations covered. Some deposition has occurred at all four cable locations mainly along the cables which protrude from the sea bed.

The ES predictions were for high scour potential around the WTG foundations on parts of the site, to a depth of 9m and a distance of 24m from the outside of each structure (i.e. radius) for mobile homogeneous fine sands and less depth and distance of scour activity in areas with coarser mixed grain sediment. The maximum scour depth observed around WTG monopiles on the Thanet site is 4.7m, whilst the maximum scour width observed was 25m diameter (including the 4.7m diameter monopile). These recordings are approximately half those estimated in the ES for fine sand locations. With regards to potential impacts to benthic ecology, as discussed in Section 6 below, a wider distribution of *S. spinulosa* aggregation was categorised as patchy (moderate) and wider aggregations of dense reef was recorded in 2012 surveys compared with the survey findings in 2007. Overall, positive growth and stable *S. spinulosa* reef aggregations found across the Thanet Project site in the 2012 survey, and no *S. spinulosa* was recorded in scour pits.

It is considered that after the first year of three years' survey results, the extent of scour is considerably less than the worst case scenario identified in the ES and S. *spinulosa* is considered to be in a stable condition of positive growth across the site.

4.3 Morphology survey – Site and Export Cable Route

4.3.1 Scope of survey

The morphology survey was undertaken in April 2012 and the results were compared with the 2005 and 2007 data. The object of the April 2012 survey was to compare the Pre-Construction Debris, Morphology and *Sabellaria spinulosa* Surveys of 2005 and 2007, to identify all hazards or obstructions on the seabed around the wind farm and export cable route, and compare with the pre-construction surveys.

4.3.2 Monitoring undertaken

Single beam and multi-beam echo sounder, sidescan sonar and magnetometer equipment were used to undertake the April surveys. Interpretation is based on multi-beam and sonar data, along with British Geological Survey (BGS) information.

4.3.3 Overview of results

Recorded data were of good quality.

Within the Thanet Project site, water depths varied from a minimum of 14.0m LAT in the east to a maximum depth of 28.7m LAT in the east. Seabed gradients across the site reach a maximum of 20° on the sand waves in the centre of the site.

The majority of the seabed is characterised as flat, open sandy areas with sand waves. Sand wave crests trend in an east-west direction, indicating that the predominant current is in a southerly direction. The site appears to consist mainly of sand with mega ripples, with some large gravel patches and exposed bedrock. This can be seen in **Figure 4.5** and **Figure 4.6** below.

Figure 4.5 **Side Scan Sonar data illustrating sand and megaripples**

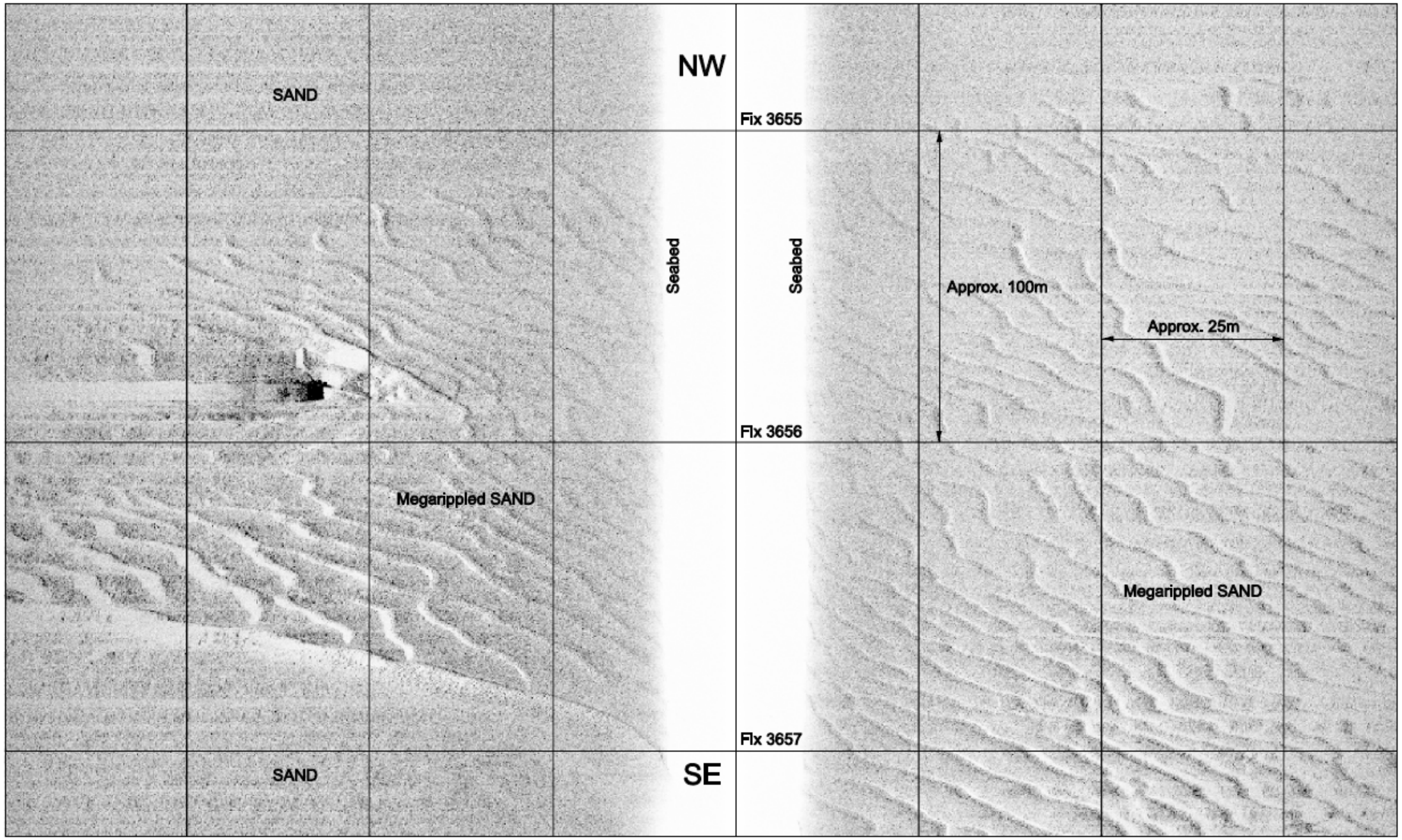
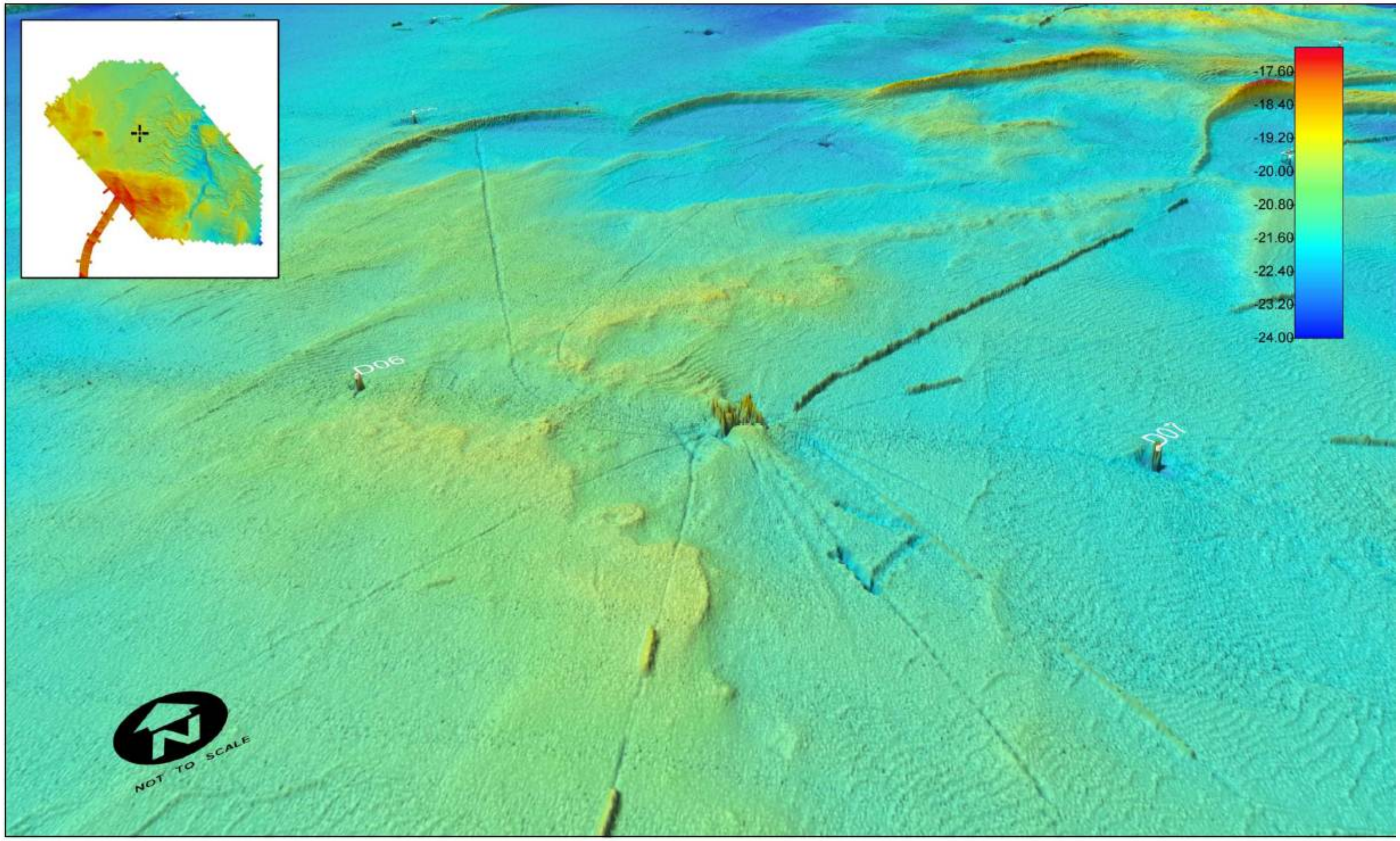


Figure 4.6 **3D Bathymetry - Illustrating the central substation and associated inter array and export cables between foundation locations D06 and D07 (rock dumping can be clearly seen on both sets of cables)**



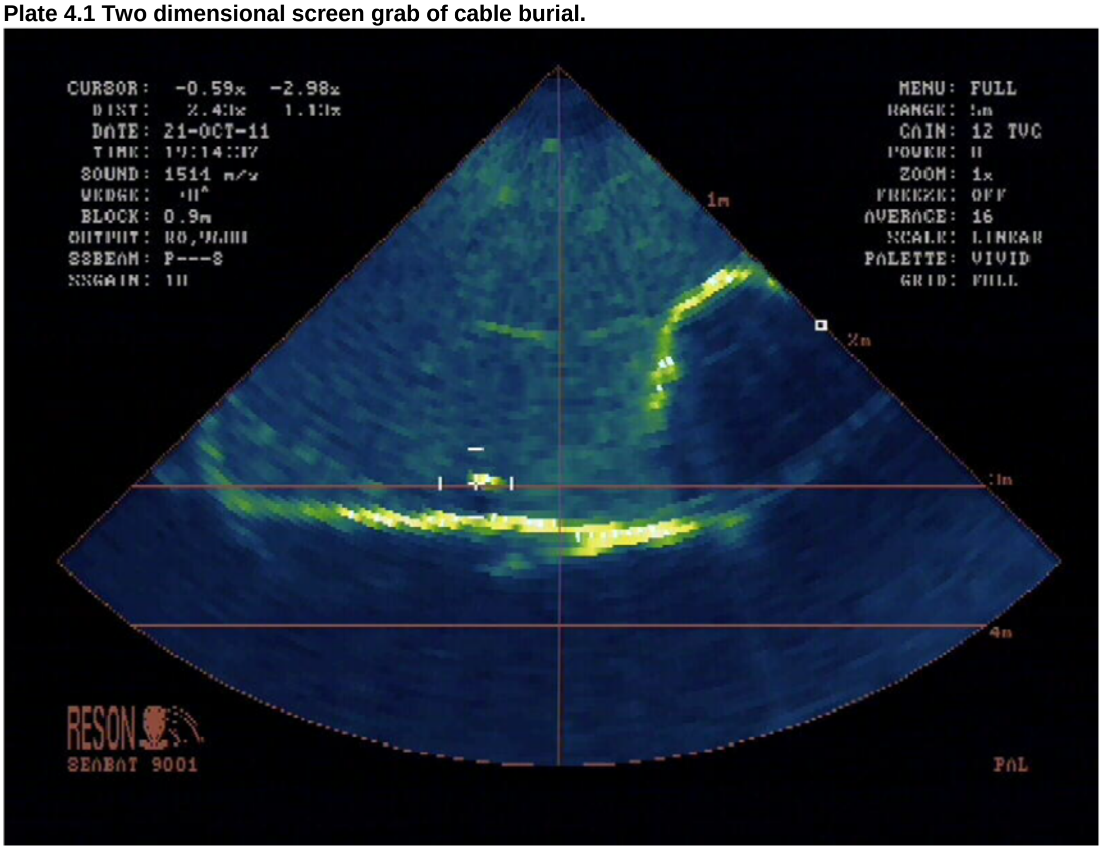
Bathymetry

The data collected through the full bathymetric survey in 2012 (including the latest available information on the area in the vicinity of the export cable is provided in **Figure 4.7, Figure 4.8**.

Due to the shallow nature of the export cable route close to shore, data acquisition commenced at a distance of 1.28 km from the shore (KP1.28). Depths along the export cable range from -2.1 metres LAT at KP1.28 to 21.4 metres LAT at KP 26.06. The position of the north and south export cables are occasionally apparent along the route, indicated by the presence of rock protection. These areas predominantly lie in the expected positions (**Figure 1.1**).

Additional information was collected during the cable repair and re-burial 0.5km south east of the Port of Ramsgate. The data is presented in **Appendix 4B**. An example of the two dimensional seabed profile is shown in **Plate 4.1** below. In this pre-burial image the cable is at 1.13m below seabed.

Plate 4.1 Two dimensional screen grab of cable burial.



Seabed Features and Sediment Types

The majority of the seabed is characterised by a medium reflectivity. A veneer of Holocene sand covers most of the export cable route; however, closer to land, this becomes very thin and occasionally the underlying chalk is exposed; see **Figure 4.9**. Numerous sand waves are seen, as well as occasional ripples. Often the seabed at the Thanet Project site has a slightly mottled appearance suggesting gravel with possible sparse aggregations of *Sabellaria Spinulosa* reef. Seabed sediments within the site consist of medium grained sand, with some occasional gravelly areas.

Figure 4.7 **Representation of bathymetry of the site and the export cable route**

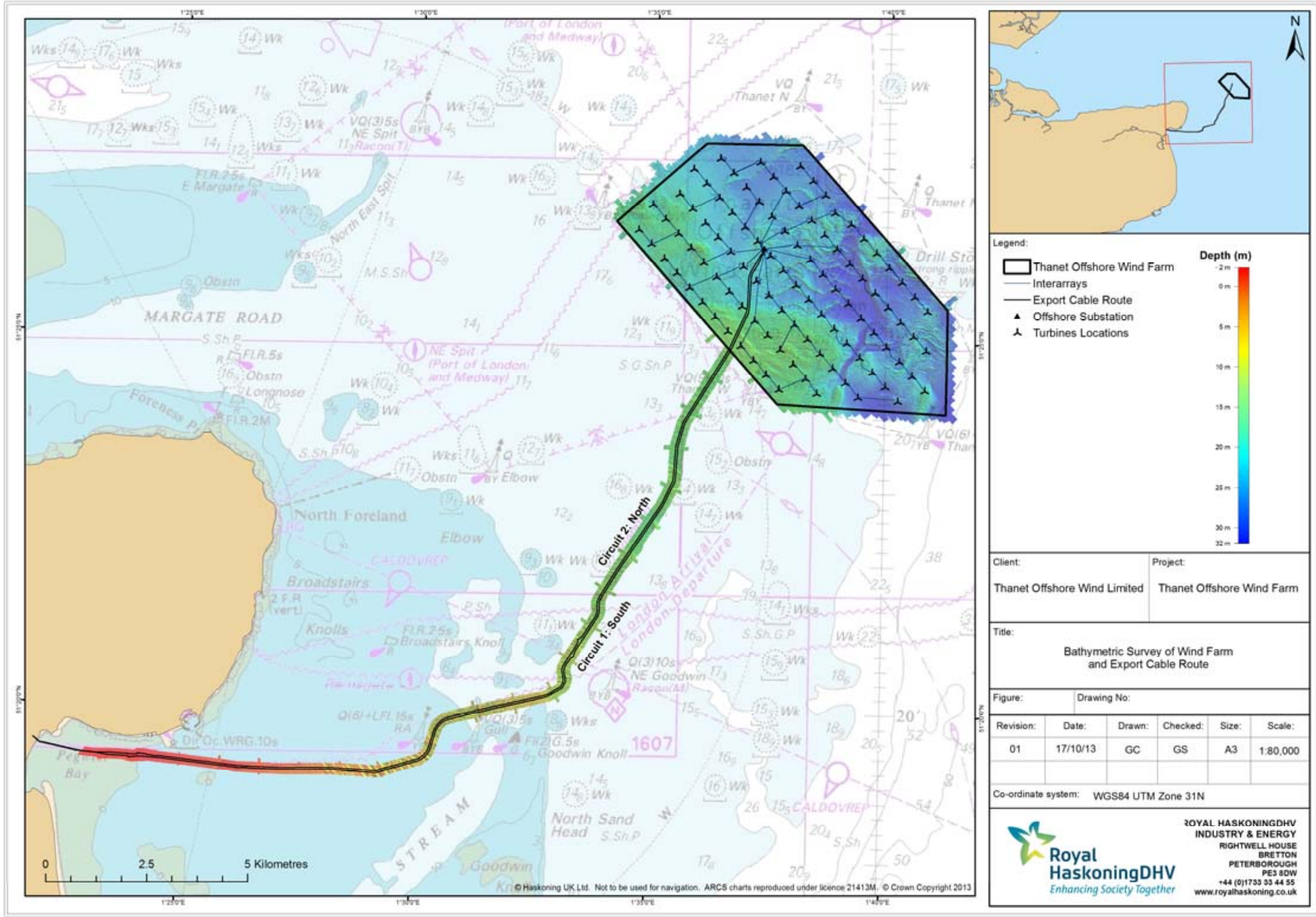


Figure 4.8 Export cable bathymetry including export cable protection

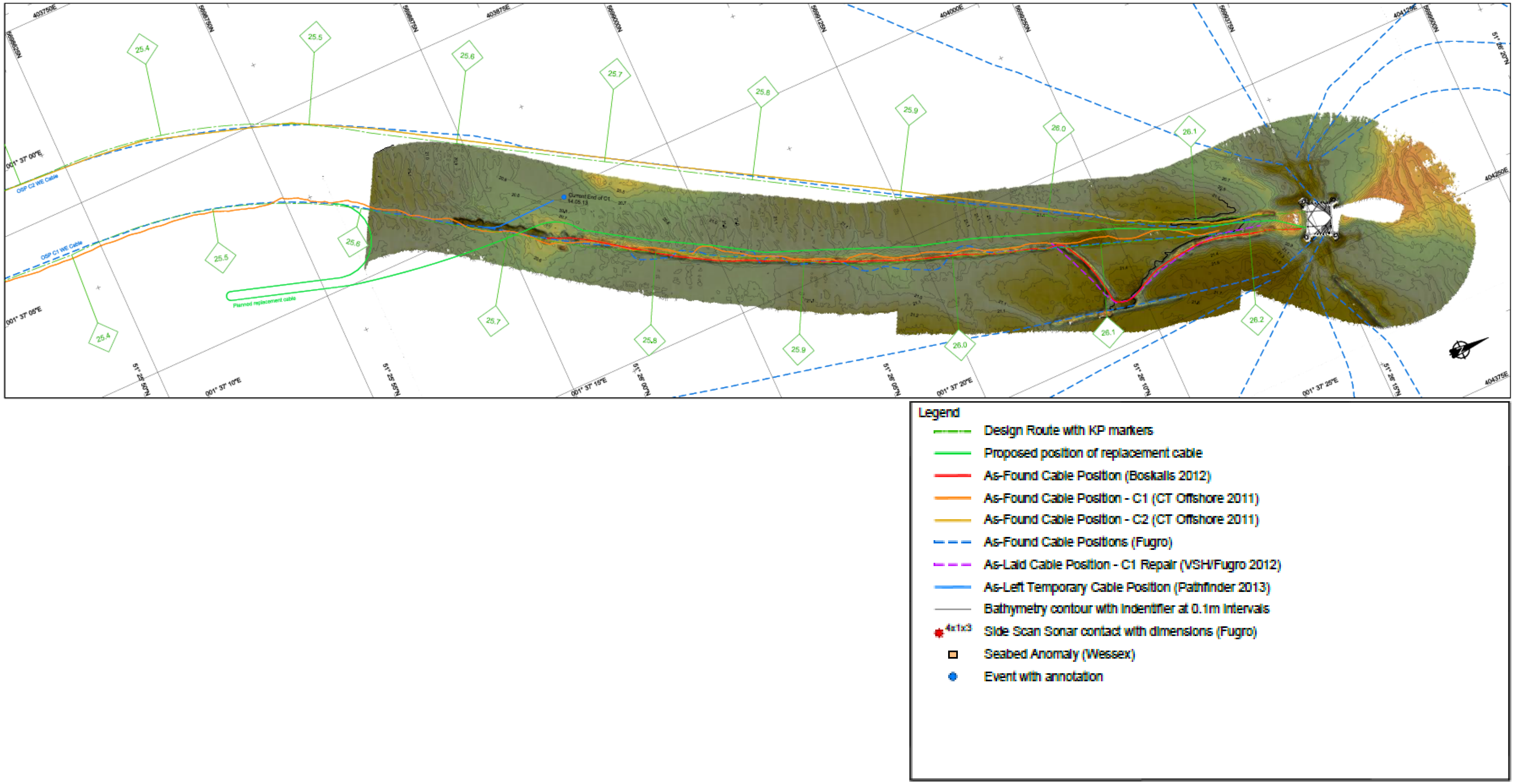
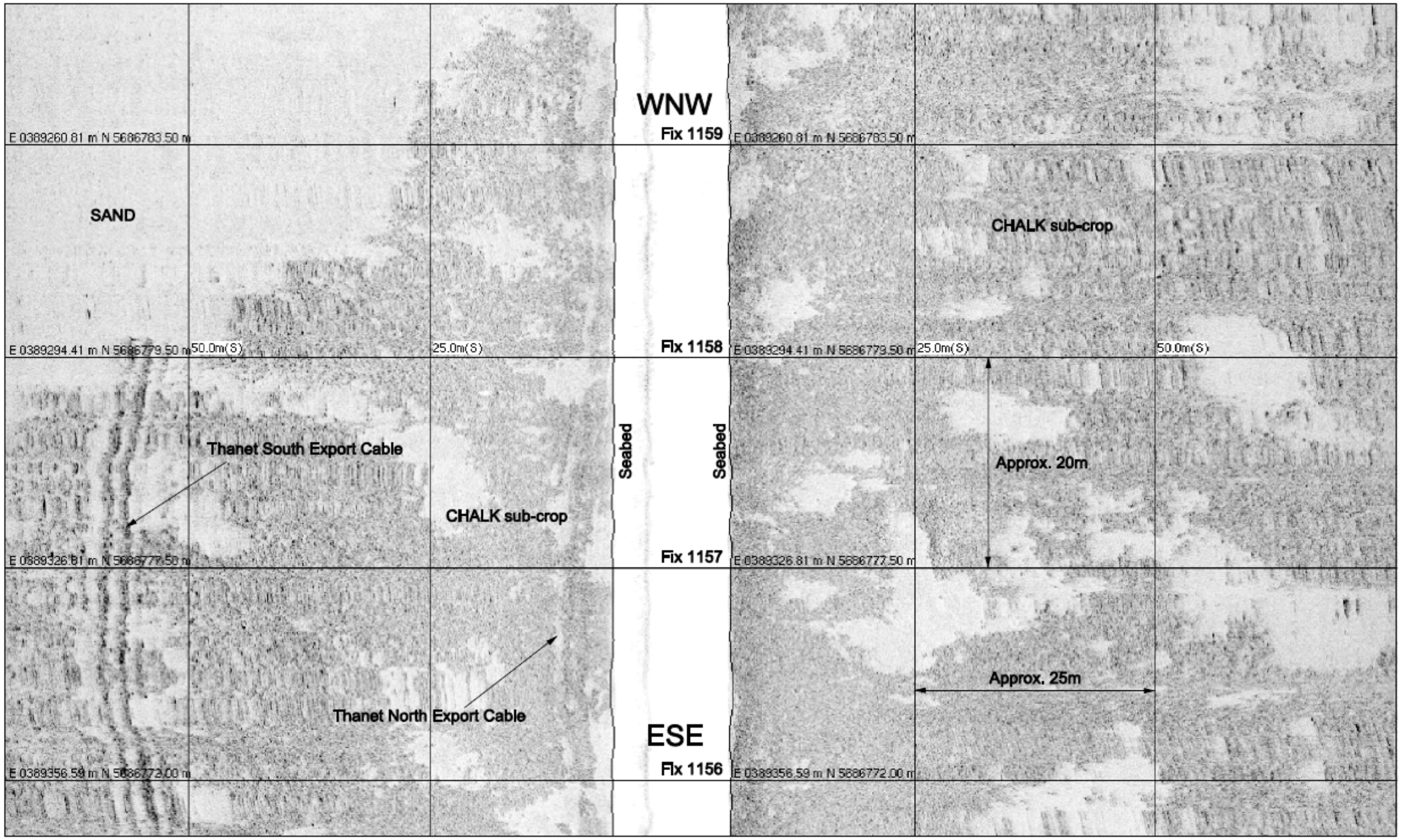


Figure 4.9 **Side Scan Sonar - Illustrating Chalk Sub-Crop towards the coast**



4.3.4 Conclusion

It is clear that when a comparison is made with the pre-construction survey data from 2007, there have been changes around all of the sand waves that are distributed across the Thanet Project site. The positions of the sand wave crests have changed; however, the shapes and distributions of the sand waves are very similar.

The majority have moved south by approximately 30m on average. Occasionally, in some instances parts of some sand waves have moved up to 50m south. The height of the sand waves has remained very similar with no obvious exceptions. Throughout the site there are three main areas of sand waves, of which difference profiles for all of these can be seen in **Figure 4.10, Figure 4.11** and **Figure 4.12**. In the north of the site are a few more isolated sand waves with similar movement to the south, shown in **Figure 4.13**. Size and distribution of sand waves and the sediment types have remained constant. The general appearance of the site has remained the same as the pre-construction survey in 2007.

