London Array Offshore Wind Farm Year 1 Post-Construction Monitoring Report

2015

MarineSpace

Making Sense of the Marine Environment ™

London Array Offshore Wind Farm Year 1 Post-Construction Monitoring Report – 2015

Prepared by:

MarineSpace Ltd

Ocean Village Innovation Centre

Ocean Way

Southampton

SO14 3JZ

Prepared for:

London Array Operations & Maintenance Base

Port of Ramsgate

Military Road

Ramsgate

CT119LG

Blue Transmission

The American Barns

Banbury Road

Lighthorne

Warwickshire

CV35 0AE

Date	Originator	Version	Action	Signature
06/03/2015	Gareth Johnson	0.1	First internal draft	
06/03/2015	Ian Reach	0.2	Quality Control	
23/03/2015	Gareth Johnson	0.3	Second internal draft	
27/03/2015	Jonny Lewis	0.4	Director sign-off	
28/05/2015	Gareth Johnson	1.0	Address LAL comments	

Data Licences

Licence No. EK001-0760-MF0210.

NOT TO BE USED FOR NAVIGATION.

Executive Summary

MarineSpace Ltd was commissioned by London Array Ltd to undertake a post-construction Annual Monitoring Report (AMR) for the London Array Offshore Wind Farm (OWF). The London Array OWF is located approximately 20 km from the Kent and Essex coasts, on, and between two subtidal sandbanks, Long Sand and Kentish Knock in the outer Thames Estuary.

The post-construction AMR summarises the findings of the Year 1 post-construction monitoring surveys that have been conducted within the London Array OWF study area, consisting of the OWF site and along the export cable corridor. The monitoring survey reports that have been summarised within this report are attached as appendices to this document. The monitoring report focusses on the delivery of Marine Licence conditions relevant to post-construction monitoring requirements. The report also addresses specific issues identified as requiring further assessment, or analysis, during future post-construction monitoring surveys. Future monitoring will occur for all receptors and this will provide more detail from which further conclusions can be drawn.

The bathymetric surveys reviewed within this report were conducted along the export cable and within the OWF site in 2013 and 2014, consisting of multibeam bathymetry and sidescan sonar data. A number of areas of interest were identified during the surveys, most noticeably the BritNed Cable Crossing, where increased levels of scour have occurred, resulting in cable free-spans. However, since the surveys have been conducted a marine licence has been granted for cable protection and scour remediation works, with these works being completed in Q4 2014. Scour has also been observed at all wind turbine foundations surveyed, with the degree of scouring at some turbine foundations exceeding predictions assessed within the Environmental Statement. However, there have been no cumulative interactions of scour pits observed between contiguous turbine foundations. Currently the effects are discrete, with no spatial overlap.

The post-construction monitoring survey for benthic habitats was conducted in summer 2014. Results have highlighted statistically significant differences between some tests conducted on the benthos during different project phases, and across seasons. However, given that these changes occurred across all project phases it is difficult to attribute them to the construction and operation of the London Array OWF.

The aforementioned change in seabed condition associated with the scour pits does not appear to be linked to the observed changes in benthic communities. The observed changes in the benthos are considered a result of natural variation.

The post-construction fish surveys were conducted within the OWF array, and at reference locations also used within the pre-construction surveys. The surveys were conducted in November 2013 and April 2014. The results of the post-construction surveys showed that there has been little change in species numbers since the 2009/2010 pre-construction surveys. Some fluctuations were observed in the presence, abundance and location of particular species, however the changes noted have been attributed to natural fluctuation. The results of the surveys suggest that there has been no statistically significant effects on fish populations within the London Array OWF.

Post-construction aerial bird and mammal surveys were carried out during November 2013-February 2014. The focus of the aerial surveys was to ascertain the density and distribution of Red-throated Diver *Gavia stellata* within the study area. Red-throated Diver are the qualifying feature of the Outer Thames Estuary Special Protection Area within which the London Array OWF is located. Red-throated Diver are sensitive to several effect pathways associated with construction and operation of the OWF. Comparing the post-construction and pre-construction survey results/reports shows that the number (and density) of Red-throated Diver within the study area declined during the construction of the OWF. However, based on the data acquired to date, it has been observed that numbers, density and distribution are now recovering to levels similar to those recorded pre-construction. More detailed modelling will be conducted within future reports utilising subsequent monitoring data that has yet to be obtained. These data will more clearly illustrate the changes in distribution patterns of Red-throated Diver within the OWF site.

Other bird species and marine mammals were also recorded during the aerial surveys. There has been a slight decrease in the number of Gannet recorded, and the numbers of Cormorant and Shag have increased, but these changes are not thought to have a negative effect overall on population levels associated with the study area.

The overall conclusion of the report is that the physical and biological changes observed in the post-construction monitoring surveys are typical of changes observed at other OWF sites and in-line with the EIA predictions. Based on the data collected to date, no statistically significant effects have been identified that are attributable to the OWF. Future monitoring will be conducted to provide a clear illustration of any changes within the study areas.

Acronyms

AMR	Annual Monitoring Report
BAP	Biodiversity Action Plan
BTLA	Blue Transmission London Array Ltd
CPA	Coast Protection Act
DDV	Drop Down Video
EIA	Environmental Impact Assessment
EIFCA	Eastern Inshore Fisheries and Conservation Authority
EMP	Environmental Monitoring Plan
ES	Environmental Statement
FEPA	Food and Environmental Protection Act
HV	High Voltage
KP	Kilometre Point
LAT	Lowest Astronomical Tide
MBES	Multi Beam Echo Sounder
MDS	Multidimensional Scaling
MLS	Minimum Landing Size
MMO	Marine Management Organisation
MW	Mega Watt
OWF	Offshore Wind Farm
PCA	Principle Components Analysis
SAC	Special Area of Conservation
SCI	Site of Conservation Interest
SPA	Special Protection Area
TOC	Total Organic Compound
WTG	Wind Turbine Generator

Table of Contents

List of Figures

List of Tables

Annexes

Annex A: Bathymetry and seabed morphology surveys

EGSi Ltd, 2013. *London Array Windfarm Export Cable Route Post-construction Survey (August/September 2013) Interpretive Report*. Report to Dong Energy.

EGSi Ltd, 2014. *London Array Windfarm Site and Export Cables Bathymetric Survey (Spring 2014) Survey Report*. Report to Dong Energy.

Annex B: Benthic habitat surveys

Natural Power, 2015. *London Array offshore wind farm Year 1 Post-construction Benthic Monitoring*. Report to Dong Energy Power (UK) Ltd.

Annex C: Fish resource surveys

Brown and May Marine Ltd, 2013. *London Array offshore wind farm Adult & Juvenile Fish and Epi-benthic Post-construction Survey*. Report ref LALOB01.

Brown and May Marine Ltd, 2014. London Array *offshore wind farm Adult & Juvenile Fish and Epi-benthic Post-construction Survey*. Report ref LALOB02.

Annex D: Aerial ornithology surveys

APEM Ltd, 2014. *London Array offshore wind farm: Ornithology Aerial Survey Report 2013 / 14. APEM Scientific Report*. 512696. London Array Ltd, January 2015, Draft, 77 pp.

APEM Ltd, 2015. *London Array Additional Analysis*. London Array Limited 512905.

1. Introduction

1.1. Overview

This report is the Annual Monitoring Report (AMR) for the Year 1 post-construction surveys of the London Array Offshore Wind Farm (OWF). The report has been produced by MarineSpace Limited, on behalf of London Array Limited, in order to comply with specific Marine Licence conditions. Summary details of the London Array OWF are provided below, along with information on the Marine Licence conditions relevant to this report and the objectives of the surveys (and this report).

The following surveys have been undertaken as part of the London Array OWF Year 1 post-construction monitoring:

- Bathymetry and seabed morphology (2013, 2014);
- Benthic habitats (2014);
- Fish ecology (2013, 2014); and
- Ornithology and marine mammal (aerial surveys) (2013, 2014).

In this report, information on each of these surveys is provided against the following sub-headings:

- Need for survey (specific reference to Marine Licence condition);
- Objectives of survey;
- Survey methodology;
- Survey results (to include comparison with pre-construction data and EIA predictions);
- Discussion; and
- Conclusions.

A discussion on the key findings and conclusions of all the surveys is presented to inform determinations of the overall environmental status of the OWF, based on the current evidence. The extent of the survey area varies with receptor (e.g. only the OWF site, or both the OWF site and export cable route) and is described at the beginning of each section.

1.2. The London Array Offshore Wind Farm

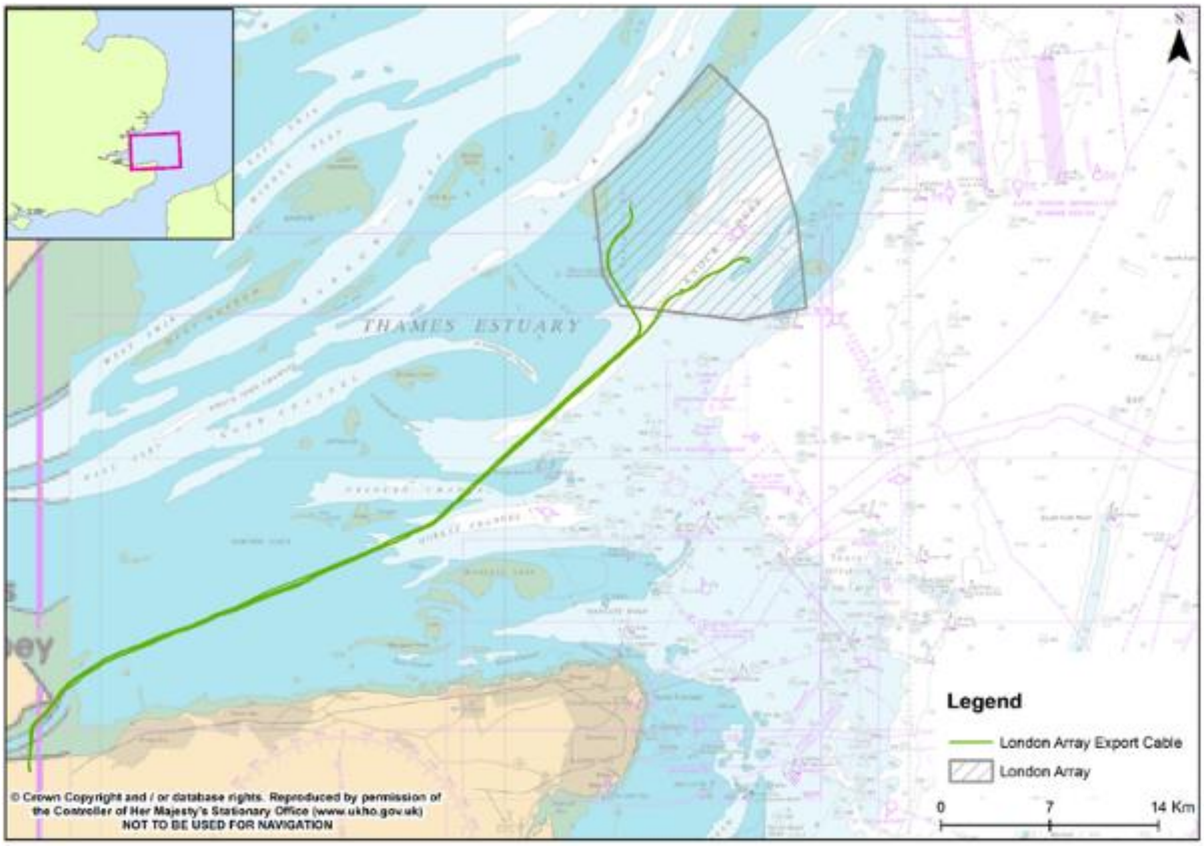
The London Array OWF is located approximately 20 km from the Kent and Essex coasts, on, and between, two subtidal sandbanks, Long Sand and Kentish Knock, in the outer Thames Estuary (Figure 1.2.1). The OWF consists of 175 turbines, each with a capacity of 3.6 MW, with a total project capacity of 630 MW.

Offshore construction of the project started in March 2011 with the main body of construction completed by December 2012. Monopile foundations were installed by pile-driving from March 2011, with the offshore substations being installed in July 2011. Installation of the inter-array cables, linking the turbines to the substation, began in August 2011 with final installation occurring during November 2012. The installation of the four export cables between the substations and the landfall at Seasalter, in the Swale, was conducted over a 12-month period between autumn 2011 and 2012.

Connection of the export cables at the onshore substation enables transfer of power to the National Grid network. The first turbine started operation in October 2012, with commissioning of the full array completed by April 2013. Inauguration of the OWF occurred in July 2013, with residual construction works continuing through summer and autumn 2013 and 2014.

The project is owned and operated by London Array Ltd, a consortium of three world-leading renewable energy companies – E.ON, DONG Energy and Masdar – and La Caisse de dépôt et placement du Québec (Caisse), one of Canada's leading financial institutions. DONG Energy is the lead Operation and Maintenance (O&M) service provider for the main site and export cable. Blue Transmission London Array Ltd (BTLA) are the assigned Offshore Transmission Owner (OFTO) for the project and own the London Array Transmission System (onshore and offshore substations and four High Voltage (HV) export cables) having acquired the transmission assets in September 2013.

Figure 1.2.1: The location of the London Array Offshore Wind Farm.



1.3. Environmental Monitoring Plan

The various elements of the environmental monitoring programme required under the conditions of the London Array OWF Marine Licence have been captured by London Array Ltd in two project-specific Environmental Monitoring Plans (EMPs):

1. Pre-Construction Marine Environmental Monitoring Plan; and
2. During- and Post-Construction Environmental Monitoring Plan (doc ref: LAL-CEM-00255 H).

This AMR reports on the Year 1 environmental monitoring with reference to both pre- and during-construction work. The requirement to produce this report is set out within the During- and Post-Construction Environmental Monitoring Plan.

The Marine Licence condition for post-construction monitoring is presented in Table 1.3.1. Specific conditions for each individual monitoring survey are presented in relevant sections within the AMR.

Table 1.3.1: Marine Licence condition - post-construction monitoring

Marine Licence Ref	Description
Condition 3.1.6	*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.*

A number of environmental surveys have been conducted for the post-construction requirements. The surveys that are summarised within this report are listed in Table 1.3.2.

Table 1.3.2: Environmental monitoring post-construction surveys summarised as part of the Annual Monitoring Report.

Report	Contractor	Survey dates	Section
London Array Offshore Wind Farm Export Cable Route Post-Construction Survey	EGSinternational Ltd	August 2013 – September 2013	2
London Array Offshore Wind Farm Site and Export Cables Bathymetric Survey	EGSinternational Ltd	Spring 2014	2
London Array Offshore Wind Farm Year 1 Post Construction Benthic Monitoring	Natural Power	July 2014	3
London Array Offshore Wind Farm Adult & Juvenile Fish and Epibenthic Post-Construction Survey	Brown and May Marine Ltd	November 2013	4
London Array Offshore Wind Farm Adult & Juvenile Fish and Epibenthic Post-Construction Survey	Brown and May Marine Ltd	April 2014	4
London Array Offshore Wind Farm Ornithology Aerial Survey Report	APEM Ltd	November 2013 – February 2014	5
London Array Offshore Wind Farm Additional Analysis	APEM Ltd	January 2015	5

1.4. Project Consents

London Array OWF was initially consented in 2006, with issue of specific FEPA and CPA consents for the offshore elements of the project. The original FEPA and CPA consents were replaced by a single Marine Licence (L/2011/00152/09) in August 2011, which has subsequently been revised on several occasions. The current Marine Licence is L/2011/00152/31 which was issued in December 2013.

The Marine Licence condition that specifies the need for an AMR for each year of environmental monitoring is listed in Table 1.4.1. This condition is satisfied by production of this report.

Table 1.4.1: Marine Licence condition – production of Annual Report

Marine Licence Ref	Description
Condition 3.1.3	*The monitoring reports must be forwarded to the Licensing Authority and Natural England on an* ***annual basis****, unless specified otherwise in this Licence….* *The various components of the monitoring programme and resultant reports, as described in conditions 3.1.3 to 3.1.10 and 3.2.2 to 3.2.4 inclusive of this Licence, should be integrated so as to compare related environmental parameters, e.g. the bird monitoring should address the conclusions of the benthic studies which should similarly draw on the sedimentary studies etc.*

2. Bathymetry and seabed morphology

2.1. Marine Licence requirements for bathymetry and seabed morphology survey

The requirement for post-construction bathymetric surveys was agreed following consultation with the MMO in 2013 (see Table 2.1.1). This consultation resulted in a revision to the original survey requirements, reducing the overall survey corridor (deemed large enough to capture the limit of scour) and surveying a reduced selection of foundations. The foundations to be monitored were determined to be locations where scour pits had the potential to develop (scour 'hot spots'). It was agreed that monitoring scour 'hot spots' would provide data representative of the entire array[1], altering the requirement for an array-wide survey programme.

Table 2.1.1: Marine Licence conditions – bathymetric surveys

Marine Licence Ref	Description
3.1.19	*The Licence Holder must undertake a bathymetric survey of the monopiles, array cables and export cable route to assess scour. The area of seabed surveyed must be agreed with the Licensing Authority in consultation with Cefas and Natural England. This shall specifically address the need for (additional) scour protection around the turbine pylons and at cable crossings. The Licence Holder must submit the data in the form of a report to the Licensing Authority, including proposals for scour protection measures by the date specified in the schedule required under condition 3.2.1. Any proposal to install scour protection measures should, where practicable, avoid the use of rock dumping. The Licence holder is required to cross-reference the occurrence of any Sabellaria spinulosa reef or reef-like structures with any detected scour pits and consult the Licensing Authority before any scour protection is deposited at the site."*
3.1.20	*The Licence Holder must undertake high resolution swath-bathymetric surveys (conducted to order IHO Standards for Hydrographic Surveys (S44) 5th Edition Order 1a) (including a pre-construction baseline) of the wind farm array and cable route to assess the extent of bedform morphology. The area to be surveyed and the frequency of surveying within the wind farm array is to be agreed with the Licensing Authority in consultation with Cefas, Natural England Trinity House and MCA. Should additional cable protection be required (e.g. rock armour) a separate application must be made for Marine Licence."*

[2] LAL-CEM-00866-MoM 23rd April 2013 MMO Post Construction Bathymetry Survey.

2.2. Objectives for bathymetry and seabed morphology survey

Two post-construction bathymetric surveys have been undertaken to date across the London Array OWF site (August 2013 and April 2014). The objectives of these surveys are summarised below:

- 2013 survey: To monitor changes in seabed morphology along the four export cables which run from OWF site to shore against the 2010 pre-construction baseline bathymetry survey; and
- 2014 survey: To monitor changes in seabed morphology along the four export cables which run from the OWF site to shore against the 2010 pre-construction baseline bathymetry survey, **and** to monitor scour around selected wind turbine generator (WTG) foundations and inter-array cables.

The objectives of the bathymetry surveys, as listed in the During- and Post-Construction Environmental Monitoring Plan (doc ref: LAL-CEM-00255 H), were:

- To provide geophysical data;
- To provide accurate bathymetry of the area;
- To produce a comprehensive interpretative report on the survey results obtained to assist the foundation installations; and
- To consider any changes in bathymetry detected between the Environmental Statement (ES) and the pre-construction base line data from the summer of 2009.

