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Contents

EXECUTIVE SUMMARY	V
1 INTRODUCTION	1
2 FEPA LICENCE REQUIREMENTS	4
3 SUMMARY OF MONITORING ACTIVITIES	5
3.1 Year 3 Post-Construction Surveys	5
3.1.1 Consultation	5
3.2 All Previous Monitoring Surveys	6
3.3 Response to Licensing Authority Comments	6
4 OVERVIEW OF FEPA COMPLIANCE, SURVEY METHODOLOGY AND RESULTS	10
4.1 Overview	10
4.2 Suspended Sediment Concentrations and Current Monitoring	12
4.2.1 FEPA requirements	12
4.2.2 Summary of the predictions made in the ESs	13
4.2.3 Summary of monitoring data	14
4.2.4 Discussion on comparability of the ES predictions and monitoring data	19
4.2.5 Conclusions	21
4.3 Beach Profiles	22
4.3.1 FEPA requirements	22
4.3.2 Summary of beach profile changes pre-construction	23
4.3.3 Summary of beach profile changes post-construction	25
4.3.4 Overview of beach re-nourishment volumes	26
4.3.5 Commentary on the validation of the UNIBEST predictions	27
4.3.6 Conclusions	28
4.4 Subsea Noise	29
4.4.1 FEPA requirements	29
4.4.2 Summary of Methodology and Results	30
4.4.3 Conclusions	32
4.5 Fish Community	34
4.5.1 FEPA Requirements	34
4.5.2 Methodology and Results of the Year 3 survey	35
4.5.3 Methodology and Results for inter-year comparisons	39
4.5.4 Results for any comparison with wider data sources	48
4.5.5 Piling versus non-piling surveys	49
4.5.6 Electro-magnetic fields	50
4.5.7 Comparisons with the LID Environmental Statements	51
4.5.8 Conclusions	52
4.6 Marine Mammals	54
4.6.1 FEPA requirements	54
4.7 Seabed Morphology & Scour	55
4.7.1 FEPA Requirements	55
4.7.2 Methodology and Results of the Year 3 survey	56
4.7.3 Methodology and Results for inter-year comparisons	62
4.7.4 Comparison with the LID Environmental Statements	66
4.7.5 Conclusions	66
4.8 Benthic Communities	68
4.8.1 FEPA Requirements	68
4.8.2 Methodology and Results of the Year 3 survey	69
4.8.3 Methodology and Results for inter-year comparisons	73
4.8.4 Comparisons with the LID Environmental Statements	79
4.8.5 Conclusions	80
4.9 Ornithological Monitoring	81
4.9.1 FEPA requirements	81
4.9.2 Aerial Bird Survey	82
4.9.3 Boat-based Bird Survey	91
4.9.4 Pseudo-Static Observations	105
4.9.5 State of the art techniques for monitoring collision impacts	107
4.9.6 Bird Detection Radar	109
4.9.7 Synthesis of Ornithological Monitoring Results	116

4.9.8	Conclusions	121
4.10	Archaeology	124
4.10.1	FEPA Requirements	124
4.10.2	Update on FEPA compliance	124
4.10.3	Conclusions	125
4.11	Drill arisings	127
4.11.1	FEPA Requirements	127
4.11.2	Methodology and Results of the Year 3 survey	128
4.11.3	Methodology and Results for inter-year comparisons	132
4.11.4	Conclusions	134
5	DISCUSSION OF INTER-RELATIONSHIPS	136
5.1	Overview.....	136
5.2	Subsea Noise and Marine Fish.....	136
5.3	Benthic Communities and Sediment Distribution.....	136
5.4	Benthic Communities and Marine Fish	137
5.5	Ornithology.....	137
5.6	Physical Processes.....	138
6	CONCLUSIONS.....	139
6.1	Key observations from the monitoring programme	139
6.1.1	Potential temporary changes from construction	139
6.1.2	Potential changes recorded post-construction.....	139
6.1.3	Evidence for no wind farm related changes.....	140
6.2	Overall Conclusion	141
7	REFERENCES	145
8	APPENDICES	150

Executive Summary

Introduction

The Lynn and Inner Dowsing (LID) offshore wind farms are comprised of 27 turbines at Lynn and 27 turbines at Inner Dowsing, and are located between 5 km to 8.5 km off the Lincolnshire coast. Construction of the wind farms commenced in 2007 and the wind farms were fully operational by March 2009.

This annual report, consisting of a Summary Report and Appendices, presents the results of the third and final year of post-construction environmental monitoring at the LID sites, and integrates the results of all previous monitoring to date. The overall purpose of this Summary Report is to fulfil the requirements of the FEPA Licences / Deemed Marine Licences (Lynn Licence 31792/10/1; Inner Dowsing Licence 31814/10/2; and drill arisings FEPA Licence 33553/07/0), which cover the offshore and near shore elements of these projects.

The LID monitoring programme covers a 10 year period, with some pre-construction surveys commencing in 2002, and the final post-construction survey taking place in 2012. The pre-construction surveys took place between 2002 and 2005, with during-construction surveys being carried out between 2007 and 2008, and the post-construction surveys taking place between 2009 and 2012. Eleven main physical and biological environmental parameters have been monitored during this monitoring programme, including suspended sediment concentrations, currents, beach profiles, subsea noise, fish communities, marine mammals, seabed morphology, ornithology, benthic ecology, archaeology, and drill arisings.

Suspended Sediment Concentrations and Currents

In response to the FEPA Licence requirements on monitoring suspended sediment concentrations (SSC) and currents, Titan Environmental Surveys (Titan) were commissioned to collect suspended particulate matter (SPM) and current measurements from four measurement sites around the LID wind farms over the course of three deployments, namely pre-construction, during construction (drilling, piling and cabling) and post-construction. The measurement sites were chosen to measure the effects of sediment release at a far-field location, within the locations of the two wind farms, and at a control point outside the influence of the two wind farms. A turbulent wake survey was also carried out post-construction, with measurements taken over a flood tidal cycle to map the turbulent vortices and wake generated in the lee of a single turbine monopile.

Elevated SSC levels were measured by Titan over the construction period. Wave conditions and construction activities (export cable installation and drilling of monopiles) were thought to be responsible for increasing sediment concentrations within the water column within the vicinity of the wind farms.

The measured currents at the two deployment sites within the wind farms agreed with the modelled results presented in the LID Environmental Statements (ESs). The elevated SSC levels recorded during construction compared favourably with the predicted values from a specific pre-construction study. The wake study confirmed the presence of a turbulent wake in the lee of a monopile, extending 400 m downstream at maximum tidal streaming during flood and in the direction of the prevailing tidal current.

Beach Profiles

The FEPA Licence requirements for the LID offshore wind farms required the Licence Holder to validate the modelling predictions of UNIBEST, as reported in the ESs and the ES Coastal Processes Addendum, using Environment Agency (EA) beach profile monitoring outlined in Annex 1 of the FEPA Licences. This validation also required knowledge of beach re-nourishment quantities applied by the EA. Beach profile monitoring undertaken by the EA is spaced every 1 km along the Lincolnshire shoreline and collected during winter and summer periods. Profile data is available for pre- and post-construction (with wind farm structure installation completed July 2008) and it is understood that this EA monitoring will continue for the foreseeable future. The UNIBEST modelling reported in the LID ESs and ES Coastal Processes Addendum was undertaken for a wind farm scheme which provides a greater blockage to the hydrodynamics (waves; tides) than the installed LID scheme, and should be considered conservative, both in the method of application and in the inputs used. As such, model predictions do not provide a direct basis for comparison with any beach profile monitoring. The conservative predictions from the ES Coastal Processes Addendum suggested that the only area with the potential for longshore transport to be influenced by the wind farms was between Skegness and Gibraltar Point, and on the basis that the wind farms would have a minor effect on waves approaching the coast. The present morphology along the coast remains heavily influenced by the Lincolnshire re-nourishment scheme and the annual and seasonal variation in the wave regime. Analysis of the EA profile data does not demonstrate that the presence of the wind farms has altered this behaviour.

Subsea Noise

The FEPA Licences required detailed post-construction data to be collected on the frequency and magnitude of underwater noise produced by the LID wind farms. A subsea noise survey was carried out at the LID sites by Subacoustech Environmental Ltd over the period 16–18 February 2011. A low noise hydrophone was deployed from the side of the survey vessel in order to carry out underwater sound recordings along six transects and in water depths of between 8 m to 30 m. Subsea noise measurements were analysed using dBht levels, which incorporates the hearing ability of a species by referencing the sound to the hearing threshold of that species. The results were interpreted in relation to the potential impact of measured subsea noise from the operational wind farms on species of fish and marine mammals in the region.

An overall increase in noise, compared to background noise, was detected in and around the wind turbine array for frequencies from 2 to 200 Hz. However, it was concluded that the increase in the species perceived noise levels at LID were within the typical variation expected for shallow water regions, and that the operational noise from the wind farms was unlikely to cause a significant behavioural response in the marine animals found in the region.

Fish Community

Pre-construction fish surveys took place during 2004/2005, with the post-construction fish surveys taking place in 2009/2010 (Year 1), 2010/2011 (Year 2) and 2011/2012 (Year 3). Four types of fish survey were carried out, otter and beam trawl, shrimp trawl, potting and longlining surveys. The longlining surveys were intended to capture electro-sensitive species, although the otter trawl gear also sample these species, such as rays and dogfish. Post-construction surveys within the LID wind farm sites were limited for a number of reasons, including safety, potential Annex I reefs, and due to vessel, weather and gear constraints. Data for each survey has been analysed using a range of univariate and multivariate analyses, to understand the spatial, seasonal and annual variations in fish and shellfish community composition. Site-specific data have also been compared with landings data for the wider area, to provide context to any season and annual variations observed. An assessment of the effect of piling noise (from the adjacent Lincs site) and electromagnetic fields (EMF) on fish community composition, and for the latter on electro-sensitive fish species, has also been undertaken.

In general, both seasonal and annual variations in the fish populations were noted from the site-specific surveys. These largely agreed with the wider patterns noted in the fisheries landings data, and therefore could not be attributed to the LID wind farms. No gross changes in species composition occurred between pre-construction and post-construction surveys. No discernible effects were noted on fish populations during the Lincs piling activities, however site-specific surveys undertaken during these piling events were limited to a few shrimp and potting surveys. Motile invertebrate species are generally thought to have low sensitivity to noise impacts, and any effects on these species would be highly localised, therefore no effects on these populations were anticipated. For EMF, whilst Thornback ray *Raja clavata* appear to have higher catch rates in the vicinity of the LID wind farm sites (the wind farms and along the export cables) post-construction compared with pre-construction, this apparent difference in catch rates was within the natural fluctuation recorded for the species across the survey sites and years. For other species of elasmobranchs, catch rates were sporadic across the survey sites and years and no general patterns could be observed. Therefore, it was concluded that no discernible EMF effect could be measured, within the known limitations of the paucity of sampling sites within the LID wind farm sites post-construction. In general, the fish monitoring surveys support the predictions made within the LID ESs, with localised changes not shown to have an impact on fish stocks over the wider area and in the longer term.

Marine Mammals

Marine mammal monitoring was carried out during the construction phase of the LID projects, and no post-construction monitoring was required by the FEPA Licences.

Seabed Morphology

Geophysical surveys were carried out over the LID sites and export cable corridors during the pre-construction (2002) and post-construction (2009, 2010, 2011) phases, in compliance with the FEPA Licence conditions. A comparison was carried out between the results of the post-construction surveys and the pre-construction survey. Bathymetric difference plots were produced using the post-construction datasets, to reveal changes over time and allow interpretation in terms of changes to seabed features, such as bedforms and features associated with infrastructure and construction (such as scour features, jack-up footprints, trial pits, the locations of the decommissioned test pile and meteorological mast and features associated with cables). In addition, side scan sonar data were compared to allow interpretation of potential changes to seabed sediment distributions.

The 2011 survey revealed that the dominant sediment type within the survey area was featureless gravelly sand to sandy gravel, which was consistent with the results from the previous surveys. The number of clay patches within the survey area was greater in the 2011 survey results than in the previous survey results, which could be attributed to

decreased sediment input or increased erosion over the sites. The location of megaripples varied across the surveys, indicating a degree of sediment mobility across the surveyed area, and erosion of areas linear seabed features was also observed over the post-construction surveys.

No notable trends in seabed elevation, in terms of either erosion or accretion, were revealed, with any observed changes being localised and generally related to features associated with construction or infrastructure. Some inter-array cables were noted as illustrating some scour (and corresponding accumulation) and a trend of sediment accumulation was recorded for the export cables across the post-construction surveys.

Localised scour is occurring around the majority of the LID wind turbine foundation locations, with the overall average of the maximum horizontal scour extent in 2011 interpreted to be 15.1 m, and the overall average of the maximum vertical scour extent interpreted to be 1.7 m. The ESs considered that the rate of scour would be most rapid immediately following construction, and would then decrease towards an equilibrium (although magnitudes and rates of scour were not detailed in the ESs). While the 2011 survey recorded the continuing development of scour at the turbines, a larger proportion of the total scour recorded occurred prior, and up to, 2009, therefore the observations to date broadly support the qualitative predictions regarding rate of scour.

The majority of the jack-up vessel footprints, created during construction in 2007 and 2008 by the MPI Resolution, are still visible in the most recent dataset (2011), up to 4 years after their creation. However, all MPI Resolution footprints have experienced accumulation in the centre of the depression and scour around the edges, with the rate of infilling being spatially variable across the sites due to locally varying availability of sediments and mobility / dynamics. In addition, the MPI Resolution footprints were not observed at all turbine locations in 2011, indicating that the footprints have infilled at such locations.

Ornithology

Three separate survey methods were employed to satisfy the FEPA Licence objectives on ornithology, namely aerial bird surveys, boat-based bird surveys and bird detection radar surveys.

Aerial bird surveys

Aerial bird surveys were used to provide broad-scale contextual information on bird distributions within the GW4 survey sector of the Greater Wash to support the fine-scale data collected at the LID sites via boat-based surveys. The monitoring dataset includes both visual and digital aerial surveys, following an evolution of the survey methods during the LID monitoring programme. Due to differences in survey design and methodology between digital and visual surveys, density surface modelling was chosen as the most appropriate method for producing abundance estimates for comparison and a z-test was used to statistically test for a difference between survey years.

Analysis of the aerial bird survey data focused on divers, auks, gulls and seaduck. **Density surface modelling results from previous visual and digital aerial surveys did not detect any** obvious increasing or decreasing trends between years for the species groups investigated, though numbers in each species group have fluctuated between years. The pooled abundance estimate of divers for all winter surveys in 2011/12 (latter stage of third year of operation, as defined by the boat-based bird survey analysis) was significantly lower than the pooled estimate in winter 2010/11 (latter stage of second year of operation, as above). **Visual patterns also suggested that some displacement of divers may have taken place during and following construction of the LID wind farms.** Auk numbers in the pooled estimate for winter 2011/12 (latter stage of third year of operation, as above) were significantly higher than the pooled estimates for all other winters with the exception of winter 2009/10 (latter stage of first year of operation, as above). There was no significant difference in pooled population estimates for gulls in winter 2011/12 compared to the pooled estimates in any previous winter seasons, and although not statistically assessed, there was no evidence for any overall change in Common scoter numbers since 2004/05.

Boat-based bird surveys

The site-specific boat-based ornithological surveys of the LID wind farm sites and a control area were conducted during the baseline characterisation (2001-2002), pre-construction (2003-2005), construction (2007-2008) and post-construction (2009-2012) monitoring phases. Analysis focused on 13 key species with a range of ecological requirements. Changes in the abundance and distribution of these key species was assessed using a variety of methods including statistical modelling and mapping of observations. Spatial modelling was also attempted but models performed poorly due to the limited numbers of observations of birds within the study area, and lack of information on prey abundance, primary productivity, temperature, salinity etc. (at appropriate spatio-temporal scales) which could possibly aid in the explanation of the observed distribution of birds.

Interpretation of the data was based on expert knowledge, behavioural observations and insights from published literature. Nine of the 13 key species showed **statistically** significant changes in abundance over time, although only four – Kittiwake, skuas (as a group), Guillemot and Sandwich tern – changed in a way that could be linked to the construction and operation of the wind farms (**however low numbers of skua species reduce confidence in these results**). Results indicated that three of these species (Kittiwake, skuas and Guillemot) were initially attracted to the

LID sites during construction, with populations subsequently falling to baseline levels during the initial operational period (years 1 and 2). In the third year of operation populations again increased. Although Lesser black-backed gull did not appear to show statistically significant changes in populations linked to the construction and operation of the wind farms, general trends suggested that they may have responded in a similar manner to the three species above. Sandwich tern appeared to show a different trend, increasing throughout the monitoring phases. **Despite the data limitations and lack of significant model results, Red-throated diver appeared to provide some evidence of disturbance and potentially displacement following the construction of the LID sites.**

A number of the key species did not appear to show any significant changes over time which could be related to the construction and operation of the LID sites. Common gull, Herring gull, Great black-backed gull and Gannet did not demonstrate any trends which could be linked with the construction and operation of the LID wind farms. **The analyses for Fulmar, skuas, Common tern and Razorbill were inconclusive due to low numbers of observations and the spread of data.**

With the possible exception of Red-throated diver, there was no particular evidence of significant or sustained displacement of the remaining key species from the wind farm sites. There was some indication that certain species may have been attracted to the wind farm sites during their construction and later during operation (third year of operation) which may be related to temporary construction activity at the adjacent Lincs wind farm or indirect 'reef effects'. There is however no evidence to support this due to the lack of available prey data at relevant spatial and temporal scales.

Bird detection radar surveys

Using a combination of radar ornithology and field observations, the use of airspace surrounding the LID wind farm sites was monitored for approximately three-quarters of the autumn migration period of Pink-footed geese during three post-construction years (2008 – 2010) and one during-construction year (2007). Near-scale horizontal avoidance of the LID turbines was apparent in this species following the installation of the wind turbines. Collision risk models based on these data indicated a low predicted mortality of one bird per autumn migration, which was within the range of values predicted in the pre-construction ornithology report (ESS, 2004).

Satisfying the FEPA Licence objectives for ornithology

Regarding objective 1 of the FEPA Licences for ornithology, namely assessing changes in usage of area by feeding birds and birds on passage, results have suggested **evidence of displacement for Red-throated diver, although data limitations inhibited the power of the statistical analysis to confirm the suggested trends. For the other key species there was no particular** evidence of significant **or sustained** displacement of birds from the wind farms. However, there was some indication that certain species were attracted to the wind farm sites during construction and later during operation (third year of operation). There was evidence for changes in usage of the area by Pink-footed geese, through near-scale horizontal avoidance of the installed wind farms during autumn migration.

Regarding objective 2 of the FEPA Licences for ornithology, namely assessing collision risk prior to construction of the wind farm and investigating techniques/methodologies for collecting data on actual collisions during and post-construction, collision risk modelling was carried out where deemed necessary during the Environmental Impact Assessment (EIA) stage and updated prior to construction. No system for the direct measurement of bird collisions with offshore wind turbines is currently commercially available. The bird detection radar studies that have taken place at LID have provided a beneficial method for observing bird avoidance behaviour of the wind farms. Although not a technique for monitoring actual collisions, this has used some of the most reliable technology available to date for determining flight activity around the wind turbines, both during daytime and night periods.

Regarding objective 3 of the FEPA Licences for ornithology, namely surveying benthos to inform reasons for possible changes in bird distribution and density on site, results of the benthic ecology surveys suggested that there was little evidence of significant change in the benthic habitat and communities over the monitoring period which might influence birds through prey availability.

Benthic Ecology

Pre-construction and post-construction benthic ecology and particle size data were collected for the LID sites in order to comply with the FEPA Licence requirements and to test the predictions made in the LID ESs. The data showed no evidence of large scale changes in the sediment composition or the benthic communities within the LID survey area. The sediments across the survey area were found to be consistent during pre-construction and post-construction surveys and the benthic infaunal community composition was found to be typical of the sediment types recorded within the survey area and for this region of the southern North Sea.

Annex I habitats (e.g. *Sabellaria spinulosa* reefs) were also recorded during both pre-construction and post-construction surveys, though many of these were ephemeral in nature, with only one area of Annex I reef identified during the most recent post-construction survey. The specific surveys carried out in the final year of post-construction monitoring, on a sample of the jack-up footprints and the drill arising mounds, showed historic impacts on benthic

communities that were highly localised to the features themselves, but also showed clear evidence of recovery of these communities since construction in 2007/2008. The post-construction benthic ecology data therefore validated the predictions made in the LID ESs, i.e. localised effects on benthic ecology with high recovery rates, and no evidence of broad scale effects.

Archaeology

The LID Archaeological Protocol required by the FEPA Licences has been updated to focus on the LID operations and maintenance phase. Once approved by English Heritage, this updated Protocol will continue to be in place throughout the lifetime of the wind farms.

The Archaeological Protocol applies to the sub-tidal and intertidal (to Mean High Water Springs mark) aspects of the projects and makes provision for the establishment of Archaeological Exclusion Zones to protect identified sites of interest. Nine Archaeological Exclusion Zones were initially identified, of which it is now proposed that four remain in place. During the construction stage of the wind farms, there were no instances of the installation jack-up vessel breaching any of the Archaeological Exclusion Zones. The FEPA Licence requirements for archaeology have been fulfilled.

Drill arisings

Six of the LID monopile locations required drilling during installation due to a hard underlying chalk formation. The resulting drill arisings mounds have been monitored at two locations within the wind farm sites, namely at LN02 and LN29. The available datasets include two diver surveys carried out following the deposition of the mound at LN29 in 2007, 3 bathymetric surveys (2009 – 2011; covering both mounds) and a benthic sampling survey (2011; also covering both mounds).

The surveys directly following spoil disposal indicated an initial (over 4 months) significant reduction in the height of the mound. Following this trend immediately after disposal, monitoring across the three post-construction years illustrated an initial trend of reducing mound height, but at a much slower rate than the period immediately following deposition, followed by stability in mound height in the more recent surveys. This was interpreted as an initial period of rapid erosion as the finer material within the spoil mound was winnowed by prevailing tidal currents, followed by relative stability.

The benthic ecology data collected during 2011 indicated that there were similarities between benthic communities at the two mound centres and those of surrounding areas. The results provided evidence of recovery of benthic habitats and communities at the mounds and in close proximity to the mounds, and that this was occurring even though the mounds were still evident.

Given the small number of drill arising mounds in the LID sites (i.e. 6), the highly localised area affected and the evidence of recovery of biological communities at the two mounds monitored, it was considered that there were no long term implications for the benthic environment of the LID sites from the presence of these mounds.

Inter-relationships

A discussion of the inter-relationships between several of these parameters is also provided, including for subsea noise and marine fish, benthic communities and sediment distribution, benthic communities and marine fish, ornithology and benthic communities, and for physical processes.

Conclusions

Potential wind farm related changes have been indicated for certain environmental parameters from the monitoring data, however for other environmental parameters, no wind farm related changes have been noted. In addition, there are parameters for which potential wind farm related changes were observed at the construction stage, where evidence now suggests recovery towards previous conditions. These 3 outcomes are discussed below.

Regarding localised changes detected during construction, this appears to be the case for suspended sediments, whereby elevated SSC levels were measured over the construction period, in contrast to generally very low levels post-construction (although in lower wave conditions relative to during construction). In relation to the impact of the jack-up vessel footprints created during construction (2007 and 2008), the benthic sampling data collected from within the jack-up footprints and at associated reference locations in 2011 provided evidence of almost complete recovery of the communities within the jack-up footprints, and there was evidence that many of these footprints are gradually disappearing due to sediment accumulation. The benthic ecology surveys also confirmed the prediction in the ESs that the impact of temporary habitat loss due to cable laying would be “low level” and “medium term”. The surveys also confirmed that effects on benthic communities from increases in SSCs and sediment deposition were limited and if adverse effects occurred, full recovery has taken place since offshore wind farm construction. It was considered that there are no long term implications for the benthic environment of the LID sites from the presence of

the drill arising mounds, given the small number of mounds in the LID sites, the highly localised area affected and the evidence of recovery of biological communities at the two mounds monitored.

In terms of potential wind farm related changes detected from the monitoring data during the post-construction surveys, although the aerial bird survey analysis for the wider Greater Wash region showed no obvious increasing or decreasing trends between years for the species groups investigated, at the site-specific level, four of the 13 key species (Kittiwake, skuas, Guillemot and Sandwich tern) demonstrated trends which could be linked with the construction and operation of the wind farms (however low numbers of skua species reduce confidence in these results). Potential reasons for the observed effects are suggested in order to provide a considered discussion of the results, with the above trends attributed to attraction effects during construction (at both LID and at the adjacent Lincs site) and potential attraction effects from increases in prey resulting from 'reef effects' associated with the presence of the wind farms, however it is noted that there is no evidence to support this from the available data. Despite the lack of statistically significant results for Red-throated diver, this species appeared to provide some evidence of disturbance and potentially displacement following the construction of the LID sites, and this was supported by visual observations from the aerial bird survey results. The bird detection radar data provided evidence for near-scale horizontal avoidance of the wind turbines by Pink-footed geese on autumn migration.

Results from other monitoring surveys provided no evidence for wind farm related changes. There was no evidence for a wind farm related effect on the Lincolnshire beach profiles, with the shoreline behaviour appearing to remain dominated by the re-nourishment activities. The recorded operational subsea noise from the wind farms was unlikely to cause a significant behavioural response in the marine animals found in the region. Variations in fish populations in the vicinity of the wind farm sites largely agreed with the wider trends noted in fisheries landings data and therefore these variations could not be attributed to the LID wind farms. Furthermore, no gross changes in fish species composition occurred between the pre-construction and post-construction surveys. The presence of the wind farms has not caused any notable changes or trends in sediment type or seabed elevation across the sites, with the possible exception of the increased observation of clay patches post-construction. The construction of the LID offshore wind farms has not had a significant effect on the benthic habitats or communities present in the vicinity of the offshore wind farms, and has not affected the ability of reef building species to form reef habitats. In addition to the observations reported above regarding potential effects on ornithological receptors, with the possible exception of Red-throated diver the boat-based bird survey monitoring suggested that there was no particular evidence for any significant or sustained displacement from the LID sites based on the remaining key species investigated. No statistical changes in the use of the LID sites and buffers that could be linked to the construction and operation of the wind farms were identified for Common gull, Herring gull, Great black-backed gull and Gannet.

A series of surveys have been carried out at the LID sites and wider survey area for a range of environmental parameters, to fulfil the requirements of the monitoring programme set out in the LID FEPA Licences. Data have been collected over a 10 year period, with the first survey taking place in 2002 and the final survey being carried out in 2012. The data collected have been explored to the best extent possible through use of various analyses, and this has enabled trends to be revealed in the data, and interpretation of these trends, in terms of possible wind farm related changes, to be made. GLID have therefore complied with the requirements of the FEPA Licences with respect to environmental monitoring and it is considered that these requirements are now closed.

1 Introduction

The Lynn and Inner Dowsing (LID) offshore wind farms are comprised of 27 turbines at Lynn and 27 turbines at Inner Dowsing, and are located between 5 km to 8.5 km off the Lincolnshire coast (Figure 1). The LID projects are owned by GLID Wind Farms Topco Ltd (GLID), and managed by Centrica Renewable Energy Ltd (CREL) on behalf of GLID.

Construction of the wind farms commenced in 2007. Installation of the foundations and transition pieces at the two sites was completed in 2007. In 2008, the turbines were installed and construction works concluded with the installation of the export and inter-array cables. During the period from May 2008 to December 2008, the wind farms were partially operational during turbine testing and the wind farms were fully operational in March 2009.

This annual report, consisting of a Summary Report and Appendices, presents the results of the third and final year of post-construction environmental monitoring at the LID sites, and integrates the results of all previous monitoring to date. The third year of post-construction monitoring is generally represented by the period January 2011 to December 2011 (inclusive)¹. A list of contributors to this Summary Report is provided in Table 1 below.

The objectives of the LID Year 3 Post-Construction Monitoring Summary Report are:

- to report on the results of the third and final year of post-construction monitoring to the Licensing Authority;
- to report on any environmental changes observed over the during-construction and post-construction monitoring period, relative to the pre-construction baseline; and
- to validate, where possible and appropriate, the predictions made in the ESs and to reveal any unexpected outcomes or impacts (CEFAS, 2010).

Table 1: List of Contributors.

Section	Topic	Company
1-3	Introduction, FEPA Licence Requirements, Summary of Monitoring Activities	RPS
4.2	Suspended Sediments and Current Monitoring	Titan Environmental Surveys Ltd, reviewed by ABPmer RPS
4.3	Beach Profiles	ABPmer
4.4	Subsea Noise	RPS
4.5	Fish Community	RPS
4.6	Marine Mammals	RPS
4.7	Seabed Morphology and Scour	RPS
4.8	Benthic Communities	RPS
4.9	Ornithology	RPS ECON
4.10	Archaeology	RPS
4.11	Drill Arisings	RPS
5	Discussion	RPS
6	Conclusion	RPS

The overall purpose of this Summary Report is to fulfil the requirements of the FEPA Licences / Deemed Marine Licences (Lynn Licence 31792/10/1; Inner Dowsing Licence 31814/10/2; and drill arisings FEPA Licence 33553/07/0), which cover the offshore and near shore elements of these projects. In this document the FEPA Licence extracts for the main offshore wind farms have been taken from the Lynn Licence, as the licences are largely identical.

¹ i.e. this corresponds with the third year following full operation of the wind farms, although the exact period varies by survey parameter (e.g. the fish surveys continued to August 2012, and the aerial and boat-based bird surveys continued to February 2012).

The remaining sections of this report are structured as follows:

- Section 2 provides details of the FEPA Licence requirements with regards to post-construction monitoring;
- Section 3 provides a summary of the Year 3 post-construction surveys carried out, in addition to all surveys carried out over the pre-construction, during-construction and previous post-construction monitoring periods;
- Section 4 then provides an overview of the methods and results for each monitoring parameter;
- Section 5 draws together the results and findings of the different monitoring activities to provide a discussion regarding the findings of the monitoring;
- Section 6 provides the overall conclusions of the monitoring programme; and
- Finally, the Appendices provide the technical reports from individual survey activities, a formal response to the Licensing Authority's comments received on the LID Year 2 Post-Construction Monitoring Report, and a table of correspondence between the Licence Holder and the Licensing Authority during the monitoring programme.

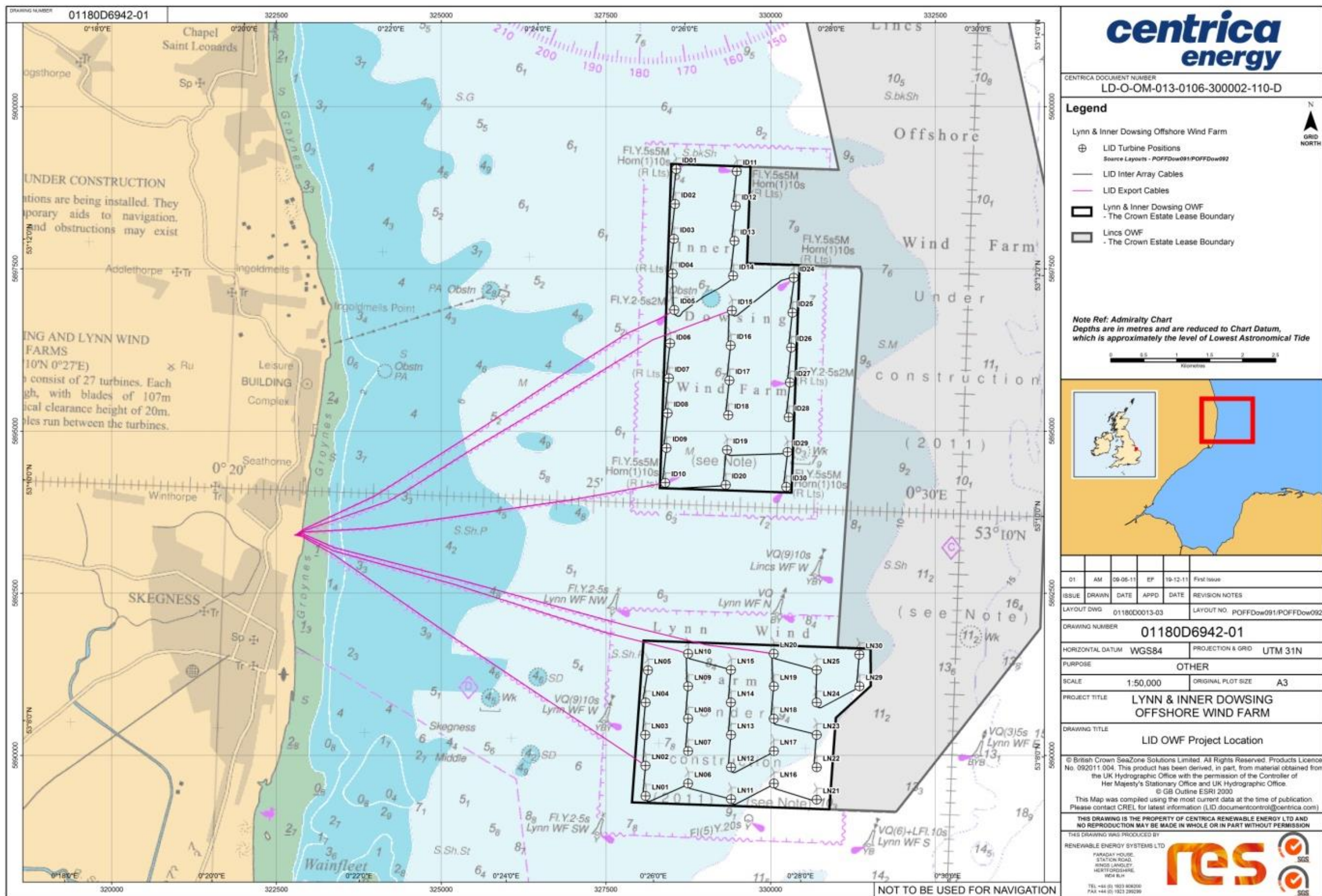


Figure 1: Location of LID wind farms and project infrastructure.

2 FEPA Licence Requirements

Post-construction monitoring at the LID wind farm sites has been carried out in order to meet the requirements of the FEPA Licences / Deemed Marine Licences (Lynn Licence: 31792/10/1; Inner Dowsing Licence: 31814/10/2; and drill arisings FEPA Licence 33553/07/0; Appendix 1). The Lynn and Inner Dowsing Licences include a series of Supplementary Conditions for the Licence Holder to fulfil, including monitoring to determine the effects of the wind farms on various environmental parameters.

The specific requirements for monitoring each environmental parameter are set out in the relevant sections of this Summary Report. Other more generic FEPA Licence requirements in relation to environmental monitoring are set out in Table 2 below.

Table 2: FEPA Requirements – Reporting.

Ref	FEPA Condition
9	The Licence Holder must submit the reports of monitoring activities set out in the following Supplementary Conditions to the Licensing Authority at the appropriate time in order to allow the Licensing Authority to consider if any action may be required to mitigate or correct any adverse effects which may be identified. The Licensing Authority reserves the right to vary or attach additional conditions to this Licence in the event that: 1. the results of monitoring studies required under the Terms of the Schedule to this Licence, or 2. any other observed effects considered to be directly associated with the works permitted by this Licence; indicate a risk of significant adverse environmental impact directly or indirectly from the wind farm.
9.4	The reports should include assessment, conclusions and an executive summary and the data within all reports should be presented in its processed and unprocessed forms. The various components of the monitoring programme and resultant reports, as described in conditions 9.5 to 9.10 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.

The FEPA Licences require that these monitoring activities are reported to the Licensing Authority on an annual basis. This Year 3 Post-Construction Monitoring Summary Report therefore presents the reports of the third and final year of post-construction monitoring activities at the LID sites. A summary of the methods and results of each monitoring activity is provided in this Summary Report, with the full reports provided in the Appendices. In response to condition 9.4 above, Section 5 of this Summary Report is aimed at addressing the inter-relationships between the different environmental parameters covered by the monitoring activities, where this is possible and appropriate.

3 Summary of Monitoring Activities

This section firstly outlines the monitoring surveys carried out during the third post-construction survey year, before presenting a comprehensive list of all surveys completed during the pre-construction, during construction, and post-construction phases, for the benefit of readers not involved in the earlier stages of the project.

3.1 Year 3 Post-Construction Surveys

Table 3 below lists the monitoring activities carried out during the third post-construction year. For ease of reference, surveys are listed in the order found in the FEPA Licences.

Table 3: Year 3 Post-Construction Surveys.

Monitoring Activity	FEPA Conditions	Contractor	Survey Period
Beach Profiles	9.6, Annex 1 (4)	N/A – monitoring carried out by the Environment Agency (EA)	Covered by EA monitoring January 2011 to December 2011
Marine Fish	9.8, Annex 1 (7)	Brown and May Marine Limited	September 2011 to August 2012
Seabed Morphology and Scour	9.23, 9.24, 9.28	EGS (International) Limited	October 2011
Benthic Organisms	Annex 1 (5)	EGS (International) Limited and Benthic Solutions Limited	October 2011
Aerial Bird Surveys	Annex 2	HiDef and WWT Consulting	November 2011 December 2011 January 2012 February 2012
Boat-based Bird Surveys	Annex 2	RPS/ECON	March 2011 to February 2012
Archaeology	9.31	Wessex Archaeology	Review of geophysical survey data in 2012
Drill arisings	FEPA Licence 33553/07/0, Annex	EGS (International) Limited and Benthic Solutions Limited	October / November 2011

3.1.1 Consultation

A table of correspondence between the Licence Holder and the Licensing Authority and their advisors over the monitoring programme for LID is presented in Appendix 10.

The LID post-construction monitoring programme was set out by the Licence Holder in a letter dated 06/05/09 to the Licensing Authority (Appendix 10; ref 10.15), which included the aims and methods for each monitoring activity. The programme was also discussed with Natural England (NE) during meetings on 28/04/09 and 28/04/10 (Appendix 10; ref 10.14 and 10.19).

Due to the proximity of the LID sites to the adjacent Lincs Offshore Wind Farm site, where construction commenced in March 2011, the Licensing Authority provided GLID with an option to delay the final year of post-construction monitoring until after the completion of Lincs construction (Appendix 10; ref 10.24). GLID considered that creating a two year gap in the dataset could compromise the monitoring at LID, and therefore the second option provided by the Licensing Authority was followed, whereby the LID post-construction monitoring continued simultaneously with construction at Lincs. The effect of Lincs construction on the LID monitoring data has been considered in this report, as requested by NE in the meeting of 21/06/12 (Appendix 10; ref 10.58).

The survey methodologies for the following Year 3 post-construction surveys were submitted to the Licensing Authority prior to surveys commencing:

- Marine Fish;
- Seabed Morphology and Scour;
- Benthic Organisms;
- Aerial Bird Surveys; and
- Drill Arisings.

The boat-based bird surveys were ongoing from previous years, with the methodology initially submitted to the Licensing Authority for the construction and post-construction surveys in 2007 (Appendix 10; ref 10.5), and discussed in subsequent meetings with NE in 2007, 2009 and 2010 (Appendix 10; ref 10.11; 10.14; 10.19)².

3.2 All Previous Monitoring Surveys

Table 4 lists all monitoring activities carried out during the pre-construction, during-construction and Year 1 and Year 2 post-construction phases (i.e. post-consent surveys), for ease of reference for those new to the projects.

A chart of all monitoring activities carried out during the pre-construction, during-construction and post-construction phases is provided in Table 5, which demonstrates the variety and frequency of surveys carried out over the entire monitoring period. Numbers are added to show the number of surveys carried out in each month where appropriate.

3.3 Response to Licensing Authority Comments

This Post-Construction Monitoring Report also presents GLID's detailed response to comments received from the Licensing Authority to the LID Year 2 Post-Construction Monitoring Report. This response is presented in Appendix 11 to this Summary Report. The majority of these comments were discussed in a meeting between GLID, MMO, NE and CEFAS on 21/06/12 (Appendix 10; ref 10.58), whereby GLID presented the approach to addressing the key comments.

² The Licensing Authority was notified of a minor change to the boat-based bird survey transect lines where these intersected with the proposed Lincs wind turbines, via email on 19/05/11 (Appendix 10; ref 10.35).

Table 4: Monitoring Surveys Pre-Construction, During Construction and Post-Construction.

Monitoring Activity	FEPA Conditions	Contractor / Source	Survey Period
Pre-Construction Surveys			
Suspended Sediments and Current Monitoring	9.26, Annex 1 (1), Annex 1 (3)	Titan Environmental Surveys Ltd	October to November 2004
Beach Profiles	9.6, Annex 1 (4)	N/A – monitoring carried out by the EA	Covered by EA monitoring 1991 to 2006
Subsea Noise and Vibration	9.7, Annex 1 (8)	Entec UK Limited	August 2005
Marine Fish	9.8, Annex 1 (7)	EMU Ltd	August 2004 to June 2005
			Mussel surveys: August 2005 to October 2005
Seabed Morphology and Scour	9.23, 9.24, 9.28	EMU Ltd	October 2001 April 2002 ³
Benthic Organisms	Annex 1 (5)	Envision Mapping Ltd	November 2004
		EMU Ltd (Lincs)	June 2005
Aerial Bird Surveys	Annex 2	WWT Consulting	13 November 2003 16 December 2003 ⁴
		DTI Strategic Survey (through WWT Consulting) (DTI, 2006)	3 November 2004 23 November 2004 26 January 2005 26 February 2005 18 May 2005 21 June 2005 27 July 2005 9 September 2005
		Department for Business, Enterprise and Regulatory Reform (BERR) Strategic Survey (through WWT Consulting) (BERR, 2007)	9 November 2005 29 November 2005 12 January 2006 4 March 2006 2 June 2006 20 June 2006 9 August 2006 19 August 2006
Boat-based Bird Surveys	Annex 2	Environmentally Sustainable Systems Ltd	August 2003 to April 2004 December 2004 to March 2005
Archaeology	9.31	Wessex Archaeology	Production of Archaeological Protocol, dated February 2006
During Construction Surveys (2 years)			
Suspended Sediments and Current Monitoring	9.26, Annex 1 (1), Annex 1 (3)	Titan Environmental Surveys Ltd	June and July 2007
Marine Mammals	9.12, 9.13, 9.14, 9.15, 9.16, 9.17	RPS	21 April 2007 to 25 November 2007
Aerial Bird Surveys	Annex 2	WWT Consulting	15 November 2007 4 December 2007 16 February 2008 30 March 2008
Boat-based Bird Surveys	Annex 2	RPS/ECON	July to December 2007 January to December 2008
Bird Detection Radar	Annex 2	RPS/FERA	1 Oct to 14 Nov 2007 (Construction) 29 Sept to 9 Nov 2008 (Year 1 Post-Construction ⁵)
Drill Arisings	Annex to FEPA Licence 33553/07/0	RPS Energy ABPmer	2007
Archaeology	9.31	Wessex Archaeology	Updated Archaeological Protocol, dated August 2006

³ These surveys were EIA characterisation surveys, however this was the only dataset available for comparison with post-construction surveys (EMU Ltd, 2002).

⁴ Note that the 2003 surveys were not used in the analysis of the aerial survey data presented in Section 4.9.2, as the analysis of previous data focussed on the months of January to March.

⁵ The autumn 2008 radar monitoring of Pink-footed goose was categorised as Year 1 post-construction monitoring, as all wind turbines were installed, although the wind farm sites were not yet fully operational.

Monitoring Activity	FEPA Conditions	Contractor / Source	Survey Period
Year 1 Post-Construction Surveys			
Suspended Sediments and Current Monitoring	9.26, Annex 1 (1), Annex 1 (3)	Titan Environmental Surveys Ltd	July and August 2009
Beach Profiles	9.6, Annex 1 (4)	N/A – monitoring carried out by the EA	Covered by EA monitoring 2006 to 2011
Marine Fish	9.8, Annex 1 (7)	Brown and May Marine Limited	August 2009 to July 2010
Seabed Morphology and Scour	9.23, 9.24, 9.28	EMU Ltd	30 June 2009 to 26 July 2009
Benthic Organisms	Annex 1 (5)	EMU Ltd	9-12 September 2009
Aerial Bird Surveys	Annex 2	WWT Consulting	27 February 2010 21 March 2010
Boat-based Bird Surveys	Annex 2	RPS/ECON	February 2009 to December 2009
Bird Detection Radar (Year 2 Post-Construction)	Annex 2	RPS/FERA	21 September to 5 November 2009
Year 2 Post-Construction Surveys			
Beach Profiles	9.6, Annex 1 (4)	N/A – monitoring carried out by the EA	Covered by EA monitoring 2006 to 2011
Subsea Noise and Vibration	9.7, Annex 1 (8)	Subacoustech Environmental Ltd	16 February 2011 to 18 February 2011
Marine Fish	9.8, Annex 1 (7)	Brown and May Marine Limited	August 2010 to June 2011
Seabed Morphology and Scour	9.23, 9.24, 9.28	EGS (International) Limited	19 July 2010 to 05 August 2010
Benthic Organisms	Annex 1 (5)	EGS (International) Limited and Benthic Solutions Limited	22 September 2010 to 31 October 2010
Aerial Bird Surveys	Annex 2	HiDef and WWT Consulting	9 January 2011 29 January 2011 14 February 2011 18 March 2011
Boat-based Bird Surveys	Annex 2	RPS/ECON	March 2010 to Nov 2010
Bird Detection Radar (Year 3 Post-Construction)	Annex 2	RPS/FERA	29 September 2010 to 12 November 2010
Archaeology	9.31	Wessex Archaeology	Review of 2010 geophysical survey data for a specific study area

Table 5: Chart of monitoring surveys.

Survey	Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Suspended Sediments and Currents	2004												
	2007												
	2009												
Subsea Noise and Vibration	2005												
	2011		3										
Marine Fish	2004								1	1	1	3	5
	2005		3	4	2	2	1						
	2009							3	4	2	1	2	
	2010			2		3	2	1	2	4	2	1	1
	2011	2	1	1	1	2	3			3	2	1	1
	2012	1	2	2		4	1	2	3				
Marine Mammals	2006				*								
	2007												
Seabed Morphology and Scour	2001												
	2002												
	2009												
	2010												
	2011												
	2011												
Benthic Organisms	2004												
	2009												
	2010												
	2011												
Aerial Bird Surveys	2003											1	1
	2004											2	
	2005	1	1			1	1	1		1		2	
	2006	1		1			2		2				
	2007											1	1
	2008		1	1									
	2010		1	1									
	2011	2	1	1								1	1
	2012	1	1										
Boat-based Bird Surveys	2003								2	4	1	2	
	2004	1		2	2								1
	2005		1	1									
	2007							1		3	3		1
	2008	1		1	1	1	1	1	1	3	2	1	1
	2009		1	1	1			1	1	3	3		1
	2010			1	1	1	1	1	1	3	3	1	
	2011			1	1	1	1	1	1	3	3		1
	2012		1										
Bird Detection Radar	2007												
	2008												
	2009												
	2010												
Drill Arisings	2007												
	2011												

Pre-construction	Year 1 Post-Construction	Year 3 Post-Construction
During Construction	Year 2 Post-Construction	* monitoring during test pile installation

4 Overview of FEPA Compliance, Survey Methodology and Results

4.1 Overview

This section provides a summary of the methods and results of the Year 3 post-construction monitoring surveys, drawing on each of the individual contractor Technical Reports provided in the Appendices. The summary of results for each environmental parameter or monitoring activity broadly includes:

- FEPA Requirements;
- Methodology and Results of the Year 3 survey;
- Methodology and Results for inter-year comparisons;
- Comparisons with the LID ESs and associated documents (where relevant); and
- Conclusions.

For completeness, this section also includes a summary of results for the environmental parameters for which the monitoring was completed in previous years, with the results already submitted to the Licensing Authority in the pre-construction, during-construction and previous post-construction monitoring reports. This ensures that this final post-construction monitoring report presents a comprehensive picture on the results of all monitoring carried out to date.

The parameters for which reporting has been completed in previous years are presented in Table 6 below:

Table 6: Parameters for which reporting already complete prior to Year 3 post-construction.

Parameter	Complete	LID Report
Suspended Sediment and Current Monitoring	✓	LID Pre-Construction Monitoring Report (CREL, 2005) LID Construction Monitoring Report (CREL, 2009) LID Year 1 Post-Construction Monitoring Report (CREL, 2010)
Subsea Noise	✓	LID Pre-Construction Monitoring Report (CREL, 2005) LID Year 2 Post-Construction Monitoring Report (CREL, 2012)
Marine Mammals	✓	LID Construction Monitoring Report (CREL, 2009)
Ornithology (radar)	✓	LID Construction Monitoring Report (CREL, 2009) LID Year 1 Post-Construction Monitoring Report (CREL, 2010) LID Year 2 Post-Construction Monitoring Report (CREL, 2012)

In order to ensure that comparisons between the monitoring results and the predictions in the ESs are robust, the LID scheme assessed in the ESs has been compared with the as-built scheme. The results of this comparison are presented in Table 7, and this has been taken into account in the reporting sections below where relevant.

Table 7: LID Offshore Wind Farms: ESs vs. As-Built Project.

Item	Lynn ES	Inner Dowsing ES	As-Built LID Project
Number of WTGs	30	30	54
MW per turbine	2 – 5 MW	2 – 5 MW	3.6 MW
Hub Height		Up to 90 m	82.75 m (CD)
Rotor diameter		Up to 120 m	107.2 m
Max tip height		150 m above mean sea level (MSL)	136 m (CD)
WTG Spacings	At least 5 rotor diameters across prevailing south-westerly wind direction; 7 diameters down the prevailing wind direction (rotor diameter 100 m).		Lynn: north/ south 480 to 500 m east / west 650 m ID: north / south 535 m east / west 920 m
Site area	2.5 km by 4 km (1.35 nm by 2.15 nm)	2 km by 5 km (1.1 nm by 2.7 nm)	Lynn: 7.882 km ² / 2.298 nm ² Inner Dowsing: 8.8067 km ² / 2.568 nm ²
Foundation type	Gravity base (caisson) (steel or concrete) – may require seabed preparation	Gravity base (caisson) foundation made of steel or concrete – may require seabed preparation	N/A
	Steel monopiles (driven)	Driven steel monopile	Monopile driven – 48
	Steel monopiles (drilled)	Drilled steel monopile	Monopile drilled – 6
Foundation size (m)	Gravity base: 4.5 to 6 m diameter steel tube up to 25 m diameter steel / concrete base	Gravity base: up to 6 m diameter at sea level	N/A
	Steel monopiles (driven): 4.5 to 6 m in diameter	Driven steel monopile: up to 6 m diameter at sea level	4.74 m diameter
	Steel monopiles (drilled) 4.5 m and 6 m diameter	Drilled steel monopile up to 6 m diameter at sea level	4.74 m diameter
Scour protection (foundations)	Rock dump Specialist matting	Anticipated not to be required for monopile options	None
Number of export cables	3 to 4 marine feeder cables	Up to 4	6
Voltage of export cables	33 kV		33 kV
Inter-array cable burial depth	Up to 2 m	1 – 3 m	Part of 6 cables in Lynn site shallow buried / exposed – application for cable protection submitted October 2012.
Voltage of inter-array cables		33 kV	33 kV
Scour protection (cables)	Cable protection mattress for local cable protection		Concrete mattress 6 m x 3 m wide, from seabed to J-tube. Total of 800 mattresses.
Export cable installation methods	Plough	Plough	Plough
Export cable burial depth	Up to 2 m		Average 2 m
Inter-tidal cable installation methods	Directional drill Lay direct (inter-tidal plough)	Trenching Directional drilling	Directional drill

4.2 Suspended Sediment Concentrations and Current Monitoring

4.2.1 FEPA requirements

The FEPA Licence requirements for monitoring suspended sediments and currents are set out in Table 8 below.

Table 8: FEPA Requirement – Suspended Sediments and Currents.

Ref	FEPA Condition
9.26	The Licence Holder must ensure that the networking of four seabed landers (Consented under CPA Consent 33610/07/0/CON) measuring suspended sediment concentrations must be maintained in operation during the cable laying. The frequency of sampling should be sufficient to monitor plumes which are episodic, i.e. the sampling should be near continuous with samples every ~30 seconds. The landers must be inspected regularly to check for bio fouling of any optical sensors. The suspended sediment concentration sensors are calibrated at spring and neap tides. The results from this monitoring should be included in the annual monitoring reports required under condition 9.4 to this licence.
Annex 1 (1)	Suspended Sediment Concentrations (SSC) The following monitoring must be undertaken to validate and confirm predictions. Monitoring must be based on spot profiling measurements (with water samples to validate instruments) during pre-construction, construction (during drilling, piling and cabling) and post construction periods. These would need to be deployed as follows: - At a representative point identified by the modelling and within the sediment plume to measure near-field effects of sediment release. - At a representative point identified by the modelling and within the sediment plume to measure far-field effects. - At a point outside the predicted area of the sediment plume to provide a 'control' measure of natural suspended sediment levels over the respective monitoring periods. Alternative approaches may be acceptable but the methodologies would have to be submitted to the Licensing Authority for review and agreement at least one month prior to the proposed commencement of the monitoring work.
Annex 1 (3)	Current Monitoring To monitor predictions made in the Environmental Impact Statement for the Lynn [and Inner Dowsing] windfarm of a wake effect downstream of each turbine further investigation is required. Post construction acoustic dopler current profiler ADCP monitoring should be undertaken taking transects through the wake region and upstream of the wind farm. The results should be compared to the predictions and discussed in the context of possible disruption to coastal processes. If changes in current velocity are significantly greater than predicted, then the consequences for the sediment transport regime will need to be re-evaluated.

The reports from the pre-construction, during construction and post-construction suspended sediment and current monitoring activities have already been submitted to the Licensing Authority as part of the Pre-Construction (CREL, 2005), Construction (CREL, 2009) and Year 1 Post-Construction Monitoring Reports (CREL, 2010). The post-construction monitoring was carried out during Year 1 post-construction only.

No further monitoring is required for suspended sediment and currents. However, this section of the Summary Report addresses the outstanding aspects of FEPA Licence Annex 1(1) and Annex 1(3), in relation to comparing the results of monitoring with the predictions made in the ESs. The status of monitoring and history of reporting for this parameter is also summarised in Table 9.

Table 9: Status of Monitoring – Suspended Sediments and Currents.

Phase	Requirement	Complete	LID Report
Pre-construction	Survey	✓	Pre-construction Monitoring Report (CREL, 2005)
During-construction	Survey	✓	Construction Monitoring Report (CREL, 2009)
Post-Construction	Survey	✓	Year 1 Post-Construction Monitoring Report (CREL, 2010)
	Comparing results of monitoring to ES predictions	✓	Year 3 Post-Construction Monitoring Report (CREL, 2012)

In order to fulfil the FEPA requirements, this section of the Summary Report aims to address the following question:

Q1	<i>Do the results from the suspended sediment concentration monitoring and current monitoring validate and confirm the predictions made in the Lynn and Inner Dowsing ESs?</i>
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4.2.2 Summary of the predictions made in the ESs

4.2.2.1 *Suspended Sediment Concentrations*

The ESs considered that the activity most likely to disturb the seabed sediments was the installation of the cables during the construction phase and other construction activities such as underwater grouting or boring of piles (Amec, 2002; OWP, 2002). The ESs considered that the cable installation was likely to cause seabed sediment to be raised into suspension and then be carried away from the source by the tidal currents. In the case of non-cohesive sediment ($>63\mu\text{m}$ – very fine sand), the ESs predicted that particles would settle back to the seabed within a period of a few hours. However, in the case of the silt and clay particles, the rate at which the particles settle was predicted to be insignificant compared to the turbulence caused by the action of waves and currents (Amec, 2002; OWP, 2002). Such sediment was considered in the ESs to be unlikely to settle, but rather disperse widely until the background sediment concentration was achieved.

Analysis of the cable installation procedure presented in the ESs showed that 2274 kg of fine silt and clay material would be created for every linear metre of cable trench. This was based on the worse-case construction technique (high-pressure water jetting and trench depth of 3 m). The amount of fine material was based on the assumption that all the clay would be broken up into its constituent parts. In reality, even using water jetting, it is likely that some of this would be excavated as larger lumps, which would be too large to be lifted into suspension. The actual dispersion of the fine material is likely to be complex and would depend on the timing of the operation with respect to the state of the tide, whether the tide was Spring or Neap and the sea conditions. However, to gain an appreciation of the likely concentrations remaining after a duration of approximately a day it was assumed in the ESs that sediment would be dispersed over a distance equivalent to the distance carried during one tidal cycle. On a Neap tide, the ESs suggested each water particle moves approximately 6 km down the coast on the flood tide, followed by approximately the same distance back up the coast on the ebb tide. The suspended sediment was predicted to be dispersed into a volume of water 6 km long by 5 m average depth by 1 m wide (Amec, 2002; OWP, 2002). Based on these calculations, the sediment concentration was calculated in the ESs to be 76 mg/l after dispersion during one tidal cycle.

The Environment Agency's (EA) water quality testing indicated that the background concentration of suspended sediment ranged from 5mg/l to 525mg/l, with an average value of 129mg/l (Amec, 2002; OWP, 2002). Therefore, the additional suspended sediment from cable installation was predicted to be unlikely to cause any greater impact than the day-to-day natural variation in suspended sediment concentrations.

A separate analysis was performed within the ESs to assess the impact of the resettlement of coarser suspended sediment. On a neap tide, the analysis showed that the majority (90%) of the sediment would settle back to the seabed within 50 m of the cable trench forming a layer on average 30 mm thick. The timing of the operation would dictate which side of the trench the material was deposited. A similar calculation performed in the ESs for the spring tide showed that the distance and thickness were 220 m and 7 mm respectively. In both instances, the ESs suggested it was likely that the actual thickness would be biased towards the immediate vicinity of the trench. It was predicted that the nature of the re-deposited sediment may have a slight short-term impact on the seabed, but that this would be unlikely to have any significant long-term environmental impact.

It is noted that in addition to the predictions made in the ESs (which as above, specifically relate to cable installation), a further study was carried out (ABPmer, 2006), and submitted in support of the FEPA Licence application for the deposit of drill arisings, to assess the potential dispersion and fate of spoil disposal from monopile drilling. Further details are provided in Section 4.2.4.2. The study predicted enhanced SSC above background levels (with peaks of 120 – 205 mg/l), but with these changes being localised and of short duration.

4.2.2.2 *Currents and Wakes*

Tidal currents were modelled using the numerical model, DIVAST, and were set up to simulate the flow of peak spring flood and ebb currents (AMEC, 2002; OWP, 2002) using Admiralty tidal stream publications to obtain the initial assessment of the current regime. The model input peak spring and neap tide velocities were of the order of 1.0 ms^{-1} and 0.5 ms^{-1} respectively. The modelling work concentrated on the peak tidal velocities because these were most likely to be more strongly affected by the presence of obstructions, such as the wind farms. The modelled results showed that for a baseline scenario (e.g. without the wind farms) the tidal current velocities ranged between 1.0 ms^{-1} and 1.3 ms^{-1} during springs. The model was then re-run to assess the impact of the wind farms on the current regime. Each wind turbine was assumed to consist of a 6 m diameter pile. A check was also made of the additional impact of a caisson foundation consisting of a 25 m^2 base protruding 2 m from the seabed (AMEC, 2002; OWP, 2002).