Figure 4.10 **Bathymetric Profile 1 - Illustrating bathymetric surface difference through sand waves in the East of the site**

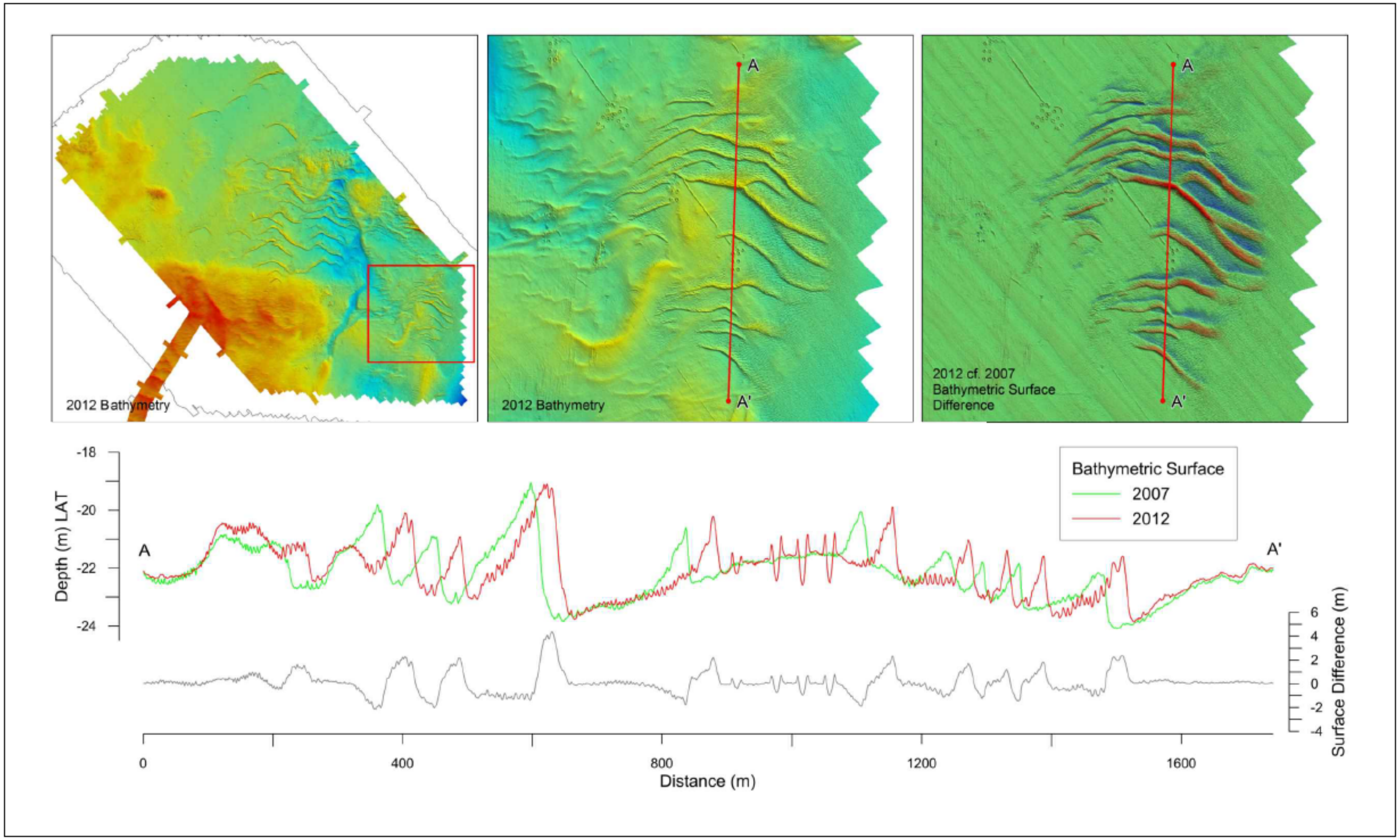


Figure 4.11 Bathymetric Profile 2 - Illustrating bathymetric surface difference through sand waves in the Centre of the site

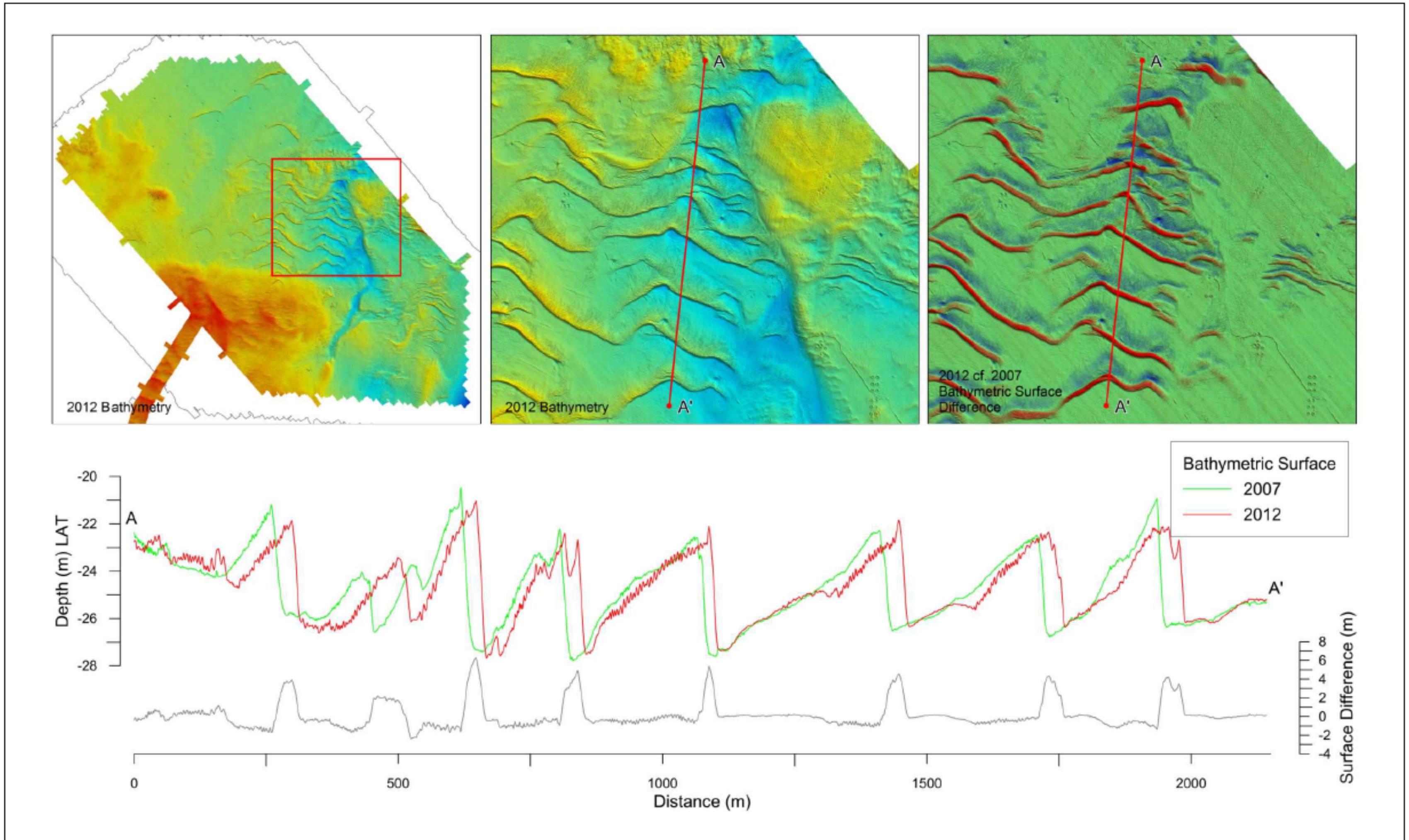


Figure 4.12 **Bathymetric Profile 3 - Illustrating bathymetric surface difference through sand waves in the North of the site**

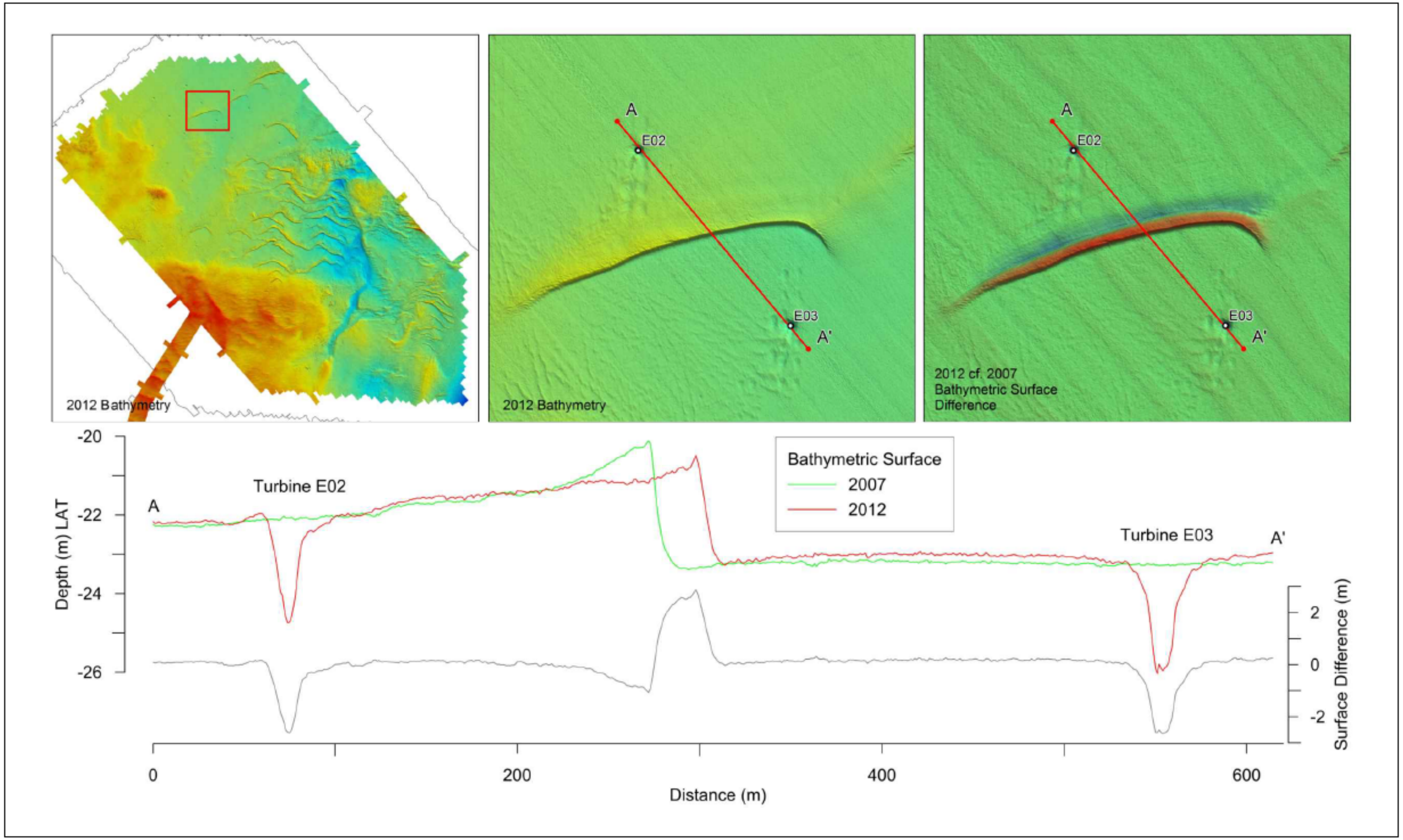
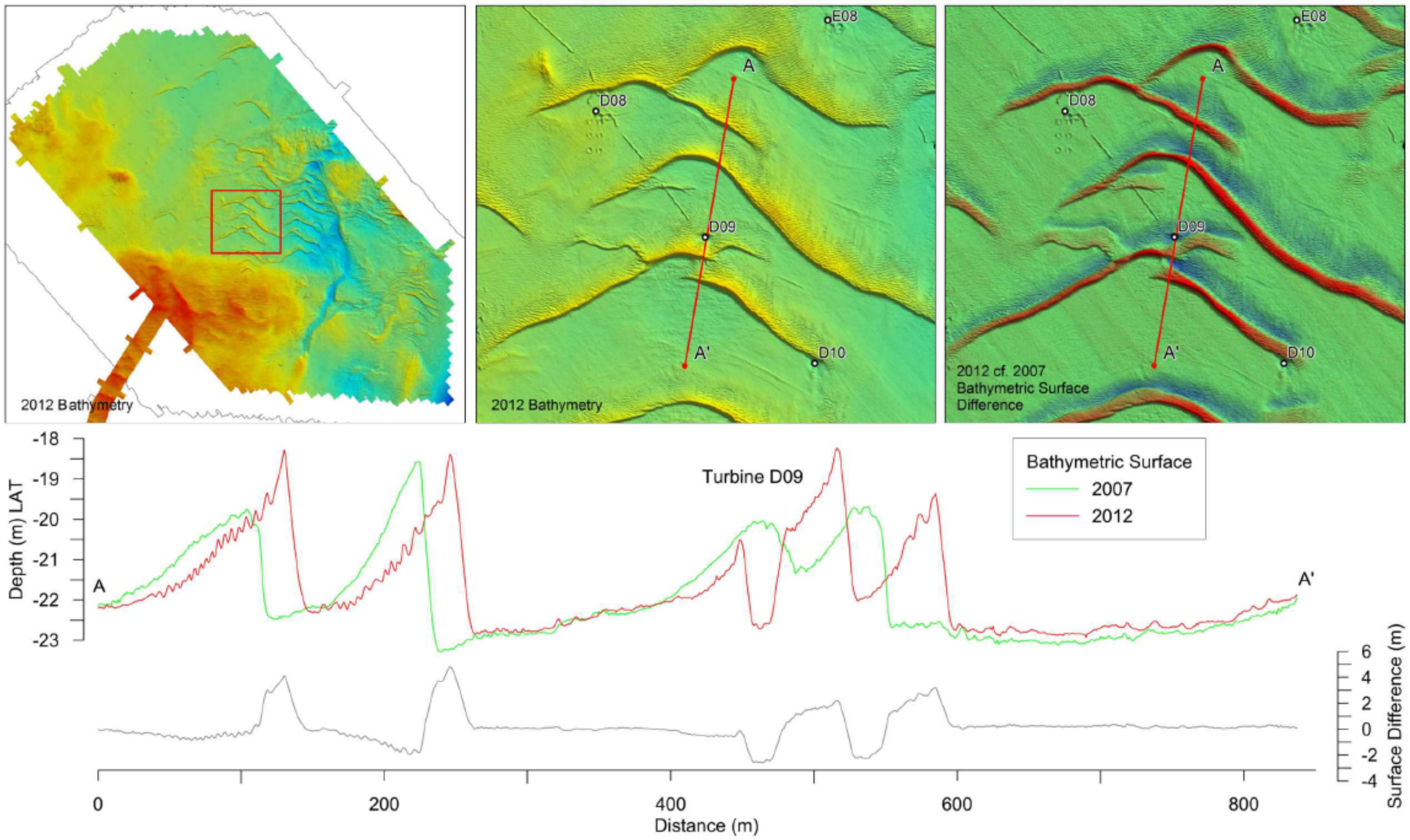
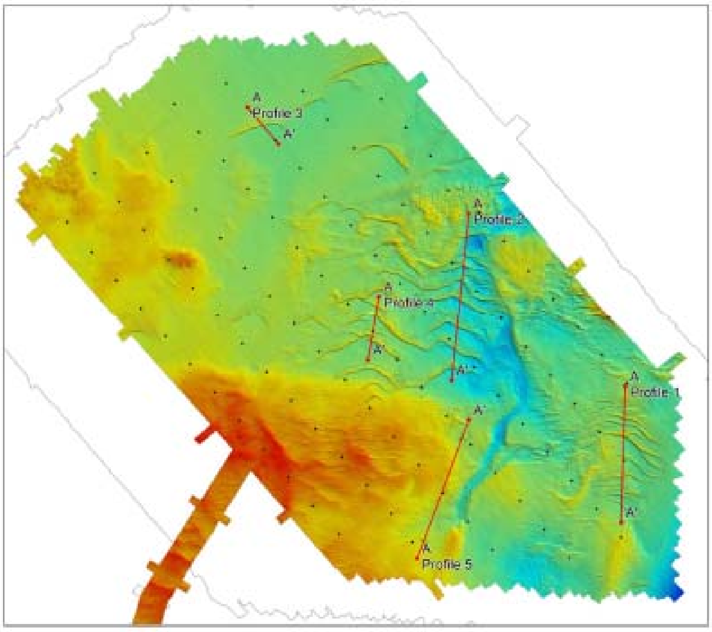


Figure 4.13 Bathymetric Profile 4 - Illustrating bathymetric surface difference through sand waves in the Centre of the site



The other main feature on the Thanet Project site is the large channel (**Figure 4.14**) orientated north-south through the centre-east of the wind farm site. No movement has been observed along this feature as compared to the 2005 or 2007 data.

Figure 4.14 Location of channel that runs straight through the wind farm



Sediment boundaries have changed slightly at the Thanet Project site; however the sediment types have remained constant. Overall, the general appearance of the site has remained the same as the pre-construction survey. Sediment boundaries along the export cable route have changed slightly, but general trends along the route have remained the same as the pre-construction survey.

It should be noted that mobile current features are present and, as such, seabed sediments will migrate with time. The results of the surveys suggest there is no impediment to movement of sandwaves from the construction of the WTGs, and this is as expected. The benthic sampling programme correlates the interpreted geophysical seabed types with actual ground conditions; this can be found in **Section 6.1**. Potential *Sabellaria spinulosa* was identified on SSS records and appears in the same general areas, with a similar density of cover as the 2007 pre-construction survey; however, the size and shape of the reef areas has changed. Please refer to the benthic monitoring section (**Section 6.1**) of this document for further details on *Sabellaria spinulosa*.

Several additional magnetic anomalies were observed during the 2012 survey. The largest have been correlated with the Thanet North and South Export Cables and wrecks identified on maps. Other smaller anomalies that do not correlate with any features on the seabed are interpreted as buried objects. The WTGs were too close to the survey lines and interfered with the magnetometer outputs. As such it was harder to pick out small magnetic anomalies close to the WTGs.

The maximum magnetic deflections were associated with wrecks and range between 600 – 3,180nT. Generally, the earth's background magnetic field ranges in strength between approximately 60,000nT in the Polar Regions to some 30,000nT at the equator (Gardline, 2012). This suggests that any anomalies identified would not create any significant additional magnitude to the E-fields which may affect sensitive species over and above background levels. The use of the word "significant magnetic anomaly" was relative to the other anomalies identified.

The morphology and debris surveys have been completed in accordance with the requirements of the FEPA licence and have confirmed that no effects on other users of the sea (particularly commercial fishing industry) will occur, as predicted in the original ES for the Thanet Project.

5 ORNITHOLOGY

5.1 Ornithology surveys

5.1.1 Objective

The overall objective of the post-construction ornithological surveys were to discern whether there was a change in the abundance and distribution of bird species within the wind farm site, as a result of the construction and operation of the wind farm, and to evaluate the predictions made in the ES regarding ornithology (Royal Haskoning, 2005). This is split into four specific objectives contained within Annex 2 of the FEPA licence (**Box 5.1**):

1. Determine whether there is change in bird use and passage, measured by species (with particular reference to red-throated diver), abundance and behaviour, of the wind farm site, 1km and 2km buffer zones and the reference site;
2. Determine whether there is a barrier effect to movement of birds through the wind farm site and the 1km and 2km buffer zones;
3. Continue to determine the distribution of wildfowl and divers in the Greater Thames estuary, covering the Thanet wind farm site, 1km and 2km buffer zones and the reference site; and
4. If objectives 1 or 2 reveal significant change of use of the wind farm site and 1km and 2km buffer zones by populations of conservation concern, at heights that could incur collision, a programme of collision monitoring will be implemented."

The post-construction surveys complete the programme of survey and monitoring for birds, which began in 2004, and allows the conditions set out in the FEPA to be met. The key points within Annex 2 are presented in the box below, and the full details within Annex 2 are presented in **Appendix 5A**.

This section of the report compares and interprets the results found across the preconstruction, construction and post-construction data collected from covering the first, second and third year's post-construction monitoring survey data from 2010 - 2013, against the pre-construction survey data undertaken from 2004 – 2005 for the ES and surveys undertaken during construction from 2009 - 2010.

5.1.2 Scope of survey

A programme of surveys was undertaken during pre-construction, construction and post-construction. The surveys followed the similar methodology and timings to allow the results to be easily compared following completion. The programme consisted of the following:

- Pre-construction surveys
    - Boat-based surveys – twelve boat based surveys were carried out at monthly intervals between November 2004 and October 2005; and

- Aerial surveys – four aerial surveys were carried out between November2004 and March 2005.

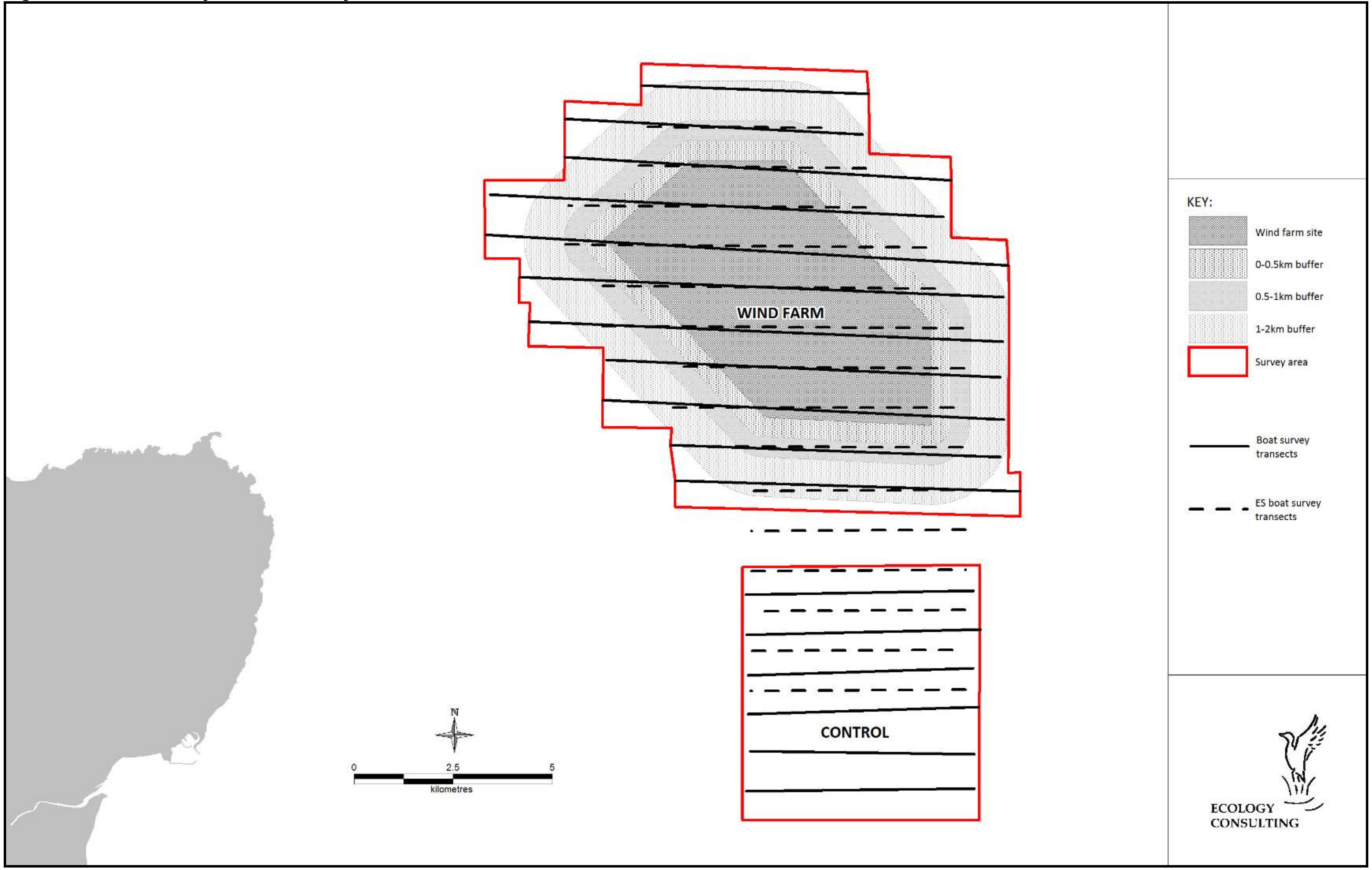
- Construction phase surveys
  - Boat-based surveys – one in February and two in March 2009; and
  - Boat-based surveys – two per month from October 2009 – March 2010.

- Post construction surveys
  - Boat-based surveys – two per month from October 2010 - March 2011 (total 12 surveys);
  - Boat-based surveys – 1-2 per month from October 2011 - March 2012 (total 10 surveys); and
  - Boat-based surveys – 1-2 per month from October 2012 - March 2013 (total 11 surveys).

The three years post construction monitoring shall be referred to hereafter as years 1, 2 and 3 post-monitoring respectively. The three years post-construction surveys were agreed prior to commencing with Natural England in line with the FEPA licence requirements. Summer surveys were not conducted as there were no species in any great number within the wind farm or buffer footprints during the summer periods in the two years of monitoring to 2007.

The study areas for the surveys included the wind farm site, a 1km buffer zone, a 2km buffer zone and a control site 38km south of the wind farm site (**Figure 5.1**), as required by Annex 2 of the FEPA licence. The 4km buffer was not carried out for these surveys to maintain consistent methodology. This was agreed with Natural England and DEFRA in 2009. These study areas shall be collectively referred to as the 'survey area' hereafter. The bird populations and densities within these study areas were assessed as part of the post-construction monitoring which aims to satisfy the four objectives above.

Figure 5.1 **Study area for Surveys**



5.1.3 Monitoring completed

Survey methodology

The survey methods used for monitoring follow those detailed in the Thanet Offshore Wind Farm – During and Post-Construction Bird Monitoring Protocol ('the Protocol') (Thanet Offshore Wind Limited, 2009). The Protocol was developed in consultation with Natural England and the Marine and Fisheries Agency (MFA) (now the Marine Management Organisation (MMO)) in order to meet the requirements of the Thanet project's FEPA licence. Further details of the survey methodology are provided in the Protocol (**Appendix 5B**).

Analysis of Results

In order to determine change in use and barrier effects, the abundance and distribution of species was analysed using the densities of different species across the survey area and assessing whether there were significant differences between these areas using a series of statistical tests

Data analysis is fully described in the post-construction ornithological monitoring reports (**Appendix 5C**) and a summary is presented here. Analysis was undertaken using DISTANCE and GIS (MapInfo) software to calculate the mean densities of species. Population sizes were subsequently estimated from this

Mean bird abundance was calculated for each wind farm zone/buffer (wind farm, 500m, 1km, 2km, and control, see **Figure 5.1**), for each period, to provide an initial visual summary of the data. This allowed a comparative analysis of temporal and spatial changes across the survey area. The analysis was limited to those parts of the main survey area covered during all surveys (**Figure 5.1**).

Contrasts were then made for each transect sub-section (of 500m), calculating the change in bird numbers between the pre-construction and the construction phase, the pre-construction with each of the post-construction years and the construction phase with each of the post-construction years. The key null hypothesis tested was that there was no difference between bird abundance for each contrast, i.e. the difference in bird abundance in the transect sub-sections was not significantly different from zero.

An additional gradient analysis was undertaken for each survey year, testing the null hypothesis of no difference in bird abundance across each wind farm zone/buffer (wind farm, 500m, 1km, 2km, 3km and control). As above the 500m sub-sections of each transect were used as the sample unit, taking into account spatial correlation as described above.

The ES pre-construction baseline did not cover as large a buffer zone around the wind farm as the later construction and post-construction phase surveys, limiting the sample from the 1-2km buffer zone. Therefore the comparative analysis across the full survey period presented here was limited to those parts of the main survey area covered during all surveys (**Figure 5.1**).

Statistical analysis was only undertaken for key species with sufficient data for a meaningful analysis to be drawn, and it is only possible to report conclusions for these species. These species were red throated diver, gannet, common gull, lesser black-backed gull, herring gull, greater black-backed gull, kittiwake, guillemot and razorbill.

Population estimates and GIS interpretation were also used to produce a visual representation of the position and abundance of species within the wind farm, buffer zones and the control site.