Impact hypotheses were established within the EMP in order to answer specific questions and demonstrate that the requirements of the Marine Licence have been met. The hypotheses are specifically linked to the wording of Regulation 48 (now Regulation 61) of the Habitats Regulations / Article 6 of the Habitats Directive. The key points to highlight are: the likelihood of a statistically significant effect; and then the risk of the development adversely affecting the integrity of the site. Appropriate scour protection and monitoring of the site will ensure that the integrity of the site is not adversely affected. The Conservation Objectives of the Margate and Long Sand Site of Community Importance (SCI) site state that site integrity will be maintained if the extent and topography of the Annex I Sandbanks slightly covered by seawater at all times is unchanged.

I. *The establishing of the London Array Offshore Wind farm causes a significant accretion/reduction in the extent of sublittoral, shallow sandbank habitat in the Margate Long Sand [SCI];*

II. *The establishing of the London Array Offshore Wind farm causes a significant alteration in topography of the sand banks in the Margate Long Sand [SCI].*

The export cable route has three main areas of interest due to observed cable exposure at these sites:

- The Kentish Flats OWF export cable crossing;
- The BritNed Cable Crossing; and
- The Princes Channel.

2.3. Survey methodology

The 2013 London Array OWF bathymetric post-construction survey was conducted from 27 August – 09 September 2013 by the survey contractor EGS International Ltd (ESGi) from the survey vessel, *MV Wessex Explorer*.

The scope of the 2013 survey work was to:

- Survey the bathymetry of the four export cable corridors (HV1-HV4) as laid, with a 25 m buffer either side of the outermost cables (H1 and H4). Where the export cable route splits into two, the buffer was 25 m either side of the outermost cable;
- Survey the bathymetry as nearshore as possible and to the limit of the pre-construction survey; and
- Where the export cable route crosses the Princes Channel, the buffer increased to 50 m either side of the outermost cables. At the crossings with the BritNed Cable and Kentish Flats OWF export cable, there was a 100 m buffer either side of the corridor.

A further bathymetry survey was conducted by EGSi Ltd from 09 April – 16 April 2014.

The scope of the 2014 survey work was to:

- Survey the four export cable (HV1-HV4) corridors with a buffer of 25 m either side of the outermost cables H1 and H4 (50 m either side at the Princes Channel and 100 m either side at cable crossings). Where the export cable route splits into two, 25 m either side of the outermost cable was surveyed. If the extent of scour around the cables was greater than 25 m away from the cable, the survey covered the entire scour area;
- Survey the 15 WTG locations with a box size of 100 x 100 m, or to the extent of scour, whichever was greater;
- Survey the 28 km of array cables with a buffer of 25 m either side of the cable, or to the extent of scour, whichever was greater;
- Survey the 20 km of fill corridors to create a criss-cross pattern across the site, with a corridor width of 50 m; and
- Survey the two substations with a box size of 200 x 200 m, or to the extent of scour, whichever was greater.

Detailed data processing was conducted for both surveys, a full description of which can be found in EGSi (2013) and EGSi (2014) in Annex A.

2.4. Survey results

Areas of focus were identified within the London Array OWF post-construction bathymetric surveys due to observed changes in seabed levels and are discussed below:

- BritNed Cable Crossing;
- Kentish Flats OWF export cable crossing;
- Intertidal landfall;
- Princes Channel;

- Substation 1;
- Substation 2;
- Sand wave migration KP38 to KP40;
- Cable loop and remnant trench along cable HV3 at KP48 to KP49.5; and
- Wind turbines.

2.4.1. BritNed crossing

The 2013 bathymetry survey indicated a cable exposure at the BritNed crossing area of the export cable route. Comparison of these 2013 data with pre-construction (2010) data showed that the deepest scour in the area was approximately 9 m deeper than the surrounding seabed. At this location depths of 14.5 m below LAT are encountered.

Data from the 2014 bathymetry survey indicated that this area had undergone further scour since the 2013 survey, with potential cable free-spans noted. In order to prevent further scour, London Array Ltd were granted Marine Licence L/2014/00379/3 to undertake scour protection works at this location and these works were completed in Q4 2014.

2.4.2. Kentish Flats Offshore Wind Farm export cable crossing

The 2013 bathymetry survey noted that cable protection in the form of rock dump was present where the Kentish Flats OWF export cables crossed the London Array export cables. In this area, water depths of 0.8 m LAT to 5 m LAT were observed. Remnant trenching was noted at either end of the rock dump with evidence of sporadic rock dumping along the side of the trench.

Since the 2013 survey, accumulation of sediment is visible in parts of the remnant trench. The difference plots in the 2014 post-construction monitoring survey display no statistically significant change in elevation along the sections of rock dump from 2013 to 2014.

2.4.3. Intertidal landfall

The intertidal landfall area was surveyed to approximately 2.5 m above LAT (drying height) in 2014, which is an increase in height compared to 2013.

Remnant trenching was still evident in the intertidal in 2014. Comparison of 2013 and 2014 data demonstrates accretion of up to 1 m at the base of the remnant trench where the cable is aligned in a north-south direction. Slight erosion or slumping of the trench wall is apparent along the full length of the trench, suggesting that the sides of the trench may be slumping inwards.

2.4.4. Princes Channel

Comparison of 2013 and 2014 bathymetry data shows a small area of sandwaves to the north of Princes Channel migrating towards the northeast. There is also an area of sandwaves and megaripples surrounding the BritNed crossings. Except for the aforementioned bedforms there are no areas of additional interest within the Princes Channel. The elevation of the seabed within this area varies between 10 m and 14 m below LAT.

2.4.5. Substation 1

Substation 1 is located within a highly mobile sandwave field. The 2013 survey found scouring up to 1.5 m deep outside of the central rock dump around the substation monopile. The inter-array cables entering the substation were also exposed.

The 2014 survey showed that there had been maximum erosion of 1.59 m around the substation since 2010 and erosion of 1.13 m between 2013 and 2014. This suggests that the level of erosion is increasing within this area, but further surveys are required to show whether this is the case.

2.4.6. Substation 2

Substation 2 is located within a sandwave field at an average depth of 12.5 m below LAT. In 2013, rock dumping was apparent around the substation base to 10.5 m below LAT, around which was a slight depression in the seabed. There was evidence of further scouring at the east and southwest of the substation monopole. Trenching was apparent outside of the central rock dump area and inter-array cables entering the substation were exposed.

Since 2013, sediment accumulation has occurred in the bases of both trenches, although the southern trench experienced the largest degree of sediment accumulation. Sediment erosion was apparent to the north and west of the substation surrounding the rock dump, though none of the inter-array cables were exposed here.

2.4.7. Sand wave migration KP38 to KP40

Between 2013 and 2014 an area of sandwaves located between cables KP38 and KP40 migrated to the southwest. The mobile sandwaves extended across all four export cable routes, although the largest vertical change in seabed elevation occurred over HV1 and HV2. Erosion of over 1 m was observed in this location, which may be an area of future potential cable exposure, although cable exposure was not been evident in the most recent 2014 data.

2.4.8. Cable loop and remnant trench along cable HV3 at KP48 to KP49.5

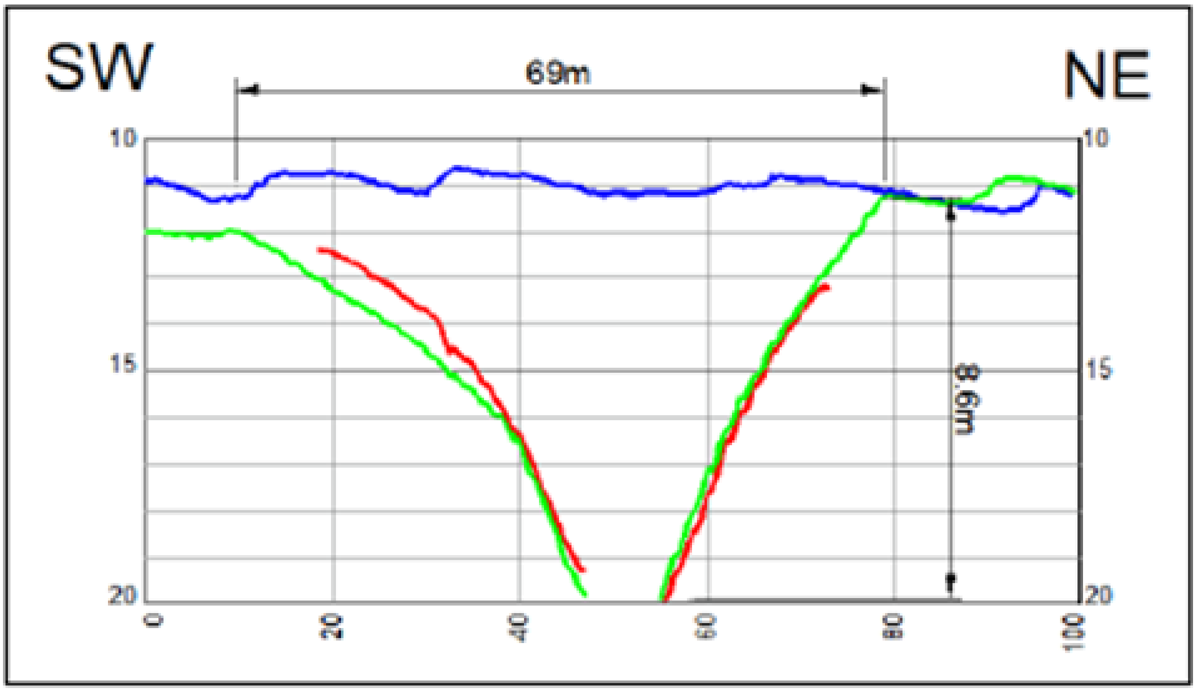
During the 2013 survey a loop of cable was observed, which was suspected to have been retrieved and re-laid during the cable laying process. A remnant trench was visible along both the cable route which follows the loop and along the direct route at the base of the route, which may have been the intended route before the cable was retrieved.

The 2014 survey showed that there had been up to 1 m sediment accretion in the base of the trench at the cable loop and 1.3 m accretion at KP49.25. Seabed elevation was approximately 22 m to 23 m below LAT in this area in 2014.

2.4.9. Wind turbine generators

Survey data from 2014 showed scour pits around every WTG surveyed to a greater or lesser degree. The deepest depression was around WTG C13, which was almost 9 m deeper in 2014 than it was in 2010, with a diameter of 69 m (Figure 2.4.1).

Figure 2.4.1: Seabed profile across WTG C13 at London Array Offshore Wind Farm in a southwest to northeast alignment. Blue line = 2010 pre-construction survey, red line = 2013 post-construction survey, green line = 2014 post-construction survey. (From: EGSi, 2014)



The increase in scour around some WTGs was greater between 2012 and 2014, compared to between 2010 and 2013. The scour pit surrounding WTG A10 was 1.3 m deep during the 2013 post-construction survey, but increased by a further 2.5 m to a total depth of 3.8 m in 2014. The diameter of the depression also increased from 22 m to 45.5 m between the 2012 and 2014 surveys.

Rapid erosion and slumping of the slopes of the depressions was also observed at some WTG foundations during 2014 post-construction monitoring. At WTG L18, slumping of up to 1.6 m occurred between 13-16 April 2014 relating to a diameter of approximately 20 m.

2.4.10. Seabed features

Other than the free-spanning cable around the BritNed Cable Crossing that has already been mentioned and that was infilled in November 2014, there were no other areas of exposed export cable as of 2014. However, there were a number of exposed inter-array cables within depressions surrounding WTGs evident in the 2014 survey.

Table 2.4.1: Wind Turbine Generators displaying exposed array cable within the London Array Offshore Wind Farm. (Source: ESGi, 2014)

Wind turbine					
A11	E06	F08	F19	J06	M16
A12	E13	F10	F20	J13	M17
A13	F01	F11	G13	J18	M18
A14	F02	F13	G18	K13	M19
B13	F03	F14	H06	K18	SS2
C06	F04	F15	H13	L13	
C13	F05	F16	H18	L18	
D06	F06	F17	I06	M14	
D13	F07	F18	I18	M15	

2.5. Discussion

2.5.1. Overview

The bathymetric post-construction surveys conducted in 2013 and 2014 indicate that there has been sediment erosion and deposition within the OWF site. Erosion was evident at the foundations of the WTGs and offshore substations, and along sections of export cable.

2.5.1.1. Export cable

The highest level of scour along the export cable was at the BritNed Cable Crossing where the seabed in 2014 was 9 m lower than the pre-construction baseline in 2010. This erosion led to an area of exposed cable, part of which was free-spanning. This issue has subsequently been addressed via cable remediation works completed in November 2014.

Scour was also recorded at both Substation 1 and Substation 2, although to a lesser degree than the BritNed Cable Crossing. At Substation 1, 1.13 m erosion occurred in one year between 2013 and 2014.

At the Kentish Flats crossing, trenching was evident at both sides of the rock dump areas. Remnant trenching was also evident at the intertidal zone with trenching visible into the Swale Channel.

On the south east spur of the outer cable route, a loop back was noted in the 2013 survey along the HV3 cable route. This is possibly associated with activity when the cable was retrieved and re-laid. Sediment accretion has already occurred in the trench between the 2013 and 2014 surveys.

Other than at the BritNed Cable Crossing, no further sites require remediation work as there are no other instances of free-spanning cable. Further monitoring of the export cable will identify if there are any future problems that need to be addressed.

2.5.1.2. *Wind Farm Array*

Within the London Array OWF array, a number of WTG foundations were found to have scour pits. The greatest observed scour pit had increased by 9 m in depth from the baseline seabed level in the 2010 survey. Some WTGs also experienced increased scour within the depressions between the 2013 and 2014 post-construction surveys. As a consequence, a number of inter-array cables are currently exposed due to scour pits surrounding the WTGs.

The level of scour around individual WTGs and the resultant inter-array cable exposure has occurred at a greater level than was anticipated in the predictions of the London Array OWF ES. London Array Ltd engineers have indicated that the degree of scour observed in 2014 surrounding individual WTGs is not sufficient to effect the physical integrity of the WTGs (pers. comm.).

Although localised effects of scour have been greater than predicted, there has been no evidence of interaction of scour holes, which would be indicative of altered physical processes across the site. Future surveys should prioritise monitoring of potential interactions between scour pits from adjacent WTGs.

2.5.2. Comparison with the Environmental Statement

The main conclusions from the London Array OWF ES are presented and discussed in Table 2.5.1.

Table 2.5.1: The predictions from the Environmental Statement regarding bathymetry within the London Array Offshore Wind Farm site and export cable route. (Source: RPS, 2005)

Environmental Statement Prediction	Status based on review of Year 1 post-construction survey data
"7.3.261 There will, however, potentially be local effects in terms of scour around the cables and turbine foundations. Assuming a worst case scenario that the buried export cables become exposed, then relatively shallow and relatively narrow scour holes will develop around the exposed cables in these sections of seabed. Such scour holes would have relatively insignificant effects on the coastal regime, but may be of concern in terms of operational integrity. Scour around turbine foundations would have greater potential effect on the coastal regime since the scour holes would be greater. It has been estimated, using first-order approximations, that a scour hole of around 5.0-7.2 m depth would occur locally around monopile foundations, depending on the precise current conditions experienced at each foundation location."	The results from the post-construction survey show that there has been a degree of cable exposure since the construction of the OWF, specifically at the BritNed Cable Crossing area. However, the level of exposure and the scour pits that have developed at this site seems to have been to a greater degree than was expected in the initial EIA. There has also been scour observed around the WTGs surveyed, as was expected from the ES. The deepest depression found around a WTG was almost 9 m, which is deeper than that predicted by the ES (5.0-7.2 m). However, it does appear that no interaction has occurred between the scour pits of adjacent WTGs.

"7.3.262 The significance of the scour holes in terms of physical processes and the physical environment can be assessed through consideration of the potential for the interaction of a scour hole arising from one turbine interacting with the scour hole from an adjacent turbine. Based on this criteria, the scour holes anticipated under each of the three foundation options are not considered significant, with the size of the scour holes relative to the spacing of the turbines meaning no interaction will occur."	As predicted in the ES it does not seem that the scour pits from adjacent WTGs have interacted.
The creation of scour holes is assessed as being **Insignificant** (Table 7.7 of RPS, 2005).	The ES assessed scour pits to be insignificant based on a determination that there would be no interaction between adjacent scour pits, which could alter physical processes. Post-construction monitoring showed that there was no interaction between scour pits, so the conclusion in the ES still holds.
"7.3.263 Using the above estimates of scour hole development, further modelling has been undertaken to determine the fate of the scoured material. The results of this, 'realistic worst case', modelling indicate that a plume of suspended sediments is created in the water column as a result of the scoured sediments. However, the plume is relatively short lived with rapidly falling concentrations. Deposition of the plume occurs over the wind farm, and surrounding area. Changes in bed thickness are generally low with small isolated areas of higher deposition (5–10mm). The plume created by the scoured sediments is not considered to be significant and the deposition of the plume sediments is considered to be of ***minor significance****. However, it should be noted that a conservative approach was adopted in the modelling of this issue.*	The deposition of sediment released during scour has not resulted in noticeable areas of deposition within the OWF area. Therefore, the assessment of 'minor significance' can be considered to remain valid.

2.6. Conclusions

The data from the Year 1 surveys indicate that the bathymetry within the London Array OWF has changed since the 2010 (pre-construction) baseline, and also changed between 2013 and 2014 surveys.

Levels of localised scour and cable exposure at both the cables and WTG locations were greater than predicted within the ES. However, no spatial interaction between adjacent scour pits has been recorded, which means that the original ES prediction – that scour is insignificant from a physical processes perspective if no spatial interaction arises – remains valid.

Future bathymetry monitoring surveys will demonstrate whether the erosion and deposition of sediment around export cables, WTG foundations and array cables continues, and whether further remediation is required in the future. Future monitoring will also demonstrate whether or not any spatial interaction of adjacent scour pits occurs.

Based on the data acquired to date, the hypotheses presented in the EMP can be rejected as there has been no significant effect detected at this point on any of the Annex I Sandbanks within the Margate and Long Sands SCI. However, monitoring of bathymetry within the site should continue in order to detect ongoing scour and identify any scour protection work that is required.

3. Benthic habitats

3.1. Marine License requirements for benthic habitat survey

Conditions in Marine Licence L/2011/00152/31 related to the need to undertake post-construction benthic surveys are presented below in Table 3.1.1.

Fish species were surveyed by epibenthic trawls during the benthic survey. Fish are also considered separately in post-construction surveys undertaken by Brown and May Ltd, in relation to Licence Condition 3.1.9, which are presented in Section 4.