The modelling of changes to tidal currents due to the presence of the wind farms (i.e. $30 \times 6\text{ m}$ diameter monopiles per wind farm), predicted elongated wakes approximately 500 m long in the lee of the structures and a reduction in velocity. Velocities around a single monopile and in the lee of the monopile reduced from 1.0 ms^{-1} to 0.5 ms^{-1} showing

a reduction of 0.5 ms^{-1} .⁶ There was also a slight change in the direction of the flow particularly in the immediate lee of the structure. These conditions related to flat calm conditions. Under natural conditions, the effect of turbulence, wave and wind driven currents, and other effects will almost certainly be dominant and the “wakes” would not be apparent. Tidal regimes outside the vicinity of the wind farm sites were not predicted to be affected, with velocity and direction remaining the same (AMEC, 2002; OWP, 2002).

The results of the current modelling showed that the wind farms would have an effect on the current regime, but that the effect was very small and localised (AMEC, 2002; OWP, 2002). It was also noted in the ESs that a conservative approach was taken in the modelling, using peak tidal currents, whereas in fact, these only occur for a relatively small proportion of the time.

The impact of the wind farms on the wave climate was assessed by comparing wave heights under a number of conditions, with the presence of the wind farms (i.e. 30 x 6 m diameter monopiles per wind farm) and without the wind farms. The conditions assessed were 1 in 1 month and 1 in 1 year waves from 0°, 30° and 90° offshore sectors. The two return periods were chosen to represent operational (day to day) and typical annual storm conditions respectively. The numerical model SWAN was used to simulate the key processes and transform the selected offshore waves to a number of inshore locations. Overall, the predicted changes to the wave heights away from the wind farms were negligible (<0.1 m). Within the area of the wind farms the wave heights were predicted to reduce by up to 0.25 m.

In terms of implications for sediment transport, the ESs identified that local variations in the current regime around the base of the turbines may cause scour, which could increase the amount of sediment available for sediment transport away from the scour site. In addition, the ESs considered the potential for changes to the overall wave and current regimes to result in far-field changes to the distribution and the movement of the seabed sediment (Amec, 2002; OWP, 2002). The current velocity required to initiate sediment transport for a range of particle sizes were calculated empirically for current only conditions using Soulsby (1997) current threshold criteria (based on depth averaged current speed). Tests undertaken on the sediment samples obtained from the wind farm sites suggested that the D_{50} grain size lay between 0.1 mm and 3.0 mm (Amec, 2002; OWP, 2002). The peak tidal currents using the DIVAST model, showed currents to vary between 1.0 ms^{-1} and 1.3 ms^{-1} and under current only conditions, which could potentially mobilise available sediment into suspension up to a grain size of 0.7 mm (OWP, 2002). The analysis of the wave and current regimes in the ESs indicated that the changes to these parameters as a result of the wind farms were very small and therefore it is reasonable to assume that the far-field effect on the movement and distribution of seabed sediments would be insignificant.

4.2.3 Summary of monitoring data

Current and turbidity measurements were taken from four sites around the LID wind farms over the course of three deployments, namely pre-construction, during construction and post-construction (Figure 2, Table 10). The deployment sites are defined as follows:

- Site 1 – north-eastern part of Inner Dowsing wind farm (LN⁷);
- Site 2 – Far Field (FF) but near shore for both of the wind farms to the west;
- Site 3 – north east of the Lynn wind farm (ID⁸); and
- Site 4 – Control site (CL) for both of the wind farms to the east of the Lynn wind farm site.

Table 10 shows the time periods over which the data were collected. At each site an instrument package comprising a bottom mounted Acoustic Doppler Current Profiler (ADCP) coupled with a recording optical backscatter sensor to measure turbidity variations were deployed for a period of approximately 30 days during each deployment period.

⁶ The text in Section 10.2.3.1 of the ESs does not reflect the modelled figure results (Figure 10.3 and 10.4 of ESs). The text in the ESs suggest that within the wakes there was a predicted reduction in current velocity of 0.1 ms^{-1} and that in the immediate vicinity of the wind turbine structures there were some localised increases in current velocity of up to 0.2 ms^{-1} . Therefore, the ES text and ES figures do not agree, and the modelled figure results are used here for comparison.

⁷ In this study, Site LN refers to Inner Dowsing site rather than Lynn site. This should be noted with reference to the associated Technical Reports.

⁸ In this study, Site ID refers to Lynn site rather than Inner Dowsing site. This should be noted with reference to the associated Technical Reports.

Table 10: Deployment Periods for all Four Monitoring Sites.

Deployment	Start Date	End Date
Pre-construction	07/10/2004 13:30	08/11/2004 04:05
During construction	12/06/2007 08:20	15/07/2007 08:00
Post-construction	20/07/2009 15:52	24/08/2009 19:04

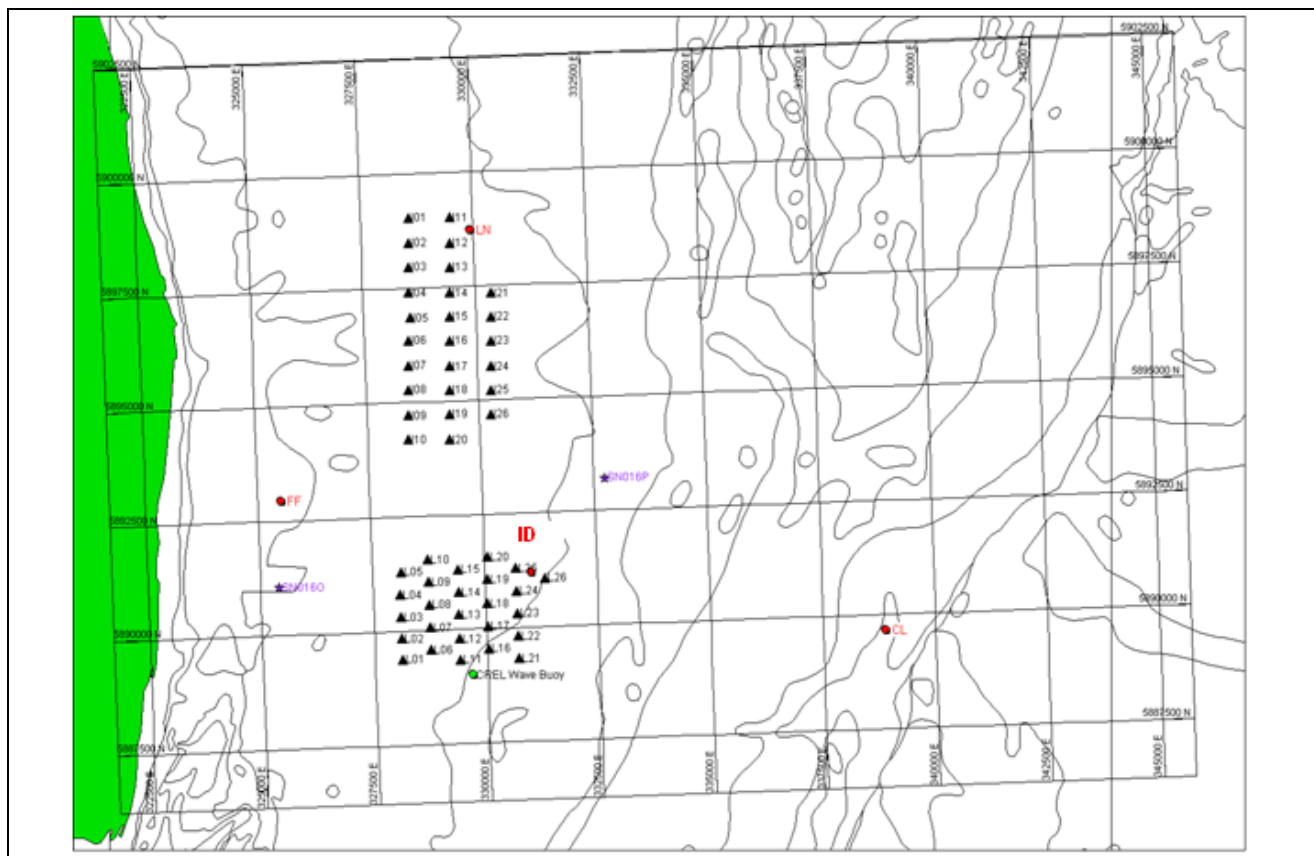


Figure 2: Location of the Monitoring Sites and DataWell Wave Rider Buoy at the LID wind farms (Note: Lynn turbine “L26” shown on the map relates to installed turbine LN29, and LN30 to the north is not shown; Inner Dowsing turbines 21 to 26 are labelled incorrectly and turbine ID30 to the south is not shown).

4.2.3.1 Suspended Sediment Concentration

Collection of near bed water samples were undertaken independently for each measurement site for each of the three monitoring campaigns (pre-construction, during construction and post-construction) over a tidal period as well as at the time of deployment and recovery of the monitoring equipment. Conversion of recorded turbidity data to SSC loads was undertaken using standard regression techniques and the calibrations reported (Titan, 2011). Table 11 shows the R values for each of the linear conversions applied to the raw turbidity data collected at each of the four sites. The majority of the correlations have R values between 0.3 and 0.8, representing a moderate level of correlation, with 0.3 and 0.8 indicating that only between 30% and 80% variance in Formazine Turbidity Units (FTU) can be explained by the variance in sediment concentrations obtained in the water samples.

Table 11: R values of the linear conversion relationships between Turbidity and SSC*.

Deployment	Lynn (ID)	Inner Dowsing (LN)	Control (CL)	Far Field (FF)
Pre-construction	0.37	0.24	0.02	0.32
During construction	0.27	0.55	0.84	0.4
Post-construction	0.52	0.62	-	-

*Note: Lynn Site is denoted as ID and Inner Dowsing Site is denoted as LN on Figure 2.

The near bed turbidity and SSC (mg/l) time series showed that in all cases, the SSC loadings during the construction phase deployments were significantly higher at three of the four monitoring sites when compared with the pre-construction and post-construction deployments. Only the Control Site located 7.5 km from the two wind farms (to

the east) showed turbidity and SSC values to be comparable with the values recorded during the pre-construction and post-construction deployments. Turbidity at the Control Site ranged from 15.8 FTU in pre-construction increasing to 51.1 FTU during construction and dropping to 31.0 FTU post-construction. Similarly SSC values were 16.3 mg/l, 28.8 mg/l and 17.3 mg/l respectively. The highest turbidity and SSC values were recorded at the Lynn (ID) site during the construction deployment period with values increasing up to 410 FTU equivalent to SSC of 243.7 mg/l. In the pre-construction and post-construction deployment phases the turbidity values at the Lynn (ID) site were 50.6 FTU and 26.2 FTU and 39.8 mg/l and 30.5 mg/l respectively (Titan, 2011).

Table 12 lists the construction activities which were taking place over the construction phase deployment period. Drilling activity occurred at ID14 (Inner Dowsing monopile No. 14) on 4 July 2007 which was located relatively close to, and south of, the Inner Dowsing (LN) site and most likely to be in the direction of any northerly ebbing tide. Drilling activity also occurred at LN02 (Lynn monopile No. 2) on 18 June 2007 and LN20 (Lynn monopile No. 20) on 15 July 2007 (however the deployment period for monitoring equipment ended at 08:00 on 15/07/07). LN20 is located relatively close to, and west of, the Lynn (ID) site (Figure 2), although the immediate advective path for any drill arising is most likely to be the north and south. In addition, cable installation activities were also taking place, as noted in Table 12 below.

Table 12: Construction Activity during Monitoring Period.

Activity	Location	Dates
Monopile installation – drilling	LN02 (Lynn)	18/06/07
Monopile installation – drilling	ID14 (Inner Dowsing)	04/07/07
Monopile installation – drilling	LN20 (Lynn)	15/07/07 (however, deployment period for monitoring equipment ended 15/07/07 at 08:00).
Cable installation	Export cable LNEXP06 – LN02 (Lynn)	Complete 13/07/07

The response of the suspended sediment concentrations to the hydrodynamic conditions (waves and currents) for the pre-construction, during construction and post-construction periods differed considerably as a consequence of the different forcing mechanisms. Therefore, direct comparisons of the resultant SSC time series between deployment phases were not possible without normalising the hydrodynamic forcing in some way. The effects of the hydrodynamic forcing agents (the currents and waves) on the sediment dynamics take place primarily through the friction they exert on the seabed. This is expressed in terms of the bed shear stress, which is the frictional force exerted by the flow per unit area of bed (Nm^{-2}).

A decision was made to calculate the wave only, current only and combined wave-current shear stresses based on the method outlined by Soulsby (1997) and using a representative grain size of 0.1 mm. The exact grain size chosen was not critical to the shear stresses calculated because the aim was to normalize the sediment response to the shear stress so that sediment entrainment over the pre-construction, during construction and post-construction deployment phases could be compared.

The time series of SSC for all four measurement sites and for the three deployments have shown that the background turbidity levels in the absence of waves, were comparable at all sites, with turbidity values increasing and decreasing in response to the spring and neap tidal cycle respectively. Background turbidity levels varied between 10 FTU over the neap tide cycle and up to 45 FTU over the spring tide cycle, which corresponded to near bed current-only shear stresses of approximately 0.5 Nm^{-2} and 2 Nm^{-2} respectively. Lowest background levels were recorded during the post-construction deployment period, where turbidity levels during the neap tides were generally <5 FTU and over the spring tide period <25 FTU.

The combined effect of wave action superimposed on the current regime played a significant role in elevating the sediment suspension levels above background turbidity levels during storms. Wave activity during the pre-construction deployment showed maximum wave heights of 3.16 m, producing near bed shear stresses capable of suspending sediment to peak turbidity levels of 100 FTU at the Far-Field Site. The same storm events did not however have the same impact at the other measurement sites, where turbidity levels throughout the pre-construction deployment period did not peak much above the background turbidity levels of approximately 45 FTU. Clearly, the shallow water conditions at the Far-Field Site induced higher shear stresses of 10 Nm^{-2} near the seabed as compared to combined shear stresses of between 3 Nm^{-2} and 5 Nm^{-2} calculated at the remaining three sites.

During the construction deployment period, there were three significant storm events with wave heights reaching 4 m. The combined effect of the currents and waves on the seabed at these times was to entrain much higher loads of sediment into suspension during these storm events at three of the four sites. Only the Control Site which was outside the wind farm construction area showed no significant change to the background turbidity levels during these periods of higher wave activity. The Lynn (ID) site measured the highest turbidity levels with peaks over the storm periods reaching 400 FTU (240mg/l), with between 250 (115 mg/l) and 350 FTU (160 mg/l) at the Far Field and Inner

Dowsing (LN) site respectively (Titan, 2011). Interestingly, the sediment remained in suspension for the duration of the storms and between storms fell back to the background turbidity levels.

The post-construction deployment was conducted in a period where there were no significant storm events and wave heights were generally <1 m. During this time, all four sites showed low background turbidity levels generally below 25 FTU, with the variation in suspension levels following the pattern of the spring and neap tidal cycle, typical for current only conditions (Titan, 2011).

It may be concluded that the construction activities being undertaken in the area (as detailed in Table 12) would have increased the supply of mobile sediment available for transport within the vicinity of the wind farms. Clearly, the prevailing wave and current conditions would have acted on this supply of sediment to entrain and transport it when entrainment thresholds were exceeded. The field data showed that the construction phase only caused a short term impact on the background turbidity levels with this entrainable excess material slowly redistributed and lost from the system. Data recorded during the post-construction period suggested suspended sediment loads at levels comparable to pre-construction conditions.

4.2.3.2 *Currents and Wakes*

Maximum tidal currents were measured at the Control Site (CL) and at the Inner Dowsing (LN) site over the spring tide periods in the post-construction monitoring period. The measured currents were 1.21 ms^{-1} during spring and 0.5 ms^{-1} during neaps and match closely the Admiralty tidal stream predictions used in the current modelling. The current direction was predominantly towards the North, North-East during ebb and towards the South, South-West on the flood. At the Lynn (ID) site, the maximum measured currents during springs was 1.16 ms^{-1} and at the Far-Field (FF) site 1.12 ms^{-1} again with maximum currents being measured in the post-construction monitoring period (Titan, 2011).

Titan also assessed the extent of the hydrodynamic interference imposed on one of the 4.7 m diameter monopiles installed within the Inner Dowsing wind farm on a peak flood spring tide (Titan, 2010). It is well recognised that when a steady current encounters a seabed mounted monopile which is roughly cylindrical in shape, the flow pattern changes in the immediate vicinity of the monopile by speeding up around the periphery of the pile, causing flow separation and consequently forming vortices. Vortex Shedding may then occur, giving rise to the beginning of the so called “von Karman vortex street” which will cause a highly turbulent wake in the region downstream of the pile. The water particles in the lee-wake vortices hold a high amount of energy and have a large influence on the morphodynamic processes. Seabed scour may occur due to the increase in the flow velocity and turbulence around the structure.

A vessel mounted ADCP was used to map the spatial extent, orientation and geometry of the wakes formed in the lee of a representative monopile. Previous experience suggested that the wake would be visible in two forms as measured by the ADCP, as an impact on the velocities themselves, and which is best described by considering the ADCP Error Velocity, and through the entrainment of air bubbles within the flow separation zone which act as strong scatterers thereby outlining the wake zone in the measurements of backscatter intensity.

The survey conducted on 15 May 2010 on a spring flood tide was focussed on the Inner Dowsing 11 turbine (position 329487mE, 5899016mN). Transect lines were spaced between 50 m upstream and 400 m downstream of the turbine along the major axis of the tidal current ellipse, with the transect lines extending 300 m to the East and 300 m to the West of the centreline. The transects were run approximately every 35 minutes for the 4 hours of the flooding tide with passes 5 and 6 being coincident with the time of peak flood current. The field data was taken over flat calm conditions in order to minimise the effects of waves and wind driven currents, masking the generation of the turbulent wakes. The results of the wake survey (Titan, 2010) showed that when the currents were $<0.3 \text{ ms}^{-1}$, turbulent wake generation in the lee of the monopile was minimal. When the current velocity ranged between 0.3 ms^{-1} to 0.85 ms^{-1} during flood, the turbulent wake vortices were present up to 100 m south of the monopile in the direction of the prevailing current. As velocity increased towards maximum tidal streaming, the turbulent wake vortices extended further away from the monopile. When the currents were 1 ms^{-1} , turbulent wake vortices were present up to 200 m downstream of the monopile. At maximum tidal streaming, when the currents were 1.2 ms^{-1} , the turbulent wakes extended 400 m downstream of the monopile as far as the limit that the transects were measured. This does not exclude the possibility that the wakes extended further downstream passed the limits of the transect, during this period of peak flood flow.

Table 13 summarises the passes undertaken with respect to predicted High Water time at Immingham.

The results of the wake survey (Titan, 2010) showed that when the currents were $<0.3 \text{ ms}^{-1}$, turbulent wake generation in the lee of the monopile was minimal. When the current velocity ranged between 0.3 ms^{-1} to 0.85 ms^{-1} during flood, the turbulent wake vortices were present up to 100 m south of the monopile in the direction of the prevailing current. As velocity increased towards maximum tidal streaming, the turbulent wake vortices extended further away from the monopile. When the currents were 1 ms^{-1} , turbulent wake vortices were present up to 200 m downstream of the monopile. At maximum tidal streaming, when the currents were 1.2 ms^{-1} , the turbulent wakes extended 400 m downstream of the monopile as far as the limit that the transects were measured. This does not

exclude the possibility that the wakes extended further downstream passed the limits of the transect, during this period of peak flood flow.

Table 13: Summary of the ADCP Passes Undertaken.

Operation	Monopile	Transects Run	Time of First & Last Passes	HW +/-
Pass1	ID11	-50 to 400	15-May-10 13:24-13:57	HW-5.09
Pass2	ID11	-50 to 400	15-May-10 14:02-14:31	HW-4.48
Pass3	ID11	-50 to 400	15-May-10 14:46-15:12	HW-3.78
Pass4	ID11	-50 to 400	15-May-10 15:24-15:55	HW-3.09
Pass5	ID11	-50 to 400	15-May-10 16:03-16:31	HW-2.47
Pass6	ID11	-50 to 400	15-May-10 16:38-17:06	HW-1.89

In reality, there are two issues working together, a reduction in the mean flow created by drag forces, as shown in the current modelling as a reduction in flow, and an increase in turbulence created by flows moving around the structure, as shown in the ADCP wake measurement study. As the current modelling in the ESs only considered the reduction in mean flow and not turbulence, the ADCP data collected (Titan, 2010) were also analysed to extract the depth averaged current flows around the 4.7 m diameter monopile structure. Figure 3 shows the depth averaged current vectors representative of maximum flow conditions around the monopile structure (depicted by the yellow circle) and downstream of the monopile during flood (Pass 6, Table 13).

The depth averaged current velocity vectors to the north of the monopile (blue transect 50 m N, Figure 3) was approximately 1.3 ms^{-1} and orientated towards the South South West. As the current flowed passed the monopile, the current direction was more variable along the transect, with the flow diverging towards the South West and South East downstream of the monopile (red transect 25 m S, Figure 3). As the current flowed further downstream, the current direction fluctuated between South South East (light blue transect 50 m S, Figure 3) and South South West (pink transect, Figure 3). The current velocity was variable along the transects ranging between 1 ms^{-1} and 1.3 ms^{-1} . It is however difficult to tell from the depth averaged vectors if there was flow reduction downstream of the monopile as the flow was variable along the transect.

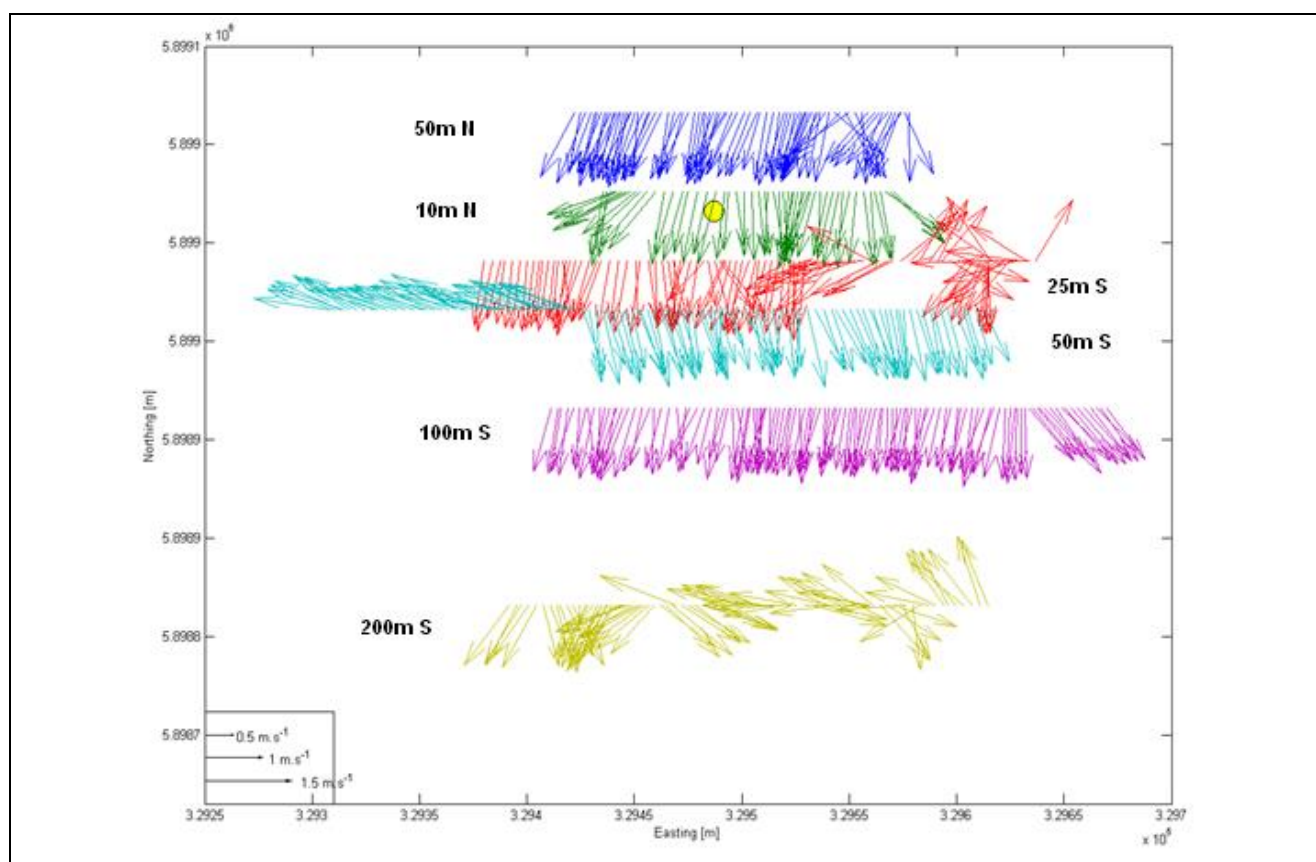


Figure 3: Depth averaged current vectors measured along each transects at maximum tidal streaming during Flood (Pass 6 in Table 13) – Titan wake survey 15 May 2010.

Figure 4 shows the depth averaged current speeds measured along each transect during Pass 6, 10 m North of the monopile (depicted in green), 25 m South of the monopile (depicted in red) and 100 m south of the monopile (depicted in pink). The zero vertical line in Figure 4 represents the position of the monopile and the chainage (m) is

the horizontal distance away from the monopile to the East and West of the monopile. The current velocities measured closest to the monopile (within 4 m to the East and West of the monopile) on the 10 m North transect and 25 m south transect were compared to determine if there was any appreciable reduction in flow immediately downstream of the monopile. Figure 4 shows that there was a distinct reduction in velocity from 1.25 ms^{-1} North of the monopile (green line) to 0.86 ms^{-1} , 25 m south of the monopile (red line) within 4 m of the monopile, showing a reduction of 0.39 ms^{-1} . This reduction in velocity in the immediate lee of the monopile was also observed in the modelled results, where a reduction of up to 0.5 ms^{-1} was predicted. The current velocity 100 m South of the structure (pink line, Figure 4) but in line with the other two measurements within 4 m of the monopile in the horizontal, showed an increase in velocity of 0.1 ms^{-1} , up to 0.96 ms^{-1} . The current direction depicted by the depth averaged vectors also suggested that flow divergence occurred in the lee of the monopile, with flow going toward the South West and South East 25 m South of the structure.

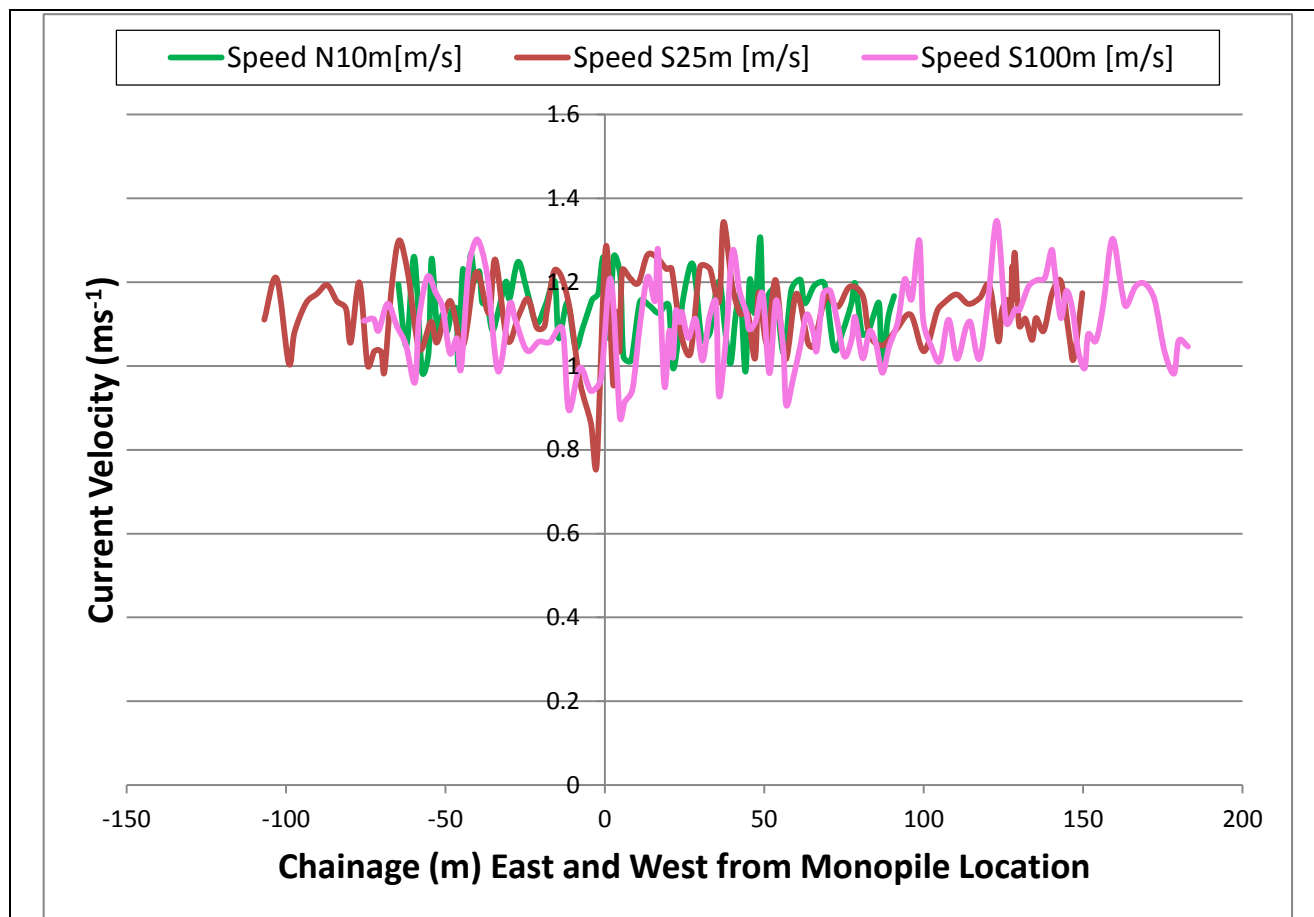


Figure 4: Current Speed for ADCP Transects to 10 m to North and 25 m and 100 m to South during Pass 6 (Table 13) – Titan wake survey – 15 May 2010.

4.2.4 Discussion on comparability of the ES predictions and monitoring data

4.2.4.1 Currents and Wakes

Whilst the ADCP is a mature technology in terms of its implementation as a tool to measure mean flow processes, and can be compared to the modelled currents from the ESs with confidence, the utilisation of this technology to investigate transient processes such as turbulent intensity and wake generation is a new application and indeed an area of active academic research, and as such, analysis of the wake survey data has been limited to qualitative interpretation of the data only. It must also be recognised that the ADCP's geometry, whilst critical in facilitating 3D measurements of flow structure and variation, does impose limitations on its ability to resolve structures smaller than 5 m in the horizontal sense. This is principally due to the instrument's transducers.

The modelled results of the currents from the ESs using the numerical model DIVAST in the presence of the wind farms showed a turbulent wake structure extending 500 m downstream of the monopile, with a decrease in current velocity in the vicinity of the monopile of up to 0.5 ms^{-1} (Amec, 2002; OWP, 2002)⁹.

⁹ When comparing the measured current flows in the vicinity of the monopile against the predicted flows, the modelled results actually showed a decrease in current velocity of up to 0.5 ms^{-1} and not an increase of 0.2 ms^{-1} as previously described in the ESs (Amec, 2002; Offshore Wind Power Ltd, 2002).

The model predictions were also representative of a spatially averaged (at 6 m resolution to be consistent with a maximum pile diameter of 6 m assumed for the ESs) change in depth averaged flow, and was not able to resolve turbulence. In contrast, the turbulent wake survey (Titan, 2010) was conducted around a 4.7 m diameter pile. The Titan wake survey detected the presence of the turbulent vortices through analysis of the ADCP error velocity and the backscatter intensity. Vortex shedding was evident, with vortices being measured spatially across the wake downstream of the monopile. The ADCP was also capable of resolving turbulent bubble structures of 10-20 m chainage length and which was found at distances of 400 m from the nearest monopile (the extent of the transect measurements).

The depth averaged current velocity vectors within the turbulent wakes were processed and analysed by Titan to allow a comparison with the modelled wake velocities as presented in the ESs (Amec, 2002; OWP, 2002). A reduction was measured in flow around the 4.7 m diameter monopile structure of up to 0.39 ms^{-1} in the immediate vicinity of the structure and increasing by 0.1 ms^{-1} 100 m away from the structure in the turbulent wakes. The result is within the predicted values from the modelled results of the depth averaged mean flows, which suggested a 0.5 ms^{-1} decrease in flow around the structure.

4.2.4.2 Suspended Sediment Concentrations

The ESs noted that the most likely disturbance to the seabed sediments would be during the cable installation. They also noted that the actual dispersion of the fine material was likely to be complex and would depend on the timing of the operation with respect to the state of the tide and the sea conditions. The ESs assumed that the sediment would disperse over a distance equivalent to one tidal cycle and be advected 6 km down the coast on flood, followed by approximately the same distance back up the coast on the ebb tide. A SSC of 76mg/l was calculated to represent levels after dispersion of the fine material over a complete tidal cycle. This estimate ignores any input from the discharge of sediment and water from the two large estuarine inputs, that would form part of background levels. This is important since these discharges could have a significant impact on the residual transport pattern of the region and hence the advective component of the suspended sediment field.

However, it should be noted that the above predictions from the ESs related to potential elevations in suspended sediments due to cable installation. As noted in Table 12, monopile drilling was also taking place during the deployment periods. An assessment of the fate of spoil disposal from proposed construction (drilling of monopiles) was undertaken and presented in ABPmer (2006). This assessment was used to predict the concentrations, spread and duration of elevated SSC, as well as the associated deposition footprints. Full details of the assumptions and scenarios used within this assessment can be found in ABPmer (2006). Two locations were assessed, each considered for an 'average' monopile installation, with one within the Lynn site and one within the Inner Dowsing site. The study provided an overview of SSC baseline levels relevant to the wind farm sites. At representative sites within LID, maximum SSC was recorded to be 40 mg/l, with a mean load of 29 mg/l (although it was noted that the instrumentation may have had an upper measurement threshold of 40 mg/l). The Southern North Sea Sediment Transport Study (HR Wallingford *et al*, 2002) provided background concentrations for the area of 8 – 128 mg/l in summer and 16 – 128 mg/l in winter. In addition, EA data (quoted previously within this report) provided levels of 5 – 525 mg/l, with an average of 129 mg/l.

ABPmer (2006) concluded that drilling operations may result in enhanced SSC measureable above background levels, but not detectable beyond a few kilometres from the drilling activity or after 7 days following dispersion, as material becomes entrained into background levels. More specifically, the results predicted high SSC immediately after release (120 – 205 mg/l) but this would be localised and of short duration. All SSC was predicted by the modelling to decrease to less than 50 mg/l after 7 days (ABPmer, 2006).

A comparison between the predicted elevations in SSC and the levels measured during the deployments is more usefully informed by the ABPmer (2006) study than the ES predictions. The ABPmer (2006) study considered the disposal of arisings from drilling activity. By contrast the ESs considered the potential elevations due to cable laying. Table 12 illustrates the construction activities that were taking place during the deployments, and it is the drilling of monopiles (associated disposal of spoil) that is the most likely cause of the elevations in SSC recorded in the field data.

The measured SSC levels during the pre-construction and post-construction monitoring phase showed low background levels over a 30 day period of <50 mg/l on average. Peaks in SSC up to 243 mg/l were observed to occur in the construction phase during storms, however the SSC peaks were of short duration. These predictions compare well with the results in ABPmer (2006), which predicted peaks in SSC immediately after release of 120 – 205 mg/l. Both the measured data and the predictions suggested these levels were of short duration. Given the limitations in the measurement of SSC data in the field outlined below, it is considered that these predicted (ABPmer, 2006) and measured data compare favourably. In addition, it is noted that the analysis presented above of the measured data

suggests that wave conditions during the construction phase deployment were likely to have contributed to the elevated SSC levels recorded.

4.2.4.3 Limitations

It should be noted that the three monitoring deployments were undertaken at different times of the year, under different wave climate conditions and tidal conditions, which would likely result in there being variations in the background suspended load of the water column from deployment to deployment. Differences resulting from variations in tidal forcing were however likely to be of a second order as the 30 day deployments covered both spring and neap tidal cycles.

The data presented by Titan (2011) did not take into account the distribution of the sediment particle size in suspension during the storm events and there was no way of quantifying the percentage contribution of fines (<63µm). Coarse material would have settled out of suspension after the storm events but may have been transported a distance away from the measurement site before settling. It must be further noted that measuring suspended sediment is highly subjective, and at best the sediment concentrations can only be gauged by an order of magnitude. Measured observations of suspended sediment concentrations are based on an optical measurement of turbidity in FTU, and are calibrated to SSC in mg/l using water samples which are a total concentration value of the sediment in suspension, which can lead to large scatter and errors in the calibration when the sediment in suspension is a mixture of cohesive and non-cohesive material.

It is noted that the model predictions for maximum wake extent did not consider the effect of turbulence (see section 4.2.4.1). It is also recognised that the ADCP could register a wake of only up to 400 m (the measurement distance limit).

4.2.5 Conclusions

Q1: Do the results from the suspended sediment concentration monitoring and current monitoring validate and confirm the predictions made in the Lynn and Inner Dowsing ESs?

Elevated suspended sediment concentration levels were measured over the construction period during the storm events. Notably, the construction activities on the seabed were thought to be responsible for increasing the supply of sediment available for suspension, within the vicinity of the wind farms. The construction phase field measurements clearly showed that during storms, there was more sediment in suspension. It is noted that a specific study investigating the disposal of drill arisings associated with monopile installation was completed (ABPmer, 2006), outside of the main ESs. This study provides a more useful reference point to compare to the measured values from the field deployments. Predictions made within the ABPmer (2006) study compare favourably to the field measurements of elevated SSC, with peaks in concentrations broadly comparable (see discussion above). In addition it is noted that wave conditions during the construction phase are likely to have contributed to the elevations in SSC observed in the field. Both the predicted SSC and the measured concentrations illustrated levels above background concentrations, however, these elevations were short lived.

The measured currents at the Inner Dowsing (LN) site and Lynn (ID) site (Titan, 2011) matched the modelled results presented in the ESs (Amec, 2002; OWP, 2002) with maximum flows of 1.3 ms^{-1} being measured in comparison to the modelled results ranging between 1.0 ms^{-1} and 1.3 ms^{-1} . The wake study confirmed the presence of a turbulent wake in the lee of a monopile extending 400 m downstream (the measurement distance limit) at maximum tidal streaming during flood and in the direction of the prevailing tidal current. The longer wake extents such as those observed in the field survey and the modelled results have the potential to increase the likelihood of interaction between groups of structures downstream of monopile ID11 particularly at WTG spacing below 500 m. However the LID wind turbines are spaced at 480 to 500 m north/south and 650 m east/west (Lynn) and 535 m north/south and 920 m east/west (Inner Dowsing). It may be concluded that the presence of the two wind farms has a negligible effect on the current regime and that any effect was very small and localised.

The current modelling in the ESs also suggested that turbulence generated around the monopiles following construction would cause local scour pits at the seabed and make sediment readily available for suspension and transport by the waves and tidal currents. The suspended sediment levels recorded by the monitoring sites during the post-construction period showed that SSC levels were generally low and varied only with the spring and neap tide cycle. However, there were no storm events during the post-construction monitoring period and the currents alone were not strong enough to suspend the non-cohesive sediment into suspension. It may be concluded from both the modelled results of the waves and currents and the field measurements of waves, currents and sediment concentration that the far-field effect on the movement and distribution of seabed sediment was insignificant and that the impact to the suspension of material off the seabed was local to the wind farm sites during construction and even then the impact was of a short term duration.

4.3 Beach Profiles

4.3.1 FEPA requirements

The FEPA requirements for monitoring beach profiles are set out in Table 14 below.

Table 14: FEPA Requirement – Beach Profiles.

Ref	FEPA Condition
9.6	The Licence Holder must validate the modeling predictions of UNIBEST using the beach profile monitoring outlined in Annex 1. Such validation will also require knowledge of any beach re-nourishment quantities.
Annex 1 (4)	Beach Profiles Regular monitoring of beach profiles is required along the Ingoldmells to Gibraltar Point frontage (this may be already carried out at a sufficient resolution by the Environment Agency). Monitoring should be undertaken to illustrate major changes in the annual profiles, and therefore should be carried out for example in September, January and April. In addition, beach nourishment quantities/locations should be provided, to be used with these profile changes in the subsequent interpretation.

Annex 1 of the FEPA Licences acknowledges that sufficient monitoring may already be carried out by the Environment Agency. Accordingly, the Year 1 and Year 2 Post-Construction Monitoring Reports have referred to the Environment Agency's reports on beach profile monitoring as part of the Anglian Coastal Monitoring Programme. The latest Environment Agency report is used in this section of the Summary Report to complete the monitoring requirements for beach profiles. The status of monitoring and history of reporting for this parameter is also summarised in Table 15.

Table 15: Status of Monitoring – Beach Profiles.

Phase	Requirement	Complete	LID Report
Pre-construction	Monitoring (via Environment Agency)	✓	Pre-construction Monitoring Report (CREL, 2005)
During-construction	Monitoring (via Environment Agency)	✓	N/A
Year 1 Post-Construction	Monitoring (via Environment Agency)	✓	Year 1 Post-Construction Monitoring Report (CREL, 2010)
Year 2 Post-Construction	Monitoring (via Environment Agency)	✓	Year 2 Post-Construction Monitoring Report (CREL, 2012)
Year 3 Post-Construction	Monitoring (via Environment Agency)	✓	Year 3 Post-Construction Monitoring Report
	Comparing results of monitoring to ES predictions (UNIBEST)	✓	Year 3 Post-Construction Monitoring Report

This section of the Summary Report aims to address the following question:

Q2	<i>Within the limitations and constraints of the data, to what extent can the beach profile monitoring be used to validate the predicted changes to long-shore transport as provided in the ESs and ES Addendum, and the conclusions of the ESs and ES Addendum?</i>
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In order to address this question, ABPmer were commissioned to carry out a desk study, with the objective of validating the modelling predictions of UNIBEST using the beach profile monitoring and knowledge of beach re-nourishment quantities. ABPmer's approach to validation presented below does not provide any further modelling, rather a review of the previous modelling approach, and key findings from this work are considered against those from the beach monitoring.

The data sources used by ABPmer to support this desk study are:

- Sediment sample analyses from Lincshore, courtesy of the Environment Agency (EA);
- Coastal Morphology Technical Note Lincshore (Environment Agency, 2012), provided in Appendix 2;
- Anglian Coastal Monitoring Programme, Lincshore coastal morphology report 2006 – 2011 (Environment Agency, 2011), provided as an Appendix to the LID Year 2 Post-Construction Monitoring Report;
- Anglian Coastal Monitoring Programme, Coastal Trends Analysis Lincolnshire (Environment Agency, 2008), provided as an Appendix to the LID Year 1 Post-Construction Monitoring Report;
- LID ESs (Amec, 2002; OWP, 2002) and ES Coastal Processes Addendum (Royal Haskoning, 2003);
- LID OWFs as-built information (Table 7 of this Summary Report); and
- Licensing Authority response to the LID Year 2 Post-Construction Monitoring Report (Appendix 10; ref 10.55).

4.3.2 Summary of beach profile changes pre-construction

Bi-annual beach profile monitoring data over a 16 year period and prior to the wind farm installation, allows for the derivation of 'natural'¹⁰ beach behaviour over the medium-term (periods of years). Of immediate interest to the present study is the behaviour of those profiles located in the Wave Shadow Zone (WSZ) of the installed wind farms (south of Skegness). Comparison with those profiles to the north of the WSZ provides a useful reference, although note should be made of the regular beach re-nourishment campaign (injection of large sediment volumes to the beach) and thus significant anthropogenic intervention, in addition to the different form of the shoreline. Figure 5 illustrates the position of the profiles considered within this section and full details pertaining to the beach behaviour are presented in EA (2008). It is of note here that the WSZ is a concept described in the ESs and is based on a limited number of wave model scenarios which take a conservative approach.

Along the Lincolnshire frontage, longshore sediment transport is to the south into The Wash and under the primary control of the wave climate. This is shown in the beach ridge and runnel systems which are orientated to the south-west and thus reflect the control of the north-easterly swell waves. Under stormy conditions, sediment is typically removed from the beach and transported offshore. Sediment deficit is such that, under the following calm periods, the beach profile is unlikely to recover to its pre-storm profile, hence, cross-shore transport plays a secondary role.

4.3.2.1 North of Wave Shadow Zone (Profiles P25, P50 and P75)

The frontage between Mablethorpe and Skegness can be characterised by the presence of hard sea defences. Historically, this shoreline has demonstrated erosive properties. However, with the introduction of beach re-nourishment activities, beach profiles indicate an increase in volume, although between re-nourishment events the beach continues to erode (EA, 2008). Should beach re-nourishment not be occurring, it is surmised that the beach would demonstrate highly erosive tendencies; indeed, it undergoes significant sediment loss shortly after a beach feed event (EA, 2008). Details relating to those profiles which were assessed within the LID ES Coastal Processes Addendum (Royal Haskoning, 2003) are presented in Table 16, with an overview presented below:

- P25 - sediment retention in upper beach, erosion of lower beach;
- P50 - sediment retention in upper beach, erosion of lower beach (2008 lower profile levels are below those of the early 1990's despite demonstrating the highest levels of sediment on the upper beach); and
- P75 - erosive tendencies, with beach levels only being maintained due to large volumes of re-nourishment sediment (following a large injection of material in 1995, the (2006) beach form had reverted to that in 1992).

4.3.2.2 Within Wave Shadow Zone (Profiles P100 and P111)

The frontage between Skegness and Gibraltar Point has no hard defences in place, and is instead characterised by a natural dune system.

South of Skegness, no beach re-nourishment activities take place. Beach profile analysis here indicates both erosive and accretive tendencies of the foreshore. Foreshore Change Parameter (FCP) for this coastal stretch ranges from -4 (retreat of both the Mean High Water (MHW) and Mean Low Water (MLW) marks, with the intertidal gradient flattening) to +6 (advance of both the MHW and MLW marks, with the intertidal gradient flattening). However, volumetric changes indicate that the beach volume has increased between the summers of 1992 and 2006. Details relating to those profiles which were assessed within the LID ES Coastal Processes Addendum (Royal Haskoning, 2003) are presented in Table 16, with an overview presented below:

- P100 - slight accretion of upper beach and erosion of lower beach. Analysis indicates an overall erosion trend, with a 4 m (approximate) retreat; and
- P111 - overall the profile exhibits accretive behaviour.

¹⁰ The use of the word 'natural' here refers to baseline behaviour in the absence of any influence from LID, but this may include other anthropogenic influences.

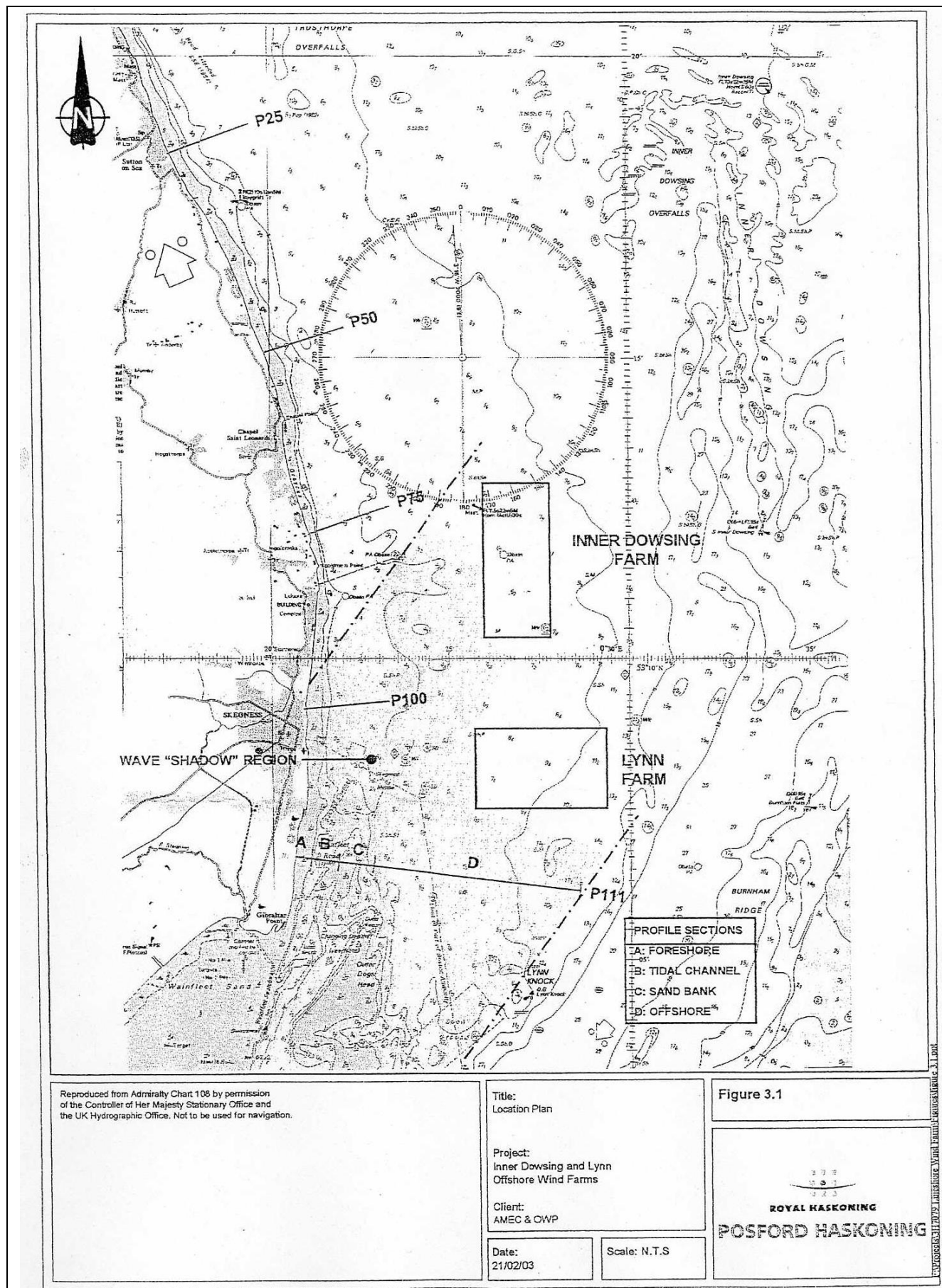


Figure 5: Position of Beach Profiles P25, P50, P75 and P100, P111 (Source: Royal Haskoning, 2003).

Table 16: Beach Profile Behaviour Pre-Construction (adopted from EA (2008)).

ES Addendum Ref (EA Profile ID, 2012; previous EA ID)	Location (approximate)	Wave Shadow Zone	Beach Re-nourishment Activity (#)	Foreshore Behaviour	Volume Change (approximate) m ² (*)
P25 (LO42; L2D8)	Sutton on Sea	No	Yes	Accretive	+400
P50 (LO48; L2C6)	Anderby Creek	No	Yes	Accretive	+250
P75 (LO54; L2B4)	Vickers Point	No	Yes	Accretive	+250
P100 (LO61; L2A3)	Skegness	Yes	No	Erosive	+200
P111 (LO64; L2A6)	Seacroft	Yes	No	Accretive	+750
Notes (*) between summer 1992 and summer 2006 (#) specific to the profiles of interest.					

4.3.3 Summary of beach profile changes post-construction

Since the completion of wind farm structure installation activities in July 2008, beach profile measurements have continued and the associated behaviour and trends are presented in the EA reports (EA 2011; 2012). Both reports comment that the Lincolnshire beach demonstrates trends consistent with those presented in previous (pre-construction) reports, with the erosive tendency of the frontage remaining. Beach re-nourishment activities remain beneficial, with a significant level of sediment being retained between 2011 and 2012 (EA, 2012). It is noted that the erosive trend is patchy both in the longshore and cross-shore due to the following behaviours:

- re-distribution of sediment from upper beach (adjacent to hard defences) to the beach berms;
- continued trend of water pooling leading to longshore depressions on the lower profile; and
- creation of island features on the lower profile resulting from channels.

This section provides a summary of any beach profile changes, with specific reference made to the five profiles of key interest.

4.3.3.1 North of Wave Shadow Zone (Profiles P25, P50 and P75)

This heavily defended section of coast remains subject to the addition of large sediment volumes as part of the shoreline management. Since 2010, beach re-nourishment has tended to take the form of a high frequency injection of smaller quantities of sediment. Further details are provided in Section 4.3.4.

Overall, this section of the Lincolnshire frontage, which includes the Profiles P25, P50 and P75, has shown signs of growth and retention of re-nourishment material along the upper beach. It has been hypothesised that this has occurred as a result of aeolian effects and the landward migration of ridges (EA, 2012). The lower beach profile still exhibits erosive tendencies, whilst the apparent annual and seasonal variability has resulted from the behaviour of ridge and runnel features. Details relating to those profiles which were assessed within the LID ES Coastal Processes Addendum (Royal Haskoning, 2003) are presented in Table 17, with an overview presented below:

- P25: 2011 - upper beach demonstrates accretion, whilst the formation of runnels and water pooling indicates erosion towards the lower beach;
2012 - water pooling remains a beach characteristic, indicating large areas of sediment depletion on the lower beach;
- P50: 2011 - no change in the historical behaviour, with upper beach indicating sediment accumulation and erosion of the lower beach. Overall, the 2011 profile has a higher elevation than in 2006;
2012 - upper beach indicates sediment accumulation, with erosion of the lower beach. The channel that existed at 60 m chainage in 2011 has been infilled and beach berm shows growth. Continued evidence of erosion over the period 2011 - 2012; and
- P75: 2011 - upper beach demonstrates accretion, with erosion of the lower beach. The beach profile transects indicate that the entire beach profile is higher in both 2010 and 2011 since 2006. It has been concluded that the sediment removed from the lower beach is transported offshore (EA, 2011); and
2012 - evidence of stability and growth on upper beach and depletion of lower beach. The stretch of coast south of Chapel St. Leonards (LO51; L2B1; P62) has retained sediment.

4.3.3.2 Within Wave Shadow Zone (Profiles P100 and P111)

Since 2008, this stretch of the Lincolnshire coastline has evolved without direct anthropogenic intervention in the form of re-nourishment or the placement of hard sea defences. Analysis of the two beach profiles of immediate interest (EA, 2011; 2012) has indicated that P100 and P111 are classified as stable and accretive, respectively. Details

relating to those profiles which were assessed within the LID ES Coastal Processes Addendum (Royal Haskoning, 2003) are presented in Table 17, with an overview presented below:

- P100: 2011 - previously considered erosive, the beach has now been classified as stable, with the beach levels higher in 2010 and 2011 than in 2006;
2012 - remains stable, with variability indicated by pooling on low flat beach. Comparison of multibeam between 2002 and 2012 shows sediment loss, with the lowering of the nearshore section by 0.25m;
- P111: 2011 - beach growth; and
2012 - beach growth.

Table 17: Beach Profile Behaviour Post-Construction (2008 - 2012).

ES Addendum Ref (EA Profile ID, 2012; previous EA ID)	Location (approximate)	Wave Shadow Zone	Beach Re-nourishment Activity (#)	Foreshore Behaviour
P25 (LO42; L2D8)	Sutton on Sea	No	Yes	Accretive
P50 (LO48; L2C6)	Anderby Creek	No	No	Accretive
P75 (LO54; L2B4)	Vickers Point	No	No	Accretive
P100 (LO61; L2A3)	Skegness	Yes	No	Stable
P111 (LO64; L2A6)	Seacroft	Yes	No	Accretive
Notes: (#) specific to the profiles of interest.				

4.3.4 Overview of beach re-nourishment volumes

The natural erosive behaviour of the frontage is skewed by beach re-nourishment activities, such that beach volumes now increase, with evidence suggesting that the greatest volume is retained on the upper beach levels. Evidence also indicates that the hydrodynamic regime is still responsible for sediment removal from the beach. Re-nourishment volumes relevant to the five profiles of interest for the pre- and post-construction periods are given in Table 18 and Table 20, respectively.

Table 18: Pre-Construction Re-nourishment Volumes (1995 to 2007) (EA, 2008).

Profile P25		Profile P50		Profile P75		Profile P100		Profile P111	
Scheme	Details (*)	Scheme	Details (*)	Scheme	Details (*)	Scheme	Details (*)	Scheme	Details (*)
28, 29	1997; 100,231 m ³	50, 51, 52, 53	1996; 70,182 m ³	74, 75,	1995; 113,666 m ³	No beach re-nourishment scheme in place			
		52, 53	2007; 19,984 m ³	74, 75, 76, 77	2006; 38,467 m ³				
		53	1999; 30,031 m ³	75	2007; 11,593 m ³				
			2001; 24,552 m ³		2000; 35,159 m ³				
			2005; 20,174 m ³		2001; 22,216 m ³				
					76, 77				
				2000; 35,159 m ³					
				2001; 22,216 m ³					

Notes: (*) date of re-nourishment; re-nourishment volume (m³)
Where more than one scheme is stated, the volumes relate to each scheme. For example Profile P25, scheme 28 had a re-nourishment volume of 100,231 m³ in 1997 and scheme 29 also had a re-nourishment volume of 100,231 m³ in 1997

Pre-2010, re-nourishment activities occurred between Mablethorpe (L2D3) to Whitehouse Corner, south of Ingoldmells Point (L2A2). From 2010, re-nourishment was concentrated in six areas (Table 19) along the Lincolnshire frontage, the location of which was ascertained based upon differences between 2010 topographic surveys and the idealised design beach profile. None of these areas coincide with the five profiles of interest.

Table 19: Location of Re-nourishment Activities Post-2010 (EA, 2011).

Site Name	Location	Profile Extent
Area 1	Trusthorpe and Sutton on Sea	L2D5 - P23
Area 2	Boygrift	P33 - P35
Area 3	Moggs Eye	P40 - P44
Area 4	Trunch Lane	P68 - P76 (*)
Area 5	Chapel Six Marshes	P55 - P61
Area 6	Wolla Bank	L2C6 - P55
Notes: (*) information relating to re-nourishment volumes suggests that this extent is P68 - P74		

Table 20: Post-Construction Re-nourishment Volumes (2008 to 2012).

Profile P25		Profile P50		Profile P75		Profile P100		Profile P111	
Scheme	Details (*)	Scheme	Details	Scheme	Details	Scheme	Details	Scheme	Details
No re-nourishment scheme in place (2008 - 2010)									
n/a	2012; 23,027 m ³	No re-nourishment scheme in place (2012)							
Notes: (*) date of re-nourishment; re-nourishment volume (m ³)									

Re-nourishment volumes applied between 2008 and 2012 along the Lincolnshire frontage, but not specifically at the five profiles, were of the order of:

- 2008: 405,943 m³;
- 2009: 435,684 m³;
- 2010: 445,114 m³; and
- 2012: 552,558 m³.