Evaluation of conservation significance

Conservation significance was determined according to whether an effect to the regional, national or international bird populations occurred, using the criteria by Percival (2007) (**Table 5.1**) and the criterion method by Holt *et al.* (2011), whereby >1% national population = nationally important, >1% international population = internationally important. The national baseline populations were taken from Baker *et al*. (2006) and Musgrove *et al*. (2011). A further category of 'local importance' has been used for species that are not considered to be of regional importance, but were still of some ecological value. This included all species on the red or amber lists of the 'Birds of Conservation Concern'. (Eaton *et al*., 2009).

Table 5.1 Sensitivity (Conservation Importance) of bird species

Sensitivity	Definitions
Very High	Species for which a site is designated (Special Protection Areas (SPAs) / Special Areas of Conservation (SACs)) or notified (Sites of Special Scientific Interest (SSSIs)). A local population of more than 1% of the international population of a species.
High	Other species that contribute to the integrity of an SPA or SSSI. A local population of more than 1% of the national population of a species. Any ecologically sensitive species, e.g. large birds of prey or rare birds (<300 breeding pairs in the UK). EU Birds Directive Annex 1, EU Habitats Directive priority habitat/species and/or Wildlife and Countryside Act 1981 (as amended) Schedule 1 species (if not covered above). Other specially protected species.
Medium	Regionally important population of a species, either because of population size or distributional context. UK Biodiversity Action Plan (BAP) priority species (if not covered above).
Low	Any other species of conservation interest, e.g. species listed on the Birds of Conservation Concern not covered above.

The evaluation of the conservation importance of the bird populations observed in the survey area during the surveys has been summarised in **Table 5.2** based on **Table 5.1** above.

Table 5.2 Evaluation of the conservation importance of the bird populations using the Thanet Offshore Wind Farm site and its surrounds, 2011-12. Species in red seen in 2012-13 but not previously.

Species	SPA sp[1]	Population Importance[2]	EU Birds Directive Annex 1	Red [R]/ Amber [A] List	UK BAP Priority Species	Sensitivity
Brent goose	Q	Regional		A	✓	Very high
Shelduck	Q	Local		A		Very high
Wigeon	Q	Local		A		Very high
Gadwall		Local		A		Low
Teal	Q	Local		A		Very high
Mallard		Local		A		Low
Shoveler		Local		A		Low
Common scoter		Local		R	✓	Medium
Eider		Local		A		Low
Red-breasted merganser		Local				Low
Red-throated diver	Q	Regional	✓	A		Very high
Black-throated diver		Regional	✓	A	✓	High
Great crested grebe	A	Local				Very high
Fulmar		Local		A		Low
Gannet		Regional		A		Medium
Cormorant	A	Local				Very high
Shag		Local		A		Low
Oystercatcher		Local		A		Low
Ringed plover	Q	Local		A		Very high
Lapwing	A	Local		R	✓	Very high
Curlew	Q	Local		A	✓	Very high

[1] Q = SPA qualifying species, A = SPA assemblage species
[2] On the basis of peak numbers in whole survey area and the 1% threshold (Baker et al. 2006, Holt *et al*., 2009, Musgrove et al. 2011).

Species	SPA sp[1]	Population Importance[2]	EU Birds Directive Annex 1	Red [R]/ Amber [A] List	UK BAP Priority Species	Sensitivity
Arctic skua		Local		R	✓	Medium
Great skua		Local		A		Low
Common gull		Regional		A		Medium
Lesser black-backed gull		Regional		A		Medium
Herring gull		Regional		R	✓	Medium
Great black-backed gull		National		A		High
Little gull		Regional	✓	A		High
Black-headed gull		Local		A		Low
Kittiwake		Regional		A		Medium
Sandwich tern	Q	Local	✓	A		Very high
Common tern	Q	Local	✓	A		Very high
Guillemot		Regional		A		Medium
Razorbill		Regional		A		Medium
Short-eared owl		Regional	✓	A		High
Skylark		Local		R	✓	Medium
Sand martin		Local		A		Low
Swallow		Local		A		Low
Meadow pipit		Local		A		Low
Pied wagtail		Nil				Nil
Robin		Nil				Nil
Whinchat		Local		A		Low
Black redstart		Local		A		Low
Blackbird		Nil				Nil
Fieldfare		Local		A		Low
Song thrush		Local		R	✓	Medium

Species	SPA sp[1]	Population Importance[2]	EU Birds Directive Annex 1	Red [R]/ Amber [A] List	UK BAP Priority Species	Sensitivity
Redwing		Local		A		Low
Goldcrest		Nil				Nil
Starling		Local		R	✓	Medium
Chaffinch		Nil				Nil
Goldfinch		Nil				Nil

Reporting

Reports were provided on a monthly basis to Royal HaskoningDHV, containing details of the surveying including the raw count, species density, population estimates and incidental marine sighting data. Count data was provided to the Environmental Liaison Officer and quarterly reports were provided to Natural England which served to highlight any observable trends. Annual reports were submitted to the Licencing Authority within two months of survey completion. The annual report documents combined the quarterly reports and included a discussion of key issues in relation to FEPA requirements, namely notable changes in bird usage, any obvious barrier effects and any discernible relationship between the abundance and distribution of birds within the Greater Thames Estuary, primarily through the analysis of the measurements taken and described above.

The annual survey reports are appended to this report (**Appendix 5C**). They include:

- Year 1 Post-construction annual monitoring report;
- Year 2 Post-construction annual monitoring report; and
- Year 3 Post-construction annual monitoring report.

5.1.4 Overview of results

A summary of the results obtained from the monitoring programme is provided below. A discussion and the conclusions that can be drawn from these results are provided in section 5.1.5.

Abundance and distribution

The densities of the main seabird species present in the survey area during October to March for the pre-construction, construction and post-construction monitoring is shown in **Table 5.2**.

The peak population estimates are shown in **Table 5.3**. Red-throated diver and razorbill peak population estimates increased in all wind farm areas post-construction relative to construction (and pre-construction), with low sample sizes recorded during construction for the red-throated diver. In contrast, common gull shows a decrease in all regions post-construction, with species such as lesser black-backed gull and guillemot having markedly higher numbers in the 1-2km buffer zone and control area relative to the wind farm site.

Table 5.2 Densities of the main seabird species present in the survey area during Oct-Mar in the pre-construction (ES), construction (2009-10) and post-construction (2010-11, 2011-12 and 2012-2013) surveys. Densities are given as mean numbers per km².

	Wind Farm					0-1km buffer					Control				
Species	**ES**	**09-10**	**10-11**	**11-12**	**12-13**	**ES**	**09-10**	**10-11**	**11-12**	**12-13**	**ES**	**09-10**	**10-11**	**11-12**	**12-13**
All Divers	0.29	0.03	0.08	0.07	0.08	0.00	0.01	0.41	0.38	0.19	0.04	0.05	0.36	0.70	0.37
Gannet	0.05	0.07	0.05	0.17	0.96	0.00	0.14	0.16	0.57	2.06	0.06	0.55	0.89	1.72	1.79
Common gull	1.70	3.39	1.15	0.42	0.77	0.00	2.51	0.75	0.37	0.55	0.03	1.07	0.46	0.35	0.29
Lesser black-backed gull	0.33	0.71	0.41	0.62	0.08	1.44	0.50	0.53	1.29	0.16	0.76	0.41	1.11	0.71	0.16
Herring gull	1.95	0.55	0.90	0.87	2.30	0.30	0.57	1.04	6.23	1.07	0.97	0.72	1.81	0.70	0.74
Great black-blacked gull	0.02	0.33	0.39	1.16	1.53	0.11	0.15	2.63	4.06	1.54	0.08	0.33	3.72	1.73	0.96
Kittiwake	0.20	0.81	1.56	0.92	0.81	0.15	0.56	0.98	1.14	0.79	0.14	0.27	1.17	1.50	0.64
All gulls	4.32	5.79	4.83	5.24	6.36	2.81	4.29	6.59	13.5	6.93	1.98	2.80	9.02	6.01	4.35
Guillemot	0.69	0.29	0.39	1.59	3.07	0.65	0.73	1.43	3.35	4.78	1.32	0.57	1.53	4.53	5.60
Razorbill	0.22	0.02	0.03	0.68	0.48	0.22	0.09	0.11	1.08	1.59	0.14	0.21	0.39	0.57	0.85
All Auks	1.00	0.31	0.58	2.88	4.72	0.26	0.00	2.01	6.21	8.79	0.10	0.00	3.60	8.40	12.92

Table 5.3 Comparison of peak population estimates for main species zones within and around the wind farm based on 'in-transect' counts corrected for distance sampling and survey coverage in 2009-10 (construction phase), and 2010-11, 2011-12 and 2012-13 (post-construction).

Species	Wind farm site				0-1km				1-2km				Control			
	09-10	10-11	11-12	12-13	09-10	10-11	11-12	12-13	09-10	10-11	11-12	12-13	09-10	10-11	11-12	12-13
Red-throated Diver	6	7	13	10	3	41	23	7	8	24	106	49	10	27	156	29
Gannet	22	12	28	138	16	12	67	157	32	31	167	131	95	99	347	141
Common Gull	716	150	67	120	430	55	45	42	222	71	102	105	342	58	70	30
Lesser Black-backed Gull	132	28	81	8	66	27	153	7	125	200	298	20	43	253	45	29
Herring Gull	52	56	102	697	36	32	1437	84	663	276	355	156	116	167	62	85
Great Black-blacked Gull	56	72	79	176	13	716	546	101	22	111	273	76	53	1,508	233	90
Kittiwake	141	287	84	122	43	52	67	48	302	62	453	38	33	145	138	106
Guillemot	95	79	187	405	93	130	234	161	99	213	1281	344	70	175	552	727
Razorbill	6	9	91	90	21	7	84	124	54	11	304	77	61	94	71	87

Flight heights

The bird monitoring programme measured flight heights of birds to determine whether the collision risk might be significant (testing the conclusions reached in the ES that it would not). **Table 5.4** compares the mean numbers within the wind farm over the pre-construction (ES – 2004 - 2005), construction (2009 - 2010) and three years' post-construction (2010 - 2013) periods with the mean number in flight at rotor height (i.e. those at risk of collision with the WTG rotors), to make a relative comparison of the likely collision risk.

The results show that gull numbers were broadly similar during post-construction and construction as assessed in the pre-construction surveys carried out for the ES baseline, though with more kittiwake activity in 2010-11 (an increase which was seen generally within the Thames in that year, J. Ford pers. comm.; Percival *et al.* 2011).

Table 5.4 Mean count in flight at rotor height for each winter within the wind farm site, Oct-Mar as a percentage of the mean count for each winter within the wind farm site, Oct-Mar

	ES (2004 – 2005)	Construction (2009 – 2010)	Post-construction yr. 1 (2010 – 2011)	Post-construction yr. 2 (2011 – 2012)	Post-construction yr. 2 (2012 – 2013)
Wigeon	0	0	0	0	0.6
All divers	0.8	0.1	0.2	0.1	0
Gannet	0.2	0.1	0.1	0.3	3.5
Common gull	4.9	35.0	13.5	4.2	4.1
Lesser black-backed gull	3.3	9.1	5.5	6.5	0.9
Herring gull	14.9	5.6	8.6	7.4	6.4
Great black-backed gull	0.1	2.0	2.9	6.7	9.8
Kittiwake	0.4	4.4	8.7	4.9	4.1
All gulls	28.9	43.3	49.3	45.4	28.2
Guillemot	0	0.1	0	0.1	0.2
Razorbill	0	0	0	0	0
All auks	0.1	0.1	0	0.2	0.2

5.1.5 Discussion

Changes to abundance and distribution

Red-throated diver: A statistically significant decline in diver abundance within the wind farm was observed within zones between construction and post-construction, providing evidence of the displacement of red-throated diver from within the wind farm zone. There was no evidence of any displacement effect extending beyond the wind farm itself. There was a lack of evidence for statistically significant changes within the wind farm after construction, which suggests that the decline observed during construction has not been reversed and that diver abundance in that zone has remained at its reduced construction phase level.

Gannet: The abundance of this species was highly variable between years, though there was no evidence of any significant reduction in abundance in any zone in comparison with the pre-construction baseline (though comparatively low numbers were seen in that year across the whole survey area). Examining the differences by individual zone, no statistically significant decline was recorded in any zone over the whole survey period. There were some statistically significantly increases noted, mainly in the control zone. These analyses indicated that there did not appear to be any statistically significant adverse effects on this species as a result of the construction and operation of the wind farm.

Common gull: The highest abundance recorded for common gull was recorded within the wind farm site during the construction surveys, suggestive of some attraction to the construction works through increased feeding opportunity. Outside that period, common gull densities were similar across zones between years, with no indication of any adverse effects of the wind farm. The only significant change observed was a decline in abundance from the construction phase to the post-construction phase, but this is attributed to the much higher numbers recorded during the construction phase. Overall, there was no evidence of any adverse effect of the wind farm on common gull, and no indication apparent of any reduced density within the wind farm.

Lesser black-backed gull: There was no statistically significant overall difference in the level of change between zones in the pre-construction and construction phases, and in comparison of the pre-construction phase with two of the three post-construction years. There was a difference in the level of change in the third of the post-construction years, though this was not likely to result from any wind farm effect (with much lower numbers recorded across all of the survey area in the third post-construction year). As well as an overall decline, there were proportionately lower numbers within the wind farm in the third post-construction year, which showed a significant, statistical reduction in numbers in comparison to the construction and second post-construction year. It is considered unlikely that this was an effect of the wind farm. Overall, there was no evidence of any adverse effect of the wind farm on lesser back-backed gulls.

Herring gull: Statistically significant declines were recorded in comparisons of the pre-construction phase with the construction and post-construction surveys within the wind farm, suggesting a possible displacement effect. However, a similar magnitude of decline was observed in the other parts of the survey area, and across the whole data set there was no statistically significant change, so the change is attributed to other factors such as food availability operating over the wider area. Overall, though herring gull numbers did decline within the wind farm during and after construction of the wind farm, similar declines elsewhere in the survey area and generally high variability in numbers between years would suggest that this was unlikely to be attributable to any effect of the wind farm.

Great black-backed gull: The numbers of this species during the pre-construction surveys were very low, making it difficult to draw comparisons with the construction and operational phase other than to note that there have been substantially more birds recorded in those years, including within the wind farm. There was no statistically significant overall difference in the level of change between zones in any of the comparisons of the pre-construction, and post-construction phases. Examining the differences by individual zone, there were no statistically significant declines recorded in any comparisons in any of the zones. Overall, comparisons of the densities within the wind farm site with those elsewhere suggest that this species has not been adversely affected by the wind farm construction or operation.

Kittiwake: There was no statistically significant overall difference in the level of change between zones in any of the comparisons of the pre-construction, and post-construction phases. Examining the differences by individual zone, the only statistically significant changes recorded were in a single zone in comparisons between the post-construction years. The 1-2km zone had a statistically significantly increase in numbers of kitttiwakes in the second year and a decrease in the following year. To summarise, there was no evidence that kittiwakes have been adversely affected by the wind farm construction or operation.

Guillemot: For guillemot there was evidence for a statistically significant decline in abundance within the wind farm during the construction phase (to 33% of the level recorded pre-construction). The reduction persisted in the first post-construction monitoring year, with a reduction to 21% of the pre-construction baseline. There was also evidence of a smaller reduction (to 75% of pre-construction level during construction and 77% during the first year of operation) within 1km of the wind farm. However, the decline in the construction and first post-construction year also occurred across the remainder of the survey area, including the control zone, suggesting that the reduction within the wind farm may not have been a result of the construction/initial operation of the wind farm but rather part of wider scale population changes. By the third year of post-construction monitoring guillemot numbers within the wind farm were higher than those recorded in the pre-construction baseline.

Razorbill: For razorbill there was evidence of a statistically significant decline in abundance within the wind farm during the construction phase (to 11% of the level recorded pre-construction). As with guillemot, the reduction persisted in the first post-construction monitoring year, with a reduction to 5% of the pre-construction baseline. There was also some evidence of a similar reduction within 500m of the wind farm, though this was not statistically significant. Whilst the numbers declined in the wind farm (and to a lesser extent in the 0-500m zone), there were increases apparent in the other zones, particularly in the control zone, suggesting that the reduction within the wind farm was probably a result of the construction/initial operation of the wind farm, though that effect appeared short-term and was not apparent by the second year of operation.

Barrier Effects

Whilst specific testing of any barrier effect is not possible without data on bird flight lines through the wind farm before and after construction (which did not form part of the agreed monitoring programme), the observed changes in flight activity within the wind farm do give some indication as to whether a barrier effect may have been operating.

Three species showed reduced activity within the wind farm after construction, red-throated diver (for all three post-construction years) and guillemot and razorbill (the latter two for the first post-construction year only). As numbers of guillemots and razorbills within the wind farm increased above the pre-construction baseline levels in the second and third post-construction years, the evidence for any barrier effect on these species was weak, and if at all was clearly only short-term.

Diver flight activity was reduced within the wind farm, so a barrier effect on this species could not be discounted, in that there was reduced flight activity through the wind farm (though it should also be noted that flight activity pre-construction in this area was also low, and it is not really possible from the data available to separate the barrier effect out from the displacement of birds through disturbance).

Conclusion in relation to conservation significance

No species were estimated to occur within the wind farm site at significant densities or at nationally important numbers, with guillemot, razorbill and auks estimated to occur at significant densities in the control area and 1km and 2km buffer areas.

Species affected have been considered in the context of their regional populations. Where official figures have been unavailable for comparison, local knowledge and professional judgement has been used.

Red-throated divers showed a statistically significant drop in diver numbers within the wind farm, equivalent to about a 82% decline during construction, and a 73% reduction in diver density there post-construction (again only within the wind farm). In population terms, this meant a reduction from a population within the wind farm from a peak population of 25 pre-construction to about 5 during construction and 7 post-construction.

The population was determined to be regionally important pre-construction. Though reduced, the construction and post-construction phases would still be considered regionally important. In the context of that regional population, the Greater Thames region has been estimated to support 8,130 red-throated divers (O'Brien et al. 2008) and the Outer Thames Estuary SPA citation gives a designated population of 6,466 individuals (Natural England/JNCC, 2010). Partial loss of a relatively low density diver foraging area outside the SPA, involving displacement of approximately 18-20 individuals is not considered ecologically significant. Caution does need to be applied to these results at this stage however as the wind farm site has supported only low numbers of this species throughout the surveys, so the sample of birds exposed to potential displacement is only small.

Guillemot showed a statistically significant drop in numbers within the wind farm during construction but a subsequent increase in the second and third post-construction years. There was a 67% reduction in density within the wind farm during construction and a 25% reduction in the 0-1km buffer within that period. A 79% reduction in guillemot numbers within the wind farm was also recorded in the first post-construction year in comparison with the pre-construction baseline and a 23% reduction in the 0-1km buffer. No reductions were apparent beyond those zones, or in the second or third post-construction year. With a pre-construction peak population in these zones estimated at about 200, this would equate to a loss of about 100 guillemots from the wind farm plus 1km buffer during construction and about 50 in the first post-construction year (though still retaining its status as regionally important in the survey area). Such losses would, in the context of this species' regional population, be negligible and not ecologically significant. It should also be noted that for this species these changes occurred across the survey area with less evidence of a greater effect within the wind farm, so the evidence for displacement of that this is more equivocal.

Razorbill also showed a statistically significant drop in numbers within the wind farm during construction but a subsequent increase in the second and third post-construction years. There was an 89% reduction in density within the wind farm during construction. A 79% reduction in razorbill numbers within the wind farm was also recorded in the first post-construction year in comparison with the pre-construction baseline. No statistically significant reductions were apparent outside the wind farm, or in the second or third post-construction year. With a pre-construction peak population within the wind farm estimated at about 20, this would equate to a loss of about 18 razorbills from the wind farm during construction and about 19 in the first post-construction year (though still retaining its status as regionally important within the survey area). Such losses would, in the context of this species' regional population, be negligible and not ecologically significant. It should also be noted that for this species these changes occurred across the survey area with less evidence of a greater effect within the wind farm, so the evidence for displacement of that this is more equivocal.

Collision risk

The assessment of flight heights showed an increased collision risk for kittiwake, due to the general increase in kittiwake activity recorded in 2010-2011 (J. Ford pers. comm; Percival et al. 2011 cited in Year 3 post-construction annual monitoring report,

Appendix 5C**). However, for all the other species assessed (see **Table 5.3**), including species of high conservation interest, such as divers, there was no notable change in flight activity within the wind farm site in comparison with the ES assessment. Therefore, no evidence was found to suggest that the conclusion reached in the ES (that there would not be any significant collision risk) is changed in light of the post-construction data.

Since the numbers of birds and species at risk of collision remained similar throughout the post-construction monitoring period, a programme of collision monitoring was not considered necessary, as changes to populations of high conservation concern were not found to have resulted in an increased collision risk.

5.1.6 Summary

The results presented in this report give conclusions based on data from three complete year's post-construction monitoring.

Red-throated diver, guillemot and razorbill showed statistical changes in abundance and distribution, based on small sample sizes throughout the three year survey period. For red-throated diver, the decline limited to wind farm and it is likely that the presence of the wind farm did cause that displacement. For guillemots and razorbills these changes occurred across the survey area with less evidence of a greater effect within the wind farm, so the evidence for displacement of that this is more equivocal. For all three species, no ecologically significant change was identified.

For kittiwake, common gull, herring gull, lesser black-backed gull, greater black-backed gull, gannet, no statistically significant changes in abundance and distribution were identified and therefore no ecologically significant change was identified.

Some collision risk was identified for kittiwake, but no other species including species of high conservation concern.

Appropriate evidence to evaluate barrier effects was not gathered, but change in flight activity was observed which provides some information. Red-throated diver, guillemot and razorbill may all have experienced barrier effects.

These small sample sizes to date and the fact that only preliminary statistical analyses have been completed mean that quantifying the magnitude of these changes should be treated with caution, but the results in relation to divers do contrast with those from the smaller Kentish Flats wind farm. Here, diver densities declined by 81% within the wind farm, 53% within 500m and 29% in the 500m-1km zone (Percival *et al.* 2011). At Thanet there have been regular sightings of small numbers of divers within the wind farm (albeit at a lower density than prior to construction) and densities have been maintained post-construction in the buffer zones around the wind farm (even in the 0-1km zone immediately adjacent to the wind farm). The comparative percentage change in density at Thanet was a 70% reduction within the wind farm comparing the pre-construction densities with those post-construction but no effect extending beyond the wind farm once construction activities were completed.

Gull numbers appear to have been largely unaffected by the construction or first two winters of operation. Indeed several species have increased in number following construction of the wind farm, including within the wind farm, though this increase likely reflected wider population fluctuations rather than any site-specific effects given the wider increase in gull numbers seen in the Outer Thames in 2010-11 (J. Ford, pers.

comm.; Percival *et al.* 2011) and the results of the spatial analysis of changes in gull numbers.

Comparison with ES Predictions

In the ES it was predicted that disturbance to and displacement of feeding seabirds during construction would be short term and of minor adverse significance, as a result of overall low densities of birds observed throughout the year and availability of similar feeding areas close by.

The results of the construction phase monitoring supported this conclusion, with some minor displacement observed of some species including divers, gannets, guillemots and razorbills.

Disturbance impacts during the operational phase of the wind farm were also predicted in the ES to result in only minor adverse effects, particularly on divers and auks. No disturbance effects were predicted on gulls. This again appears from the results to date to be borne out by the results of the monitoring programme, with evidence of displacement of divers, gannets, guillemots and razorbills, and none for gulls.

In relation to collision risk, the data on bird flight activity collected as part of the post-construction monitoring has not found any evidence to suggest that the conclusion reached in the ES (that there would not be any significant collision risk) would be changed by the recent post-construction data (though no direct monitoring of collision risk has been undertaken).

Overall, therefore, the predictions made in the ES relating to the ornithological impacts of the wind farm have been supported by the results of the post-construction monitoring.

6 MARINE ECOLOGY

6.1 *Sabellaria spinulosa* mapping

6.1.1 Objective

The objective of the survey was to assess if the Thanet Project has had any impacts on the dense aggregations of *Sabellaria spinulosa* found within the Thanet Project site. The objectives are described in further detail in the licence condition requirements outlined below.

6.1.2 Scope of survey

During the environmental characterisation surveys and pre-construction benthic surveys of 2005 and 2007 respectively, large aggregations of *S. spinulosa* were identified within the Thanet Project site. These surveys informed the micro-siting of WTGs and cables within the Thanet Project site during the construction phase of the wind farm to prevent any damage to the reef habitat.

Post-construction, a further geophysical survey using side scan sonar (SSS) was used to identify potential reef assessment stations. These stations were to be targeted by seabed imagery methods (still photography) during the benthic grab sampling campaign. Limpenny *et al.* (2010) provide a review of the best methods to monitor *S. spinulosa*. Seabed imagery (stills or video) and SSS are likely to provide the best non-destructive methods for sampling.

The potential seabed imagery stations were selected to confirm the extent and condition of *S.spinulosa* reef observed in the geophysical survey data that were consistent with the signature identified for *S. spinulosa* aggregations in 2005 and 2007. The 2012 survey area matched that of the 2007 survey to allow comparison between the pre- and post-construction status of *S. spinulosa*. The extent of the survey area in the 2005 survey is not directly comparable with 2007 and 2012.

6.1.3 Monitoring completed

During April 2012, high resolution (500kHz) SSS data that was collected and assessed, identified 34 seabed imagery stations for *S. spinulosa* reef assessment. These drop down sites were then surveyed during the benthic grabbing campaign in August 2012.

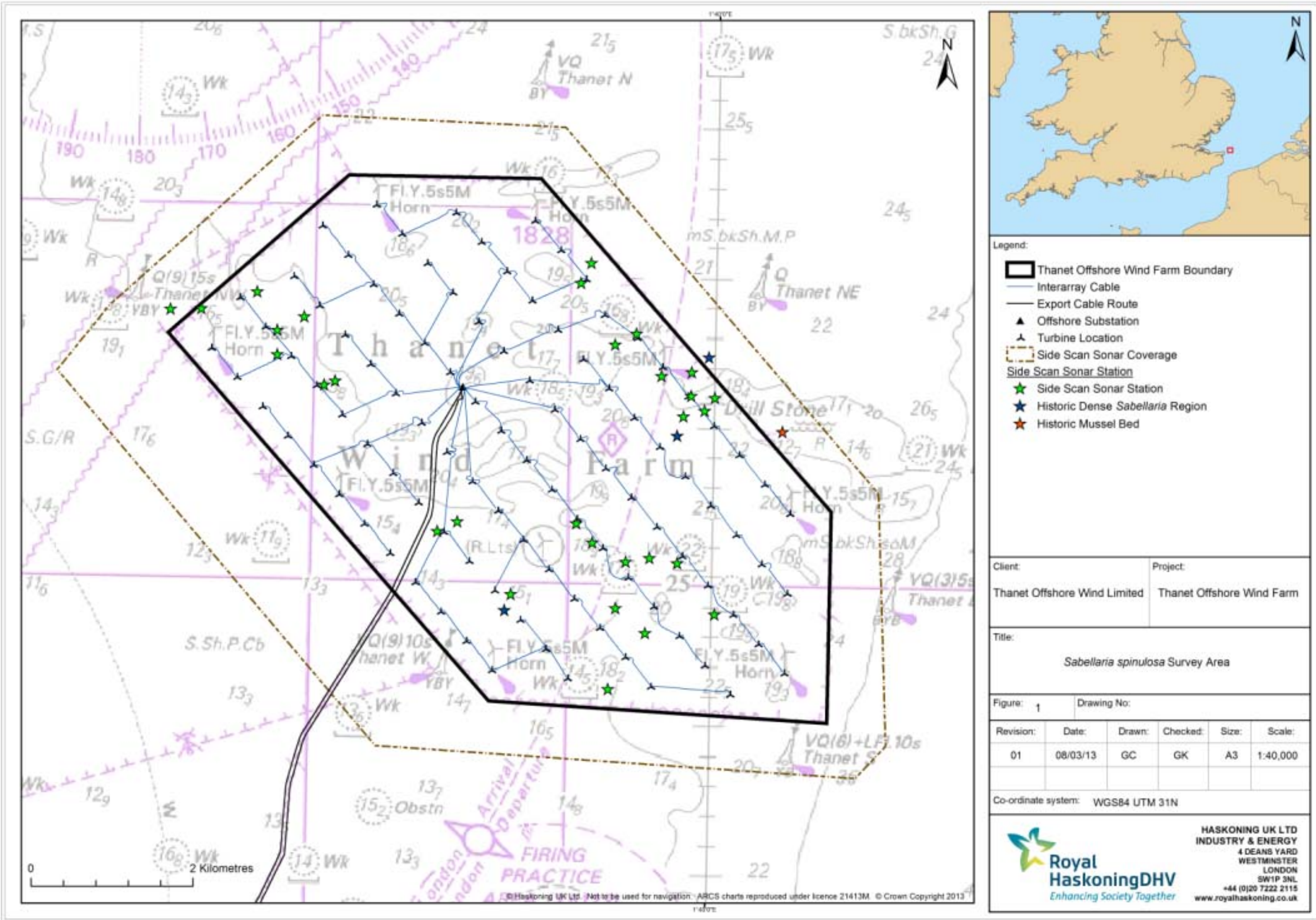
Figure 6.1 shows the sample positions of these stations across the Thanet Project site. Each ground-truthing station was sampled with a freshwater camera system, which was developed for use in turbid water conditions, prevalent at this site and where *S.spinulosa* thrives. Five images were taken at each sample station to give an indication of the nature of the reef aggregations identified within the geophysical survey.