Table 3.1.1: Marine Licence conditions for London Array Offshore Wind Farm – benthic surveys

Marine Licence Ref	Description
3.1.6	*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.*
Annex 1 Point 4	*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).* *Based on the existing biotope map for the site from the submitted application, it is anticipated that 144 sample locations will be sufficient to define pre-construction baseline conditions and post-construction monitoring, with approximately one third selected for replicate sampling. This would equate to 258 individual samples for analysis.* *The general approach taken is to maximise ground coverage by using single replicate sampling in most instances, with three replicates at circa 10% of sites in order to confirm the replicability over small scales broadly based around a grid of 1-2 km spacing.* *Colonisation of monopiles and scour protection must be determined by video observations and analysis with some accompanying sample collection for verification and identification.* *NB. The sedimentary and benthic data sets must be closely related.* *A pre-construction survey to determine the location and abundance of Sabellaria spinulosa with particular reference to reef and reef-like structures should be undertaken in the proposed turbine array area and along the export cable route.*

3.2. Objectives of benthic habitat survey

A benthic habitat survey was undertaken prior to construction of the London Array OWF in order to provide baseline information on benthic species and habitats within and around the construction area. This was conducted within the array footprint and along the export cable corridor. The aim of the post-construction benthic habitat survey undertaken in July 2014 was to monitor the benthic environment in and around the London Array OWF development and test hypotheses made within the EMP:

Benthic ecology:

H0 The establishing of the London Array OWF will not lead to significant changes in benthic organisms at the wind farm site.

H1 The establishing of the London Array OWF will lead to significant changes in benthic organisms at the wind farm site.

Sediment composition:

H0 The establishing of the London Array OWF will not cause a significant change in sediment composition across the sandbanks in the Margate Long Sand [SCI].

H1 The establishing of the London Array OWF will cause a significant change in sediment composition across the sandbanks in the Margate Long Sand [SCI].

Monopile colonisation:

H0 The establishing of London Array OWF will not lead to colonisation of monopiles by marine organisms typical of the region.

H1 The establishing of London Array OWF will lead to colonisation of monopiles by marine organisms typical of the region.

H0 Colonisation of the London Array monopiles by marine organisms typical of the region will have no resulting effect on the surrounding benthic ecology.

H1 Colonisation of the London Array monopiles by marine organisms typical of the region will have a resulting effect on the surroundings.

The benthic monitoring requirements for Year 1 of the post-construction phase included surveys of the seabed by benthic grab and epibenthic beam trawls corresponding with the OWF array and export cable route.

3.3. Survey methodology

The Year 1 post-construction benthic survey was undertaken from the 16-31 July 2014. Survey methods were based on those described in the EMP prepared by London Array Ltd. Areas of seabed surveyed as part of the EIA characterisation in 2003-2004 (CMACS, 2005), and the pre-construction baseline surveys (EMU Ltd, 2010a) were resampled in 2014.

The 2014 survey was designed to enable determination of any post-construction changes in sediment composition, and benthic habitats and species within the potential area of influence of the London Array OWF.

A total of 144 benthic grab sampling stations, with approximately one third of the stations sampled in triplicate, were located within six different effect zones. These areas were the same as those sampled in the pre-construction survey (Table 3.3.1; Table 3.3.2, Figure 3.3.1).

Table 3.3.1: Benthic grab sampling stations for the post-construction benthic survey for the London Array Offshore Wind Farm. (Source: Natural Power, 2015)

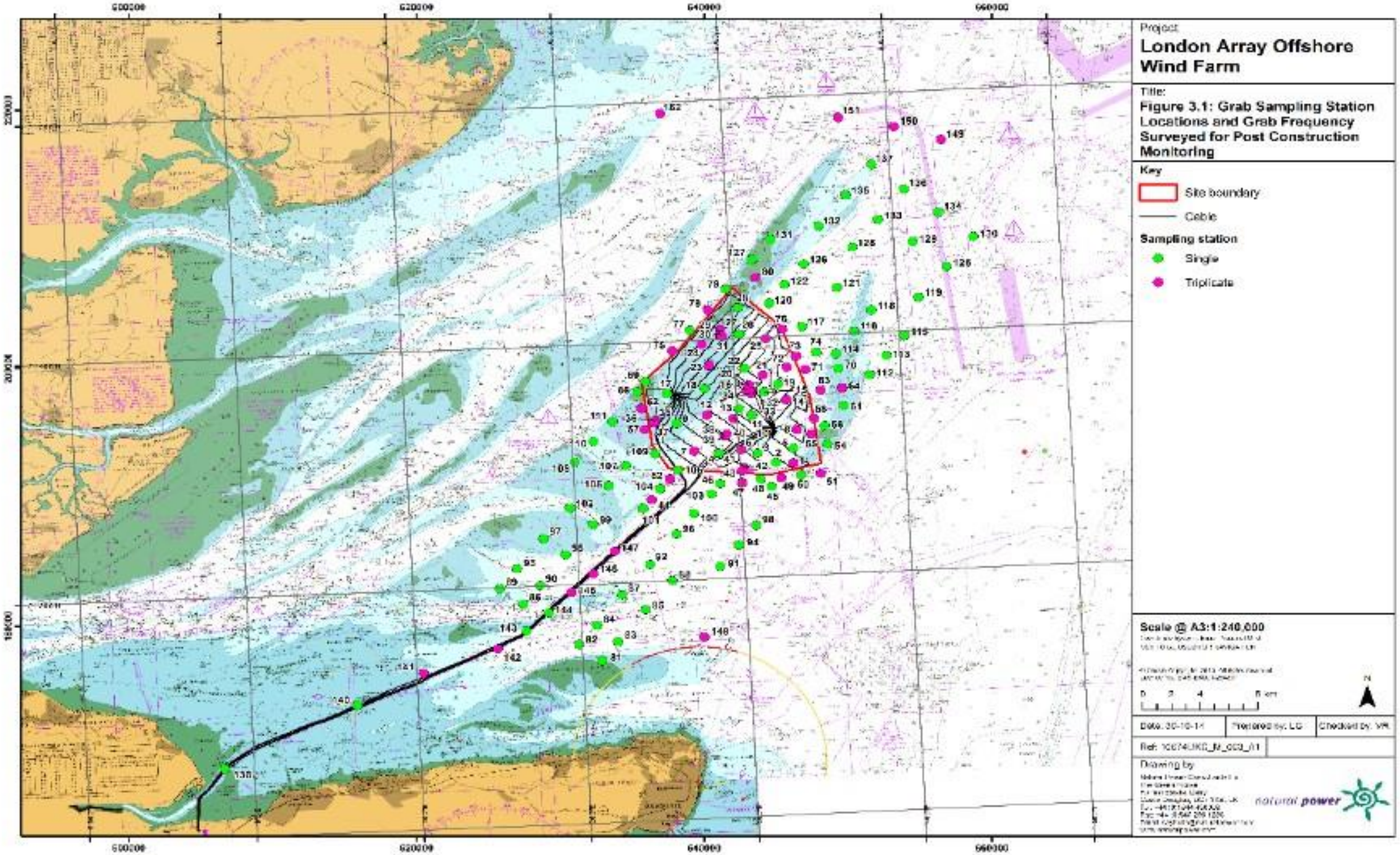
Effect zones	Sampling stations	Number sampled singly (sampling station numbers)	Number sampled in triplicate (sampling station numbers)
Phase 1 development area	28	14	14
Primary effects of turbines	15	0	15
Secondary effects (near-field)	31	13	18
Tertiary effects (far-field)	56	56	0
Cable route	9	4	5
Reference sampling stations	5	0	5
Total	**144**	86	58

In addition, 20 stations were also sampled with an epibenthic beam trawl. These were located within the same effect zones described for the benthic grab samples (Table 3.3.2).

Table 3.3.2: Epibenthic beam trawl sampling stations and effect zones for the London Array Offshore Wind Farm post-construction benthic survey. (Source: Natural Power, 2015)

Effect zones	Sampling Stations (Sampling Station Numbers)
Phase 1 development area	5
Secondary effects (near-field)	2
Tertiary effects (far-field)	9
Cable route	4
Total	**20**

Figure 3.3.1: Grab sampling station locations and grab frequency surveyed for post-construction monitoring of the London Array Offshore Wind Farm (From: Natural Power, 2015)



Survey techniques were based on those provided in the *During- and Post-Construction Environmental Monitoring Plan* and followed best practice guidelines as set out in the *JNCC Marine Monitoring Handbook* (Thomas, 2001; Wilding *et al.,* 2001) and aligned with Natural Power's standard operating procedures. These techniques were consulted with statutory and technical advisers, and agreed fit-for-purpose by the MMO.

Full details of the survey methodologies and information on sample processing and data analyses are provided in Annex B.

3.4. Survey results

3.4.1. Benthic Grab Survey Results

A total of 291 distinct species were recorded during the 2014 post-construction grab sampling survey. The most abundant species across the survey area were the bivalve mollusc *Abra alba* and polychaete worm *Magelona johnstoni,* which were present within roughly half of the sampling stations (Table 3.4.1).

Table 3.4.1: The top ten most abundant taxa recorded during the 2014 post-construction Year 1 surveys at the London Array study area. (Source: Natural Power, 2015)

Species	Abundance	No. Sampling Stations found (n=143)	No. Individual grabs found (n=257)
Abra alba	1663	64	88
Magelona johnstoni	937	62	93
Lanice conchilega	735	36	47
Spiophanes bombyx	725	72	112
Ampelisca spinipes	462	22	27
Lagis koreni	350	34	43
Sabellaria spinulosa	324	10	15
Kurtiella bidentata	289	20	23
Nephtys cirrosa	258	78	110
Ascidiacea juv	256	8	12

All biodiversity indices (mean number individuals, number of species, Margalef's richness Index, Shannon-Wiener diversity Index, Pielou's Evenness, Simpson's Index) were significantly different between effect zones in the 2014 survey. Species diversity and species richness were consistently highest along the export cable route. The lowest species diversity and species richness was found in the secondary effects area and in the OWF array area. However, these values were all equivalent to those recorded in the pre-construction survey.

The difference in community structure between effect zones was statistically significant using multivariate analyses, though with relatively small effect sizes. The largest differences were seen between 1) the secondary effects zone and the cable route; and 2) the OWF array and the cable route. Any dissimilarities in community structure were not due to the presence or absence of specific species, but changes in relative abundances of the same constituent species. The mollusc *Abra alba* was present in all groups, with polychaete worms *Nephtys cirrosa* and *Spiophanes bombyx* present in the majority. Examination of localised effects of turbines found there to be no statistically significant differences in infauna communities sampled at different distances from the wind turbines.

Community structure was significantly different between all project phases: characterisation and pre-construction; characterisation and post-construction; and pre-construction and post-construction. The biggest difference in community structure was between the characterisation and pre-construction surveys along the cable route, before any construction had even started.

During the 2014 survey, there were statistically significant differences in sediments from different effect zones, but with a very small effect size and within the expected distribution for sediment types indicating no practical difference. A moderately strong relationship between benthic infauna assemblages and the four sediment size components, indicated that sediment composition might have a strong influence on determining infauna community structure. In addition, there were statistically significant differences in sediments from different project phases, but with very low effect sizes indicating no practical difference. Any changes in sediment composition were within the range of what was expected as part of natural variation over time. Examination of localised effects of WTGs found there to be no significant differences in sediment composition.

The biotopes present were:

- **SS.SSa.IMuSa.FfabMag** - *Fabulina fabula* and *Magelona mirabilis* with venerid bivalves and amphipods in infralittoral compacted fine muddy sand;
- **SS.SSa.IFiSa.NcirBat** - *Nephtys cirrosa* and *Bathyporeia spp.* in infralittoral sand;
- **SS.SSa.CMuSa.AalbNuc** - *Abra alba* and *Nucula nitidosa* in circalittoral muddy sand or slightly mixed sediment;
- **SS.SCS.CCS.MedLumVen** - *Mediomastus fragilis, Lumbrineris spp.* and venerid bivalves in circalittoral coarse sand or gravel;
- **SS.SSa.IFiSa.IMoSa** - Infralittoral mobile clean sand with sparse fauna;
- **SS.SCS.ICS.Glap** - *Glycera lapidum* in impoverished infralittoral mobile gravel and sand; and
- **SS.SCS.CCS** – Circalittoral coarse sediment.

3.4.1.1. Comparisons with previous biotopes

The infauna assemblages were similar from 2003 to 2014, with the same five main biotopes consistently present throughout the study area (**SS.SSa.IFiSa.NcirBat**, **SS.SSa.IFiSa.IMoSa**, **SS.SSa.IMuSa.FfabMag**, **SS.SCS.CCS.MedLumVen**, and **SS.SCS.ICS.Glap**). Some variation was evident between years, reflecting the naturally dynamic environment at the site, and differences are summarised in Table 3.4.2

Table 3.4.2: Biotopes assigned across different project phases. (Source: Natural Power, 2015)

Characterisation 2003-2004 Biotopes	Pre-construction Baseline 2010 Biotopes	Post-construction Year 1 2014 Biotopes
SS.SSa.IFiSa.NcirBat	**SS.SSa.IFiSa.NcirBat**	**SS.SSa.IFiSa.NcirBat**
SS.SSa.IFiSa.IMoSa	**SS.SSa.IFiSa.IMoSa**	**SS.SSa.IFiSa.IMoSa**
SS.SSa.IMuSa.FfabMag	**SS.SSa.IMuSa.FfabMag**	**SS.SSa.IMuSa.FfabMag**
SS.SCS.CCS.MedLumVen	**SS.SCS.CCS.MedLumVen**	**SS.SCS.CCS.MedLumVen**
SS.SCS.ICS.Glap	**SS.SCS.ICS.Glap**	**SS.SCS.ICS.Glap**
-	**SS.SCS.CCS**	**SS.SCS.CCS**
-	**SS.SSa.IMuSa**	-
SS.SBR.PoR.SspiMx	-	-
-	-	**SS.SSa.CMuSa.AalbNuc**

3.5. Epibenthic beam trawl

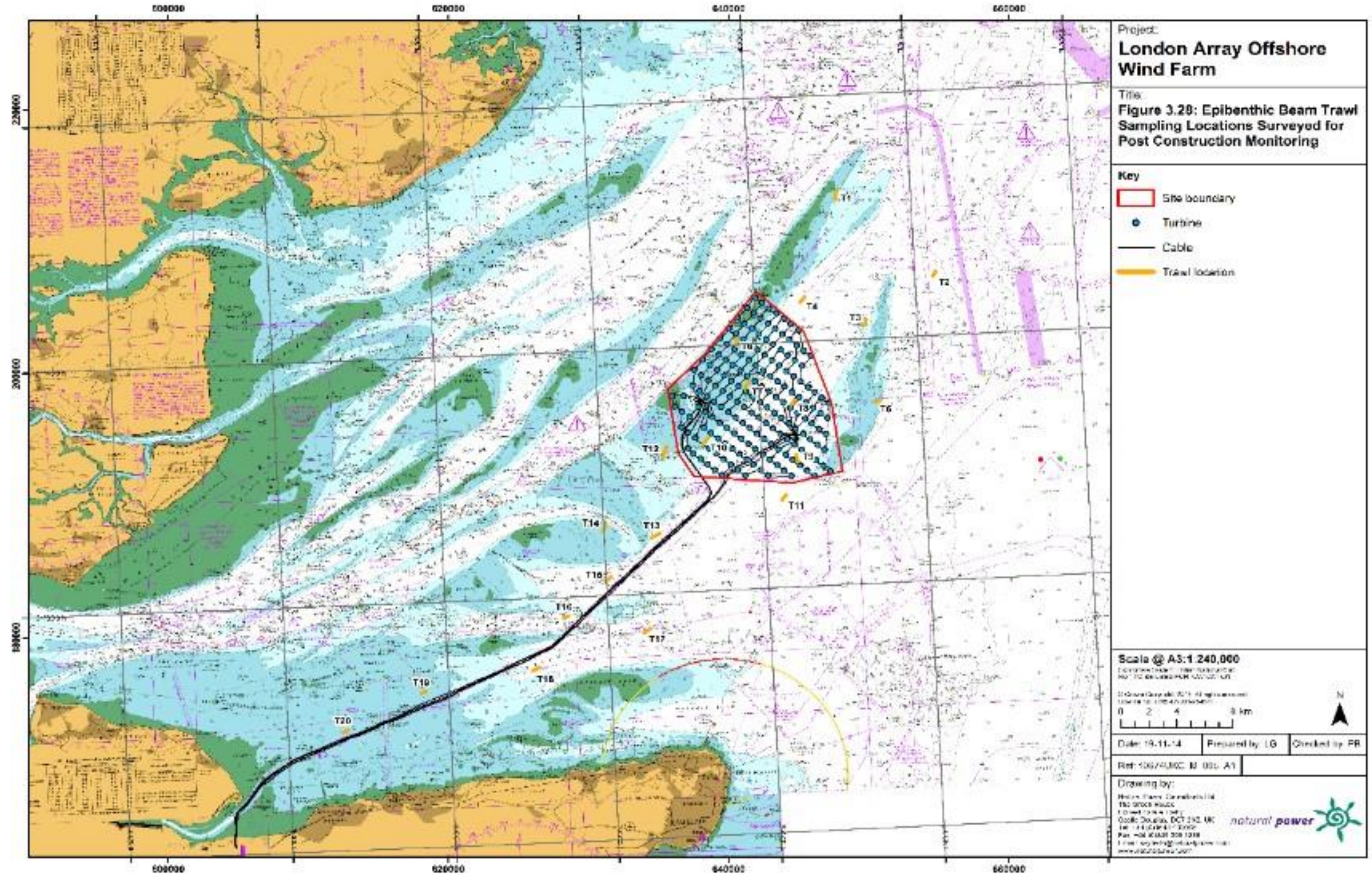
In the 2014 post-construction survey, 18 fish species and 23 macro-invertebrate species were found. The most abundant fish species were Gobies *Pomatoschistus* spp., Dover Sole *Solea Solea*, Pogge *Agonus cataphractus*, Whiting *Merlangius merlangus*, and Poor Cod *Trisopterus minutus*. While many of the species captured were of commercial importance, the vast majority of individuals were juveniles under the minimum landing size, which was consistent with previous surveys.

In particular, the majority of Dover Sole caught were small juveniles (70-79 mm) below the minimum landing size of 240 mm. Whiting were dominated by small juveniles (60-69 mm) below the minimum landing size of 270 mm and the majority of Dab caught were small juveniles (50-59 mm).

Three electro-sensitive species were found on this survey: ten Lesser-spotted Dogfish *Scyliorhinus canicula*, eight Thornback Ray *Raja clavata* and one Smooth-hound *Mustelus mustelus*.

The most abundant invertebrates captured during the survey were the brittlestar *Ophiura albida* and Brown Shrimp *Crangon crangon*, with brittlestars being found in very high abundances in only a few trawls, and Brown Shrimp being found in high abundances in most trawls.

Figure 3.5.1: Epibenthic beam trawl sampling locations surveyed for post-construction monitoring. (From: Natural Power, 2015)



In the 2014 survey, the differences in mean fish abundance and mean number of fish species between effect zones was statistically significant. Mean fish abundance was highest on the cable route, whilst mean number of fish species was highest in the secondary effect zone. Differences in mean invertebrate abundance and mean number of invertebrate species was also statistically significant. Both were highest along the cable route and lowest in the OWF array. Patterns in mean invertebrate abundance were driven by Brown Shrimp and brittlestars, which were by far the most dominant invertebrates and were present in much higher numbers during the summer months.

There were statistically significant differences in the mean catch per tow between project phases, for both number of fish, number of invertebrates, number of fish species and number of invertebrate species. The highest numbers of fish were found on the post-construction survey, but the highest number of fish species was recorded during the characterisation. The highest number of invertebrates and the highest number of invertebrate species were both found during pre-construction surveys.