Notes: It is assumed that a re-nourishment volume of a similar amount to that for other years was added to the Lincolnshire frontage during 2011.

Whilst intended to immediately improve the natural state of the beach where applied, re-nourishment activities benefit the entire shoreline, particularly those stretches to the south of any re-nourishment. The timings of the beach feed (typically May - July) are such that it is unlikely that storm events immediately occur after the re-nourishment. Instead more benign hydrodynamic conditions are likely to occur. This would suggest that the removed 'new' beach material is redistributed to the south, rather than being transported offshore.

Future re-nourishment strategies remain unknown at the present time. Correspondence with the EA infers that whilst Lincolnshire will continue to require management in the near future, shoreline protection schemes that do not include beach re-nourishment activities may be considered.

4.3.5 Commentary on the validation of the UNIBEST predictions

4.3.5.1 Method of Application

The UNIBEST numerical model comprises three modules, with UNIBEST-LT referred to in the ESs and the Coastal Processes Addendum (Royal Haskoning, 2003) to study the *potential* rate of longshore transport at the coast. A set of five beach profiles were selected in the lee of the LID development sites from Sutton on Sea to the north and close to Gibraltar Point in the south.

UNIBEST-LT is driven by tide and wave inputs. Here, the application of UNIBEST-LT assumed a single water level representing MHWS, no currents and a uniform wind condition of 0.1 m/s. In addition, a uniform sediment size ($D_{50} = 0.6$ mm) was adopted for all profiles and across 400 m in the nearshore zone. The exception is the southern most profile which extended seaward to account for the complex channels and banks. Areas seaward of 400 m were excluded from the calculation on the assumption of being composed of immobile consolidated clay. It is noted that the Lincolnshire beach recharge aims to deliver sediments with a D_{50} in the range 0.55 to 0.75 mm, and occasionally these tolerances are exceeded. Whilst the uniform sediment size applied to UNIBEST-LT is consistent within this range, the model does not take account of any beach re-nourishment volumes.

The sensitivity of the longshore transport rate was assessed 'with and without' a representation of the wind farms for the following idealised wave conditions:

- Four wave directions (0, 30, 90, 150°N); and
- Two return periods (1 in 1 month and 1 in 1 year).

The 1 in 1 month event was considered to be representative of typical day-to-day wave conditions and the 1 in 1 year event typical of a storm. For each scenario the predicted *potential* rate of longshore transport is given as an annual rate based on the applied uniform wave conditions. Therefore, these rates are a conservative over-estimate of any actual net annual rate which might result from a full annual time series of waves comprising many lesser events and from various directions.

The SWAN wave model was used to drive UNIBEST-LT. The representation of the wind farms in SWAN was achieved using a 6 m resolution grid to provide an equivalent dimension to the proposed pile diameter and by blocking out the cells for each of the 60 assumed wind turbine locations (30 per wind farm). In comparison, the as built wind farms have a total of 54 wind turbines with pile diameters of 4.7 m (Table 7). Hence, modelling a larger number of larger piles than the as-built case is likely to introduce conservatism. The wave model blocked the direct wave energy transmission through any cell deemed to represent a pile. Diffraction and reflection of wave energy were not considered, so the energy losses due to blocking are also likely to be conservative.

In summary, UNIBEST-LT has been applied in a comparative manner using a small set of stochastic conditions to assess the sensitivity of *potential* longshore transport rates to changes in wave conditions created by the LID development sites. Furthermore, any results from UNIBEST-LT remain conservative for the points noted previously. UNIBEST-LT has not been applied in any deterministic mode to predict future changes in beach profiles that might enable a direct comparison to the EA monitoring.

4.3.5.2 Model Results

The estimated *potential* sediment transport rates from UNIBEST-LT were developed using three different formulas which demonstrated a far greater variance between predictions than any difference due to the wind farms underpinned by conservative assumptions (i.e. there is more uncertainty in the method of calculation than the application of the calculation).

The frontage between Skegness and Gibraltar Point shows the greatest relative sensitivity to the wind farms with a *potential* for reduced rates of southerly drift. In part, this is due to a slight change in the orientation of the coast (from Ingoldmells Point to the north) relative to incident waves. If this modelled effect was to occur in reality then it would contribute to better local retention of material that was passing along the coast under the action of waves.

4.3.6 Conclusions

Q2: Within the limitations and constraints of the data, to what extent can the beach profile monitoring be used to validate the predicted changes to long-shore transport as provided in the ESs and ES Addendum, and the conclusions of the ESs and ES Addendum?

The developmental parameters of the two wind farms pertinent to this present study are presented in Table 7. It is clear that the scale of the installed development is smaller than the consented scheme. Key differences pertinent to the present study include the number, size and spacing of the turbine structures / foundations. The installed scheme provides less blockage to the hydrodynamics (tides; waves) than the consented scheme. The ESs and the Coastal Processes Addendum (Royal Haskoning, REF; 2003) reports that:

- *The wind farms would, to some extent, shelter the southern length of the Lincolnshire coast from the effects of extreme storm events; and*
- *Overall, the percentage reduction in wave heights in the lee of the wind farms is in the range of 3% to 5%.*

It is therefore considered that any potential effects which may result from the installed wind farms are likely to be less than as concluded in the ES and the Coastal Processes Addendum (Royal Haskoning, 2003).

A consideration of beach profile behaviour along the Lincolnshire coast, as reported by the EA (2008; 2011; 2012) and presented in previous sections, concludes that the current behavioural tendencies remain as reported historically. To the north of the WSZ, the beach demonstrates erosive characteristics which have been mitigated by beach re-nourishment activities such that, typically, the upper profile is accretive and the lower profile erosive. The profiles considered within the WSZ are reported as both stable and accretive, **however, it is acknowledged that only two beach profiles within the WSZ were available for inter-year analysis.**

Evidence of the net southerly longshore drift between Skegness and Gibraltar Point is clearly visible in the monitoring data whilst growth of the spit at Gibraltar Point also provides further evidence of this process. The sediment volume available for longshore transport remains dependent on the availability of supply and is in response to the primary mechanism for transport. For this section of frontage, the supply is enhanced by the beach re-nourishment scheme to the north and the prevailing northerly winds and waves which drive some of this material in a net southerly direction. The timing of beach monitoring in summer and winter periods and the timing of any beach re-nourishment will be a further determining factor of the beach profile shape. It is further noted that beach re-nourishment has taken place since 1995, but can occur in different places at different rates each year.

The shoreline behaviour remains dominated by the re-nourishment activities. The analysis undertaken by the EA does not demonstrate that the presence of the wind farms has altered this behaviour. **This conclusion is based on analysis of the specified beach profiles over the period since construction of the wind farms (3 years).**

Whilst the UNIBEST predictions are judged to be conservative, both in the method of application and in the inputs used, they do not provide a direct basis for comparison with any beach profile monitoring. The conservative predictions show that the only area with a potential for longshore transport to be influenced by the wind farms is between Skegness and Gibraltar Point. This prediction was made on the basis that the wind farms will have a minor effect on waves passing to the coast. No such effects have been observed at the coast.

Therefore, it is considered that the scale of any variation in beach profiles along the Lincolnshire frontage will remain dominated by the variation in re-nourishment volumes and annual and seasonal variation in the wave regime.

4.4 Subsea Noise

4.4.1 FEPA requirements

The FEPA requirements for monitoring subsea noise are set out in Table 21 below.

Table 21: FEPA Requirement – Subsea Noise.

Ref	FEPA Condition
9.7	The Licence Holder must make provision during the construction phase of the windfarm to install facilities to enable sub-sea noise and vibration from the turbines to be assessed and monitored during the operational phase of the windfarm. Before completion of the construction phase the Licence Holder must supply specifications to the Licensing Authority of how it proposes to measure sub-sea noise and vibration - at various frequencies across the sound spectrum at a selection of locations immediately adjacent to, and between turbines, within the array and outside the array at varying distances - in order to fulfil the monitoring requirement outlined in Annex 1 attached to this Licence. Such a study would need to reflect differences in foundation/tower type, water depths and sediment types within the site and would need to be supported by adequate baseline data.
Annex 1 (8)	Noise and Vibration Detailed post construction data must be collected on the frequency and magnitude of underwater noise produced by the Lynn [and Inner Dowsing] windfarm. The choice of sites for installing monitoring equipment should reflect the different conditions such as sediment type, water depth and pile type. This data is required for a variety of purposes, including: - In combination with the biological aspects of the monitoring programme proposed in Annexes 1 and 2, the data would help to elucidate any interactions between noise generation and the provision of new habitat and fish aggregation effects of the turbine support structures. - Determining the effects of distance depth and background sources on noise propagation.

A different approach was taken in planning the operational subsea noise monitoring to that set out in FEPA Licence condition 9.7 and Annex 1(8). Facilities to enable monitoring of subsea noise and vibration were not installed as fixed infrastructure during the construction phase. Instead, monitoring was carried out in a survey during the operational phase, and the methodology was agreed by the Licensing Authority (Appendix 10; ref 10.33).

The subsea noise survey was carried out in February 2011 and the results presented to the Licensing Authority as part of the Year 2 Post-Construction Monitoring Report (CREL, 2012). No further monitoring is deemed necessary and the FEPA requirements are considered to be complete for this parameter. However this Summary Report provides an overview of the results of the monitoring again for completeness, compares these results to the predictions made within the ESs (this section), and provides a discussion of subsea noise monitoring in relation to the LID fish surveys (Section 5). The status of monitoring and history of reporting for this parameter is summarised in Table 22.

Table 22: Status of Monitoring – Subsea Noise.

Phase	Requirement	Complete	LID Report
Pre-construction	N/A	N/A	N/A
During-construction	N/A	N/A	N/A
Post-Construction	Survey	✓	Year 2 Post-Construction Monitoring Report (CREL, 2012)
	Discussion of subsea noise monitoring in relation to LID fish surveys	✓	Year 3 Post-Construction Monitoring Report (Section 5)
Phase	Additional Items	Complete	LID Report
Pre-construction	Survey	✓	Submitted as addendum to Pre-construction Monitoring Report in 2006 (Appendix 10; ref 10.02)
Post-Construction	Comparisons with ES predictions	✓	Year 3 Post-Construction Monitoring Report (Section 4.4)

This section of the Summary Report provides a summary of monitoring carried out to address the following questions:

Q3	<i>Do the post-construction subsea noise survey results suggest that marine mammals and fish species will be impacted by any detected increase in subsea noise?</i>
Q4	<i>How do these results compare with the predictions made in the Environmental Statements regarding the effects of operational subsea noise on fish and marine mammals?</i>

4.4.2 Summary of Methodology and Results

A subsea noise survey was carried out at the LID sites by Subacoustech Environmental Ltd over the period 16 – 18 February 2011 using the survey vessel *Katie Louise*. The results have been interpreted in relation to the potential impact of measured subsea noise from the operational wind farms on fish and marine mammals in the region¹¹. An overview of the methodology and results is provided below and an updated Technical Report to that provided in the LID Year 2 Post-Construction Monitoring Report, with minor updates and clarifications, is provided in Appendix 3 (Subacoustech Environmental Ltd, 2012).

4.4.2.1 Methods

4.4.2.1.1 Survey

A low noise hydrophone was deployed from the side of the survey vessel in order to carry out underwater sound recordings. Underwater noise equipment measured the underwater sound to levels well below sea state zero noise, and over the frequency range to characterise anthropogenic noise in the ocean and the hearing response range of species of fish and marine mammals (Subacoustech Environmental Ltd, 2012). Measurements were taken along six transects (see Figure 6) and in water depths of between 8 m to 30 m. The vessel's engines and other equipment were turned off during measurements and the boat allowed to drift along the relevant transect.

Transects were started as close as possible from an operational turbine (between 10 m and 40 m) and measurements were taken out to a range of 5000 m when possible. Background noise conditions at the LID sites were acquired each day, at a distance of 10 km from the wind farm sites (Subacoustech Environmental Ltd, 2012).

Conductivity, temperature, depth and salinity measurements were also taken during the surveys, to check for any conditions which may affect underwater noise transmission. Wind speed was measured from an anemometer on the boat, and wind speed data from the operational wind turbines were also obtained (Subacoustech Environmental Ltd, 2012). An overview of the survey conditions on each day is provided in Table 23.

Table 23: Subsea Noise Survey Conditions February 2011.

Survey Date	Survey Duration	Conditions	Wind speed (vessel anemometer)	Wind speed (recorded from wind turbines)	Swell
16 February 2011	0800 - 1700	Good, visibility > 5 km for most of the day, patch of cloud and fog middle of day for ~4 hours	1.5 m/s to 6.7 m/s	Lynn: 3.84 to 7.48 m/s Inner Dowsing: 4.21 to 6.58 m/s	< 0.5 m
17 February 2011	0900 – 1700	Visibility of < 2 km for majority of the day	3.3 m/s to 6.9 m/s	Lynn: 3.82 to 6.20 m/s Inner Dowsing: 3.91 to 6.19 m/s	< 0.5 m
18 February 2011	0800 - 1400	Visibility at around 2 km	5.5 m/s to 9.1 m/s	Lynn: 5.80 to 7.27 m/s Inner Dowsing: 5.80 to 7.08 m/s	1.5 m 2 m at 1400 (measurements abandoned)

4.4.2.1.2 dBht (*Species*)

Subsea noise measurements were analysed using dBht levels, which incorporates the hearing ability of a species by referencing the sound to the hearing threshold of that species. The dBht metric therefore evaluates the level of sound that a species can perceive (Subacoustech Environmental Ltd, 2012). A high level of sound on the dBht scale is likely to result in an avoidance response by a species, and it is considered that levels of 90 dBht (*species*) and above will cause a significant avoidance reaction by most individuals (based on measurements from fish; Nedwell *et al.*, (2005) in Subacoustech Environmental Ltd, 2012).

The species of fish and marine mammals included in the LID study for dBht analysis were selected due to regional importance (or as proxies for species that are regionally important) and availability of a good quality audiogram. These are: herring, cod and dab (fish species), and bottlenose dolphin, harbour porpoise, striped dolphin and harbour seal (marine mammals).

¹¹ The survey took place prior to the commencement of construction at the adjacent Lincs offshore wind farm, as per Licensing Authority requirements (Appendix 10; ref 10.33).

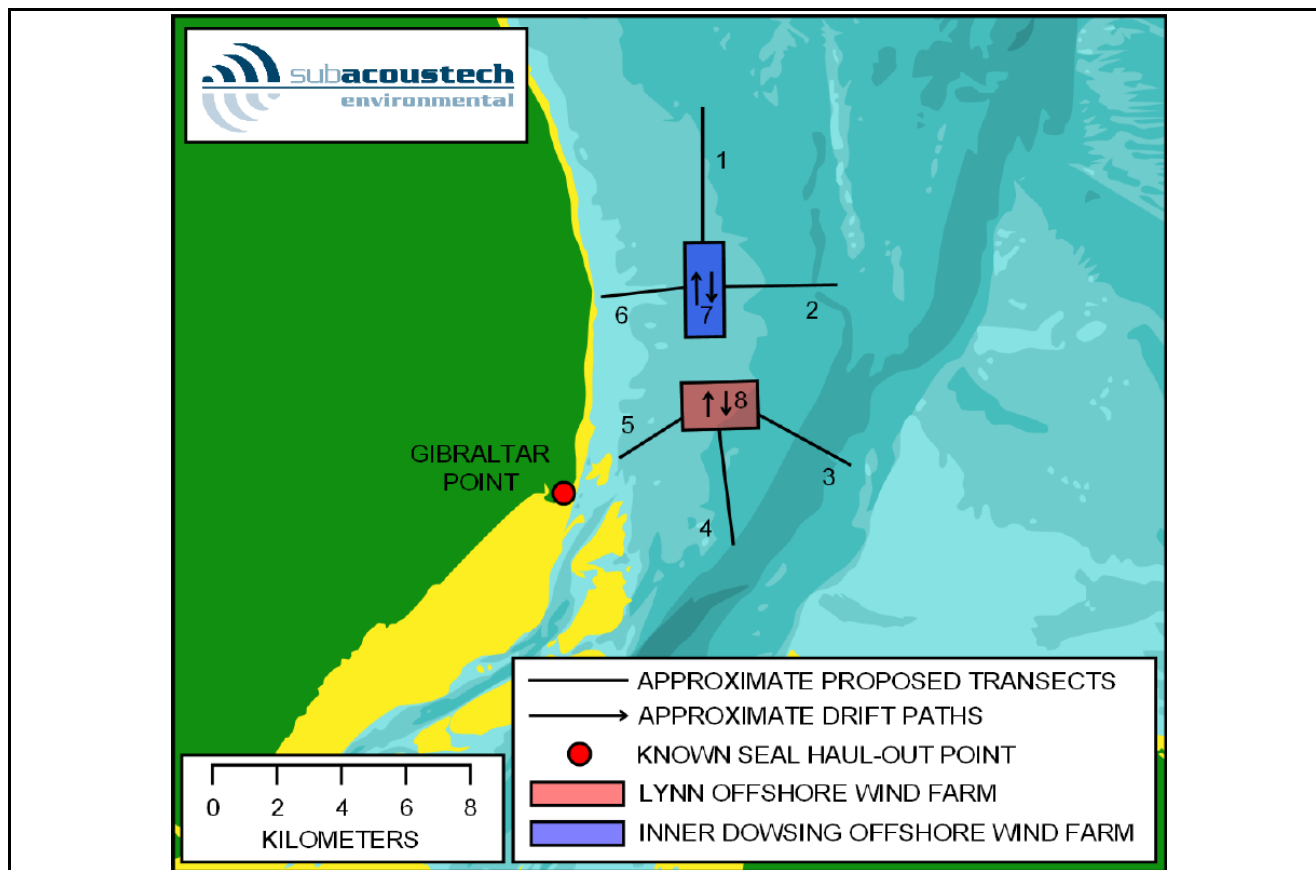


Figure 6: Sketch map of the LID wind farms, and tracks of various boat drifts when taking measurements (from Subacoustech Environmental Ltd, 2012).

4.4.2.2 Results

It was found that the unweighted¹² noise level from the turbines fell below the average background level at a distance of 200 m, and to below the minimum background level at a distance of 800 m. This noise was attributed to tidal flow around the turbine structure. An increase in noise in and around the turbine array for frequencies from 2 to 200 Hz was also detected, and attributed to increased wind and wave noise interacting with the turbine structures (Subacoustech Environmental Ltd, 2012).

The mean species perceived sound levels recorded at varying range from the wind farms for the species included in this study are provided in

Table 24. The mean species perceived sound levels at a range of less than 100 m from a wind turbine were up to 19.0 dBht higher than background dBht levels (range over 10 km) for fish, and up to 4.4 dBht higher for marine mammals. However, it was considered that noise levels are within the typical variation expected for shallow water regions from weather, sea state and tidal flow conditions (Subacoustech Environmental Ltd, 2012). None of the dBht levels measured exceed the 90 dBht level and therefore are below the level considered to result in a significant avoidance response.

Figure 7 shows the highest noise level recorded plotted against distance from the wind farms, for each marine species. This shows that for the fish species, sound is above mean background levels for up to 10 km. By contrast for marine mammals, sound is above mean background levels for up to 800 m. These distances were considered to be the worst case scenario, as the sound produced by the wind turbines was indistinguishable from background noise, for the majority of measurements.

A fish may therefore perceive the wind farm generated sound out to a maximum distance of 10 km, and marine mammals may perceive the sound out to a maximum distance of 800 m. However, it was concluded that the operational noise from the wind farms is unlikely to cause a significant behavioural response in the marine animals found in the region (Subacoustech Environmental Ltd, 2012).

Table 24: dBht levels recorded at varying range from the LID sites (Source: Subacoustech, 2012).

¹² "The unweighted sound level is the sound level calculated from the recorded data without any kind of modification such as filtering. Filtering the data is needed to calculate the dBht level. Unweighted data is the most commonly used metric of underwater sound and is expressed in units of dB re. 1µPa" (Subacoustech Environmental, *pers comm.*, October 2012).

Species	Herring	Cod	Dab	Bottlenose Dolphin	Striped Dolphin	Harbour Seal	Harbour Porpoise
Level							
Mean Source level ¹³¹⁴	70.6	59.0	43.4	71.0	75.0	64.0	81.5
Max Source level	80	85	54	85	82	64	88
Mean dBht level (range 5 m to 100 m)	41.2	38.9	23.0	50.6	50.8	37.7	59.9
Max dBht level (range 5 m to 100 m)	60.6	75.0	55.3	67.5	69.1	64.4	81.3
Mean dBht level (range 100 m to 1 km)	37.3	34.6	19.5	51.6	51.4	36.8	60.5
Max dBht level (range 100 m to 1 km)	61.1	55.9	44.6	68.6	69.9	59.2	77.2
Mean dBht level (range 1 km to 5 km)	30.4	25.8	8.8	50.2	50.9	34.8	59.7
Max dBht level (range 1 km to 5 km)	38.1	33.8	24.7	72.3	73.7	49.3	80.9
Mean dBht level (background, range over 10 km)	26.0	20.0	4.0	47.0	47.7	33.3	56.2
Max dBht level (background, range over 10 km)	32.3	29.6	13.8	49.4	49.8	35.7	60.2

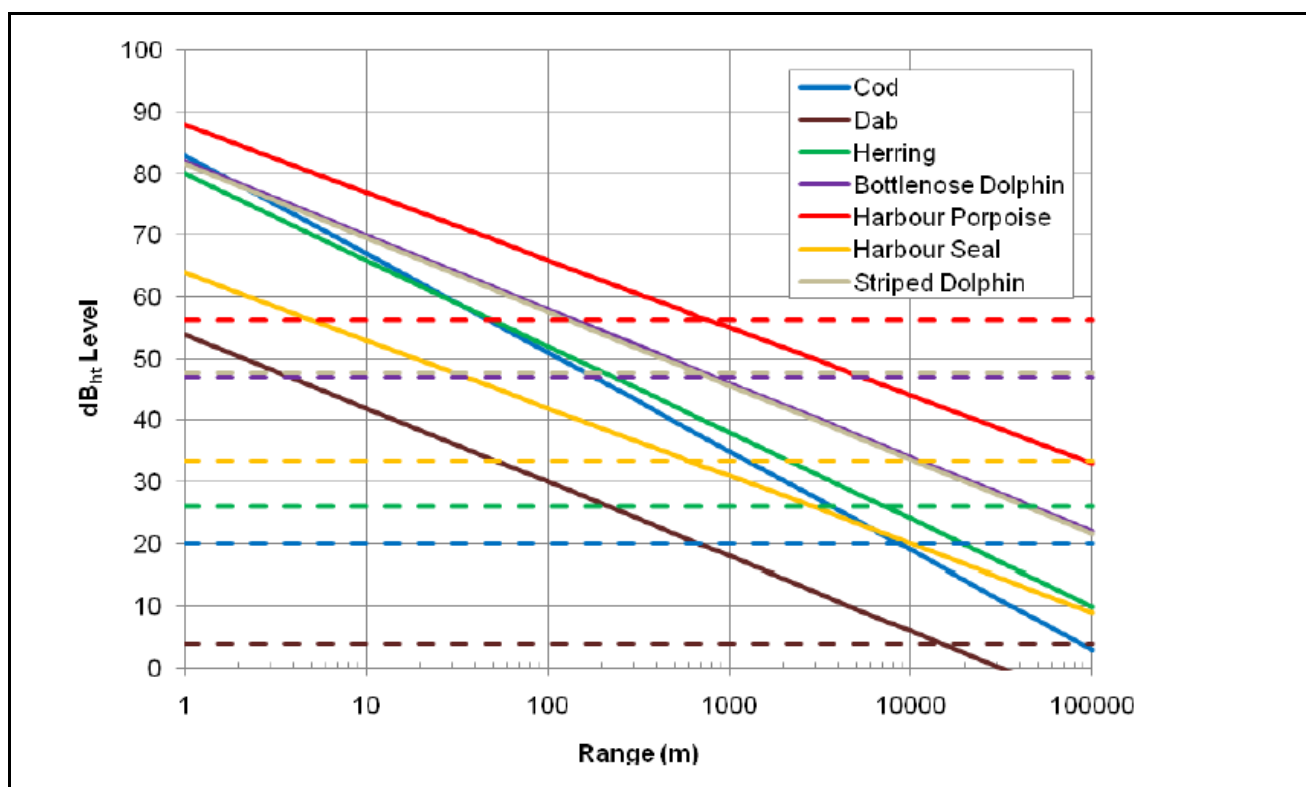


Figure 7: The highest noise level recorded plotted against range for each marine species included in the study. Solid lines indicate the fit to measured data and the dashed lines indicated the mean background level recorded for the species studied (Source: Subacoustech, 2012).

4.4.3 Conclusions

These results have been reviewed in order to address the questions outlined at the beginning of this section:

¹³ Source Level: "Where there is a single and well-defined source of noise, underwater sound pressure measurements may be expressed as dB re 1 μ Pa @ 1 m, which represents the *apparent* level at a distance of one metre from the source. In fact, since the measurements are usually made at some distance from the source, and extrapolated back to the source, the true level at one metre may be very different from the Source Level" (Subacoustech Environmental, 2012, p.4).

¹⁴ "However for the majority of transects taken there was not a sufficient amount of noise presented above background levels, which meant that the source level was not able to be determined. Undeterminable source levels were not counted when calculating the average source level" (Subacoustech Environmental, 2012, p.20).

Q3: Do the post-construction subsea noise survey results suggest that marine mammals and fish species will be impacted by any detected increase in subsea noise?

The post-construction subsea noise survey results do not suggest that marine mammals and fish species will be significantly impacted by the detected operational noise, based on the perceived levels of sound for the marine species considered by Subacoustech. The Licensing Authority agreed “that operational noise from the wind farms is unlikely to cause a significant behavioural response in the marine animals found in the region”, in their response to the LID Year 2 Post-Construction Monitoring Report (Appendix 10; ref 10.55).

The interaction between subsea noise and fish species is further considered in Section 5 of this Summary Report in relation to the fish survey data collected in the vicinity of the wind farm sites. The FEPA Licence requirements for subsea noise and vibration have therefore been fulfilled.

Q4: How do these results compare with the predictions made in the Environmental Statements regarding the effects of operational subsea noise on fish and marine mammals?

The effects of changes in subsea noise and vibration on fish and marine mammals were assessed in the LID ESs through a literature review¹⁵. The impact assessments for the operational phase of the LID wind farms assessed the activity of “turbine operation” only¹⁶. Turbine vibration was considered to be the most likely source of underwater sound, with airborne noise likely to reflect off the water surface. The ESs did not take into account the subsea noise generated from the flow of wind, waves and currents around the wind turbine structures, or from maintenance vessels.

For marine mammals, the ESs referred to a study from the Svante wind farm in Sweden. Measurements of the underwater acoustic environment were taken in 1994 at a range of distances, depths and wind speeds. Beyond frequencies of 100 Hz, sound levels were below ambient sea levels of around 80 dB at 100 m from the turbine. Below frequencies of 100 Hz, the noise ranged from approximately 80 to 100 dB in intensity with a peak of 103 dB at 16 Hz (Westerberg 1994 and Westerberg 1999; in NWP Offshore Limited (2002)¹⁷). The ESs state that these values are at the lower end of the scale for anthropogenic noise and beyond the behavioural reaction sensitivity for most species including harbour seal and harbour porpoise. Sound intensity was reported to be generally 35-40 dB above ambient at a distance of 1 m from the wind turbine, which was stated to be significantly less than other anthropogenic sources. The ESs concluded that operational noise would be low level and largely below background conditions, and where detectable, the marine mammal species would become habituated to this low level noise.

For fish, the ESs cite studies which suggest that fish are attracted to offshore wind farms, although it was also noted in the Lynn ES that herring may show an avoidance reaction as they have good auditory perception. Noise generated by an offshore wind farm was considered unlikely to have any discernible adverse effect on fish abundance or distribution, with noise expected to be within the range of noises to which fish are tolerant.

The cumulative impact assessment of noise on marine mammals predicted that operational noise levels may increase at locations between the two wind farm sites, with likely minimal impacts. It was concluded that no impacts other than those predicted to occur individually at each site would result from the operation of both the Lynn and Inner Dowsing sites.

As reported above, the LID post-construction subsea noise survey detected an overall increase in noise, compared to background noise, in and around the wind turbine array for frequencies from 2 to 200 Hz. However, Subacoustech concluded that the increase in the species perceived noise levels at LID are within the typical variation expected for shallow water regions. A fish may perceive the wind farm generated sound out to a maximum distance of 10 km, and marine mammals may perceive the sound out to a maximum distance of 800 m. However, it was concluded that the operational noise from the wind farms is unlikely to cause a significant behavioural response in the marine animals found in the region.

The Lynn ES acoustics and vibration chapter concluded that no adverse impacts were expected from the operational phase. This prediction is supported by the results of the operational subsea noise monitoring.

¹⁵ Presented in Chapters 6, 7 and 12 of the Lynn ES, and Chapters 6 and 12 of the Inner Dowsing ES.

¹⁶ With the exception of change to shipping routes, concluded to have minimal impact on marine mammals.

¹⁷ For clarity, the text in the LID ESs has been supplemented with further detail.

4.5 Fish Community

4.5.1 FEPA Requirements

The FEPA requirements for monitoring marine fish are set out in Table 25 below.

Table 25: FEPA Requirement – Fish Surveys.

Ref	FEPA Condition
9.8	Since very little is known about the potential effect of windfarms in terms of enhancing or aggregating fish populations, the Licence Holder must produce proposals for adequate pre-construction baseline and post-construction surveys of fish populations in the area of the windfarm. The Licence Holder shall, in drawing up such proposals, canvas the views of local fishermen. The proposals must be submitted to the Licensing Authority at least one month prior to the proposed commencement of the monitoring work. (See also Annex 1 in relation to monitoring of electro-sensitive species).
Annex 1 (6)	Electromagnetic Fields The Licence Holder must provide the Licensing Authority with information on attenuation of field strengths associated with the cables, shielding and burial described in the Method Statement (to be submitted to the Licensing Authority as soon as possible) and related to data from the Rødsand windfarm studies in Denmark and any outputs from the COWRIE tendered studies in the UK (where appropriate). This is to provide reassurance that the cable shielding and burial depth(s), both between the turbines and along the cable route to shore, given the sediment type(s) at the Lynn [and Inner Dowsing] site are sufficient to ensure that the electromagnetic field generated is negligible. Should this study show that the field strengths associated with the cables are sufficient to have potential significant adverse effects on electro-sensitive species, further biological monitoring to that described in Section 7 of this Annex may be required to further investigate the effect.
Annex 1 (7)	Marine Fish The Environmental Impact Assessment observed electro-sensitive species (e.g. Thornback Ray) in this area of the Lynn [and Inner Dowsing] site (although the frequency and abundance were not quantified). In the absence of any evidence that electromagnetic fields do not pose a risk to such organisms, monitoring work is required to determine the numbers and distribution of such species in the vicinity of the Lynn [and Inner Dowsing] windfarm (this should include the establishment of a baseline and the use of adequate controls). The results should be presented and discussed in combination with the EMF studies described in the preceding section (6).

Pre-construction fish surveys took place during 2004/2005, with the post-construction fish surveys taking place in 2009/2010 (Year 1), 2010/2011 (Year 2) and 2011/2012 (Year 3). The results of these earlier surveys were provided to the Licensing Authority in the LID Pre-Construction Monitoring Report (CREL, 2005), and the LID Year 1 and Year 2 Post-Construction Monitoring Reports (CREL, 2010; CREL, 2012). The Year 3 Post-Construction Monitoring Report presents the results of the final survey year, and provides a comparison of the findings across the different monitoring years. This section also discusses the results of the fish surveys in relation to the latest research available on the effects of EMF from subsea cables on fish.

Four types of fish survey were carried out, otter and beam trawl, shrimp trawl, potting and longlining surveys. In addition, mussel surveys were carried out during the pre-construction phase, although did not continue through to the post-construction stage due to concern over interaction with the installed cables. The longlining surveys were intended to capture electro-sensitive species, although the otter trawl gear also sample these species, such as rays and dogfish. The status of monitoring and history of reporting for this parameter is summarised in Table 26. No further monitoring is considered to be required.

Table 26: Status of Monitoring – Fish Community.

Phase	Requirement	Complete	LID Report
Pre-construction	Survey	✓	Pre-construction Monitoring Report (CREL, 2005)
During-construction	N/A	N/A	N/A
Year 1 Post-Construction	Survey	✓	Year 1 Post-Construction Monitoring Report (CREL, 2010)
Year 2 Post-Construction	Survey	✓	Year 2 Post-Construction Monitoring Report (CREL, 2012)
Year 3 Post-Construction	Survey	✓	Year 3 Post-Construction Monitoring Report
	Consideration of EMF effects	✓	Year 3 Post-Construction Monitoring Report

This section of the Summary Report presents the complete results from the pre-construction and post-construction monitoring programmes, in order to address the following questions:

Q5	<i>To what extent does the post-construction monitoring validate the predictions made in the ESs, particularly in regard to electro-sensitive species?</i>
Q6	<i>Are the same species assemblages represented in the post-construction surveys compared with the pre-construction surveys, including electro-sensitive species?</i>
Q7	<i>Is there evidence for any increasing or decreasing trends in species abundance and whether this could be attributable to the wind farms?</i>
Q8	<i>Is there evidence for changes in species distribution within the vicinity of the wind farm sites and whether this could be attributable to the wind farms?</i>

4.5.2 Methodology and Results of the Year 3 survey

4.5.2.1 Methodology

The Year 3 post-construction surveys (otter and beam trawl, shrimp trawl, potting and longlining), as far as practicably possible, replicated that of the Year 1 (August 2009 to July 2010) and Year 2 (August 2010 to June 2011) post-construction surveys and pre-construction surveys (August 2004 to July 2005). During the third year of post-construction, a total of 22 surveys were undertaken in the vicinity of the LID sites, comprising of 4 otter and beam trawls, 6 shrimp trawls, 6 potting surveys and 6 longlining surveys. Full details are provided in Appendix 4.

It should be noted that the number of sampling stations for the fish surveys has varied over time. Some survey stations have been omitted on certain surveys due to bad weather, or site constraints such as construction activities or presence of potential *Sabellaria* reef. In particular, a number of survey stations were omitted since May 2011 (affecting the Year 3 and end of Year 2 surveys) due to the commencement of construction of the adjacent Lincs site. The survey type, ID, dates and the number of stations sampled and omitted are given in Table 27. The proposed sampling stations for the Year 3 post-construction otter and beam trawls, shrimp trawl, potting and longlining surveys are shown in Figure 8. The start and end times, coordinates and durations of each survey are given in Appendix 4.

Table 27: Survey Type, ID and Date of Year 3 Post-Construction Surveys (September 2011 – August 2012) and the Number of Stations Sampled and Omitted (Source: BMM, 2012).

Survey	Survey ID	Date of Survey	No. of Stations Sampled	Stations Omitted & Reasons
Otter & Beam Trawls	OBS13	10 th - 12 th October 2011	5 of 11	OB03, OB04 & OB09 - Lincs Construction Area OB08 - Lynn Construction Exclusion Zone OB05 - Proximity to <i>Sabellaria</i> sp. Reef OB10 - High Density of Static Gear
	OBS14	20 th - 22 th March 2012	6 of 11	OB03, OB04 & OB09 - Lincs Construction Area OB08 - Lynn Construction Exclusion Zone OB05 - Proximity to <i>Sabellaria</i> sp. Reef
	OBS15	11 th - 13 th May 2012	6 of 11	
	OBS16	9 th August 2012	5 of 11	OB03, OB04 & OB09 - Lincs Construction Area OB08 - Lynn Construction Exclusion Zone OB05 - Proximity to <i>Sabellaria</i> sp. Reef OB10 - High Density of Static Gear
Shrimp Trawl	SS19	19 th - 20 th September 2011	6 of 11	ST02, ST09 & ST10 - Lincs Construction Area ST08 - Lynn Construction Exclusion Zone ST03 - Avoid <i>Sabellaria</i> sp. Reef
	SS20	16 th - 17 th November 2011	6 of 11	
	SS21	16 th - 17 th February 2012	6 of 11	
	SS22	16 th - 17 th May 2012	6 of 11	
	SS23	10 th - 11 th July 2012	6 of 11	
	SS24	23 rd - 24 th August 2012	5 of 11	ST02, ST09 & ST10 - Lincs Construction Area ST08 - Lynn Construction Exclusion Zone ST03 - Avoid <i>Sabellaria</i> sp. Reef ST04 - Operations and Maintenance Activity
Potting	PS19	22 nd - 26 th September 2011	6 of 9	P02, P04 & P07 - Lincs Construction Area
	PS20	13 th - 17 th October 2011	6 of 9	
	PS21	16 th - 24 th January 2012	5 of 9	P02, P04 & P07 - Lincs Construction Area P08 - Proximity to Unburied Cable
	PS22	24 th - 28 th May 2012	6 of 9	P02, P04 & P07 - Lincs Construction Area
	PS23	2 nd - 6 th July 2012	6 of 9	
	PS24	13 th - 20 th August 2012	6 of 9	
Longlining	LS15	24 th September 2011	5 of 10	L01, L02, L03, L05 & L09 - Lincs Construction Area
	LS16	11 th December 2011	5 of 10	
	LS17	5 th February 2012	5 of 10	
	LS18	15 th March 2012	5 of 10	
	LS19	23 rd May 2012	5 of 10	
	LS20	27 th June 2012	5 of 10	

4.5.2.1.1 Otter and Beam Trawl Surveys

The surveys were undertaken aboard the commercial trawler “Jubilee Spirit”. A commercial otter trawl with a 100 mm mesh cod-end, and a 2 m scientific beam trawl with a 5 mm mesh cod-end, were used for sampling. Otter trawls were towed for approximately 20 minutes and beam trawls for approximately 10 minutes.

For otter trawl samples, the whole catch from each trawl was retained, boxed, labelled, photographed, iced and stored at +2°C before being transported to the CEFAS laboratory for analysis. The samples were analysed for number of species and individuals, sex ratio of species, spawning condition and length distribution¹⁸. Catch rates, expressed as the number of individuals caught per hour, by survey and station were also calculated for each species.

For beam trawl samples, the whole catch was retained, boxed, labelled and photographed. Sub-sampling was undertaken when large homogenous samples were caught. Samples were fixed in 4% seawater buffered formalin solution before being transported to Jacobs Engineering for analysis. The samples were analysed for number of species and individuals (fish and invertebrates), presence for where counts were inappropriate, and fish length distribution¹⁸. Catch rates, expressed as the number of individuals caught per hour, by survey and station were also calculated for each species.

4.5.2.1.2 Shrimp Trawl Survey

The survey vessels, the “Lynn Princess” and the “Wash Princess”, both commercial shrimp trawlers, were used for the shrimp surveys. Two commercial beam trawls with 22 mm mesh cod-end liners were used for sampling from both vessels; the equipment being transferred from one vessel to the other to eliminate bias. Shrimp trawls were towed for approximately 10 minutes.

For each tow, the whole catch from both nets was retained and sorted into shrimp and by-catch species. Samples were analysed on-board for carapace length (up to 60 individuals for each) of Pink shrimp (*Pandalus montagui*) and Brown shrimp (*Crangon crangon*) for each station, total volume of shrimp by species for each station (l), weight and number of individuals of a 0.25l subsample of *P. montagui* and *C. crangon* and an estimate of number of individuals of each for the whole catch from each 0.25l subsample.

For by-catch, the number of species and individuals were counted (presence for where counts were inappropriate) and species length distribution measured¹⁸.

Catch rates, expressed as the number of individuals caught per hour, by survey and station were also calculated for each species.

4.5.2.1.3 Potting Survey

The commercial potting vessel the “Two Brothers” was utilised for the potting surveys, using 25 baited standard parlour pots for each fleet¹⁹. Each fleet was left to soak for approximately four days. The number of individuals by species, including by-catch, was counted and the number of Edible crabs (*Cancer pagurus*), Lobster (*Homarus gammarus*) and Whelk (*Buccinum undatum*) kept and returned to the sea recorded.

All Lobster (*H. gammarus*) were sexed and measured, and their general condition (berried, soft shell, etc.) noted. For every fifth pot, the length¹⁸ of *B. undatum*, the length¹⁸, sex and general condition of *C. pagurus*, and the length¹⁸ and sex of by-catch crabs was recorded.

Catch rates (number of individuals caught per pot per day) were calculated for each species, for each survey site.

4.5.2.1.4 Longlining Survey

The “Sukat II” was used for the longlining surveys, with standard 100 m commercial longlines.

Longlines were baited with squid, deployed at each sampling station and left to soak for approximately 2-3 hours before hauling. The number of species and individuals caught by species was recorded, as was the sex of elasmobranchs. Catch rates, expressed as the number of individuals caught per hour, by survey and station were also calculated for each species.

¹⁸ Crab: carapace width (mm); Lobster (*Homarus gammarus*): carapace length (mm); Whelk (*Buccinum undatum*): shell height (mm); Scallops: shell width (mm); Cephalopods: mantle length (mm); Finfish: length (nearest cm below; nearest ½ cm below for herring (*Clupea harengus*)); Rays: length and wing-width (nearest cm below).

¹⁹ For pre-construction surveys, it should be noted that the number of pots on each string varied from 20-50 pots.



37

4.5.2.2 Results

4.5.2.2.1 Otter and Beam Trawl Surveys

Otter Trawl Survey

A total of 22 species were caught during the Year 3 post-construction surveys. Whiting (*Merlangius merlangus*) was the most abundant, with a total of 364 individuals and a catch rate of 49.7/hr, followed by Thornback ray (*Raja clavata*; 61; 9.3/hr) and then Dab (*Limanda limanda*; 53; 7.2/hr).

The greatest total catch rate was recorded during the autumn survey (OBS13 Oct 2011; 170.7/hr), with *M. merlangus* representing the greatest proportion of the catch (88.8%).

The catches from stations OT02 (to the north of the wind farm sites) and OT07 (west, in proximity to one of the Lynn export cables) were the most diverse with 15 species present, followed by OT06 (14 species; west, in proximity to one of the Inner Dowsing export cables) and then OT01 (13 species; to the north of the wind farm sites). *M. merlangus* represented the greatest proportion of the catch at each station during the Year 3 post-construction surveys.

The three elasmobranchs caught, Thornback ray *R. clavata*, Starry smoothhound *Mustelus asterias* and Lesser spotted dogfish *Scyliorhinus canicula*, were far more prevalent in the spring survey, than at other times of the year. Elasmobranch species were caught to the north, west and to a lesser extent to the south of the wind farm sites (no samples were collected within the wind farm sites during Year 3 post-construction).

Beam Trawl Survey

A total of 24 fish and 103 motile invertebrate species were caught during the Year 3 post-construction beam trawl surveys.

Sand goby (*Pomatoschistus minutus*) was the most prevalent fish species caught (354.7/hr), followed by Dab (*L. limanda*; 59.3/hr) and then Common dragonet (*Callionymus lyra*; 29.9/hr). The greatest total catch rate was recorded during the autumn survey (OBS13 Oct 2011; 1,471.6/hr), this was attributed to the high numbers of *P. minutus* caught, followed by the winter survey (OBS14 Mar 2012; 259.0/hr), and then the summer survey (OBS16 Aug 2012; 245.9/hr).

The most abundant motile invertebrate species was Pink shrimp (*P. montagui*; 10,194.4/hr), followed by Brown shrimp (*C. crangon*; 4,193.4/hr), and then Common starfish (*Asterias rubens*; 4,183.9/hr). The catch rate was highest during the autumn survey (OBS13 Oct 2012; 84,309.7/hr). This was attributed to high catches of *P. montagui*, *C. crangon* and *A. rubens*, followed by the spring survey (OBS15 May 2012; 9,373.4/hr). The greatest species diversity was recorded during summer (55 species), followed by spring (51) and then the autumn survey (47).

4.5.2.2.2 Shrimp Trawl Survey

Shrimp Catch

The greatest numbers of *P. montagui* were found in survey SS19, during piling operations at the adjacent Lincs site (Sept 2012; 19,130) with a catch rate of 18,719.2/hr. The lowest number of *P. montagui* was recorded during survey SS23 (Jul 2012; 1,448; 1,452.8/hr). *P. montagui* were recorded in greatest numbers at station ST01 (23,312; to the north of the wind farm sites) with a total catch rate of 22,743.4/hr, followed by ST07 (13,535; 13,660.2/hr; west, in proximity to the LID export cable routes). Comparatively low numbers (<5,000) were recorded at stations ST05 and ST06 (4,039; 3,906.6/hr and 837; 856.5/hr, respectively), both west, in proximity to the Inner Dowsing export cable routes.

The highest numbers of *C. crangon* were recorded during survey SS19 during piling operations at the adjacent Lincs site (Sept 2012; 47,637) with a catch rate of 46,614.1/hr, followed by SS20 (Nov 2012; 12,114; 12,040.4/hr) and then SS24 (Aug 2012; 11,427; 13,703.3/hr). The lowest numbers of *C. crangon* were recorded during survey SS22 (May 2012 1,095) with a catch rate of 1,085.7/hr.

C. crangon were recorded in the greatest numbers at station ST05 (26,656) with a total catch rate of 25,782.3/hr, followed by ST06 (22,052; 22,566.0/hr). Station ST04 recorded the lowest total catch of *C. crangon* (504; in the Inner Dowsing wind farm) with a catch rate of 602.2/hr. Overall, *C. crangon* represented 54.7% of the total Year 3 post-construction catch with 60.6% of *C. crangon* being recorded during survey SS19 (Sept 2012).

By-Catch

By-catch was also recorded, with a total of 44 fish and 29 motile invertebrates species caught. *A. cataphractus* was the most abundant fish species (1,146 individuals; 195.4/hr), with the greatest numbers of individuals found in survey SS21 (Feb 2012) during piling operations at the adjacent Lincs site (461), followed by *C. lyra* (907; 154.6/hr) and then *L. limanda* (777; 132.5/hr). The aforementioned species represented 39.9% of the total fish by-catch.

The greatest number of species was recorded during survey SS22 where 30 species of fish were caught, whilst survey SS20 recorded the lowest number of species (21).

A. rubens was the most abundant motile invertebrate species caught (2,115; 360.6/hr), with the greatest numbers of individuals found during survey SS22 (1,371), followed by Harbour crab (*Liocarcinus depurator*; 666; 113.5/hr) and then Sunstar (*Crossaster papposus*; 261; 44.5/hr). The aforementioned species accounted for 77.5% of the total motile invertebrate by-catch.

The greatest species diversity was found during survey SS20 where 20 species were caught and the lowest species diversity was recorded during survey SS21, during piling operations at the adjacent Lincs site (Feb 2012; 10).

4.5.2.2.3 Potting Survey

A total of 16 species were caught during the Year 3 post-construction surveys. Shore crab (*Carcinus maenas*) was the most abundant species (4,708), followed by Edible crab (*Cancer pagurus*; 4,274) and then Hermit crab (*Pagurus bernhardus*; 3,725). The aforementioned species represented 82.4% of the total Year 3 catch. The greatest numbers of individuals were caught at station P06 (4,135), with a catch rate of 0.91 individuals per pot per day.

C. pagurus were recorded at every station during all of the Year 3 post-construction surveys. The greatest numbers were found at station P09 (1,167; south of LID) with a total catch rate of 0.26 crabs per pot per day, followed by station P08 (881; 0.31/pot/day, also south of LID), and then station P03 (813; 0.18/pot/day, to the east of Lincs). The greatest total catch rate was recorded during survey PS23 (July 2012) where 0.28 individuals were caught per pot per day. The majority of *C. pagurus* (77.5%) caught were male, with survey PS24 recording the highest proportion of male *C. pagurus* (77.5%), with the highest number of females recorded in PS19 (Sept 2011; 37.8%).

H. gammarus was found in all Year 3 surveys. The greatest numbers of individuals were recorded at station P08 (123; south of LID), with a catch rate of 0.04 per pot per day, followed by station P09 (40; 0.01/pot/day, to the south of LID). The greatest total catch rate was recorded during survey PS24 (Aug 2012) where 0.02 individuals were caught per pot per day. Sex ratio for *H. gammarus* was approximately even (51% males), with the highest number of males recorded in survey PS20 (Oct 2011; 78.1%).

Whelk (*Buccinum undatum*) was present during all Year 3 surveys. The greatest numbers were caught at station P06 (1,181) with a catch rate of 0.26/pot/day. Relatively low numbers of *B. undatum* (<10 individuals) were recorded at stations P08 and P09 (4 and 6 respectively). Survey PS21 (Jan 2012) recorded the highest catch rate for the species (0.12/pot/day).

4.5.2.2.4 Longlining Survey

A total of eight species were caught during the Year 3 post-construction surveys. The greatest numbers of individuals were caught in survey LS16 (Dec 2011; 69 individuals). Overall, *M. merlangus* was the most abundant species caught (112), followed by Smoothhound (*Mustelus sp.*; 34) and then *R. clavata* (22). The latter two elasmobranch species were more predominate in the summer surveys (May and June) than at other times of the year.

Station L04 recorded the greatest number of individuals caught during the Year 3 post-construction survey (61; Inner Dowsing export cable route) followed by station L08 (45; Lynn export cable route) and then station L07 (28; east of Lincs).

4.5.3 Methodology and Results for inter-year comparisons

4.5.3.1 Methodology

See Section 4.5.2.1 for a general overview of the survey methodologies used for the Year 3 post-construction fish surveys, which were previously employed for pre-construction and Year 1 and Year 2 post-construction surveys, with some exceptions. These exceptions are briefly described in Section 4.5.3.1.1 below, and described in detail in Appendix 4.

4.5.3.1.1 Data Limitations

The dates, survey vessel, sampling gear used and number of stations sampled and omitted for pre-construction and post-construction surveys are given in Appendix 4 (Tables 4.1, 4.2 and 4.3). Figures comparing the location of sampling stations between pre-construction and post-construction surveys are also given in Appendix 4 (Figures 4.1 to 4.4). For the majority of post-construction sampling, the stations have remained in close proximity to those of the pre-construction surveys. Where this was not possible, every effort has been made to ensure that stations have remained at a similar depth to their original location.

The number of stations sampled varied between the pre-construction and Years 1, 2 and 3 post-construction surveys. During Year 1 post-construction surveys (2009/2010), the Licensing Authority agreed to postpone all fishing surveys within the LID sites pending completion of the Year 1 post-construction benthic survey, to reduce the risk of damaging

the reefs with fishing gear. Safety concerns were also identified with construction vessels still working within the wind farm sites and construction exclusion zones still in place.

Surveys at some otter, beam and shrimp trawl stations within the Inner Dowsing wind farm site were omitted for the final few Year 2 surveys and the Year 3 post-construction surveys, following dissemination of the Year 2 benthic survey results, which identified areas of potential *Sabellaria* reef. During the Year 2 and Year 3 post-construction surveys (since May 2011), stations situated within the Lincs wind farm site were also omitted, due to the commencement of construction in this area. In some instances additional stations were also omitted from specific surveys, due to damaged/lost gear, rough ground, poor weather conditions or high concentrations of static gear. In general, post-construction survey coverage of the LID wind farm sites themselves was poor, meaning that comparisons between the wind farm sites and reference sites outside the development boundary are limited.

The number of pots varied during the pre-construction surveys, and to standardise this, catch rates (number of individuals per pot per day) have been used to take into account the variation in number of pots¹⁹ and soak times. However, this standardisation may not take into account all differences between surveys, as soak time to yield is not considered to be a linear relationship.

During potting surveys, parlour pots were used due to their suitability for sampling the main target species for these surveys, *C. pagurus* and *H. gammarus* (these are also routinely used by local commercial fisheries). These pots are not specifically used to target other species recorded during potting surveys (including *B. undatum*) and therefore the results of these surveys should be interpreted with care where these species are concerned.

A number of post-construction surveys were undertaken whilst piling operations were on-going at the adjacent Lincs site. These are detailed in Section 4.5.5 and are discussed in light of these piling events in that section.

It should also be noted that it was not always possible to use the same vessel for the post-construction surveys as used for the pre-construction surveys due to availability/vessels being taken out of service (Appendix 4; Table 4.2).

4.5.3.1.2 Statistical Data Analysis

For the purposes of statistical data analysis, stations were grouped *a priori* using the following factors:

- Geographic area (i.e. north, south, east of the wind farms, and along export cable routes/coastal)²⁰;
- Season (summer, autumn, winter, spring);
- Pre-construction and Years 1, 2 and 3 post-construction; and
- Pre-construction and all three post-construction years combined.

Multivariate (PRIMER) analysis was undertaken, using methods as described in Clarke and Warwick (2001). All analyses were carried out on square or fourth root transformed data and similarities calculated using the Bray-Curtis Coefficient of Similarity. Hierarchical cluster analysis, represented by a dendrogram, and non-metric Multi-Dimensional Scaling (MDS) ordinations in either 2 or 3 dimensional plots, were used to show the 'relatedness' of sites, based on their community composition i.e. sites closer together in the MDS plots are more similar to each other than those far apart, as a result of similar species occurring at each site and similar abundances of those species.

The significance of any observed patterns of sites grouping by factor in these plots were tested using 2-way crossed ANOSIM. This tests for the differences between sites by one factor e.g. by season or by survey year, taking into account differences that may be occurring because of another factor e.g. spatial/geographic. In this way, a true picture of which *a priori* factor is contributing most to the observed patterns in community composition can be understood. Two values are calculated, a "p" value, which tests the significance of any difference (p=0.001 is significant, p>0.001 is not), and the "R" value. The greater the R value, the larger the difference between the two groups of sites being considered; a small R would indicate that the groups of sites have a high degree of overlap, and are therefore not very different from each other. A global value (R and p) is given for the overall relationship between the two factors being considered, e.g. a value for season across survey year, and a value for survey year across season. Should this value have a significant p value, then pairwise statistics (R and p) can also be reviewed, e.g. between different pairs of seasons, summer and autumn, spring and summer etc., and interpreted in the same way.

SIMPER (Similarity of Percentages) was then used in order to understand what species, and species abundances were contributing to similarities within groups, and dissimilarities between groups. SIMPER ranks, in order of importance, each species by calculating their overall contribution to the average similarity within a group.

Other statistical analyses were undertaken although are not described in this summary report (see Appendix 4 for details).

²⁰ Stations with less than three years data were omitted from statistical analysis undertaken of sites from geographic areas.

4.5.3.1.3 Commercial Fisheries Landing Data

In order to provide context to the site-specific fish surveys, in terms of the broader changes occurring in fish populations across the wider area, fisheries statistics for ICES Rectangle 3SF0 from 2004 to 2010²¹ were collated. For the over-10 m fleet this included EC daily log sheets, and for under-10 m this included dock side checks by local fisheries officers, as well as the Shellfish Entitlement Scheme (2004) and the Registration of Buyers and Sellers of First Sale Fish and Designation Auction Site Scheme (2005).

4.5.3.2 Results

The fish surveys were designed to provide a general overview of the fish populations between pre-construction and post-construction survey years, to test the predictions of the ESs, and in particular, in response to FEPA Licence condition 9.8 on potential for enhancement of fish populations and Annex 1 (7) to assess for general changes in electrosensitive elasmobranch species, such as *R. clavata* as a result of the cables. As noted in Section 4.5.3.1.1, comparisons between surveys within the LID wind farm sites, and at reference sites outside these development areas, are limited by the general paucity of data collection within the wind farm sites post-construction. However, general comparisons between reference areas (north and south) and sites along the export cable route (potential electromagnetic fields) have been possible.

4.5.3.2.1 Otter and Beam Trawl Surveys

Otter Trawl Survey

Cluster analysis and MDS plots for otter trawl sampling sites labelled with factors (geographic area, season, survey year and pre-construction and post-construction) are provided in Appendix 4. Of these plots, some groupings of sites by season (Figure 9 below; summer to the top right, spring towards the bottom left) and by survey year (Figure 10 below; pre-construction to the top right, Year 2 post-construction towards the bottom left) were apparent, but not by geographic area. ANOSIM was used to test for differences between these factors.

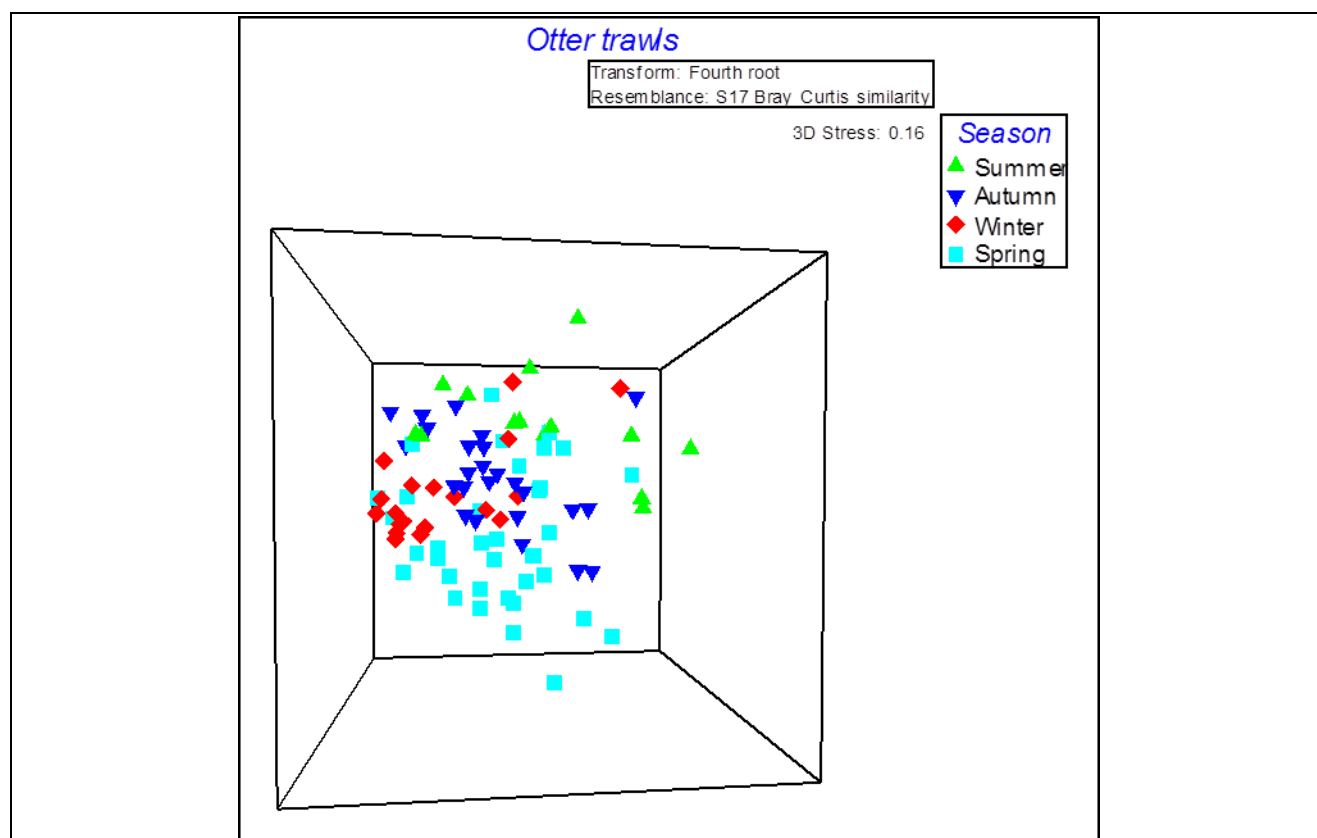


Figure 9: 3-Dimensional MDS Plot of Otter Trawl data by Season (Source: BMM, 2012).