Each seabed image was interpreted taking into consideration methods discussed in Gubbay (2007) and Hendrick & Foster-Smith (2006) and assigned a description based on the observed habitat features. Each site was then assigned a broad categorisation and a *S. spinulosa* categorisation score of 0-3, as described in **Table 6.1**. All images are presented in **Appendix 6A** along with the classifications and a full description.

Table 6.1 ***Sabellaria*** **assessment scores and justification**

Score	Assessment
0	No *Sabellaria* Present
1	*Sabellaria* Accretions / Sparse *Sabellaria* region
2	Moderate *Sabellaria* Growth / Patchy Reef
3	Dense *Sabellaria* Growth / Reef

Figure 6.1 ***Sabellaria* survey area 2012**



6.1.4 Overview of results

The **Figure 6.2a, b and c** shows *S. spinulosa* reef was found over large parts of the Thanet Project site in 2012 (approximately 16% of the SSS survey area) and exists in different densities, ranging from patchy coverage to dense reef. It can be estimated that from the area surveyed by SSS, 2.2% constitutes of dense *S. spinulosa* growth (reef); 5.1% patchy *S. spinulosa* reef (moderate); and 8.6% sparse coverage of *S. spinulosa*. Regions of dense *S. spinulosa* growth that constitute reef are located to the eastern and central-southern regions of the Thanet Project site. Areas of patchy and sparse *S. spinulosa* coverage were found towards the north-west, central-west, surrounding the areas of dense reef.

The 2007 and 2012, *S. spinulosa* distribution found at the Thanet Project site is shown in **Figure 6.2a**, allowing comparison of growth or reduction of reef coverage. In 2012 a wider distribution of S*. spinulosa* aggregation was categorised as patchy (moderate) and wider aggregations of dense reef was recorded compared with the survey findings in 2007. In comparison, the 2007 survey, showed dense aggregations of *S. spinulosa* reef was located towards the eastern and central-southern portion of the Thanet Project site, and that the extent of the *S. spinulosa* aggregations were reduced and aggregations that were identified were mostly recorded as being sparse to patchy (moderate) in density. As discussed in Section 6.1.2, the survey data from 2005 is not directly comparable with the 2007 and 2012 surveys. However comparison of the southern extent, covered by the 2005 survey area (shown in **Figure 6.2a**) shows a large amount of change between years.

Figure 6.2a shows the location of the WTGs and cables in relation to the *S. spinulosa* aggregations recorded in 2012, 2007 and 2005 Figure 6.2b and c shows the location of the rock protection in relation to *S. spinulosa* recorded in 2012 and 2007. No *S. spinulosa* reef aggregations were identified in seabed imagery collected from scour pits around surveyed monopiles. It can be assumed that impacts associated with scouring are restricted to the base of the monopile plus an approximate 5 metre circumference (Titan Environmental Surveys Ltd, 2012).

Figure 6.2a **Map of *S.spinulosa* findings extrapolated from side scan sonar and seabed imagery in 2012, 2007 and 2005**

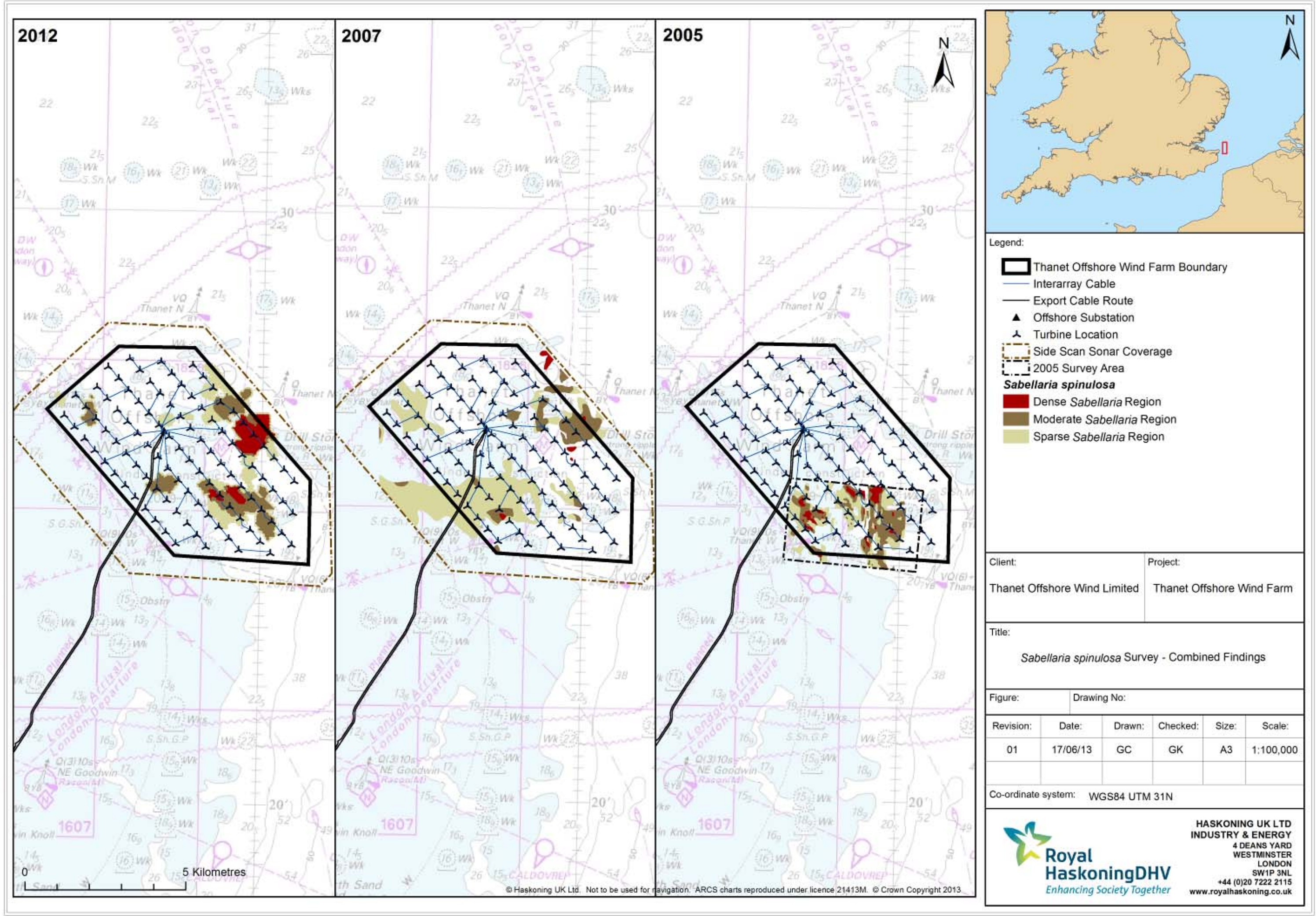


Figure 6.2b Map of *S.spinulosa* findings extrapolated from side scan sonar and seabed imagery in 2012,

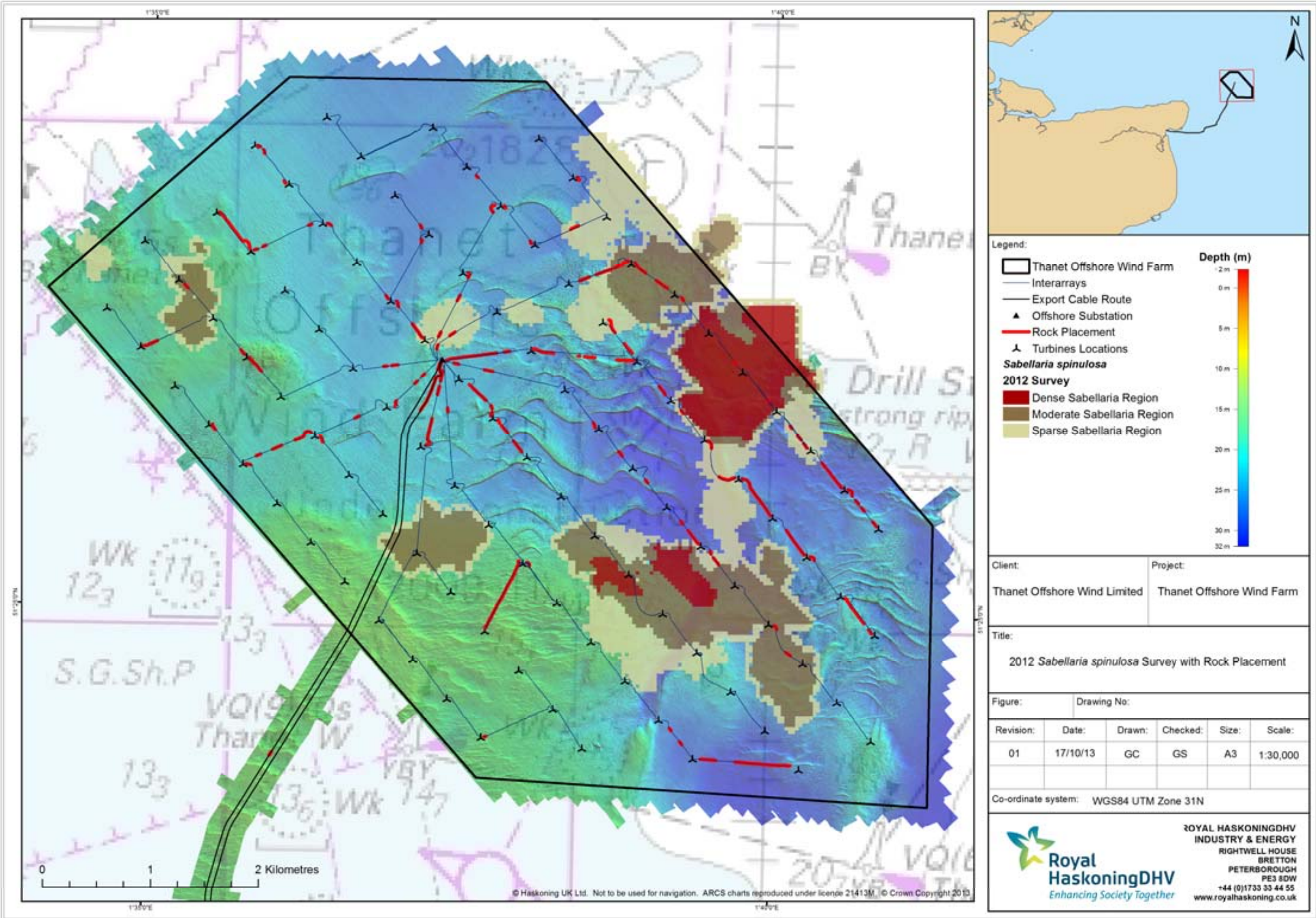
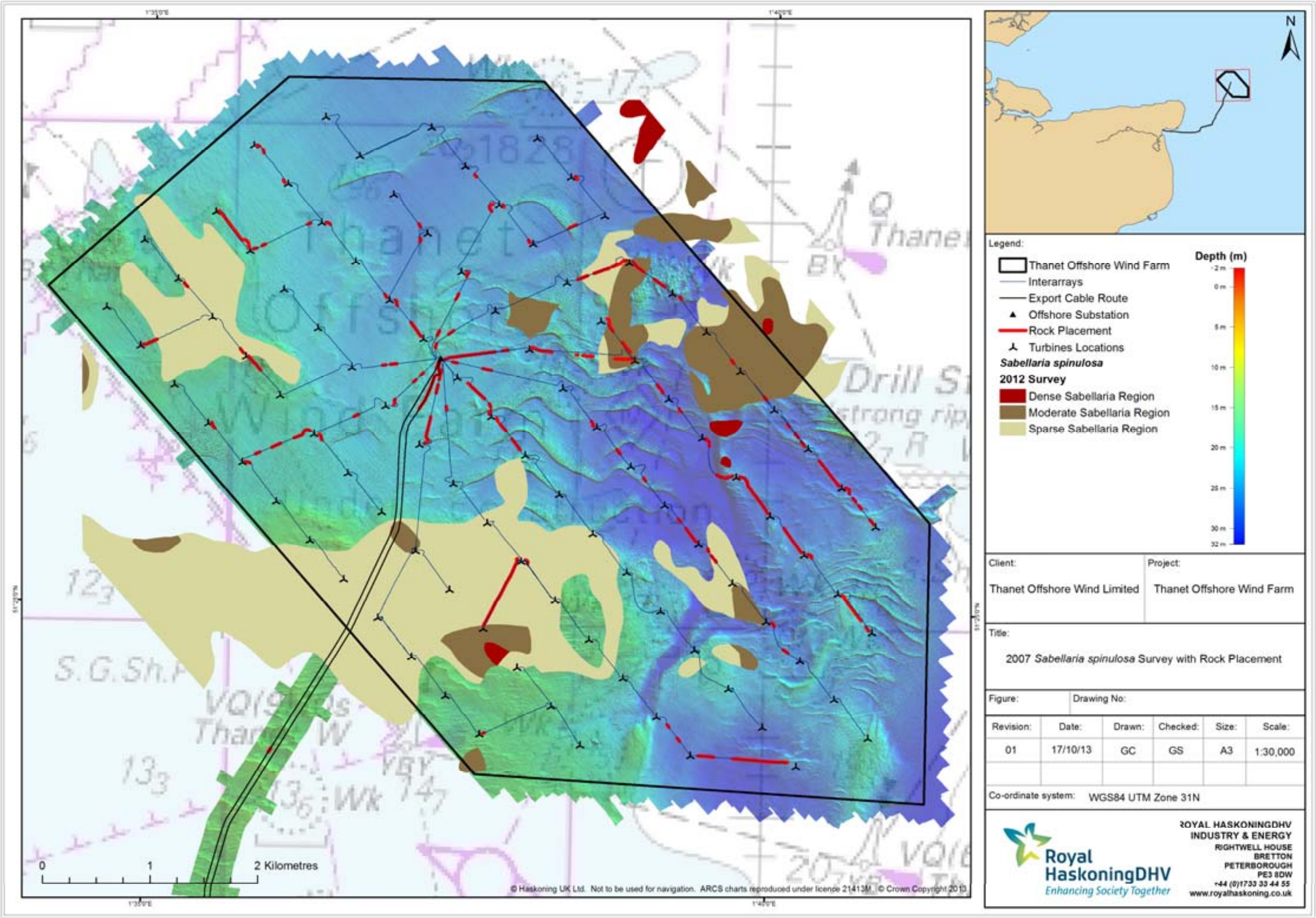


Figure 6.2c **Map of *S.spinulosa* findings extrapolated from side scan sonar and seabed imagery in 2007**



A comparison between 2007 and 2012 data indicates that some moderate S. *spinulosa* aggregations in 2007 have developed into dense aggregations in 2012, and sparse into moderate. However an area of sparse S. *spinulosa* to the south west of the survey area in 2007 appears to have reduced in its extent in the 2012 survey findings (**Figure 6.2b and c**; **Table 6.2**).

Table 6.2 below provides the mapped area of the dense, moderate and sparse S. *spinulosa* aggregations for 2007 and 2012 shown in **Figure 6.2** (2005 is excluded as the survey area is not comparable).

Table 6.2 Areas of s.*spinulosa* aggregations

	Dense *S. spinulosa*	Moderate *S. spinulosa*	Sparse *S. spinulosa*
2007	0.195km²	2.138km²	7.732km²
2012	1.284km²	2.876km²	3.524km²

These mapped areas are based on multiple data sources (side scan sonar, imagery, grab sampling) and as a result statistical analysis of the mapped changes is not appropriate. However MESL (2013) provides statistical analysis of the grab sampling results which shows that *S. spinulosa* is in the top ten species (6th) contributing to the most change between the pre- and post-installation results with 2.5% of the dissimilarity (18.3% of the cumulative dissimilarity with the first five species).

As discussed in Section 6.1.2, environmental characterisation surveys and pre-construction surveys were completed in 2005 and 2007 respectively. Comparison between 2005 and 2007 shows the dynamic nature of *S. spinulosa* with an almost complete change in the distribution of aggregations. Of the area surveyed in 2005, a general decline in *S. spinulosa* aggregations in 2007 was reported (Marine Ecological Surveys Ltd, 2013). Marine Ecological Surveys Ltd (2008) concluded that this decline could have been attributed to damage from benthic trawling within the wind farm site. During both the 2005 and 2007 surveys *S. spinulosa* aggregations were generally found to be sparse or patchy. There were numerous accounts of aggregations that constituted mainly *S. spinulosa* rubble and broken tubes, showing damage from bottom fishing gear. In comparison, the 2012 survey showed that there was a significant increase in areas of dense *S. spinulosa* reef (see **Figure 6.2b**). Moreover, there was a reduction in the number of sites described as having recorded *S. spinulosa* rubble and damage, as compared to the 2005 and 2007 data (MESL, 2013).

6.1.5 Conclusions

The longevity of *S. spinulosa* aggregations is a key feature in establishing the importance of the biogenic reef habitat (MESL, 2013). It is expected that a long lived colony of *S. spinulosa* has a greater value in providing a stable biogenic habitat enabling more species diversity. However, *S. spinulosa* is a very dynamic species, influenced by a number of environmental factors and is fragile and easily broken. Monitoring of the Wash and North Norfolk SAC (Foster-Smith, 2001) to the north of the Thanet Project site also found significant special and temporal variation in *S. spinulosa* aggregations and Foster-Smith (2001) suggests it is difficult to assess the importance of relatively small scale changes.

The 2012 side scan sonar and seabed imagery found *S. spinulosa* to be present over a large portion of the Thanet Project site (approximately 16% of the SSS survey area). Regions of dense growth that constituted reef were located to the eastern and central-southern regions of the Thanet Project site. Areas of sparse and patchy growth were found towards the north-west and central-west portions of the Thanet Project site as well as surrounding areas of dense reef growth.

In line with the FEPA licence condition 9.6, pre- and post-installation *S. spinulosa* distribution data is mapped in **Figure 6.2a, b and c**, allowing comparison. **Figure 6.2** and **Table 6.2** illustrate that in 2012, there was a wider distribution of *S. spinulosa* aggregation categorised as moderate (patchy) growth and dense growth. The methodology for extrapolating *S. spinulosa* maps from the side scan sonar and grab sampling data is outlined in MESL (2013, Appendix 21).

In 2012, less signs of damage (e.g. rubble and scars) to the *S. spinulosa* aggregations were recorded when compared with the 2005 and 2007 data (MESL, 2013). It is assumed that the positive growth and stable *S. spinulosa* reef aggregations found across the Thanet Project site in the 2012 survey may be partially attributed to the reduction in destructive bottom fishing activities as a result of the presence of the offshore wind farm and associated cable infrastructure (MESL, 2013).

There has been no recorded evidence of damage to *S. spinulosa* aggregations from construction or operational activities associated with the development of the offshore wind farm. In response to FEPA licence condition 9.28, no *S. spinulosa* was recorded in scour pits.

The benthic data collected was in line with the licence requirements and shows that although the *S. spinulosa* reef aggregations have migrated within the site, the positive growth and increase in dense and moderate aggregations of *S. spinulosa* in 2012 compared with 2005 and 2007 suggests there has been no detrimental impact caused by the construction of the wind farm. Therefore, no significant adverse impact, over and above that determined in the ES, has occurred on the Annex I protected species.

6.2 Subtidal benthic surveys

6.2.1 Objective

The subtidal benthic surveys were intended to assess any long-term changes to the subtidal benthic ecology as a result of the construction and operation of the Thanet Project site. This objective is in line with meeting the FEPA licence condition requirements outlined below and discussions with Natural England and Cefas. It should be noted that due to weather constraints, the study to assess the monopile colonisation has been rescheduled for 2014.

6.2.2 Scope of survey

Subtidal infaunal sampling was undertaken at 25 stations, with a $0.1m^2$ mini Hamon grab. Stations were selected according to which faunal group and sediment type they were classified under historically. This process ensured that the 2012 post-construction sampling array was representative of key habitats across the region. This approach is in accordance with the survey Terms of Reference (Marine Ecological Surveys Ltd, 2011), approved by the MMO and its advisors on June 14th 2012. Three replicate grab samples were collected at each sample station in accordance with FEPA licence Annex 1 conditions. Where sampling at a station failed after three attempts, or *S.spinulosa* was collected in a grab sample, seabed imagery was collected instead.

6.2.3 Monitoring completed

The grab sampling campaign was undertaken in August 2012. The seabed imagery survey (where grab sampling had not been possible) was undertaken in November 2012. The gap between these sampling events was a result of very poor weather conditions experienced at the Thanet Project site throughout this period. 11 of the 25 stations were surveyed using drop down imagery rather than grab sampling due to a result of poor ground conditions. As discussed above, the monopile colonisation survey was not completed as a result of poor weather conditions encountered. This will be undertaken during the first appropriate weather window in 2014, as approved by the MMO and their advisors (MESL, 2013).

A total of 53 faunal grabs, 42 sediment samples for particle size analysis and 21 sediment samples for organic content analysis were collected during the 2012 survey (MESL, 2013).

6.2.4 Overview of results

<u>Species</u>

A wide range of benthic invertebrate species were recorded in the Thanet Project site. A total of 264 taxa were recorded during the post-construction survey with a mean of 27 taxa per sample. The mean number of organisms per sample was 172, and the mean biomass per sample was 1.71g AFDW (Ash Free Dry weight) (MESL, 2013).

The percentages of Annelida, Crustacea, Mollusca, Echinodermata and miscellaneous phyla recorded in 2012 are shown in **Figure 6.4** below.

Figure 6.4 A histogram illustrating the relative contribution of the main faunal groups to the total abundance, diversity and biomass sampled across the Thanet Project site and adjacent areas (Source: Marine Environmental Surveys Ltd, 2013)

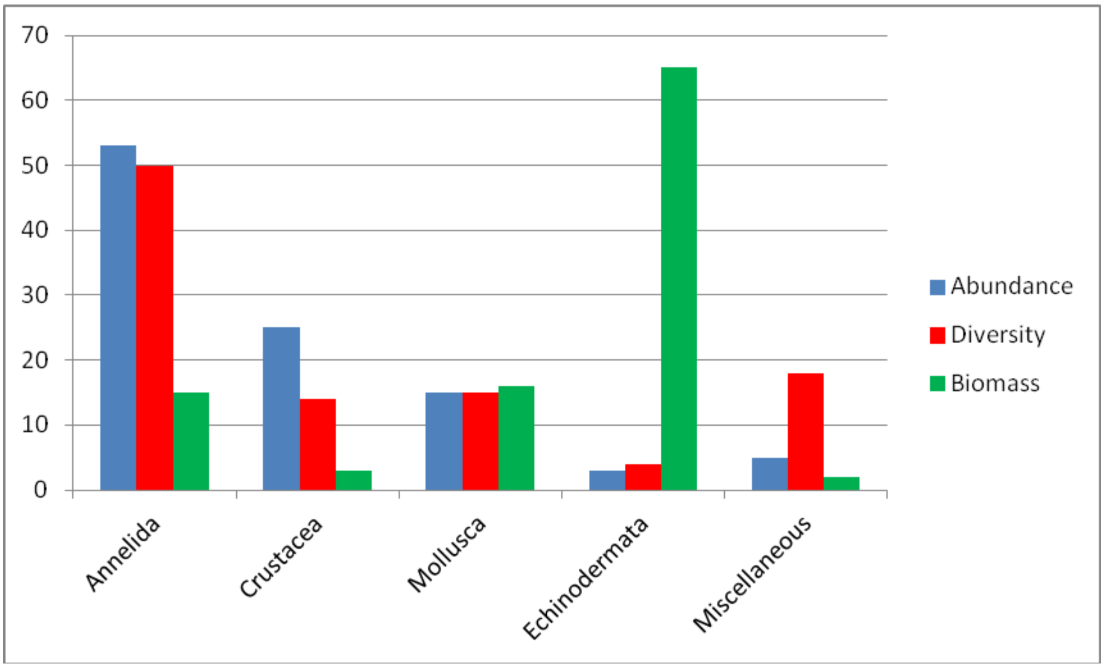
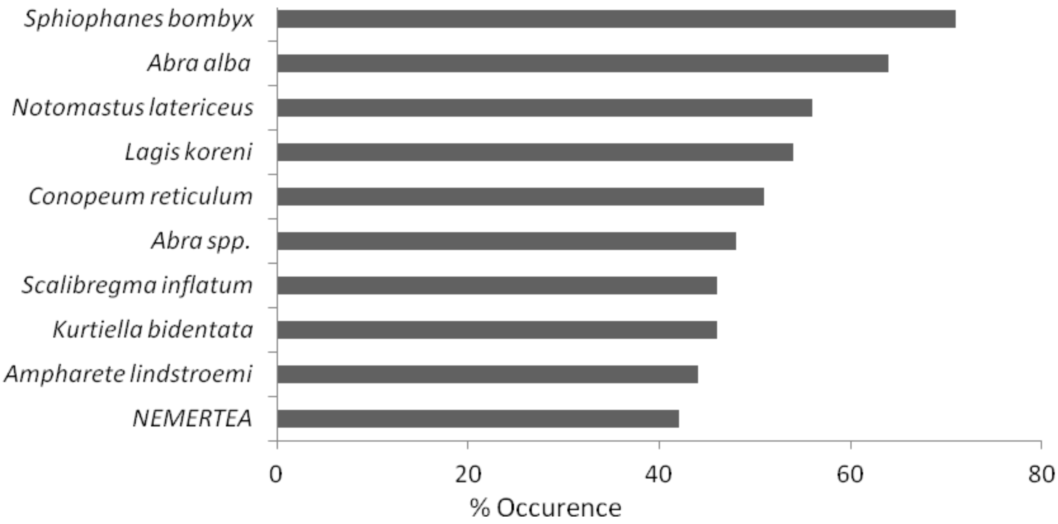


Figure 6.5 illustrates the taxa that occurred in the highest proportion of samples, during the 2012 survey. Five of these taxa belong to the Phylum Annelida and of these, the bristle worm *Spiophanes bombyx* occurred most frequently. Despite not being frequently recorded, *S. spinulosa* was the third most abundant species during the 2012 survey, due to being recorded in high abundance at a limited number of stations.