3.6. Notable taxa and habitats

Notable infauna and epifauna taxa were recorded throughout the 2014 post-construction survey. These taxa included:

- *Sabellaria spinulosa* Ross Worm – aggregations of worm tubes can form Annex I reef habitat;
- *Mytilus edulis* Blue Mussel – aggregations of bivalves can form Annex I reef habitat;
- *Aequipecten opercularis* Queen Scallop – commercially important;
- *Tubificoides galiciensis* a Tubificid annelid worm – taxonomic status uncertain; and
- *Pontocrates arcticus* (Type I) an amphipod crustacean – taxonomic status uncertain.

Sabellaria spinulosa was only recorded in large quantities in one trawl and one grab. It was not possible to assess whether this constituted reef habitat without information on elevation, patchiness and extent from drop-down video (DDV) footage. Low numbers of *Sabellaria spinulosa* were also present at an additional ten sampling stations.

A number of biotopes assigned from the post-construction survey data are listed as component biotopes of Annex I habitat features under the EC Habitat Directive and are included in the UK Biodiversity Action Plan:

- **SS.SSa.IFiSa.NcirBat**;
- **SS.SSa.IMuSa.FfabMag**; and
- **SS.SCS.CCS.MedLumVen** (this biotope is a sub-biotope of a priority habitat: SS.SCS.CCS – *Circalittoral coarse sediment*).

3.7. Comparison with pre-construction data

3.7.1. Benthic Infauna Communities

Differences in species assemblages were statistically significant between all project phases, including characterisation (2003-04), pre-construction (2010), construction (2011-2013) and post-construction (2014).

As there were statistically significant differences in infauna and epifauna communities between characterisation and pre-construction surveys, before any construction had started, it suggests that there are additional factors other than construction of the OWF that are causing the differences between pre- and post-construction survey data. One explanation is that the differences are due to natural fluctuations in species populations over time. This possibility is supported by the fact that the difference in community structure is not driven by the presence or absence of particular species, but rather subtle changes in the abundance of the same component species. The described species are all common, characteristic species of permeable sediments, and would be capable of rapid re-establishment from adjacent seabed following episodic disturbance such as the installation of WTG foundations and cables.

The biotopes identified within each project phase showed good consistency over time, with **SS.SSa.IFiSa.NcirBat**, **SS.SSa.IFiSa.IMoSa, SS.SSa.IMuSa.FfabMag**, **SS.SCS.CCS.MedLumVen**, and **SS.SCS.ICS.Glap** present throughout all project phases. When mapped, the biotopes showed high spatial variability, although all biotopes assigned were characteristic of their environment.

3.7.2. Epibenthic Data

Variations over time in the abundance of the dominant macrofaunal species (Brown Shrimp and brittlestars) were evident in the data. Brown Shrimp abundance was significantly higher in post-construction catch, whereas brittlestars were higher during pre-construction. When examined across all project phases (including characterisation where surveys were undertaken quarterly), it was evident that the seasonal variations in the timing of the surveys was the driving factor behind the changes in abundance between years. Considering the high numbers of these species in the catch, the analysis of change between project phases was re-calculated without Brown Shrimp or brittlestars in the data. This caused no change in the overall result, with significant differences still present between matching seasons in the different project phases.

Between the characterisation (2003/04) and pre-construction (2010) surveys, high numbers of larger Sole, Whiting, and Dab were recorded. During the post-construction survey, these species were similarly dominant in terms of commercially important species, however most of the individuals captured were juveniles and were below their minimum landing sizes. The abundance of juveniles in the catch is as expected due to the timing of the summer survey, and its location in the outer Thames Estuary which is an important nursery area for many species.

3.8. Discussion

3.8.1. Benthic Infauna Communities

Univariate and multivariate analyses revealed statistically significant differences in infauna community structure all effect zones and between all project phases. Statistically significant differences were observed in abundance and species diversity between project phases and between effect zones. Due to the fact that these changes have occurred across project phases and between groups, it is difficult to attribute any differences in species assemblage to the installation (construction) and operation of the London Array OWF. Determination of the reasons for change is outside the scope of this study, however, it is reasonable to speculate that the changes were driven by natural variability, as is common in such shallow, high energy, outer-estuarine environments. The North Sea is a shelf sea which exhibits seasonal fluctuations in environmental variables, particularly in the shallower southern basin and inter-annual variation in benthic infaunal communities is a common characteristic of the region (Reiss *et al*., 2010).

3.8.2. Epibenthic data

The lack of reference sampling stations makes comparisons with control areas impossible, however, as the change in community composition was present between all project phases, it is unlikely that any change in epibenthic species assemblage can be attributed to the installation and operation of the London Array OWF.

3.8.2.1. Wind Farm Array

Many studies have reported the 'artificial reef' effects of structures placed in the marine environment on fish and invertebrate assemblages (Coates *et al.* 2011; Jensen, 2002; Jensen *et al.* 2000; Charbonnel *et al.* 2002; Langhamer 2012), and the increased attraction of fish to structures may result in fish spillover into adjacent areas (Langhamer 2012). However, the measurable distance over which this effect is likely to be seen in large pelagic species is not predicted to be greater than several hundred metres from the structures, whilst for smaller demersal species such as gobies, the effects are likely only measurable at very close proximity to the WTG foundations (Wilhelmsson *et al.* 2006). Where there were significant differences between pre- and post-construction surveys for a specific effect zone, there were also significant differences between characterisation and pre-construction surveys, suggesting that the infrastructure has had no effect on wider fish and invertebrate assemblages outside of natural temporal variability.

As the majority of the trawl locations surveyed during this study were situated up to tens of kilometres from the OWF it is not possible to attribute any changes in species assemblage to the installation of WTG foundations, or operation of the London Array Development.

3.8.2.2. Export cable

Analysis of the species composition from trawls taken from the export cable route were not significantly different from trawls from elsewhere in the study area, indicating that, as predicted in the ES, once the cable has been installed, no effects are detectable post-construction on fish and epifauna assemblages.

3.8.3. Comparison with bathymetry survey data

The bathymetric survey indicates that there has been a greater degree of scour at the export cables, WTG foundations, and offshore substations, than was predicted in the London Array OWF ES.

Localised effects of scour and scour protection around WTG foundations on benthic infauna and sediment composition was investigated at five WTG locations in the benthic survey. Two of the WTGs surveyed, C06 and J18, were identified within the bathymetry survey as having scour pits and exposed inter-array cable as a result. The results of the infauna and sediment analysis show that there was no statistically significant difference in benthic community structure or sediment composition compared to nearby sediments, and that these had not changed over project phases.

When the 2014 bathymetry and benthic habitat survey results are viewed together, it is evident that localised effects of scour around WTGs are not having a consequential effect on nearby sediment composition or benthic community structure. It is difficult to spatially relate surveys that have been designed independently in order to look at effects across receptors. For example, areas where the highest levels of scour have been observed along the export cable route have not necessarily been sampled in the benthic survey. As there is no way of reliably predicting *a priori* where scour may occur, it is recommended that an adaptive survey design be adopted in future in order to sample sediment near to any new areas of scour and compare with characterisation survey data and reference areas.

3.8.4. Comparison with the Environmental Statement

The ES for the London Array OWF predicted a number of minor or negligible effects to the benthic environment from construction and operation of the development (Table 3.8.1).

Table 3.8.1: London Array Offshore Wind Farm Environmental Statement benthic ecology predictions

Environmental Statement Prediction	Status based on review of Year 1 post-construction survey data
<u>Construction</u>	
Permanent loss of seabed habitat, turbine, met mast and substation installation: *"7.4.136 The anticipated impact at each location, in the context of the development area as a whole, is therefore of **negligible significance**, especially as recovery of the communities and species present is, in all cases, thought to be high."*	Based on review of the Year 1 post-construction benthic data together with characterisation and pre-construction data, the ES predications remain valid and impacts of **negligible significance** appear to have occurred at each location or recovery has already happened.
Permanent loss of seabed habitat, cable installation: *"7.4.137 Given the nature of the sublittoral communities, it is likely that considered that these effects represent a very localised impact from which full recovery would be made in the short term. Overall the impact is considered to be of **minor significance**."*	Based on review of the Year 1 post-construction benthic data together with characterisation and pre-construction data, the ES predications remain valid and impacts of **minor significance** appear to have occurred or recovery has already happened.

Environmental Statement Prediction	Status based on review of Year 1 post-construction survey data
Permanent loss of seabed habitat, mobilisation of contaminated sediments: *"7.4.140 Mobilisation of sediments during construction activities will cause an impact of **negligible significance** to the benthos in terms of arsenic contamination."* *"7.4.142 In practice changes in levels of contaminants due to sediment movements would be unlikely to be detectable, and therefore of **negligible significance**."*	Based on review of the Year 1 post-construction benthic data together with characterisation and pre-construction data, the ES predications remain valid and impacts of ***negligible significance*** appear to have occurred or recovery has already happened.
Suspended sediment during foundation installation: *"7.4.143 Given the high tolerance of the local communities to suspended sediments the impacts are considered to be of **negligible significance**."*	Based on review of the Year 1 post-construction benthic data together with characterisation and pre-construction data, the ES predications remain valid and impacts of ***negligible significance*** appear to have occurred or recovery has already happened.
Suspended sediment during cabling activities: *"7.4.144 Given the high tolerance of the local communities to suspended sediments the impacts are considered to be **negligible or possibly minor significance**, and recovery from any impacts would be rapid."*	Based on review of the Year 1 post-construction benthic data together with characterisation and pre-construction data, the ES predications remain valid and impacts of ***negligible or minor significance*** appear to have occurred or recovery has already happened.
Release of chemicals during installation: *"7.4.146 Given the large amounts of water movement typical of the area, the relatively low levels of contaminants in almost all instances, and the relatively small amount of disturbance likely to occur, it can be concluded that this would be **unlikely to lead to any significant increases** in levels of contaminants in the water column. "*	Comment on any monitoring of chemicals during installation is outside the scope of this AMR.
Effects of construction noise: *"7.4.151 Any noise impacts are considered to be of **negligible significance."***	Comment on any construction phase noise monitoring is outside the scope of this AMR.
Operation	
Colonisation of turbine bases and rock armour: *"7.4.156 The positive changes seen as a result of colonisation would be localised, permanent and probably overall of **minor significance**."*	Comment on colonisation of turbine bases and rock armour is outside the scope of this AMR. No samples were collected from the turbine bases or rock armour.
Operational effects of noise and vibration: *"7.4.158 The effects upon marine benthos are not expected therefore any impacts will be of **negligible significance**."*	No samples were taken that would allow consideration of the effects of noise during operation, but impacts are assumed to be **not significant.**

Environmental Statement Prediction	Status based on review of Year 1 post-construction survey data
Changes in water quality: *"7.4.159 It is considered that there will **be no noticeable impacts** upon benthic communities."*	No samples were taken that would allow consideration of the effects of changes in water quality during operation, but impacts are assumed to be **not significant.**
Effects on heating on benthic species: *"7.4.161 Anticipated to be of **negligible significance** even if all six mains cables to shore are installed within tens of metres of each other."*	No samples were taken that would allow consideration of the effects of heating during operation, but impacts are assumed to be **not significant.**
Changes in fishing patterns: *"7.4.162 Any changes within the proposed array area, although long term and positive in nature, will be small, restricted to the deeper, slightly less naturally disturbed sea bed areas, and be of **negligible or minor significance**."* *"7.4.163 Any impacts on the benthos, although potentially negative and long term, would be of **negligible or minor significance**."*	No changes in fishing pattern were considered within the scope of the post-construction benthic monitoring and are assumed to be of **negligible significance** in terms of impacts to the benthos.

The changes observed in the benthic ecology at the site of the London Array OWF and export cable in the 2014 survey are typical of natural temporal variation, evidenced by similar changes between characterisation and pre-construction surveys. Consequently, the predictions in the ES of minor to negligible impacts on benthic ecology are judged to remain valid.

3.9. Conclusions

There were statistically significant differences in benthic community structure between pre- and post-construction phases. Given that these differences occurred across all project phases (i.e. also between characterisation and pre-construction) it is impossible to attribute them to the installation and operation of the London Array Development. Furthermore, any effects were small and due to changes in relative abundance of the same component species. In benthic communities of the southern North Sea, particularly those of mobile sand banks, both inter- and intra-annual change is to be expected due to their dynamic nature and periods of episodic natural disturbance.

The following Null Hypotheses posed in the EMP were, therefore, found to be true:

H_0 The establishing of the London Array Offshore Wind Farm will not lead to significant changes in the benthic organisms at the wind farm site.

H_0 The establishing of the London Array Offshore Wind Farm will not cause a significant change in sediment composition across the sandbanks in the Margate Long Sand [SCI].

The results of the 2014 survey also validate predictions made in the ES, that there would be only minor or negligible benthic impacts from the installation and operation of the OWF and export cable route. It is, therefore, recommended that further post-construction monitoring may not be required as the predictions of the ES have been validated.

The primary effects of WTG foundations on benthic ecology were investigated at three distances (50 m, 100 m, and 250 m), however no statistically significant effects were found that could be attributed to the presence of these structures.

Studies have shown any effects due to the presence of epifauna communities and associated predation halos from mobile predators at WTG foundations, interacting with surrounding benthos, is likely to be only evident much closer than 50 m e.g. changes of surrounding infauna communities appear to be limited to a small area around reefs or structures, generally no more than tens of metres distant (Zucco *et al*., 2006). It was therefore not possible to confirm the following null hypothesis, and the sampling strategy will require adaptation to robustly address the null hypothesis:

H_0 *Colonisation of the London Array monopiles by marine organisms typical of the region will have no resulting effect on the surrounding benthic ecology.*

4. Fish resources

4.1. Marine Licence requirements for fish survey

Conditions within Marine Licence L/2011/00152/31 that relate to a requirement to undertake fish surveys are listed in Table 4.1.1 below.

Table 4.1.1: Marine Licence conditions – fish surveys

Marine Licence Ref	Description
3.1.9	*The Licence Holder must produce proposals for a post-construction survey of fish populations in the area of the wind farm, to investigate the potential for the London Array offshore wind farm in enhancing or aggregating fish numbers as proposed in the Environmental Statement. 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 3.2.1. The Licence Holder must undertake these surveys as detailed in the agreed specification and report by the date specified in the schedule required under condition 3.2.1.*
Annex I Point 5	*Marine Fish – Thornback Rays 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 London Array offshore wind farm. The results should be presented and discussed in combination with the EMF studies described in the following section.*

4.2. Objectives of fish survey

Post-construction fish and epibenthic surveys were undertaken in the area of the London Array OWF between 22 – 27 November 2013, and the 8 – 15 April 2014. These surveys were undertaken specifically to address the Marine Licence requirements for fish as identified in Table 4.1.1. Epibenthic species were also sampled within the fish surveys but any outputs related to these epibenthic samples are not connected to the epibenthic data (collected via 2 m beam trawl) reviewed in the previous section on benthic surveys. Hypotheses for the fish surveys were not presented in the EMP.

The aim of the survey was to establish abundance and composition of adult and juvenile fish, and epibenthic species, within the area of the London Array OWF in autumn and spring post-construction. A further aim was to define any notable changes in species composition with reference to the pre-construction surveys undertaken in 2009 and 2010.

The scope of works for the survey were:

Otter trawl samples and analysis:

- Eight tows of 20 min duration within the OWF and ten control tows in adjacent locations.

- Number of individuals and catch rate by species;
- Length distribution by species;
    - Finfish and sharks (except Atlantic Herring and Sprat): individual lengths (nearest cm below);
    - Herring and Sprat: individual lengths (nearest 0.5 cm below); and
    - Rays: individual length and wing-width (nearest cm below).
- Sex ratio by species;
- Spawning condition;
    - Finfish species (except Atlantic Herring and Mackerel): Cefas Standard Maturity Key – Five Stage;
    - Herring: Cefas Nine Stage Maturity Key;
    - Mackerel: Cefas Six Stage Maturity Key; and
    - Ray and shark species: Cefas Standard Elasmobranch Maturity Key – Four Stage (males and immature females only due to live return policy).

Beam trawl samples and analysis

- Eight tows of approx. 200 m distance within the OWF and ten control tows in adjacent areas.
- Number of individuals and catch rate by fish species;
- Length distribution (nearest mm below) for fish species;
- Number of individuals and catch rate by motile invertebrate species; and
- Presence/absence of sessile/encrusting species.

4.3. Survey methodology

Fish surveys were conducted within and adjacent to the London Array OWF site from the *Jubilee Spirit*. A commercial otter trawl with a 130 mm mesh cod-end was used for the otter trawl sampling. A 2 m scientific beam trawl was used for juvenile fish and epi-benthic sampling.

4.4. Survey results

4.4.1. Otter trawl results

4.4.1.1. Catch rates

Autumn

A total of 24 species of fish and shellfish were caught in the November 2013 otter trawl; 22 at the control stations and 19 within the OWF array. Overall, Thornback Ray *Raja clavata* was the most abundant species, followed by Whiting *Merlangius merlangu*s and Lesser-spotted Dogfish *Scyliorhinus canicula*.

Atlantic Cod *Gadus morhua* and Dover sole *Solea solea* were found in all sampling areas, although they were present in relatively low numbers; the highest total catch rates were recorded at the control stations for both species (8.4/hr and 4.5/hr respectively). Overall, the total catch rate for all species caught in the otter trawl was higher within the OWF site than at the control stations.

Spring

A total of 23 species of fish and shellfish were caught during the April 2014 otter trawl; 21 at the control stations and 15 within the wind farm. Overall, Lesser Spotted Dogfish was the most abundant species caught, followed by Whiting and Thornback Ray.

Lesser-spotted Dogfish were caught in all sampling areas with the greatest total catch rate recorded within the control area (144.8/hr).

Atlantic Cod and Dover Sole were found in relatively low numbers in 12 and 7 sampling stations respectively; the highest total catch rates were recorded at the control stations for both species (5.4/hr and 3.0/hr respectively). Unlike in the autumn surveys the overall total catch rate for all species caught in the otter trawl was lower within the OWF site than at the control stations.

4.4.1.2. Length distribution

Autumn and Spring

The length distribution of the five most abundant species showed that there was no discernible pattern of spatial distribution between the most abundant species caught using the otter trawl.

4.4.1.3. Minimum landing size

Autumn

The London Array OWF is situated outside of the 6 nm limit and as such the minimum landing sizes (MLS) for fish and shellfish species are set by the EC under Regulation No. 850/98 (Annex XII).

The majority of skates and rays and Whiting caught at control stations were below the MLS, whereas the distribution in OWF site samples were approximately even. Most of the Atlantic Cod found in both sampling areas were above the MLS, whereas the majority of Plaice were below the MLS. All of the Dover Sole caught in the survey were above the MLS.

All remaining species with a set MLS were caught in low numbers.

Spring

The majority of skates and rays and Whiting caught in both sampling areas were below the MLS. Most of the Atlantic Cod found in both sampling areas were below the MLS; likewise, the majority of Plaice were below the MLS. All Dover Sole caught were above the MLS.

All remaining species with a set MLS were sampled in low numbers (5 or less individuals).

4.4.1.4. Sex ratios

Sex ratio studies provide information on the numbers of male and female fish present in a population and indicate the dominance of sex of fish species within a population. Sex ratio provides basic information necessary for the assessment of the potential of fish reproduction and stock size estimation.