²¹ Data for 2011 was also collated but was provided in a different format to previous year datasets and therefore it was not possible to directly compare to the previous datasets supplied. A large percentage of the landings from ICES rectangle 35F0 were classed as confidential by the MMO and it was therefore not possible to fully assess the fishing activity which occurred in 2011.

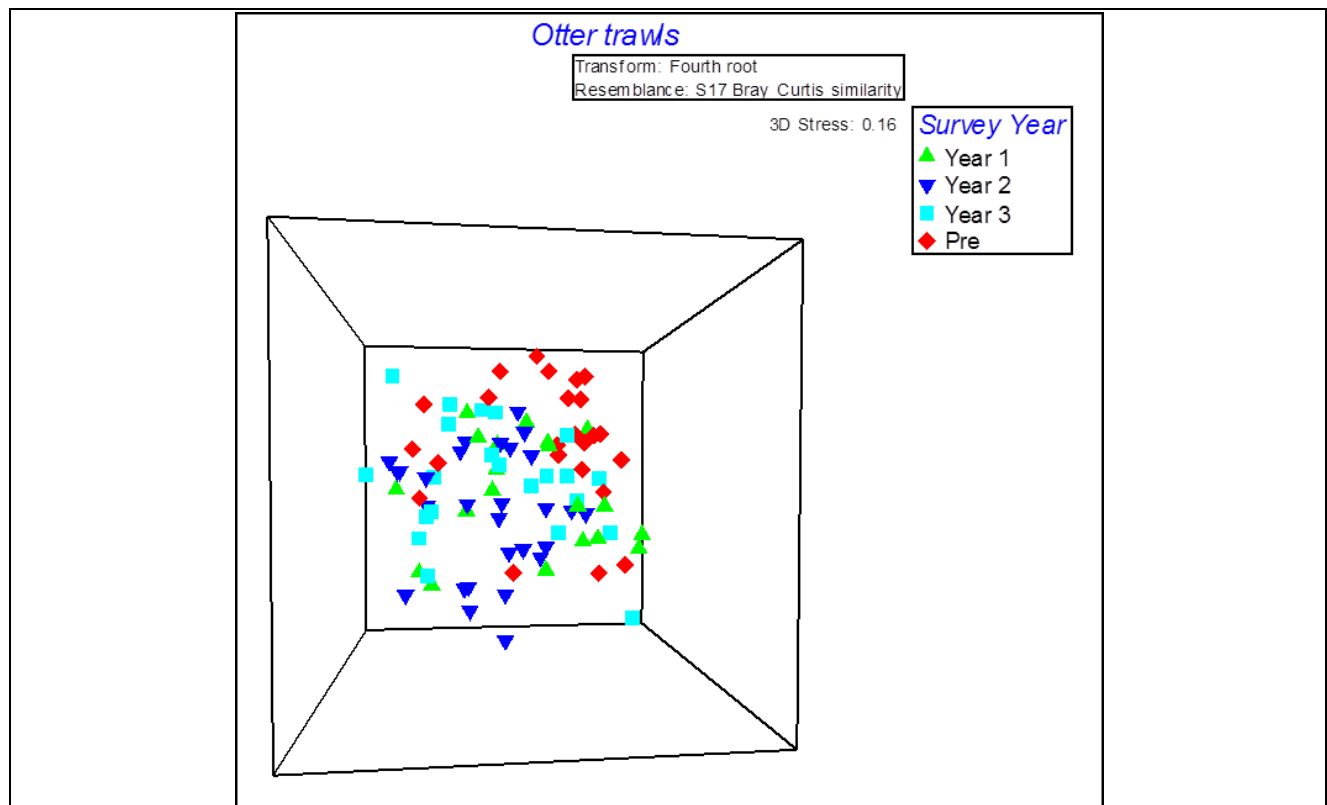


Figure 10: 3-Dimensional MDS Plot of Otter Trawl data by Survey Year (Source: BMM, 2012).

As expected, there was no significant difference for different geographic area across seasons (ANOSIM, $R = 0.076$, $p = 0.028$) or for different seasons across geographic area (ANOSIM, $R = 0.19$, $p = 0.003$).

There was a significant difference for different seasons across survey years (ANOSIM, $R = 0.383$, $p = 0.001$), and for different survey years across seasons (ANOSIM, $R = 0.26$, $p = 0.001$). Both had low global R values, and therefore indicate a high degree of overlap of sites between seasons, and between survey years. From reviewing the individual pairwise tests, it was apparent that the largest differences between seasons were between summer and winter ($R = 0.697$, $p = 0.001$), summer and autumn ($R = 0.609$, $p = 0.001$) and summer and spring ($R = 0.589$, $p = 0.001$), with spring and winter also significantly different ($R = 0.478$, $p = 0.001$). For survey year, only Year 2 post-construction and pre-construction were statistically different, with an R value of 0.618 ($p = 0.001$). There was no evidence of gradation between the consecutive surveys years, nor was the ANOSIM for pre-construction compared to all post-construction years combined (across seasons) significant.

The main differences between seasons were due to differing abundances of *M. merlangus* and *L. limanda*. *M. merlangus* was more abundant in autumn and winter, and *L. limanda* more abundant in summer and autumn. Moreover, winter samples were characterised by the presence of high densities of *M. scorpius* and *A. cataphractus*. This is reflected in catch rates, with high *M. merlangus* catch rates of 141.5 to 632.0 individuals per hour caught in October to December; generally <50 individuals per hour for other months with a few exceptions. For *L. limanda*, the abundances were less obvious in the summer/autumn, with highest catches varying between months, but generally with comparatively high catches in autumn (September/October), plus a summer month.

Differences between the pre-construction phase and Year 2 post-construction were mainly due to the high abundances of *M. merlangus*, *M. scorpius* and *A. cataphractus* during 2004 and 2005. SIMPER analysis indicated the same differences between the pre-construction phase and all other survey years (including Year 1 and Year 3), even though ANOSIM did not detect any differences between these survey year groups. It should be noted that not all seasons were sampled in each year and two of the four pre-construction surveys were conducted in winter, which may explain some of the differences observed between years. These seasonally related high catch rates in the pre-construction year are obvious in the data, with high catch rates of *M. merlangus* in September 2004 to February 2005 (3 surveys; 82.4 to 132.2 individuals per hour) compared to only peaks in autumn (October) for the three post-construction years (141.5 to 324.8 individuals per hour) compared to <50 individuals in other survey months. A similar, but less defined pattern occurs for *M. scorpius* and *A. cataphractus*.

The elasmobranch *R. clavata*, whilst not occurring in high numbers, was recorded in numbers >15 individuals per hour in two surveys (September and October) in Year 2 post-construction and in May in Year 1 and Year 3 post-construction, but generally at low levels for all other survey years (i.e. pre-construction) and seasons.

The statistical analyses suggest that the general trends are relatively strongly dominated by seasonal variations, not influenced by geographic location, and that there is some annual variation, albeit that this was not necessarily a pre-construction to post-construction trend.

Beam Trawl Survey

Cluster analysis and MDS plots for beam trawl sampling sites (all taxa, and for fish only) labelled with factors (geographic area, season, survey year and pre-construction and post-construction) are provided in Appendix 4. For all taxa, the cluster and MDS plots suggested some groupings of sites by season (Figure 11 below for MDS plot; summer to the bottom left, spring front, winter back and autumn towards the top left) and by survey year (Figure 12 below for MDS plot; pre-construction to the top left, Year 2 and Year 3 post-construction, then Year 1 post-construction towards the bottom) were apparent, but not by geographic area. For fish only, similar patterns were observed, albeit less distinct groupings (see Appendix 4 for figures). ANOSIM was used to test for differences between these factors.

As expected, there was no significant difference for different geographic area across seasons (ANOSIM, $R = 0.105$, $p = 0.005$) for all taxa, and whilst significant for fish only, the low R value (ANOSIM, $R = 0.2$, $p = 0.001$) indicated no difference between geographic areas.

Seasonal differences (across geographic areas) gave a significant but small global R (ANOSIM $R = 0.3$, $p = 0.001$) for all taxa i.e. large overlap between seasons. Pairwise comparisons however, showed that autumn to winter, autumn to spring and autumn to summer were all significantly different with intermediate R values ($R = 0.483$, 0.425 and 0.486 respectively, $p = 0.001$). This seasonal pattern was more strongly reflected in the seasons across survey year ANOSIM ($R = 0.645$, $p = 0.001$), with autumn to winter, autumn to spring and autumn to summer having high R values ($R = 0.929$, 0.764 and 0.574 respectively, $p = 0.001$). Spring to winter and spring to summer showed more subtle differences, with intermediate R values ($R = 0.489$ and 0.442 ; $p = 0.001$).

For fish only, seasonal differences were more subtle (ANOSIM $R = 0.27$, $p = 0.001$, across geographic areas), with only the autumn to winter and autumn to summer comparisons statistically significant and with intermediate R values (0.532 and 0.526 , $p = 0.001$), but autumn to spring was not significant. For fish only, season (ANOSIM $R = 0.3$, $p = 0.001$, across survey years) differences were more obvious, but not as clear as for all taxa. R values for pairwise comparisons between autumn to winter, autumn to spring and autumn to summer ($R = 0.601$, 0.442 and $R = 0.617$; $p = 0.001$), whilst still reasonably large, were not as large as for the same all taxa comparisons. Spring to winter was not significant, and spring to summer had a low R value ($R = 0.344$, $p = 0.001$), suggesting no obvious difference between these seasons for fish only.

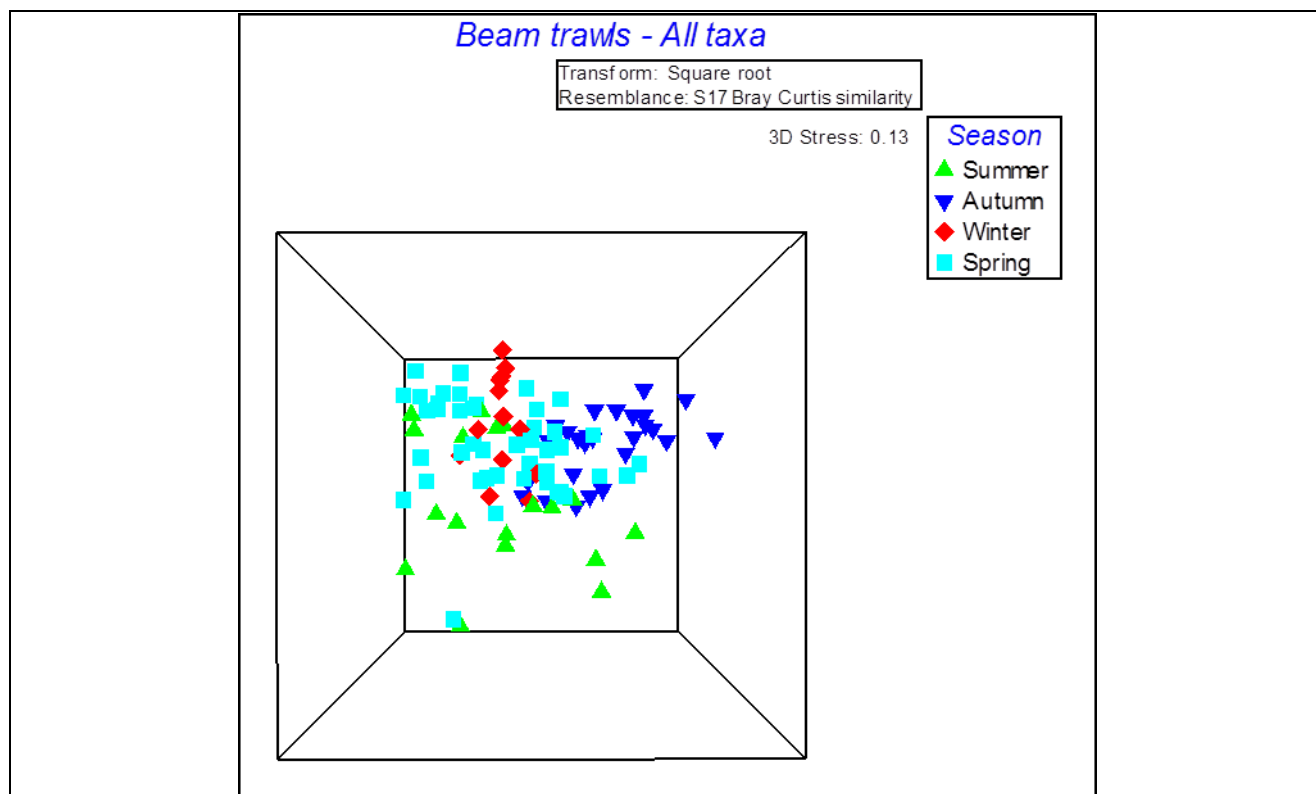


Figure 11: 3-Dimensional MDS Plot of Beam Trawl all Taxa by Season (Source: BMM, 2012).

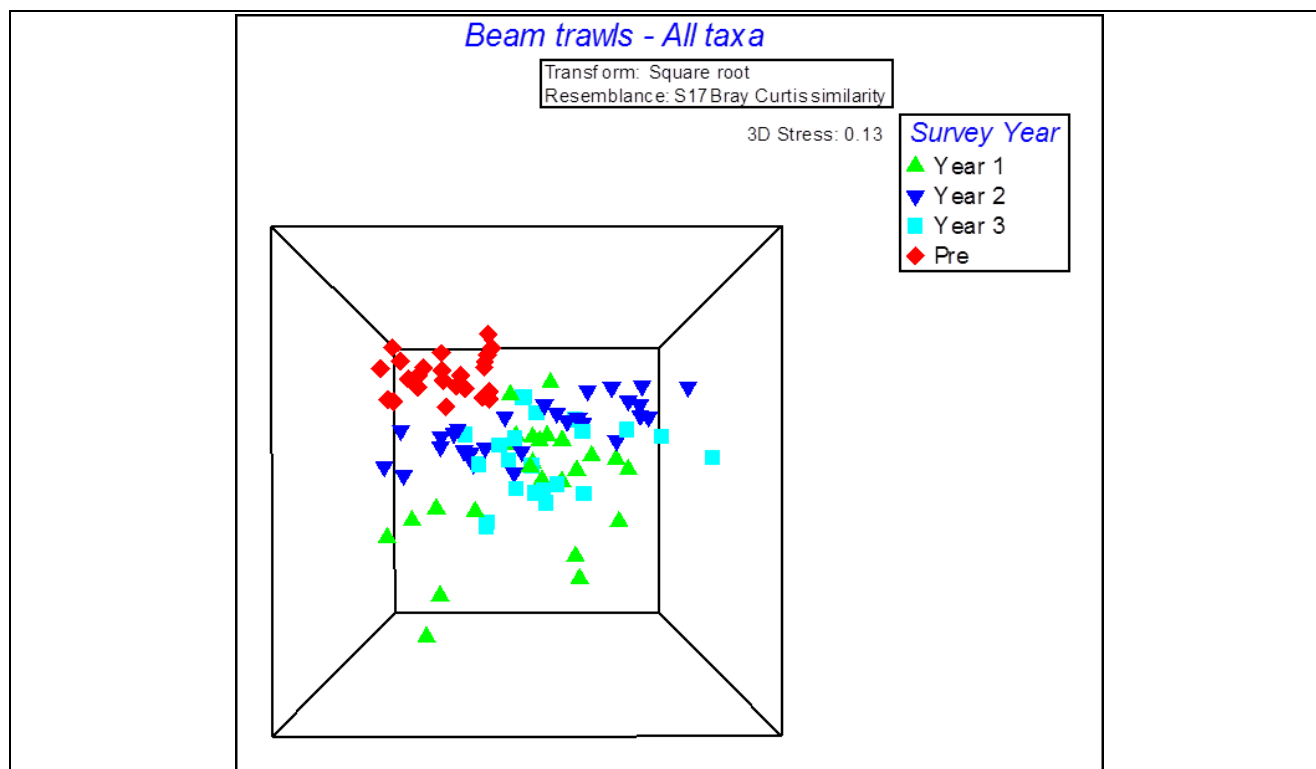


Figure 12: 3-Dimensional MDS Plot of Beam Trawl all Taxa by Survey Year (Source: BMM, 2012).

Differences between surveys years (across seasons) for all taxa were significant, with a global R of 0.0623 ($p=0.001$), and this was reflected in the pairwise comparisons between survey years, which were all significant. Large R values were returned for comparisons between Year 1, Year 2 and Year 3 post-construction and pre-construction ($R=0.743$, 0.808 and 0.884 , $p=0.001$). Pairwise comparisons between Year 1 and Year 2 post-construction ($R=0.649$, $p=0.001$) also suggested differences between these year groups. Intermediate ($R=0.455$, $p=0.001$) and small ($R=0.244$, $p=0.001$) R values were returned for Year 2 and Year 3 post-construction, and Year 1 and Year 3 post-construction pairwise comparisons respectively, suggesting greater overlap between sites within these survey years.

Differences between survey years (across seasons) for fish did not reflect that shown for all taxa, with a small global R of 0.3 ($p=0.001$), and similar small R values, where significant, for pairwise comparisons. Only pre-construction compared to Year 1 post-construction gave an intermediate R value ($R=0.41$, $p=0.001$), which suggests a reasonable degree of overlap between sites within these survey years.

For all taxa, seasonal and survey year differences were largely due to variations in the abundance of *P. montagui* and *C. crangon*, which were abundant in autumn, and less so in the other seasons, particularly in the summer. For survey years, highest abundances of both species were recorded in Year 2 post-construction, with catch rates for both species an order of magnitude higher for September and October 2010 (Year 2 post-construction, autumn) and October 2011 (Year 3 post-construction, autumn), with tens of thousands of individuals caught per hour, rather than the general hundreds or thousands caught per hour.

For fish only, seasonal differences were due to differing abundances of *Pomatoschistus* spp., *C. lyra*, sea snail (*Liparis liparis*) and *L. limanda*, which were abundant in the autumn. Winter samples were also characterised by the occurrence of *M. merlangus* and sprat (*Sprattus sprattus*). Annual variations were not significant and were therefore not considered further.

4.5.3.2.2 Shrimp Trawl Survey

Cluster analysis and MDS plots for shrimp trawl sampling sites (all taxa, and for fish only) labelled with factors (geographic area, season, survey year and pre-construction and post-construction) are provided in Appendix 4. The MDS plots suggested some loose groupings of sites by survey year (pre-construction sites to the bottom right; Figure 13) but no observable patterns for season or geographic area (see Appendix 4 for figures). Factors were also applied for non-piling versus piling surveys (surveys which were undertaken when Lincs piling was underway), for which no observable pattern was shown, i.e. grouping of the piling sites.

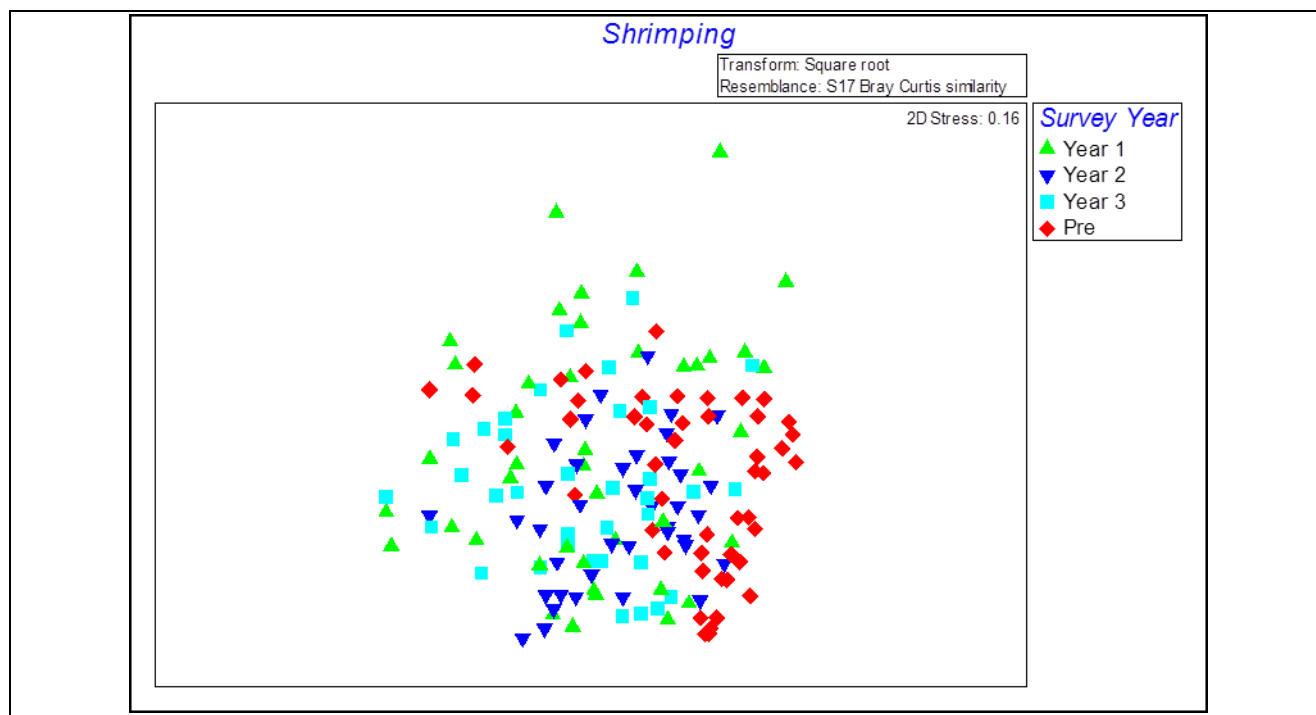


Figure 13: 3-Dimensional MDS Plot of Shrimp Trawl by Survey Year (Source: BMM, 2012).

No significant difference (ANOSIM $R=0.072$, $p=0.011$) was observed between geographic areas (across season). ANOSIM global R values for seasonal differences across geographic areas ($R=0.157$, $p=0.001$) and across survey years ($R=0.165$, $p=0.001$) were small, indicating little seasonal variation. Despite the apparent pattern observed in Figure 13, the global R value for survey year differences across season ($R=0.239$, $p=0.001$) indicates no real difference for sites between survey years, nor did pairwise comparisons indicate any difference between survey years.

As the shrimp surveys were specifically designed to capture *P. montagui* and *C. crangon*, and only collected other species as a by-catch, it is unsurprising that these species dominated the catches across all seasons and survey years. The dominance of these two species clearly obscure the seasonal and annual fish (and invertebrate) species community composition patterns observed in the multivariate analyses for the otter and beam trawl.

For these two species, subtle variations in catch rates were observed between sites, with the greatest variation noted between survey years. The greatest numbers of *P. montagui* were recorded during the Year 2 post-construction survey with a catch rate of 20,907.1/hr, followed by Year 1 (11,924.9/hr) and then Year 3 (11,074.5/hr). *C. crangon* were most prevalent during the Year 2 survey with a catch rate of 14,157.6/hr, followed by Year 3 (13,395.3/hr) and then Year 1 (12,956.8/hr). Pre-construction surveys recorded the lowest catch rate for both species: *P. montagui* (9,316.9/hr) and *C. crangon* (1,233.0/hr). This may be as a consequence of the pre-construction surveys being undertaken predominantly in autumn/winter months, whereas recruitment and therefore higher abundances generally occurs in spring and summer months. Catch rates for May/June and August/September (post-construction Years 1, 2 and 3) are generally 10,000 to 40,000/hr; none of these months were surveyed pre-construction.

4.5.3.2.3 Potting Survey

Cluster analysis and MDS plots for potting sampling sites labelled with factors (geographic area, season, survey year and pre-construction and post-construction) are provided in Appendix 4. The cluster and MDS plots suggested some groupings of sites by season (Figure 14 below for MDS plot; winter to the right, all other seasons to the left) and possibly also by geographic area (Figure 15 below for MDS plot; "cable" sites to the bottom right), but not by survey year. Note that pre-construction potting data was excluded from these analyses due to differences in the survey methodology applied (number of pots/soak times). Non-piling and piling as factors was also applied (related to surveys carried out during piling events at the adjacent Lincs site), but did not show any observable patterns i.e. grouping of the piling sites. ANOSIM was used to test for differences between these factors.

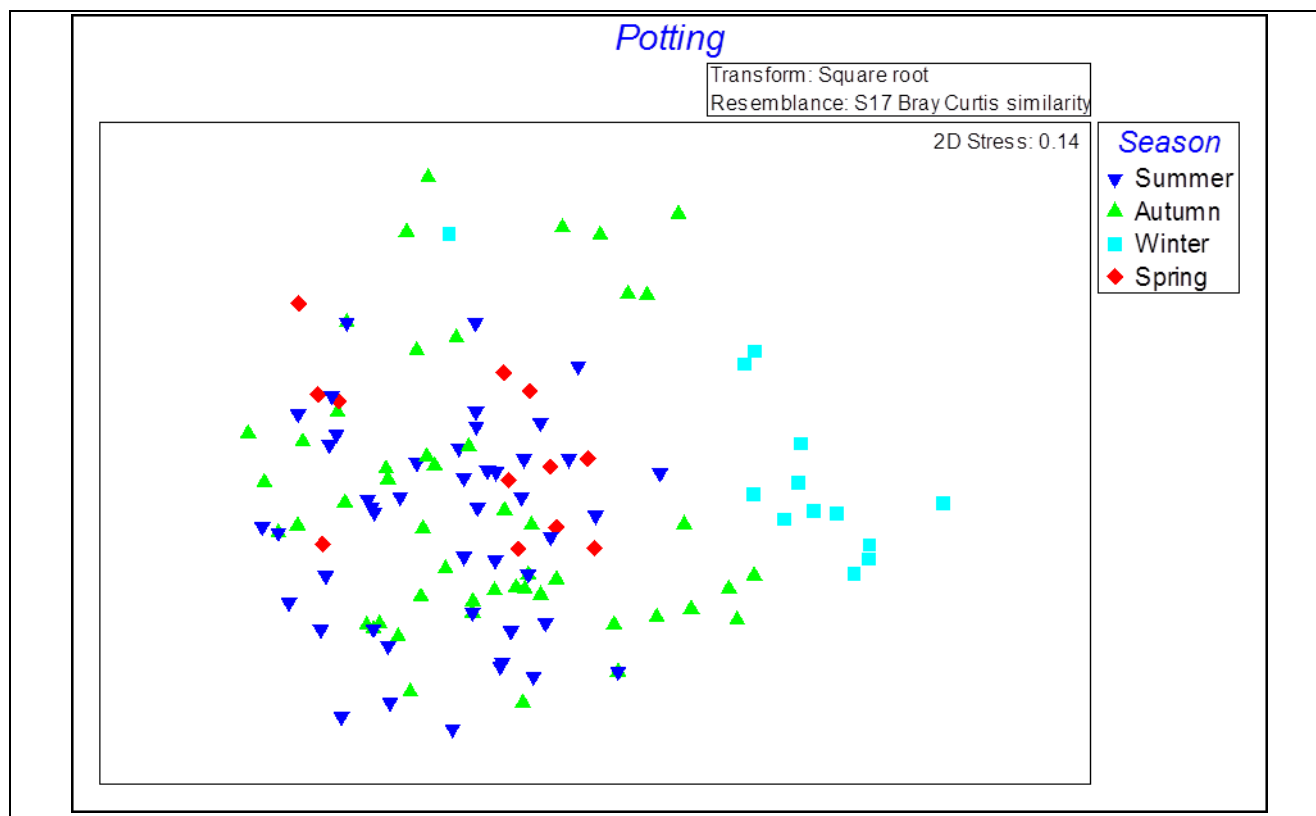


Figure 14: 3-Dimensional MDS Plot of Potting data by Season (Source: BMM, 2012).

A small global R value ($R=0.197$, $p=0.001$) was observed indicating no differences between survey years across seasons, with no statistically different pairwise comparisons. ANOSIM for seasonal differences across geographic area and survey years, whilst significant, had small global R values ($R=0.294$ and 0.223 respectively, $p=0.001$), however pairwise comparisons for both showed winter to be strongly different to the other seasons, with R values for seasons across geographic areas of $R=0.922$, 0.857 and 0.648 ($p=0.001$) for winter to spring, winter to summer and winter to autumn. No other seasonal pairwise comparisons were significant.

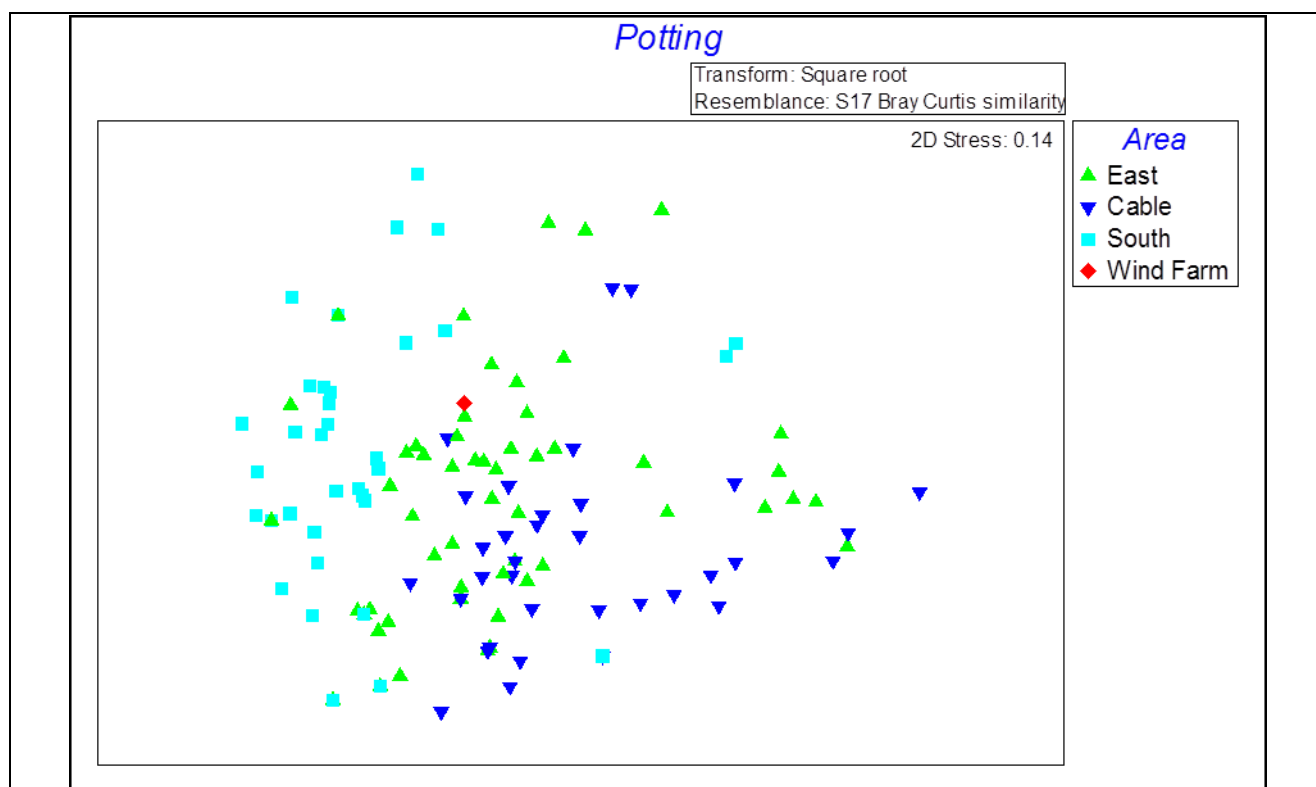


Figure 15: 3-Dimensional MDS Plot of Potting data by Geographic Area (Source: BMM, 2012).

For geographic areas (across seasons) the global R value was again small ($R=0.307$, $p=0.001$) however pairwise comparisons showed that sites found in the vicinity of the export cables, and those to the south of the wind farms, were significantly different ($R=0.601$, $p=0.001$).

SIMPER analysis showed that winter and the other seasons were characterised by the same species, but with differing abundances, with winter characterised by higher *P. bernhardus* and *B. undatum* (i.e. low abundances of *C. pagurus* and *C. maenas*), whereas all other seasons were dominated by *C. pagurus* and *C. maenas*.

The “cable” area was characterised by higher abundances of *P. bernhardus* and *B. undatum*, whereas the south area was characterised by higher abundances of *C. pagurus*.

During the pre-construction surveys the catch rates of *C. pagurus* and *H. gammarus* were considerably greater than that of the post-construction surveys (primarily at P06). Commercial landings data reflected this pattern for *C. pagurus*, with landings of this species being twice as high pre-construction than post-construction. *H. gammarus* landings data did not reflect the patterns detected in surveys, with similar levels reported both pre and post-construction.

4.5.3.2.4 Longlining Survey

Overall, considerably higher numbers of individuals were caught during the pre-construction surveys (785) than in the Year 1, 2 and 3 post-construction surveys (313, 161 and 178 respectively). The pre-construction surveys recorded the greatest number of species (9), followed by post-construction Years 1 and 3 (8) and then Year 2 (7), although these differences are marginal.

M. merlangus represented the highest proportion of the total catch in the pre-construction and the Year 1, 2 and 3 post-construction surveys. *M. merlangus* represented 80.4% of the total catch during the pre-construction surveys, compared with 45.7%, 56.5% and 62.9% in the Year 1, 2 and 3 post-construction surveys respectively. The large total catch size was therefore as a direct result of the large catches of this species, and to a lesser extent cod *Gadus morhua*.

There were generally higher abundances of elasmobranchs caught in early summer (May/June), with lower, but relatively consistent abundances at the end of the summer/early autumn also (September). Abundances of elasmobranchs were generally low pre-construction compared to Year 1, 2 and 3 post-construction.

4.5.4 Results for any comparison with wider data sources

4.5.4.1 Otter and Beam Trawl Surveys

4.5.4.1.1 Otter Trawl Survey

Landings data for otter trawls in the wider area (ICES 35F0) provided data for three key species groups measured: *G. morhua*, *M. merlangus* and skates and rays. Relatively small landings were taken in 2004/2005 (pre-construction) and 2009/2010 (post-construction)²², with higher landings in the intervening years (2006 to 2008). For rays and skates, the low catch rates recorded by the LID otter trawl surveys in 2004/2005 (the pre-construction years) is reflected in the landings data. Whilst the site-specific data for both post-construction Year 1 and Year 2 had higher catch rates for *R. clavata*, only a peak in skate and rays landings in 2009 was discernible. The higher annual catch rate of *M. merlangus* recorded for the pre-construction survey years (2004/2005) compared to the LID Year 2 post-construction (and other post-construction) survey years was not observed in the landings data, although it should be noted that the higher catch rates in the site-specific pre-construction survey were likely to be as a result of a predominance of autumn/winter surveys undertaken in 2004/2005.

Seasonally, the landings data display an autumn/winter peak in *M. merlangus*, which reflects the general strong seasonal pattern shown in the site-specific data. A landing data peak for skates and rays noted in February (winter), was not reflected in the site-specific data for *R. clavata*, which generally had higher catch rates in autumn and spring. Skates and rays, however, did not occur in high enough abundances in the site-specific otter trawl surveys to influence the overall community composition patterns in the site-specific data.

The seasonal variations noted in the site-specific surveys were generally reflective of the wider patterns observed in the landings data. Annual variations did not marry as well, however the landings data did show that large annual variations in species composition across the wider area occur, and that pre-construction and post-construction variations are more likely to be as a result of these natural variations (and predominance for autumn/winter surveys in the pre-construction survey year) than attributable to the wind farms.

4.5.4.1.2 Beam Trawl Survey

Whilst there may be other variables influencing landings data e.g. landing value dictating volume landed, the annual variations observed in the wider area (ICES 35F0) indicated relatively low annual landings in the pre-construction years (2004 and 2005), compared to the Year 1 (and partly Year 2) post-construction years (2009 and 2010)²², with approximately 200-250 tonnes landed annually pre-construction, and 400-450 tonnes landed annually Year 1 (and partly Year 2) post-construction for *C. crangon*²¹. *P. montagui* was recorded at much lower and consistent levels (<25 tonnes) for each year. This annual variation in *C. crangon* is reflected in the site-specific data, with low catches in 2004/2005 (pre-construction) compared to Year 1 and in particular Year 2 post-construction.

Seasonal patterns observed in the landings data indicate high abundances for *P. montagui* in September through to December (peaks in October and November) and for *C. crangon* in May to September. This seasonal pattern is reflected in the site-specific data with high abundances in autumn and low abundances in summer for both species.

The annual and seasonal variations noted in the site-specific surveys were generally reflective of the wider patterns observed in the landings data, which suggests that these variations are not attributable to the wind farms.

4.5.4.2 Shrimp Trawl Survey

The annual variation in *C. crangon* landings (see Section 4.5.4.1.2) is reflected in the site-specific data, with both species (*C. crangon* and *P. montagui*) recorded in lower abundances (and weights) in the pre-construction surveys, than in the post-construction surveys (in particular Year 2). This suggests that any annual variation in the abundances of these species is as a result of wider annual variation and not as a result of construction of the LID wind farms.

Seasonal patterns observed in the landings data (see Section 4.5.4.1.2), whilst reflected in some years for *P. montagui* (2004 and 2009), were not peak months for other years when the site-specific surveys were undertaken, and no clear seasonal pattern was observable for *C. crangon* in the site-specific surveys in the shrimp trawl data.

As with beam trawls, the annual and seasonal variations noted in the site-specific surveys were generally reflective of the wider patterns observed in the landings data, which suggests that these variations are not attributable to the wind farms.

²² Post-construction Year 1 (August 2009 to July 2010) and Year 2 (August 2010 to June 2011).

4.5.4.3 Potting Survey

Seasonal patterns in abundances observed in the site-specific potting data are broadly reflected in the landings data, with lower abundances of *C. pagurus* in winter months compared to other seasons. The relatively higher abundances of *B. undatum* in winter months in the site-specific data are not reflected in the landings data, however, it is likely that the late winter/early spring peaks in landings are a reflection of lower available landings of other key species, rather than an observable seasonal trend in abundances.

4.5.4.4 Longlining Survey

Landings data for longlining indicates low levels of activity prior to 2008. This could however be an artefact of poor record keeping prior to this date and therefore comparisons between site-specific data and landings data need to be viewed cautiously. For 2008 to 2010²², the highest numbers recorded in the landings data are for *G. morhua*, skates and rays, with the lowest numbers observed for *M. merlangus*. This does not reflect the site-specific catch rates, with *M. merlangus* having much higher catch rates than any other species, and *G. morhua* very low catch rates. Landings records may therefore reflect the much higher commercial value and popularity of *G. morhua* over *M. merlangus*. Seasonal trends in landings data do show a peak for skates and rays in April and June, which is broadly reflected in the site-specific peaks in catches for these species. Both *G. morhua* and *M. merlangus* had higher catch rates in 2004/2005 (pre-construction) compared to post-construction in the site-specific data, however the opposite is shown in the landings data, although note that this data should be viewed with caution as described above. *G. morhua* was generally caught more in the winter months for the site-specific surveys and this is also reflected in the landings data. *M. merlangus*, as with the annual catches, recorded small landings throughout compared to *G. morhua*, however landings made were in autumn/winter, as noted in the site-specific longlining surveys.

Generally, seasonal patterns between the two datasets were comparable. Annual variations generally did not agree, although comparisons should be viewed with caution.

4.5.5 Piling versus non-piling surveys

A number of post-construction surveys were undertaken whilst piling operations were on-going at the adjacent Lincs site, these are detailed below in Table 28. Multivariate analyses undertaken for each of the surveys types (shrimp and potting) were used to test whether there was any significant difference between surveys undertaken during piling (e.g. survey taking place on the same date as piling) versus general non-piling conditions (e.g. survey taking place on a date when no piling was occurring) by applying these conditions as factors. No patterns were observed in the respective MDS plots, or through ANOSIM tests.

Table 28: Lincs Piling Events during Surveys (Source: BMM, 2012).

Survey		Piling Event
Shrimp	SS17 (1 st to 2 nd June 2011)	02/06/2011
	SS19 (22 nd to 26 th September 2011)	19/09/2011
	SS21 (16 th to 17 th February 2012)	17/02/2012
Potting	PS18 (6 th to 10 th June 2012)	10/06/2012
	PS21 (16 th to 24 th January 2012)	16/01/2012

Information on the impact of underwater noise on marine invertebrates is scarce. Studies that looked at the effect on crustacean catch rates in response to seismic air guns observed little or no effect (Parry and Gason, 2006). There is, however, evidence that shows cephalopods are susceptible to high intensity, low-frequency sound underwater (e.g. André *et al.*, 2011). There is some indication that cephalopods and crustaceans may be capable of 'hearing' low frequency noise, such as piling noise, suggesting that piling noise may have the potential to impact the behaviour of local populations (Lovell *et al.*, 2005; Hu *et al.*, 2009). Crustaceans could also detect sound as it propagates through the water from a piling event by detecting the particle velocity aspect of the wave (e.g., the vibration of the water molecules which results in the pressure wave) and ground borne vibration. Whilst it is generally thought that their hairs provide the sensitivity, they also have other sensor systems, which could be capable of detecting vibration. Although behavioural effect of vibration in the seabed on crustaceans is unknown, vibration generated in the seabed would be anticipated to decay more rapidly than the acoustic pressure component in the water, which is regarded as the prevalent component when considering impact of underwater noise on marine life. Crustacean sensitivity thresholds to particle motion reported in the literature vary from around 0.1 to 1.0 μm at frequencies of around 100 Hz or less. This is several orders of magnitude less sensitive than fish threshold sensitivity to particle motion (which is the main sensitivity response for many fish species) and they are therefore less likely to be affected than fish or only be affected at ranges much less than those predicted for fish.

For the key species caught by these survey types (shrimp and potting), no effect of piling noise would be anticipated, as motile invertebrates are not considered to be highly sensitive to noise impacts.

4.5.6 Electro-magnetic fields

Geographic areas were used as a proxy for assessing the potential effect of electro-magnetic fields (EMF) on fish communities through the monitoring surveys. Whilst the number of surveys that were undertaken in the LID wind farms themselves was limited, surveys were undertaken in proximity to the export cables for both wind farms pre-construction and post-construction, and at 'reference' locations to the north and south of the wind farms. No geographic changes in community composition were noted for any of the trawl surveys (otter, beam and shrimp) or the longlining survey. The only survey for which geographic differences were noted was for potting, with differences between the "cable route" sampling sites and sites to the south. The "cable" area was characterised by higher abundances of *P. bernhardus* and *B. undatum*, whereas the south area was characterised by higher abundances of *C. pagurus*.

EMF will result from the installation of the export cables and inter-array cables. The transport of electricity through export and inter-array power cables has the potential to emit a localised EMF which could potentially affect the sensory mechanisms of some species of fish and shellfish, particularly electrosensitive species (including elasmobranchs) and migratory fish species (CMACS, 2003).

EMF comprise both the electric (E) fields, measured in volts per metre (V/m), and the magnetic (B) fields, measured in tesla (T). Background measurements of the magnetic field are approximately 50 μT in the North Sea, and the naturally occurring electric field in the North Sea is approximately 25 $\mu\text{V m}^{-1}$ (Tasker *et al.*, 2010). It is common practice to block the direct electrical field (E) using conductive sheathing around the cable, meaning that the EMFs that are emitted into the marine environment are the magnetic field (B) and the resultant induced electrical field (iE). A key misconception in the understanding of the effects of EMF has been the assertion that cable burial will work to mitigate iE and B field effects and that there will be no externally detectable electric fields generated by industry standard subsea power cables. The conclusion of the COWRIE EMF study (Gill *et al.*, 2005) and subsequent clarification in the Phase 2 COWRIE EMF report (Gill *et al.*, 2009) highlight the fact that it is impractical to assume that cables can be buried at depths that will reduce the magnitude of the B field, and hence the sediment-sea water interface iE field, below that at which they could be detected by certain marine organisms.

A variety of design and installation factors affect EMF levels in the vicinity of the cable. These include current flow, distance between cables, cable insulation, number of conductors, configuration of cable and burial depth. The flow of electricity in an AC cable changes direction (as per the frequency of the AC transmission) and creates a constantly varying electric field in the surrounding marine environment (Huang, 2005).

The modelling of iE fields for AC cables requires consideration of the size of an organism and its distance from the cable. Modelling of iE fields in a small shark of 150 cm length, swimming 0.6 m above and parallel to a 60 Hz AC cable buried to 1 m produced a maximum iE field strength of 765 $\mu\text{V m}^{-1}$ (Normandeau *et al.*, 2011). Other orientations will result in lower values of iE fields. Ultimately, the effects would depend on site and project specific factors related to both the magnitude of EMFs and the ecology of local populations including spatial and temporal patterns of habitat use.

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

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

Elasmobranchs (i.e. sharks, skates and rays) are known to be the most electro-receptive of all fish. They possess specialised electro-receptors which enable them to detect very weak voltage gradients (down to 0.5 $\mu\text{V m}^{-1}$) in the environment naturally emitted from their prey (Gill *et al.*, 2005). Both attraction and repulsion reactions to E-fields have been observed in elasmobranch species. Gill and Taylor (2001) found limited laboratory based evidence that the *S. canicula* avoids DC E-fields at emission intensities similar to those predicted from offshore wind farm AC cables (i.e. 10 $\mu\text{V cm}^{-1}$). A COWRIE-sponsored mesocosm study demonstrated that *S. canicula* and *R. clavata* were able to respond to EMF of the type and intensity associated with subsea cables; the responses of some ray individuals suggested a greater searching effort when the cables were switched on. However, the responses were not predictable and did not always occur (Gill *et al.*, 2009).

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

At LID, whilst there are differences in the crustacean species abundances in the vicinity of the export cable routes and to the south of the wind farms (with higher abundances of *C. pagurus* in the south), no annual variations were apparent, albeit with comparisons to pre-construction surveys excluded from the multivariate analyses due to the limitations of this dataset (varying number of pots and soak times for strings). It is therefore likely that the geographic difference is as the result of other natural parameters, for example, the cable area being located closer to the shore in shallower water. For all other surveys (trawls) where no geographic differences in community composition were detected, this is considered to be unsurprising, as EMF effects, as described above, are likely to be limited to a localised area around a cable (within 10 m), and therefore trawls which sample a strip of seabed (~500 m), are unlikely to aid in detecting any locally discernible effects.

The data have also been reviewed specifically for changes in the occurrence of electro-sensitive elasmobranch species within the wind farm sites (which contain the inter-array cables), and along the export cables, compared to areas to the north and south of the wind farm sites, for otter trawl and longlining²³. *R. clavata* catch rates for both survey types are higher in the wind farm sites and along the export cables post-construction (where surveyed) than pre-construction, however this apparent change is within the natural variability of catch rates for the geographic areas and survey years considered. There is also variation across areas and survey years for the other elasmobranch species recorded.

More generally, abundances of elasmobranchs were low pre-construction compared to Year 1, 2 and 3 post-construction (for longlining and otter trawls), with low pre-construction abundances also apparent in the landings data (although note the limitations of the pre-2008 longlining landings data) so potentially reflective of wider annual variations in skate and ray numbers.

The monitoring surveys have therefore found no evidence of elasmobranch species being more prevalent in the vicinity of the LID export and inter-array cables, within the limitations noted for the paucity of post-construction surveys undertaken within the wind farm sites.

4.5.7 Comparisons with the LID Environmental Statements

Q5: To what extent does the post-construction monitoring validate the predictions made in the ESs, particularly in regard to electro-sensitive species?

Predictions made in the LID ESs for fish stocks (as part of the commercial fisheries chapters for each ES (Amec, 2002; OWP, 2002)) were as follows:

- **Increase in suspended sediment and turbidity during construction:** Localised impact only, and therefore no discernible adverse effect on fish stocks. Not significant in the long term.
- **Sediment redistribution during construction:** Localised impact only, and therefore no discernible adverse effect on fish stocks. Not significant in the long term.
- **Loss of habitat during construction and operation:** Localised effect only, so no discernible adverse effect on fish stocks. Not significant in the long term.
- **Creation of new habitat during operation:** Potential positive effect with turbines/foundations acting as fish aggregation device.

The predictions made in the LID ESs of localised effects that would not be discernible, are borne out by the site-specific monitoring data, with the general annual variations noted also occurring in the wider fisheries data (landings data, noting the limitations of the longlining data pre-2008), and not attributable to the wind farm construction activities. However, the key limitation to this conclusion is the paucity of surveys undertaken within the wind farm

²³ Only two longlining sampling sites “within” the LID wind farms undertaken post-construction, in Year 2 (September 2010, December 2010 and March 2011 surveys): sites L05 (actually located between Lynn and Inner Dowsing) and L09 (directly to the east of the Lynn wind farm site and partly within the Lynn Construction Exclusion Zone as per the extent of this zone before March 2011).

development areas post-construction, which limits the assessment of any localised effects of seabed disturbance from the construction activities on fish and shellfish populations.

- **Noise and vibration:** No discernible adverse effect anticipated from construction or operational noise.

Within the limits of the site-specific fish survey data collected (i.e. lack of data collection within the LID wind farm sites post-construction; the only wind farm based site sampled in Year 3 being shrimp trawl ST04), no discernible effects of the wind farms on the fish community composition were observed, including effects of operational noise.

In general, the site-specific fish monitoring surveys were not designed to detect changes in fish community composition as a result of construction noise and vibration. However, there was opportunity to appraise the effects of construction noise given the Lincs piling events coinciding (e.g. on the same date) with a limited number of LID site-specific shrimp and potting surveys. This is discussed in Section 4.5.5, with no discernible adverse effects of construction noise on the fish community composition and specifically on shellfish populations noted.

- **Electromagnetic fields:** Possible behavioural effects on EMF sensitive fish species such as elasmobranchs, however, no discernible effect on fish stocks anticipated.

Effects of EMF are discussed in Section 4.5.6, with no discernible adverse effects on fish populations noted, and possible effects on shellfish populations more likely to be attributable to geographic variations rather than as a result of the presence of the LID export cables e.g. coastal, shallow waters, versus offshore, deep water reference sites. General observations of catches in electro-sensitive species such as skates and rays in site-specific longlining and otter trawl surveys gave lower catch rates of these species pre-construction versus post-construction, and therefore could suggest attraction of these species to the general area of the LID wind farms, and associated inter-array and export cables. However, this also followed the general annual variation trend observed for the wider landings data (noting that the longlining data pre-2008 is limited), and therefore is unlikely to be attributable to the LID wind farms.

4.5.8 Conclusions

In general, the comparisons between pre-construction and post-construction Year 1, 2 and 3 site-specific monitoring data show, as would be expected, strong seasonal changes for most survey types, in particular otter and beam trawl and potting data, but no seasonal differences observed for shrimp trawl surveys, which were dominated by two motile invertebrate species *P. montagui* and *C. crangon*. Any seasonal community changes (in fish and other invertebrates) were thereby obscured by the dominance of these two species. General seasonal differences included higher abundances of *M. merlangus* in autumn and winter, and *L. limanda* in summer and autumn for otter trawl surveys. For beam trawl, seasonal differences were dominated by the abundance of *P. montagui* and *C. crangon*, which through the beam trawls were found to be more abundant in autumn, and less so in the other seasons, particularly in the summer. For fish only, *Pomatoschistus* spp., *C. lyra*, *L. liparis* and *L. limanda* (as noted also in the otter trawls) were higher in autumn, with winter samples also characterised by *M. merlangus* (as was the case for the otter trawls) as well as *S. sprattus*. For potting, winter surveys had higher abundances of *P. bernhardus* and *B. undatum* (i.e. low abundances of *C. pagurus* and *C. maenas*), whereas all other seasons were dominated by *C. pagurus* and *C. maenas*. These seasonal trends in site-specific survey data were generally reflective of seasonal variations in the wider fish communities, as shown by the comparisons to the landings data (Section 4.5.4).

Q7: Is there evidence for any increasing or decreasing trends in species abundance and whether this could be attributable to the wind farms?

Inter-annual variations were also obvious, although not as dominant as seasonal variations. Differences were noted for pre-construction and post-construction years (in particular post-construction Year 2; in some cases weaker differences between post-construction Years 1, 2 and 3 were also noted) for the otter and beam trawl surveys. For otter trawls, differences between pre-construction and post-construction years were mainly due to high abundances of *M. merlangus*, *M. scorpius* and *A. cataphractus* during pre-construction, and for beam trawls higher abundances of *P. montagui* and *C. crangon* in the Year 2 post-construction surveys (an order of magnitude higher catches than other survey years). For shrimp surveys, inter-annual variation was obscured by the dominance of *P. montagui* and *C. crangon*, as was the case for seasonal variation comparisons. However, general data observations showed higher catches of both species in Year 2 post-construction, compared to pre-construction, with post-construction Year 1 and 3 in between. No inter-annual differences were observed for the potting data, noting that pre-construction was excluded from this comparison due to the differences in survey methodology (number of pots and soak times) between pre-construction and post-construction survey. Inter-annual variation across all four survey types generally showed higher catches for *M. merlangus*, *G. morhua* and a number of other fish species but lower catch rates for motile invertebrates *P. montagui*, *C. crangon* and *R. clavata* pre-construction compared to post construction (particularly when compared to Year 2). The higher catches of *M. merlangus* and *G. morhua* in the pre-construction surveys was likely due to the predominance of autumn/winter surveys undertaken in 2004/2005. These inter-annual variations, as with seasonal variations, were generally reflected in the wider fish community composition for the beam

and shrimp trawl surveys but not so for otter or longlining. The site-specific otter data, as previous, was likely to be affected by the autumn/winter predominance of surveys pre-construction, and the longlining landings data was limited by possible poor record keeping pre-2008. In addition, landings of *G. morhua* versus *M. merlangus* are likely to be reflective of the higher commercial value of the former species.

More generally, abundances of elasmobranchs were lower pre-construction compared to post-construction (for longlining and otter trawls), with low pre-construction abundances also apparent in the landings data for both survey types, so potentially reflective of wider changes in skate and ray numbers.

Given that these inter-annual site-specific variations are generally reflective of variations in the wider fish community (based on landings data as a proxy), there is no evidence to link cause and effect with the construction of the LID wind farms. The limitation to this conclusion, is that there was a general lack of sampling within the LID sites post-construction, which meant that any effects local to the wind farm development sites, as predicted in the LID ESs (Amec, 2002; OWP, 2002) would be undetectable.

Q6: Are the same species assemblages represented in the post-construction surveys compared with the pre-construction surveys, including electro-sensitive species?

As described above, the general changes between pre-construction and post-construction surveys are of abundances in species, rather than reflecting a change in the species composition between these survey years. No gross change in species composition between pre-construction and post-construction surveys has been observed for any of the site-specific survey types.

Q8: Is there evidence for changes in species distribution within the vicinity of the wind farm sites and whether this could be attributable to the wind farms?

Changes across geographic areas were also assessed using the pre-construction and post-construction site-specific monitoring survey data. Whilst the number of surveys that were undertaken within the LID wind farms themselves was limited, surveys were undertaken in proximity to the export cables for both wind farms pre-construction and post-construction, and at 'reference' locations to the north and south of the wind farms. No geographic changes in community composition were noted for any of the trawl surveys (otter, beam and shrimp) or the longlining survey. The only survey for which geographic differences were noted was for potting, with differences between the "cable route" sampling sites and sites to the south. The "cable" area was characterised by higher abundances of *P. bernhardus* and *B. undatum*, whereas the south area was characterised by higher abundances of *C. pagurus*. Whilst the potential for EMF from LID export cables was considered, it was thought that this change is more likely to be attributable to the shallow coastal locations of these survey sites, compared to the offshore, deeper water southern sites.

4.6 Marine Mammals

4.6.1 FEPA requirements

The FEPA requirements for monitoring marine mammals are set out in Table 29 below.

Table 29: FEPA Requirements – Marine Mammals.

Ref	FEPA Condition
9.12	During construction the Licence Holder must ensure that disturbance to cetaceans, pinnipeds (seals) and basking sharks is minimised by operating 'soft start' procedures for all drilling and/or driving operations.
9.13	The Licence Holder must ensure that suitably qualified and experienced Marine Mammal Observers (MMO) are appointed and Natural England notified of their identity and credentials before any construction work commences. The MMO must maintain a record of any sightings of marine mammals within the mammal monitoring zone and action taken to avoid any disturbance being caused to the species.
9.14	The Licence Holder must ensure that piling activities do not commence until half an hour has elapsed during which marine mammals have not been detected in or around the site. The monitoring should be undertaken both visually (by MMOs) and acoustically using appropriate passive acoustic monitoring equipment. Both the observers and equipment must be deployed at a reasonable time before piling is due to commence.
9.15	The Licence Holder must ensure that at times of poor visibility (e.g. night time, foggy conditions, sea state greater than that associated with force 4 winds) enhanced acoustic monitoring of the zone is carried out prior to commencement of relevant construction activity.
9.16	The Licence Holder must ensure that once the half hour non-detection period has past, piling only commences using an agreed soft start procedure. The duration and nature of this procedure must be discussed and agreed prior to commencement of operations with the MMO following consultation with Natural England.
9.17	The Licence Holder must make provision for a reporting methodology to be in place before works commence to enable efficient communication between the MMOs and the skipper of the piling vessel.

Marine mammal monitoring was carried out during the construction phase of the LID projects, with the results provided to the Licensing Authority in the Construction Monitoring Report (CREL, 2009). No post-construction monitoring was required for marine mammals although incidental observations of marine mammals have been routinely recorded during the boat-based bird surveys²⁴. The status of monitoring and history of reporting for this parameter is also summarised in Table 30.

Table 30: Status of Monitoring – Marine Mammals.

Phase	Requirement	Complete	LID Report
Pre-construction	N/A	N/A	N/A
During-construction	Monitoring	✓	Construction Monitoring Report (CREL, 2009)
Post-Construction	N/A	N/A	N/A
Phase	Additional Items	Complete	LID Report
Pre-construction	No FEPA requirement, however baseline report provided.	✓	Submitted via letter 06/04/07 (Appendix 10; ref 10.7)

²⁴ All observations of marine mammals from the boat-based bird surveys are presented in the survey summary sheets in the Appendices to the boat-based bird survey reports (e.g. ECON, 2012b).

4.7 Seabed Morphology & Scour

4.7.1 FEPA Requirements

The FEPA requirements for monitoring seabed morphology and scour are set out in Table 31 below.

Table 31: FEPA Requirements – Seabed Morphology & Scour.