Figure 6.5 A histogram illustrating the 10 most commonly occurring taxa sampled across the Thanet Project site and adjacent areas during August 2012 (Source: Marine Ecological Surveys, 2012)



There was considerable variation in abundance between sampling stations, with the number of individuals ranging from 4 to 1574 per station. Some of the high abundances recorded reflect the presence of high numbers of the long clawed porcelain crab *Pisidia longicornis* as well as *S. spinulosa*. Species numbers varied from 4 to 81 species per station throughout the Thanet Project site (MESL, 2013).

The distribution of infaunal biomass was relatively uniform across the Thanet Project site, with the majority of stations (86%) having a biomass of between 0.01 to 2.39g AFDW. High biomass values were recorded to the north of the site and were mainly due to the presence of the common heart urchin *Echinocardium cordatum* and serpent's table brittlestar *Ophiura albida* (MESL, 2013).

Analysis of the benthic communities recorded in the 2012 survey, distinguishes 4 infaunal communities across the Thanet Project site (MESL, 2013):

- Faunal Group A occurred at 6 stations located towards the north of the site and was the second most diverse group recorded, consisting of 37 taxa. Characterising fauna of this group included:
  - *Ophelia borealis;*
  - *Spiophanes bombyx;*
  - *Abra alba;*
  - *Kurtiella bidentata; and*
  - *Owenia fusiformis.*

- Faunal Group B was the most diverse group recorded, consisting of 44 taxa (at the 90% cut-off) and occurred at 4 stations across the area. Key characterising fauna of Group B include:
  - *Pisidia longicornis; and*
  - *Sabellaria spinulosa*

- Faunal Group C was the least diverse group, consisting of 5 taxa (at the 90% cut-off) and occurred at 2 stations, located towards the south east of the sampling area. Key characterising fauna of Group C include:
  - *Urothoe brevicornis; and*

- *Mytilidae*

- Faunal Group D comprised 4 stations within the central portion of Thanet Project and consisted of 18 taxa (at the 90% cut-off). Key species include:
    - bristle worms *Ophelia borealis;*
    - *Spiophanes bombyx; and*
    - *Mytilidae.*

The 2012 infaunal data demonstrates an increase in mean infaunal abundance, number and biomass across the Thanet Project site compared with the site characterisation and pre-construction surveys in 2005 and 2007 respectively. High infaunal abundance and number associated with dense *S. spinulosa* aggregations at 2 stations will have significantly influenced this increase however omitting data obtained from these 2 stations still shows that there was a relatively considerable increase in mean abundance, number and biomass (MESL, 2013).

In 2005, 2007 and 2012 taxa belonging to the group Annelida were the greatest contributors to abundance and species number, although the percentage was not as high in 2012. Taxa belonging to the group Crustacea demonstrated an increase in the percentage contribution to 2012 abundance. This can be accounted for by the high abundance of *Pisidia longicornis* associated with *S. spinulosa* aggregations. In terms of biomass constituents, Mollusca made up the greatest contribution to overall biomass in 2005 & 2007 and Echinodermata in 2012. This can be ascribed to the presence of *Echinocardium cordatum* and *Ophiura albida* which, though present in relatively small numbers in 2012, represent a significant proportion of the biomass (MESL, 2013).

These results show some statistically significant differences in the faunal composition across the survey area when comparing pre and post-construction data. It can be expected that both spatial and temporal comparisons of marine benthic assemblages are likely to reveal a high degree of natural variability. By using reference stations in similar habitats outside the influence of the Thanet Project, the level of natural variation can be measured. Benthic assemblages recorded from reference stations showed the same level of temporal variability to those from within the Thanet Project site. Although statistically significant, the differences in the faunal data between the pre and post-construction were minor in relation to the ecology and differences between the benthic communities within the Thanet Project site can be attributed to a level of natural variation corroborated by the variability recorded at the reference stations (MESL, 2013).

In the 2012 geophysical survey, some localised scour was measured to a range of between 3.5m and 4.5m in a circular shape around the base of the monopiles. On average the sediments in the scour pits were coarser than those recorded from samples elsewhere in the Thanet Project site. Analysis of infaunal samples from scour pits at two locations revealed that the most abundant and commonly occurring taxa (including *Sphiophanes bombyx, Abra alba, Conopeum reticulum*) were similar to those found across the Thanet Project site and surrounding region. Potential scour effects on *S. spinulosa* were minimised by initial micro-siting to avoid *S. spinulosa* aggregations and no *S. spinulosa* was recorded in any of the monitored scour pits (MESL, 2013).

It is generally considered that wind farms have the potential to act as ‘stepping stones’ permitting the spread of alien species by providing new substrates for potential colonisation. During the course of the monitoring plan no alien species were recorded in high abundance. The amphipod *Monocorophium sextonae* is an alien species and was recorded at one station in 2012 (1 individual). However it was also recorded during the 2005 site characterisation survey and is not deemed to be a matter for concern. No other alien species (e.g. *Didemnum vexillum*) have been recorded at the site. The monopile colonisation study will report on any alien /invasive species recorded during the survey which is expected to take place during spring 2013 (MESL, 2013).

Sediment

The monitoring program has shown that the sediments within the Thanet Project site comprise a mixture of coarse sands, fine sands and cobbles, with bedrock outcrop within the central-southern portion of the site. The organic content of these sediments varied between <0.20% and 1.50%, representing low to moderate levels (Marine Ecological Surveys Ltd (MESL), 2013).

Research undertaken by MESL (2007) suggests that biodiversity can be directly related to sediment type and the more heterogeneous the sediments, the greater the number of species they are likely to support. This is because a greater mix of particle size increases the number of potential habitat types for benthic species. Statistical techniques revealed a significant relationship between patterns observed in the particle size distribution (PSD) and the faunal communities across the Thanet Project site data in the 2012 survey. An analysis of similarity (ANOSIM) test was carried out on the combined 2005 and 2007 PSD data compared with the 2012 PSD dataset. The results indicated that there was no overall significant difference in the data between these years.

6.2.5 Conclusions

A total of 264 benthic invertebrate species were recorded across the Thanet Project site. Taxa belonging to the phylum Annelida dominated the benthic communities in terms of abundance and species diversity. Taxa belonging to the phylum Echinodermata made a considerable contribution to the total biomass (MESL, 2013).

Statistically significant differences were detected between benthic communities pre- and post-construction. However this is largely expected of benthic communities, since similar changes were found at the five reference stations. It is most likely that the changes observed are a factor of natural variation. There was also considerable variation in abundance (4 to 1574 individuals per station) and diversity (30 to 81 species per station) recorded across the Thanet Project site (MESL, 2013).

Statistical analysis revealed a significant relationship between patterns observed in the PSD data to those seen in the faunal communities (MESL, 2013).

Analysis of 2 scour pit locations revealed that the most abundant and commonly occurring taxa were similar to those found across the Thanet Project site and surrounding region. However, the sediments were generally slightly coarser (MESL, 2013).

The seabed within the Thanet Project site is characterised by a mixture of coarse sands, fine sands and cobbles, with bedrock outcrops in the central-southern portion of the site. The organic content of these sediments varied between <0.20% and 1.50%, representing low to moderate levels. There was no significant change in the overall sediment type between pre and post-construction surveys and therefore no additional impact to benthic communities is evident from the construction of Thanet Offshore Wind farm (MESL, 2013).

7 FISH RESOURCES

7.1 Herring spawning

7.1.1 Objective

The Thanet Project FEPA licence condition relating to the presence of Atlantic herring *Clupea harengus*, within the Thames Estuary is detailed in the box below.

7.1.2 Purpose of the consent condition

Herring spawning surveys were conducted on behalf of TOWL using a standard commercial pelagic trawler between 2007 and 2009 inclusive (TOWL, 2007; 2008a; and 2009b) to ascertain herring spawning areas and seasonality in proximity to the Thanet Project site (**Appendix 7A**). Underwater noise modelling and monitoring (Subacoustech 2007; 2009; and 2010) was also undertaken to establish whether construction and/or operational noise from the wind farm had potential to impact upon these spawning grounds (**Appendix 9A**).

The herring surveys were undertaken prior to (2007 – 2008) and during (2009) piling operations at the Thanet project. Despite slightly differing gear being used between the first two and the third survey (a 32mm mesh cod end then and 8mm mesh) the data show comparable annual patterns. Similar numbers of individuals were caught each year and all surveys verified the expected spawning period of mid-February through until April (TOWL, 2007; TOWL, 2008a; and TOWL, 2009b), as described in a previous report on Herne Bay (cited in TOWL, 2007). The results from the herring spawning monitoring undertaken between 2007 and 2009 did not indicate that any change in spawning behaviour occurred due to piling operations at the Thanet Project site.

Underwater noise modelling and monitoring was undertaken on behalf of the Thanet project (Subacoustech 2007; Subacoustech Environmental 2009; and Subacoustech Environmental 2010). The results of the monitoring indicated that no piling noise was detected in the spawning ground located close to Studhill Bank, Herne Bay, indicating that the piling noise attenuated to below background noise levels before reaching the area. This was the case with the smallest piles (4.1m diameter, with hammer blow forces reaching 300kJ) and the largest piles (4.9m diameter where the maximum energy needed to drive the bigger piles was 1300kJ). In the latter scenario, the noise levels were the highest generated during the construction phase.

With regard to the operational phase of the Thanet Project, work on underwater noise from operational wind farms concludes that, for herring, there is either limited propagation of detectable operational noise (4-5km) (Thomsen *et al*., 2006), or that, based on the results of four operational UK offshore wind farms, operational noise is negligible when compared with ambient noise levels (Nedwell *et al*., 2007a).

As such, TOWL proposed and agreed with the Licensing Authority to remove the requirement for post-construction herring surveys, based on the following reasons:

- Even at the highest levels, there has been no detectable noise from the piling operations at the Thanet Project site within the spawning area;
- Operational noise effects from the Thanet Project site will be undetectable in Herne Bay; and
- There has been no discernible change to the herring stock or its behaviour during the construction phase of the Thanet Project, which is clearly the period with the most risk of adverse impact.

Available evidence, collected by TOWL and others, presented a compelling argument against further disruptive sampling of the herring stock during its spawning period. In its response to the first version of the Post-Construction Environmental Monitoring Plan submitted to the Licensing Authority, the Licensing Authority stated that:

"*Due to supporting information/surveys already conducted and the vulnerability of the herring stock in the area, the MMO is content for the post construction herring surveys to be dropped from the TOWF license*."

As such, TOWL has not undertaken any further surveys of the Thames herring stock post construction.

7.2 Elasmobranch survey

7.2.1 Objective

The objective of the survey was to provide an overview of numbers and distribution of elasmobranch species within the wind farm site, and to compare the data with previous data from the Thanet project.

These objectives are in line with meeting the FEPA licence condition requirements outlined below.

7.2.2 Scope of survey

The scope of the survey was agreed with the MMO prior to each of the surveys. Where possible the survey stations were aligned with pre-construction surveys.

7.2.3 Monitoring completed

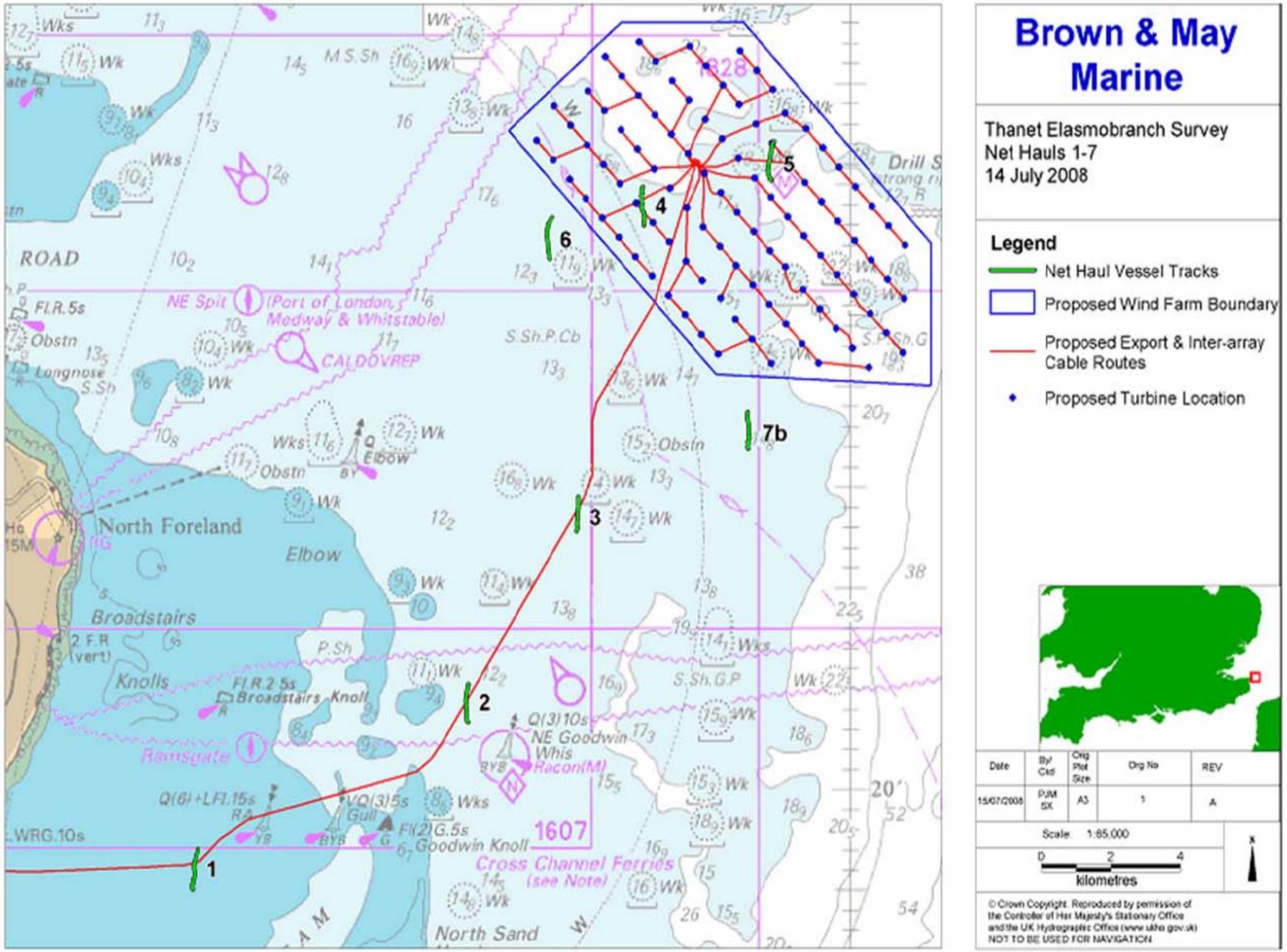
Survey methodology

Pre-construction elasmobranch surveys were undertaken on 5/6th September 2007 and 13/14th July 2008. Seven combination fleets were used, each comprising of four 6" mesh nets to target round elasmobranchs (e.g. dogfish, smoothhound, tope) and four 10" mesh nets for skates and rays at seven sampling locations all with a 24 hour soak time. Each fleet had a total of length of 91m, giving an overall length of 730 meters per fleet. Two fleets were set within the proposed wind farm site, two in adjacent (control) areas and the remaining three along the proposed export cable route.

Post-construction surveys were undertaken on 26/27th August and 9/10th September 2012 replicating the methodology and sampling stations used pre-construction to enable comparison of the results.

The position of the sampling locations used during the surveys can be found in **Figure 7.1** and **Appendix 7A**. Stations 1-3 represent the sampling sites within the cable corridor, stations 4 and 5 sites within the wind farm and stations 6 and 7b the control sites.

Figure 7.1 **ElasmobranchSampling Locations**



Sample analysis

For each sample the following parameters were recorded:

- Number of individuals and percentage distribution by species;
- Average length and length distribution by species; and
- Sex ratio by species.

The whole catch from each fleet was emptied into boxes, labelled, photographed, measured and sexed. After analysis all individuals were returned to the sea.

7.2.4 Overview of results

The numbers of individuals per species caught in all surveys both pre-construction (September 2007, July 2008) and post-construction (August and September 2012) are shown in **Table 7.1**.

Table 7.1 Elasmobranchs: Number of individuals caught for all sites and all surveys

Species		Sep-07								Jul-08								Aug-12								Sep-12							
		No. Individuals by Sampling Station								No. Individuals by Sampling Station								No. Individuals by Sampling Station								No. Individuals by Sampling Station							
Common Name	Scientific Name	F01	F02	F03	F04	F05	F06	F07b	Total	F01	F02	F03	F04	F05	F06	F07b	Total	F01	F02	F03	F04	F05	F06	F07b	Total	F01	F02	F03	F04	F05	F06	F07b	Total
Starry Smoothhound	*Mustelus asterias*	3	5	6	4	15	9	5	47	44	15	4	5	2	4	2	76	0	0	0	0	0	9	0	9	0	0	0	3	5	12	0	20
Thornback Ray	*Raja clavata*	1	8	2	0	0	2	0	13	3	6	0	0	14	19	0	42	0	2	3	16	3	0	3	27	1	11	6	16	12	0	3	49
Lesser Spotted Dogfish	*Scyliorhinus canicula*	2	2	4	0	2	3	2	15	3	7	1	5	6	2	6	30	0	0	0	4	12	2	0	18	0	0	2	8	12	2	2	26
Common Smoothhound	*Mustelus mustelus*	0	0	0	0	0	0	0	0	16	3	2	0	0	4	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tope	*Galeorhinus galeus*	1	2	2	0	3	4	1	13	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Spotted Ray	*Raja montagui*	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Thresher Shark	*Alopias vulpinus*	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
No. Individuals by Station		7	17	14	4	20	18	8	**88**	66	31	7	11	26	29	10	**180**	0	2	3	20	15	11	3	**54**	1	11	8	28	29	14	5	**96**
No. Species by Sampling Area and Total No. Species		4			3		4		**4**	4			6		5		**7**	1			2		3		**3**	2			4		3		**4**

For all surveys the number of species of elasmobranch caught was relatively low. A total of seven species were represented in the catch, four in September 2007, seven in July 2008, three in August 2012 and four in September 2012. The greater diversity of species (and numbers) caught in July suggests there may be a seasonal movement of some species.

In general, starry smoothhound *Mustelas asterias* were caught in the greatest numbers pre-construction and thornback ray *Raja clavata* were more predominant in the post-construction surveys. Lesser spotted dogfish *Scyliorhinus canicula* was found in almost equal numbers during both pre- and post-construction surveys. Individuals were distributed across most of the sites in the pre-construction survey peaking in summer, but were predominantly caught in the wind farm and control sites in the post-construction surveys peaking in autumn.

Greater numbers of tope *Galeorhinus galeus*, spotted ray *Raja montagui* and thresher shark *Alopias vulpinus* were found in the pre-construction surveys. It should be noted that the tope, spotted ray and thresher shark were caught in very low numbers overall and this precluded the use of statistical analysis of the pre- and post-construction abundance data.

<u>Sex ratio and length distribution</u>

The length distribution data for starry smoothhound in the September 2007 pre-construction survey indicates the majority of individuals were captured in the control sites. These were adults between 80-99cm, of which 85.7% were female. In July 2008 while the length distribution of individuals caught remained the same, as did the female prevalence (98.6%), the majority of individuals were instead caught inshore along the cable route sites.

The post-construction surveys captured less individuals overall, but retained the length distribution trend. In the August 2012 survey all individuals (100% female) were caught at control sites, whereas in September 2012 individuals were caught across control and wind farm sites with wind farm sites showing a predominance of males (62%) and the control sites females (91.7%). Common smoothhound showed a very similar length distribution and sex ratio to starry smoothhound although this species was only caught in one survey (summer July 2008) and in low numbers (25 in total).

In July 2008 the length distribution of lesser spotted dogfish showed smaller individuals (46-52cm) dominating cable corridor sites with a male skew (60%), while the majority of individuals were found at control sites and tended to be larger (58cm) and predominantly female (80%). Post-construction results reflected these trends, with the majority of individuals captured at the wind farm sites

Length distribution data for thornback ray in the summer (July 2008) survey showed the predominance of larger females (60-69cm) in the cable route area, whereas in the control sites, there was almost an equal ratio of male and females. The autumn pre-construction survey again showed a predominance of larger females (80%) in the cable route, with smaller individuals (100% female) at the control sites, which included the Thanet Project site. Post construction surveys carried out in the autumn showed smaller individuals were caught on the wind farm sites and there was little difference in numbers of male and females. However there were no significant differences between pre and post construction numbers of individuals overall or between different areas (control wind farm and cable corridor) for thornback ray captured in Elasmobranch summer surveys.

7.2.5 Conclusions

Seasonal movements

A notable temporal variability in abundance of specific species indicates seasonal movement between inshore areas in the summer and offshore in winter. For both the starry and common smoothhounds, the majority of individuals were captured at station F01 on the cable corridor, which is closest to the coast. This species is known to exhibit a seasonal movement to inshore areas in the spring and subsequently to deeper water in autumn and winter (Farrel *et al*., 2010).

The autumn surveys (2007 and 2012) show greater numbers offshore within the wind farm and at the control sites, suggesting offshore movement over autumn/winter. The predominance of females along the cable corridor area in the summer suggests possible use of inshore sites for pupping. The autumn surveys (2008 and 2012) showed evidence of the movement of females offshore to associate with males within the wind farm.

Statistical analysis (two way ANOVA) on catch rates of individual species indicates a significant difference between mean catch rates pre- and post-construction for lesser spotted dogfish at the wind farm and control stations (see **Appendix 7B**). However, such results should be viewed with caution, since post construction surveys were both carried out in the autumn (late August and September) whilst pre-construction surveys were done in the summer (July) and autumn (September) and the seasonal movements described may skew these results. Since the independent seasonal movement of males and females remains there is little to suggest that the wind farm has had a significant difference on either the length distribution or species abundance.

A greater number of smoothhounds (76) were caught in summer than in the autumn (47) pre-construction surveys, compared to 20 during the post-construction surveys.

Common smoothhound was only caught in the summer pre-construction survey of 2008 and in low numbers. Its similar ecological traits with the starry smoothound suggests similar seasonal movements are likely. The absence of this species in the pre- and post-construction autumn surveys suggests that neither the wind farm or control areas are common deeper water wintering grounds for this species. As no individuals were captured before or after the wind farm construction there is little evidence to suggest that the presence of the wind farm has had any influence on the abundance and distribution of common smoothhound.

Slightly more Thornback ray were caught in the post-construction surveys; however, the difference between pre and post construction surveys was not found to be significant (see **Appendix 7B**). The majority of individuals were found on the wind farm or control sites although some were caught in the cable corridor. Thornback ray tend to move inshore in spring/summer for breeding purposes and offshore to deeper water in the winter. There is little evidence from the results of the survey that the presence of the wind farm had any effect on the species abundance or distribution.

Lesser spotted dogfish followed a very similar pattern to the starry smoothhound and were primarily found offshore within the wind farm site through autumn and winter, moving inshore particularly along the cable route in summer months. Pre-construction surveys showed a predominance of individuals over 54cm in the control sites (including the proposed wind farm area) and slightly smaller individuals in the cable area (46-50cm). Equal numbers of male and females were caught at both sites. A similar pattern was seen in the post-construction surveys although, in the August survey, only females were caught at both the wind farm and control sites. This species is known to spawn in either shallow sublittoral habitats, where the eggs are laid on macroalgae, as well as further offshore on grounds with biogenic fauna (e.g., sponges, hydroids and bryozoans). Statistical analysis showed that there were significant differences in catch rate between the cable route sites and the control sites (cable route catches exceeded control sites). This may be related to seasonal movements for breeding, since one of the pre-construction surveys was carried out in the summer whereas both the post construction surveys were undertaken in the autumn.

Tope were only found in small numbers in three out of the four surveys namely September 2007, July 2008 and September 2012 when 13, 2 and 1 individuals were caught respectively. Due to the small numbers caught a statistical analysis was not possible and the conclusion is that there is little effect of the wind farm on species distribution and abundance. This is also the case with spotted ray and thresher shark where total numbers caught were 4 and 1 respectively across all four surveys.

Electro-sensitive species

The overarching aim of the monitoring surveys for elasmobranch species was to investigate the possible effects of electromagnetic fields on electro-sensitive species (specifically lesser spotted dogfish, thornback rays, starry smoothhounds and other elasmobranch species) with respect to cabling associated with the wind farm and export cable corridor.

Although a number of marine species have shown the ability to detect electro-magnetic fields for purposes such as navigation during migration or location of prey species, research into the effect of anthropogenic electric fields is still relatively new and inconclusive. Studies have shown that various electro-sensitive species show both an attraction and an avoidance to 132kV cables commonly used in offshore wind farms.

Of the elasmobranch species captured, three were commonly caught in the cable corridor sites. These include starry smoothhound, thornback ray and lesser spotted dogfish, which are common along the North Sea coastline. The greatest number of individuals (63) caught in proposed cable corridor sites were starry smoothhound (mainly female) in the July 2008 pre-construction survey. However the lack of starry smoothhound in the cable corridor post-construction may be as a result of the timing of the surveys (autumn 2012) rather than any effect of cabling, since this species is known to move into deeper waters in the autumn. There was little difference in the number of thornback ray caught in the cable corridor sites between pre- and post-construction autumn surveys. The low numbers of lesser spotted dogfish caught suggests that this area is not an important spawning or nursery ground.

Based on the data collected, three species of elasmobranch; starry smoothhound, lesser spotted dogfish and thornback ray were selected for statistical analysis of pre- and post-construction abundance. Of these, only the lesser spotted dogfish showed significant differences between pre- and post-construction surveys. This species showed significantly greater catches in the pre-construction (summer) elasmobranch surveys. In terms of difference in abundance between the cable route and the wind farm site the results did not provide any evidence that elasmobranchs are affected by EMF or that they collect around cable installation. The following mitigation measures in place at the Thanet Project, for the amelioration of electromagnetic fields, may have had an influence and include:

- Reduction of current by transmitting power at the highest practicable voltage – electromagnetic fields (B-fields) are proportional to current therefore high cable operating voltages will reduce the potential impact;
- Burial in the seabed to at least 1m which will attenuate magnetic fields although this may still be perceived by sensitive species; and
- Use of armour cladding, which will reduce the escape of E-fields but not B-fields.

7.3 Adult and Juvenile fish survey

7.3.1 Objective

The objective of undertaking adult and juvenile fish surveys was intended to provide an overview of numbers and distribution of fish populations during the operational phase and compare this with baseline fish population data. This objective is in line with meeting the FEPA licence condition requirement outlined below.

Through consultation with the MMO, Cefas and Natural England (22nd April 2010) it was agreed that TOWL would undertake a single year of post-construction adult fish surveys i.e. a spring (April) and summer (July) and a concurrent juvenile fish survey. This approach was intended to provide snapshot data of the abundance and distribution of adult and juvenile fish populations between sites within the wind farm site and external control sites.

7.3.2 Scope of survey

<u>Adult fish</u>

The post-construction surveys repeated the pre-construction methodologies, as far as was practicable, in order to ensure consistency and comparison between datasets. Analysis aims to discern temporal and/or spatial changes in the presence and abundance of key species before and after the wind farm was constructed, for sites within and beyond the array. The baseline data collected in spring and summer of 2005 was also made available for comparative purposes only since the methodology differed slightly with tows of 30 minutes being carried out as opposed to 20 minutes duration during post-construction surveys. The pre-construction surveys were conducted for adult fish species only and a number of trawling positions differ to the post construction survey sites. Post-construction sites were re-located due to potential interactions with inter array and export cable locations. For this reason data can be compared, but statistical analysis should be viewed with caution.

Juvenile fish

Juvenile fish species were collected concurrently with surveys of the epifaunal assemblage.