Autumn

During the autumn survey the sex ratio for Thornback Ray caught at control stations was approximately even, whereas within the wind farm site a higher proportion of individuals were male. Most of the Whiting and Lesser-spotted Dogfish caught in all sampling areas were female.

The highest proportion of the fourth most abundant species, Bib *Trisopterus luscus,* (when sex could be determined) at the control stations were female, whereas within the wind farm the majority were male.

Spring

During the spring survey most of the Lesser-spotted Dogfish caught in all sampling areas were female. Likewise, the majority of Thornback Ray caught at all sampling stations were female with a similar percentage of found at both the control and wind farm sites for both species.

The majority of the Whiting (when sex could be determined) at the control stations were female (49.8%), whereas within the wind farm the majority were male (56.0%). Most of the Plaice caught in all sampling areas were female with similar percentages found at the control and wind farm sampling sites.

4.4.1.5. Spawning condition

Spawning condition is a key parameter to access fish fecundity at a population level.

Autumn

It should be noted that it was not possible to confidently determine the sex of a number of immature fish, and as such they have been categorised as 'unsexed' and were not included in any data analysis.

The majority of Thornback Ray caught at control stations and within the wind farm were immature individuals. In both sampling areas Whiting were predominantly maturing and immature individuals. The highest proportion of the Lesser-spotted Dogfish caught were immature females in both sampling areas. Approximately two thirds of Dab sampled from control locations were maturing; low numbers of individuals were recorded in the wind farm site. Almost all of the Atlantic Cod caught at control locations were immature and maturing individuals. Low numbers were recorded within the wind farm site, two thirds of which of which were female. Dover Sole caught at the control stations were principally maturing females.

Spring

In the otter trawls the highest proportion of the Lesser-spotted Dogfish caught were fully matured males in both the control and wind farm sampling areas. In both sampling areas Whiting were predominantly immature. The majority of Thornback Ray caught at control stations and within the wind farm were immature individuals. Most of the Dab sampled from the control locations were maturing; low numbers of Dab individuals were recorded in the wind farm site. Almost all of the Atlantic Cod caught at control locations were immature and maturing individuals. Low numbers were recorded within the wind farm site, two thirds of which of which were female. Dover Sole caught at the control stations were principally maturing females.

4.4.2. Beam trawl results

4.4.2.1. Catch rates

Autumn

In the autumn beam trawl survey a total of 19 species of fish were caught, 15 of which were found at the control stations and 14 within the wind farm. Overall, Lozano's Goby *Pomatoschistus lozanoi* was the most abundant species recorded, followed by Pogge *Agonus cataphractus* and then Solenette *Buglossidium luteum*.

Overall, the total catch rate was higher at control stations (286.0/hr) than within the wind farm (172.0/hr).

Spring

A total of 17 species of fish were caught, 13 of which were found at the control stations and 14 within the wind farm. Overall, Dover Sole was the most abundant species in samples, followed by Sand Goby *Pomatoschistus minutus* and then Pogge *Agonus cataphractus*.

Unlike the autumn survey the overall total catch rate was higher within the wind farm (91.3/hr) than at control stations (56.4/hr).

4.4.2.2. Length distribution

Autumn

The results of the length distribution showed that there were larger Pogge, Solenette and sandeel caught at the control sites. The largest Dover Sole individuals were caught within the OWF site.

Spring

The length distributions for the beam trawl surveys showed that there were larger individuals of Dover Sole and Solenette at the wind farm sampling sites than the control sampling sites. Other than this there was no discernible pattern of spatial distribution between the most abundant species caught using the otter trawl.

4.5. Comparison with pre-construction data

4.5.1. Otter trawl

Overall, the number of species recorded in the pre- and post-construction surveys were similar. In total, 37 species were recorded in all the surveys conducted. In the autumn (November 2009) pre-construction survey 25 species were recorded, in the spring pre-construction survey (March 2010) 21 were recorded and in the autumn post-construction survey (November 2013), and the spring post-construction survey (April 2014) there were 24 and 23 species recorded respectively.

The three most prevalent species recorded were Thornback Ray, Whiting and Lesser-spotted Dogfish. The Thornback Ray was the most abundant species recorded in both the spring pre-construction and the autumn post-construction surveys. In the autumn pre-construction survey, Whiting was the most abundant species and in the spring post-construction survey Lesser-spotted Dogfish was the most abundant.

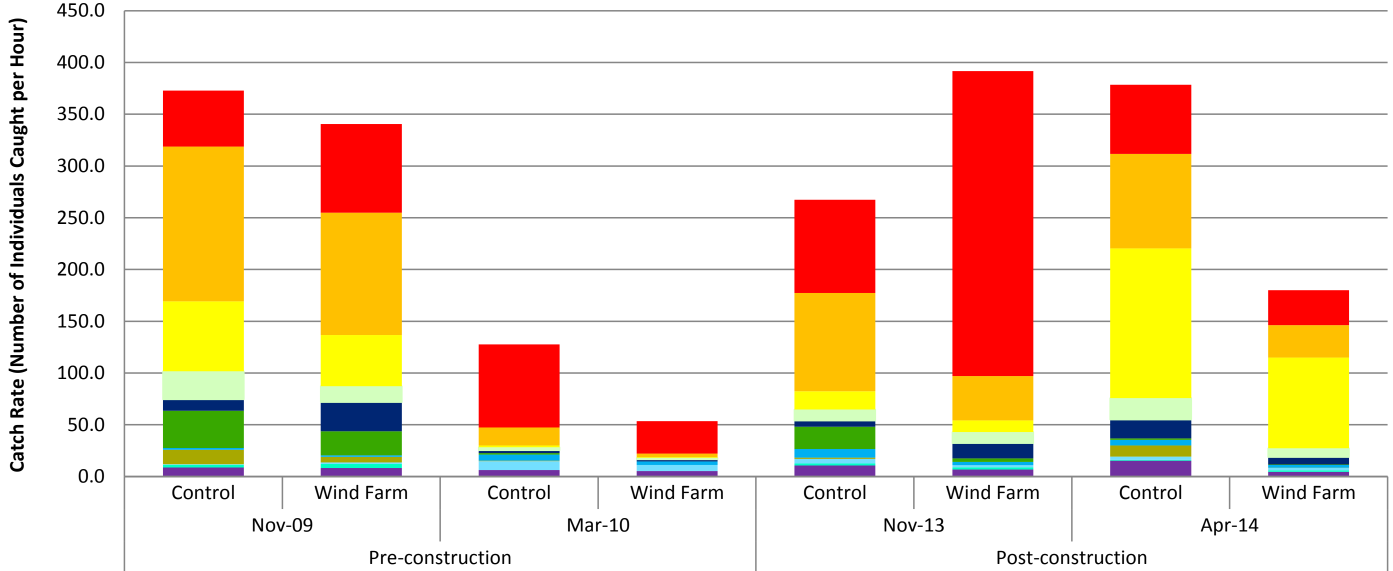
Thornback Ray was recorded in all sampling areas in all surveys. The greatest total catch rate for this species was in the autumn post-construction survey and the highest catch rate was within the OWF area. Both of the autumn surveys recorded higher catch rates within the OWF area. The highest catch rates within both of the spring surveys were at control locations.

Whiting were recorded in all sampling areas in all surveys. The highest catch rates were recorded in the autumn pre-construction survey, with greatest catch rates at a control location. The spring pre-construction survey recorded relatively low catch rates at both sampling locations. The catch rates recorded at both locations during the autumn and spring post-construction surveys were of a comparably similar level.

Lesser-spotted Dogfish were recorded in all sampling areas in all surveys. The greatest catch rates recorded during the spring post-construction survey; the greatest numbers were recorded at control locations. Low catch rates were recorded during the spring pre-construction survey and the autumn post-construction survey. Moderate catch rates were recorded at both sampling locations during the autumn pre-construction survey.

The total overall catch rates were greatest at the control stations in both pre-construction surveys and in the spring post-construction survey, whereas in the autumn post-construction survey the total catch rates were highest within the OWF.

Figure 4.5.1: Catch rates for the most abundant fish and shellfish species by survey and by sampling area for otter trawl surveys within the London Array Offshore Wind Farm from November 2009 to April 2014 (From: Brown and May Marine Ltd, 2014)



	Nov-09 Control	Nov-09 Wind Farm	Mar-10 Control	Mar-10 Wind Farm	Nov-13 Control	Nov-13 Wind Farm	Apr-14 Control	Apr-14 Wind Farm
Thornback Ray	53.9	85.7	80.2	31.5	90.1	294.6	66.7	33.6
Whiting	149.7	118.2	17.4	3.4	94.9	42.9	91.2	31.3
Lesser Spotted Dogfish	67.4	49.5	1.8	0.7	17.7	11.2	144.8	87.7
Dab	27.2	15.5	2.9	1.5	10.8	10.8	20.6	8.6
Plaice	11.1	27.9	2.7	1.9	5.7	14.6	18.2	7.1
Bib	35.9	23.4	1.5	0.0	21.6	3.4	1.5	0.4
Cod	1.8	1.5	5.9	3.4	8.4	3.4	5.4	2.6
Starry Smooth Hound	13.8	5.3	0.6	0.0	1.2	0.0	10.8	0.4
Dover Sole	0.6	1.5	8.5	6.0	4.5	1.9	3.0	2.2
Tub Gurnard	2.7	3.8	0.0	0.0	1.8	2.2	0.9	1.5
Other Species	8.7	8.3	6.2	5.2	10.8	6.7	15.3	4.5

Survey and Sampling Area

4.5.2. Beam trawl

4.5.2.1. Fish

Similar numbers of species were recorded at both sampling locations throughout the autumn and spring pre-construction surveys (November 2009 and March 2010) and the autumn and spring post-construction surveys (November 2013 and April 2014). A total of 33 species was recorded across all the surveys conducted with 24 and 18 species recorded in the autumn and spring pre-construction surveys and 19 and 17 species recorded in the autumn and spring post-construction surveys respectively.

The most commonly recorded species in the beam trawl surveys were the Sand Goby, Dover Sole and Lozano's Goby.

The Sand Goby was recorded as the most abundant species in the autumn pre-construction survey, however none were recorded in the spring pre-construction or the autumn post-construction survey. This species was recorded in much lower numbers in the spring post-construction survey. There were high catch rates of this species in both the OWF site and control areas during the autumn pre-construction survey.

Dover Sole was recorded in all surveys at both sampling areas. The highest catch rate for this species was within a control area during the autumn pre-construction survey. Comparably low numbers were recorded during the autumn post-construction survey.

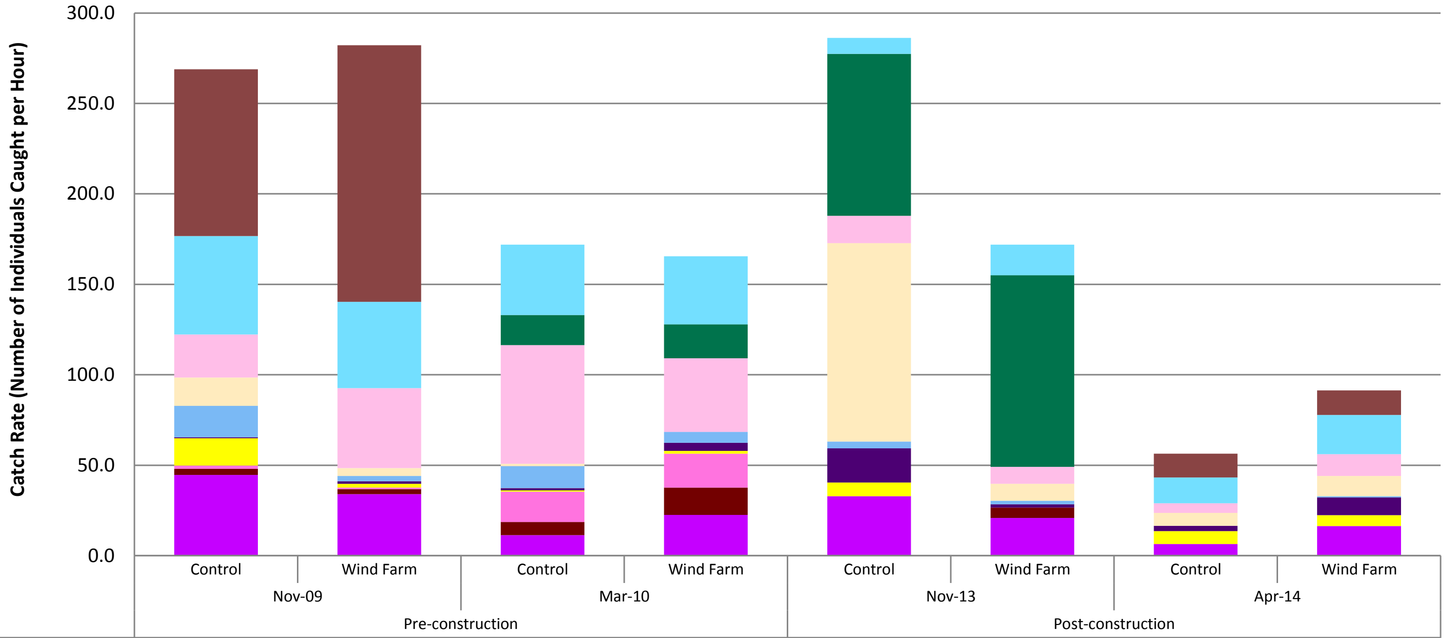
Lozano's Goby was not recorded in the autumn pre-construction and spring post-construction surveys. Catch rates of this species were considerably higher in both sampling areas during the autumn post-construction survey than in the spring pre-construction survey.

The catch rate recorded at control locations during the autumn post-construction survey is comparatively similar to those recorded during the pre-construction surveys, however the catch rate within the OWF is comparatively lower. Comparatively low catch rates were recorded during the spring post-construction survey in both sampling areas.

4.5.2.2. Invertebrates

In the November 2009 pre-construction survey the Brown Shrimp *Crangon crangon* was the most abundant species at the control stations and the shrimp *Crangon allmani* within the OWF site, whereas in the November 2013 post-construction survey *C. allmani* was most abundant at both sampling locations. During the March 2010 pre-construction survey, the Serpent's Table Brittlestar *Ophiura albida* was prevalent in both sampling areas However during the April 2014 post-construction survey *O. albida* was most prevalent at control stations

Figure 4.5.2: Catch rates for the most abundant fish and shellfish species by survey and by sampling area for beam trawl surveys within the London Array Offshore Wind Farm from November 2009 to April 2014 (From: Brown and May Marine Ltd, 2014)



	Nov-09 Control	Nov-09 Wind Farm	Mar-10 Control	Mar-10 Wind Farm	Nov-13 Control	Nov-13 Wind Farm	Apr-14 Control	Apr-14 Wind Farm
	Pre-construction				Post-construction			
Sand Goby	92.1	141.8	0.0	0.0	0.0	0.0	13.1	13.5
Dover Sole	54.5	47.7	38.8	37.6	8.8	17.0	14.2	21.7
Lozano's Goby	0.0	0.0	16.7	18.8	89.5	105.8	0.0	0.0
Solenette	23.8	44.1	65.6	40.6	15.1	9.4	5.3	12.0
Pogge	15.6	4.3	1.3	0.0	109.6	9.4	7.1	11.2
Common Dragonet	17.4	2.9	12.0	6.0	3.8	1.9	0.0	0.7
Greater Sandeel	0.6	1.4	1.3	4.5	18.9	1.9	3.0	9.7
Lesser Spotted Dogfish	15.1	2.2	0.7	1.5	7.6	0.0	7.1	6.0
Lesser Sandeel	1.7	0.7	16.7	18.8	0.0	0.0	0.0	0.0
Sprat	3.5	2.9	7.4	15.0	0.0	5.7	0.0	0.0
Other Species	44.6	34.0	11.4	22.6	32.9	20.9	6.5	16.5

Survey and Sampling Area

4.6. Discussion

4.6.1. Otter trawl

The total numbers of species found in the pre- and post-construction surveys and catch rates during the two surveys were equivalent. This indicates that the presence of the OWF is not having a statistically significant effect on local fish and shellfish populations. The highest total catch rates were recorded in the autumn pre- and post-construction surveys, with the spring pre-construction surveys recording similar catch rates, suggesting a strong seasonal influence on local species abundance.

Catch rates of Thornback Ray were consistent in both pre-construction surveys, whereas the catch rate recorded in within the OWF site in November 2013 was considerably higher, the majority of which were recorded at one station within the OWF site. The highest catch rates recorded during the autumn pre- and post-construction surveys were recorded in the OWF site, whereas the highest catch rates were recorded at control locations during the spring 2010 pre-construction survey and spring 2014 post-construction survey. Observed differences are likely to be at least partially attributable to naturally occurring seasonal variation.

Whiting catch rates were higher at control locations in all surveys. Lowest catch rates were recorded during the spring 2010 pre-construction survey compared to autumn 2009 and 2013 surveys, and spring 2014 survey.

Atlantic Cod and Dover Sole have been recorded in all sampling areas in all pre- and post-construction surveys. Catch rates of both species have remained relatively stable through the pre- and post-construction surveys, with some seasonal fluctuation. In all surveys the highest catch rates for both species were recorded at control locations.

4.6.2. Beam trawl

Overall, the number of fish species caught in all surveys at the control stations and within the OWF site were similar, which indicates that the presence of the OWF site is not having a statistically significant effect on local fish populations.

The total catch rates for fish species at both sampling locations were similar throughout pre-construction surveys. The catch rates recorded at control locations during the autumn 2013 post-construction survey were comparable to those recorded during the pre-construction surveys. However, the overall catch rates recorded during the spring 2014 survey were considerably lower. This is likely to be attributable to naturally occurring variation.

Similar numbers of invertebrate taxa were captured during pre- and post-construction surveys. In the autumn 2009 and 2013 and spring 2014 surveys, higher numbers of individual taxa were recorded at control locations. This pattern was reversed during the spring 2010 pre-construction survey where greater numbers were found within the OWF.

4.6.3. Comparison with benthic survey data

The most common fish species identified in the benthic beam trawl survey and the fish beam trawl survey were broadly similar. The benthic survey identified Gobies, Dover Sole, Pogge, Whiting and Poor Cod as the most abundant species. The fish beam trawl survey also identified Gobies as being the most common. Pogge and Dover Sole were also recorded in large numbers and Solenette was also one of the most common species in the autumn fish beam trawl survey.

As in the benthic survey the most common invertebrates identified were brittlestars and Brown shrimp. In the benthic beam trawl survey Brown shrimp *Crangon crangon* was identified as the most common species, whereas in the fish beam trawl survey *C. allmanni* was the most common species. In the fish survey both *C. crangon* and *C. allmani* were present, whereas in the benthic beam trawl survey only *C. crangon* was identified. It is probable that *C. allmani* was present in the benthic beam trawl data and has been erroneously identified as *C. crangon*.

The lack of reference sampling stations within the benthic beam trawl survey makes comparisons with control areas impossible, however, as the change noted in community composition was present between all project phases, any change in epibenthic species assemblage is due to factors other than construction of the OWF. The catch rates recorded at control locations during the autumn 2013 post-construction fish survey were comparable to those recorded during the pre-construction surveys. The differences observed in the fish survey data have been attributed to natural temporal and spatial variation, with lower catch rates being observed in the spring 2014 survey.