Ref	FEPA Condition
9.23	The Licence Holder must undertake a bathymetric survey to assess changes in the bathymetry within the array and the need for (additional) scour protection around the turbine pylons. The survey is to be undertaken within 3-6 months after construction (weather permitting) and 9-12 months after construction. The necessity for further surveys should then be reviewed and where necessary surveys extended to the following two years (one survey each spring). The decision on the need and scope of these further surveys rests with the Licensing Authority. The spatial scope of the survey should include the base of all turbines as well as an area around 4 adjacent turbines to look at inter-turbine features. The Licence Holder must submit the data in the form of a report to the Licensing Authority, including proposals for scour protection measures.
9.24	To ensure the integrity of the windfarm infrastructure and minimise hazards to mariners the monitoring described in 9.23 should also investigate the cable route to ensure that the cable remains buried (such monitoring would need to continue throughout the lifetime of the windfarm although the frequency must be reviewed in discussions with the Licensing Authority at the end of the first year of monitoring).
9.27	The Licence Holder must ensure that the position of the cable (both horizontally and vertically) is well recorded with due regard to horizontal/vertical datums, spheroids etc. Thus if the seabed does erode the resulting depth of burial can be estimated.
9.28	The Licence Holder must ensure that the cable route (both within the array and the export cable) are surveyed on an annual basis using swath bathymetry for the first three years. Digital data must be supplied to the Licensing Authority with the annual reports. After 3 years the frequency and coverage will be reviewed. The results from this monitoring should be included in the annual monitoring reports required under condition 9.4 to this licence.
9.29	If the monitoring results carried out under Supplementary Condition 9.23 indicate that scour protection is not required, or if the Licence Holder's plans for scour protection differ substantively from the measures detailed in the Provisional Method Statement or in the Environmental Statement, the Licence Holder must seek approval from the Licensing Authority for the change in the works previously notified to the Licensing Authority.
9.33	The Licence Holder must undertake a pre-construction bottom and side scan sonar survey in grid lines across the area of development (turbine array, cable route, and any vessel access routes from the local service port(s) to the construction site) following discussions with the Licensing Authority as to those parts of the operation for which this is deemed necessary. Local fishermen must be invited to send representatives to be present during the survey. All obstructions found on the seabed must be recorded and plotted on a suitable chart. A post construction survey must be undertaken along the same grid lines (within operational and safety constraints), any new obstructions must be removed at the developers expense.
Annex 1 (2)	Seabed Morphology and Scour Monitoring of seabed morphology should include the cable route (both between the turbines and to shore) to assess sediment movements in relation to the cable burial depth and the long-term integrity of the cable.

Geophysical surveys have been carried out over the LID sites and export cable corridors during the pre-construction (2002) and post-construction (2009, 2010, 2011) phases, in compliance with the FEPA conditions. The results from the 2009 and 2010 surveys were presented to the Licensing Authority in the LID Year 1 and Year 2 post-construction monitoring reports (CREL, 2010; CREL, 2012).

This section of the Summary Report presents the results of a third year of post-construction geophysical surveys at the LID sites and export cable corridors. The Technical Report is provided in Appendix 5. This section reports on the comparison of the results of this latest survey with the previous two post-construction surveys carried out by EGS Ltd in 2010 and EMU in 2009, and the initial geophysical survey carried out by EMU in 2002 (where possible), in order to highlight any changes in sediment type and distribution, seabed features, and seabed elevation, as per the FEPA requirements.

Further monitoring will be planned for the lifetime of the wind farm to monitor cable burial, as required by FEPA condition 9.24, and this will be subject to a separate discussion between GLID and the Licensing Authority. The status of monitoring and history of reporting for this parameter is also summarised in Table 32.

Table 32: Status of Monitoring – Seabed Morphology and Scour.

Phase	Requirement	Complete	LID Report
Pre-construction	Survey	✓	Lynn and Inner Dowsing ESs (Amec, 2002; OWP, 2002)
During-construction	N/A	N/A	N/A
Year 1 Post-Construction	Survey	✓	Year 1 Post-Construction Monitoring Report (CREL, 2010)
Year 2 Post-Construction	Survey	✓	Year 2 Post-Construction Monitoring Report (CREL, 2012)
Year 3 Post-Construction	Survey	✓	Year 3 Post-Construction Monitoring Report
Ongoing	Further surveys to be agreed over the lifetime of the wind farm	-	N/A

The specific questions addressed by this Summary Report are as follows:

Q9	<i>Has the third post-construction geophysical survey carried out in 2011 revealed similar or different sediment types and distributions across the survey area compared with the surveys of 2002, 2009 and 2010?</i>
Q10	<i>Are there any similarities or differences in the presence or location of seabed features between 2011, 2010, 2009 and 2002?</i>
Q11	<i>Are there any changes in seabed elevation and topography between survey years and if so, how has this affected inter-array and export cable burial depth?</i>
Q12	<i>Is there evidence of scour around the wind turbine foundations?</i>
Q13	<i>Are any new obstructions apparent between the 2002 and post-construction surveys which may be debris left from the construction of the wind farms?</i>
Q14	<i>Has the monitoring confirmed the predictions in the ESs in relation to scour?</i>

Section 4.7.2 below provides a summary of the key findings from the Year 3 (2011) geophysical survey. Section 4.7.3 then summarises a comparison of successive pre-construction and post-construction geophysical survey results to allow any trends in seabed morphology and scour to be identified and discussed. A comparison of the results and findings from the monitoring with the predictions of the LID ESs is provided in Section 4.7.4, and Section 4.7.5 concludes by addressing each of the questions listed above.

4.7.2 Methodology and Results of the Year 3 survey

4.7.2.1 Methodology

A multibeam echo sounder (MBES) and side-scan sonar (SSS) survey of the LID wind farm sites and export cable route corridors was carried out by EGS (International) Ltd in October 2011, in order to identify sediment types and seabed features and provide further information for comparison with previous datasets. The methodology was submitted to and agreed with the Licensing Authority, based on the survey replicating the methodology of the previous survey completed in 2010 (with the exception of the inshore area of the export cables as agreed with the Licensing Authority).

The 2011 survey was carried out via the vessel “EGS Pioneer”, using a line plan of 40 m spacing in both the LID wind farm sites and export cable route corridors. A client representative was onboard the vessel to provide advice and ensure quality of data collection (EGS Ltd, 2012a). Full details of the survey equipment specification is provided in Appendix 5. The survey area is shown in Figure 16 below.

For both the LID wind farm sites and export cable route corridors, 100% coverage was acquired with the multibeam echo sounder and 200% coverage acquired with the SSS.

4.7.2.2 Results

Figure 17 shows a bathymetric image of the survey area, illustrating the turbine locations within the LID sites and also the locations of some of the key features noted within the survey and discussed in the following sections. A summary of the results for specific areas of interest in relation to the FEPA Licence conditions is provided below.

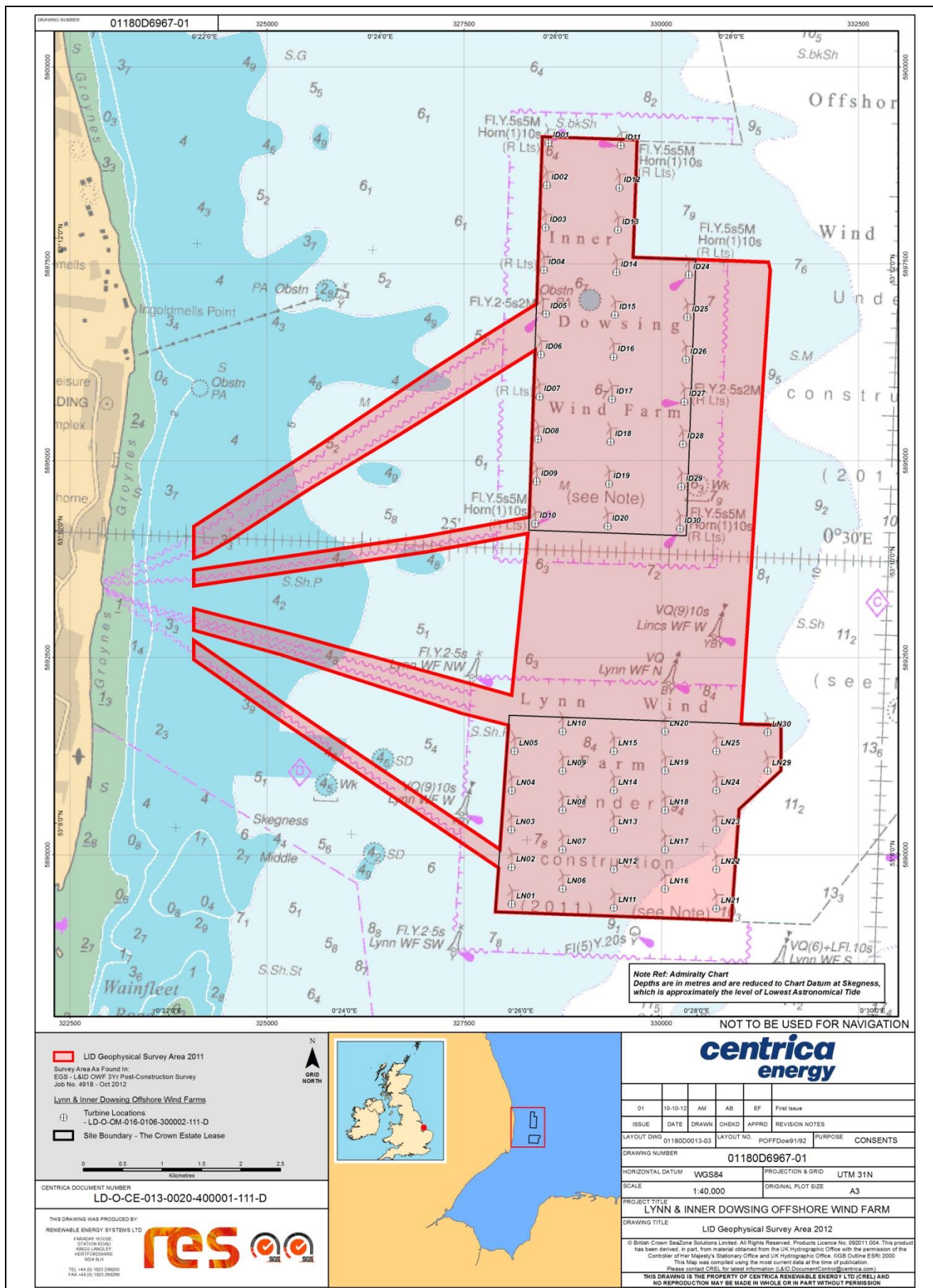


Figure 16: LID wind farms geophysical survey area 2011.

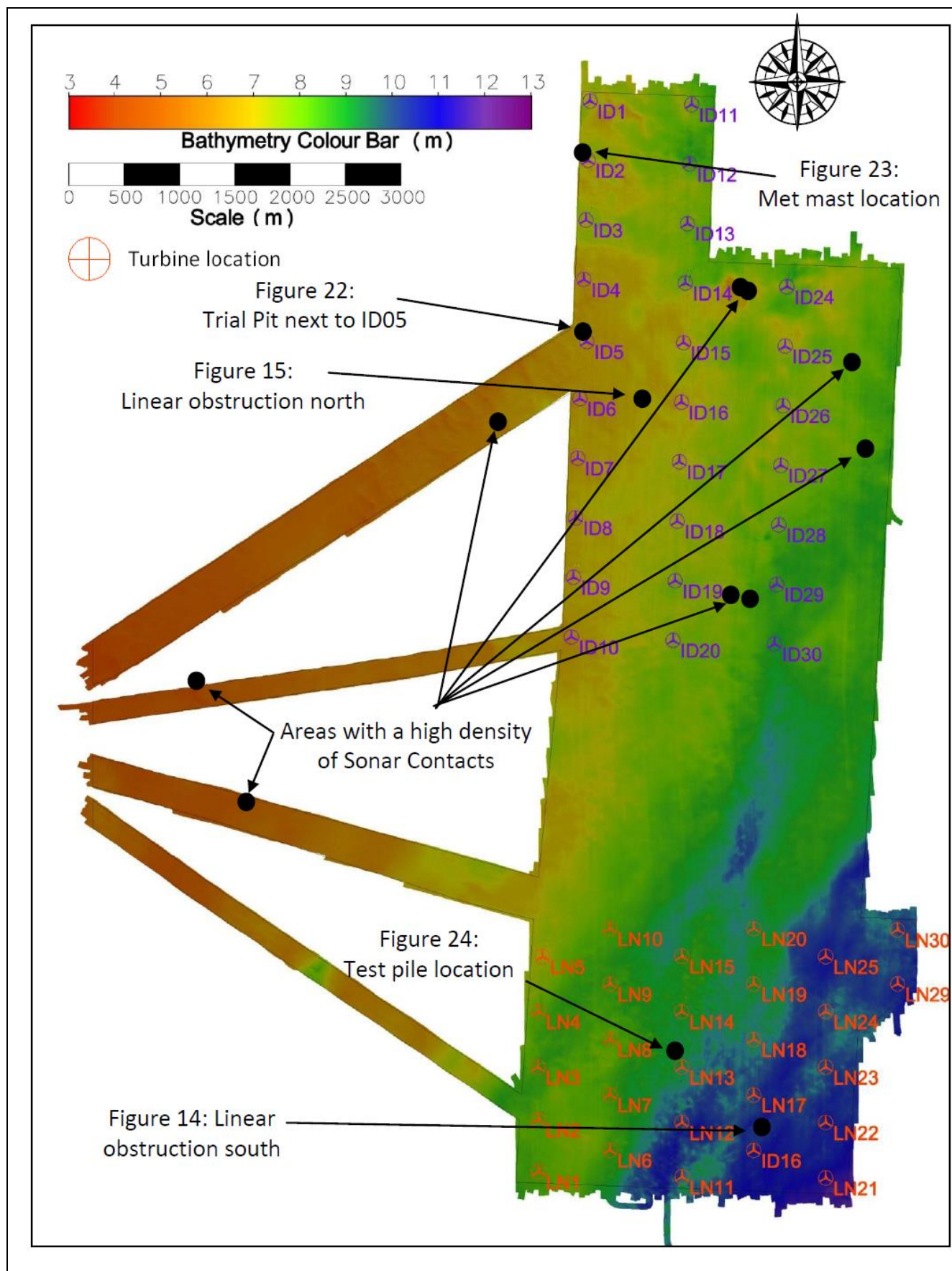


Figure 17: Bathymetric image of the survey area and locations of key features (EGS Ltd, 2012a) (Note: Figure references within the drawing relate to EGS Ltd (2012a), not this report, see Appendix 5).

4.7.2.2.1 Seabed sediments and bedforms

The SSS and benthic sampling data collected in 2011 revealed five main sediment types in the LID survey area (noting, sediment descriptions are in accordance with EGS Geo Standards and based on British Standards classifications (BS 5930)):

- Featureless gravelly SAND to sandy GRAVEL;
- Numerous CLAY patches;
- Gravelly SAND to sandy GRAVEL with megaripples;
- GRAVEL and COBBLES; and
- Bands of SAND and GRAVEL.

It is important to note that the majority of the seabed within LID sites comprises featureless gravelly SAND and sandy GRAVEL. The predominantly featureless seabed also contains areas of coarser sediments (interpreted as GRAVEL and COBBLES) and patches of CLAY. There are also recorded areas of alternating GRAVELS and SANDS in the southern sections of the survey area.

The majority of bedforms identified from the survey are located along the export cable corridors. Megaripples are most frequently mapped to occur along the southern most export cable corridor, with occurrences also in the other export corridors and in the south east of the main wind farm sites. The features have wavelengths of 2 - 4 m and heights of 0.1 – 0.2 m (EGS Ltd, 2012a). The megaripples are orientated west-northwest to east-southeast, but notably without any discernible asymmetry with which to confirm a sediment transport direction. Further bedforms are also recorded in EGS Ltd (2012a) in the northern-most export cable corridor with similar orientations to the megaripples above (in this case northwest to southeast), but markedly longer wavelengths (100 – 200 m) and heights of 0.5 – 0.9 m. The features are recorded by EGS Ltd (2012a) as low relief banks. Some sand ribbons are present in the south of the main LID sites and along the export cable corridors.

4.7.2.2.2 Sonar Contacts / Obstructions

The 2011 analysis identified 2328 sonar contacts. Contacts were included in the Contact List on the basis of having an acoustic shadow in addition to a primary dimension of at least 0.4 m. The number of sonar contacts identified is a large increase from the previous surveys carried out in 2002, 2009 and 2010, due to the different identification parameters used in terms of cut off for target sizes, and due to the higher resolution and quality of the 2011 survey compared with previous years (EGS Ltd, 2012a).

Two of these sonar contacts were classed as obstructions (SC5196 and SC5197) (as shown in Figure 17 above) due to their large size, and EGS Ltd (2012a) report that these were first identified in the 2002 pre-construction survey. EGS Ltd (2012a) state that both of these contacts are listed in the LID Archaeological Protocol (Wessex Archaeology, 2006b), where contact SC5196 is termed “debris” (3001), and SC5197 is termed “SSS anomaly” (3017) (EGS Ltd, 2012a). However, Wessex Archaeology consider that it is unlikely that these contacts relate to the archaeological anomalies for three reasons: 1) due to the distances between them (the location of these features are different between that presented in the Archaeological Protocol and that interpreted from the 2011 geophysical dataset, by 25 – 36 m); 2) the obstructions reported in EGS Ltd (2012a) appear to have been found in the 2011 bathymetric dataset whereas the anomalies presented in the Archaeological Protocol were identified from the 2002 side scan data; and 3) it is possible that the seabed has changed between 2002 and 2011, with anomalies that were visible in 2002 since being covered or even moved (Wessex Archaeology, *pers comm.*).

Nine “areas with numerous sonar contacts” were also identified (defined as a density of 5 or more contacts in an area of 100 m by 100m), with the largest of these areas concentrated in the north of the main wind farm sites around areas of “GRAVEL and COBBLES”. It was considered likely that the majority of contacts in these areas are boulders (EGS Ltd, 2012a).

4.7.2.2.3 Jack-up footprints

Jack-up footprints are visible at all wind turbine locations, and have resulted in the exposure of the underlying clay around some of the wind turbines. The footprints of two jack-up vessels can be seen in the bathymetric images: the 6 legs of the MPI Resolution, used during construction of the wind farms in 2007 and 2008, and the four legs of the MS Wind, used for maintenance during 2011. The MS Wind footprints are more prominent, as they have been created more recently, however the MPI Resolution footprints remain clearly defined at most wind turbine locations (EGS Ltd, 2012a).

Figure 18 below provides an example of the presence of jack-up footprints from a bathymetric image at turbine LN02. The larger, and more widely spaced, footprints from the MPI Resolution can be seen to the north of the turbine, whilst the closer spaced footprints from the MS Wind can be seen immediately to the east and southeast of the turbine. The plot also illustrates the presence and location of a drill arising mound. The development of these jack-up footprints

over time, as recorded by successive post construction geophysical surveys across the site, is discussed in more detail within Section 4.7.3.2.2.

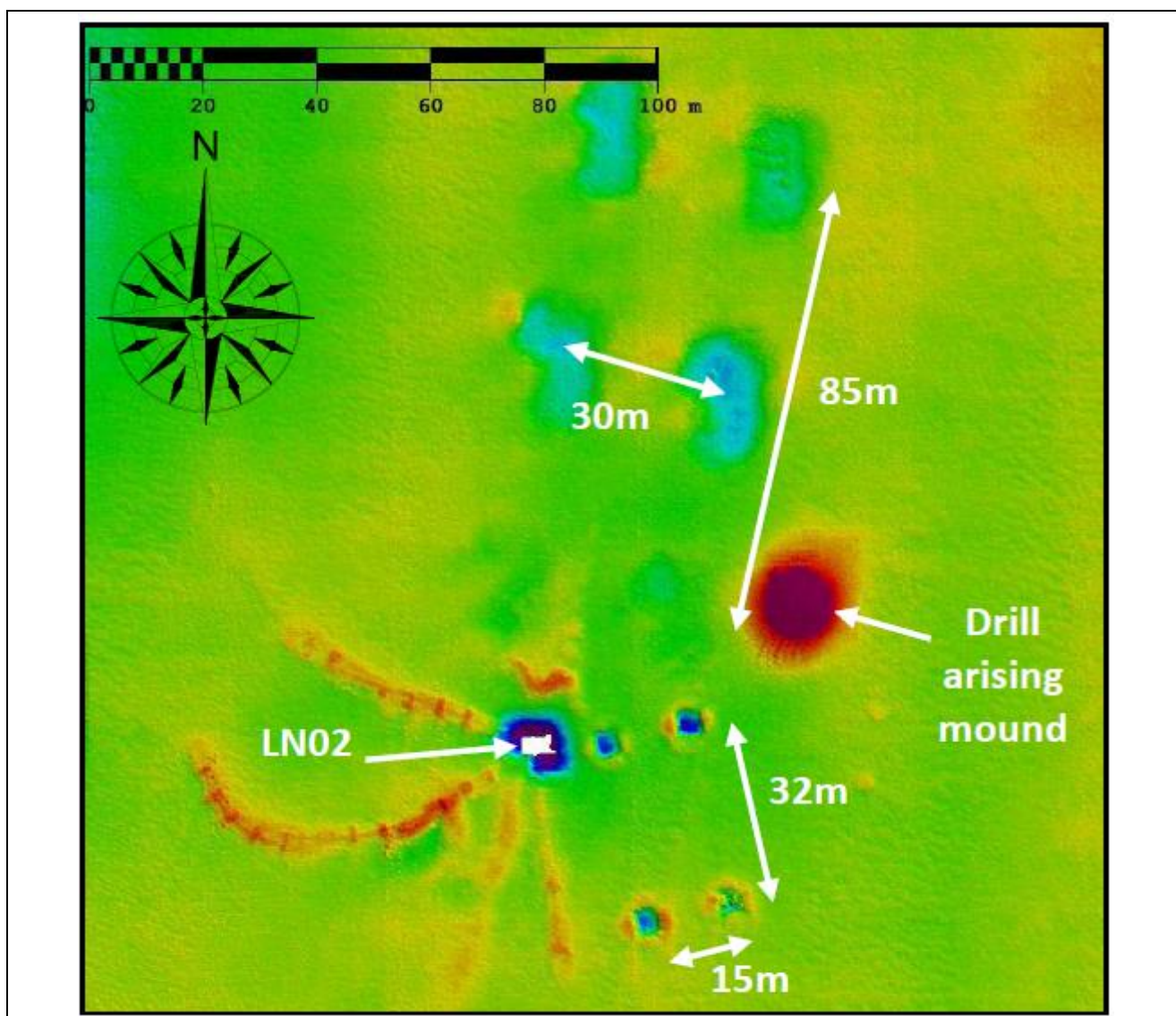


Figure 18: MBES image of both types of jack-up footprints at turbine LN02 (EGS Ltd, 2012a).

4.7.2.2.4 Inter-array cables

The Year 3 post construction geophysical survey (EGS Ltd, 2012a) illustrates the position of inter-array cables as linear features of higher relief than the surrounding seabed. These are interpreted to represent relic plough features from cable installation. An example of linear elevated relic plough features is provided in Figure 19.

Within the Lynn wind farm site, it is known that shallow buried cables are present²⁵. The presence of the plough features are still visible within the Lynn wind farm site (EGS Ltd, 2012a).

²⁵ Remediation works took place between January and May 2012 with the aim of increasing cable burial depth, however these works were not completely successful, and an application was subsequently submitted to the Licensing Authority for cable protection on 02/10/12.

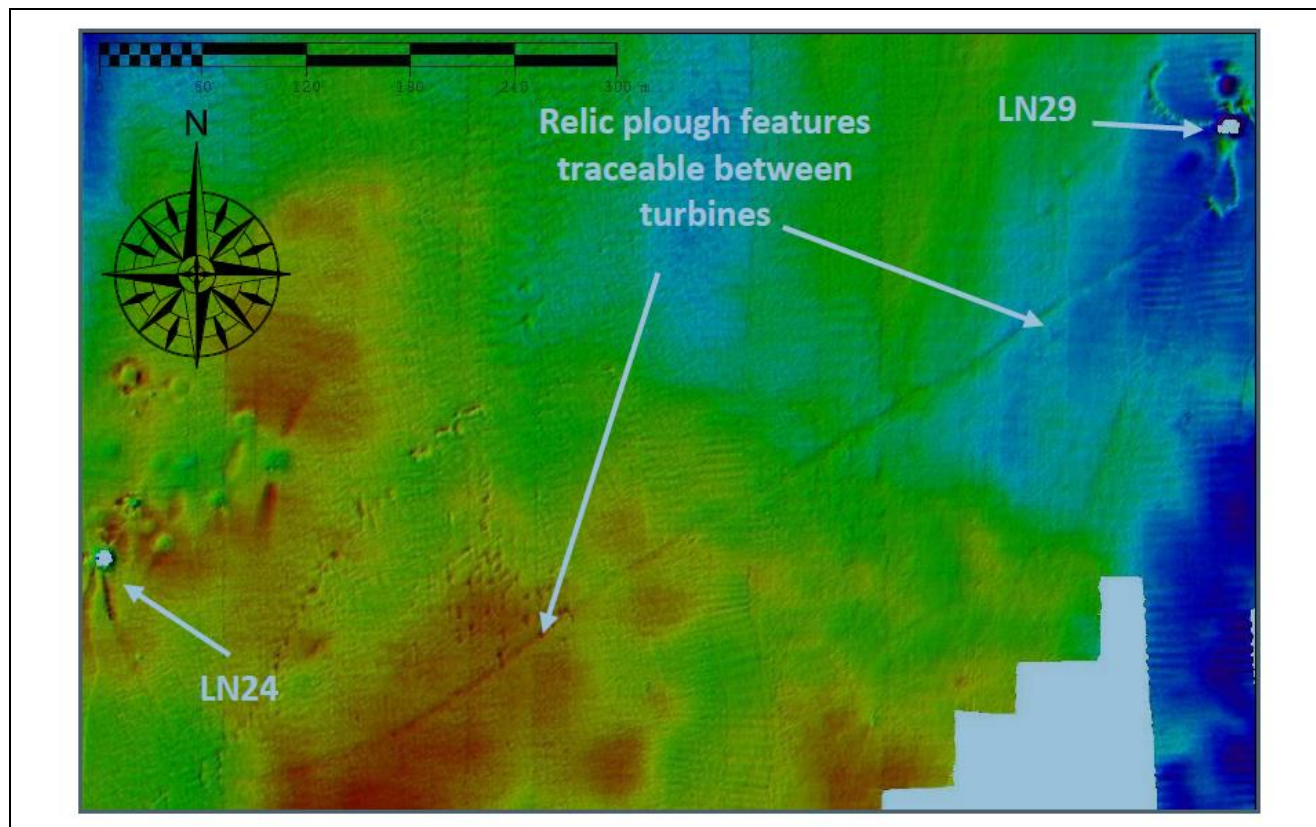


Figure 19: Image of visible relic plough features showing relief between turbines LN24 and LN29 (Note: vertical exaggeration has been used to emphasise the feature) (EGS Ltd, 2012a).

4.7.2.2.5 Trial pit

A trial pit, which was excavated in 2005 for gravity foundations, is present in proximity to wind turbine ID05. The trial pit was recorded to measure 40 m x 40 m in size and 5 m in depth from the 2011 survey. It is located in close proximity to an inter-array cable, and therefore there is concern over protection of the cable in the event of increased erosion of the sides of the trial pit (EGS Ltd, 2012a). The development of the seabed over time at the location of the trial pit, as recorded by successive bathymetric surveys for the Years 1, 2 and 3 of the post-construction survey period, is discussed in Section 4.7.3.2.4.

4.7.2.2.6 Decommissioned meteorological mast and trial pile

In March 2011, the meteorological mast within the Inner Dowsing site and the trial pile within the Lynn site were removed using the MPI Resolution. The meteorological mast was removed to a depth of 0.2-0.3 m below seabed and the trial pile was removed to a depth of 1 m below seabed. The 2011 survey revealed jack-up footprints at both the meteorological mast and trial pile locations and depressions corresponding to the pile removals (EGS Ltd, 2012a).

4.7.2.2.7 Scour

Scouring has occurred around the bases of the majority of the LID wind turbines. The Year 3 post-construction survey data has been used to quantify the vertical and horizontal extent of scour around the base of each turbine in the LID sites. These data are presented in EGS Ltd (2012a) (see Appendix 5). The overall average of the maximum horizontal scour recorded at each turbine was interpreted to be 15.1 m, with the overall average of the maximum vertical scour recorded at each turbine interpreted to be 1.7 m. The average of the maximum vertical scour recorded in the Year 3 post-construction survey around turbines within the Inner Dowsing site is higher than the corresponding average within the Lynn site (average of the maximum vertical scour extents of 1.94 m and 1.51 m respectively). The greatest vertical scour extent recorded in 2011 was 2.68 m at turbine ID30, with a corresponding maximum horizontal scour extent of 14.54 m. Figure 20 below provides an example illustration of the scour pit recorded in the Year 3 (2011) data at this turbine (ID30). The greatest horizontal scour extent recorded in 2011 was 24.50 m, at turbine LN21, with a vertical scour extent of 2.67 m. LN21 therefore showed the greatest amount of scour in 2011 (EGS Ltd, 2012a). A discussion of the development of scour around each turbine over time, as recorded in successive post-construction monitoring surveys, is provided in Section 4.7.3.2.5 below.

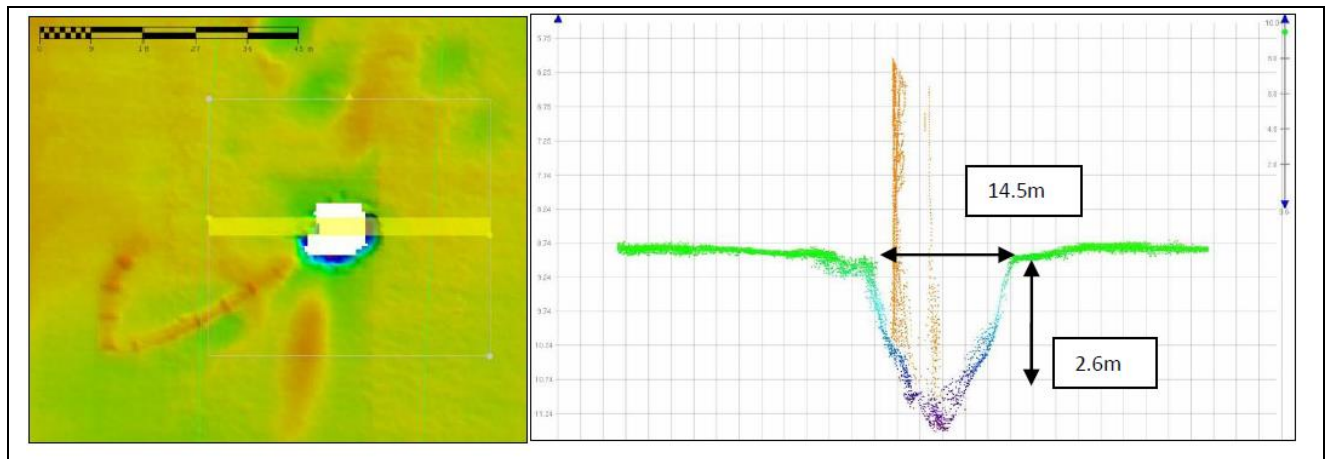


Figure 20: Scouring recorded at turbine ID30. Left: MBES colour shaded 0.5 m grid image. Right: Colour coded soundings showing cross section of seabed at base of turbine. Scour measurement arrows are not to scale (EGS Ltd, 2012a).

4.7.3 Methodology and Results for inter-year comparisons

4.7.3.1 Methodology

A comparison was carried out between the results of the Year 3 (2011) post-construction geophysical survey, the Years 1 and 2 (2009 and 2010) post-construction surveys, and the pre-construction (2002) survey. Table 33 below shows the instruments used for each of these surveys (EGS Ltd, 2012a).

Table 33: Overview of Previous Surveys (from EGS Ltd (2012)).

Year	Bathymetry	Side Scan Sonar (SSS)	Currents	Seismic	Magnetic
2002	SBES ²⁶ (100 – 250 m line spacing)	SSS	ADCP	Boomer	Magnetometer
2009	MBES ²⁶ (1 m grid)	SSS	N/A	N/A	N/A
2010	MBES (1 m grid)	SSS	N/A	N/A	N/A
2011	MBES (1 m grid)	SSS	N/A	N/A	N/A

The post-construction (Years 1 to 3; 2009, 2010 and 2011) MBES and SSS data are directly comparable, however the 2002 bathymetric data cannot be directly compared with the post-construction datasets as this early survey involved singlebeam bathymetry equipment. Nevertheless, seabed features have been compared between 2002 and the post-construction datasets (EGS Ltd, 2012a).

In order to compare the survey results, bathymetric difference plots were produced using the post-construction datasets, to reveal changes over time and allow interpretation in terms of changes to seabed features, such as bedforms and features associated with infrastructure and construction (such as scour features, jack-up footprints, trial pits, test piles and features associated with cables). In addition, SSS data has been compared to allow interpretation of potential changes to seabed sediment distributions.

4.7.3.2 Results

4.7.3.2.1 Seabed sediments and bedforms

The primary seabed sediment type across the survey area has remained unchanged between the initial 2002 survey and Years 1, 2 and 3 of the post-construction monitoring surveys. Whilst there are some differences in the classification schemes used for sediments between surveys, each survey illustrates the primary sediment type to be gravelly Sand to sandy Gravel.

The bands of Gravel and Sand observed in the Year 3 (2011) survey are in a similar position to that observed during the Year 2 (2010) survey. During the 2002 survey these features are recorded but further to the east within the survey area (EGS Ltd, 2012a).

²⁶ Singlebeam Echo Sounder (SBES); Multibeam Echo Sounder (MBES).

The 2002 survey does not record the Clay patches observed during the subsequent Year 1 (2009), Year 2 (2010) and Year 3 (2011) surveys. In addition, a comparison of the Year 2 and Year 3 surveys reveals that the frequency of these Clay patches increased between 2010 and 2011.

In terms of bedforms, the megaripples, described above for the Year 3 survey, are recorded in the Year 2 survey to be of a similar size and also with no discernible asymmetry (EGS Ltd, 2012a). These megaripples are also recorded in the southern section of the survey area in the 2002 survey. In 2002 these are of a similar size to those recorded in the post-construction surveys (EGS Ltd, 2012a). However, a comparison of the survey data does reveal some difference in the bedforms over time, with areas of bedforms recorded as present in the Year 1 survey that are not present in the Year 3 surveys and vice versa. These differences are recorded as occurring in the export cable route corridors and also across the southern part of the main wind farms survey area.

These recorded differences in bedforms across the survey area are an indication of a degree of sediment mobility across the site. It is not possible to attribute the recorded changes to the presence of the wind farms and its associated infrastructure. The appearance of Clay patches across the sites may be an indication of increased exposure of the underlying glacial till caused by a reduced throughput of sediment or increased erosion (EGS Ltd, 2012a). However, it is highlighted that these patches are localised and the predominant sediment types across the surveyed areas has not changed.

In addition, the comparison of successive post-construction survey data (Years 1, 2 and 3) have revealed the erosion of areas of noted seabed features. Specifically EGS Ltd (2012a) identified three areas of scattered shallow features within the Year 1 (2009) bathymetric dataset (referred to as “scattered shoal features”). These features were located between turbines ID08 and ID10, to the south of ID10 and in the vicinity of LN04 and LN05 (see Figure 17 for turbine locations). The features are relatively low in relief (the features between turbines ID08 and ID10 are 0.6 m higher than the surrounding seabed) and linear in nature. The survey data illustrates that these features have been eroded over the course of the post-construction monitoring period. As noted, the pre-construction survey (2002) was singlebeam and hence it is not possible to determine if these features were present at this time.

4.7.3.2.2 Jack-up footprints

A comparison of the first, second and third year of post-construction surveys has revealed a number of trends in terms of the jack-up footprints from construction and maintenance activities. Changes between the Year 1 survey (i.e. the survey closest in time to the creation of the MPI Resolution footprints from construction) and the Year 3 survey (i.e. the most recent survey), illustrate that all MPI Resolution footprints have experienced accumulation in the centre of the depression and scour around the edges of the footprints. This is interpreted to be a progress of the infilling of the central area of the depression and a lowering of the elevated areas surrounding the depressions. The rate of infilling is spatially variable across the sites. This spatial variability is likely to be attributable to locally varying availability of sediments and mobility / dynamics. At certain turbine locations (e.g. LN04 and LN05) the MPI Resolution footprints are not observed in the Year 3 (2011) data, whereas the footprints at these turbines are clearly visible in the Year 1 (2009) data, indicating the footprints have infilled. This trend of infilling would be expected to continue over time and the 4 smaller jack-up footprints caused by the MS Wind are expected to follow a similar trend of gradual infilling over time (EGS Ltd, 2012a).

An illustration of the trends described above, recorded in successive years of post-construction monitoring of the footprints, is illustrated in Figure 21 below. This figure presents difference plots at turbine ID12, and associated jack-up footprints.

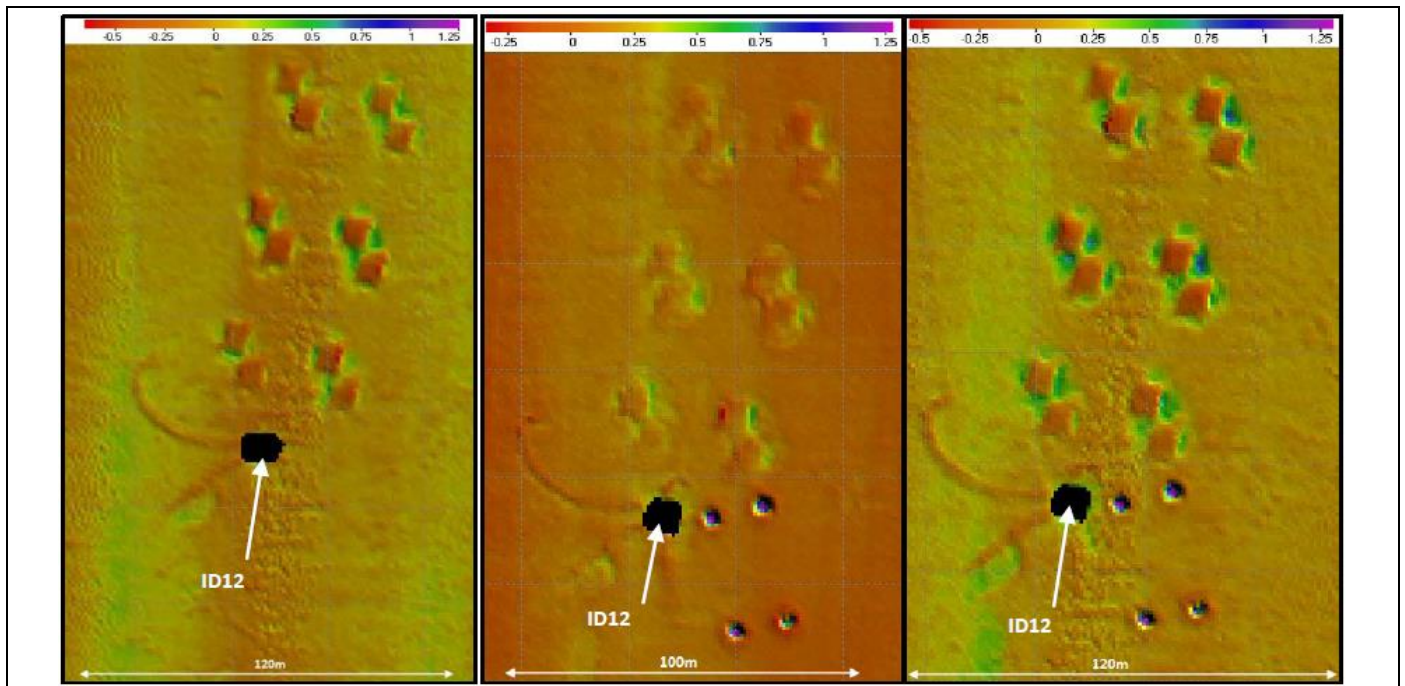


Figure 21: difference plots displaying the change in seabed elevation around jack-up footprints at ID12 – red colours denote sediment accumulation whilst purple denotes erosion (EGS Ltd, 2012a). Left: Comparison of Year 1 (2009) and Year 2 (2010) data. Centre: Comparison of Year 2 (2010) and Year 3 (2011) data. Right: Comparison of Year 1 (2009) and Year 3 (2011) data.

4.7.3.2.3 Inter-array and export cables

A comparison of post-construction surveys across cables (both export and inter-array) revealed a number of trends. Notable changes in seabed level between the Year 1 post-construction survey and the Year 3 survey were recorded along inter-array cables joining the following turbines (EGS Ltd, 2012a) (see Figure 16 for turbine locations):

- **LN01 – LN06 – LN11 – LN16 – LN21**;
- **LN08 – LN09**;
- LN12 – LN17;
- LN19 – **LN18 – LN23** – LN22;
- LN24 – LN29 – LN30; and
- ID05 – ID14.

At these locations areas of both erosion (scour) and accretion are recorded. The maximum change between the first (Year 1) and most recent (Year 3) post-construction survey is recorded between turbines LN06 and LN11, where scour of 0.4 m is recorded adjacent to accumulations of 0.4 m. A bathymetric plot along this length of inter-array cable is presented in Figure 22 (top image), together with a difference plot between the Year 1 and Year 3 surveys (bottom image).

The EGS Ltd (2012a) data reveals a number of interesting spatial trends in the recording of bathymetric changes across inter-array cables. Firstly, the majority of inter-array cables experiencing changes in seabed level are located within the Lynn site. In this respect it is of note that the Lynn site contains the cable sections identified by GLID as requiring remediation due to insufficient burial depth²⁷. The cable sections highlighted in bold and underlined above correspond with the 6 cables identified as requiring remediation, and therefore these insufficiently buried cables may be contributing to the observed changes in bathymetry, for example by trapping sediment. During construction, burial of these 6 cables was attempted using a lay and trench ROV, whereas the remaining inter-array cables were installed via a plough. As noted above, the maximum change was recorded between LN06 and LN11, which coincides with one of the identified cable sections for remediation. Secondly, the majority of changes occur over inter-array cables with an east – west axis (as opposed to a north – south axis). This may be attributable to the fact that the dominant axis of tidal flows is north – south (EGS Ltd, 2012a).

In terms of the export cables, EGS Ltd (2012a) report sediment accumulation across the 3 years of post-construction monitoring, although it is noted that some areas of export cable show no change between years.

²⁷ Six sections of the Lynn inter-array cables have been identified as requiring remediation following insufficient burial during construction due to seabed conditions. The Lynn Construction Exclusion Zone therefore remains in place. An application for cable protection was submitted to the Licensing Authority on 02/10/12.

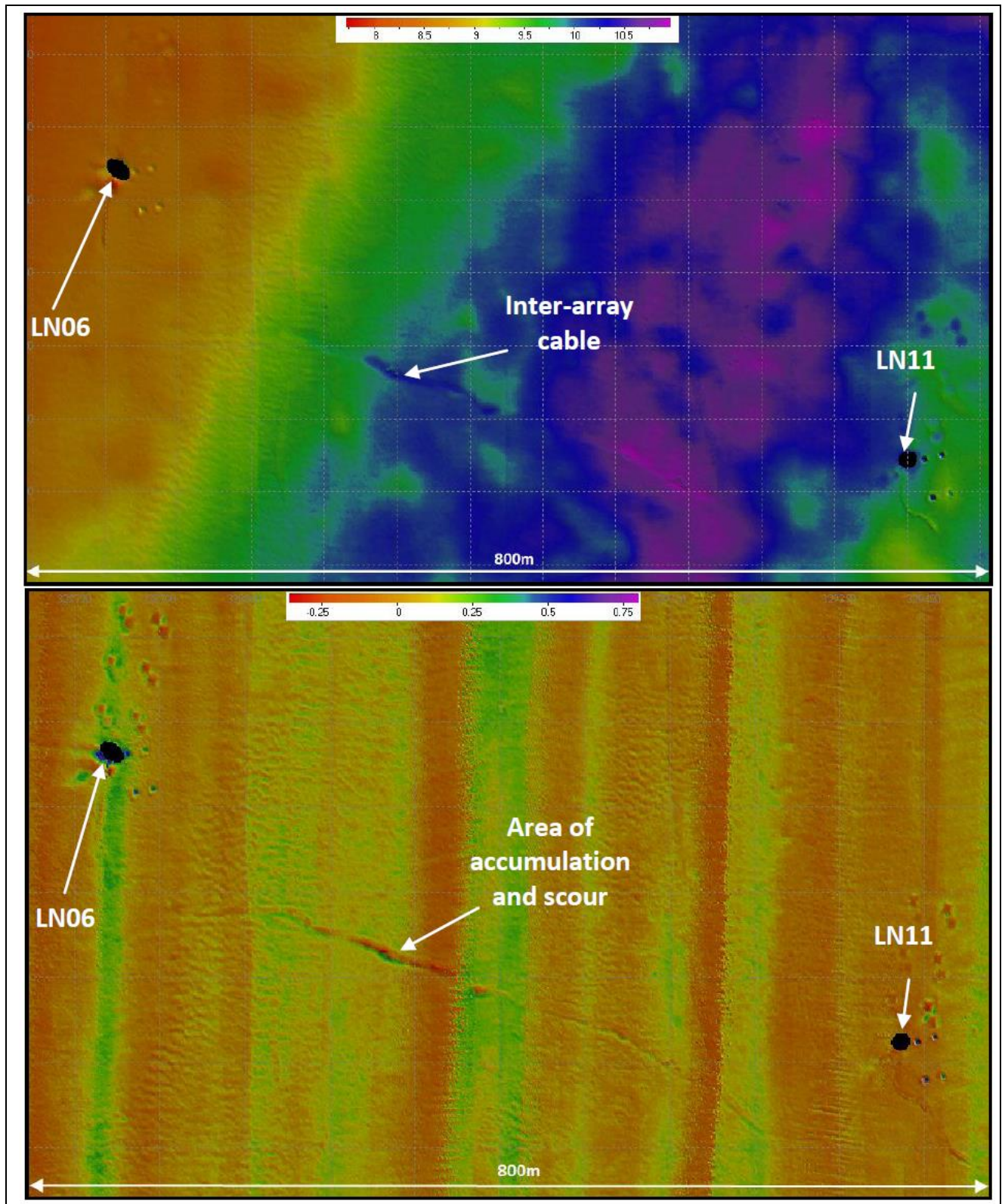


Figure 22: Multibeam datasets centred on the LN06-LN11 inter-array cable: Top image – 2011 data of the inter-array cable, red colours denote shallow areas whilst purple denotes deeper areas; Bottom image – difference plot displaying scour and accumulation along the inter-array cable, red colours denote sediment accumulation whilst purple denotes erosion (EGS Ltd, 2012a).

4.7.3.2.4 Trial pit

A comparison of the Year 1 and Year 3 post-construction surveys across the area of the trial pit revealed sediment accumulation in the base of the trial pit of approximately 1.1 m. EGS Ltd (2012a) attribute this to the edges of the trial pit having eroded or slumped into the pit. The largest erosion was observed to have occurred on the eastern edge of pit, with a maximum erosion of 1.4 m. This is of concern due to the proximity of an inter-array cable along the eastern edge of the trial pit (EGS Ltd, 2012a).

4.7.3.2.5 Scour

The magnitude of scour recorded within the Year 3 post-construction survey has been discussed in Section 4.7.2.2.7. This represents the most recent record of the maximum extent of scour at each turbine location. In addition, EGS Ltd (2012a) provide a comparison of the Year 1 (2009) and Year 3 (2011) scour extents to provide an understanding of the development of the scour pits at the turbine bases over time.

All but 8 turbines within the Lynn site experienced an increase in the maximum vertical scour recorded between the 2009 survey and the 2011 survey. At the Inner Dowsing site, all but 4 turbines recorded an increase in maximum vertical scour across the corresponding period. From these data it is clear that scour development has continued between the first survey following construction (2009) and the most recent (Year 3) post-construction survey at the majority of the turbines. However, it should also be noted that at the majority of turbines, a greater proportion of the maximum scour recorded during the most recent survey (Year 3, 2011) had occurred at the point of the Year 1 survey (i.e. more scour was recorded between construction and the Year 1 post-construction survey, than occurred between the Year 1 survey and the Year 3 survey).

In both years, turbine LN21 was found to have the greatest amount of scour around the turbine base, with an increase in vertical scour extent between 2009 and 2011 of 0.8 m. LN21 also experienced the greatest amount of sediment accumulation between 2009 and 2011 on the northern side of the turbine (whereas scour occurred on the southern side) (EGS Ltd, 2012a). There is currently no scour protection around the LID foundation locations.

4.7.4 Comparison with the LID Environmental Statements

In Chapter 10 of the Lynn ES and the Inner Dowsing ES (Amec, 2002), it was considered that the distribution and movement of seabed sediment could be affected by the wind farms, through both local variations in the current regime around the base of the turbines which may cause scour, and changes to the wave and current regimes resulting in far-field changes to the distribution and movement of seabed sediment. From the monitoring results summarised above, the dominant character and sediment type within the surveyed sites remains unchanged across the pre- and post-construction surveys. A number of localised clay patches have been observed in the post-construction surveys that were not observed in the pre-construction survey. These may be related to exposure of the underlying clay through erosion of sediments or reduced sediment transport. Whilst this may be attributable the wind farms, it is not possible to directly link these localised changes to the presence of the wind farms. A number of localised areas of small scale bedforms are recorded across the sites. In some cases the location of the bedforms has changed across the survey period and in other cases some erosion has occurred. Changes to recorded bedforms are likely to reflect a degree of mobility of these features.

Chapter 10 of the Lynn ES and Inner Dowsing ES (OWP, 2002) reported the results of current modelling, whereby it was found that velocities increased locally around the turbine foundations. It was considered that this may result in localised scour, however that this would be unlikely to have a widespread effect. The rate of scour was predicted to be most rapid immediately following construction, and then decreasing towards an equilibrium. The post-construction monitoring has allowed quantification of magnitude of scour across the sites and these results have been presented for the Year 1 and Year 3 post-construction monitoring surveys (EGS Ltd, 2012a). The results record scour to have occurred around the turbine bases at the point of the Year 1 survey. Scour has, for the majority of turbines, continued to develop from this point, to the Year 3 survey. It is noted that whilst the post-construction surveys suggest scour was continuing to occur at the point of the Year 3 survey, a greater proportion of the total scour recorded occurred between construction and the Year 1 survey, compared to the period from the Year 1 survey to the Year 3 survey (i.e. the rate of scour development was initially greater, and whilst the process appears to be ongoing, this was at a reduced rate for the majority of turbines). The monitoring confirms that scour is localised to the turbines themselves and the extents of scour recorded across the post-construction monitoring period are not of a magnitude that would result in the interaction of scour pits from adjacent turbines.

4.7.5 Conclusions

From the results above, it is possible to address the questions presented at the beginning of this section:

Q9: Has the third post-construction geophysical survey carried out in 2011 revealed similar or different sediment types and distributions across the survey area compared with the surveys of 2002, 2009 and 2010?

The 2011 survey has revealed that the dominant sediment type within the survey area is featureless gravelly SAND to sandy GRAVEL, which is consistent with the results from the previous pre-construction (2002) and post-construction (2009, 2010) surveys.

The number of clay patches within the survey area was greater in the 2011 survey results than in the previous post-construction (2010, 2009) surveys, and clay patches were not noted from the 2002 survey results. This could be attributed to decreased sediment input or increased erosion over the sites, resulting in localised exposure of Pleistocene glacial till (EGS Ltd, 2012a).

Q10: Are there any similarities or differences in the presence or location of seabed features between 2011, 2010, 2009 and 2002?

As noted above, the majority of the surveyed area of seabed, particularly within the wind farm sites, comprises featureless Gravel and Sand. There are localised exceptions to this absence of bedforms, with areas of bedforms recorded in certain areas of the survey area. Megaripples were recorded across the sites in both the pre-construction and post-construction surveys. These features were a similar magnitude in terms of size across both the pre- and post-construction surveys, although their location varied across surveys. This is indicative of a degree of sediment mobility across the surveyed area of seabed. A number of areas of low relief, linear seabed features, were observed in the first year of post-construction (2009). The following Year 2 and Year 3 surveys illustrated erosion of these features, with the features not recorded in the most recent (2011) dataset.

Q11: Are there any changes in seabed elevation and topography between survey years and if so, how has this affected inter-array and export cable burial depth?

A comparison of the successive years of bathymetric surveys across the wind farm sites has not revealed any notable trends in seabed elevation (in terms of either erosion or accretion). There have been observed changes in seabed levels when the data is compared across years, however these changes have been localised and generally related to features associated with construction or infrastructure (noting the above discussion of bedform variability over time). Therefore any changes observed around inter-array cables are related more to the localised processes of scouring associated with the presence of the cables (or relic plough features) themselves, as opposed to changes to burial depths as part of a wider net trend in seabed levels. Some inter-array cables have been noted as illustrating some scour (and corresponding accumulation). This process is more commonly recorded for east – west orientated cables (as opposed to north – south). This is potentially related to the east – west aligned cables being perpendicular to the predominant north – south orientated flows. The maximum recorded scour around inter-array cables (between the Year 1 and Year 3 survey) was 0.4 m (EGS Ltd, 2012a).

In terms of the export cables, a trend of sediment accumulation is recorded across the post-construction surveys (EGS Ltd, 2012a)

Q12: Is there evidence of scour around the wind turbine foundations?

Scour is occurring around the majority of the LID wind turbine foundation locations. The greatest amount of scour was observed at location LN21 from both the 2009 and 2011 datasets.

Q13: Are any new obstructions apparent between the 2002 and post-construction surveys which may be debris left from the construction of the wind farms?

A larger number of sonar contacts were detected during the 2011 survey analysis compared with all previous survey years, attributed to the different identification parameters used for each survey, and due to the higher resolution and quality of the 2011 survey compared with previous years. Two contacts were identified as obstructions from the 2011 analysis, and it was considered by EGS Ltd (2012a) that these were first detected in the 2002 pre-construction survey. It would therefore appear that these two obstructions are not related to the construction of the wind farms.

Q14: Has the monitoring confirmed the predictions in the ESs in relation to scour?

The results of the monitoring survey in 2011 have revealed that the overall average horizontal scour extent was interpreted to be 15.1 m, with the overall average vertical scour extent interpreted to be 1.7 m. This confirms the predictions in the ESs that the scour is localised. The magnitude of scour recorded in the post-construction monitoring surveys confirms that scour pits from individual turbines will not interact with scour pits from adjacent turbines, again supporting the prediction that scour is localised.

The ESs considered that the rate of scour would be most rapid immediately following construction, and then would decrease towards an equilibrium (although magnitudes and rates of scour were not detailed in the ESs). The datasets presented in EGS Ltd (2012a) suggest that scour processes are ongoing, as recorded by the increased vertical scour extents between the Year 1 and Year 3 post-construction surveys. This relatively slow development of scour is likely to be related to the nature of the underlying clay substrate. It is also noted that while the Year 3 survey records the continuing development of scour at turbines, a larger proportion of the total scour recorded occurred prior, and up to, the Year 1 survey, therefore the observations to date broadly support the qualitative predictions regarding rate of scour.

4.8 Benthic Communities

4.8.1 FEPA Requirements

The FEPA requirements for monitoring benthic communities are set out in Table 34 below. Parts of the condition in relation to benthic organisms have been crossed out below, as firstly, the requirement for monopile colonisation surveys was removed with agreement from the Licensing Authority (Appendix 10; ref 10.26); and secondly, directional drilling was used during construction and therefore this part of the condition is not applicable.

Table 34: FEPA Requirements – Benthic Communities

Ref	FEPA Condition
Annex 2 (5)	Benthic Organisms Sample locations for ongoing monitoring must be determined by factors such as precise monopile locations, location of cables etc. Sample locations must take full account of factors such as sensitive areas, coastal processes modeling outputs (for sediment transport/deposition information) and geophysical surveys (to ensure adequate coverage of seabed habitats). The samples should be taken to adequately cover the extent and direction of the full tidal excursion and have adequate controls. The number and location of the sample points needs to be submitted to the Licensing Authority along with a plan and rationale and agreed with CEFAS and Natural England at least one month prior to the survey works commencing. The survey should be designed in line with the approach described in the DTLR publication 'Guidelines for the Conduct of Benthic Studies at Aggregate Dredging Sites, May 2002' which can be downloaded from the CEFAS website at www.cefas.co.uk/publications/files/02dp1001.pdf. ~~Colonisation of monopiles and scour protection must be undertaken and could be determined by diver operated or drop down video observations and analyses, with some accompanying collection (as appropriate) for verification and identification.~~ The Lynn [and Inner Dowsing] offshore wind farm site supports a rich community of <i>Sabellaria spinulosa</i> and reefs built from the sediment by <i>S. spinulosa</i> are known in the area, such reefs are a Biodiversity Action Plan habitat. The Licence Holder is therefore required to undertake, as part of the benthic monitoring programme, appropriate monitoring techniques to identify reefs built by <i>Sabellaria spinulosa</i> both existing and any that may develop post-construction. The identification of areas likely to support <i>Sabellaria spinulosa</i> reef should be undertaken using acoustic ground discrimination systems (AGDS), ground-truthed using grab and drop-down video observations. Areas of likely reef identified by the AGDS should be surveyed at a fine scale using video observations to confirm the presence or otherwise of reef. The number and location of fine scale survey points and frequency of the monitoring should be agreed with Natural England and CEFAS at least 6 weeks prior to the survey works commencing. Guidance on the methodology can be found in Natural England Research Report 543 '<i>Sabellaria spinulosa</i> in the Wash and North Norfolk Coast cSAC and its approaches: Stage III Summary of knowledge, recommended monitoring strategies and outstanding research requirements'. ~~If directional drilling is not used intertidally, intertidal invertebrate sampling must be undertaken at lower, mid and upper shore sampling stations along three transects running perpendicular to the shore in the area of the cable landfall. The precise details of the monitoring for the cable route and the reinstatement works are dependent on the methodologies used. The Licence Holder must therefore provide the details of the methodology used for cable laying at least 2 months prior to works commencing so that recommendations on the benthos monitoring specifications can be made.~~ NB. The sedimentary and benthic data sets must be closely related and the resultant reports should include quality assurance, statistical analyses and full species lists.

Benthic sampling and Annex I habitat surveys have taken place at the LID wind farm sites and export cable route corridors during the pre-construction (2005 (Envision, 2005; EMU 2006)) and post-construction (2009 (EMU, 2009), 2010 (EGS Ltd, 2011b), 2011 (EGS Ltd, 2012b)) phases. The pre-construction survey (Envision, 2005) was presented to the Licensing Authority in the LID Pre-Construction Monitoring Report, the results of the first post-construction Annex I habitat survey (EMU, 2009²⁸) were submitted to the Licensing Authority in the LID Year 1 Post-Construction Monitoring Report, and the results from the post-construction benthic ecology survey carried out in 2010 were submitted to the Licensing Authority in the LID Year 2 Post-Construction Monitoring Report. The other 2005 (EMU, 2006) survey is the Lincs baseline characterisation survey, however some of the sampling sites overlap with the LID post-construction sample sites and were taken in replicate, and it was therefore considered that this dataset was more suitable for statistical analysis than the LID pre-construction survey carried out by Envision.