7.3.3 Monitoring completed

Adult fish

The Thanet Fisherman's Association (TFA) recommended demersal otter trawling to be the most appropriate sampling method for the EIA surveys for the Thanet project. As per local practice, the net was fitted with a tickler chain ahead of the ground line to increase the potential for the capture of flatfish and rays. A rock-hopper ground-line was also fitted to allow trawling to accommodate localised rocky outcrops and areas of rough ground.

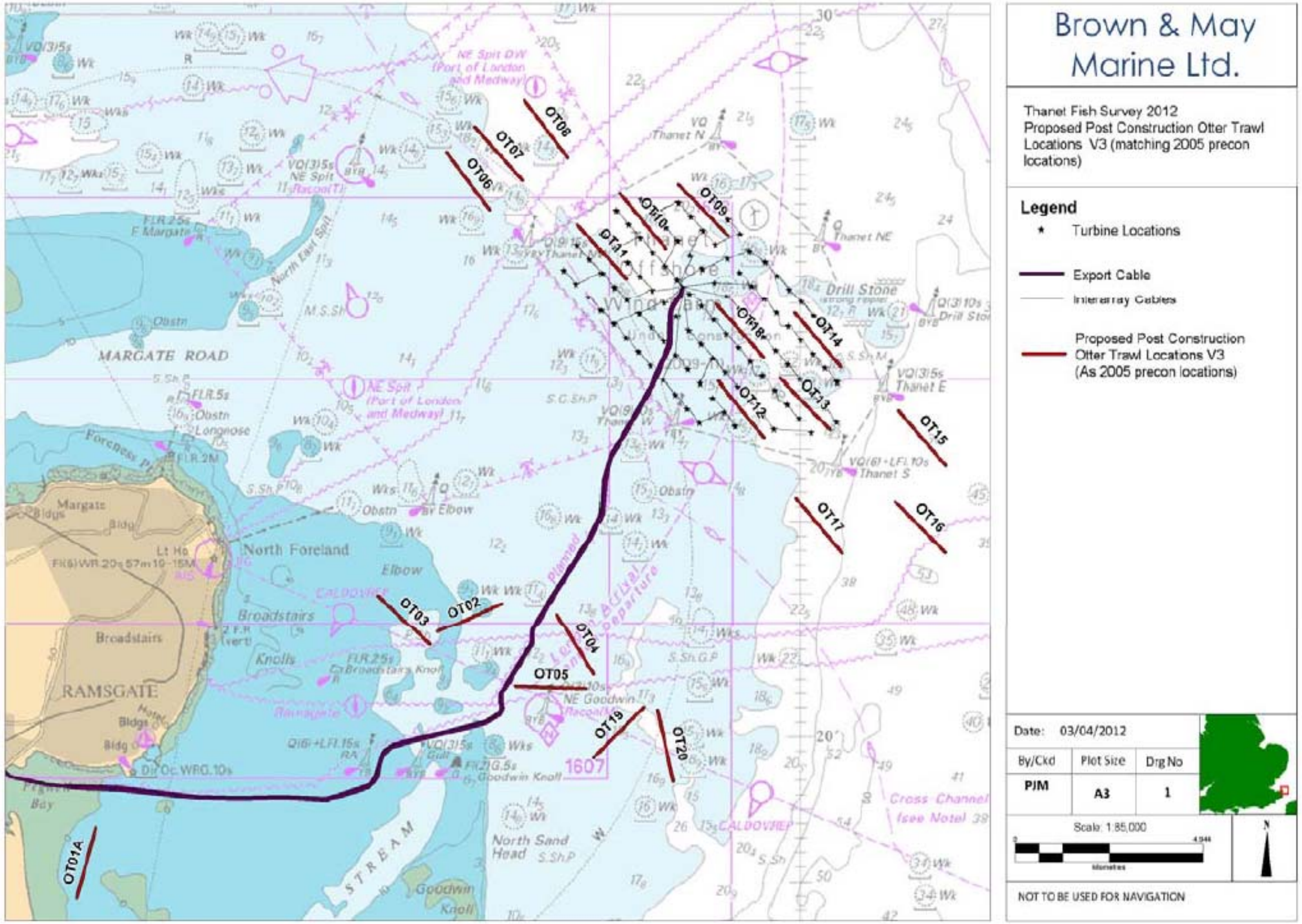
Two post construction surveys were undertaken, the spring survey between the 11th - 13th April 2012 and the summer survey between the 3rd - 6th July 2012. Pre-construction surveys were carried out on the 18/19th April 2005 and 25th - 27th July 2005.

For each survey (pre-construction and post-construction) six tows durations were taken within the Thanet project and 13 control tows in adjacent areas the duration of tows differed slightly as described above. The location of each site for both pre- and post-construction is shown in **Appendix 7A** and for post-construction surveys, in **Figure 7.2**. While every effort was made to replicate the sites used in the 2005 pre-construction surveys, a number of sites were relocated for the post-construction survey as necessary, for safety reasons. Details of trawls which were relocated can be found in **Appendix 7A**.

For each adult survey site the following data was recorded:

- Number of individuals by species;
- Sex ratio, samples of principal commercial species;
- Spawning condition by species; and
- Length distribution by species:
  - Finfish: Total individual lengths to cm below;
  - Crabs: Carapace width;
  - Lobsters: Carapace length;
  - Whelks: Shell height; and
  - Scallops: Shell width.

Figure 7.2 Otter trawl locations



Juvenile fish

Beam trawl surveys were undertaken between the 11th-13th April and the 3rd-6th July 2012. The location of the beam trawl surveys are shown on **Figure 7.3**.

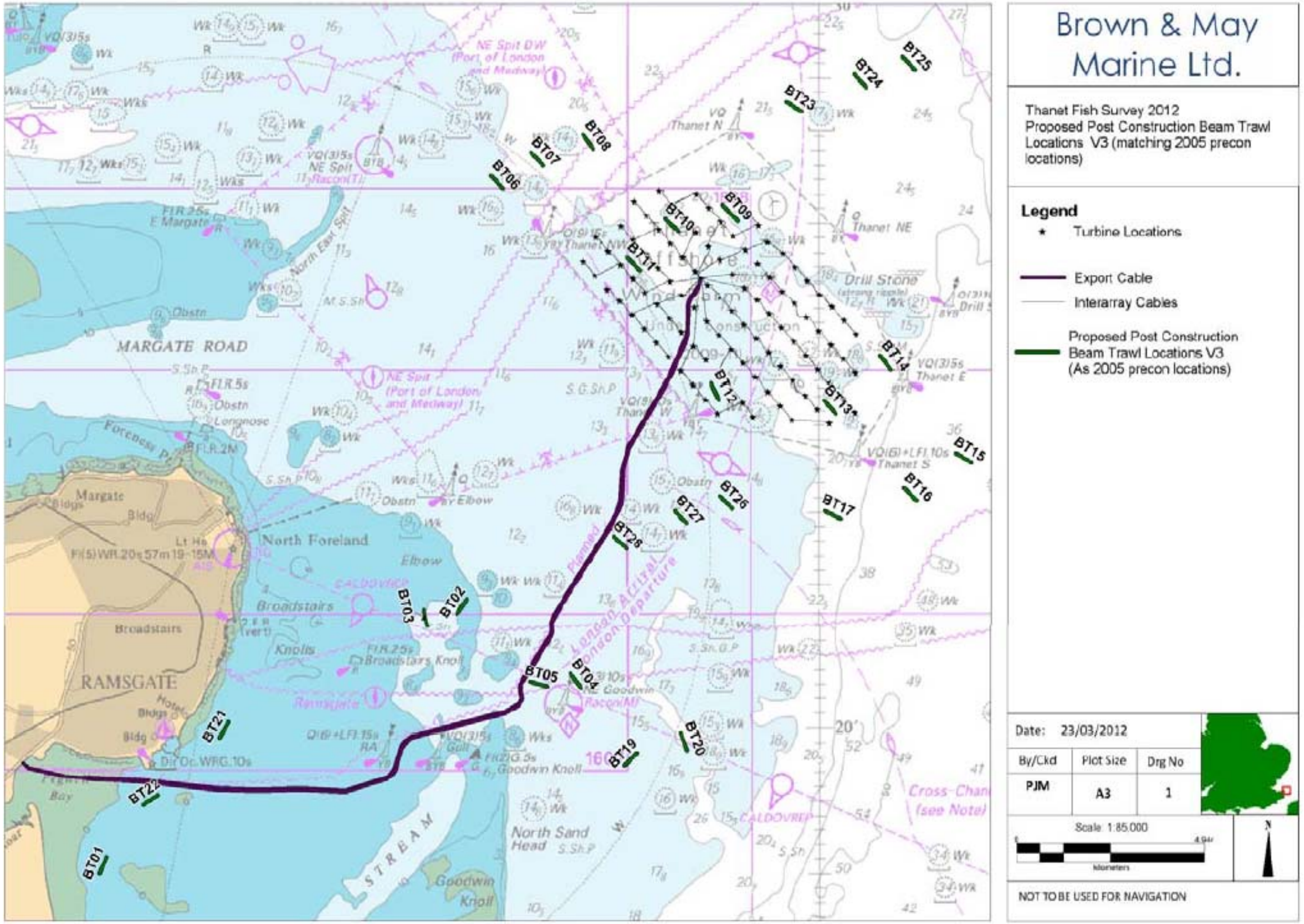
The survey involved the use of a 2m beam trawl, with a fine mesh cod-end, rock-hopper, ground line and chain mat. The survey methodology was maintained at all phases of surveying and involved slow trawling speeds, between 1 to 1.5 knots, over a standard time of five minutes or over a standard distance of 200m, to ensure sampling of different sediment types and sustained contact of the gear with the seabed.

For each trawl, a record of the trawl number, date, time and co-ordinates of the tow was taken, together with a description and a photograph. All fish were sorted and retained except large adult fish, which were identified, measured, documented and returned.

For each survey suite the following data was recorded:

- Number by species;
- Length distribution by species; and
- Width of carapace of crustaceans.

Figure 7,3 **Beam trawl locations**



7.3.4 Overview of results

Adult Fish

Catch rates for all species caught in all trawls in both pre- and post-construction surveys are shown in **Table 7.2** and catch rate and species composition for the top ten species for each site and species is illustrated in **Figure 7.4**.

Sites which were identified in the pre-construction surveys as being in the cable corridor, inshore and at control sites are all considered as control sites since this was the protocol used in the post-construction surveys.

In the four surveys, a total of 25 species were caught (15th April 2005, 12th July 2005, 17th April 2012, 16th July 2012). All surveys showed a greater number of species at the control sites than the wind farm sites except for July 2012. A total of 465 individuals were caught in the spring survey compared to 573 during the summer sampling. The general trends in abundance (see **Table 7.2**) are summarised as follows below:

- Lesser spotted dogfish *S. canicula* and dab *Limanda limanda* were the most abundant species in the pre-construction surveys, whereas lesser spotted dog fish and thornback ray were most prevalent in the April 2012 survey, with dab and lesser spotted dog fish being most prevalent in July 2012.

- Catch rates for lesser spotted dogfish, thornback ray and whiting were higher in the April 2012 post-construction survey than in the pre-construction surveys or the July 2012 post-construction survey. Catch rates for plaice, starry smoothhound, Dover sole *Solea solea*, bib *Trisopterus luscus*, lemon sole *Microstomas kitt* and tub gurnard *Trigla lucerna* were higher in the pre-construction surveys, with the highest catch rates observed at control stations in the July 2005 pre-construction survey.

- Cod *Gadus morhua*, flounder *Platichthys flesus* and herring *Clupea harengus* were found only in the April pre- and post-construction surveys. Poor cod *Trisopterus minutus* were found only in the pre-construction surveys. Bass *Dicentrarchus labrax*, scaldfish *Arnoglossus laterna*, lesser weever *Echiichthys vipera* and spurdog *Squalus acanthias* were found only in the April 2012 post-construction survey.

- Blonde ray *Raja brachyura*, spotted ray *Raja montagui*, pogge *Agonus cataphractus* and red gurnard *Aspitrigla cuculus* were only found in the July 2012 post-construction survey. Starry ray *Raja radiata* were found only in the July 2005 pre-construction survey in low numbers, and grey gurnard *Eutrigla gurnardus* were caught only in the April 2005 pre-construction survey.

Statistical analysis

Statistical analysis was carried out on catch rate of the five most commonly occurring species of fish and elasmobranchs in both pre- and post-construction surveys using two-way analysis of variance (ANOVA). Treatment categories included differences between pre-and post-construction for each survey season (between treatment) as well as differences between location (wind farm, control or cable corridor) (between treatments within blocks). Full details of the methodology can be found in **Appendix 7B** and shown in **Table 7.3** below.

The results of the analysis showed a significant difference in mean catch rate between treatments only for Dover sole in the spring surveys between wind farm and control sites. For other species e.g. dab and plaice there was no significant difference between pre- and post-construction catch rates although there were differences in catches between control, cable route and wind farm stations (see **Table 7.3**). No consistent trends were found that could be attributed to the presence of the wind farm.

There was no significant difference pre- and post-construction in the summer surveys although there were significant differences between sites for dab, plaice and Dover sole. In both seasonal surveys plaice was the only species to record significantly higher catches in the control areas in comparison to both wind farm and cable route sites. Catches for plaice from the wind farm site were significantly greater than those for cable routes.

Table 7.2 Catch rates for all fish species by survey and sampling area

Species		Catch Rate (Number of Individuals Caught per Hour)							
		Pre-construction				Post-construction			
		Apr-05		Jul-05		Apr-12		Jul-12	
Common Name	Scientific Name	Control	Wind Farm	Control	Wind Farm	Control	Wind Farm	Control	Wind Farm
Lesser Spotted Dogfish	*Scyliorhinus canicula*	21.0	11.8	17.2	4.1	58.0	118.7	8.1	6.0
Thornback Ray	*Raja clavata*	2.6	3.2	2.6	3.6	12.7	48.9	2.4	14.5
Dab	*Limanda limanda*	11.4	9.9	4.8	6.3	1.7	5.0	9.0	6.0
Plaice	*Pleuronectes platessa*	8.0	1.6	13.9	5.8	2.0	3.5	6.8	4.5
Whiting	*Merlangius merlangus*	2.3	4.1	2.9	2.8	12.0	8.5	2.6	3.0
Starry Smoothhound	*Mustelus asterias*	4.3	1.6	4.5	1.4	8.6	2.0	3.6	3.0
Dover Sole	*Solea solea*	0.9	0.0	4.5	4.4	2.2	5.0	1.7	2.5
Bib	*Trisopterus luscus*	1.2	1.9	9.5	3.0	1.0	0.0	0.6	1.0
Cod	*Gadus morhua*	0.2	0.3	0.0	0.0	7.3	2.5	0.0	0.0
Lemon Sole	*Microstomus kitt*	0.5	0.0	0.4	6.3	0.5	0.0	0.0	1.0
Flounder	*Platichthys flesus*	0.3	0.0	0.0	0.0	2.0	2.0	0.2	0.5
Poor Cod	*Trisopterus minutus*	0.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0
Tub Gurnard	*Trigla lucerna*	0.3	0.3	0.7	0.0	0.2	0.0	0.2	0.0
Bass	*Dicentrarchus labrax*	0.0	0.0	0.0	0.0	1.0	0.5	0.2	0.0
Herring	*Clupea harengus*	0.6	0.3	0.0	0.0	0.5	0.0	0.0	0.0
Scaldfish	*Arnoglossus laterna*	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Blonde Ray	*Raja brachyura*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Pogge	*Agonus cataphractus*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Spotted Ray	*Raja montagui*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Starry Ray	*Raja radiata*	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Lesser Weever	*Echiichthys vipera*	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Spurdog	*Squalus acanthias*	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Grey Gurnard	*Eutrigla gurnardus*	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Red Gurnard	*Aspitrigla cuculus*	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0

Table 7.3 Summary of significant test results (two way ANOVA)

Spring Fish surveys				
Species	**Block pairwise comparisons**		**Test**	**F**
	1	**2**		
Starry smoothhound *Mustelus asterias*	Cable route	Control	Between treatments	0.617672
			Between treatments within blocks	11.13018*
Dab *Limanda limanda*	Cable route	Wind farm	Between treatments	0.807983
			Between treatments within blocks	4.095515*
Plaice *Pleuronectes platessa*	Cable route	Control	Between treatments	0.322574
			Between treatments within blocks	8.93716*
	Wind farm	Control	Between treatments	0.278833
			Between treatments within blocks	5.894294*
	Cable route	Wind farm	Between treatments	1.844145
			Between treatments within blocks	2.614586*
Dover sole *Solea solea*	Wind farm	Control	Between treatments	11.50434*
			Between treatments within blocks	0.486989

* Denotes a statistical significant difference between mean catch rates at α=0.05

Summer Fish surveys				
Species	**Block pairwise comparisons**		**Test**	**F**
	1	**2**		
Starry smoothhound *(Mustelus asterias)*	Cable route	Wind farm	Between treatments	0.146608
			Between treatments within blocks	**2.83787***
Lesser spotted dogfish *Scyliorhinus canicula*	Cable route	Control	Between treatments	0.659935
			Between treatments within blocks	4.34584*
	Cable route	Wind farm	Between treatments	1.090901
			Between treatments within blocks	4.949331*
Dab *Limanda limanda*	Cable route	Control	Between treatments	0.940705
			Between treatments within blocks	3.65165*

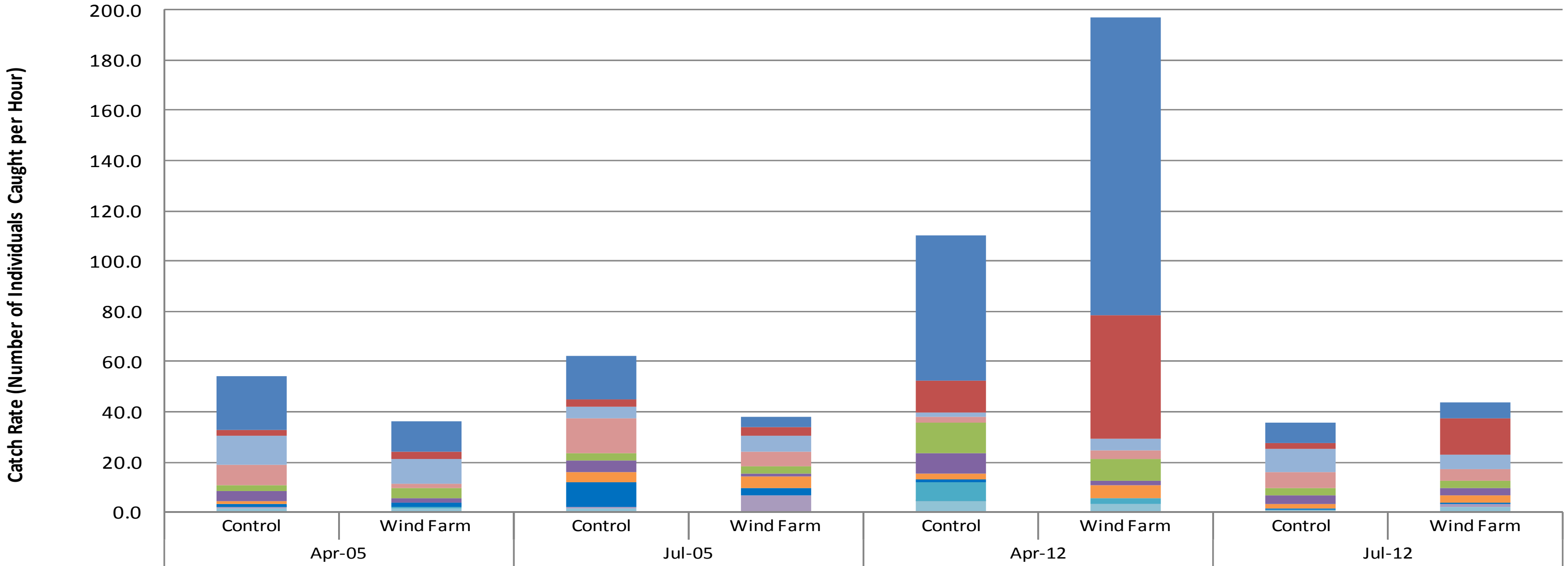
	Cable route	Wind farm	Between treatments	1.373445
			Between treatments within blocks	2.65529*
Plaice *Pleuronectes platessa*	Cable route	Control	Between treatments	0.023087
			Between treatments within blocks	7.51220*
	Cable route	Wind farm	Between treatments	0.02887
			Between treatments within blocks	7.09563*
Dover sole *Solea solea*	Cable route	Control	Between treatments	1.238083
			Between treatments within blocks	4.280502*

*Denotes a statistical significance between mean catch rates at α=0.05

Summer Elasmobranch survey				
Species	**Block pairwise comparisons**		**Test**	**F**
	1	**2**		
Lesser spotted dogfish *Scyliorhinus canicula*	Cable route	Control	Between treatments	27.8400*
			Between treatments within blocks	0.2115
	Cable route	Wind farm	Between treatments	0.0334
			Between treatments within blocks	5.8459*
Autumn Elasmobranch Survey				
Lesser spotted dogfish *Scyliorhinus canicula*	Wind farm	Control	Between treatments	1.1294
			Between treatments within blocks	12.3423*
	Cable route	Wind farm	Between treatments	0.2505
			Between treatments within blocks	21.6751*

*Denotes a statistical significance between mean catch rates at α=0.05

Figure 7.4 **Catch rates and species composition for the top ten species by site and survey period**



	Apr-05 Control	Apr-05 Wind Farm	Jul-05 Control	Jul-05 Wind Farm	Apr-12 Control	Apr-12 Wind Farm	Jul-12 Control	Jul-12 Wind Farm
Lesser Spotted Dogfish	21.0	11.8	17.2	4.1	58.0	118.7	8.1	6.0
Thornback Ray	2.6	3.2	2.6	3.6	12.7	48.9	2.4	14.5
Dab	11.4	9.9	4.8	6.3	1.7	5.0	9.0	6.0
Plaice	8.0	1.6	13.9	5.8	2.0	3.5	6.8	4.5
Whiting	2.3	4.1	2.9	2.8	12.0	8.5	2.6	3.0
Starry Smoothhound	4.3	1.6	4.5	1.4	8.6	2.0	3.6	3.0
Dover Sole	0.9	0.0	4.5	4.4	2.2	5.0	1.7	2.5
Bib	1.2	1.9	9.5	3.0	1.0	0.0	0.6	1.0
Cod	0.2	0.3	0.0	0.0	7.3	2.5	0.0	0.0
Lemon Sole	0.5	0.0	0.4	6.3	0.5	0.0	0.0	1.0
Other Species	1.4	1.6	1.7	0.3	4.2	3.0	0.8	2.0

Survey and Sampling Area

Juvenile Fish

Juvenile surveys were only carried out post-construction in the spring (April) and summer (July) 2012. During the spring survey a total of 25 species were caught, 14 of which were within the wind farm and 22 at control sites (which included the cable corridor). Lesser spotted dogfish were the most abundant species within both wind farm and control sites. Sole and whiting were the other predominant species. In the summer (July 2012) survey the number of species increased to 32 and, of these, 31 were found at the control sites and 19 within the wind farm. The predominant species at both wind farm and control sites was an unidentified species of goby *Gobidae sp*. Catch rates were generally higher during the summer survey.

The highest catch rate was found at an offshore control site with 2,209.4 individuals per hour of goby caught (site BT06), compared to 265.9 individuals of pogge *Agonus cataphractus* caught per hour from a control site along the inshore area of the cable corridor (site BT21) in the spring survey. Spring catch rates were generally higher in the control sites (91 per hour) than the wind farm (70.9 per hour) but this was reversed during the summer surveys with (569.1 per hour within the wind farm and 517.3 per hour in the control sites. Length distribution between the spring and summer surveys showed some variation, with a markedly smaller length range of thornback ray and solenette caught during the spring survey.

7.3.5 Conclusions

Adult Fish

The Thanet Project site is situated within heterogeneous sands and gravels, supporting benthic communities of low diversity and abundance, as reflected by the associated fish populations found there. Species diversity in the Thanet Project site is generally low compared to other areas within the Thames (112 species) (Swaby & Potts, 1998) and comprises a mixture of commercially important and non-commercial species. In both pre and post-construction surveys the predominant species included: lesser spotted dogfish, plaice, dab and to a lesser extent thornback ray and Dover sole, with the exception of lesser spotted dogfish, this data reflects the regional patterns of commercial fisheries landings data.

There is little evidence that the Thanet Project site has had a significant impact on either adult fish species abundance or diversity since only Dover sole and lesser spotted dogfish showed significant differences between pre and post construction and only in the spring surveys. Temporal differences in catch rates between pre and post-construction (i.e. greater numbers caught in the April 2012 survey) suggests there may be the potential for a slight fish aggregating effect from the wind farm infrastructure although the drop in numbers for the summer surveys also suggests seasonal changes in spatial distribution.

Although there were some significant differences in catch rates for elasmobranchs and fish species there was no consistent pattern of statistical difference. The post construction surveys generally support the assessment in the ES that there would be little effect on the abundance of the main species of fish due to habitat disturbance (see **Appendix 7A**).

Juvenile Fish

General increased abundances of fish during the summer months indicate temporal variability in many species, particularly in the inshore areas for breeding purposes. There is also evidence of spatial variability in abundance, not only across the study area but also between spring and summer surveys. Smaller fish were generally found in the more inshore areas and larger individuals further offshore.

The area in which the Thanet Offshore Wind Farm is placed can be viewed in a wider context as being in an area of relative low species diversity (as compared to diversity in the Thames area) although there is evidence that the area does support juvenile populations. The general conclusion based on the evidence provided indicates that there has been little effect on the juvenile population in relation to habitat disturbance. Juvenile fish are predominantly caught in inshore areas where wind farm activities tend to be restricted to cable corridor construction, cable installation and maintenance activities. The inshore areas affected by these activities are small compared to those within the WTG site thus the effect of habitat disturbance on juvenile abundance is considered to be minimal.

8 MARINE MAMMALS

8.1 Objective

The objective of the marine mammal monitoring is outlined below.

8.1.1 Discussion of the need for survey

TOWL agreed with the Licensing Authority that post-construction marine mammal surveys were not required and instead committed to presenting incidental sightings recorded during the ornithological surveys as part of the annual ornithological report, making comparisons to all pre- and during-construction data.

In its response to the first version of the PCEMP submitted to the Licensing Authority, the Licensing Authority stated that:

"As specific marine mammal data was not collected pre-construction the MMO agrees that there is no merit in gathering specific post-construction data. Incidental sightings data should be presented as part of the ornithological reports and compared to pre and during construction data".

8.1.2 Incidental sightings

The mean number of marine mammal sightings recorded across the post-construction monitoring period for birds are presented in **Table 8.1**. The incidental sightings cover the wind farm site, 0-1km buffer and 0-2km buffer. The numbers were adjusted for survey coverage to give a survey area population estimate.

Table 8.1 Mean number of incidental sightings of marine mammals recorded throughout pre-construction, during construction and post-construction monitoring periods

Species	Pre-construction (2004 – 2005)	Construction (2009 – 2010)	Year 1 (2010 – 2011)	Year 2 (2011 – 2012)	Year 3 (2012 – 2013)
Common seal	0.18	0.23	0.25	0.82	0.45
Grey seal	0.00	0.00	-	0.55	1.36
Seal sp	0.00	0.00	0.25	0.64	0.54
Harbour porpoise	7.81	8.54	6.92	30.09	46.45

The data indicates that the population of seal species is generally low throughout the survey area, whereas harbour porpoise has a relatively high population in comparison. The numbers of harbour porpoises recorded in 2012-13, was considerably higher than previously, particularly in March when a peak of 265 was seen (compared with peaks of 87 and 21 in the previous two winters, those peaks again being seen in March). A similar seasonal pattern of occurrence was observed during the construction phase surveys.