Overall, the benthic beam trawl survey and the fish survey data were broadly similar, with many of the same species being recorded in high numbers. No statistical analysis was performed on the fish survey data and it is therefore not possible to determine if there was any statistically significant differences between pre- and post-construction data. However, both surveys concluded that the differences observed between pre- and post-construction surveys are attributable to natural variation. Therefore, the 2014 post-construction survey indicates that the installation and operation of the London Array OWF has not had any effect upon local fish populations within the area.

4.6.4. Comparison with the Environmental Statement

The main conclusions from the London Array OWF ES are presented and discussed in Table 4.6.1.

Table 4.6.1: The predictions from the Environmental Statement regarding fish resources within the London Array Offshore Wind Farm site and export cable route. (Source: RPS, 2005)

Environmental Statement Prediction	Status based on review of Year 1 post-construction survey data
7.4.261 The operating turbines will produce noise and vibration in the near field, which fish will detect as hydrodynamic motion as the pressure wave displaces particles. As both hearing specialist and non-hearing specialist species utilise particle displacement for the detection of prey and predators it is possible that the operating turbines will mask this hydrodynamic motion. However, Hoffman (2000) states that the low frequency hydrodynamic fields generated by operating turbines will be perceived very differently by fish from fields generated by other animals. Noise from operating turbines should not therefore, impair fish in their ability to detect and interpret fields from different sources such as predators or prey within the near field. The sound generated by operating turbines is also considered to be harmonic in nature as well as operating at a constant level above background noise. It is possible that fish will show adaptation and habituation to the operating turbines at the London array site and will accumulate around such structures as has occurred at other offshore installations.	Based on review of the Year 1 post-construction fish data together with characterisation and pre-construction data, the ES predications remain valid and impacts of **negligible significance** appear to have occurred.
*7.4.263 Any impacts from maintenance/tourists boats are considered to be of **negligible significance**.*	Based on review of the Year 1 post-construction fish data together with characterisation and pre-construction data, the ES predications remain valid and impacts of **negligible significance** appear to have occurred.
*7.4.264 Taking into account evidence from other wind farms and noise generating offshore structures the impacts of operational turbine noise on fish is also considered to be of **negligible significance**.*	Based on review of the Year 1 post-construction fish data together with characterisation and pre-construction data, the ES predications remain valid and impacts of **negligible significance** appear to have occurred.
*7.4.275 The overall impact of the development would therefore be potentially beneficial in the local area, and long term, but probably of **minor overall significance**.*	Based on review of the Year 1 post-construction fish data together with characterisation and pre-construction data, the ES predications remain valid and impacts appear to be of ***minor overall significance***.

4.7. Conclusions

The results of the 2014 post-construction fish survey show predominately that the same fish species are present in similar numbers to pre-construction. Although there are some differences in terms of catch rates of specific species, this can be partly attributed to natural variation in spatial distribution and population flux. In some cases, catch rates are equivalent between pre- and post-construction surveys.

The numbers of Thornback Ray and other elasmobranch species, which are noted species in Annex I Point 5 of the Marine Licence conditions (see Section 2.1), have been consistent throughout pre- and post-construction surveys. There were higher numbers of Thornback Ray recorded within the OWF site in the post-construction surveys, whereas there were higher numbers in control locations during pre-construction surveys. The results suggest that the presence of the OWF and electro-magnetic fields associated with sub-sea cables have not had any effect on populations of Thornback Ray and other electro-sensitive fish species within the area.

The results of the 2014 post-construction survey suggest that the presence of the London Array OWF is not currently having an effect on fish and motile macro-invertebrate species within the area. However, it is difficult to establish the magnitude of any effects from one year of monitoring and future monitoring surveys, and comparison of subsequent data sets, will clarify post-construction trends.

5. Aerial ornithology surveys

5.1. Marine Licence requirements for aerial survey

Conditions within Marine Licence L/2011/00152/31 that relate to a requirement to undertake ornithological surveys are listed in Table 5.1.1 below.

Aerial surveys are potentially the most critical component of the post-construction monitoring surveys as Red-throated Diver are a qualifying feature of the Outer Thames Estuary Special Protection Area (SPA) and potential effects upon this species needs to be closely monitored.

Table 5.1.1: Marine Licence conditions – aerial surveys

Marine Licence Ref	Description
3.1.10	*The Licence Holder must ensure ornithological monitoring is 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.*
Annex 2	*Ornithological Monitoring 'Grampian' conditions* *'Grampian' type conditions imposed on the Licence Holder will ensure that no further development beyond the proposed Initial Development Area will take place until such time that further evidence of potential impacts is obtained and that any further development permitted will not have adverse effects upon the integrity of the potential Greater Thames SPA. Therefore monitoring between construction of the Initial Development Area and subsequent developments will be required and if significant effects are identified then further developments may not take place.* *Monitoring will comprise a Before and After Control Impact (BACI) design and will be undertaken at the survey areas consisting of the windfarm site, a 1km and 2-4km buffer zone surrounding the windfarm and the selected reference site. The monitoring programme will be implemented in advance of construction and continue through the initial construction phase. Should further developments be permitted to occur then additional construction monitoring will be required at each subsequent phase of development. There is also a requirement to conduct post-construction monitoring to provide a minimum of three years data from the initial operating phase of the Initial Development Area and any and each permitted subsequent phases of development. These data will need to be empirically comparative with baseline data provided within the project's Environmental Statement. The detailed specification for the monitoring programme, including the location and extent of the reference site, 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 (see licence condition 3.1.10).* *The aforementioned monitoring conditions, agreed with Natural England, will ensure that further evidence of potential impacts is obtained before any such further development beyond the proposed Initial Development Area is permitted.*

Marine Licence Ref	Description
	The need for additional ornithological monitoring, 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. This will have regard to the magnitude of any change in bird populations observed during the initial three years operational monitoring period applicable to each phase of permitted development (as per licence condition 3.3.1). *The ornithological monitoring programme may have to be adapted and amended as new technologies and research findings become available, as determined by Natural England and the Licensing Authority.* *Ornithological monitoring reports will be provided to Natural England on a quarterly basis as a draft report update and as a final annual report. This may be more frequent where the results of the data may trigger further, more intensive monitoring work. Monitoring of the agreed reference site will also continue parallel to the windfarm site and the 1km and 2-4km buffer zones surrounding the windfarm.* *Monitoring will need to fulfil the following objectives:-* *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 windfarm site, 1 km and 2-4 km buffer zones and the reference site.* *2. Determine whether there is a barrier effect to movement of birds through the windfarm site and the 1km and 2-4 km buffer zones.* *3. Continue to determine the distribution of wildfowl and divers in the Greater Thames Estuary, covering the London Array windfarm site, 1km and 2-4 km buffer zones and the reference site.* *4. IF objectives 1 or 2 reveal significant change of use of the wind farm site and 1 km and 2-4 km buffer zones by populations of conservation concern, at heights that could incur collision, a programme of collision monitoring will be implemented."*
3.2.8	*The Licence Holder is permitted to undertake export cable installation work within the intertidal area of the cable route for a total of 23 days, during the period October 2011 to March 2012. An increased level of ornithological monitoring must take place during any construction works between October and March and the monitoring plan for these works must be agreed with the Licensing Authority prior to works commencing. The Licensing Authority and Natural England must be given a minimum of one weeks' notice of the intended installation period for the second cable. Unless agreed otherwise all other cable laying operations within the intertidal area of the export cable must take place within the April to September consent window or during high tidal state in order to minimise disturbance to overwintering wader assemblages.*

5.2. Objectives of aerial survey

The post-construction monitoring aerial bird survey was conducted over the winter of 2013/2014 by APEM Ltd. The aim of the monitoring was to provide information regarding the response of bird species to the construction and operation of the London Array OWF. Primarily, the survey enables examination of the response of Red-throated Diver *Gavia stellata*, although other bird species and marine mammals within the region were studied. The Red-throated Diver is listed under Annex I of the EC Birds Directive and is the qualifying feature of the Outer Thames Estuary SPA.

The objectives described in the EMP are:

1. Provide post-construction surveys of the London Array OWF site after wind farm construction finishes;
2. Provide post-construction surveys of control zones for the OWF site;
3. Describe temporal and spatial variation in bird numbers across the OWF and control sites;
4. Produce population estimates, with a given level of precision, for birds across the OWF and control sites;
5. Produce updated estimates of red-throated diver abundance and distribution within the OWF and control sites, with respect to the proposed Special Protection Area [now SPA] in the outer Thames Estuary.

5.3. Survey methodology

High-definition aerial surveys to record the presence of birds and marine mammals were conducted during the winter period from November 2013 – February 2014.

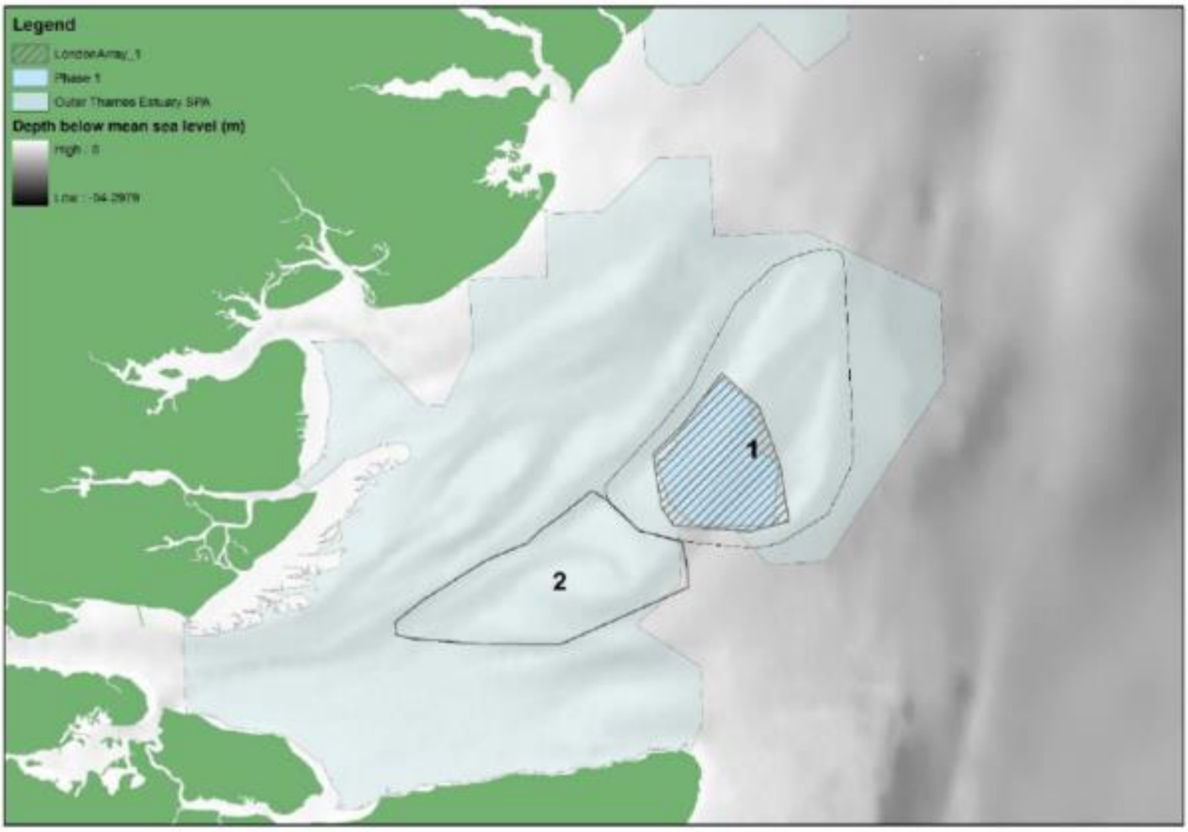
A number of survey zones were identified within the EMP, with seven zones being identified and six of these zones being surveyed in the pre-construction surveys. For the post-construction survey, two zones were surveyed out of the original six zones surveyed in the pre-construction surveys[2].

The two zones surveyed in the post-construction aerial survey are:

- Zone 1: area encompassing the London Array OWF including the Phase 1 development site plus a buffer surrounding the OWF site; and
- Zone 2: control zone to south west of London Array OWF site.

[2] The four zones not surveyed during November 2013-February 2014 were previously surveyed with the aim of supporting a Phase 2 development. It was agreed with the regulator, and statutory advisors that the additional sites were not required for post-construction monitoring requirements for the Phase 1 construction i.e. the London Array Offshore Wind Farm.

Figure 5.3.1: The location of Zone 1 and Zone 2 that were surveyed for the London Array Offshore Wind Farm pre-construction and post-construction aerial surveys. (From: APEM Ltd, 2014)



The methodology used for the surveys was that described in the EMP. Each survey was flown on a 500 m grid at a 3 cm ground sampling distance (GSD) resolution. The primary aim of APEM Ltd's grid survey methodology is to derive sufficient independent estimates of bird density (and distribution) to target a pre-defined level of precision around population estimates. The spacing of the grid (an image is collected at each grid internode) is determined by the predicted number of samples required to achieve the predefined level of confidence (CV<0.16).

Aerial surveys were undertaken using either a Vulcanair P68 Observer twin engine survey aircraft or a Vulcanair P68C twin engine survey aircraft (APEM Ltd, 2014).

The following data were recorded from the aerial surveys:

- Count (number of individuals of diver species, other bird species and marine mammal species);
- Behaviour (flying/sitting);
- Position (easting, northing);
- Size (body length);
- Heading; and
- Date and time stamp of image collection.

The dates that the surveys were conducted are listed in Table 5.3.1.

Table 5.3.1: Survey dates for the London Array Offshore Wind Farm aerial surveys conducted during winter 2013/2014.

Survey	Month surveyed	Day surveyed	
		Zone 1	Zone 2
Survey 1	November	10	09
Survey 2	December	11	09
Survey 3	January	10	11
Survey 4	February	03	02

Density distribution maps were produced. An additional analysis of diver species density was also conducted (APEM Ltd, 2015).

A full description of the survey methodologies used can be found in Annex D.

5.4. Survey results

During the 2013/2014 post-construction bird surveys, a total of fourteen bird species, two bird species groups, a single species of marine mammal, and a marine mammal group were recorded across the surveys

5.4.1. Diver species

The most commonly identified species within the survey zones for each survey conducted was the Red-throated Diver, which was recorded in both zones in all months surveyed. In November 2013 relatively low numbers were recorded, with a raw count of 26. Peak numbers of Red-throated Diver were recorded in December 2013 in Zone 1 (raw count=974), this can be seen in Figure 5.4.1.

Black-throated Diver and Great Northern Diver were also identified as present during the survey, though Red-throated Diver constituted 97.4% of the total divers identified. For purposes of assessment, the distribution of Red-throated Diver, Black-throated Diver and Great Northern Diver were analysed collectively and the collective data set is referred to as diver species hereafter[3].

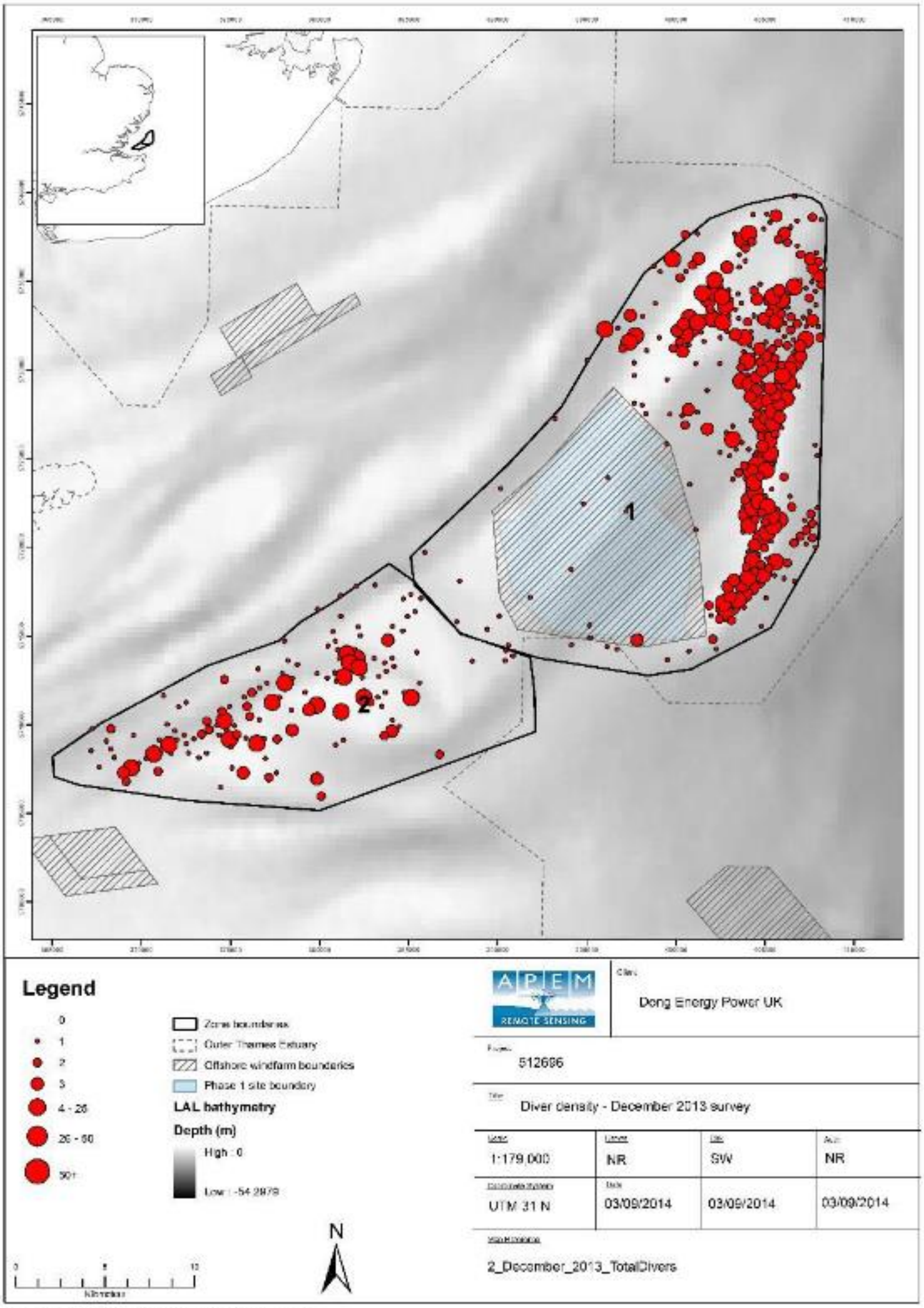
The number of birds counted and the population abundance estimates for Red-throated Diver and for all diver species are presented in Table 5.4.1. Further detail on the results of the diver survey can be viewed in the full report that is presented in Annex D.

[3] Over 97% of the divers recorded were positively identified as Red-throated Diver and, therefore, discussion within the AMR considers this aggregate representative of the qualifying feature of the Outer Thames Estuary SPA.