²⁸ The 2009 survey was an Annex I habitat survey only.

This section of the Summary Report presents the results of the latest survey carried out in October 2011 by EGS Ltd and Benthic Solutions Ltd (EGS Ltd, 2012b) and includes a comparison of these results with the previous pre-construction and post-construction survey results. Full details are provided in Appendix 6. The status of monitoring and history of reporting for this parameter is also summarised in Table 35.

Table 35: Status of Monitoring – Benthic Communities.

Phase	Requirement	Complete	LID Report
Pre-construction (2005)	Surveys (Grab and Drop Down Video, DDV)	✓	Pre-construction Monitoring Report (CREL, 2005)
During-construction	N/A	N/A	N/A
Year 1 Post-Construction (2009)	Survey (DDV)	✓	Year 1 Post-Construction Monitoring Report (CREL, 2010)
Year 2 Post-Construction (2010)	Survey (Grab and DDV)	✓	Year 2 Post-Construction Monitoring Report (CREL, 2012)
Year 3 Post-Construction (2011)	Survey (Grab and DDV)	✓	Year 3 Post-Construction Monitoring Report
Year 3 Post-Construction (2011)	Discussion of the benthic survey results in relation to the sedimentary datasets	✓	Year 3 Post-Construction Monitoring Report (Section 5)
Phase	Additional Items	Complete	LID Report
Year 3 Post-Construction (2011)	Jack-up footprint survey (Grab and DDV)	✓	Year 3 Post-Construction Monitoring Report

In order to fulfil the FEPA requirements, the specific questions which are addressed in this section are as follows:

Q15	<i>Do the results of the annual post-construction monitoring surveys provide evidence that the construction of the wind farms has had an effect (positive or negative) on the benthic communities present in the vicinity of the wind farms? If the findings of the monitoring surveys have shown negative effects of wind farm construction, is there evidence of recovery of the communities present?</i>
Q16	<i>Do the results of the three annual post-construction monitoring surveys provide evidence that the construction of the wind farms have had an effect (positive or negative) on Annex I biogenic reef communities (specifically Sabellaria spinulosa and mussel reefs)? Do the results of the monitoring surveys provide information on the changes in locations, distribution and extents of Annex I reef features between pre-construction (2005) and post-construction (2009, 2010 and 2011)?</i>
Q17	<i>Do the results of the Year 3 post-construction monitoring survey provide evidence that benthic (epifaunal and infaunal) communities within jack-up footprints are significantly different from those outside the jack up footprints?</i>
Q18	<i>Has the monitoring confirmed the predictions of the ESs in relation to impact on benthic communities?</i>

4.8.2 Methodology and Results of the Year 3 survey

4.8.2.1 Methodology

A survey was carried out by EGS (International) Ltd and Benthic Solutions Ltd in October 2011 at the LID sites and surrounding area. Post-construction surveys were designed based on relevant guidance documents, including those produced by Cefas for monitoring studies (i.e. Guidelines for the Conduct of Benthic Studies at Aggregate Extraction sites; CEFAS, 2002). This comprised a two-phase survey, with a geophysical survey undertaken as part of Phase 1 and a benthic ecology survey undertaken as part of Phase 2. The commentary here focuses on the results of the Phase 2 benthic ecology surveys, with appropriate reference to the Phase 1 geophysical survey data. Full details of these surveys are provided in Appendix 5 and Appendix 6.

Figure 23 shows the location of the sample sites. A total of 12 locations were sampled within and around the LID sites in order to assess for the effect of construction on benthic infaunal communities. Table 36 presents a summary of the number of locations sampled and rationale for sampling, including the impacts to be investigated through post-construction monitoring. Sampling at potential reef habitats (i.e. *Sabellaria spinulosa*, *Mytilus edulis* or *Ampelisca* reefs) was undertaken using drop down video sampling, with three of the 12 monitoring locations and an additional two locations surveyed to monitor the condition of potential reef habitats identified in previous surveys (i.e. post-construction surveys in 2009 and 2010; see Table 36).

In addition, sampling was undertaken within the footprints of the jack-up vessel used during construction of the LID sites in order to determine the extent of recovery of benthic communities following jack-up operations during the construction phase. There was no requirement for such surveys in the FEPA Licences, however this was carried out in

order to investigate the longer term effects of the remnant depressions from jack-up operations, which were still visible in the Year 1 and Year 2 geophysical survey data.

Table 36: Summary of benthic ecology sampling (2011) and rationale for sampling including impacts to be investigated.

Rationale for Sampling	Impact Investigated in ESs	Number of sampling Locations	Sample Site ID	Cumulative Number of Sampling Stations
Sampling location within development area	Temporary habitat loss/disturbance, scour, increased suspended sediments and sediment deposition.	5	L&ID1 L&ID2 L&ID3 L&ID4 L&ID5	12
Near field sampling locations within tidal excursion	Increased suspended sediments and sediment deposition, potential changes to the hydrodynamic regime.	3	L&ID6 L&ID7 L&ID8	
Far field sampling within tidal excursion	Possible increased suspended sediments and sediment deposition. ²⁹ Potential changes to the hydrodynamic regime. ²⁹	2	L&ID9 L&ID10	
Reference sites	N/A	2	L&IDR1 L&IDR2	
Potential Reef Habitats (DDV survey)	N/A	5 (3 coinciding with the above)	L&ID2 L&ID3 L&ID9 L&ID17 L&ID18	14
Jack-up Footprints	Seabed disturbance due to construction vessels	4 (two within footprints, two in adjacent areas of seabed)	H, G, J, K	18

Two methods were used to acquire benthic ecology data during these surveys:

1. Grab sampling (three replicate grab samples per monitoring location (12 sample sites)); and
2. Drop down video (DDV) / still photography (14 sample sites).

Grab samples collected during the benthic ecology survey were analysed for particle size analysis (PSA) and all benthic infauna were identified and enumerated. These were then analysed using univariate and multivariate statistical analyses to help aid in the description of the communities present. These analyses included:

- Number of species (S);
- Abundance (N);
- Univariate diversity measures such as Shannon Weiner Diversity Index (H'), Margalef Richness Index (d), Pielou's Evenness (J') and Simpson's Diversity 1-λ; and
- Multi Dimensional Scaling (MDS) and cluster analysis.

DDV footage was reviewed in order to assess reef potential following relevant guidance notes, where these are available (e.g. Gubbay, 2007). Full details of the methods used to analyse benthic ecology data are presented in Appendix 6.

For the jack-up footprint survey, grab and DDV sampling was undertaken within two jack-up footprints within the LID sites and at 'reference' sites located 250 m to the west of the footprints, in sediments similar to the respective footprints (Figure 24). As with the benthic sampling undertaken for post-construction monitoring, these were analysed for PSA and benthic infaunal community composition and compared using univariate and multivariate analyses. Full details for this survey are presented in Appendix 6.

²⁹ ESs predicted effects in the immediate vicinity of construction operations and near field effects. No far field effects were predicted.

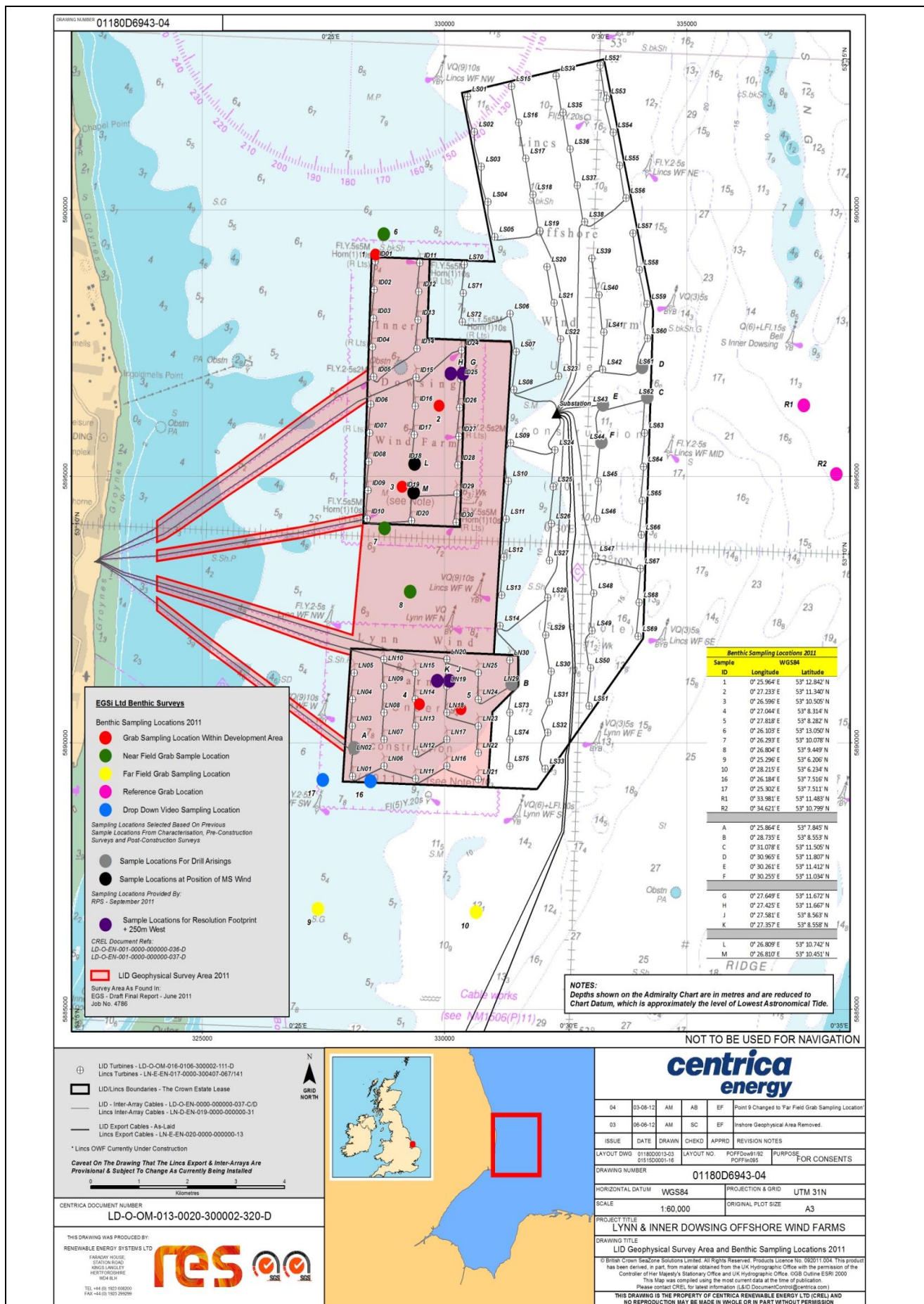


Figure 23: LID Benthic Sampling Locations 2011.

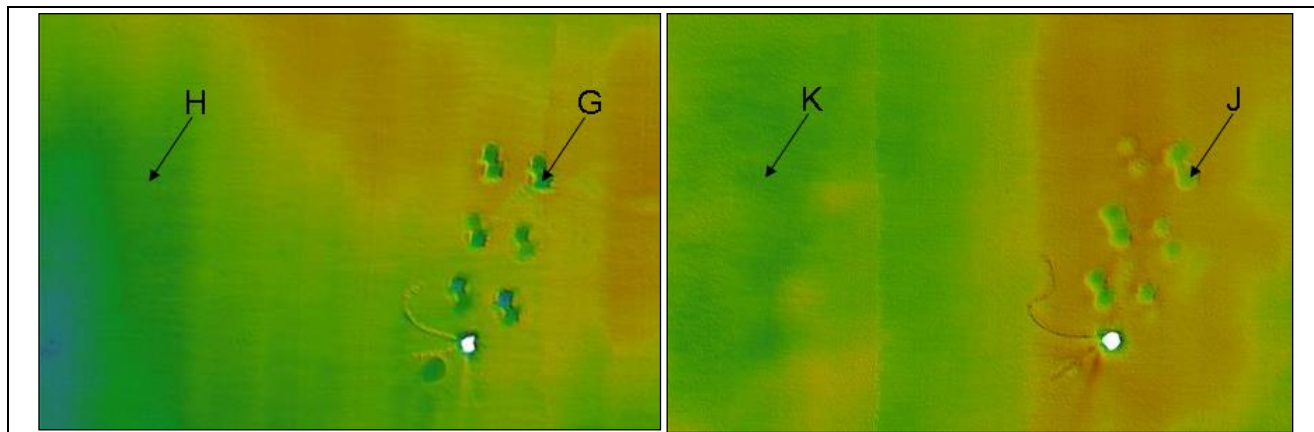


Figure 24: Bathymetric images of benthic ecology sampling locations within jack up footprints and in adjacent areas of seabed at wind turbines ID25 (left) and LN19 (right) (from EGS Ltd, 2012c).

4.8.2.2 Results

4.8.2.2.1 Benthic Infauna

The benthic communities recorded during the Year 3 post-construction monitoring survey were dominated by annelids (accounting for approximately 50% and 60% of the species (S) and total abundances (N), respectively), with crustaceans and molluscs accounting for much of the rest of the infauna. Echinoderms, nemertea, cnidaria and other phyla were also present, though these were generally recorded at low abundances. Benthic infaunal communities were generally consistent across all sample sites with regard to number of species (S), with the proportions of annelid, crustacean and mollusc species recorded being comparable at each sample site. Abundances (N) of these species varied considerably from site to site, with the reef forming polychaete species *S. spinulosa* recorded at extremely high abundances at some stations (e.g. 300-400 individuals per 0.1 m² at site L&ID3) and not at all at other stations (e.g. 0-1 individuals per 0.1 m² at site L&ID2), as is typical for this species. In addition, other species which were recorded at highly variable abundances included the crustaceans *Aora gracilis*, *Pisidia longicornis* and the reef forming amphipod *Ampelisca* spp., as well as the mollusc *Nucula nucleus*.

Univariate measures calculated for the Year 3 dataset supported this pattern, with low variability in the numbers of species recorded across sample sites and high variability in abundances (N=6 to 560 individuals per 0.1 m²). Diversity indices were also similar across most of the sample sites, with high richness (d=6.4 to 9.1) and evenness scores (J'=0.48 to 0.89). The exceptions were L&ID3 which was dominated by extremely high abundances of *S. spinulosa* (approximately 300-400 individuals per 0.1 m²). In addition L&IDR1 was found to be relatively impoverished, with low numbers of species (S=10), abundances (N=15-17 individuals per 0.1 m²) and richness scores (d=2.3) compared to the other sites. This pattern was also recorded in previous pre-construction and post-construction surveys (see Section 4.8.3.3).

Similarly, multivariate analyses highlighted these trends, with most of the sites found to be significantly (using the SIMPROF statistical test) similar to one another and L&IDR1 significantly different from all other sites in the survey area. The species characterising the infaunal communities across most of the survey area were typical for this region of the southern North Sea and similar to those recorded in previous surveys of the LID sites. As discussed above, the communities were dominated by polychaetes such as *S. spinulosa*, *Scoloplos armiger* and *Pholoe assimilis*, with crustaceans including *P. longicornis* and *Ampelisca diadema*. Subtle differences in the infauna were recorded between sample sites, with locally abundant populations of the mollusc *N. nucleus* and the amphipod *A. gracilis* accounting for these subtle differences between sites. L&ID1 was significantly different to the rest of the sites, primarily due to the dominance of *P. longicornis* at this site and lower abundances of other key species (e.g. *S. spinulosa*).

Full details of the benthic analyses undertaken on the Year 3 survey data are presented in Appendix 6 and further discussion of the changes to benthic communities during pre-construction and post-construction surveys is presented in Section 4.8.3.3.

4.8.2.2.2 Annex I Habitats

As detailed in Table 36, five locations were specifically targeted to assess potential reef habitats identified in previous surveys, though all monitoring locations were subjected to DDV sampling and Annex I reef assessment. The Year 3 survey only identified reef habitat at one location, with an Annex I *S. spinulosa* reef identified at L&ID3 (within the Inner Dowsing boundary, adjacent to wind turbine ID19). This was identified as a low lying reef extending over an area of 40,000 m² and was found to be similar in nature to the reef identified at the same location in Year 2.

Full details of the Annex I habitat assessments undertaken using the 2011 survey data are presented in Appendix 6 and further discussion of the extent and distribution of Annex I habitats during pre-construction and post-construction surveys is presented in Section 4.8.3.3.

4.8.2.2.3 Jack-up Footprint Survey

Q17: Do the results of the Year 3 post-construction monitoring survey provide evidence that benthic (epifaunal and infaunal) communities within jack-up footprints are significantly different from those outside the jack up footprints?

The findings of the jack-up footprint survey showed that the benthic communities were broadly similar within and outside the jack-up footprints. PSA data within and outside jack-up footprints were similar, though a slightly lower proportion of fine sediments was recorded within both footprints (4.2% and 19.4%) compared to the respective jack-up 'reference' sites (8.0% and 21.3%, respectively). These variations may be due to natural variability, though these differences may be due to minor scour related reworking of the surface fine sediments within the jack-up footprints. Evidence from the Phase 1 geophysical survey indicates that many of these footprints are gradually disappearing due to sediment accumulation in the footprints. It was also reported that the footprints were not clearly visible during DDV sampling, though small irregular areas of boulder clay were recorded at the edge of the jack-up footprints, where underlying clay may have been pushed to the surface during jack-up operations.

Infaunal communities within the jack-up footprints were found to be similar to those at the 'reference' locations, with the results of the SIMPROF statistical test showing no significant differences between the infaunal communities within and adjacent to the jack-up footprints when replicate grabs were combined. There were, however, slight differences between the communities when replicate samples were compared, with mollusc species including *A. alba* and *N. nucleus*, recorded at lower abundances within jack-up footprints than at adjacent reference locations, largely accounting for the differences observed. This was also reflected in the biomass data, with mollusc biomass considerably lower within the jack-up footprints than at reference locations. For other taxonomic groups, the community composition was similar between the footprints and reference locations, with polychaetes (including *S. spinulosa*, *Spio* spp. and *S. armiger*) and crustaceans (including *P. longicornis*, *Pagurus pubescens* and a number of amphipod species) characterising the infaunal communities recorded and present at similar abundances within and outside the jack-up footprints. This was also reflected in the biomass, with comparable biomass data recorded for these two taxonomic groups.

DDV footage and grab data also showed that epifaunal communities were similar between jack-up footprints and adjacent 'reference' locations. Epifaunal species recorded both within footprints and at reference locations included species common to this part of the southern North Sea, such as the keelworm *Pomatoceros triqueter*, the slipper limpet *Crepidula fornicata* (an invasive species), anemones such as *Urticina felina* and bryozoans such as *Flustra foliacea*.

These results are in line with the information available on these species and recovery of these habitats following an impact such as jack-up leg placement (i.e. temporary habitat loss/disturbance). Published literature on the recovery rates of these species shows that many of the polychaete, crustacean and epifaunal species recorded within the LID sites have high recovery rates, i.e. "Full recovery will occur but will take many months (or more likely years) but should be complete within about five years" (<http://www.marlin.ac.uk/recoverabilityranking.php>; Jackson and Hiscock 2008; Hiscock, 2008; Marine Ecological Surveys Ltd., 2008). **Similar findings have also been reported in other offshore industries including the aggregates industry, where Pearce *et al.* (2007) showed evidence of recovery of *S. spinulosa* within 18 months.** Although *A. alba* also has a high recovery rate (Marine Ecological Surveys Ltd., 2008), recovery rates for *Nucula* spp. have been predicted to be high to moderate, i.e. "Only partial recovery is likely within 5 years and full recovery is likely to take up to 10 years" (Sabatini and Ballerstedt, 2008). This pattern was largely reflected in the results of the jack-up footprint survey, with recolonisation of the footprints by most species to abundances comparable with reference areas, approximately three years following construction.

The reduced abundances of *N. nucleus* and *A. alba* within the footprints may be due to the slower recovery rates associated with these species, though it may equally be because of natural variability in the distribution of these species (*Nucula* spp. are known to occur in locally dense communities; Marine Ecological Surveys Ltd., 2008). Due to the small size of the dataset, it is not possible to draw conclusions about the reasons for the differences in abundances of these species, however the survey shows clear evidence of almost complete recovery of the communities within the jack-up footprints.

4.8.3 Methodology and Results for inter-year comparisons

4.8.3.1 Methodology

In order to examine the changes in benthic communities as a result of construction of the LID offshore wind farms, PSA and benthic infauna data from the pre-construction and post-construction surveys were compared using a range of methods.

PSA data from pre-construction and post-construction surveys were compared in order to assess changes in the sediment composition during or after the construction phase. Comparisons between geophysical datasets from the pre-construction (2002) and post-construction (Year 1, 2 and 3) surveys were also undertaken. These are fully reported in the Phase 1 geophysical survey report (Appendix 5).

Benthic infauna data from pre-construction surveys (2005) and post-construction surveys (Year 2 and 3) were compared using univariate analyses. These measures were used to assess for any changes occurring between the pre-construction and post-construction surveys and included:

- Number of species (S);
- Abundance (N); and
- Univariate diversity measures such as Shannon Weiner Diversity Index (H'), Margalef Richness Index (d), Pielou's Evenness (J') and Simpson's Diversity ($1-\lambda$).

In addition, multivariate analyses, i.e. MDS and cluster analysis (including SIMPROF), were used to compare the pre-construction dataset (EMU, 2005) with the Year 2 and Year 3 post construction survey datasets. These analyses provide further detail on whether significant differences exist between the pre-construction and post-construction benthic communities.

In order to investigate the effect of the LID offshore wind farms on reef habitats, the distribution and extents of these habitats were mapped during the 2009 post-construction Annex I habitat survey and the 2010 and 2011 post-construction benthic ecology surveys. The extents of these habitats were compared over the three post-construction survey periods and are discussed below (Section 4.8.3.3.3).

4.8.3.2 Limitations

There were a number of limitations associated with the pre-construction data which limited the extent of statistical analyses which could be undertaken to compare pre-construction and post-construction datasets.

Data from the pre-construction survey carried out by EMU in 2005 were presented with five replicates combined (EMU, 2006) and the pre-construction survey carried out by Envision in 2005 collected only one grab replicate per sampling location (Envision, 2005).

The pre-construction survey data were of relatively poor quality, i.e. the number of species and individuals recorded per sample in the EMU 2005 survey was extremely low compared to those of the Year 2 and Year 3 post-construction surveys (i.e. the number of species recorded per sample was approximately 3 times greater in Year 2 than the EMU 2005 pre-construction survey and the number of individuals recorded was approximately 4.5 times greater in Year 3 than the EMU 2005 pre-construction survey). The reasons for this discrepancy is unclear, though possible explanations include seasonal differences in the datasets (pre-construction surveys were undertaken in June, while post-construction surveys were undertaken in September/October), onboard sample processing or inconsistencies in the sample analysis undertaken.

The grab sampling method provides quantitative data on abundances of benthic infaunal species, though for species with patchy distribution (e.g., *S. spinulosa* and *M. edulis*) results can be highly variable and therefore should be interpreted with care. For this reason, grab sampling was employed in combination with drop down video sampling, to ensure the patchy distribution of reef building species was properly accounted for during surveys.

4.8.3.3 Results

4.8.3.3.1 Particle Size Analyses

The Year 3 post-construction geophysical survey revealed that the seabed at the LID offshore wind farm sites was dominated by featureless sandy GRAVEL to gravelly SAND. This was confirmed by the Year 3 benthic ecology survey which showed that the PSA at most sites across the LID survey area was dominated by gravelly sediments, with varying proportions of sand and mud/silt. The results of the pre-construction geophysical survey (2002) also indicated a similar sediment type (i.e. featureless sandy GRAVEL to gravelly SAND) across the LID offshore wind farm sites. Comparison of PSA data from pre-construction and post-construction surveys again supported the relatively consistent sediment type across surveys, with the sediments at most sites during the post-construction survey similar in character to those recorded during the pre-construction survey. PSA data from the pre-construction survey showed a slightly higher proportion of sands compared to the post-construction dataset, though this pattern was also recorded in unimpacted reference locations. This was concluded to be related to small seasonal differences between the datasets, with the post-construction surveys undertaken following periods of poor weather conditions, which may have temporarily resuspended fine sand particles.

4.8.3.3.2 Benthic Infauna

Q15: Do the results of the annual post-construction monitoring surveys provide evidence that the construction of the wind farms has had an effect (positive or negative) on the benthic communities present in the vicinity of the wind farms? If the findings of the monitoring surveys have shown negative effects of wind farm construction, is there evidence of recovery of the communities present?

Benthic communities recorded during pre-construction and post-construction monitoring surveys were generally found to be typical for this region of the southern North Sea. In general, the benthic infauna was found to be dominated (by number of species and total abundance) by polychaete species, with crustaceans and molluscs also present in varying abundances.

Comparison of univariate indices (i.e. number of species, abundance, and diversity indices) showed that number of species (S) was higher during the pre-construction surveys than the Year 2 and Year 3 post-construction surveys at most comparable sampling locations (including unimpacted reference sites), though not all. Abundances (N) were generally higher at most comparable sampling locations during post-construction surveys compared to the pre-construction surveys, though these were highly variable across sampling locations and years (due to the dominance of reef building species such as *S. spinulosa*, *M. edulis* and *Ampelisca* sp.). Diversity measures were variable across pre-construction and post-construction surveys. In general, diversity measures were comparable or higher during post-construction surveys compared with the pre-construction surveys, though there was considerable variation in these measures across surveys. Diversity measures were generally lower in Year 2 compared with Year 3. Extremely low diversity measures were recorded at two locations (L&ID2 and L&IDR1) in Year 2 due to the dominance of *M. edulis* at these locations. *M. edulis* was recorded at extremely high abundances at some locations during Year 2 survey (i.e. L&ID2, L&ID4 and L&IDR1), though during the Year 3 survey (and the pre-construction surveys), abundances were considerably lower. This highlights the considerable variation in abundances of these reef building species. Similarly, diversity indices were low at L&ID3 during the Year 2 and Year 3 post-construction surveys due to the dominance of the reef building polychaete *S. spinulosa* (a low lying *S. spinulosa* reef was recorded at this location during both surveys; discussed in Section 4.8.3.3.3). **Although abundances of *S. spinulosa* as recorded in grab samples were lower during the 2011 survey compared to 2010, this does not necessarily equate to a significant change in the habitats or biotopes present within the survey area. *S. spinulosa* typically occurs in a patchy distribution (see Section Error! eference source not found.) and as such, drop down video footage was collected to supplement grab data to assist with Annex I reef investigations and to undertake general ground truthing of the habitats present. As discussed in Appendix 6.1, the dominant biotope across the LID sites in 2011 was the *S. spinulosa* dominated SS.SBR.PoR.SspiMx biotope which was in line with the findings of pre-construction surveys (Envision, 2005; EMU, 2006) and previous post-construction surveys (EGS Ltd, 2011b; EMU, 2009).**

Multivariate analyses showed that data from the EMU 2005 pre-construction survey were completely distinct from those of the post-construction surveys. It is likely that these differences were primarily due to the differences in the datasets (see Section 4.8.3.2), rather than any effects of construction or operation of the LID offshore wind farms. The analyses undertaken to compare pre-construction and post-construction datasets showed that the pre-construction and post-construction communities at unimpacted reference locations were as distinct as those within the potential sphere of influence, indicating that these differences could not be directly attributed to construction or operation of the wind farms.

Multivariate analyses also showed differences between the two post-construction survey datasets, though these were less pronounced than those of the pre-construction and post-construction datasets. When Year 2 and Year 3 datasets were compared, sites usually clustered by year rather than survey location, which was indicative of annual natural variability in the communities present. This was evident in the abundances of *M. edulis* which, as discussed above, was recorded at high abundances during the Year 2 survey and at lower abundances in the Year 3 and pre-construction datasets. Differences in the abundance of this species was identified as one of the main reasons accounting for the differences between the 2010 (Year 2) dataset and the other pre-construction and post-construction datasets. Other species accounting for the differences between the pre-construction and post-construction datasets included *S. spinulosa* (present during all surveys, though at variable abundances) and the polychaetes *Polycirrus medusa*, *Lumbrineris gracilis*, *S. armiger*, *Glycera lapidum* and *P. assimilis*, many of which were present at higher abundances during the post-construction surveys. When multivariate analyses comparing the EMU 2005 pre-construction data and the Year 2 and 3 post-construction data were repeated with abundances phylum, as opposed to for each species, the pre-construction and post-construction datasets were indistinguishable from one another, indicating that there was no evidence of large scale functional changes in the benthic community composition (e.g. a shift from an annelid dominated community to one dominated by molluscs), between pre-construction and post-construction.

Many of the species recorded during pre-construction and post-construction surveys, have ecological traits which make them vulnerable to impacts associated with offshore wind farm construction, i.e. temporary habitat loss and disturbance and sediment deposition. Species such as the polychaetes *S. armiger*, *L. gracilis*, *G. lapidum* and *P. medusa* have life history traits such as limited mobility, slow growth rates, long life span and low dispersal potential which

makes them vulnerable to temporary habitat loss and sedimentation and which can delay recovery following this type of disturbance (Marine Ecological Surveys Ltd., 2008). These species were recorded in both pre-construction and post-construction surveys, with *S. armiger* one of the main characterising species recorded during the 2010 and 2011 post-construction surveys. This suggests that the impacts of offshore wind farm construction, e.g. temporary habitat loss, increased suspended sediment concentrations (SSC) and sediment deposition, have had a limited effect on benthic ecology and have not led to any broad scale changes in benthic habitats or communities of the LID sites.

The data from the post-construction datasets also indicated that there was a high degree of natural variability in the benthic communities present at the LID offshore wind farm sites. This was evident from the varying abundances of *M. edulis* and *S. spinulosa*, as previously discussed, with *M. edulis* recorded at high abundances at L&ID2, L&ID4 and L&IDR1 and *S. spinulosa* recorded at high abundances at L&ID4, L&ID7 and L&IDR2 in 2010, but at lower abundances (or absent) in 2011. *S. spinulosa* abundances were consistently high at L&ID3 during the 2010 and 2011 surveys, with this location classified as a low lying reef during both surveys, though multivariate analysis showed evidence of annual variability at this location, with the communities at L&ID3 in 2010 and 2011 found to be statistically different from one another. Natural variability was also evident in the data for the reference locations, with the L&IDR2 clustering by year as opposed to by site. These observations suggest that variations in the benthic communities occur on an annual basis and that these temporal variations are likely to be larger than the subtle spatial variations in the communities across the LID offshore wind farm sites. The other reference location, L&IDR1, was found to cluster by site, though at a low similarity. This suggested significant differences between the communities at this location and the rest of the survey area, likely due to the high proportion of coarse, gravelly sediments at this location compared to the rest of the survey area, which was characterised by more mixed gravelly sediments.

The results of the pre-construction and post-construction monitoring surveys indicate that the construction of the LID offshore wind farms has not had a significant effect on the benthic habitats or communities present in the vicinity of the offshore wind farms. The communities recorded are typical for this region of the southern North Sea and are naturally variable, with changes in the communities recorded annually. Furthermore, many of the species recorded during post-construction surveys are indicative of habitats which have not been recently exposed to large scale disturbance or sediment deposition. Section 4.8.4 provides a more detailed discussion on how the monitoring survey data has helped to validate the predictions made in the LID ESs.

4.8.3.3.3 Annex I Habitats

Q16: Do the results of the three annual post-construction monitoring surveys provide evidence that the construction of the wind farms have had an effect (positive or negative) on Annex I biogenic reef communities (specifically *Sabellaria spinulosa* and mussel reefs)? Do the results of the monitoring surveys provide information on the changes in locations, distribution and extents of Annex I reef features between pre-construction (2005) and post-construction (Year 1, 2 and 3)?

As discussed above, the benthic communities within the LID offshore wind farm sites were dominated by the reef forming species *S. spinulosa* and *M. edulis*, both of which are known to create Annex I reef habitats. In addition, the amphipod *Ampelisca* spp. also creates reef habitats, though these do not qualify as Annex I habitats. As part of the post-construction surveys in 2009, 2010 and 2011, potential reef habitats were surveyed, assessed for Annex I reef potential (based on relevant guidance notes (where available)) and extents mapped. Table 37 and Figure 25 provide a summary of the sites assessed for biogenic reef potential.

It should be noted that the guidance for Annex I *S. spinulosa* reef assessment (Gubbay, 2007) was produced after the pre-construction surveys were carried out and therefore it is difficult to make direct comparisons between the potential reef habitats identified in pre-construction and post-construction surveys. During the pre-construction surveys, potential *S. spinulosa* reef habitats were recorded at L&ID9, L&ID10 (both far field sites to the south of the Lynn site) and L&IDR2 (a reference site to the east). These reef habitats were not recorded in post-construction surveys in Year 2 and 3. Due to the distance between these sample sites and the LID offshore wind farm sites, the likely absence of these reefs post-construction cannot be directly attributed to the presence of the offshore wind farms. A possible explanation for the likely absence of reef habitats from these locations post-construction are that the criteria used for identifying potential *S. spinulosa* reef habitats in 2005 were different to those used to assess Annex I reef potential in 2010 and 2011 (i.e. Gubbay, 2007). A more likely explanation is the ephemeral nature of *S. spinulosa* reef habitats and the high variability in the distribution of this reef building species from year to year.

The assessments undertaken post-construction showed high variability in these habitats, with most of the reefs identified only recorded during one of the survey events and rarely in subsequent years. This indicates that although some areas of the LID offshore wind farm sites may have qualified as potential Annex I habitats during one survey, the absence of such habitats in subsequent years suggests that these are ephemeral and not long lived reef habitats.

The exceptions to this were the *M. edulis* seed bed recorded at L&ID16, on the southern boundary of the Lynn site, and the *Ampelisca* reef at L&ID17, to the southwest of the Lynn site, recorded during both the Year 1 and Year 2 post-

construction surveys. The results of the 2011 survey, however, indicated that these habitat features were no longer present at these locations.

The other potential Annex I habitat recorded within the LID offshore wind farm sites was the low lying *S. spinulosa* reef recorded at L&ID3, within the Inner Dowsing site adjacent to wind turbine ID19, which was recorded during both 2010 and 2011 surveys. This reef was low lying (typically 2-3 cm elevation from the substrate), with patchy distribution of *S. spinulosa* (10-15%) and was estimated to extend over an area of approximately 40,000 m². *S. spinulosa* abundances were also found to vary considerably both within the reef and annually, with 96-180 individuals per 0.1m² recorded in 2010 and 48-626 individuals per 0.1m² recorded in 2011. Although this reef location was recorded over two survey events and therefore had greater longevity than other areas of *S. spinulosa* reef identified during pre-construction and post-construction surveys, the dynamic nature of the environmental conditions (e.g. winter storms) may result in this habitat being lost in future years.

The data collected on Annex I reef habitats during the pre-construction and post-construction surveys provided further evidence of the high natural variability expected for habitats dominated by these three reef forming species. During pre-construction surveys, the only potential reef habitats were recorded at far field sites to the south of the LID offshore wind farm sites and at a reference location to the east, with no reef habitats recorded within the offshore wind farm boundaries. During post-construction surveys, reef habitats were recorded within and around the LID offshore wind farm sites, with most of the potential reef habitats identified as being ephemeral in nature (i.e. recorded during one survey only). Although some areas of reef were identified as being more long lived, the presence, distribution and extents of these habitats in the future is likely to be heavily influenced by the dynamic nature of the environment and the natural variability of these reef building species. The pre-construction and post-construction data indicate that the presence of the LID offshore wind farms has not affected the ability of reef building species to form reef habitats, with Annex I reef habitats recorded post-construction within the offshore wind farm sites and outside the offshore wind farm boundaries.

Table 37: Summary of sites assessed for reef potential (Annex I *S. spinulosa* and *M. edulis* reefs and non-Annex I *Ampelisca* reefs) during pre-construction and post-construction surveys; yellow indicates reef.

Sample Site ID	2005	2009	2010	2011
L&ID1	<i>S. spinulosa</i> – No Reef	Not sampled	No Reef	No Reef
L&ID2	No Reef	Not sampled	<i>M. edulis</i> (seed bed)	No Reef
L&ID3	<i>S. spinulosa</i> – No Reef	Not sampled	<i>S. spinulosa</i> – Low Reef	<i>S. spinulosa</i> – Low Reef
L&ID4	<i>S. spinulosa</i> – No Reef	Not sampled	<i>S. spinulosa</i> – No Reef	<i>S. spinulosa</i> – No Reef
L&ID5	<i>S. spinulosa</i> – No Reef	Not sampled	No Reef	<i>S. spinulosa</i> – No Reef
L&ID6	<i>S. spinulosa</i> – No Reef	Not sampled	No Reef	No Reef
L&ID7	Not sampled	No Reef	<i>S. spinulosa</i> – No Reef	<i>S. spinulosa</i> – No Reef
L&ID8	Not sampled	No Reef	<i>S. spinulosa</i> – No Reef	<i>S. spinulosa</i> – No Reef
L&ID9	<i>S. spinulosa</i> – Possible Reef	Not sampled	<i>Ampelisca</i> Reef	<i>S. spinulosa</i> – No Reef
L&ID10	<i>S. spinulosa</i> – Possible Reef	Not sampled	<i>S. spinulosa</i> – No Reef	<i>S. spinulosa</i> – No Reef
L&IDR1	<i>S. spinulosa</i> – No Reef	Not sampled	<i>M. edulis</i> – No Reef	No Reef
L&IDR2	<i>S. spinulosa</i> – Possible Reef	Not sampled	<i>S. spinulosa</i> – No Reef	No Reef
L&ID11	Not sampled	<i>S. spinulosa</i> – Low Reef	No Reef	Not sampled
L&ID12	Not sampled	<i>S. spinulosa</i> – Low Reef	No Reef	Not sampled
L&ID13	Not sampled	<i>S. spinulosa</i> – Low Reef	No Reef	Not sampled
L&ID14	Not sampled	<i>S. spinulosa</i> – Low Reef	<i>S. spinulosa</i> – No Reef	Not sampled
L&ID15	Not sampled	<i>M. edulis</i> (seed bed)	Relic <i>M. edulis</i> bed	Not sampled
L&ID16	Not sampled	<i>M. edulis</i> (seed bed)	<i>M. edulis</i> (seed bed)	<i>S. spinulosa</i> – No Reef
L&ID17	Not sampled	<i>Ampelisca</i> Reef	<i>Ampelisca</i> Reef	<i>S. spinulosa</i> – No Reef
L&ID18	Not sampled	<i>Ampelisca</i> Reef	No Reef	Not sampled

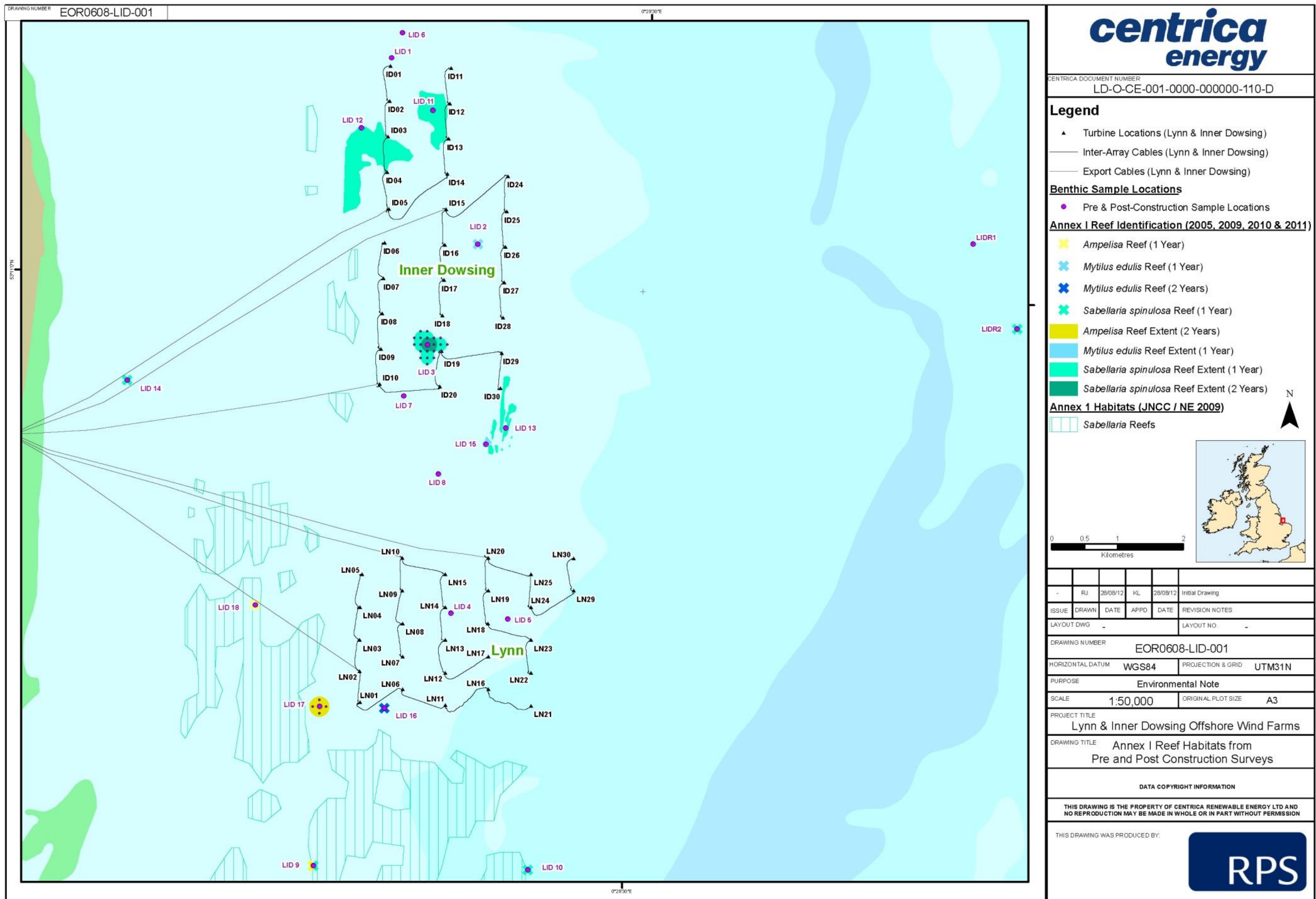


Figure 25: Annex I habitats from pre-construction and post-construction surveys.

4.8.4 Comparisons with the LID Environmental Statements

Q18: Has the monitoring confirmed the predictions of the ESs in relation to impact on benthic communities?

The following impacts were assessed in Chapter 6 of the LID ESs and those highlighted in bold were those investigated during pre-construction and post-construction monitoring.

- **Seabed habitat loss due to cable laying;**
- **Seabed sediment disturbance during construction of foundations and cable laying; and**
- **Seabed disturbance due to construction vessels.**
- Loss of seabed habitat due to introduction of monopiles or foundations;
- Release of seabed contaminants;
- Accidental spillage of contaminants from construction vessels;
- Release of contaminants from grouting and other construction materials;
- Seabed construction noise/vibration impacts;
- Creation of increased scour on seabed (monitoring of scour undertaken during geophysical surveys, Section 4.7);
- Introduction of new substrata including the monopile and surrounding protection/foundations;
- Accidental release of contaminants from service vessels;
- Operational noise/vibration impacts; and
- Operational electromagnetic impacts from subsurface cables.

The predictions made in the ESs that have been tested by the pre-construction and post-construction monitoring, and the results of this monitoring, are described further below.

4.8.4.1 Seabed habitat loss due to cable laying

The impact of temporary habitat loss due to cable laying on benthic ecology was predicted to be “low level” and “medium term” with damage to the composition and structure of the infauna and epifauna predicted during the construction phase. Disturbance to the *S. spinulosa* dominated community was predicted to result in a decline in the diversity and abundance of the associated fauna. Due to the limited area affected by ploughing the fauna either side of the ploughed area were predicted to quickly re-colonise the disturbed seabed, with recovery expected within 2-3 years.

The communities within the LID offshore wind farms were characterised by species which are typical for this region of the southern North Sea and species which have intermediate to low recoverability following temporary habitat loss/disturbance. The pre-construction and post-construction surveys showed that communities within the LID offshore wind farms, i.e. within the sphere of influence of cable laying operations, were not significantly different from unimpacted reference locations. Furthermore, post-construction surveys undertaken in Year 1 showed potential Annex I habitats at a number of locations along the export cable routes for these offshore wind farm sites, i.e. low reefs of *S. spinulosa* were recorded at L&ID12 and L&ID14, a *M. edulis* seed bed was recorded at L&ID16, and *Ampelisca* reef habitats (not Annex I) were recorded at L&ID17 and L&ID18. The results indicate that cable laying operations affected a limited area and that recolonisation by benthic species occurred quickly following disturbance (i.e. within 2-3 years, though possibly within 1 year). This confirms the predictions made in the LID ESs.

4.8.4.2 Seabed sediment disturbance during construction of foundations, drilling and cable laying

Increases in SSCs of approximately 76 mg/l were predicted from cable laying activities after dispersion during one tidal cycle, which was predicted to be within natural inshore background levels³⁰. Consequential impacts on the benthic ecology, including the epifaunal species, due to raised suspended sediment levels, were predicted to be very low.

Similarly sediment deposition derived from the suspended sediments were predicted in the ESs to be less than 1.5 cm as a maximum and was not predicted to result in any adverse impacts on the local infauna or epifauna, due to the mobile nature of the naturally occurring sediments in the area.

The results of the pre-construction and post-construction monitoring surveys indicate that effects on benthic communities from increases in SSCs and sediment deposition were limited and if adverse effects occurred, then full recovery has taken place since offshore wind farm construction. This was evident due to the prevalence of species which are sensitive to sediment deposition at locations within the offshore wind farm sites, at near field and at far

³⁰ The subsequent pre-construction study by ABPmer (2006) predicted SSC levels from monopile drilling activity of 120 – 205 mg/l immediately after release, which was predicted to be localised and of short duration, as discussed in Section 4.2.

field locations, during the post-construction surveys. The results of the monitoring surveys therefore validate the predictions made in the LID ESs.

4.8.4.3 Seabed disturbance due to construction vessels

Effects on benthic ecology were predicted to comprise disturbance to the faunal community, including mortality of the larger or more delicate species including *S. spinulosa* crusts. It was predicted that infaunal species would be unlikely to be impacted. Due to the relatively small area affected, re-colonisation was predicted to be rapid. Recovery to a similar community was predicted to occur within two years.

The jack-up footprint survey confirmed the predictions made in the ESs, with almost full recovery of the benthic infaunal and epifaunal communities within the footprints within approximately 3 years of construction. Although some species of mollusc were recorded at lower abundances within the jack-up footprints than at reference locations, it is unclear whether this is due to the natural variability in the distribution of these species or the slower recovery time for these species. The jack-up footprint surveys showed full recovery of key components of the benthic community, including:

- Recovery of *S. spinulosa* to abundances similar to those of reference areas;
- Recovery of epifaunal communities, with epifaunal species typical of this region of the North Sea (e.g. *F. foliacea*, *P. triqueter* and *P. longicornis*) recorded in both grab samples and DDV footage; and
- Polychaete and crustacean species characterising the benthic infaunal communities both within footprints and at undisturbed reference locations.

4.8.5 Conclusions

The data showed no evidence of large scale changes in the sediment composition or the benthic communities within the LID survey area, confirming the predictions made in the ES. Localised effects on benthic ecology and related sediments were predicted in the ES and these were detected in jack-up footprints and drill arisings from construction operations. Highly localised historic impacts on benthic communities were evident in the datasets, though there was also clear evidence of recovery of these communities since construction in 2007/2008 (which was also predicted in the ESs). Annex I habitats (e.g. *Sabellaria spinulosa* reefs) were also recorded during both pre-construction and post-construction surveys, though many of these were ephemeral in nature, with only one area of Annex I reef identified during the most recent post-construction survey.

4.9 Ornithological Monitoring

4.9.1 FEPA requirements

The generic FEPA requirements for ornithology are presented in Table 38 below. The specific ornithological survey requirements are presented separately below for each type of survey.

Table 38: FEPA Requirements – Ornithology.

Ref	FEPA Condition
Annex 2	Monitoring should be linked, where appropriate, with the benthic monitoring.
Annex 2	Monitoring will need to fulfil the following objectives: 1. Assess changes in usage of area by feeding birds and birds on passage. 2. Assess collision risk prior to construction of the windfarm and investigate techniques/methodologies for collecting data on actual collisions during and post construction. 3. Survey benthos to inform reasons for possible changes in bird distribution and density onsite.
Annex 2	Measurement of extent and distribution of benthic communities which are a food source for SPA birds to provide information to inform interpretation of any changes in density / distribution of birds using the site.

Regarding objective 2 of Annex 2 as presented in Table 38 above, collision risk assessments were carried out during the Environmental Impact Assessment stage, and updated prior to construction in the pre-construction ornithology report (ESS, 2004). Section 4.9.5 presents a review of available technologies for monitoring actual collisions at offshore wind farms, and highlights the limitations with the technology currently available. Nevertheless, state of the art techniques have been deployed at LID during and post-construction in order to quantify predicted Pink-footed goose (*Anser brachyrhynchus*) collision risk, through the use of bird detection radar, which is further discussed in Section 4.9.6.

Ornithological monitoring has taken place at the LID wind farm sites during the pre-construction, during-construction and post-construction phases, involving boat-based, aerial and radar surveys. The results of this monitoring have been reported to the Licensing Authority in the LID Pre-Construction (CREL, 2005), Construction (CREL, 2009) and Year 1 and Year 2 Post-Construction Monitoring Reports (CREL, 2010; CREL, 2012). The status of monitoring and history of reporting for this parameter is also summarised in Table 39.

Table 39: Status of Monitoring – Ornithology.

Phase	Requirement	Complete	LID Report
Pre-construction	Survey	✓	Pre-construction Monitoring Report (CREL, 2005)
During-construction	Survey	✓	Construction Monitoring Report (CREL, 2009)
Year 1 Post-Construction	Survey	✓	Year 1 Post-Construction Monitoring Report (CREL, 2010)
Year 2 Post-Construction	Survey	✓	Year 2 Post-Construction Monitoring Report (CREL, 2012)
Year 3 Post-Construction	Survey	✓	Year 3 Post-Construction Monitoring Report
	Comparison of monitoring results to ES predictions	✓	Year 3 Post-Construction Monitoring Report

The specific questions which are addressed in this overall ornithology section, in relation to the species and species groups considered, and the ornithological monitoring objectives, are as follows:

Q19	<i>Has the post-construction monitoring revealed any significant changes in the abundance and distribution of the key species and species groups?</i>
Q20	<i>Are the changes observed attributable to the wind farms?</i>
Q21	<i>Has the monitoring confirmed the predictions of the ESs / ES Ornithological Addendums in relation to impact on bird species abundance and distribution?</i>

4.9.2 Aerial Bird Survey

4.9.2.1 FEPA Requirements

The aim of the aerial bird surveys was to provide broad-scale contextual information on bird distributions within the GW4 survey sector of the Greater Wash to support the fine-scale data collected at the LID sites via boat-based surveys. The surveys are intended to help satisfy ornithological monitoring objective 1 of the LID FEPA Licences, detailed above in Table 38, to assess changes in usage of the area by birds.

The specific FEPA requirements for aerial bird surveys are set out in Table 40 below. Following discussion at a meeting with NE and the Licensing Authority on 19 July 2011, it was agreed that the winter 2011/2012 survey programme would comprise one survey per month during November, December, January and February.

Table 40: FEPA Requirements – Aerial Bird Survey.

Ref	FEPA Condition
Annex 2	Pre Construction, during and Post Construction 4 per year, two in September, one in February and one in March. The Licence Holder should make all reasonable efforts to undertake the 4 surveys at these times. However, if circumstances dictate that the Licence Holder cannot reasonably undertake the surveys at these times, the surveys should be distributed over the rest of the winter months (October - January), with the key survey emphasis on monitoring Sea Duck populations. The Licence holder is to make the licensing authority and Natural England aware of any changes to survey times.

Aerial bird surveys have taken place over the LID wind farm sites and wider Greater Wash area during the pre-construction, construction and post-construction phases. The results have been reported to the Licensing Authority in the LID Pre-Construction Monitoring Report (CREL, 2005), Construction Monitoring Report (CREL, 2009), and the Year 1 and Year 2 Post-Construction Monitoring Reports (CREL, 2010; CREL, 2012). The status of monitoring and history of reporting for this parameter is also summarised in Table 41.

Table 41: Status of Monitoring – Aerial Bird Surveys.

Phase	Requirement	Complete	LID Report
Pre-construction	Survey	✓	Pre-construction Monitoring Report (CREL, 2005)
During-construction (Yr 1)	Survey	✓	Construction Monitoring Report (winter 2007/2008) (CREL, 2009)
During-construction (Yr 2)	Survey	✗	No survey in winter 2008/2009 for safety reasons
Year 1 Post-Construction	Survey	✓	Year 1 Post-Construction Monitoring Report (winter 2009/2010) (CREL, 2010)
Year 2 Post-Construction	Survey	✓	Year 2 Post-Construction Monitoring Report (winter 2010/2011) (CREL, 2012)
Year 3 Post-Construction	Survey	✓	Year 3 Post-Construction Monitoring Report (winter 2011/12)

This section summarises the results of a third year of post-construction aerial bird surveys covering the GW4 survey block carried out in winter 2011/12, in addition to the results of comparisons with the previous post-construction, during-construction and pre-construction survey datasets. Full details provided in Appendix 7.1. The key species / species groups of particular interest identified in the LID ESs are:

- Divers;
- Gannets;
- Terns³¹; and
- Auks.

In relation to the aerial surveys, the FEPA Licences identify the following species group to be of particular interest:

- Seaduck.

³¹ Note: aerial surveys not carried out at a time of year when terns are present.

4.9.2.2 Methodology and Results of the Year 3 survey

As agreed with NE and the Licensing Authority, four aerial surveys were completed throughout the winter months on 23 November 2011, 20 December 2011, 13 January 2012 and 25 February 2012. The survey area is shown in Figure 26.

During these surveys a series of transects were flown using four super high definition video cameras mounted on the underside of the aircraft, with each camera covering a strip 50 m wide (thus the total strip width was 200 m). These transects were spaced 2.5 km apart over the main survey area (GW4 survey block) and 1.25 km apart in a high interest region, all oriented east-west to ensure that the transects were perpendicular to depth contours. The high interest region was defined around the LID and Lincs wind farm sites and in an area to the south extending across the entrance to The Wash (see Figure 26).

Images were scrutinised to detect birds and identify the species or species group with an associated level of confidence in the identification. Birds which were identified as flying were assigned to one of the following height bands: 0-20 m, 20-50 m, 50-100 m, 100-200 m and >200 m relative to sea level.

4.9.2.3 Analysis Methodology

Two types of statistical analysis were performed on data collected using the digital video, as well as the previous visual, aerial survey methods:

1. *Strip transect analysis* used each of the survey transects as a statistical sample to calculate the abundance of seabirds within the study site. For the visual aerial survey technique, where detection of birds decreases further away from the survey transect line, it was necessary to consider this effect via the use of distance modelling.
2. In making comparisons between different abundance estimates, it must be assumed that the sampling protocol is broadly similar between the two estimates. This was not the case during the change from visual to digital aerial survey methods, therefore *density surface modelling* was also used to calculate abundance estimates, from the modelled distribution of seabird densities across the study area. Both analysis results are presented here, but only the abundance estimates from density surface modelling were used for between-year comparisons (see Section 4.9.2.5).

4.9.2.4 Results

4.9.2.4.1 General numbers and distribution of seabirds

Thirteen seabird species were identified during the surveys, totalling 849, 234, 511 and 1,775 individual birds in Flights 1-4 respectively. A total of 54%, 30%, 21% and 85% respectively of detected birds were identified to species level, with the remainder of records being identified to group level, for example 'auk' species or 'large gull' species.

Little gulls *Hydrocoloeus minutus* made up the majority of birds identified to species level in Flight 1 (November), with 210 birds recorded. Other records were made up mainly of other gull species, with identified birds including Black-headed gulls *Chroicocephalus ridibundus* (13), Great black-backed gulls *Larus marinus* (21), Lesser black-backed gulls *L. fuscus* (18), Common gulls *L. canus* (43) and Herring gulls *L. argentatus* (3). Some 240 auks were detected during the survey, with 35 'diver species', of which five were identified as Red-throated divers *Gavia stellata*, and 22 Common scoters *Melanitta nigra*.

Little gull was again the most frequently detected species in Flight 2 (December), albeit at a lower frequency (23 individuals). Only 12 divers were recorded, of which three were identified as Red-throated divers. There were 127 observations of unidentified auks. No Common scoters were recorded.

Auks were the most numerous species group during the Flight 3 (January) survey, when 168 were recorded. Small and medium-sized gulls were next most numerous, with 26 Kittiwakes *Rissa tridactyla*, 19 Black-headed, 14 Little and 21 Common gulls. A total of 25 'diver species' were detected and seven of these were identified as Red-throated divers, and an additional 15 birds were identified as either large auks or divers.

During the Flight 4 (February) survey, Common scoter comprised 57% of all bird observations, with large flocks totalling 995 individuals. The most numerous gull species were Black-headed (286), Common (80) and Herring (59) gulls. Ninety-one detections of unidentified auks were also made, as well as 77 divers, of which 48 were identified as Red-throated divers.

Density surface modelling showed that although seabirds were present in all parts of the study area, numbers were generally highest in shallower water off the north coast of Norfolk, inshore off the north-eastern Lincolnshire coast, and across the entrance to The Wash. Comparatively low numbers of most seabird species tended to occur within the LID offshore wind farm sites.