Harbour porpoises were recorded across most of the survey area during 2012-13, though with higher numbers in the eastern part of the survey area, including within the wind farm, and in the control area.

A similar analysis has been undertaken for harbour porpoise as for the key bird species as there were sufficient records to carry out a meaningful analysis (though numbers seen during the pre-construction, construction phases and in the first post-construction year were low so some caution in required in the interpretation of the results for those periods). Records of harbour porpoise decline during the construction period within the wind farm and within a 500m buffer, and this decline continued into the first post-construction year, but after that numbers increased substantially across the whole survey area, including within the wind farm. It would appear that there was some partial displacement of this species from the wind farm (and up to a 500m buffer) during construction and operation, though only during construction and the first year of operation.

The results of the gradient analysis of harbour porpoise abundance with distance from the wind farm found no statistically significant difference in abundance between the distance zones in the pre-construction year ($F_{3,148}$=0.18, p=0.91), but the densities did differ significantly between zones in the construction phase ($F_{5,272}$=5.6, p<0.001), and for the first ($F_{5,272}$=3.8, p=0.002) and second ($F_{5,272}$=3.0, p=0.012) of the post-construction years. There was no statistically significant difference between harbour porpoise densities across the zones in the third post-construction year ($F_{5,272}$=2.0, p=0.072).

In conclusion there was evidence for a statistically significant decline in harbour porpoise abundance within the wind farm during the construction phase (with no records of this species there during the construction phase, a 100% reduction albeit from a low baseline level). That reduction persisted in the first post-construction monitoring year, with a reduction to 25% of the pre-construction baseline. There was also some evidence of a similar reduction within 500m of the wind farm, though this was not statistically significant. Whilst the numbers declined in the wind farm (and to a lesser extent in the 0-500m zone), there were increases apparent in the other zones, particularly in the control zone, suggesting that the reduction within the wind farm was probably a result of the construction/initial operation of the wind farm, though that effect appeared short-term and was not apparent by the second year of operation.

Harbour porpoise tended to be higher in number in December and January relative to the other survey months.

No other discernible trends can be drawn from the data.

9 SUBSEA NOISE MONITORING

9.1 Objective

The objective of the operational noise survey is to assess the level of noise produced by the operation of the Thanet Project site so that potential impacts on fish (in particular herring) and marine mammals can be determined. This objective is in line with meeting the FEPA and Marine licence condition requirements outlined below.

9.1.1 Discussion of the need for surveys

The Thanet Project site is located between a number of significant shipping routes between the UK and Europe and, in the Thanet Project ES, the baseline noise environment was considered to be dominated by anthropogenic noise, due to the shipping traffic.

The operational noise from the WTGs at other offshore wind farms has been recorded as low and unlikely to cause an adverse impact, even to the highly sensitive species such as herring and harbour porpoise (Nedwell *et al*., 2007). The COWRIE sponsored research programme undertaken by Nedwell *et al.* (2007) concluded that the operational noise recorded at offshore wind farms in the outer Thames region, such as Kentish Flats, was very low. The operational noise is associated with rotating machinery which declined with distance from the WTGs. It was noted at Kentish Flats that even in the immediate vicinity of the WTGs, the WTG noise only dominated over the background noise in a few limited bands of frequency and even then was only a few decibels (dB) above the background noise.

Given the number of studies of this nature that have been carried out to date and, taking into account the evidence from other projects, TOWL proposed that a desktop study of the operational noise was undertaken in comparison to the information collected pre- and during construction.

The MMO agreed with this approach and that that post-construction noise monitoring surveys were not required:

> *In reference to Deemed Marine Licence condition 33119/10/1: Annex 1, paragraph 7. After the PCEMP was produced, TOWL requested to consider the use of desk-based modelling studies to assess the potential effects of sub-sea noise and vibration caused by the OWF on marine biota. The MMO agree that this is an acceptable approach, provided that this modelling work is based on a comprehensive dataset of noise propagation, measured for the Thanet OWF and if possible, on data from other OWFs in the Thames Estuary and other regions. The data within all reports should consist of its processed and unprocessed forms (as Appendices), and reports of the various components of this monitoring programme will be integrated so as to compare related environmental and biological parameters. Once the results of the modelling exercise are available, the MMO will make a final decision on the need for conducting further sub-sea noise monitoring.*

9.2 Scope of study

Subacoustech were commissioned to undertake a desk based modelling assessment to assess the potential effects of underwater noise and vibration caused by the operational Thanet Project site on marine fauna. The report can be seen in **Appendix 9A**.

The desk based assessment reviewed all the available literature on operational noise criteria which are used to judge the influence of noise on marine species. In order to supplement the desk based study, the background levels of noise at the Thanet Project site were recorded during breaks between the piling operations undertaken during construction in 2009 (Nedwell *et al*. 2009).

The background data was used in combination with existing operational wind farm underwater data (from Kentish Flats and Barrow) to extrapolate the likely operational noise levels at the Thanet Project site. The operational values were compared with the criteria to determine any likely operational effects on marine species.

9.3 Assessment completed

9.3.1 Desk based analysis

The analysis of the operational underwater noise was carried out by estimating the noise levels produced by the WTGs (based on comparisons with other operational wind farms). A comparison of this noise level was then undertaken with the following effect criteria:

- Assessment of behavioural effects on marine fauna using dBht (Species);
- Assessment of lethality and physical injury using un-weighted levels;
- Marine mammal criteria for assessing auditory damage using the Southall criteria; and
- Operational noise relative to background levels.

The species considered for the assessment were considered to be representative of the range of fish found in the seas around Thanet (cod, dab and herring); and the approximate weighted noise levels for marine mammals was considered for harbour porpoises, dolphins (striped and bottlenose) and seals (generic rather than species specific).

9.3.2 Background noise levels at Thanet – field survey

Underwater noise measurements were recorded at the Thanet Project site by Subacoustech on 20th, 21st, 29th and 31st March 2009 during breaks in piling activity. The recordings were undertaken when the wind was minimal (maximum of 2ms^{-1}) and the sea state was low with at-worst, a slight swell. Recordings were undertaken at two sites: Site I was close to the wind farm boundary and Site II was in the herring spawning ground near Studhill Bank, just off Herne Bay. The results were analysed in terms of linear unweighted levels and the dBht metric for key marine species.

Measurements covering the frequency 1Hz to over 12 kHz were undertaken at the site, which covers the frequency range over which fish and marine mammals can hear. The measurements were taken using a Brüel & Kjær Type 8106 and 8105 hydrophones.

9.4 Field Study

9.4.1 Background noise levels at Thanet Offshore Wind Farm

The mean background noise levels for the four survey days are displayed below in **Table 9.1**.

Table 9.1 Background noise levels at Thanet Offshore Wind Farm

	Site I					Site II				
	20/03	21/03	29/03	31/03	**Mean**	20/03	21/03	29/03	31/03	**Mean**
SEL (dB re 1 μPa^2-s)	121	116	125	124	**123**	109	105	105	103	**106**
Herring dB_{ht}	41	38	34	46	**42**	23	20	17	21	**21**
Cod dB_{ht}	34	30	26	40	**35**	19	15	14	15	**16**
Dab dB_{ht}	18	15	17	22	**19**	7	1	2	4	**4**
Harbour porpoise dB_{ht}	59	53	51	56	**56**	51	53	53	55	**53**
Bottlenose dolphin dB_{ht}	51	44	39	46	**46**	42	44	44	46	**44**
Common seal dB_{ht}	44	39	28	46	**43**	29	36	26	29	**31**
Striped dolphin dB_{ht}	51	44	41	45	**47**	42	42	44	48	**44**

Values presented are either one second, RMS Sound Exposure Levels (un-weighted data) or one second dB_{ht} levels for selected species. Values are the mean level recorded during the day (or over the four days).

The two sites are separated by a few tens of kilometres and Site I (close to the wind farm boundary) is consistently noisier. The higher level may be due to the wind farm site being located in an area that is more exposed to prevailing weather conditions. The lower levels at Site II will be used as the comparison data.

The data suggests that low frequency components varied more over the four days than the high frequency components. The variation is likely to be related to the heavy shipping in the area since the noise from distant large vessels such as oil tankers or containers, is one of the dominant low frequency noise sources (frequency band between 20Hz to 80Hz).

9.5 Operational noise

9.5.1 Background information

The operational noise from an offshore wind farm should be considered as an extended noise source (as opposed to a 'point source') and is believed to be mechanically generated vibration from the WTGs which is transmitted into the sea through the structure of the support pile and foundations (Nedwell *et al*., 2003). It is extremely unlikely that any significant airborne sound generated above the water surface will pass from the air to the water. It may be expected that the nature and frequency spectrum will have similarities with the noise measured in air.

The noise has been observed to be relatively broadband with a tonal component (Lindell 2003 & Nedwell 2007a). The exact position and level of the tonals may be expected to be wind-speed and WTG-make dependent. More generally, it has been observed that the sound can be broken into three distinct bands:

- Nominal DC to approximately 10Hz – spectra are relatively featureless with measurement levels dominated by hydrodynamic pressure changes;
- From 10Hz to 200Hz – spectra tend to be dominated by tonal noise; and
- From 200Hz to 10kHz broadband noise – nature of the noise is consistent with generated noise (i.e. independent of the wind farm; caused by the wind interacting with the rough sea surface).

A detailed study from Nedwell (2007a) presented detailed information from operational wind farms, including several of them from fairly close to the Thanet Project site and/or using similar WTGs in similar bathymetric conditions. This can be used as a comparison herewith.

9.5.2 Expected operational noise for Thanet Offshore Wind Farm

The expected operational noise from Thanet has been calculated in **Table 9.3** based on a comparison with measurements from two other similar operational wind farms (see **Table 9.2**).

Table 9.2 Wind farm characteristics

	Thanet	Kentish Flats	Barrow
Type of turbine used	Vestas V90-3MW	VestasV90-3MW	Vestas V90-3MW
Number of turbines	100	30	30
Water depth	14-23	3-5	12-16
Turbine separation (representative)	600m	700m	600m

The recordings of operational noise undertaken at Kentish Flats and Barrow demonstrated that the operational noise produced was at such a low level that it was difficult to measure relative to the background noise. This issue was dealt with by considering the operational noise spectra in terms of levels within and outside (relatively close so that some measurements above background level could be detected) the wind farm. In **Table 9.3** below the larger of the measurements (either inside the wind farm or those taken outside the boundary) have been displayed. The Sound Exposure Level (SEL) has been included to provide an indication of the SEL over a 24 hour period to give the total exposure over a day.

Table 9.3 **Measured operational noise & corrected worst case for Thanet Offshore Wind Farm**

	Kentish Flats	Barrow	Corrected worst case for Thanet*
Unweighted noise levels (dB re 1 μPa)	113	124	**129**
SEL (μPa^2-s)	N/A	N/A	**178**
Cod dB_{ht}	29	40	**45**
Dab dB_{ht}	15	N/A	**20**
Herring dB_{ht}	34	42	**47**
Bottlenose/striped dolphin dB_{ht}	37	41	**46**
Harbour porpoise dB_{ht}	50	49	**55**
Common seal dB_{ht}	38	37	**42**

N.B. *Corrected worst case – correction factor of 5dB added since the Thanet Project has 70 WTGs more than Barrow and Kentish. The correction is an increase of $10*\log_{10}(100/30)$ or approximately 5dB, which is appropriate to non-coherent summation of the acoustic energy.

The measurements at Barrow were taken at wind speeds between 8 and 11ms^{-1} whilst those at Kentish Flats were taken at speeds between 6 and 8ms^{-1}. The increase in wind speed only results in small increases in underwater noise above 8ms^{-1}. It should be noted, however that the increase in background noise due to surface agitation and waves is expected to be appreciable in this regime with increases to the spectral level being several dB re.1μPaHz-1/2 (see Lurton 2010 for an example).

9.6 Anticipated effects of operational noise from Thanet Offshore Wind Farm on marine fauna

A comparison will be made in the following paragraphs between the criteria presented in the upfront sections and the expected operational noise for the Thanet Project site is displayed in **Table 9.3**.

9.6.1 Behavioural impacts on marine fauna (dB_{ht} (*Species*))

The perceived level of noise (see **Table 9.3**) at the Thanet Project site for all species is below the 90 dBht threshold criteria at which a strong avoidance reaction is expected by virtually all individuals. The maximum expected level is 55 dBht for the Harbour porpoise. Overall therefore, the expected levels of operational noise are at such a low level that behavioural changes are not considered likely to occur, even before habituation is taken into account.

9.6.2 Lethality and physical injury (un-weighted levels)

The expected un-weighted operational noise level of 129 dB re.1 μPa (see **Table 9.3**) is well below the threshold criteria of 240 dB re.1 μPa and 220 dB re.1 μPa, corresponding to the levels for lethal and direct injury. This is not surprising since these levels correspond to very 'loud' occurrences (such as piling or naval sonar) and are considerably louder than anything expected on an operational wind farm.

9.6.3 Marine mammal injury (Southall criteria)

When the results for the estimated SEL of 178 μPa_2-s (see **Table 9.3**) is compared with the thresholds for all species (see Table 9.2), it is clear that the exposure levels for all, over the 24 hours is well below that of the Southall criteria.

9.6.4 Comparison with background levels at the Thanet Offshore Wind Farm

The background noise levels of the Thanet Project site have been compared with the expected levels produced by the operational wind farm, on a species-by-species basis (see **Table 9.4** below). It should be noted that the dB_{ht} value with respect to a specific species is the level of perceived noise above that species' hearing threshold, so 0 dB_{ht}(Species) would be the minimum that the species is able to hear, and will be at a different absolute level for different species. The dB_{ht}(Species) metric has been developed as a means for quantifying the potential for a behavioural impact on a species in the underwater environment. For instance, the same construction event might have a level of 70 dB_{ht} (*Salmo salar*) for a salmon, and 110dB_{ht} (*Tursiops truncatus*) for a bottlenose dolphin.

Table 9.4 **Comparison of estimated operational noise levels to measured background levels at the Thanet Offshore Wind Farm site**

	Operational noise level	**Background Level Site I**	**Background Level Site II**
Cod dB_{ht}	45	35	16
Dab dB_{ht}	20	19	5
Herring dB_{ht}	47	42	21
Bottlenose/ striped dolphin dB_{ht}	46	47	47
Harbour porpoise dB_{ht}	55	56	53
Common seal dB_{ht}	42	43	32

From **Table 9.4** it can be seen that the perceived levels of noise for the fish species are more pronounced than for marine mammals. This is to be expected since the audiograms of fish are most sensitive in the lower frequencies where most of the underwater energy is concentrated.

For the fish species, it appears that the operational noise is above the background level particularly at the quieter site II.

It is clear from **Table 9.4** that there is a large variation in the level of background noise – even between two locations which are relatively close (tens of km separation). The Automatic Identification System (AIS) shows that 'large shipping' (typically container vessels) is found to pass close to the Thanet Project site regularly. Subacoustech has made several measurements of this type of vessel and the dBht (Species) levels at 120m for such a vessel is provided in **Table 9.5.**

Table 9.5 **Representative dBht (Species) values for shipping found near the Thanet Project site**

Species	dBht Level
Cod	52
Dab	38
Herring	51
Bottlenose/striped dolphin	68
Harbour porpoise	74
Common seal	59

The dBht levels in **Table 9.5** are significantly higher than the operational noise values given in **Table 9.4**. For the same vessel, a level of 152.5 dB re.1 µPa (RMS) was obtained.

When the level of shipping noise is considered in relation to the operational noise levels, both the un-weighted receive levels and the dBht levels receive levels are much higher in the presence of the existing shipping. Therefore, the noise of shipping passing nearby dominates over both the ambient background and the underwater operational noise from the wind farm.

9.7 Literature review on the effects of operational noise

Lindell (2003) reported on the underwater sound measurements taken in the vicinity of the Utgrunden wind farm in Sweden, between November 2002 and February 2003. The wind farm is comprised of seven 1.5 MW GE Wind Energy turbines, arranged along a line, in water between 4 and 10 metres deep. Three hydrophones were located on the sea bed along a radial line emanating from the WTG in the middle of the array; the ranges from the WTG were 83, 160 and 463m. Using sound pressure values, it was found that, apart from the tonal components, the sound reduced to background levels within about 300m of the WTG. The highest tonal component, at about 180Hz, reduced to background level at about 2km, while the other three components (at about 360, 530 and 730Hz) reduce to background level at about 450m. The report concluded that the underwater sound was dominated by a few frequencies between 30Hz and 800Hz, related to gearbox meshing. Also, noise from passing ships dominated the field for frequencies above about 63Hz.

The same research documented the variation of noise produced with wind speed. They found that the exact position of tonals increased with wind speed – consistent with the belief that this aspect of the noise is driven by mechanical aspects of the WTG. Furthermore, they showed that although the broadband noise contribution rises with increasing speed, this is a relatively small effect for variation of speed between 8 and $13ms^{-1}$.

A review of the effects of underwater sounds from wind farms and their effects on marine mammals (Madsen *et al* 2006) concluded that for operational wind farms, the effects were negligible especially in comparison to other anthropogenic sources such as shipping noise.

Teilmann *et al.* (2006a) reported on monitoring of harbour porpoises around the Horns Reef and Nysted wind farms located respectively in the North Sea and the south-western Baltic Sea, off the coast of Denmark. The former farm has 80 2MW WTGs, and the latter 72 2.3MW WTGs. T-PODs (devices which sensed and recorded porpoise clicks) were deployed on the sea bed around the two sites to take measurements before, during and after the construction of the farms. Their conclusions were that there was no reduction of porpoise activity at Horns Reef in its operational phase, while there was some reduction at Nysted when it was in operation, but that it was recovering to pre-construction levels after about two years.

Teilmann *et al*. (2006b) monitored harbour and grey seals at the Horns Reef and Nysted wind farm sites noted above. This study used visual monitoring and satellite tracking of tagged animals. Their conclusion was that 'no general change in behaviour at sea or on land could be linked to the wind farms'.

Terhune *et al.* (2013) recommended the use of dB_{ht}(*Species*) in a study assessing the impact of anthropogenic noise on harbour porpoises, concluding that "it will not be appropriate to use [unweighted metrics] when assessing the potential impact of anthropogenic underwater noise… because of the low frequency insensitivity of harbour porpoise".

Cefas (2010) reviewed the monitoring of underwater sound around wind farm sites around the UK coast, with a view to establishing the compliance with licensing requirements. The review concluded, inter alia, that in the operational phase the sound generated was only slightly above ambient noise levels and would be expected to have a negligible effect on marine fauna.

9.7.1 Conclusions

The expected level of underwater noise for the operational Thanet Project site has been considered against a number of assessment criteria for effects on marine fauna. Whilst the limitations of the dBht(Species) criteria have been acknowledged, i has been demonstrated that for the three criteria (lethal or injurious levels; marine mammal Southall criteria and behavioural avoidance dBht levels), any contribution from operational underwater noise is extremely unlikely to contribute to injury or behavioural changes in the marine fauna.

For completeness, the expected operational level of noise was compared with measured background levels. At each stage of the process, an attempt was made to choose the worst case (i.e. choosing the lowest background noise). This has been achieved by:

- Choosing the quieter of the two sites from which measurements were made;
- Using data from a period when weather conditions were good; and
- Taking measurements when there was no nearby shipping.

It has been shown that underwater operational noise may indeed be slightly above the level of background noise in the quietest conditions, but it also demonstrates that the presence of a single tanker in the vicinity completely overwhelms the background and underwater operational noise at the Thanet Project site. Since shipping is common in the region of the wind farm, it appears that the contribution of existing shipping noise would be the dominant factor.

Noise generation as a result of the construction of WTGs (especially those requiring percussive piling for the installation of the support structures) is considered to have the potential to affect fish species at varying distances from the source of the sound. The fish aggregating/new habitat effects of the WTG supports would really only start once the structure was in place and therefore once piling noise had ceased. Once colonisation of the support structures was established noise effects would be restricted to that from operation and maintenance activities. It is considered that the level of noise during operation and maintenance would not have a significant effect on the community established on the structures.

10 SALTMARSH MONITORING

10.1 Botanical survey

10.1.1 Objective

Although not a requirement of the Thanet Project's license conditions, TOWL agreed with Natural England to undertake surveys of the saltmarsh vegetation within Pegwell Bay to monitor recolonisation following the installation of two 132kV export cables in January 2010. The monitoring surveys commenced with monthly surveys between March 2010 and August 2010 (six surveys in total) and then annual surveys in August 2011 and September 2012.

10.1.2 Scope of survey

The first monitoring survey was undertaken in response to a request from Natural England who wanted to assess the impact of the works on the saltmarsh and see how long recolonisation of the cable route took. It involved monthly surveys between March 2010 and August 2010 (six surveys in total). Each monthly survey involved the photographic comparison of specific survey locations over the 6 months, as well as an assessment of the plant species composition (Royal Haskoning, 2010 & **Appendix 10A**). A recommendation of the report summarising these surveys, was that two further surveys at the end of the summers of 2011 and 2012 should be undertaken to confirm that successional development of the saltmarsh was occurring.

Prior to the start of the survey in 2011 it was decided, through consultation with Natural England, that a quadrat assessment of the site would also be undertaken to allow for comparison between the cable route and the surrounding saltmarsh (i.e. the control area) and provide a more quantitative assessment of the recolonisation process. The survey (including both the photographic and quadrat assessment) was undertaken in August 2011. Following this survey, further consultation was undertaken with Natural England and it was confirmed that whilst there was evidence of saltmarsh recolonisation a final survey in 2012 should still be completed.

10.1.3 Monitoring completed

The scope of the monitoring surveys has followed the approaches outlined below.

<u>Fixed point photography</u>

Each monthly survey (between March and August 2010) involved taking a series of photographs using a Global Positioning System (GPS) camera and recording the coordinates for each monitoring survey point. The photographs were taken in similar locations to those taken during the site visit undertaken in February 2010 (shortly after the installation of the cable) to enable an effective temporal comparison. Each of the monthly surveys and the subsequent annual surveys included photographs at these similar locations.

Quadrat assessment

The 2011 and 2012 annual surveys included data recorded from $1m^2$ quadrats for areas of saltmarsh both within the cable corridor (i.e. the study area) and outside of the footprint of the cable corridor (i.e. the control area). Two quadrats were recorded for each vegetation zone in the surrounding saltmarsh and in similar areas of the cable corridor. The locations of the quadrats were determined by the site surveyor whilst on site and by visual assessment of the zonation of plants. Each survey location was recorded using a hand held GPS.

The percentage cover of each plant species within the quadrat was estimated within a grid of 20cm squares. This allowed for the comparison of the original saltmarsh with the recolonising area and provided an overview of the general recovery of the area within the cable corridor through the presence or absence of key saltmarsh plant species.

Prior to 2011, an assessment of saltmarsh plant species present and their recolonisation of the site was made by visual identification on site by the surveyor instead of by using quadrats.

10.1.4 Overview of results

2010 Monthly Monitoring Survey Results

In total, eight surveys (not including the February 2010 site visit which provided baseline photos) of the cable route were undertaken between 2010 and 2012 by two suitably qualified Royal Haskoning ecologists.

During the first two monthly surveys of the site, undertaken in March and April 2010, the general appearance of the study area was one of bare ground with the occasional scattered individual plant (see **Plate 10.1**). Dominant plant species recorded were glasswort species which is typical of the pioneer stage of saltmarsh establishment.

Plate 10.1 Cable route in March 2010 (looking down towards sea)

During the fourth survey which was undertaken in June 2010 (5 months after completion of the cable installation), sea aster, a perennial species was recorded along the lower foreshore indicating the establishment of lower marsh communities. Typically, sea aster spreads rapidly in the lower areas of marsh. It has a high seed production and although it is often a long-lived perennial it can also be present in lower areas as a biennial or short-lived perennial species, sometimes even being found among colonising species (Boorman, 2003). Another species recorded during the June 2010 survey associated with the lower marsh was common saltmarsh grass. Sea aster, common saltmarsh grass and sea purslane (recorded in the May survey) represent peak development of the lower marsh and their presence on site is indicative of this process.

The six monthly surveys indicated that the middle and upper reaches of the saltmarsh became colonised at a slower rate than the lower saltmarsh, as is to be expected from the development of a saltmarsh. The key species identified as colonising the upper foreshore area during the May, June and July surveys included sea beet, grass-leaved orache, and greater sea spurrey. In addition, all of these species were recorded more frequently as the surveys progressed. The grass species (specifically common cord grass and sea couch) was more widespread along the upper reaches of the saltmarsh and the boundary between the cable route and the existing saltmarsh became less dominant (see **Plate 10.2**).

Plate 10.2 Cable route in June 2010 (looking down the cable route towards the sea)

At the end of the six month monitoring survey period, the majority of the cable route had become recolonised with typical saltmarsh species. However there were still some areas of bare mud within the upper sections and where colonisation is naturally slower (see **Plate 10.3**). The saltmarsh species which were recorded to dominate the cable route were typically the pioneer species, such as glasswort and common saltmarsh grass.

Plate 10.3 Development of saltmarsh in the cable route corridor from March 2010 (top) to August 2010 (bottom)

2011 Annual Monitoring Survey Results

Further evidence of saltmarsh recolonisation was recorded during the August 2011 monitoring survey. Some areas such as those in the higher ground of the middle and upper shore, showed signs of accelerated saltmarsh growth which is thought can be attributed to optimal tidal inundation levels. Other areas of the saltmarsh recolonisation within the cable corridor also showed signs of saltmarsh recovery (albeit less dominant) and generally, the continued establishment of the saltmarsh was evident in comparison to August 2010.

The quadrat assessment highlighted that whilst the saltmarsh recolonisation within the cable corridor showed signs of recovery and had become more diverse since August 2010, there was still a clear differentiation between the existing saltmarsh within each zone and the recolonised saltmarsh within the cable corridor. Typically, it appeared that the recovering saltmarsh was more similar to the saltmarsh within the control site in the preceding zone (towards the lower shore) than in the adjacent control site.

Additionally, during the 2011 monitoring survey, it was noted that, within the cable corridor, there were areas of slightly higher ground towards the upper foreshore area where the saltmarsh was more established than in other areas of the cable corridor (see **Plate 10.4**). It was anticipated that over time, the cable corridor will naturally accrue further sediment and stabilise. However, although some areas of the cable route corridor were more established with saltmarsh species than others, the saltmarsh was establishing as would be expected in a pioneer saltmarsh community.

Plate 10.4 **Saltmarsh establishment in the upper section of the cable route corridor in August 2011**

Overall the 2011 monitoring survey indicated that the cable corridor was almost fully vegetated with typical saltmarsh species, although not yet at a comparable stage with the surrounding saltmarsh (see **Plate 10.5**).

Plate 10.5 **Saltmarsh establishment in the cable route corridor in August 2011**

2012 Annual Monitoring Survey Results

The saltmarsh recolonisation had continued within the cable corridor, specifically within the higher reaches of which a large section had been bare mud in 2011. The area had become fully colonised by saltmarsh species in 2012. Further evidence of the successful saltmarsh reestablishment zones was shown in the reduced presence of the pioneer species, (e.g. glasswort species) in the mid to upper levels.

The quadrat assessment indicated that since the 2011 monitoring survey, the saltmarsh had continued to re-establish and colonise the cable corridor and the area more closely represented the wider saltmarsh area in 2012. In particular, the low to mid zone (Zone 3) very closely represented the adjacent saltmarsh. In the other zones, the saltmarsh was developing as would be expected in a pioneer saltmarsh community.

The survey indicated that natural saltmarsh succession had taken place within the site and whilst further development and spread of plants such as sea couch would continue to occur, the cable corridor had become analogous with the surrounding area (see **Plate 10.6**).