Table 5.4.1: Monthly counts and population estimates for Red-throated Diver *Gavia stellata* and all diver species during the 2013/2014 post-construction monitoring survey for London Array Offshore Wind Farm. (Source: APEM Ltd, 2014)

Month	Zone	Red-throated DIver		All diver species	
		Count	Population Estimate		
November 2013	Zone 1	15	94	15	108
	Zone 2	11	80	11	80
December 2013	Zone 1	974	4,473	1,023	4,698
	Zone 2	231	1,056	231	1,056
January 2014	Zone 1	259	1,865	261	1,879
	Zone 2	136	982	136	982
February 2014	Zone 1	278	2,007	279	2,015
	Zone 2	127	1,003	128	1,011

Figure 5.4.1: Relative distribution of divers recorded in Zone 1 and Zone 2 in December during 2013-14 post-construction winter. London Array Offshore Wind Farm array falls within the hatched blue area. Other hatched areas also show the Kentish Flats Offshore Wind Farm (inside Zone 3), Gunfleet Sands Offshore Wind Farm (north-west of Zone 5) and Thanet Offshore Wind Farm (south of Zone 1). Location of Zone 1 and Zone 2 is shown in the inclusion. (From: APEM Ltd, 2014)



Contains Ordnance Survey Data © Crown Copyright and database right 2014

5.4.1.1. Absolute diver density

The lowest diver densities were observed during November surveys, with diver species densities increasing in each subsequent month until the end of winter. Pre-construction diver species densities were broadly even throughout Zone 1 with notably the highest densities recorded outside the London Array OWF site. The highest diver species density was recorded during the February 2011 pre-construction survey at a distance of 12 km from the wind farm area. This is suggestive of the optimal habitat likely to exist along the flanks of Long Sands Head and Kentish Knock. The full results can be viewed in Annex D.

5.4.1.2. Relative diver density

Pre-, during- and post-construction data were grouped by month. The relative density estimates allow any changes in diver species distribution over time to be considered once the variation in overall numbers between surveys has been factored. The full results can be viewed in Annex D.

5.4.2. Bird species excluding diver species

The peak counts of all bird species, other than diver species, are presented in Table 5.4.2. The peak counts show that, following diver species, the next most commonly identified groups were auk species and large gull species, and there were also high numbers of Cormorant and Shag recorded.

Table 5.4.2: Peak counts and population estimates for bird species (excluding Red-throated Diver) recorded in the 2013/2014 post-construction monitoring aerial survey for London Array Offshore Wind Farm. (Source: APEM Ltd, 2014)

Species/group	Zone	Month	Count	Population estimate
Total diver species	1	December	1023	4698
Black-throated Diver	1	December	27	124
Great Northern Diver	1	December	22	101
Fulmar	1	January	1	7
Gannet	1	November	10	72
Total Cormorant and Shag	2	December	99	452
Grebe species	1	February	1	7
Pomarine Skua	1	November	1	7
Total small gull species	1	January	78	562
Kittiwake	1	January	76	547
Black-headed Gull	2	November	7	51
Common Gull	1	December	11	51
Total large gull species	1	December	120	551
Lesser Black-backed Gull	1	December	19	87
Herring Gull	2	November	43	314
Great Black-backed Gull	1	December	79	363
Total auk species	2	February	147	1,161

5.4.3. Marine mammals

The most common marine mammals recorded during the winter 2013/14 surveys were seals (64%) with a peak population estimate of n=433 in Zone 1 during the February 2014 survey. The remaining marine mammals were identified as dolphin/porpoise (27%) and Harbour Porpoise *Phocoena phocoena* (9%). The numbers recorded during the 2013/14 survey can be seen in Table 5.4.3.

Table 5.4.3: Peak counts and population estimates for mammal species recorded in the 2013/2014 post-construction monitoring aerial survey for London Array Offshore Wind Farm. (Source: APEM Ltd, 2014)

Species/group	Zone	Month	Count	Population estimate
Harbour Porpoise	1	November	5	36
Seal	1	February	60	433

Harbour Porpoise and seal were recorded within both Zone 1 and Zone 2. The majority of marine mammals recorded within Zone 1 were outside of the London Array OWF site, however, individuals of both Harbour Porpoise and seal were recorded within the OWF site during the survey. In February 2014 high numbers of seal were recorded within Zone 1, located north of the array.

5.5. Comparison with pre-construction data

The results of the 2013/2014 post-construction monitoring survey have been compared with the results of previous aerial bird surveys, to draw conclusions about changes to bird populations within the London Array OWF site.

5.5.1. Diver species

Diver abundance and distribution has changed over the last four years. The raw counts and the population estimates for all divers from 2010/11 – 2013/14 can be seen in Table 5.5.1.

Table 5.5.1: Peak population estimates and counts for divers within Zones 1 and 2 recorded by the London Array Offshore Wind Farm aerial surveys over four winters from 2010/11-2013/14. (Source: APEM Ltd, 2014)

Zone	Year	Month	Count	Population estimate
1	2011	February	1,257	8,194
	2012	January	181	1,474
	2013	February	665	3,153
	2014	December	1,023	4,698
2	2011	February	144	909
	2012	February	433	1,980
	2013	February	241	1,144
	2014	December	231	1,056

A high peak diver species number of 8,194 was estimated as being present in Zone 1 during the pre-construction surveys of 2010/11. The peak diver species abundance fell by 82% to 1,474 during the 2011/12 construction survey before increasing by 53% to 3,153 during the second 2012/13 construction survey. The peak diver species abundance recorded in Zone 1 increased by a further 33% to 4,698 diver species between the 2012/13 construction and 2013/14 post-construction Phase 1 surveys.

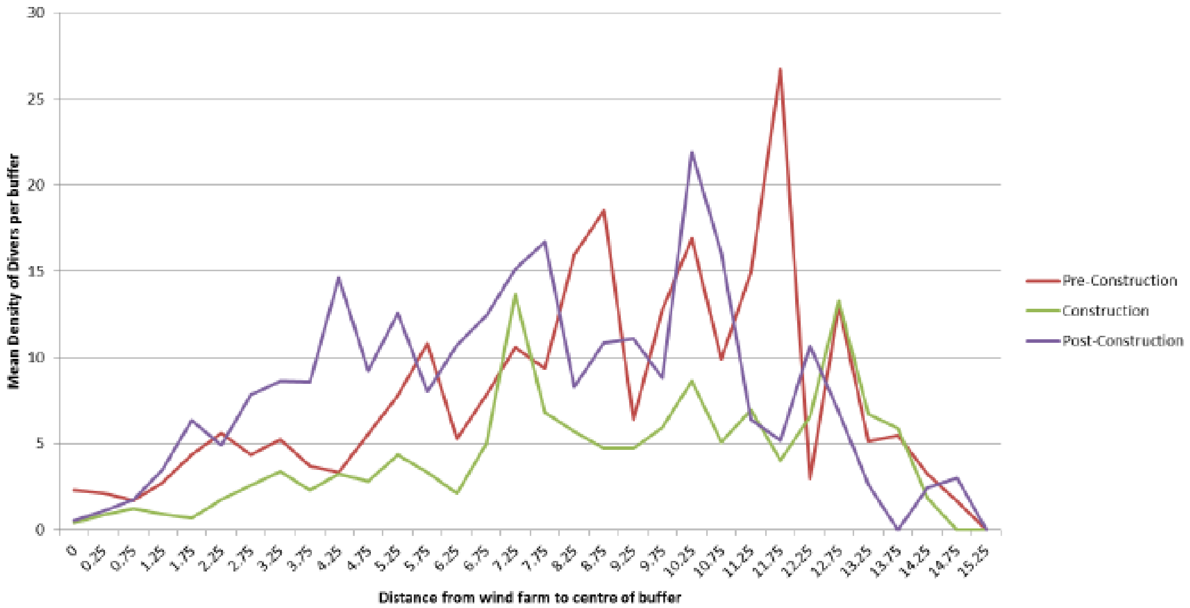
The pattern of the numerical change in diver species numbers observed in Zone 2 appears to be the inverse of that of Zone 1, especially during the 2011/12 winter when there was a large proportional decline in diver species numbers in Zone 1 and a large proportional increase in Zone 2. In Zone 2, diver species abundance rose by 46% between the peak pre-construction survey of 2010/11 and the peak 2011/12 construction survey (a change from 909 to 1,980), before falling by 42% to the peak construction survey 2012/13 (1,144 divers). The peak diver species abundance in Zone 2 fell by a further 8% to 1,056 during the 2013/14 winter post-construction survey.

5.5.1.1. Diver species density

During the construction phase of the London Array OWF, mean diver species density was lower across the majority of the concentric buffer areas surrounding the OWF compared to pre-construction surveys (see Figure 5.5.1), with a statistically significant decrease between pre- and during-construction diver species densities.

Lower numbers of diver species were recorded during the 2011/12 during-construction survey of the London Array OWF; with an 82% decrease in peak diver species abundance recorded between 2010/11 pre-construction surveys and the first 2011/12 during-construction survey.

Figure 5.5.1: Mean density of diver species recorded during pre-, during- and post-construction aerial surveys within each 500 m buffer area surrounding the London Array Offshore Wind Farm. (From: APEM Ltd, 2015)



5.5.2. Bird species excluding diver species

The numbers of most bird species recorded in the post-construction surveys were similar to the numbers recorded in pre- and during-construction surveys. However, there were some notable changes in numbers. The number of Gannet recorded was much lower in the post-construction surveys with an estimated peak number of 72 individuals recorded in November 2013, this is compared to the pre- and during-construction surveys, when peak estimates of 749 and 593 individuals were present.

Relatively high numbers of Cormorant and Shag were present in Zone 2 with numbers peaking at 425 during the December 2013 survey, an increase from the 2012/13 peak count of 325 individuals. The numbers of Kittiwake peaked at an estimated 617 individuals across Zone 1 in January 2014; a higher number than that observed during the previous winter surveys when peak estimates of 376, 229, 196 in 2012/13, 2011/12 and 2010/11 were recorded, respectively. The number of Great-black Backed Gulls recorded also increased in the post-construction survey.

5.5.3. Marine mammals

Low numbers of marine mammals were identified within the post-construction surveys, this was also the case in the previous surveys, although high numbers of mammals were recorded in the February 2011 survey with an estimation of n=365. In previous surveys only dolphin and porpoise were recorded, with the Harbour Porpoise making up all, or most of, these sightings. Harbour Porpoise also made up all, or most of, the recorded individuals in the post-construction survey. High numbers of seal were also recorded in the post-construction aerial survey, where they had not previously been recorded.

5.6. Discussion

5.6.1. Diver species

Red-throated Diver are highly sensitive to disturbance and displacement effects from anthropogenic objects and structures present on the sea surface, or on the horizon, and have been noted as being highly sensitive to disturbance associated with shipping traffic (Kube 1996, Garthe and Hüppop 2004; King *et al.* 2009). Red-throated Diver have been reported to be easily displaced by the visual presence of ships and to be flushed by approaching vessels (Percival, 2009; Schwemmer *et al.*, 2011).

It has also been stated that once Red-throated Diver are flushed, the majority of birds appear to relocate to a distance considerably greater than 1 km from the source of disturbance (Natural England, 2013). Therefore, the reduction in diver species numbers observed in Zone 1 during the construction of the London Array OWF is to be expected as the birds would most likely have been displaced by construction vessels present during this phase.

As previously mentioned, the Outer Thames Estuary SPA has been designated for a total of 6,466 diver species with a total of 8,130 individuals estimated across the wider Greater Thames Estuary (O'Brien *et al.* 2008; Webb *et al.* 2009). During the post-construction aerial survey, diver species abundance across both zones peaked at a total of 5,748, which demonstrates that numbers within the London Array OWF site are approaching pre-construction levels.

This Year 1 post-construction survey only provides a ‘snapshot’ of monitoring of bird species within the area and, as such, it is only able to provide an indication of how Red-throated Divers, and other diver species, are affected by the London Array OWF. Further monitoring of Red-throated Divers and other diver species within the London Array OWF area is needed in order to assess whether the numbers of these birds present are able to return to the numbers observed during the pre-construction survey. Future surveys will also further indicate whether the change in diver species numbers can be attributed to environmental conditions as well as the presence of the London Array OWF.

5.6.1.1. Diver density

January and February have previously been identified as peak months for Red-throated Diver wintering in the Greater Thames Estuary (Webb *et al.* 2009). The large numbers of diver recorded during February are thought to represent pre-migration aggregations of birds, with pairs returning to territories from the UK typically in March and April (Wernham *et al.* 2002).

5.6.2. Bird species excluding diver species

Fulmar and Gannet are known to be widely distributed throughout the North Sea following dispersal from their breeding colonies during September (Stone *et al*. 1995). Therefore, low numbers of Fulmar within the outer Thames Estuary are to be expected. The timing of the over-winter surveys may reflect the passage of Gannet through the North Sea from their over-wintering sites to breeding grounds further north (Wernham *et al.* 2002). Lower numbers of Gannet were observed during the 2013/14 surveys than in previous years and this may be as a result of this species avoiding the vicinity of wind farms.

Relatively high numbers of Cormorant and Shag were present in Zone 2 with numbers peaking at n=425. Cormorant and Shag are found in coastal areas year round and so their presence within this area, which is less than 20 km from the coast, is expected. Cormorant numbers can increase in the vicinity of built wind farms using the infrastructure as a roost that provides opportunities for the birds to dry their wings out after foraging (Krijgsveld *et al*. 2011).

The London Array OWF environmental statement predicted that there would be no statistically significant effects on seabird species (with the exception of divers). The results of the data obtained so far show that this largely seems to be the case, although the numbers of Gannet have decreased slightly, likely due to avoidance of wind turbines, however this avoidance behaviour is unlikely to significantly affect Gannet populations within the area.

5.6.3. Marine mammals

The high number of seal recorded during February 2014 was due to a congregation of seals hauled out together on a transient sandbank within the survey area. These seals may have been either Common or Grey seals as both species are frequently recorded in the Thames Estuary. It is likely that the majority of individuals recorded as dolphins/porpoises were also Harbour Porpoises since this species is most often seen between January and April in the south-eastern North Sea (Reid *et al.* 2003). All marine mammals in previous surveys have been considered likely to be Harbour Porpoises.

5.6.4. Comparison with the Environmental Statement

The main conclusions from the London Array OWF ES are presented and discussed in Table 5.6.1 below.

Table 5.6.1: The predictions from the Environmental Statement regarding fish resources within the London Array Offshore Wind Farm site and export cable route. (Source: RPS, 2005)

Environmental Statement Prediction	Status based on review of Yr1 post-construction survey data
Overall this assessment has identified only a single bird group that would be likely to be significant affected by the proposed development, divers (primarily red-throated and to a lesser degree black-throated), using a precautionary worst-case assessment. The main impact on these birds would be likely to be displacement from a zone around the wind turbines (though the extent of such a zone is uncertain), and to a lesser extent collision risk (though these two impacts would be likely to be mutually exclusive). The main concern is not so much that there would definitely be a significant impact but that the current state of knowledge of such species at offshore wind farms and at the proposed scale of the London Array site is not sufficient to be able to conclusively demonstrate that a significant effect would not occur.	The results of the monitoring surveys have shown that there has been a statistically significant change in the numbers of divers present within Zone 1 during the construction phase of the London Array OWF, with the abundance of divers within this area decreasing during 2011/12 and the abundance of divers in Zone 2 increasing. These results are in agreement with the predictions made within the London Array OWF ES (RPS, 2005) that there would be displacement of divers around the zone of the OWF. This suggests that these birds have been displaced as a result of disturbance effects from the OWF construction phase. However, the abundance of divers within Zone 1 has subsequently increased closer to pre-construction numbers since the construction phase has been completed. Further monitoring is required in the future to fully determine the effects of the OWF on the diver population.
Lower significance effects would also be likely to occur on a range of other species, including gulls and a range of other seabirds, and migratory waterfowl, but none of these would be likely to be significant in the context of the EIA Regulations.	As was predicted within the ES there have been no statistically significant changes to other seabirds, with the exception of Cormorants and Shags that have shown an increase in numbers.
Construction *7.3.86 The degree of effects on seals would be adverse but significance **Minor**. The overall level of effects would therefore be Low-adverse.* *Operation* *7.3.87 The effects on seals from onshore operations would be **Negligible**.*	As was predicted within the London Array ES, there has been no noticeable impact upon marine mammals within the area.

The change in the abundance of divers within Zone 1 reflected the predictions made by the London Array OWF ES (RPS, 2005). The ES predicted that the construction of the OWF was likely to cause displacement effects on divers. The results of further post-construction surveys will provide further information on whether diver numbers continue to rise within Zone 1.

5.7. Conclusions

The majority of divers recorded in the survey were Red-throated Divers (97.4%) with the remainder being Black-throated (1.4%) and Great Northern divers (1.2%). All divers were identified to species level.

Over the four years that aerial surveys have been carried out for London Array OWF diver abundance and distribution has changed in Zones 1 and 2. Peak diver population estimates in Zone 1 fell between the 2010/11 pre-construction winter and 2011/12 first construction winter. Diver numbers started to rise in 2012/13 after the main body of work was completed, and this rise continued into 2013/14. In Zone 2 peak diver numbers increased in 2011/12 when numbers correlating with the decline in Zone 1, before returning to similar numbers to those recorded in the 2010/11 pre-construction surveys in 2012/13 and 2013/14.

It is possible that the drop in diver numbers in Zone 1 was a consequence of the OWF construction, and the increased shipping traffic associated with this. As a result divers may have re-distributed themselves into Zone 2.However, diver numbers in Zone 1 increased rapidly from January 2013 onwards following the completion of the main body of construction in December 2012, although commissioning of all turbines was not completed until April 2013. The increase suggests that divers that used the area in 2010/11 moved back into Zone 1 after initial displacement. Future surveys will show whether the diver numbers continue to rise.

The construction of the London Array OWF is unlikely to have been the only driver of changing diver abundance and distribution over the last three years. Diver numbers in the outer Thames Estuary are known to fluctuate. This may be due to a combination of effects including changes in environmental conditions near and far, diurnal movements, hydrodynamic variables as well local developments (APEM Ltd, 2015).

Whereas the relatively short period of wind farm construction appears to have led to a change in diver species distribution there is no clear evidence that this change in distribution continued once the construction activity ceased.

Several other bird species/groups were recorded on the surveys, the most abundant of which were gulls (including Kittiwake, Black-headed Gull, Common Gull, Lesser Black-backed Gull, Herring Gull, and Great Black-backed Gull). Gull numbers have not shown large amounts of change from previous years and gull species are known to be tolerant of shipping activity (Cook and Burton, 2010) The observed increase in Cormorant numbers may be related to the wind farm as may be the decline in Gannet numbers (Krijgsveld *et al*. 2011).

Seal were the most commonly recorded marine mammals across all zones (64% of total marine mammals) and were most abundant in Zone 1 in February 2014 when observed hauled out on a sandbank. The numbers of marine mammals within the survey area have not shown a high degree of fluctuation compared with previous surveys.

6. Discussion

6.1. Bathymetry and seabed morphology

The bathymetric survey indicates that there has been a greater degree of scour at the export cables, WTG foundations, and offshore substations, than was predicted in the London Array OWF ES. The greatest scour is at the BritNed Cable Crossing, where the seabed level recorded in the 2014 bathymetric survey was up to 9 m lower than pre-construction levels and has, therefore, resulted in exposed and free-spanning cable (which was addressed with additional scour protection in 2014). Lesser levels of scour has been detected at Substations 1 and 2, although there was a substantial increase in erosion at Substation 1 between 2013 and 2014 surveys. In addition, a number of array cables are still currently exposed due to depressions surrounding the WTGs. The degree of scour surrounding the WTGs was greater than was predicted, though there has been no interaction between scour holes from adjacent turbines, meaning that the assessments of the ES are still valid with respect to underlying physical processes in this area.