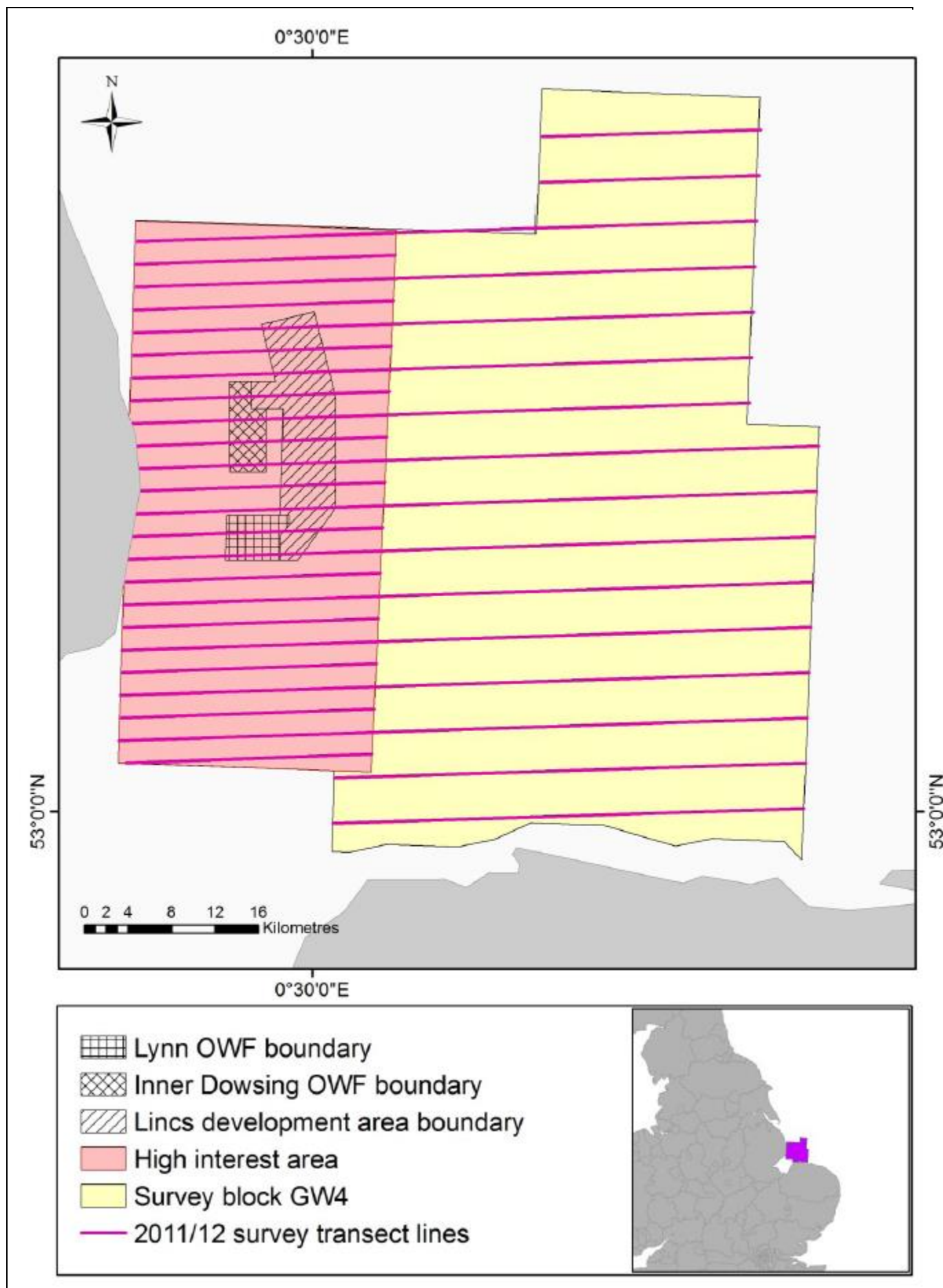


Figure 26: Winter 2011/12 survey area showing planned transect lines, GW4 survey block, high interest area, and the wind farms sites (Source: HiDef and WWT Consulting, 2012).

4.9.2.4.2 Key species population abundance and distribution

The tables below provide a summary of peak population estimates for key species or species groups within the total survey region and high interest region, using strip transect analysis (Table 42) and density surface modelling (Table 43).

Table 42: Peak population estimates for key species recorded during aerial bird surveys winter 2011/12, derived from strip transect analysis.

Species or species group	Peak population estimate in total survey region (with 95% Confidence Interval)	Month of peak population estimate
Common scoter	8,819 (311 - 25,206)	Feb
Red-throated diver	428 (177 - 678)	Feb
Diver species	686 (386 - 1,006)	Feb
Gannet	216 (63 - 383)	Nov
Common gull	712 (321 - 1,114)	Feb
Little gull	1,890 (751 - 3,044)	Nov
Kittiwake	866 (606 - 1,132)	Nov
Herring gull	535 (234 - 836)	Feb
Small gulls	3,235 (1,901 - 4,603)	Nov
Auk species	2,140 (1,308 - 3,012)	Nov
All birds	16,417 (4,231 - 34,948)	Feb

Table 43: Peak population estimates recorded during aerial bird surveys winter 2011/12, derived from density surface modelling where records were sufficiently numerous.

Species or species group	Peak population estimate in total survey region (with 95% Confidence Interval)	Peak population estimate in high interest region (with 95% Confidence Interval)	Month of peak population estimate
Common scoter	10,363 (0 - 46,703)	0	Feb
All divers	865 (672 - 1,100)	110 (47 - 202)	Feb
Common gull	758 (417 - 3,112)	628 (353 - 1,074)	Feb
Little gull	2,723 (1,972 - 3,745)	555 (336 - 784)	Nov
Kittiwake	995 (688 - 1,365)	327 (213 - 455)	Nov
All gulls	5,212 (2,410 - 8,614)	4,808 (1,978 - 8,595)	Feb
All auks	2,843 (2,270 - 3,497)	1,214 (916 - 1,594)	Nov
All seabirds	19,980 (4,622 - 44,668)	5,426 (2,345 - 8,949)	Feb

Divers

Figure 27 shows the location of observations of all divers during all winter 2011/12 surveys. Divers were widely distributed throughout the survey block during winter in small numbers, but generally they were located in the southern part in waters between 10 and 30 m deep. Of the 63 divers identified to species level in all four surveys, all were found to be Red-throated divers. It is assumed, therefore, that the distribution patterns of all divers detected during this survey largely relate to Red-throated divers.

Numbers of divers were highest during the February survey (peak estimate of 865 individuals, 672 - 1,100 95% Confidence Interval (CI) using density surface modelling and 686 individuals, 368 - 1,006 95% CI using strip transect analysis), and assuming nearly all were Red-throated divers, levels reached national importance within the GW4

region (>170 birds). This late winter peak is consistent with trends from previous years, possibly as birds gather before beginning their northward migration to breeding grounds. Birds tended to make greatest use of the offshore and deeper waters at this time. During the February survey, concentrations were found to occur off the north coast of Norfolk and extending approximately north-east from the northern mouth of The Wash. Conversely, density surface modelling revealed that the lowest inshore density of divers occurred in the region of the Lincs and Lynn wind farms, with slightly higher density around Inner Dowsing wind farm.

Within the high interest region, divers tended to concentrate inshore of the LID offshore wind farms, with very small numbers in outer offshore parts of the high interest region. Numbers did not reach national importance and there were only two records of divers in the project areas: one in the Inner Dowsing offshore wind farm in February, and one in the construction area for Lincs offshore wind farm in November.

Gannets

Figure 28 shows the location of observations of Gannets during all winter 2011/12 surveys. Low numbers of Gannets *Morus bassanus* were recorded during the surveys. The peak occurred in November 2011 when 25 were observed; and none were recorded in January and February 2012. Gannets were found mostly inshore during the November survey with a concentration over shallow banks at the northern entrance to The Wash. There was one observation within the Lincs site and two at the periphery of the Lincs site. There were too few observations to allow the calculation of population estimates using density surface modelling, but a peak population estimate of 216 individuals (63 – 383 95% CI) in November was made from strip transect analysis.

Auks

Auks were recorded in greatest numbers during the November survey and although widely dispersed, mainly occurred in shallower water either side of the deep water channel from The Wash. In the later surveys, when there were fewer birds overall, there was a persistent aggregation of auks located in the southern part of the high interest area over and either side of the deep water channel at the mouth of The Wash. Very few auks were however present in the LID offshore wind farm footprints, but some were present in the Lincs site. Distribution maps are included in Appendix 7.1. Density surface models were created for each of the survey flights and support this overall pattern, with persistent aggregations to the south of the LID offshore wind farms and the Lincs development site. In general, the density of auks was lower around the LID and Lincs wind farm footprints than the surrounding area, but this pattern was weak.

Seaduck (Common scoter)

Figure 29 shows the location of observations of Common scoters during all winter 2011/12 surveys. Common scoters were recorded during the November and February surveys, in three localities off the north coast of Norfolk, in water between 10 and 20 metres deep. Previous aerial surveys using visual techniques also recorded highly aggregated flocks of Common scoters (up to 3,000) in very similar locations, and occasionally off the Lincolnshire coast. As in previous years, nationally important numbers were found within the total survey region, this time in February, although the confidence intervals around that estimate are very wide (peak estimate of 10,363 individuals, 0 - 46,703 95% CI using density surface modelling and 8,819 individuals, 311 - 25,206 95% CI using strip transect analysis). No records were within the high interest region (and therefore the wind farms sites).

Gulls

Gulls were the species group that made greatest use of waters within the footprint of the LID offshore wind farms and the Lincs site, and their presence in the latter may have been associated with construction activity. The majority of 'gull species' records were found in the high interest area, principally in the western and southern portion. The main exception were Little gulls, which also used the shallower waters up to 20 m deep off the north coast of Norfolk especially during Flight 1, and Kittiwakes which made extensive use of the entire study area particularly during Flight 1.

Density surface models were generated for all gull species combined in each of the survey flights separately. These showed highest numbers close to the coast of Lincolnshire and off the coast of Norfolk. Peak numbers of Common gulls, Little gulls and Kittiwakes occurred during the February, November and November flights respectively (Table 43). Although there is no national population estimate for Little gulls, the peak numbers in the study area and in the high interest area were considered likely to reach importance at least at a regional level. Distribution maps for gulls are presented in Appendix 7.1.

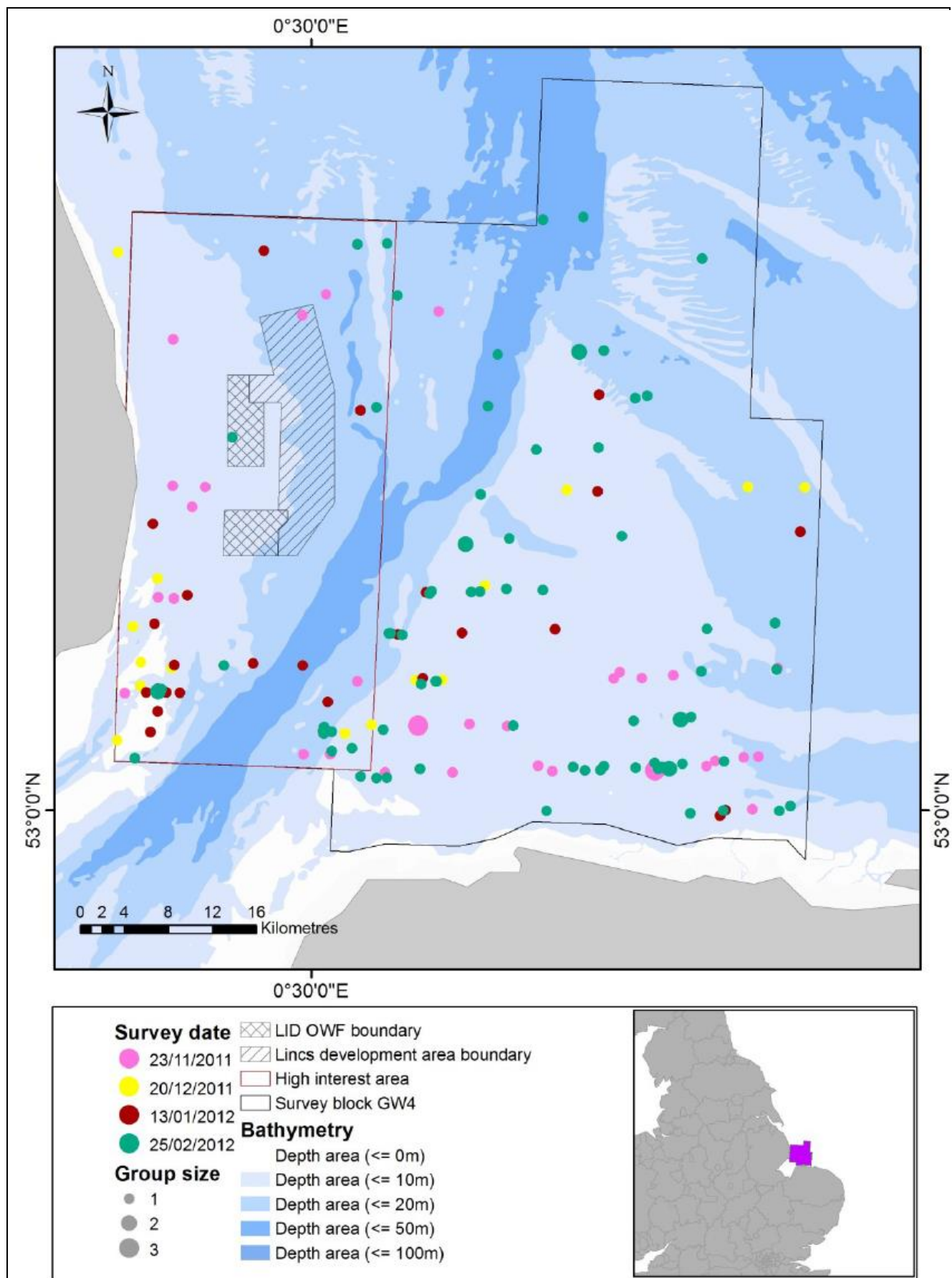


Figure 27: Location of observations of all divers during all winter 2011/12 surveys separated by survey date and related to bathymetry (Source: HiDef and WWT Consulting, 2012).

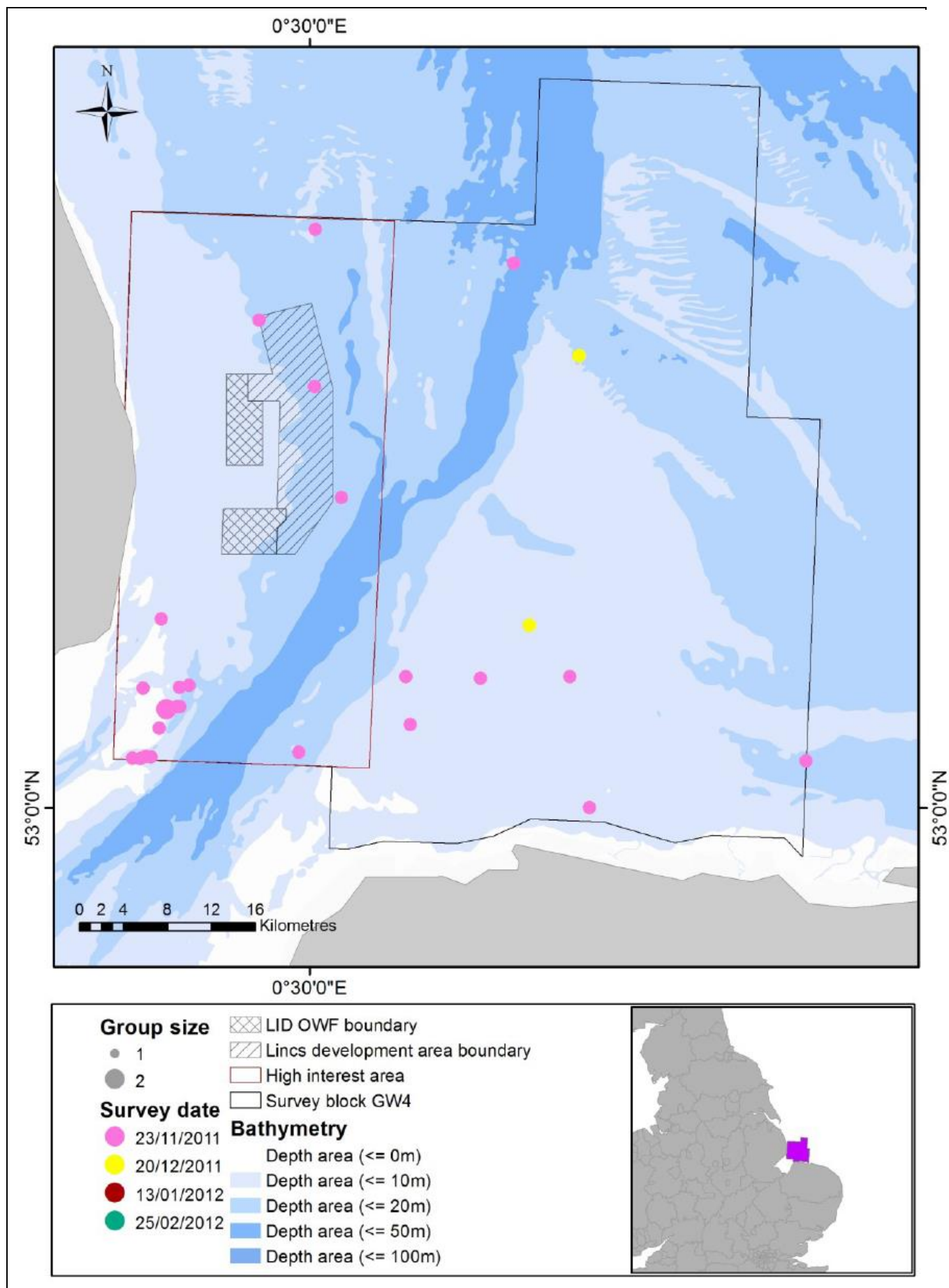


Figure 28: Location of observations of Gannets during all winter 2011/12 surveys (Source: HiDef and WWT Consulting, 2012).

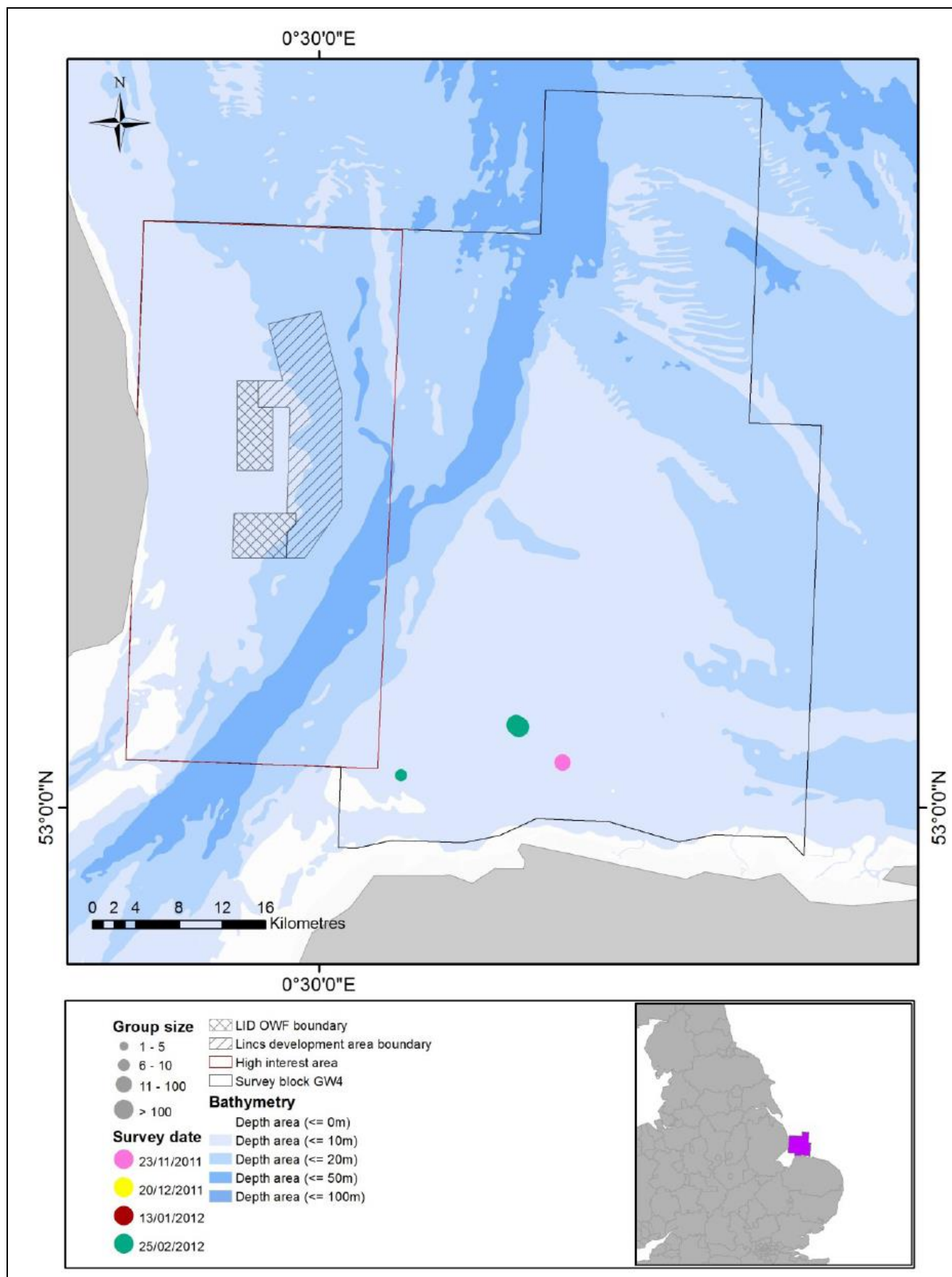


Figure 29: Location of observations of Common scoters during all winter 2011/12 surveys (Source: HiDef and WWT Consulting, 2012).

4.9.2.5 Methodology and Results for inter-year comparisons

Abundance estimates calculated from the visual aerial and digital aerial surveys conducted since 2004/05 have been compared with the estimates from the digital aerial survey data collected in winter 2011/12. Due to differences in survey design and methodology between digital and visual surveys, density surface modelling was chosen as the most appropriate method for producing estimates for comparison. In some of the previous survey years it was not always possible to generate abundance estimates from individual surveys for each species or species group using density surface modelling, generally because there were too few observations, resulting in poor fitting of the models. For this reason, comparisons between winter seasons were carried out using survey data that were pooled across the winter period for all divers, gulls and auks only. A z-test was used to statistically test for a difference between a winter 2011/2012 estimate and a previous estimate. See Table 1 in HiDef and WWT Consulting (2012) (Appendix 7.1) for a full list of previous surveys and which of these surveys have been incorporated into the analysis³².

Results showed that the pooled abundance estimate for divers in winter 2011/12 in the GW4 study area was significantly lower than the pooled estimate for 2009/10, but there was no significant difference with any of the other winter survey years. This suggests that there have been annual fluctuations in numbers of divers in the Greater Wash, as might be expected for a highly mobile species group such as this, but no trend in numbers was detected at the scale of the GW4 survey area. However, it is notable that there were only two observations of divers within the footprint of the LID offshore wind farms in aerial surveys during and after turbine construction, compared with 12 during fewer surveys before construction. Density surface models of diver distribution before construction (2004/05 and 2005/06) suggest that the highest density of divers was around the coast of Lincolnshire in three out of four surveys compared with other parts of GW4, yet this observation was not apparent around the development sites in subsequent years other than in February 2010. There was an anomaly in the density surface modelling map for February 2010, when predicted density in and around the LID wind farms was predicted to be high, in spite of there being few observations in the corresponding region, which suggests that there was a poor fit of the model in this area. It cannot be concluded from a visual inspection of data in this way that changes in distribution were a direct consequence of construction of the wind farms.

There was no significant difference in pooled population estimates for gulls in winter 2011/12 compared to the pooled estimates in any previous winter seasons, suggesting that overall numbers have stayed the same in the study area. However, these comparisons mask any changes that might have occurred to individual species. Density surface models for all gulls did not reveal a strong association with the proposed site of the wind farms prior to construction in 2004 to 2006. The same pattern was apparent in surveys carried out following construction, suggesting that overall gull distribution was not affected by operation of the LID offshore wind farms.

For auks, there were significantly higher pooled estimated numbers in the GW4 study area in winter 2011/12 than for those in 2004/05, 2005/06, 2007/08 and 2010/11, and no significant difference in pooled abundance with 2009/10. This suggests that there is annual variation in auk numbers between years, as would be expected for a mobile prey-pursuing species during the non-breeding season.

Section 4.9.7 and Section 4.9.8 below further consider the results of these aerial surveys in combination with the results from the other ornithological surveys, in order to provide conclusions in relation to the ornithological interest of the LID sites as a whole.

³² Previous data from the months of January to March were incorporated into the analysis.

4.9.3 Boat-based Bird Survey

4.9.3.1 FEPA Requirements

The FEPA requirements for boat-based bird surveys are set out in Table 44 below.

Table 44: FEPA Requirements – Boat-Based Bird Survey.

Ref	FEPA Condition
Annex 2	Pre Construction Monitoring 19 per year, two per month in August, October, February and April. 4 per month in September and March and one per month in November, December and January. The four surveys in March and September are permitted to be 2 sets of concurrent days. During Construction monitoring 14 per year, one survey to be carried out over January/February, and November/December, one survey per month for the rest of the year apart from September and October when 3 per month, should be conducted. Post Construction monitoring 14 per year, one survey to be carried out over January/February, and November/December, one survey per month for the rest of the year apart from September and October when 3 per month, should be conducted.

Boat-based bird surveys of the LID sites and a control area³³ commenced with baseline characterisation surveys to inform the EIA (2001-2002), and have been carried out through the pre-construction (2003-2005), during-construction (2007-2008) and post-construction (2009-2012) phases. The results have been presented to the Licensing Authority in the LID Pre-Construction (CREL, 2005), Construction (CREL, 2009) and Year 1 Post-Construction Monitoring Report (CREL, 2010), and as an Appendix to the Year 2 Post-Construction Monitoring Report (ECON, 2012a). The status of monitoring and history of reporting for this parameter is also summarised in Table 45.

Table 45: Status of Monitoring – Boat-based bird surveys.

Phase	Requirement	Complete	LID Report
Pre-construction	Survey	✓	Pre-construction Monitoring Report (CREL, 2005)
During-construction (Yr 1)	Survey	✓	Construction Monitoring Report (CREL, 2009)
During-construction (Yr 2)	Survey	✓	Construction Monitoring Report (CREL, 2009)
Year 1 Post-Construction	Survey	✓	Year 1 Post-Construction Monitoring Report (CREL, 2010)
Year 2 Post-Construction	Survey	✓	Year 2 Post-Construction Monitoring Report (ECON, 2012a)
Year 3 Post-Construction	Survey	✓	Year 3 Post-Construction Monitoring Report
	Inclusion of pre-construction dataset in modelling, reference to wider context provided by aerial surveys, comparison with ES predictions	✓	Year 3 Post-Construction Monitoring Report

This section presents the results of a third year of post-construction boat-based bird surveys covering the LID sites and control site, in addition to the results of comparisons with the previous post-construction, during-construction and pre-construction/baseline survey datasets. Full details are provided in Appendix 7.2. The reporting focuses on the following 13 sensitive ornithological receptors:

- Red-throated diver;
- Northern fulmar;
- Northern gannet;
- Skuas (as a group to increase the available data);
- Black-legged kittiwake;
- Common gull;
- Lesser black-backed gull;
- European herring gull;
- Great black-backed gull;
- Sandwich tern;
- Common tern;
- Common guillemot; and
- Razorbill.

³³ The control site for the construction and post-construction surveys differed to that for the pre-construction surveys, due to an improvement in the survey design – this is further discussed in Appendix 7.2.

The 13 species encompass several ecologically different groups with the potential to experience the range of possible impacts associated with the construction and operation of the wind farms (ECON, 2010). Species of conservation concern, those classed as sensitive ornithological receptors at LID as well as at other sites in The Greater Wash, and those occurring in at least regionally important numbers using the sites are included. The selection is further justified in Appendix 7.2.

4.9.3.2 Methodology and results of the Year 3 survey

4.9.3.2.1 Boat-based survey methods

Boat-based surveys were conducted using a 20 m vessel with an eye height of 5.7 m. Surveys were carried out by experienced ornithologists trained to systematically record seabirds and migrant species using a modified version of the COWRIE methodology (Camphuysen *et al.*, 2004). A minimum of two skilled surveyors and a dedicated data recorder were used on the observation platform of the survey vessel at all times.

The survey area consisted of the two LID sites (both with 1 km buffers) and a control site (with a 500 m buffer) to the northwest of the LID wind farms which incorporated an area with similar bathymetry to the LID sites (Figure 30). This control area provided a similar survey area to the combined LID sites with their respective buffers. **Buffers were used to provide greater survey effort given the small size of the sites.** The survey schedule was as specified in the FEPA Licence conditions.

Surveys consisted of a line transect route to survey birds on the water and incorporated 'snapshots' at 500 m intervals for birds in flight. Instantaneous snapshots are designed to reduce the effects of movement bias. Line transect surveys were carried out with an effective strip width of 600 m (2 x 300 m either side of the vessel). All birds on the water were recorded within bands corresponding to 0-50 m (A), 50-100 m (B), 100-200 m (C), 200-300 m (D), >300 m (E) width, perpendicular to the vessel. When birds were seen in groups or aggregations across distance bands, these were split appropriately between the bands in which they were seen. Birds >300 m distant were 'out of transect' although still recorded.

During designated snapshots, flying birds were recorded within radial bands of 0-50 m (A), 50-100 m (B), 100-200 m (C), 200-300 m (D), >300 m (E) width on each side of the vessel i.e. within a 180° scan. Although only snapshot data are used to derive the abundance of flying birds, all flying birds seen both in and out of transect were also recorded during the surveys. All birds in flight were assigned to one of three flight height bands: 1 = <20 m, 2 = 20-120 m and 3 = >120 m.

All birds were initially detected by eye and then identified using high quality binoculars. A time of the observation (hr:min:sec) was immediately noted. Additional information regarding age, sex, plumage and behaviour of birds was recorded wherever possible. Feeding activity, birds on structures, associations between birds and vessels or other birds and any other specific bird behaviour were also recorded. Spatial positioning of bird observations was later achieved using the boat track, time of observations and respective distance bands.

Whenever possible, the preferred ship speed was 8-10 knots. Sea state and other variables that can influence observer efficiency were recorded. No observations above sea state 5 were used during the analysis of the data. Registration of tidal status (low, medium or high) accompanied by specific depth measurements at all snapshot locations were also recorded. Activity of other vessels within or in the vicinity of the wind farms accompanied by their name, number, position, size, type and estimated speed was recorded on a specific form.

The methods described above were used throughout the construction and post-construction monitoring (2007 – 2012). However, earlier baseline and pre-construction monitoring surveyed different areas and used a subtly different and less refined method. The change in methods and survey areas followed consultation with statutory bodies and were seen as improvements to the existing methods. The original baseline and pre-construction survey methods are outlined in more detail in Appendix 7.2 and differences between the two survey regimes are discussed.

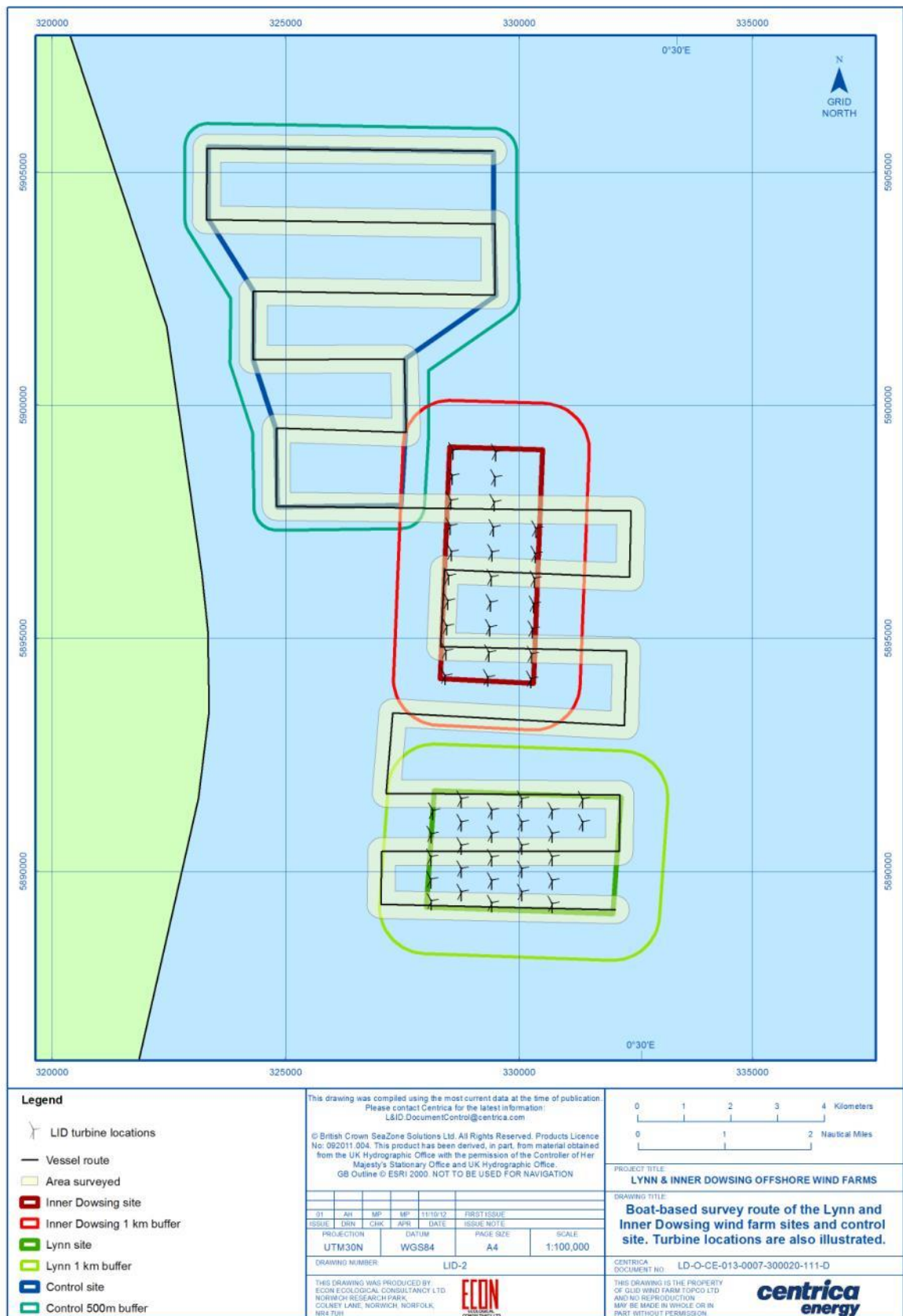


Figure 30: Survey blocks, survey route and turbine locations for the control site + 500 m buffer, Inner Dowsing site + 1 km buffer and Lynn site + 1 km buffer.

4.9.3.2.2 Estimation of population size

Population estimates for each species during the Year 3 post-construction surveys (and for all surveys 2007 – 2012), were calculated by multiplying the species densities for each of the LID sites and the control site (including 1 km buffers for the Lynn and Inner Dowsing sites and 500 m buffer for the control site) by the corresponding site areas (Lynn site & 1 km buffer = 26.17 km²; Inner Dowsing site & 1 km buffer = 27.09 km²; and control site & 500 m buffer = 46.64 km²). **The buffers were used in these calculations to include the greatest survey effort possible and make best use of the available datasets.**

Densities were calculated using three methods which allowed for the correction of distance sampling errors where possible.

1. The standard ESAS methodology of combining densities for birds on the water (line transects) and flying birds (snapshots) was used to produce basic density estimates;
2. Simple correction factors were derived from survey records for pooled auks, small gulls and large gulls on the water surface. Corrected estimates of birds on the water (for each species within each group) were then combined with flying bird densities from snapshots; and
3. The more sophisticated Distance 6.0 software was also used wherever possible to produce detection functions for birds on the water, however this was only possible for Guillemot due to lack of data for other species. The selected estimate for birds on the water was then added to that for birds in flight. See Appendix 7.2 for further detail on the calculation of correction factors and use of Distance software.

North-south transects connecting the east-west transects (end-lines) were used during the calculation of densities using the standard ESAS methodology (see Stone *et al.* 1995). The inclusion of the end-lines provided greater survey effort and in some cases allowed population estimates to be calculated when their exclusion would have prevented it (see Appendix 7.2), whilst not appearing to strongly bias the population estimates. In contrast, Distance analyses and corrections require independent transect lines and therefore end-lines were not used when Distance could be applied.

4.9.3.2.3 Results of the Year 3 boat-based surveys

A total of 3,553 birds were recorded in the study area during the Year 3 boat-based surveys representing 38 individual species and a further 12 unidentified taxa. Of these, 885 individuals were recorded in the Lynn site and buffer (25 identified species), 470 in the Inner Dowsing site and buffer (19 identified species) and 1,754 in the control site and buffer (35 identified species). Guillemot, Herring gull, Gannet, Kittiwake and Sandwich tern represented the dominant species (maximum densities and peak populations) within the LID sites and buffers (Table 46).

Table 46: Total counts, maximum densities and peak population estimates derived for the 13 key bird species/groups examined in this report from the year 3 operational period surveys.

Species	Lynn OWF + buffer			Inner Dowsing OWF+ buffer			Control + buffer		
	Total count	Max density	Peak popn.	Total count	Max density	Peak popn.	Total count	Max density	Peak popn.
Red-throated diver	6	0.186	5	7	-	-	36	0.479	22
Fulmar	0	-	-	0	-	-	2	0.049	2
Gannet	111	3.574	94	35	0.253	7	163	0.801	37
Skuas species	16	0.383	10	4	0.122	3	22	0.322	15
Kittiwake ¹	173	3.449	90	131	2.786	75	50	0.560	26
Common gull ¹	58	1.528	40	24	1.266	34	154	1.900	89
Lesser black-backed gull ¹	30	1.150	30	13	0.910	25	56	0.537	25
Herring gull ¹	26	0.767	20	57	3.912	106	236	5.265	246
Great black-backed gull ¹	77	1.222	32	41	1.101	30	175	1.251	58
Sandwich tern	69	2.569	67	16	0.734	20	76	0.694	32
Common tern	1	-	-	0	-	-	8	0.322	15
Guillemot ²	150	7.101	186	51	3.626	98	152	6.523	304
Razorbill ¹	7	0.725	19	4	0.244	7	34	1.205	56

Notes:

¹. Densities derived by combining birds on the water, using simple correction factors, with snapshot densities.

². Densities derived from combining birds on the water derived using DISTANCE software with snapshot densities.

Further details of all survey results and summaries of density and population estimates are provided in Appendix 7.2. Results from previous monitoring phases, including the baseline and pre-construction surveys, are also summarised and reviewed within Appendix 7.2 prior to more detailed analyses.

4.9.3.3 Methodology and results for inter-year comparisons

4.9.3.3.1 Assessment of changes in the abundance and distribution of key bird species

A broad set of analytical methods were used to investigate whether there had been changes in the abundance and distribution of the key bird species in the study area over the baseline/pre-construction, construction and post-construction monitoring phases. To facilitate these analyses, boat-based surveys were split into the following monitoring phases:

1. Baseline/characterisation (October 2001 – November 2002: 18 surveys);
2. Pre-construction (March 2003 – March 2005: 20 surveys);
3. Construction (July 2007 – July 2008: 14 surveys);
4. Year 1 Operation (August 2008 – December 2009: 20 surveys)³⁴;
5. Year 2 Operation (March 2010 – November 2010: 13 surveys); and
6. Year 3 Operation (March 2011 – February 2012: 14 surveys).

Statistical modelling, using Generalised Additive Models (GAMs), was used to test for significant changes in the populations of the key species between the different monitoring phases, and between the wind farm sites and the control site. Buffer data were included for both the LID sites and control site to encompass the greatest amount of survey effort. Data from the buffers was generally gathered closer to the sites and any effect of the wind farm is assumed to have influenced birds in this area too. Whilst fine scale displacement may be a possibility it would likely be difficult to detect any significant difference between the sites and buffers given the reductions in survey effort if they were split for the analyses. The monitoring programme was designed to compare the results between the wind farm sites and the control site rather than to examine gradient effects (normally achieved using multiple different sized buffers around the sites with similar survey effort). A gradient analysis would not have been readily achieved for LID given the location of the sites, close to the shore, given variations in bathymetry and the proximity of the adjacent Lincs wind farm development.

GAMs are non-linear multivariate analyses that use smooth functions to compute the relationship between explanatory and dependent variables and allow the assessment of complex non-linear relationships that tend to better reflect ecological and biological processes (see Hastie & Tibshirani, 1990). Modelling of changes in the wind farm sites alone (hereafter referred to as 'Model 1') was undertaken over the entire monitoring period incorporating the baseline, pre-construction, construction and operational data. 'Monitoring phase' was used as an explanatory variable and took into account a seasonal variable in the form of 'Year day' (days since the 1st of January) to incorporate within-year variations in the abundance of birds.

The difference between the monitoring phases and between the wind farm sites (combined) and the control site was then assessed using the construction and operational data only (hereafter referred to as 'Model 2'), which were gathered using surveys conducted in a consistent manner and which made use of the same control site. Thus, the difference between the monitoring phases and between the wind farm sites (combined) and the control site could be assessed. This modelling used 'site-monitoring phase' as an explanatory variable and again used 'Year day' to compensate for seasonal variation. Specific details of the modelling methods and all results are presented in Appendix 7.2.

Spatial modelling ('Model 3') was also attempted to examine trends in distribution (see Appendix 7.2), however the models performed poorly as a result of very low abundance of birds generally present within the LID sites and control site but also because of the relatively small survey area. The less refined Jacob's selectivity index (Jacobs, 1974) was therefore used to examine the relative use of the different sites (i.e. LID sites and control site) in relation to the survey areas over the different monitoring periods. This index indicates preference or selection for a particular area relative to its size with values varying from +1 (exclusive selection for an area) to -1 (total avoidance), whilst values close to 0 indicate no selection. Boere *et al.* (2006) discuss the use of the index as a tool for evaluating changes in the distribution and abundance of birds in relation to wind farms. Here, it is used to assess whether there was any change in site (wind farm sites and control sites³⁵ with respective buffers) preference during the different monitoring phases (Appendix 7.2).

To provide a 'sense check' for the results of these analyses, maps illustrating the distribution of bird observations during each monitoring phase were produced. These maps segregated the bird observations into breeding, autumn passage, winter and spring passage periods, where appropriate, to aid in the identification of seasonal trends. Species specific maps are provided within the species accounts in Appendix 7.2.

³⁴ As there is not a clearly defined transition between the end of construction and the start of operation, the first 'year' of operation was categorised to also include the majority of the period of wind turbine testing, specifically August to December 2008.

³⁵ Note this analysis used data from the two different control sites (baseline/pre-construction control site and construction/post-construction control site).

The power of these models to detect statistically significant effects in relation to the construction and operation of the wind farms is linked to the quantities of bird observations and distributions of the data. Attempts were made to mitigate the effects of low numbers of observations within limited surveys, and occasional high numbers of observations within one or two surveys, using a range of techniques (e.g., appropriate error distributions and aggregation of survey data). However, for a number of species the statistical power of these models was limited. The proximity to the Lincs wind farm project, which was under construction during the final year of LID monitoring (since March 2011), also potentially confounded the results. The frequency and timing of surveys as specified in the FEPA Licences (see Appendix 7.2) and the compatibility of the two separate survey regimes employed over time, also hindered the analysis. The limitations of the data are discussed in more detail in Appendix 7.2.

4.9.3.3.2 Summary of results

Most of the 13 key species were recorded in the LID project areas during both the construction and operational monitoring phases, indicating that birds were not entirely averse to the use of the project areas despite the construction activity and presence of turbines. Whilst there was a lack of gross negative response (i.e. complete evacuation of the wind farm areas in a particular phase) by any species, significant changes in abundance were revealed by the results of 'Model 1' (Table 47) and 'Model 2' (Table 48). Note that 'Model 1' results represent a comparison of populations between the results from each monitoring phase with the baseline data; 'Model 2' results represent a comparison of populations between the results from each monitoring phase and area (wind farm sites or control site) with the baseline (the control site during construction).

Table 47: Summary results from 'Model 1' models examining changes in populations of birds using the LID sites and buffers (combined) alone during all monitoring phases (i.e. including baseline and pre-construction monitoring). Results for the model covariates present the degrees of freedom (df) and associated probability (P) of significance.

Species	Total No. birds seen in (surveys of 63)	Model covariates		% deviance explained	Trend and comments
		S(Year day)	F(Phase)		
Red-throated diver	73 (11)	---	---	---	No significant change over time. Low numbers of records.
Fulmar	43 (13)	---	---	---	No significant change over time. Low numbers of records.
Gannet	219 (23)	df=2.41 P<0.001	df=5 P=0.001	64.2	Significantly lower populations during pre-construction, construction and the 1 st and 2 nd years of operation.
Skuas	91 (14)	df=2.95 P<0.001	df=5 P=0.002	77.7	Significantly higher populations during the construction phase and 3 rd year of operation. Low numbers of records.
Kittiwake	754 (30)	df=2.98 P<0.001	df=5 P=0.002	54.7	Significantly higher populations during the construction phase and 3 rd year of operation.
Common gull	1,107 (41)	df=29.2 P<0.001	---	38.9	No significant change over time.
Lesser black-backed gull	336 (21)	df=2.94 P<0.001	---	13.7	No significant change over time.
Herring gull	408 (34)	df=2.94 P<0.001	---	33.2	No significant change over time.
Great black-backed gull	1,239 (37)	df=2.84 P<0.001	df=5 P<0.001	56.6	All estimates subsequent to the baseline, were significantly higher.
Sandwich tern	507 (19)	df=2.96 P<0.001	df=5 P=0.002	78.6	All estimates subsequent to the baseline, were significantly higher.
Common tern	200 (9)	df=2.84 P<0.001	---	41.1	No significant change over time. Low numbers of records in all but one survey.
Guillemot	1,795 (33)	df=2.98 P<0.001	df=5 P<0.001	36.4	Significantly higher estimates in the 3 rd year of operation.
Razorbill	73 (8)	---	---	---	No significant change over time. Low numbers of records.

Table 48: Summary results from ‘Model 2’ models examining changes in populations of birds using the LID sites and buffers (combined) and control site and buffer during construction and operational monitoring periods. Results for the model covariates present the degrees of freedom (df) and associated probability (P) of significance.

Species	Total No. birds seen in (surveys of 42)	Model covariates		% deviance explained	Trend and comments
		S(Year day)	F(Site-Phase)		
Red-throated diver	67 (12)	df=2.95 P<0.001	---	39.1	No significant change over time. Low numbers of records.
Fulmar	79 (15)	df=2.88 P=0.006	---	20.1	No significant change over time. Low numbers of records.
Gannet	312 (22)	df=2.97 P<0.001	df=7 P<0.001	46.9	Significantly lower estimates in the LID sites during construction, year 1 and 2 of operation, when compared to the control site during construction. Estimates were also significantly lower in the control site during year 1 and 2 of operation relative to construction.
Skuas	97 (13)	df=2.91 P<0.001	df=7 P<0.001	65.5	Significantly lower estimates in the 2 nd year of operation in the LID sites when compared to the control site during construction. Estimates were also significantly lower in the control site during year 1 and 2 of operation relative to construction. Low numbers of records.
Kittiwake	944 (23)	df=2.99 P<0.001	df=7 P<0.001	55.0	Significantly lower estimates in the 1 st and 2 nd years of operation in the LID sites when compared to the control site during construction. Significantly lower estimates in all operational years in the control site relative to construction.
Common gull	2,135 (30)	df=2.80 P<0.001	df=7 P=0.002	44.1	Significantly lower estimates in the LID during the 1 st and 3 rd year of operation when compared to the control site during construction. Significantly lower estimate in the 3 rd year of operation in the control site relative to construction.
Lesser black-backed gull	653 (32)	df=2.89 P<0.001	df=7 P<0.001	33.9	Significantly lower estimates in the LID sites in the three operational years when compared to the control site during construction. Significantly lower estimates in the 1 st and 3 rd years of operation in the control site relative to construction.
Herring gull	1,093 (30)	df=2.91 P<0.001	df=7 P<0.001	40.7	Significantly lower estimates during construction, year 1 and year 2 of operation when compared to the control site during construction. No significant difference in the control site estimates relative to construction.
Great black-backed gull	2,116 (33)	df=2.90 P<0.001	df=7 P=0.020	44.6	No significantly different estimates when compared to the control site during construction. Significantly higher estimate in the 2 nd year of operation in the control site relative to construction.
Sandwich tern	621 (16)	df=2.44 P<0.001	df=7 P=0.001	87.2	All estimates significantly higher in the LID sites when compared to the control site during construction. Significantly higher estimates during the operational years in the control site relative to construction.
Common tern	237 (8)	df=2.81 P<0.001	---	32.3	No significant change over time. Low numbers of records.
Guillemot	2,391 (28)	df=2.94 P<0.001	df=7 P<0.001	35.4	Significantly lower estimate in the 1 st and 2 nd years of operation in the LID sites relative to the control site during construction, followed by a significant increase in the 3 rd year of operation. Significantly lower estimates in the 1 st and 2 nd years of operation in the control site relative to construction.
Razorbill	155 (8)	df=2.97 P<0.001	---	39.1	No significant change over time. Low numbers of records.

The incorporation of the baseline data in 'Model 1' models helped determine the longer-term trends in the abundance of several species and aided in the interpretation of whether there had been a response to the construction and operation of the wind farms. **Analysis of Common gull, Lesser black-backed gull and Herring gull, did not reveal any significant trends over time** (Table 47) and thus seem unlikely to have been affected by the wind farms. However, 'Model 2' **analysis** (Table 48) suggested Lesser black-backed gull did show some significant differences in population size in the LID sites and control site over time, and general observations based on the raw population data indicated that there was an increase during the construction phase followed by an initial decrease and later increase during the three years of operational monitoring. **Low numbers of observations (often clustered in specific surveys) of Red-throated diver, Fulmar, skua species, Common tern and Razorbill resulted in inconclusive analyses or less confidence in the model results.**

Despite the lack of significant results from the modelling (likely due to the data structure and numbers of observations), Red-throated diver did provide some evidence of disturbance and displacement from the LID sites. Mean population estimates for each period suggested that Red-throated diver were mainly seen in the control site, relative to the LID sites following construction. This suggests that, in agreement with data from aerial surveys (HiDef, 2012), there may have been avoidance of the wind farms by this species and displacement to the control area. The lack of data in the control site, prior to construction, hampers this conclusion as it is not known whether this area was already preferred by Red-throated diver or not. Red-throated diver are known to be sensitive to disturbance (see above) which would correspond with the above observations.

Table 49 provides a brief summary of the findings of the Jacob's selectivity index. These analyses demonstrated some of the spatial variations in the abundance of birds in the boat-based survey area during the construction and operation of the wind farms. **Of the two sites**, the Lynn site and buffer was clearly favoured by a number of species (skua species, Kittiwake, Sandwich tern, and Guillemot) throughout the monitoring. These species were generally those which had exhibited attraction to the LID sites during the construction phase and the third year of operation. The Inner Dowsing site and buffer seemed to be used far less in comparison. Common gull, Herring gull and Great black-backed gull all showed some form of preference for the control site and buffer, either throughout the construction and post-construction surveys or during some of the monitoring phases. These species did not appear to demonstrate any particular response to the construction and operation of the LID wind farms and their preference for the control site habitat could explain this.

Table 49: Summary of key findings based on Jacob's selectivity index results.

Species	Key findings
Red-throated diver	The Lynn site and buffer seemed to be favoured over the Inner Dowsing site and buffer. However there were variations in the relative use of the control site and the Lynn site (with buffers) throughout the monitoring, with the control site appearing to be favoured in the latter study periods. The species was found in low numbers and therefore results should be treated with caution.
Fulmar	The control site and buffer was consistently preferred over the LID sites and buffers throughout the construction and operational monitoring. However, Fulmar were seen in relatively low numbers and the results should be treated with caution.
Gannet	The control site and buffer generally harboured relatively higher numbers of Gannet throughout the construction and operational monitoring compared to the LID sites and buffers but appeared to favour the Lynn site and buffer during the third year of operation.
Skua species	Skua species favoured the Lynn site and buffer during the construction phase and first year of operation compared to the Inner Dowsing site and buffer and control area and buffer. In the second year of operation the control site appeared favoured and in the third year there did not seem to be any selection for a particular area. Low numbers of bird observations means that these results should be treated with caution.
Kittiwake	The Lynn site and buffer was consistently favoured throughout the construction and operational phases. There was some evidence for the periodical avoidance of the control site and buffer.
Common gull	This species was seen in similar numbers throughout the boat-based survey area during construction and operational modelling. However, there did appear to be a slight preference for the control site during the course of the monitoring.
Lesser black-backed gull	In general, there was no evidence for the strong selection of any particular area during the construction and operational monitoring. However, the control site did appear to be favoured during the first year of operation.
Herring gull	The control site and buffer was always favoured, relative to the LID sites and buffers. The Lynn site seemed to be least favoured during the construction and operational monitoring.
Great black-backed gull	Great black-backed gull did not provide any evidence for strong selection of any of the survey areas, apart from during the second year of operation when the control site and buffer was favoured over the LID sites and buffers.
Sandwich tern	The Lynn site and buffer was generally favoured, relative to the Inner Dowsing and control sites (with buffers) throughout the construction and operational monitoring. However, there was no strong selection for any particular area in the first year of operational monitoring. The Inner Dowsing site

Species	Key findings
	seemed to be avoided in the second and third years of operation.
Common tern	The Lynn site and buffer was initially favoured (during construction) and then the control site was used relatively more during the second and third years of operation. The Inner Dowsing site appeared to be least favoured throughout the construction and operational monitoring. Low numbers of bird observations means that these results should be treated with caution.
Guillemot	The Lynn site and buffer was generally selected during the operational phases of monitoring. There did not appear to be any selection or avoidance of the Inner Dowsing site and buffer. However, the control site and buffer seemed to be used the least during the first and second years of operational monitoring.
Razorbill	Razorbill exhibited a strong selection for the control site and buffer during the operational monitoring. The species was not present in the LID sites and buffers during the first and second years of operation. Low numbers of bird observations means that these results should be treated with caution.

There were few examples of what appeared to be significant changes in the use of the control site and LID sites (with respective buffers). However, **Red-throated diver, in agreement with the mean population data, seemed to favour the control site following construction of the wind farms.** Gannet also generally favoured the control site and buffer until the third year of operation when the Lynn site and buffer was used relatively more. Skua species also appeared to switch from the Lynn site to the control site during the second year of operation before switching back again in the third year of operation. Many of the species did not show any strong selection for a particular area.

Results of these analyses indicate that there could be important habitat affiliations, reflecting variations in prey availability, proximity to colonies and environmental conditions which could be connected with bathymetry, distance to coast, hydrodynamic variables and potentially benthic features.

In **addition to the potential displacement of Red-throated diver following construction,** three main trends in bird populations with respect to the construction and operation of the wind farms **were identified, these are** illustrated in stylised form in Figure 31 and described as follows:

1. Background variation in population estimates with no statistical changes in the use of the LID sites and buffers that could be linked to the construction and operation of the wind farms (Common gull, Herring gull, Great black-backed gull and Gannet);
2. An increase in birds during the construction phase followed by a return to baseline levels during the first two years of wind farm operation and an increase in population estimates in the third year of operation (Kittiwake, **skuas**, Guillemot and possibly Lesser black-backed gull) **(however low numbers of skua species reduce confidence in these results);** and
3. A general increase in population estimates in the wind farm site throughout construction and operation (Sandwich tern).

The analyses for Fulmar, skuas, Common tern and Razorbill were inconclusive due to low numbers of observations and the spread of data. However, skuas did appear to exhibit the second type of response as described above, and Razorbill showed similar but far less pronounced results to Guillemot.

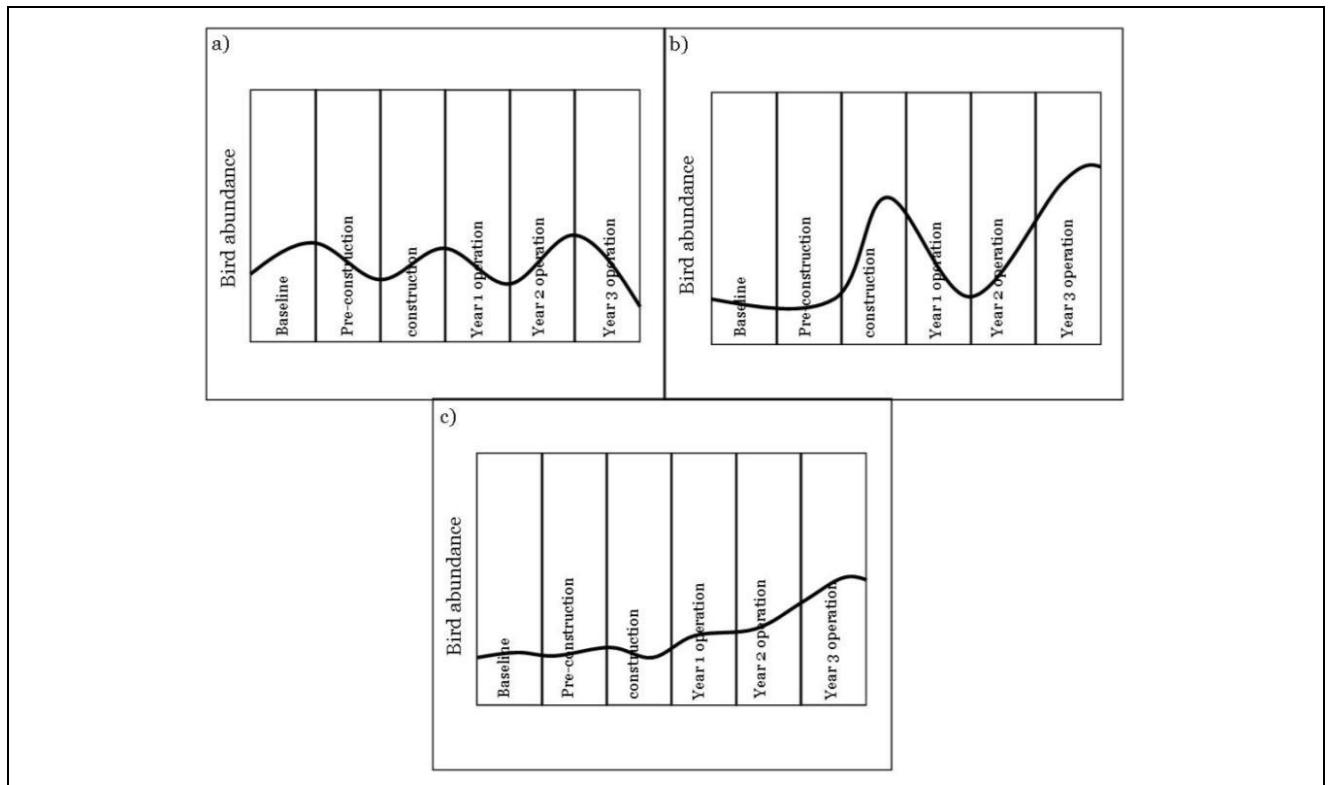


Figure 31: Stylised representation of the three main trends in population estimates, for the key bird species in this report, in the LID wind farm sites and buffers where: a) no response with background variation, b) increase during construction and the third year of operation and c) an increase during construction and operation.

Figure 32, Figure 33 and Figure 34 provide species-specific examples of these key trends within peak population estimates of Common gull, Guillemot and Sandwich tern, by monitoring phase and season respectively. Peak populations of Common gull within the LID sites and buffers were generally larger during the winter (Figure 32). Numbers were variable throughout the monitoring phases with no obvious trends associated with the construction and operation of the wind farms (Figure 32). Guillemot were generally present in peak numbers during the autumn passage period (Figure 33). This species showed an obvious increase in peak populations in the LID sites during the construction phase, followed by a decrease in Years 1 and 2 of operation and another increase in Year 3 of operation. Sandwich tern were also mainly present in the LID sites during the autumn passage period but showed an increase in the peak abundance throughout the monitoring phases in the Lynn site (Figure 34).