Plate 10.6 **Pegwell Bay saltmarsh in 2010, 2011 and 2012 (fence marks boundary of cable corridor, looking down towards the sea)**

10.1.5 Conclusions

During the 2010 monitoring survey, the difference between the first monitoring survey (undertaken in March 2010) and the sixth monitoring survey (undertaken in August 2010) was significant, indicating the initial stages of saltmarsh recolonisation of the cable route corridor. Since the 2010 monitoring survey, the saltmarsh has continued to develop and become more established within the cable corridor. The quadrat assessments undertaken in 2011 and 2012 indicated that whilst there are still some minor differences in saltmarsh coverage between the cable corridor and the wider area, particularly in the lower zones, the cable corridor has recolonised with saltmarsh and has become analogous with the surrounding area. Predominantly, all the saltmarsh species recorded within the wider saltmarsh areas have been recorded within the cable route.

The areas of saltmarsh within Pegwell Bay can be classified as a mix of pioneer and lower saltmarsh plant communities. These are typically early stage saltmarsh communities and not considered highly diverse. However, due to external conditions the progression to middle and higher saltmarsh communities may not occur, as is the case within the wider Pegwell Bay saltmarsh. Previous monitoring surveys of the wider area identified some saltmarsh species, typical of middle saltmarsh communities such as sea lavender (Royal Haskoning, 2007) but these species were uncommon and the monitoring surveys have found no evidence of their spread.

11 SUMMARY AND CONCLUSION

The following tables lay out each licence condition in turn, and summarise the conclusions from the monitoring report justifying how each condition has been met.

11.1 Hydrodynamics and Geomorphology

Marine Licence L/2011/00321/4 (Export Cable Replacement) Section 3.3.4	
Survey required to confirm that cable has been buried to depth of at least 1metre and that substrate has returned to a normal state with no obstacles to safe fishing	Surveys have been undertaken of the entire cable route. The survey confirmed that the northern cable route is buried along the entire length surveyed. The southern export cable route has a spudcan scar on the route and a depression near the Central Control Station which are possible exposures however the majority is covered and buried to a depth of 1metre and no freespans are seen along the entire surveyed route. No construction debris was observed during the surveys.
Marine Licence L/2012/00423/1 (Inter array cable protection) Section 3.3.3	
Must conduct a full bathymetric survey of the Thanet Offshore Wind Farm site, including the additional 312m of export cable protection.	Full bathymetric surveys have been completed of the Thanet Project and export cable.
Marine Licence L/2011/00232/2 (Inter-tidal joint replacement): Condition 2.3	
Post construction surveys of the excavation will be undertaken. The sonar mounted on the Rotech Twin R2000 will provide a two dimensional profile of the seabed and excavations made and digital grapbs may be taen of the profiles if required	This has been completed and was submitted to the MMO. Please see Appendix 4B.
Marine Licence L/2011/00077 (Midline Joint and Cable Crossing Protection) Section 3.3.1	
Must ensure that a bathymetric survey of the berm structures and the sections of the export cable covered by rock placement are undertaken once the Works are completed.	Full bathymetric surveys have been completed of the Thanet Project and export cable.
FEPA Licence 33119/10/1: Condition 9.28, 9.29, 9.31, 9.33 & 9.41	
9.28 To undertake a swath bathymetric survey around a sample of adjacent turbines (minimum of four) and at cable crossings to assess scour within the array and at the crossings.	The scour surveys were completed twice in 2012 at four WTGs (E01, E02, F01 and F02) and four cable crossings. This will be repeated at six monthly intervals for a further two years.

The number of turbines and the area of seabed and at the crossings surveyed should be determined in consultation with the Licensing Authority based on the outputs of the computer models used to inform the Environmental Statement. The precise location and timing of this survey will be agreed with the Licensing Authority (in consultation with Cefas and Natural England). The survey will be repeated at six monthly intervals for a period of three years (in total 6 surveys). The survey shall specifically address the need for (additional) scour protection around the turbine foundations and at the crossings. The Licence holder is required to cross-reference the occurrence of any *Sabellaria spinulosa* reef with any detected scour pits and consult Natural England before any scour protection is deposited at the site.	The surveys were discussed and agreed with the MMO and scour protection may be required on the southern export cable towards the control station. No *Sabellaria spinulosa* has been detected within the scour pits.
9.29 To undertake a swath bathymetric survey in the event of a major storm event with wave heights exceeding 1 in 10.	The information provided to date has not indicated that a major storm event has taken place.
9.31 To undertake two (winter and summer) high resolution swath-bathymetric surveys of the wind farm array and cable route to assess the extent of any bed form morphology.	Scour monitoring was undertaken on a 6 monthly basis, with one survey in the late winter period and the other in the late summer period in order to capture possible scour pit evolution after winter storms and infilling after calmer, summer weather.
9.33 To ensure that the export cable is buried by trenching or ploughing to depth of not less than one metre across the inter tidal zone.	Surveys have been undertaken of the entire cable route. The survey confirmed that the northern cable route is buried along the entire length surveyed. The southern export cable route has a spudcan scar on the route and a depression near the Central Control Station which are possible exposures however the majority is covered and buried to a depth of 1metre and no freespans are seen along the entire surveyed route.
9.40 To ensure that any debris or temporary works placed below MHWS are removed on completion of the works authorised by this Licence. (Any drill cuttings, arising and associated with the use of water-based muds, are permitted to be left on the seabed within the boundaries of the turbine array).	No construction debris was observed during the surveys.
9.41 To undertake a post-construction bottom and side scan sonar survey along the same grid lines (within operational and	Full bathymetric post-construction surveys have been undertaken at the site. No construction debris or obstructions have been observed during post-construction surveys.

safety constraints) as the pre-construction survey, as soon as reasonably practicable and submitted to the Licensing Authority. All reasonable efforts must be made at the developer's expense to remove any debris and/or obstructions located which were not previously recorded during the pre-construction survey.	

11.2 Ornithology

FEPA Licence 33119/10/1: Condition 9.4, 9.12, 9.13 & Annex 2	
9.4 The Licence Holder must carry out a programme of ornithological monitoring as outlined in Annex 1 and 2.	A programme of ornithological monitoring has been undertaken in line with the requirements specified in Annex 1 and 2.
9.12 Ornithological monitoring must be carried out as outlined in Annex 2 attached to this Schedule. The full specification for the monitoring programme will be subject to separate written agreement with the Licensing Authority following consultation with Natural England prior to the proposed commencement of the monitoring work.	The survey methods used for monitoring follow those detailed in the Thanet Offshore Wind Farm – During and Post-Construction Bird Monitoring Protocol. The Protocol was developed in consultation with Natural England and the Marine and Fisheries Agency (MFA) (now the Marine Management Organisation (MMO)) in order to meet the requirements of the Thanet project's FEPA licence.
9.13 Post-construction monitoring during the operational phase of the wind farm must be undertaken annually for three years. The level of any subsequent ornithological monitoring, during the lifetime of the wind farm's operation, will be determined, in consultation with Natural England, having regard to the magnitude of any change in bird populations observed during the initial monitoring period.	The three years post-construction surveys were agreed prior to commencing with Natural England in line with the FEPA licence requirements
Annex 2	
Monitoring will comprise a Before and After Control Impact (BACI) design and will be undertaken at the survey areas consisting of the wind farm site and 1km and 2-4km buffer zones surrounding the wind farm and the selected reference site, with a requirement being to provide a minimum of three	Operational data has been collected for 3 years

years data from the operational phase.	
Monitoring will need to fulfil the following objectives: 1. Determine whether there is a change in bird use and passage, measured by species (with particular reference to red throated diver), abundance and behaviour, of the wind farm site, 1km and 2-4km buffer zones and the reference site. 2. Determine whether there is a barrier effect to movement of birds through the wind farm site and the 1km and 2-4km buffer zones. 3. Continue to determine the distribution of wildfowl and divers in the Greater Thames estuary, covering the Thanet wind farm site, 1km and 2-4km buffer zones and the reference site. 4. If objectives 1 or 2 reveal significant change of use of the wind farm site and 1km and 2-4km buffer zones by populations of conservation concern, at heights that could incur collision, a programme of collision monitoring will be implemented.	In relation to collision risk, bird numbers and species at risk of collision have also been similar, so there would be no need to implement any additional programme of collision risk monitoring. As concluded in the monitoring reports, there is no evidence to suggest that the conclusion reached in the ES (that there would not be any significant collision risk) would be changed by the recent post-construction data.

11.3 Marine Ecology

Marine Licence L/2012/00423/1: Section 3.3.2	
Must map the post laid footprint of the cable protection and overlay onto a *Sabellaria spinulosa* map using the most recent benthic data available.	The figures illustrate that in 2012, there was a wider distribution of S. spinulosa aggregation categorised as moderate (patchy) growth and dense growth than in 2007.
FEPA Licence 33119/10/1: Condition 9.28 & 9.6	
9.28 The occurrence of any Sabellaria spinulosa reef with any detected scour pits will be cross referenced with the pre-construction surveys.	No S. spinulosa reef aggregations were identified in seabed imagery collected from scour pits around surveyed monopiles. It can be assumed that impacts associated with scouring are restricted to the base of the monopile plus an approximate 5 metre circumference
9.6 The licence holder must ensure that during post-construction benthic and bathymetric surveys, areas of Sabellaria spinulosa are mapped to allow comparison with areas	In 2012 there were less signs of damage (e.g. rubble and scars) to the S. spinulosa aggregations, when compared with the 2005 and 2007 data. It is assumed that the positive growth and stable S. spinulosa reef aggregations found across the Thanet Project in the 2012 survey may be partially attributed to the

of reef mapped during pre-construction surveys and any impacts of construction activities, including jetting of inter array cables, on the reef areas assessed.	reduction in destructive bottom fishing activities as a result of the presence of the offshore wind farm and associated cable infrastructure.

11.4 Subtidal Benthic Surveys

FEPA Licence 33119/10/1: Condition 9.4 & Annex 1	
9.4 The Licence Holder must carry out a programme of sedimentary, hydrological, benthic, ornithological and other monitoring, as outlined in Annex 1 and 2 attached to this Schedule. The full specification for the monitoring programme will be subject to separate written agreement with the Licensing Authority following consultation with CEFAS and Natural England at least four months prior to the proposed commencement of the monitoring work.	Subtidal benthic surveys were in line with meeting the FEPA licence condition requirements outlined below and discussions with Natural England and Cefas
Annex 1	
• Sample locations for ongoing monitoring must be determined by factors such as precise monopile locations, location of cables etc. Sample locations must also take full account factors such as coastal process modelling outputs (for sediment transport / deposition information) and geophysical surveys (to ensure adequate coverage of sea bed habitats);	Due to weather constraints, the study to assess the monopile colonisation has been rescheduled for 2014.
• Sampling should involve a minimum of three replicates at each station and the number and location of stations should be determined making use of the data used to characterize the site as part of the Environmental Statement. This monitoring should include a suitable baseline data set and make adequate use of control sites; and	Three replicate grab samples were collected at each sample station Subtidal infaunal sampling was undertaken at 25 stations with a $0.1m^2$ mini Hamon grab. Stations were selected according to which faunal group and sediment type they were classified under historically.

• Colonisation of monopiles and scour protection must be determined by video observations and analysis with some accompanying sample collection for verification and identification.	In the 2012 geophysical survey, some localised scour at the base of the turbines was measured to a range of between 3.5m and 4.5m in a circular shape around the base of the monopiles. On average the sediments in the scour pits were coarser than those recorded from samples elsewhere in the Thanet Project site. Analysis of infaunal samples from scour pits at 2 locations revealed that the most abundant and commonly occurring taxa (including Sphiophanes bombyx, Abra alba, Conopeum reticulum) were similar to those found across the Thanet Project site and surrounding region. Potential scour effects on S. spinulosa were minimised by initial micro-siting to avoid S. spinulosa aggregations and no S. spinulosa was recorded in any of the monitored scour pits.

11.5 Herring spawning

FEPA Licence 33119/10/1: Annex I, paragraph 4	
As a result of the herring timing being removed from the previous licence 33119/07/2 additional post construction spawning surveys are required. The methodology of these must be submitted to the Licensing Authority (in consultation with Cefas) four months prior to the commencement of the survey.	Available evidence, collected by TOWL and others, presented a compelling argument against further disruptive sampling of the herring stock during its spawning period. In its response to the first version of the PCEMP submitted to the Licensing Authority, the Licensing Authority stated that: “*Due to supporting information/surveys already conducted and the vulnerability of the herring stock in the area, the MMO is content for the post construction herring surveys to be dropped from the TOWF license*.” As such, TOWL has not undertaken any further surveys of the Thames herring stock post construction.

11.6 Elasmobranch Survey

FEPA Licence 33119/10/1: Annex I, paragraph 4	
A number of elasmobranchs (lesser spotted dogfish, thornback rays, starry smoothhounds) are common to the general area surrounding the proposed wind farm site. Survey work is therefore required to determine the general status (numbers and distribution) of this and other elasmobranch species in the vicinity of the Thanet Offshore Wind Farm.	The scope of the survey was agreed with the MMO prior to each of the surveys The conclusion can be drawn that the abundance and diversity of elasmobranch species in the wind farm and cable corridor has not significantly altered due to the presence of the infrastructure.

The results should be presented and discussed in combination with the EMF studies (Annex I, paragraph 5).	Of the elasmobranch species captured, three were commonly caught in the cable corridor sites. These include starry smoothhound, thornback ray and lesser spotted dogfish which are common along the North Sea coastline.

11.7 Adult and Juvenile fish survey

FEPA Licence 33119/10/1: Condition 9.10	
The Licence Holder must within six months of the date of this licence produce proposals for a post-construction survey of fish populations in the area of the wind farm. The Licence Holder shall, in drawing up such proposals, canvas the views of local fishermen. The proposals must be submitted to the Licensing Authority by the date specified in the schedule required under condition 9.2. The License Holder must undertake these surveys as detailed in the agreed specification and report by the date specified in the schedule required under FEPA licence condition 9.2.	Through consultation with the MMO, Cefas and Natural England (22nd April 2010) it was agreed that TOWL would undertake a single year of post-construction adult fish surveys i.e. a spring (April) and summer (July) and a concurrent juvenile fish survey. There is little evidence that the TOWL has had a significant impact on either adult fish species abundance or diversity. The post construction surveys generally support the assessment in the ES that there would be little effect on the abundance of the main species of fish due to habitat disturbance. The general conclusion based on the evidence provided indicates that there will be little effect on the juvenile population in relation to habitat disturbance.
Marine Licence L/2012/0023/1: Condition 3.3.4	
The Licence Holder must produce charts identifying where the stone has been laid and distribute to local fishermen	As built information was provide to the UKHO, Kingfisher House and The Crown Estate. In addition, Vattenfall provided hard copies of Appendix 11A to local fishermen as well as the French and Belguim fleets.

11.8 Marine Mammals

FEPA Licence 33119/10/1: Annex 1, Paragraph 6	
Marine mammal monitoring, over an initial three year period and on-going during the lifetime of the wind farm's operation, will be determined, in consultation with Natural England and the Licensing Authority and reviewed at agreed periods	TOWL agreed with the Licensing Authority that post-construction marine mammal surveys were not required and instead committed to presenting incidental sightings recorded during the ornithological surveys as part of the annual ornithological report, making comparisons to all pre- and during-construction data.

11.9 Subsea noise monitoring

FEPA Licence 33119/10/1: FEPA 9.9 & Annex I Paragraph 7	
9.9 The Licence Holder must make provision during the construction phase of the wind farm to install facilities to enable subsea noise and vibration from the turbines to be assessed and monitored during the operational phase of the wind farm. Before completion of the construction phase the Licence Holder must supply a specification to the Licensing Authority of how it proposes to measure subsea noise and vibration – at various frequencies across the sound spectrum at a selection of locations immediately adjacent to, and between turbines, within the array and outside the array at varying distances – in order to fulfil the monitoring requirement outlined in Annex 1 attached to this Licence.	*In reference to Deemed Marine Licence condition 33119/10/1: Annex 1, paragraph 7. After the PCEMP was produced, TOWL requested to consider the use of desk-based modelling studies to assess the potential effects of sub-sea noise and vibration caused by the OWF on marine biota. The MMO agree that this is an acceptable approach, provided that this modelling work is based on a comprehensive dataset of noise propagation, measured for the Thanet OWF and if possible, on data from other OWFs in the Thames Estuary and other regions. The data within all reports should consist of its processed and unprocessed forms (as Appendices), and reports of the various components of this monitoring programme will be integrated so as to compare related environmental and biological parameters. Once the results of the modelling exercise are available, the MMO will make a final decision on the need for conducting further sub-sea noise monitoring*.
Annex 1	
Detailed data must be collected on the frequencies and magnitude of underwater noise produced by the offshore wind farm both during construction and once operational. This is required for a variety of purposes, including:	A desk based modelling assessment was undertaken to assess the potential effects of underwater noise and vibration caused by the operational TOWL site on marine fauna
• In combination with the biological aspects of the monitoring programme proposed in Annexes 1 and 2, the data will elucidate any interactions between noise generation and the provision of new habitat and fish aggregation effects of the turbine support structures.	It is considered that the level of noise during operation and maintenance would not have a significant effect on the community established on the structures.
• Determining the effects of distance, depth, seabed topography and background sources on noise propagation.	For completeness, the expected operational level of noise was compared with measured background levels. At each stage of the process, an attempt was made to choose the worst case (i.e. choosing the lowest background noise). This has been achieved by: • Choosing the quieter of the two sites from which measurements were made; • Using data from a period when weather conditions were good; and

	• Taking measurements when there was no nearby shipping. It has been shown that underwater operational noise may indeed be slightly above the level of background noise in the quietest conditions, but it also demonstrates that the presence of a single tanker in the vicinity completely overwhelms the background and underwater operational noise at the Thanet Project. Since shipping is common in the region of the wind farm, it appears that the contribution of existing shipping noise would be the dominant factor in noise around.
• Detecting potential marine mammal disturbance.	Overall the expected levels of operational noise are at such a low level that behavioural changes are not considered likely to occur, even before habituation is taken into account.

11.10 Saltmarsh monitoring

No licence condition	
Monitor recolonisation of saltmarsh vegetation	Surveys undertaken 2010, 2011 and 2012. The quadrat assessments undertaken in 2011 and 2012 indicated that whilst there are still some minor differences in saltmarsh coverage between the cable corridor and the wider area, particularly in the lower zones, the cable corridor has recolonised with saltmarsh and has become analogous with the surrounding area. Predominantly, all the saltmarsh species recorded within the wider saltmarsh areas have been recorded within the cable route.

12 REFERENCES

Baker, H., D. A. Stroud, N. J. Aebischer, P. A. Cranswick, R. D. Gregory, C. A. McSorley, D. G. Noble, and M. M. Rehfisch, 2006. Population estimates of birds in Great Britain and the United Kingdom. *British Birds* (99):25-44.

Boorman, L.A., 2003. *Saltmarsh review. An overview of coastal saltmarshes, their dynamic and sensitivity characteristics for conservation and management*. JNCC Report number 334.

Cefas, 2010. Strategic Review of Offshore Wind Farm Monitoring Data Associated with FEPA Licence Conditions. Annex 4: Underwater Noise. CEFAS Report ME1117. [http://cefas.defra.gov.uk/media/393553/annex-4-underwater-noise.pdf].

Eaton, M.A., Brown, A.F., Noble, D.G., Musgrove, A., Hearn, R.D., Aebischer, N., Gibbons, D.W., Evans A. and Gregory, R.D., 2009. Birds of Conservation Concern 3: the population status of birds in the United Kingdom, Channel Islands and Isle of Man. *British Birds* (102): 296-341.

Farrell, E.D., Mariani, S. & Clarke, M.W. 2010. Reproductive biology of the starry smooth-hound shark (*Mustelus asterias*): geographic variation and implications for sustainable exploitation. *Journal of Fish Biology*, 77: 1505-1525.

Foster-Smith, 2001. *Sabellaria spinulosa* reef in the Wash and North Norfolk Coast cSAC and its approaches: Part II, fine scale mapping of the spatial and temporal distribution of reefs and the development of techniques for monitoring condition.

Gubbay, 2007. Defining and managing *Sabellaria spinulosa* reefs: Report of an inter-agency workshop 1-2 May, 2007. JNCC Report No.405. JNCC, Peterborough.

Gardline Geosurvey Limited, 2012. Thanet Offshore Wind Ltd., Thanet Offshore Wind Farm, Post Construction Geophysical Surveys – Spring 2012, Gardline Geosurvey Limited.

Hendrick, V.J. & Foster-Smith, R.L., 2006. Sabellaria spinulosa reef: a scoring system for evaluating 'reefiness' in the context of the Habitats Directive. *Journal of Marine Biological Association of the United Kingdom*, 88: 665-677.

Holt, C.A., G.E., Austin, N.A., Calbrade, H.J. Mellan, C. Mitchell, D.A. Stroud, S.R. Wotton & Musgrove, A.J., 2011. *Waterbirds in the UK 2009/10: The Wetland Bird Survey*. BTO/RSPB/JNCC, Thetford.

Lindell, H., 2003. *Utgrunden off-shore wind farm – Measurements of underwater noise. Ingemansson* Technology Report 11-00329-03012700.

Limpenny, D.S., Foster-Smith, R.L., Edwards, T.M., Hendrick, V.J., Diesing, M., Eggleton, J.D., Meadows, W.J., Crutchfield, Z., Pfeifer, S., and Reach, I.S., 2010. *Best methods for identifying and evaluating Sabellaria spinulosa and cobble reef*. Aggregate Levy Sustainability Fund Project MAL0008. Joint Nature Conservation Committee, Peterborough.

Lurton, X. 2010. An introduction to Underwater Acoustics – Principles and Applications 2nd edition. Springer publishing.

Madsen, P.T., Wahlberg, M., Tougaard, J., Lucke, K. and Tyack, P. (2006). Wind turbine underwater noise and marine mammals: implications of current knowledge and data needs. *Marine Ecology Progress Series* (309): 279-295.

Marine Ecological Surveys Ltd (MESL), 2012. Thanet Offshore Wind Farm, a post-construction monitoring survey of benthic resources. Prepared for Thanet Offshore Wind Ltd.

Marine Ecological Surveys Ltd (MESL), 2011. Terms of Reference: Benthic Ecological Survey of the Thanet Offshore Wind Farm. 33pp.

Marine Ecological Surveys Ltd (MESL), 2008. Benthic and conservation resources study Technical report. POSTHA1007 prepared for Haskoning UK Ltd. 166pp

Marine Ecological Surveys Limited (MESL), 2007. Predictive Framework for Assessment of Recoverability of Marine Benthic Communities Following Cessation of Aggregate dredging. Technical Report to the CEFAS and Defra.

Musgrove, J.A., Austin, G.E., Hearn, R.D., Holt, C.A., Stroud, D.A., & Wotton, S.R. 2011. Overwinter population estimates of British waterbirds. *British Birds* (104): 364-397.

Nedwell, J.R., Brooker, A.G., Cummins, D., Barham, R., Bird, H. & Cheesman, S., 2009. Measurement and assessment of underwater noise during impact piling operations to monopole foundations at the Thanet Offshore Wind Farm. Subacoustech Environmental Report No 819R0210.

Nedwell, J. R, Parvin, S. J., Edwards B., Workman, R., Brooker, A. G. & Kynoch, J. E. , 2007a. *Measurement and Interpretation of Underwater Noise during Construction and Operation of Offshore Wind farms in UK Waters*. Subacoustech Report No. 544R0738 to COWRIE Ltd.

Nedwell, J.R., Turnpenny, A.W.H., Lovell, J., Parvin, S.J., Workman, R., Spinks, J.A.L. & Howell D., 2007. *A validation of the dBht as a measure of the behavioural and auditory effects of underwater noise* .Subacoustech Ltd Report No. 534R1231. Published by the Department of Business, Enterprise and Regulatory Reform.

Nedwell, J.R, Turnpenny, A.W.H. & Lambert, D. 2003. Objective design of acoustic fish deflection systems. US EPA Symposium on Cooling Water Intake Systems to Protect Aquatic Organisms.

Parvin, S.J., Nedwell, J.R. & Harland, E., 2007. *Lethal and physical injury of marine mammals, and requirements for Passive Acoustic Monitoring*. Subacoustech Report 565R0212. Report prepared for the UK Government Department for Business, Enterprise and Regulatory Reform.

Percival, S.M., 2011. *Kentish Flats Offshore Wind Farm Extension Environmental Statement: Section 9: Offshore Ornithology*. Royal Haskoning, London.

Royal Haskoning, 2012. Thanet Offshore Wind Farm Post-Construction Environmental Monitoring Plan. Royal Haskoning, London.

Royal Haskoning, 2010. Thanet Offshore Wind Farm Saltmarsh recovery monitoring survey.

Royal Haskoning, 2008. Thanet Offshore Wind Farm Pre-Construction Environmental Monitoring Plan. Royal Haskoning, London.

Royal Haskoning, 2007. Thanet Offshore Wind Farm: Export Cables – Alternative Landfall Assessment Report. Report for Thanet Offshore Wind Ltd.

Royal Haskoning 2005. Thanet Offshore Wind Farm Environmental Statement: Section 8: Ornithology.

Teilmann, J., Tougaard, J & Carstensen, J., 2006a. *Summary on harbour porpoise monitoring 1999-2006 around Nysted and Horns Rev Offshore Wind Farms*. Report to Energi E2 A/S and Vattenfall A/S. Danish Ministry of the Environment.

Teilmann, J., Tougaard, J, Carstensen, J., Dietz, R. & Tougaard, S., 2006b. *Summary on seal monitoring 1999-2005 around Nysted and Horns Rev Offshore Wind Farms*. Technical report to Energi E2 A/S and Vattenfall A/S. Danish Ministry of the Environment.

Terhune, 2013. A practical weighting function for harbor porpoise underwater sound level measurements. J. Acoust. Soc. Am. 134 (3), Pt. 2

Thanet Offshore Wind Farm (TOW), 2010. *Measurement and assessment of underwater noise during impact piling operations to install monopile foundations: additional monitoring report: Version 2* (9T6750/R00017/KRH)

Thanet Offshore Wind Limited, 2009b 2009 *Herring Spawning Survey of Thanet Offshore Wind Farm*. Undertaken by Brown & May Marine Ltd. for Thanet Offshore Wind Ltd.

Thanet Offshore Wind Farm (TOW), 2009c. *Measurement and assessment of underwater noise during impact piling operations to install monopile foundations* (9T6750/R0012/KRH).

Thanet Offshore Wind Limited, 2008a. *2008 Herring Spawning Survey of Thanet Offshore Wind Farm*. Undertaken by Brown & May Marine Ltd. for Thanet Offshore Wind Ltd.

Thanet Offshore Wind Limited, 2007. 2007 *Herring Spawning Survey of Thanet Offshore Wind Farm*. Undertaken by Brown & May Marine Ltd. for Thanet Offshore Wind Ltd. 2008.

Thomsen, F., Lüdemann, K., Kafemann, R. and Piper, W. (2006). Effects of offshore wind farm noise on marine mammals and fish. Funded by COWRIE Ltd. July 2006.

Titan Environmental Surveys Ltd, 2012 For Gardline Geosurvey Ltd on behalf of Thanet Offshore Windfarm CS0372 - Thanet OWF Post Construction Survey Campaign 2 Final Report No: V1 October 2012.

13 APPENDICES

Appendix 4A Hydrodynamics and Geomorphology

Appendix 4B Cable Burial

Appendix 5A Licences

Appendix 5B Thanet Bird Monitoring Protocol

Appendix 5C Ornithology Monitoring Reports

Appendix 6A Post-Construction Benthic Resources Report 2012

Appendix 7A Fish Resources Reports

Appendix 7B Statistical Analysis of Fish Survey Data

Appendix 9A Underwater Noise Assessment

Appendix 10A Saltmarsh Monitoring Report

Appendix 11A Fishing Publication