6.2. Benthic habitats

There were statistically significant differences in benthic communities between different project phases, and across seasons. Given that these statistically significant changes occurred across all project phases, i.e. between characterisation and pre-construction as well as between pre-construction and post-construction Year 1, it is difficult to attribute them to the installation and operation of the London Array project. In benthic communities of the southern North Sea both inter- and intra-annual change is to be expected, a situation that is also characteristic of mobile sand banks.

The results obtained, therefore, also validate the predictions made in the ES; that there would be only minor or negligible benthic impacts from the installation and operation of the OWF and cable route. It is recommended that further post-construction monitoring may not be required as all but one of the predictions of the ES have been validated.

The primary effects of WTG foundations on benthic ecology were investigated at three distances (50 m, 100 m, and 250 m), however no statistically significant effects were found that could be attributed to the presence of these structures. Studies have shown any effects due to the presence of epifauna communities on WTG foundations, and predation halos associated with mobile invertebrate predators, is likely to be only evident much closer than 50 m. As such it has not been possible to confirm the following null hypothesis:

H_0	*Colonisation of the London Array monopiles by marine organisms typical of the region will have no resulting effect on the surrounding benthic ecology.*

It should however be noted that in relation to fish aggregating at the WTG foundations, and foraging on infaunal communities, peer review data supports the hypothesis presented above.

The data obtained from the bathymetry survey showed that higher levels of scour have been observed than was predicted in the ES. This scour has the potential to effect benthic communities, however the results of the benthic survey do not suggest that there has been any effect. However, as benthic ecology was investigated at distances of 50 m, 100 m and 250 m it is difficult to determine if there has been any effect closer to the WTG foundations. Additionally, these surveys were not designed with the intention of monitoring the effects of bathymetry changes on benthic communities. Future monitoring surveys will provide more information regarding the results of this effect.

6.3. Fish resources

The results of the Year 1 post-construction fish survey show that the results from both the otter and beam trawl surveys indicate similar numbers of species recorded. Although there are some differences between surveys for catch rates of specific species this can be at least partly attributed to natural variation. It is also not possible to state whether the differences are statistically significant. In some cases the catch rates are comparable between pre- and post-construction surveys.

The numbers of Thornback Ray and other electro-sensitive fish species, which are noted in the marine licence conditions, have been consistent throughout the pre- and post-construction surveys. There were higher numbers of Thornback Ray recorded within the OWF array in the post-construction surveys, whereas there were higher numbers in control locations during pre-construction surveys. The results suggest that electromagnetic fields associates with the OWF and associated sub-sea cables have not had any effect on populations of Thornback Ray and other electro-sensitive fish species.

A comparison of the fish survey data with the epibenthic beam trawl data obtained in the benthic surveys shows that both surveys have produced similar results and conclusions. The two surveys found the same most abundant fish and invertebrate species. Both surveys concluded that the differences observed between surveys are attributable to natural variation rather than as a result of the construction and installation of the London Array OWF.

The results of the Year 1 post-construction survey suggest that the presence of the London Array OWF is not currently having any effect on fish populations and invertebrate species within the area. However, future monitoring surveys and comparison of subsequent data sets will more clearly demonstrate whether this continues.

6.4. Ornithology and marine mammals

The main bird species of concern is the Red-throated Diver, which is a designated feature of the Outer Thames Estuary SPA, and is known to be sensitive to anthropogenic disturbance, particularly vessel presence. Comparing the post-construction report to surveys conducted during construction and to the pre-construction surveys suggests that the numbers of Red-throated Diver within the OWF area declined during the construction of the OWF, but that numbers are now recovering to pre-construction levels.

The data obtained so far suggests that Red-throated Diver are increasingly utilising the OWF area now that the level of vessel disturbance associated with construction has decreased. Future ornithology surveys will give a clearer indication of Red-throated Diver distribution.

Other bird species and marine mammals were also recorded during the surveys. There has been a slight decrease in the number of Gannets recorded, and the numbers of Cormorants and Shags have increased. The decrease in Gannets is likely due to the avoidance of the wind turbines and the increase of Cormorants and Shags is due to the increased number of structures available to roost upon. The distribution changes of these species are not thought to have an effect upon the overall populations within the area.

The numbers of marine mammals recorded within the area has shown little variation. Large numbers of seals were recorded during the February 2014 survey due to a congregation hauled out together on a transient sandbank within the area.

7. Concluding Statement

A series of post-construction environmental surveys have been undertaken at the London Array OWF. These have primarily been designed and completed in order to ensure compliance with conditions within the Marine Licence for this project.

The following surveys have been undertaken:

- Bathymetric and sidescan sonar;
- Benthic grab and epibenthic beam trawl;
- Fish otter trawl and beam trawl; and
- Aerial bird surveys.

In summary, the results of these surveys enable the following concluding statements to be made, based on Year 1 post-construction monitoring:

- Physical effects, including localised scour around WTG foundations, are typical of those seen at all other UK OWF sites. Whilst some areas of scour identified occur at levels greater than predicted at the EIA stage, the key predictions presented in the London Array ES with respect to marine physical processes, remain valid, as there has been no interaction of adjacent scour pits and no measurable change in large-scale physical processes as a result of the operation of the London Array OWF;
- With respect to benthic ecology, the post-construction benthic data indicates that effects of construction and operation of the London Array OWF are similar to those recorded at all other UK OWF projects. Statistically significant differences in benthic communities between different project phases have been recorded. However, these changes have arisen not only between pre- and post-construction phases, but also between EIA characterisation stage and pre-construction, when the London Array OWF was neither being constructed or in operation;

- Therefore, it is difficult to attribute any changes to the installation and operation of the London Array OWF and it is concluded that these changes are more a factor of natural spatial and temporal variation in benthic communities;
- With respect to the prediction of benthic impacts presented in the London Array ES (RPS, 2005), data from these Year 1 post-construction surveys indicate that all but one of the predictions of the ES have been validated and, therefore, there is a case to be made for ceasing any further benthic surveys in the future as the predictions have already been confirmed. There has also been no change in the type of biotopes found across the benthic study area, further illustrating the lack of effect of this project on benthic communities in the wider region;
- Composition and number of fish species recorded in pre- and post-construction surveys were similar and catch rates were also equivalent. Thornback Ray and other elasmobranch species were of particular focus at the EIA and consenting stage, due to their potential sensitivity to electro-magnetic effects from installed sub-sea cables. Data from the Year 1 fish surveys indicate that numbers of these species have been consistent throughout the pre- and post-construction surveys, indicating that the OWF has not had an effect on Thornback Ray population or populations of other electro-sensitive fish species within the study area;
- Overall, results of the post-construction survey suggest that the presence of the London Array OWF is not currently having an effect on fish species within the area. Therefore, a case can be made for not undertaking any additional fish surveys following Year 1 post-construction as the assessments in the ES have been validated;
- From an ornithological perspective, Red-throated Diver has been the key focus of EIA work and subsequent monitoring to date. Survey data indicates that numbers of Red-throated Diver declined within the OWF area during the construction phase, but now are increasing towards pre-construction levels, based on data from the Year 1 post-construction aerial surveys. It is suggested that Red-throated Diver are beginning to increasingly utilise the OWF area now that the level of vessel disturbance associated with construction has decreased;
- Other post-construction results show a slight decrease in the number of Gannet recorded, and an increase in the number of Cormorant and Shag. A decrease in Gannet may be due to avoidance of the WTGs and an increase of Cormorant and Shag is likely due to an increased number of available structures to roost upon. A change in the distribution of these species is not thought to have any effect on overall populations within the area;
- In conclusion, the physical and biological changes recorded via the London Array Year 1 post-construction surveys are overall typical of similar changes recorded from other UK OWF projects and are also, in the main, in-line with predictions made via the original EIA process and presented in the London Array ES (RPS, 2005). The fundamental ecological processes supported by the physical environment on the subtidal sandbanks, and within the outer Thames Estuary appear unchanged. Near-bed sediment transport supporting the bank system has not been affected by construction of the London Array OWF, and ecological functionality of the bank system, apart from some localised changes due to scour, remains unchanged as a result of the project;
- Based on the data collected to date, no statistically significant effects have been identified that are attributable to the OWF and it is recommended that discussions now be initiated

between London Array Ltd and the MMO to discuss how the scope of future post-construction surveys be reduced or modified as a consequence.

8. References

APEM Ltd, 2010. *London Array offshore wind farm: Aerial survey methods, data collection and statistical analysis*. APEM Scientific Report 410955. London Array Ltd., August 2010 v3 Final, 40 pp.

APEM Ltd, 2011. *London Array offshore wind farm: Ornithology Aerial Survey Report 2010/11*. APEM Scientific Report 411245. London Array Ltd., October 2011, Final, 73 pp.

APEM Ltd, 2012. *London Array offshore wind farm: Ornithology Aerial Survey Report 2011 / 12*. APEM Scientific Report 411869. London Array Ltd., June 2012, Final, 77pp.

APEM Ltd, 2014. *London Array offshore wind farm: Ornithology Aerial Survey Report 2013 / 14. APEM Scientific Report*. 512696. London Array Ltd, January 2015, Draft, 77 pp.

APEM Ltd, 2015. *London Array Additional Analysis*. London Array Limited 512905

Bonte D., Van Dyck H., Bullock J. M., 2012. Costs of dispersal. *Biological Review* 87: 290–312.

Blott S. J., and Pye K., 2012. Particle size scales and classification of sediment types based on particle size distributions: Review and recommended procedures. *Sedimentology*. 59 (70): 2071-2096.

Bremner J., Paramor O.A.L., and Frid C.L.J., 2006. *Developing a methodology for incorporating ecological structure and functioning into designation of Special Areas of Conservation (SAC) in the 0-12 nautical mile zone*. School of Biological Sciences, University of Liverpool. 158pp.

Brown and May Marine Ltd, 2013. *London Array offshore wind farm Adult & Juvenile Fish and Epi-benthic Post-construction Survey*. Report ref LALOB01

Brown and May Marine Ltd, 2014. London Array *offshore wind farm Adult & Juvenile Fish and Epi-benthic Post-construction Survey*. Report ref LALOB02

Camphuysen K.J., Fox A.D., Leopold M.F., and Petersen I.K., 2004. *Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K*. Report commissioned by COWRIE Ltd for The Crown Estate. Royal Netherlands Institute for Sea Research, Texel, 38 pp.

Charbonnel E., Serre C., Ruitton S., Harmelin J.G., and Jensen A., 2002. Effects of increased habitat complexity on fish assemblages associated with large artificial reef units (French Mediterranean coast). *ICES Journal of Marine Science: Journal du Conseil*, 59(suppl.), S208-S213.

Coates D., Vanaverbeke J., Rabaut M., Vincx M., 2011. Soft-sediment macrobenthos around offshore wind turbines in the Belgian Part of the North Sea reveals a clear shift in species composition. In: Degraer S., Brabant R., Rumes B. (Eds.), *Wind Farms in the Belgian Part of the North Sea: Selected Findings from the Baseline and Targeted Monitoring*. Royal Belgian Institute for Natural Sciences, Management Unit of the North Sea Mathematical models, pp. 47e63.

Connor D. W., Allen J. H., Golding N., Howell K. L., Lieberknecht L. M., Northen K. O. and Reker J. B., 2004. *The Marine Habitat Classification for Britain and Ireland Version 04.05*. JNCC, Peterborough. ISBN 1 861 07561 8.

Cook A.S.C.P., and Burton N.H.K., 2010. *A review of the potential impacts of marine aggregate extraction on seabirds*. Marine Aggregate Levy Sustainability Fund, Marine Environment Protection Fund Project 09/P130.

CMACS, 2005. *Field Survey report – Benthic Sampling Using Beam Trawls, Otter Trawls and Day grabs in the Thames Estuary during 2003 and 2004*. A Centre for Marine and Coastal studies Report for Powergen. Report no. J3010/01-05.

Cramp S. and Simmons K.E.L., (eds) 2004. *BWPi: Birds of the Western Palearctic interactive*. [PC DVD] BirdGuides, London.

EGSi Ltd, 2013. *London Array Windfarm Export Cable Route Post-construction Survey (August/September 2013) Interpretive Report*. Report to Dong Energy

EGSi Ltd, 2014. *London Array Windfarm Site and Export Cables Bathymetric Survey (Spring 2014) Survey Report*. Report to Dong Energy

EMU Ltd, 2010a. *London Array – Phase 1 Pre-Construction Baseline Benthic Ecology Study*. 39pp. Shell UK Ltd, 2004. London Array Wind Farm. Volume 1. Development Area Details Survey report. Report No. 10/J/1/03/1544/1077.

EMU Ltd, 2010b. *London Array offshore wind farm* Sabellaria spinulosa *Investigation*. Final Report to: London Array Ltd.

Folk R. L., 1954. The distinction between grain size and mineral composition in sedimentary nomenclature. *Journal of Geology***,** 62**,** 344 – 359 pp.

Fretwell S. D., and Lucas H. L., 1970. On territorial behavior and other factors influencing habitat distribution in birds. I. Theoretical Development. *Acta Biotheoretica* 19: 16–36.

Garthe S., and Hüppop O., 1999. Effect of ship speed on seabird counts in areas supporting commercial fisheries. *Journal of Field Ornithology*, 70, 28-32.

Hamilton W.D., and May R.M., 1977. Dispersal in stable habitats. *Nature* 269:578–581

Jensen A., 2002. Artificial reefs of Europe: perspective and future. *ICES Journal of Marine Science: Journal du Conseil*, 59(suppl.), S3-S13.

Jensen A., Collins K., and Lockwood P., 2000. Current issues relating to artificial reefs in European seas. *Artificial Reefs in European Seas*, 489-499. Springer: Netherlands.

King S., Maclean I. M. D., Norman T., and Prior A., 2009. *Developing Guidance on Ornithological Cumulative Impact Assessment for Wind Farm Developers.* COWRIE

Krijgsveld K.L., Fijn R. C., Japink M., van Horssen P. W., Heunks C., Collier M. P., PootM. J. M., Beuker D., and Dirksen S., 2011. *Effect studies Offshore Wind farm Egmond aan Zee: Final report on fluxes, flight altitudes and behaviour of flying birds.* Report 10-219. Bureau Waardenburg, Culemborg.

Kube J., 1996. Spatial and temporal variations in the population structure of the softshell clam *Mya arenaria* in the Pomeranian Bay (southern Baltic Sea). *Journal of Sea Research*, 35, 335-344.

Lack P., 1986. *The Atlas of Wintering Birds in Britain and Ireland*. T & AD Poyser, London

Langhamer O., 2012. Artificial reef effect in relation to offshore renewable energy conversion: state of the art. *The Scientific World Journal*, *2012*.

Lima L. S., 2009. Predators and the breeding bird: behavioural and reproductive flexibility under the risk of predation. *Biological Review* 84: 485-513.

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, 134 pp. ISBN: 978-0-907545-33-0

London Array Limited, 2013. During and Post Construction Marine Environmental Monitoring Plan Marine Licence Number: L/2011/00152/26. Doc No: LAL-CEM-00255 H

MarineSpace, 2014. *BritNed Cable Crossing Scour Remediation and Cable Protection Supporting Information Document – 2014*. Report prepared for London Array Operations and Maintenance Base and Blue Transmission

MMO, 2013. London Array offshore wind farm Phase 1. Request to revise post-construction bathymetric monitoring scope of work Response 2. Letter to Dong Energy Ltd.

Natural England and JNCC, 2010. *Departmental Brief: Outer Thames Estuary Special Protection Area*. JNCC/NE, Peterborough. [Online] Available at: *http:www.naturalengland.org.uk/Images/Thames-brief_tcm6-21728.pdf*

Natural England, 2013b. Appendix A: Natural England advice on the method to assess impacts to red throated divers in the Outer Thames Estuary SPA and aggregate extraction.

Natural Power, 2015. *London Array offshore wind farm Year 1 Post-construction Benthic Monitoring*. Report to Dong Energy Power (UK) Ltd

O'Brien S.H., Wilson L.J., Webb A., and Cranswick P.A., 2008, Revised estimate of wintering Red-throated Divers *Gavia stellata* in Great Britain. *Bird Study*, 55, 152-160 pp.

Percival S., 2009. *Kentish Flats wind farm: Review of Monitoring of Red Throated Divers 2008-2009***.** Report by Ecology Consulting On Behalf of Vattenfall Wind Power. 37pp.

Reid J.B., Evans P.G.H., and Northridge S.P., 2003. Atlas of Cetacean distribution in north-west European waters. Joint Nature Conservation Committee.

Reiss H., Degraer S., Duineveld G. C. A., Kroncke I., Aldridge J., Craeymeersch J., Eggleton J. D., Hillewaert H., Lavaleye M. S. S., Moll A., Pohlmann T., Rachor E., Robertson M., vanden Berghe E., van Hoey G., and Rees H. L., 2010. Spatial patterns of infauna, epifauna, and demersal fish communities in the North Sea. *ICES Journal of Marine Science*, 67: 278–293.

RPS, 2005. *Environmental Statement. Volume 1: Offshore works*. Report for London Array Limited

Schwemmer P., Mendel B., Sonntag N., Dierschke V. and Garthe S., 2011. Effects of ship traffic on seabirds in offshore waters: implications for marine conservation and spatial planning. *Ecological Applications*, 21, 1851-1860 pp.

Skov H., Heinänen S., Lohier S., Thaxter C., Zydelis R. and Stock A., 2010. *Modelling the abundance and area use of wintering red-throated divers in the Outer Thames Estuary*. DHI draft report to London Array Ltd.

Stone C. J., Webb A., Barton C., Ratcliffe N., Reed T.C., Tasker M. L., Camphuysen C. J. and Pienkowski M. W., 1995. *An atlas of seabird distribution in north-west European waters*. JNCC, Peterborough.

Tasker M.L., Webb A., Hall A.J., Pienkowski M.W., and Langslow D.R., 1987. *Seabirds in the North Sea*. Nature Conservancy Council, Peterborough.

Thomas N. S., 2001. Procedural Guideline No. 3-9 Quantitative sampling of sublittoral sediment biotopes and species using remote-operated grabs. Marine Monitoring Handbook. Peterborough, JNCC. ISBN 1 86107 5243

Webb A., Dean B. J., O'Brien S. H., Söhle I., McSorley C. A., Reid J. B., Cranswick P. A., Smith L. E. and Hall C., 2009 *The numbers of inshore waterbirds using the Greater Thames during the non-breeding season: an assessment of the area's potential for qualification as a marine SPA*. JNCC Report 374, JNCC, Peterborough.

Wernham C. V., Toms M. P., Marchant J. H., Clark J. A., Siriwardena G. M., and Baillie S. R., (eds) 2002. *The migration atlas: Movements of the birds of Britain and Ireland.* T. & A. D. Poyser, London.

Wilhelmsson D., Malm T., and Öhman M. C., 2006. The influence of offshore windpower on demersal fish. *ICES Journal of Marine Science: Journal du Conseil*, *63*(5), 775-784.

Zucco C., Wende W., Merck T., Köchling I., and Köppel J., 2006. *Ecological Research on offshore windfarms: International exchange of experiences (Part B Literature Review of Ecological impacts)*. pp. 284.

9. Annexes