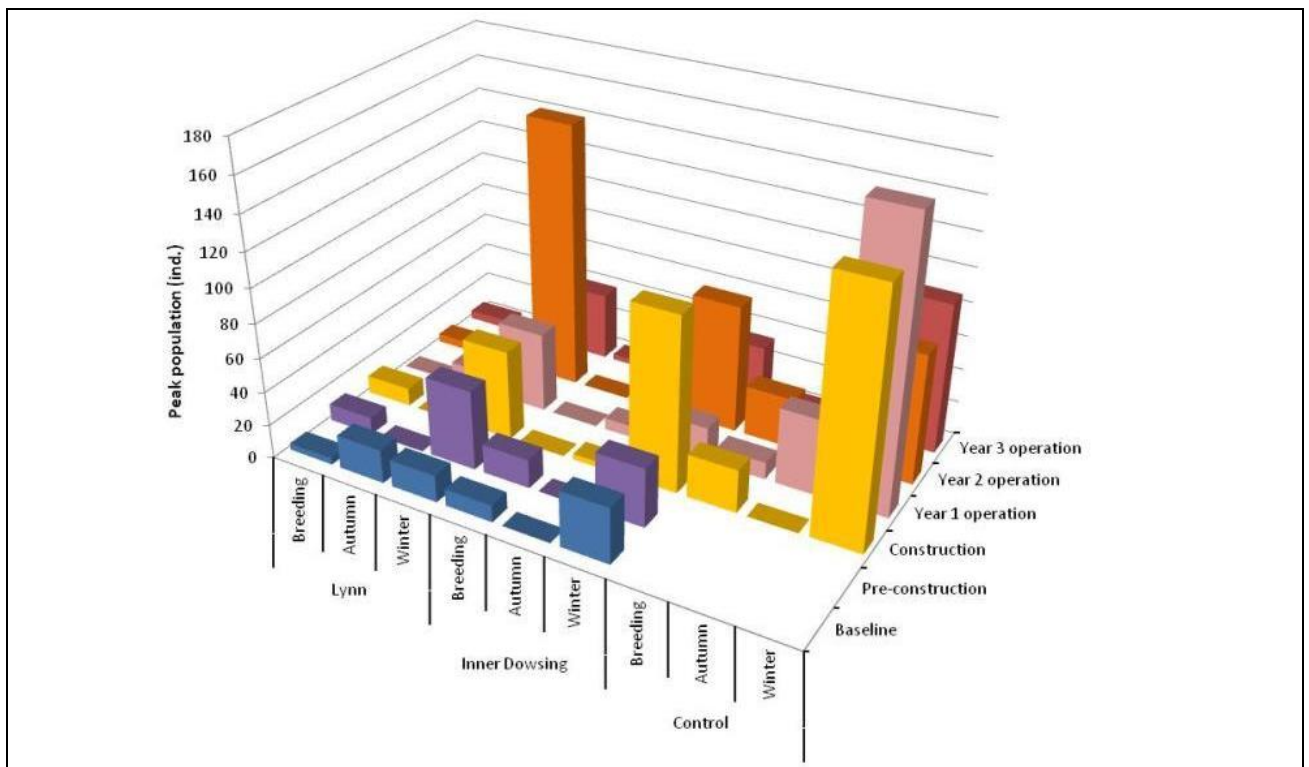


Figure 32: Peak population estimates for Common gull in the LID wind farms and the control site shown by specific seasons and during each monitoring phase. Note the exclusion of data for the control site during the baseline and pre-construction phases due to the differences in the control site surveyed before construction began.

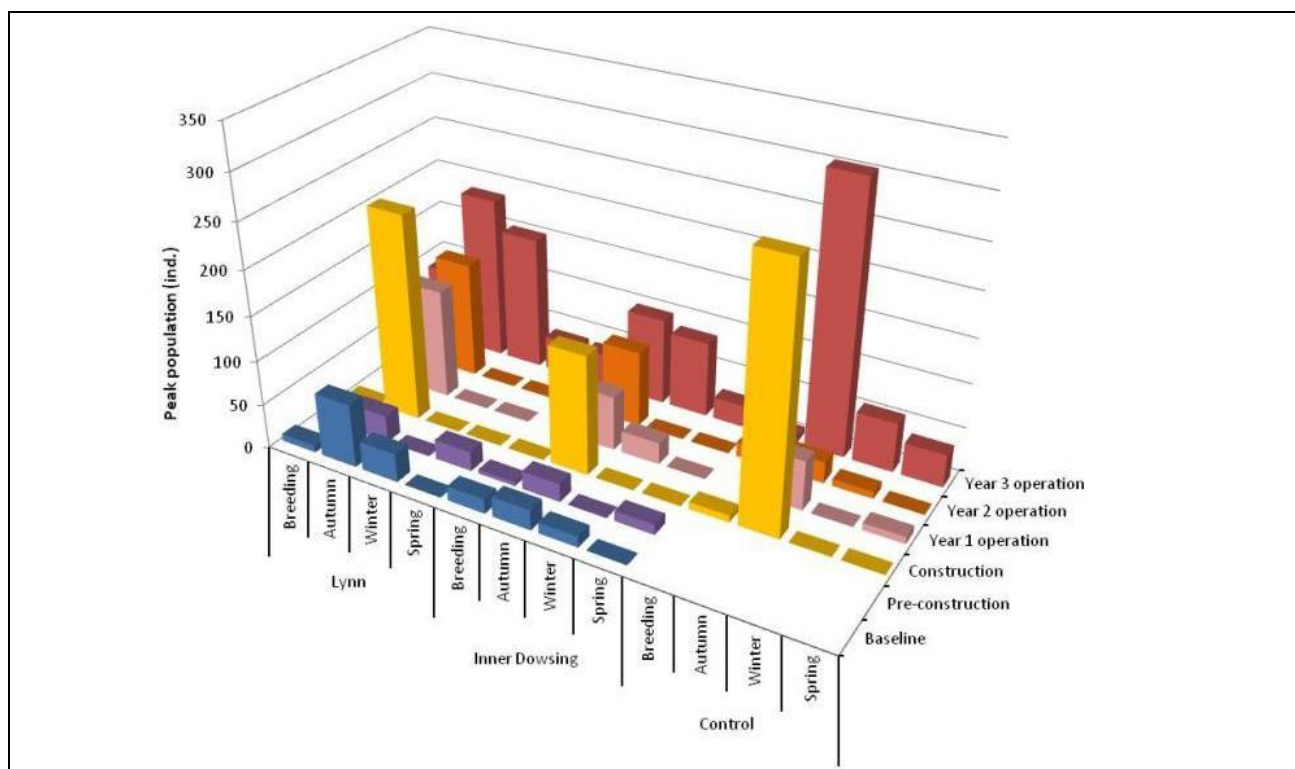


Figure 33: Peak population estimates for Guillemot in the LID wind farms and the control site shown by specific seasons and during each monitoring phase. Note the exclusion of data for the control site during the baseline and pre-construction phases due to the differences in the control site surveyed before construction began.

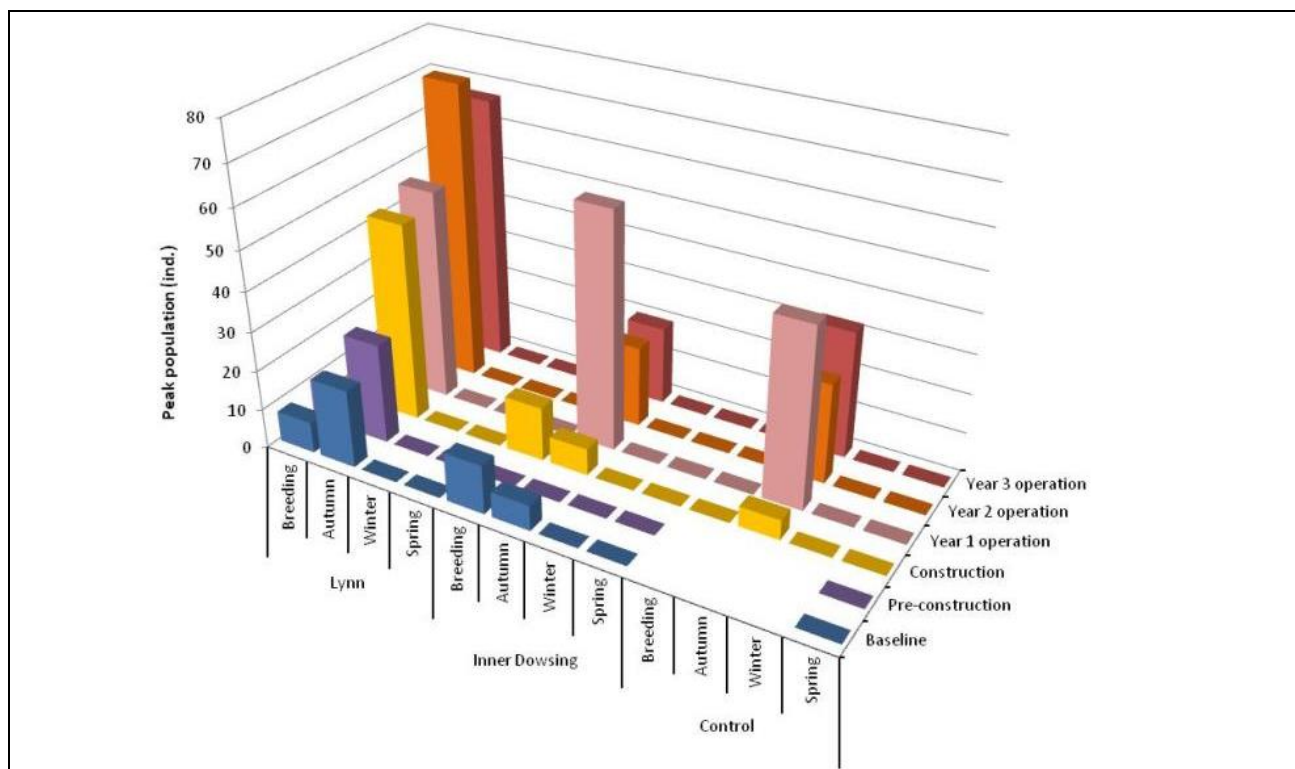


Figure 34: Peak population estimates for Sandwich tern in the LID wind farms and the control site shown by specific seasons and during each monitoring phase. Note the exclusion of data for the control site during the baseline and pre-construction phases due to the differences in the control site surveyed before construction began.

4.9.3.4 Discussion

Much of this discussion remains speculative, due to the lack of supporting evidence associated with the observed trends, but is based on expert knowledge, behavioural observations and insights from published literature. Trends in the populations of birds in any area may reflect annual changes in productivity at often distant breeding colonies, as well as local abundance of key resources, principally habitat and prey populations. There was some evidence from the Jacob's selectivity index results (Table 49) and distribution maps that some species naturally favoured particular parts of the survey area, irrespective of the presence of the wind farms. For example, skuas, Kittiwake, Sandwich tern, and Guillemot all appeared to prefer the Lynn site and buffer (Appendix 7.2). Such a preference might be explained by the deepening bathymetry in the southeast corner, which may conceivably provide greater prey availability of fish (including sprat, herring and mackerel) using the deep channel through the mouth of The Wash. Digital aerial surveys also suggested that the mouth of The Wash was an important area for some bird species such as auks. Conversely, the Inner Dowsing site and buffer seemed to be used far less by birds in general. **Red-throated diver were more abundant in the control area relative to the wind farm sites following construction of the LID wind farms.** Gannet were **also** found to generally favour the control site and buffer until the third year of operation when the Lynn site and buffer was used comparatively more. Skuas appeared to switch from the Lynn site to the control site during the second year of operation, before switching back again in the third year of operation.

With no detailed information on habitat affiliations (e.g. with specific water depths or distance from coast), there was no possibility of accounting for any effect **these** may have on the abundance and distribution of birds within the analyses. Therefore, it was possible that the response of a particular species to the wind farms may be masked, especially when the response may be a complex mixture of negative (disturbance and displacement) and positive (attraction) elements driven by different sensitivities and the perception of risk. **However, despite the data limitations and lack of significant model results, Red-throated diver did appear to provide some evidence of disturbance and potentially displacement following the construction of the LID sites. Mean population estimates were much higher in the control site, relative to the LID sites following construction, with very few birds being sighted in the wind farms and their respective buffers. The lack of data for the control site prior to the construction of the wind farm sites limits the evaluation of displacement to the control site, as birds may have had a preference for this area irrespective of the construction of the wind farms.**

The potential decrease in use of the wind farm sites by Red-throated diver may have implications for the species, limiting available foraging area within The Wash. Given the proximity of the control site to the LID sites, similarities in bathymetry, and taking into account further available habitat nearby, there is no reason to suspect exclusions from the LID sites will have a significant impact on the species unless prey resources are substantially different. The LID sites only harboured relatively low numbers of Red-throated divers prior to construction, further suggesting that the impacts of displacement would be limited in terms of the wider population.

Modelling did however suggest statistically significant differences in the population sizes for a number of species that was consistent with some effect of construction and operation. Kittiwake, Guillemot and skuas (**despite the low numbers of observations**) showed a significant increase in abundance during the construction phase, followed by a return to baseline levels during the first two years of wind farm operation and an increase in the third year of operation.

Given the differences in the ecology of these species, it seems as though these may have responded to different drivers. During construction, the observation of Kittiwakes using turbine bases as resting/roosting sites (and perhaps as lookouts for foraging opportunities) suggests this may have been an important mechanism (Appendix 7.2). Great cormorant *Phalacrocorax carbo* has also been shown to preferentially use wind farms because of the presence of resting sites on turbine bases both at Egmond aan Zee (Lindeboom *et al.*, 2011) and Robin Rigg (Richard Walls, Natural Power *pers comm.*). The presence of skuas, particularly Arctic skua, a facultative kleptoparasite upon other seabirds, was in turn most likely linked to the presence of Kittiwake and terns (see below). Both fish-eating Guillemot and Kittiwakes, and thus skuas, may also have responded to increased foraging opportunities resulting from piling activity as fish are affected. However, there is a lack of **hard** evidence to support this and any effects of piling on fish is likely to be short lived. Nevertheless, observations of foraging birds were generally more numerous during the construction phase in the LID sites, suggesting some influence of prey availability (Appendix 7.2).

During operation, the reductions in populations of these species (**Red-throated diver**, skuas, Kittiwake and Guillemot) may accord with an increased perception of risk associated with the presence of rotating turbine blades and / or a reduction in the attractive influences associated with construction. Although low-flying auks are not at risk of collision, a negative reaction to unthreatening objects has previously been demonstrated for other species such as Common eiders *Somateria mollissima*, which even avoid standing towers when in flight (Larsen & Guillemette, 2007). Habituation of even easily-disturbed species such as Common scoter *Melanitta nigra* is then known to occur as a wind farm ages (Petersen & Fox, 2007). The increase in Kittiwake, skuas and Guillemot in the third year of operation at LID points to such acclimatisation.

Attraction of birds later in the life of the wind farms (third year of operation) may also be related to potential increases in prey abundance around the turbine bases (reef effects – Linley *et al.*, 2007) or, at LID, could even be linked to the construction of the adjacent Lincs wind farm site. A reef effect, increasing the presence of small shoaling fish around turbine bases offers the best explanation for the continued increase in populations of post-breeding Sandwich tern throughout the operational phase. This continued an initial increase during construction, perhaps linked to disturbance of fish during pile-driving as implied for other species (see above). **There is no strong evidence for the presence of reef effects or impacts of pile-driving in relation to LID given the lack of dedicated studies.**

The population-scale implications of these trends for the key species, in terms of the cumulative effects upon individual fitness and thus survival and subsequent breeding performance, are likely to be very limited given the relatively small numbers of birds found within the sites and **that only Red-throated diver showed signs of disturbance or displacement. For those species where the analyses were inconclusive, due to the low numbers of observations and distribution of the data, the impacts remain uncertain. However, both the suggested avoidance and attraction responses in relation to** the use of the LID sites could influence the prospect of individual collision risk within a species-specific context, dependent on the proportion of time spent flying at risk height.

Results of the benthic ecology surveys (EGS Ltd, 2012) suggested that there was little evidence of significant change in the benthic habitat and communities over the monitoring period which might influence birds through prey availability. No species (e.g. Common scoter) that could make use of benthic fauna, such as mussels, were present in any number in the survey area and therefore there was no anticipation that there would be any correlations between benthic data and the distributions of birds illustrated in the dataset.

Section 4.9.7 and Section 4.9.8 below further consider the results of these boat-based bird surveys in combination with the results from the other ornithological surveys, in order to provide conclusions in relation to the ornithological interest of the LID sites as a whole.

4.9.4 Pseudo-Static Observations

4.9.4.1 FEPA Requirements

The FEPA requirements for 'pseudo-static' observations are set out in Table 50 below.

Table 50: FEPA Requirements – Pseudo-Static Observations.

Ref	FEPA Condition
Annex 2	3 sea based 'pseudo-static' stations coupled with 1 terrestrial station. Sea based stations should be arranged such that one is sited between the development site and shore (3-3.5km from the coast) another in the development site and another east of the development site. The observations at each station should be of 30 minutes duration. It is important that all four counts should be as close in time as possible to aid comparability. Static observations at each station should be undertaken on each boat survey in August, September, October, February, March and April. The terrestrial observations should occur at the same time as the boat surveys. Further terrestrial 'pseudo-static' observations will be conducted as part of the during and post construction monitoring of autumn migration (4 surveys in September +/- October) and 2 surveys in February +/- March during key sea duck migration times.

Pseudo-Static Observations (observations from 'stationary' vessels and/or land based vantage points) were carried out during the pre-construction phase at LID, to detect divers, seaducks and SPA migrants (ESS, 2004), however such observations were not conducted during the construction or post-construction phases. The following section therefore reviews the prevalence and value of carrying out pseudo-static observations for offshore wind farm projects to support why a decision was made not to continue these observations at LID. The construction and post-construction boat-based bird survey programme, using standard boat-based bird surveys only (as also carried out pre-construction) was proposed to the Licensing Authority by email dated 20/02/07 (Appendix 10; ref 10.5), with the construction and post-construction survey programmes agreed in meetings between the Licence Holder and NE on 02/05/07, 28/04/09 and 28/04/10 (Appendix 10; ref 10.11; 10.14; 10.19).

4.9.4.2 Prevalence and Value of 'Pseudo-Static' Observations

The LID FEPA Licences require observations from three sea based 'pseudo-static' stations coupled with one terrestrial station in order to test Objective 1 of these Licences (Table 38): "Assess changes in usage of area by feeding birds and birds on passage". The aim of this requirement was to provide information on the passage of Special Protection Area (SPA) birds between the coast to the development sites and their zone of influence.

During the pre-construction boat-based bird surveys, the three sea based stations were arranged such that one was sited between each development site and the shore (3-3.5 km from the coast), another in the development site, and another east of the development site. These observations were coupled with data collected from one of two terrestrial stations, either Gibraltar Point or Chapel Point (ESS, 2004). These surveys took place in August, September, October and November 2003, March and April 2004, December 2004, and February and March 2005, and were intended to cover the main passage periods for SPA migrants (ESS, 2004; ESS, 2005).

It was considered that 30 minutes of pseudo-static observations per boat survey at four locations was of little benefit due to lack of time to calculate meaningful passage rates (ESS, 2004). It was suggested that an additional observer was deployed on the boat-based bird surveys, which would be more efficient and effective in addressing the concerns of the then English Nature, than the pseudo-static and corresponding land based surveys (ESS, 2004). Therefore in the LID pre-construction monitoring report (CREL, 2005), it was recommended that rather than carrying out further pseudo-static observations, a second observer was employed on the boat-based bird surveys, to focus on the passage of migrants (ESS, 2004). It should be noted that a minimum of two surveyors and a dedicated data recorder were used on the LID construction and post-construction surveys carried out by ECON (ECON, 2012b).

In a review of UK Round 1 offshore wind farm monitoring data associated with FEPA licence conditions (Budgey and Ormston, 2009), the Lynn and Inner Dowsing projects were the only sites out of ten where such pseudo-static surveys took place. The procedure remains uncommon at offshore wind farms, including in the UK. However, there are more recent examples of pilot pseudo-static surveys being undertaken, and the conclusions and value of these studies are discussed below.

Pilot vantage point surveys were carried out at Kentish Flats Offshore Wind Farm in 2008/2009, for 30 minutes on each boat survey, to observe Red-throated diver activity in the vicinity of the wind farm. The aim of the surveys was to determine whether it might be a useful technique to provide more information on how divers were behaving around the wind farm and understand better any changes in numbers observed (Percival, 2009). The surveys recorded a total of seven diver flights in four hours of observations, only one of which involved a bird flying through the wind farm. It was concluded that with the recorded level of bird activity it would require a major investment of time to obtain a robust dataset, and given that most of the birds that were observed simply avoided flying in proximity to the wind turbines, it was considered unlikely that it would add much to the knowledge of the interaction of divers and the wind farm. No further surveys were carried out in the subsequent year for these reasons (Percival, 2010).

Vantage point surveys from a pseudo-stationary vessel were carried out in June and July 2011 within an operational area of the Greater Gabbard Offshore Wind Farm, in order to ground-truth collision risk modelling calculations for gulls for the adjacent Galloper Wind Farm Environmental Impact Assessment, and quantify and characterise the flight activity of Lesser black-backed gulls within the rotor swept area of an operational wind farm (GWFL, 2011).

During the four surveys, flight activity was relatively low, with a total of 190 flights of all species recorded over the 72hr (2 surveyors x 36hr) survey period. No collisions were recorded, and due to the relatively small sample size it was not possible to accurately estimate avoidance rates of gulls using this dataset. Data were however obtained on flux rate through this proportion of the wind farm which could be compared to average pre-construction data during the breeding season. Average flock sizes could also be compared which may be related to changes in fishery activities within an operational wind farm. Further surveys were not undertaken due to the timeframe of the Galloper project and high costs of obtaining a robust dataset that could be used to accurately calculate collision or avoidance rates.

At the Thorntonbank Offshore Wind Farm in Belgium, measurements of flux rates were made of migratory birds from a stationary ship at four fixed positions within the wind farm and a control area in spring and autumn 2008 (Vanermen and Stienen, 2009). Surveys lasted between two and four hours at each point. Most observations were of gulls, in particular Lesser black-backed gull with an estimated flux rate of over 1,000 birds per hour during spring migration. It was however concluded that fluxes of gulls may well have been overestimated due to attraction to the ship and that radar research could give a more comprehensive insight into the bird flux through the wind farm area (including large-scale avoidance), although this should be supported by visual flux counts from the wind farm's "transformator" platform, or the wind turbines themselves.

4.9.4.3 Conclusions

In summary, pseudo-static observation studies are not a common method of obtaining bird data for offshore wind farms, mainly due to a combination of the limited survey area and the high survey effort and costs associated with obtaining a sufficiently large dataset, in comparison with standard boat-based surveys.

Although this type of survey has clear limitations, this technique can be used to ground-truth radar observations, by identifying samples of birds to a species level, as well as providing some information on flight behaviour, and information on changes in flux rates and flock sizes of abundant species in operational wind farms. However, the radar surveys that have been carried out at LID (see Section 4.9.6) provide a more informative dataset, with higher temporal and spatial coverage than visual boat-based observations, for gathering information on bird activity within the vicinity of the wind farm.

It was recommended in the LID pre-construction report that future efforts focused on improving the efficiency of the standard boat-based bird surveys rather than continuing with pseudo-static observations, which was taken forward during the construction and post-construction phases with the use of three surveyors on the boat-based bird surveys.

4.9.5 State of the art techniques for monitoring collision impacts

4.9.5.1 FEPA Requirements

The FEPA requirements for monitoring collision impacts are set out in Table 51 below. The following section provides an update on the status of such techniques for monitoring collision impacts at offshore wind farms and concludes with what techniques have been used at LID.

Table 51: FEPA Requirements – Collision Monitoring Techniques.

Ref	FEPA Condition
Annex 2	Update collision risk assessment using the year of pre-construction monitoring data. Prior to construction, the Licence Holder will undertake a study into use of state of the art techniques for monitoring collision impact, including radar, infrared technology, camera and impact noise monitoring. Post-construction, subject to the results of the study described above, the Licence Holder to support a project to further assess the equipment or install or maintain the equipment on site for a period of three years and report on the findings.

4.9.5.2 Overview of Techniques for Monitoring Collisions

To date, virtually no data are available on actual collisions with offshore turbines. It is not clear whether the collision rates are likely to be in any way similar to those observed at onshore wind farms, due to the greater difficulties in obtaining evidence of collisions (e.g. corpses are quickly displaced from the turbine by waves).

According to Collier *et al.*, (2011a) the main requirements of remote systems should be the ability to:

- Verify that a collision actually occurred;
- Determine which species, or species group was involved;
- Operate during daytime and night time periods;
- Collect data from multiple turbines, to avoid biased results;
- Collect data from across the rotor area (as opposed to one small part of the rotor blade);
- Protect the equipment from weather conditions and salt water; and
- Access remote systems located offshore.

In addition, if the requirement is to establish the collision risk of species offshore rather than only the collision rate, it is necessary to not only measure the rate of collisions, but also the flight intensity of species through the wind farm.

Collier *et al.*, (2011a) compiled a summary review of the potential methods for monitoring collisions of birds with wind turbines offshore. The study identified three main methods for recording collisions: (1) sensors (contact and non-contact); (2) imaging; and (3) radar.

1. It was concluded by Pandey *et al.*, (2006) that non-contact sensors, particularly acoustic sensors (microphones), are better at recording collisions than contact sensors, as they are less sensitive to vibrations, more cost-effective and do not require hardware to be mounted on rotors;
2. Imaging cameras can record either still images or videos to confirm collisions with turbines. To cover the hours of darkness, infrared and thermal imaging cameras can be used, although both suffer from poorer resolution than visible light cameras; and
3. Radar has the potential to collect a large amount of data over a large temporal and spatial scale. Surveillance radar has been the most common radar type used for studies at offshore wind farms (Kalhert *et al.*, 2004; Desholm *et al.*, 2006; Krijgsveld *et al.*, 2010). In general, radars can detect flying birds at a range of between up to 10 km, to up to 200 km (Desholm *et al.*, 2006; Walls *et al.*, 2009). Radar can operate during periods of darkness, although detection levels may vary depending on weather conditions. A disadvantage is that it is often difficult to interpret radar data due to false echoes (clutter), and under certain circumstances the radar may fail to detect, or lose a flock of birds (e.g. flocks flying close to the sea surface or through or behind existing wind turbines). In addition, tracks cannot often be identified to species, or sometimes even species-group, and the number of individuals within a track can often not be assessed.

4.9.5.3 Potential detection systems

Systems known to have been tested under field conditions or have been used in wind farms were presented by Collier *et al.*, (2011a). These have been divided into two groups: (i) those that allow the direct detection of collision events, incorporating some form of trigger mechanism that is activated during a collision event, and (ii) those that monitor bird activity close to the turbine so that collisions may be recorded and monitored indirectly. This latter system may be more suited to the assessment of micro-avoidance rates and bird activity close to the turbines rather than recording actual collisions.

4.9.5.4 Advantages and Disadvantages of Collision Monitoring Systems

The two systems designed to directly measure collisions of birds with wind turbines (as opposed to indirectly by recording flight activity in the airspace around them) that were reviewed by Collier *et al.*, (2011a and 2011b) are WT-Bird and ID Stat (Table 52). Both of these are subject to ongoing testing. According to Collier *et al.*, (2011a), WT-Bird has a number of advantages over ID Stat for use in the offshore environment, with the main one being that infrared cameras provide validation as to whether the source of the collision trigger was a bird, as well as possible identification of the species concerned. Further ongoing testing is however required before this system could be operational on offshore turbines, particularly for species identification during periods of darkness. Several systems currently in use are capable of monitoring bird movements close to the turbines, each of which has its own advantages and disadvantages (see Table 52).

Table 52: Collision Monitoring / Detection Systems – advantages and disadvantages (from Collier et al. 2011a).

System	Advantages	Disadvantages
WT-Bird	- Collisions can be recorded both day and night. - Species identification during daylight possible. - Field tests onshore have been performed with satisfactory results.	- Image quality currently insufficient to enable species identification during darkness. - Suitability for offshore wind turbines unknown, although tests are currently in progress.
ID Stat	- Collision detection sensors, flags potential collision events. - Initial field tests for collision detection are promising.	- No visual verification of collision events with cameras, therefore of limited use offshore. - Signalling may have to be adapted if used in areas with poor phone network coverage, such as offshore.
TADS	- Infrared (thermal imaging) video camera enables detection during darkness and periods of poor visibility. - Operational in offshore areas.	- Limited field of view and resolution of infrared (thermal imaging) cameras. - High false-positive detection rate (99.7% records were not triggered by birds). - Detection events require human interpretation to conclude whether collision occurred and species involved.
DTBird	- Operational in wind farms, although currently only onshore. - May provide information on both micro-avoidance and collisions. - Resolution of visual light cameras likely to provide good images for use in species recognition.	- Detection of low-flying, small and fast flying birds and with a range of backgrounds uncertain. - Detection events require human interpretation to conclude whether collision occurred. - Only suitable for daytime use and limited use during periods of poor visibility.
VARS	- Operational in offshore areas. - Infrared (active infrared) video camera enables detection during darkness.	- Narrow field of view and detection range. - Rotors have to be excluded from the field of view to exclude false positives. This limits the use for detection of collisions. - Detection events require human interpretation to conclude if a collision possibly occurred.
Merlin Avian Radar	- Available and already being used at LID and other offshore wind farms. - Can provide information on micro avoidance both during day and night. - Coverage of multiple turbines.	- No verification of potential collision events. - Detection during precipitation or fog can be unreliable. - No information on species or absolute numbers.

4.9.5.5 Conclusions

In order to assess the level of collision related mortality of birds with wind turbines, direct measurement of collisions is required in order to verify indirect estimation of collision related mortality made using collision risk models. No system for the direct measurement of bird collisions with offshore wind turbines is currently commercially available.

Radar studies that have taken place at LID (see Section 4.9.6) during the construction and post-construction phases, whilst primarily for use in monitoring Pink-footed goose, have provided a beneficial method for observing bird avoidance behaviour of the wind farm. Although not a technique for monitoring actual collisions, this has used some of the most reliable technology that is available to date for determining flight activity around the wind turbines, both during daytime and night periods.

4.9.6 Bird Detection Radar

4.9.6.1 FEPA Requirements

The FEPA requirements for bird detection radar studies are set out in Table 53 below.

Table 53: FEPA Requirements – Bird Detection Radar Monitoring.

Ref	FEPA Condition
Annex 2	During Construction monitoring Land based radar located at Ingoldmells Point during October 2007, for a 30 day period, (or 4 weeks period if surveys can be carried out over the weekends) specifically to validate collision risk models for Pink Footed Geese migration. The licence holder and Natural England are to agree an adaptation of the technology used during the pre-construction monitoring to specifically monitor Pink Footed Geese numbers and flight lines, heights and patterns. Post construction monitoring The licence holder should conduct a radar study to calculate and quantify the avoidance behaviour of the windfarm site by Pink-Footed Geese. The detailed specification for the monitoring programme, including the location and extent of the reference site, timing and Geographic coverage of the radar study will be subject to separate written agreement with the Licensing Authority following consultation with Natural England 4 months prior to the proposed commencement of the monitoring work (see licence condition 9.10).

Bird detection radar surveys covering the LID sites have taken place during the construction (2007) and post-construction (2008-2010) phases, recording the flight patterns of migratory Pink-footed goose. The results of this monitoring were presented to the Licensing Authority in the LID Construction Monitoring Report (CREL, 2009), and the Year 1 and Year 2 Post-Construction Monitoring Reports (CREL, 2010; CREL, 2012). A detailed response to the MMO's comments on the radar study contained within the LID Year 2 Post-Construction Monitoring Report is provided in Appendix 7.3 of this report. The status of monitoring and history of reporting for this parameter is summarised in Table 54.

Table 54: Status of Monitoring – Bird detection radar surveys.

Phase	Requirement	Complete	LID Report
Pre-construction	N/A	N/A	N/A
During-construction	Survey	✓	Construction Monitoring Report (CREL, 2009)
Year 1 Post-Construction	Survey	✓	Construction Monitoring Report (CREL, 2009)
Year 2 Post-Construction	Survey	✓	Year 1 Post-Construction Monitoring Report (CREL, 2010)
Year 3 Post-Construction	Survey	✓	Year 2 Post-Construction Monitoring Report (CREL, 2012)
	Comparison with pre-construction predictions	✓	Year 3 Post-Construction Monitoring Report

All radar monitoring was completed for LID in autumn 2010, which represented the third post-construction survey for this monitoring parameter, as the first year of post-construction for this monitoring activity was defined as when the wind turbines were present and being tested (2008), rather than when fully operational (2009).

This section provides a summary of the results of bird detection radar monitoring to date at LID, in relation to Pink-footed goose.

4.9.6.2 Methods and Results

RPS coordinated the survey design and project management of four six week radar ornithology studies on the migration behaviour of Pink-footed geese along the coastline at Skegness, Lincolnshire; survey dates are provided in Table 55. The methods employed were arrived at in consultation with NE and reflected the best practice guidance on the use of remote techniques (Desholm *et al.*, 2004, Walls *et al.*, 2009b). Data collection was carried out by the Food and Environment Research Agency (FERA).

Table 55: Dates of radar ornithology studies at LID.

Year	Start date	End date
2007	01/10/2007	14/11/2007
2008	29/09/2008	09/11/2008
2009	21/09/2009	05/11/2009
2010	29/09/2010	12/11/2010

These studies are not complete surveys of the autumn migration, nor were they required to be. Nevertheless, the periods of surveillance are considered to have covered the majority of the autumn goose migratory movements in the region and provide a representative sample.

The study area is shown in Figure 35. S-band radar was used to provide two dimensional flight lines of goose skeins flying through the study area. Standard marine band radar sets were used with the output displayed and captured on a computer. This output was replicated to a second computer running Merlin bird detection software (<http://www.detect-inc.com>). Whilst Merlin has the ability to automatically identify, clean and store bird tracks, this functionality was not used for the goose surveys, as it was not designed to track goose or goose-like flocks and therefore does not operate adequately in this respect. Consequentially, Merlin was used to assist the radar ornithologists in identifying goose-like tracks by flagging likely targets based on a pre-assigned set of attributes only. Screen capture software was used to record the Merlin radar picture every few seconds. This permitted subsequent replay of the radar images during post-processing by experienced radar ornithologists who identified and digitised goose-like flocks manually.

Under certain circumstances the radar can fail to detect, or lose, a goose flock:

- Flocks flying close to the sea surface can become lost amongst the returns from the waves, and therefore disappear in this 'sea clutter' or background noise; and
- When the flock flies through or behind existing turbine arrays.

Additionally there may be occasions when false positives occur. For example a flock of curlews *Numenius arquata* can create a goose-like track.

Whilst cases of a radar tracked flight line stopping within a turbine array as described above, may initially seem alarming, they are in fact of no greater consequence than flights that extend beyond the turbine arrays. As long as a flock enters a turbine array, the Band model calculates the probability of collision, and such flocks contribute to the predicted mortality. The conditions necessary for an entire flock to be struck by a single turbine mean it is extremely unlikely to ever occur (the average recorded flock size is 73 birds). Radar shadow from solid objects or environmental conditions such as rain are the most likely cause of premature termination of flight lines.

The constant radar monitoring throughout the survey period was supplemented by visual observations of flock size and estimated height during the day time period (0900 – 1600 UTC). During the post-construction surveys heights were estimated in multiples of particular turbines from the perspective of the observer. Actual heights were calculated mathematically in post processing.

On completion of the LID post-construction monitoring requirements in 2010, the radar was configured to overlook the Lincs site. The power output and nominal range of six nautical miles remained identical to the previous study but the window within which radar returns are observed was extended approximately two nautical miles eastwards thus extending the range in this direction to eight nautical miles. Radar signals and returns are transmitted and received far beyond the nominal six nautical mile range so altering the viewing window allowed these returns to be recorded. This novel technique was judged to produce comparable detection rates to those obtained from the nominal range therefore data from this additional survey were included in the LID 2010 dataset where appropriate. The different areas covered by the two radar configurations are presented in Figure 35.

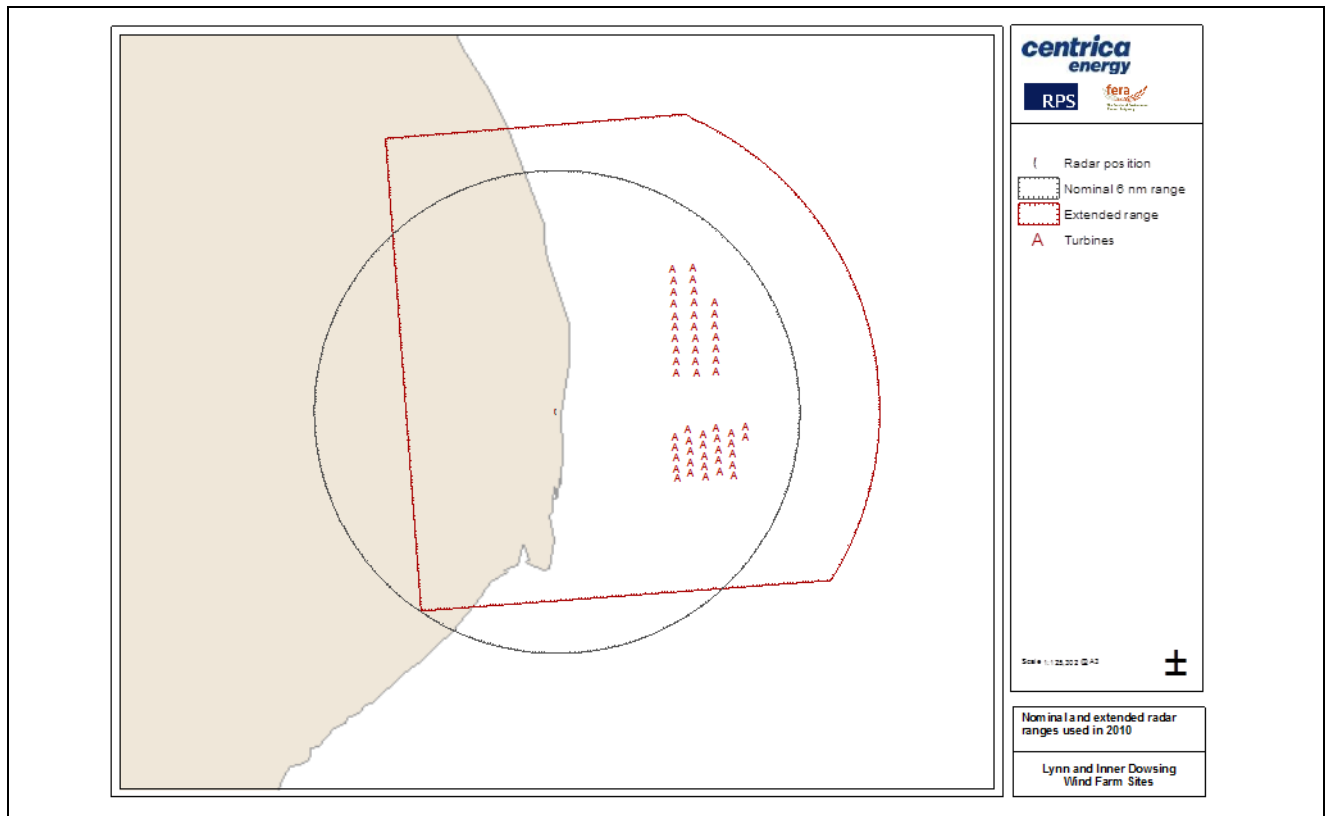


Figure 35: Nominal and extended radar ranges used during the 2010 survey. The nominal six-nautical mile range was used during all previous surveys of LID.

Collision risk analysis was carried out following the methodology of Scottish Natural Heritage (2005). Unknown values of height and flock size (e.g. at night) were assigned in proportion to, or given average values from the known data for each survey year respectively. Collision risk was calculated between the survey start and end dates only due to uncertainty regarding the start and end dates of the migration. This proviso notwithstanding, following comment from NE, results have now also been extrapolated to an assumed 60 day migration period to allow comparison between years – this is the first time that such extrapolated results are presented for LID.

The following rules were applied during the collision risk modelling:

- Any flight which entered a polygon describing the exterior boundary of the turbine towers buffered by 200 metres was included in the analysis; and
- Flights that were estimated to be at rotor height at any point were designated to be at collision risk height for this analysis (i.e. such flocks were considered to fly at rotor height throughout their observation).

The latter rule was applied as RPS have lower confidence in the accuracy of height estimations than of two dimensional positions.

In 2010, 285 flights were recorded of which 208 were observed by the field staff. A total of 13,110 geese were counted in 206 flocks (two were not counted). Thirty five flights occurred when the observers were present but were missed either due to poor visibility or a pulse of flights occurring at the same time. Goose flights occurred on 28 of 45 survey days and nine nights during the radar survey.

All flights detected by radar from 2007 to 2010 are presented in Figure 36, Figure 37, Figure 38 and Figure 39. The number and mean azimuth of Pink-footed goose flights at or below maximum turbine height (136 m or below) in 2010 is shown in Figure 40. Whilst variable in number between years, the pattern of flights across the radar window is consistent with that of previous post-construction years, whereby course changes in the vicinity of the turbines and clustering along the western edge of the arrays is displayed, suggestive of avoidance behaviour. The subset of these that were visually observed and were estimated to be at collision risk height during any part of their transit of the radar window in 2010 is shown in Figure 41.

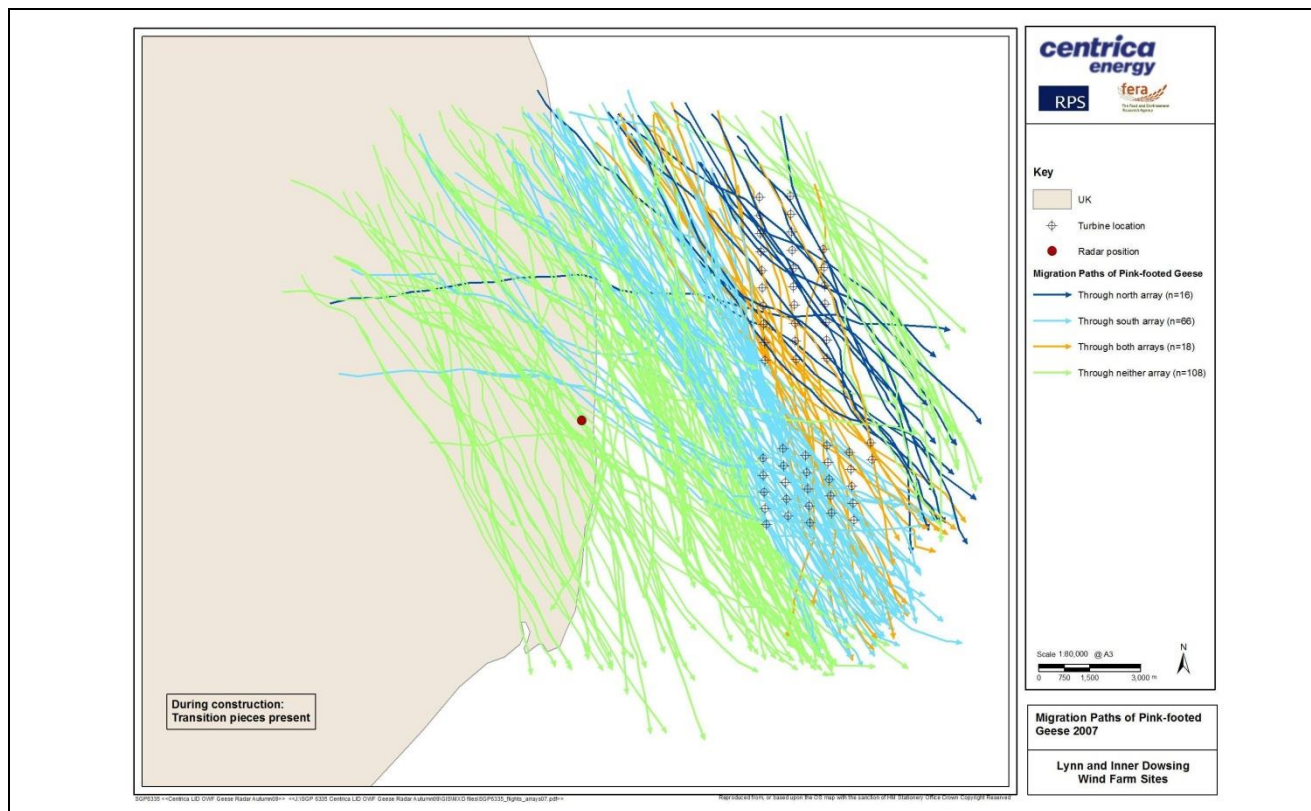


Figure 36: All goose skeins recorded by radar between 1st October – 14th November 2007 (note: Transition pieces present).

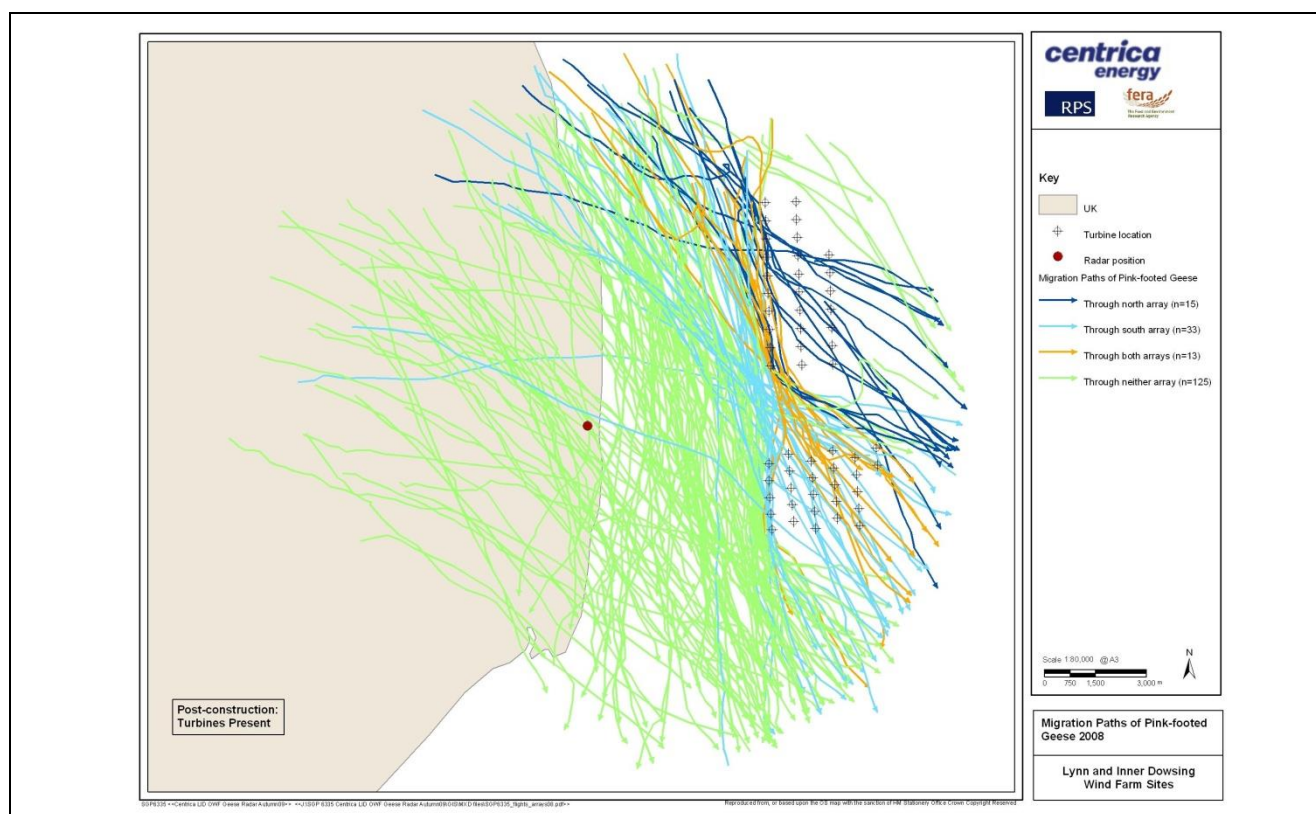


Figure 37: All goose skeins recorded by radar between 29th September and 9th November 2008.

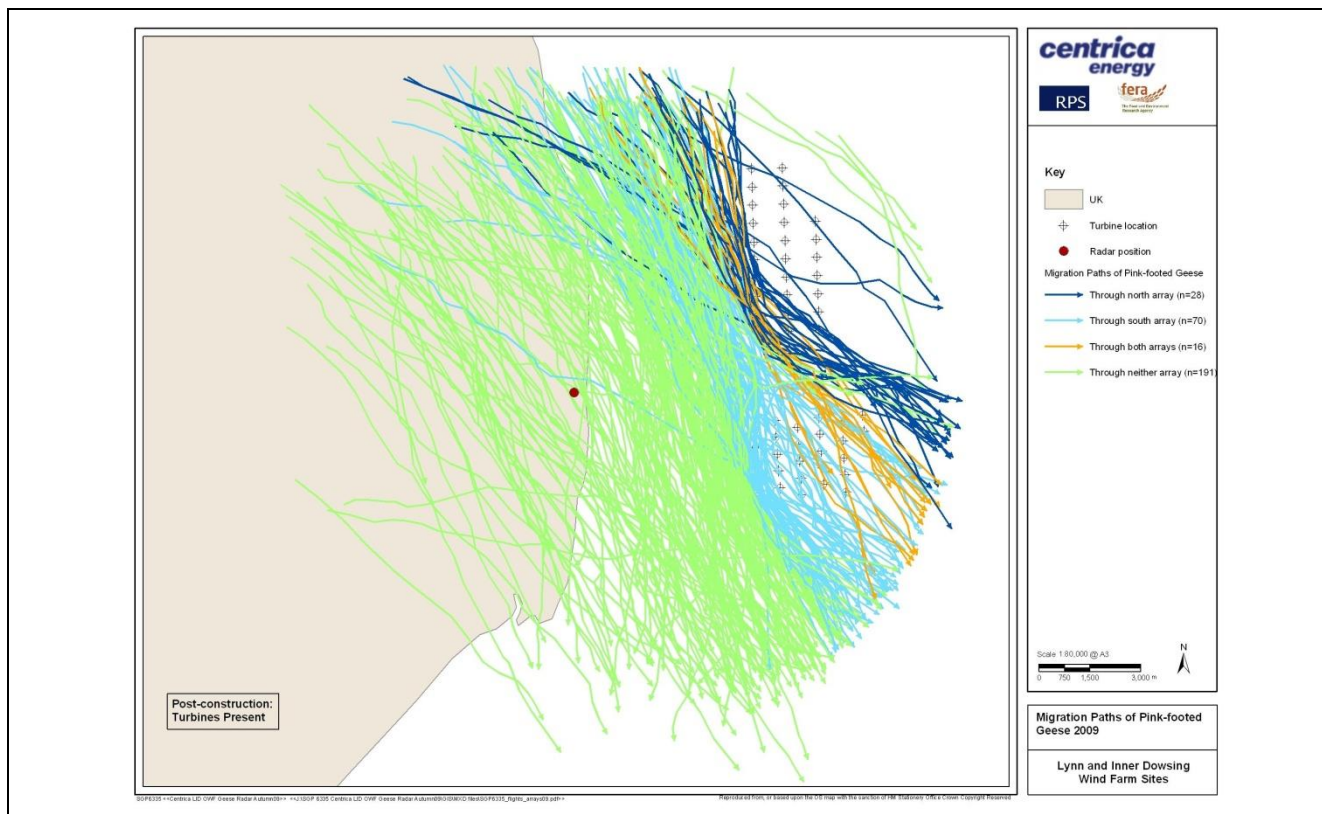


Figure 38: All goose skeins recorded offshore between 22nd September and 5th November 2009.

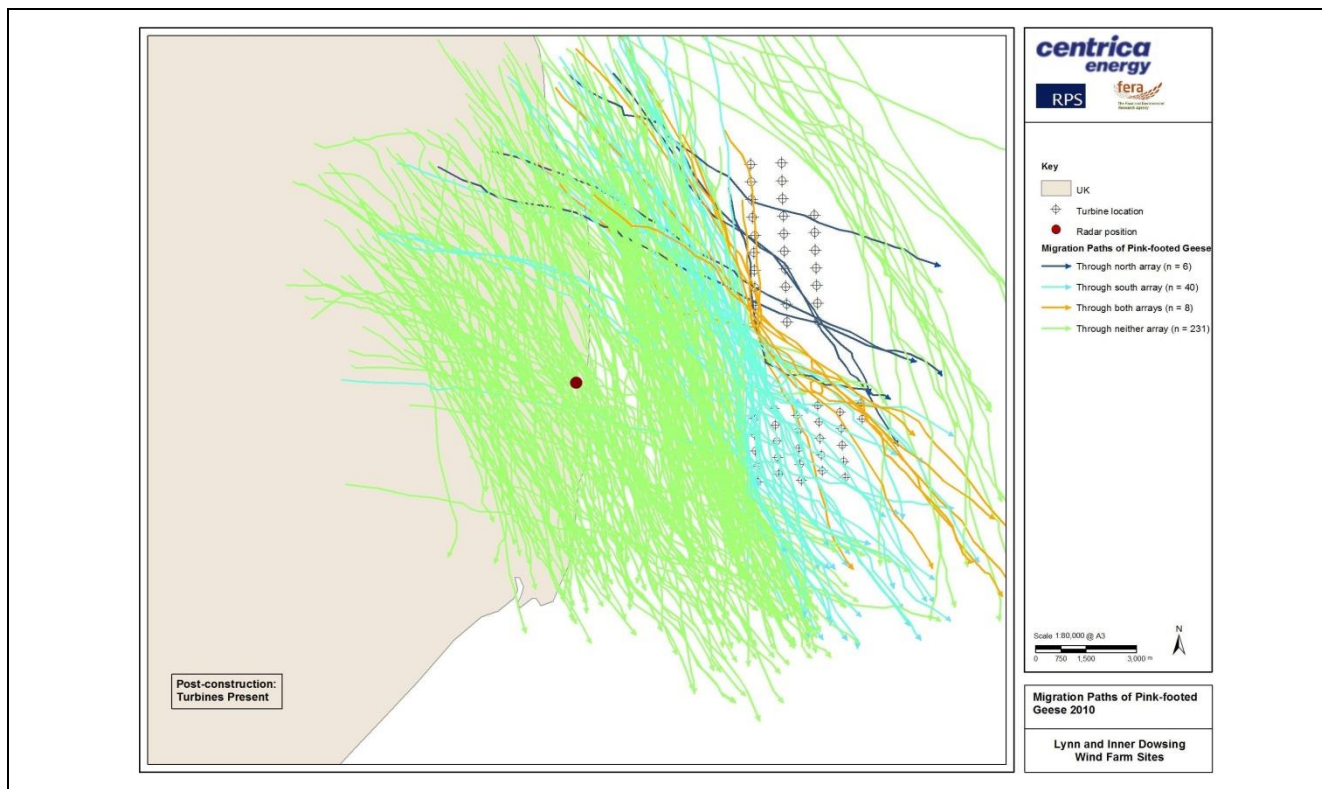


Figure 39: All goose skeins recorded offshore between 29th September and 12th November 2010. Note the change in radar range.

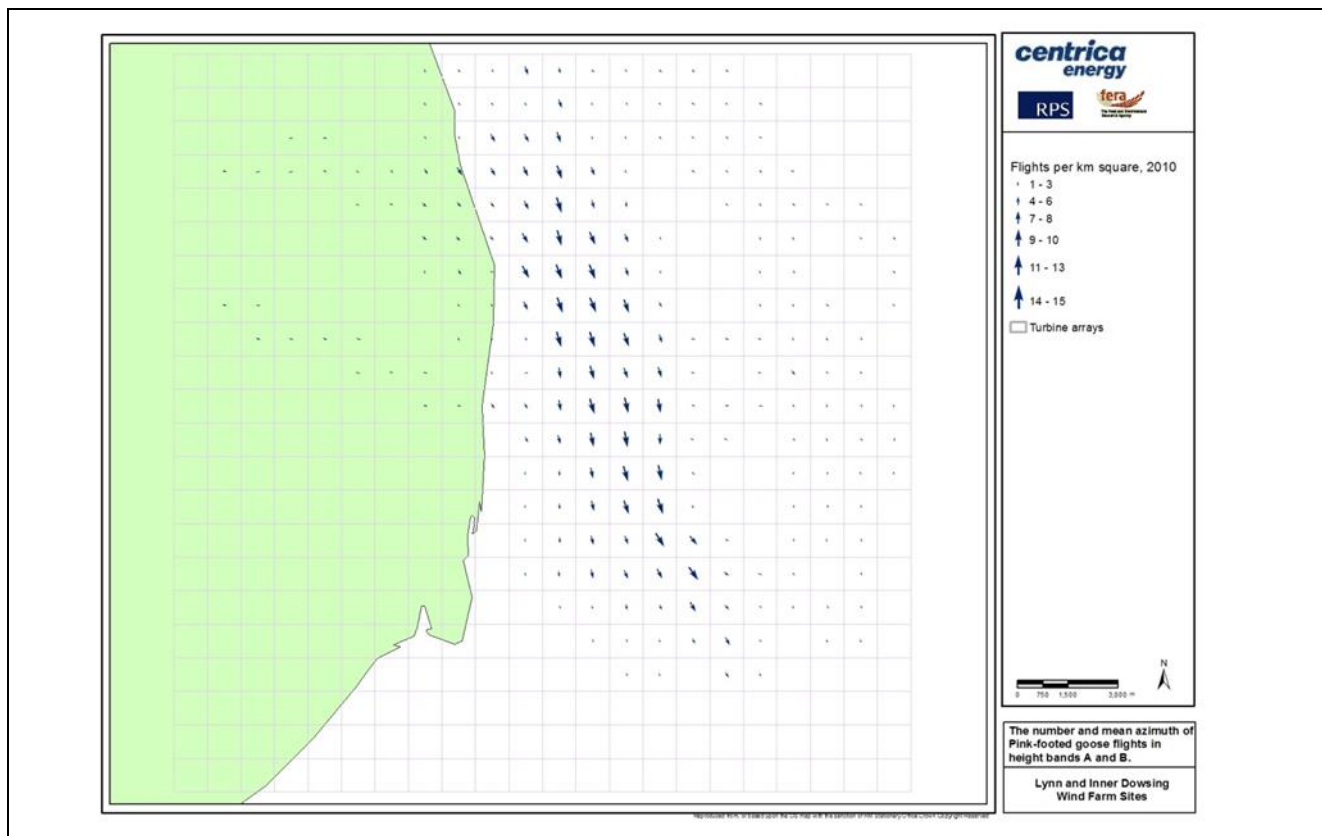


Figure 40: The number and mean azimuth of Pink-footed goose flights at or below maximum turbine height (136 m or below) in 2010. Arrow size is proportional to the number of flights.

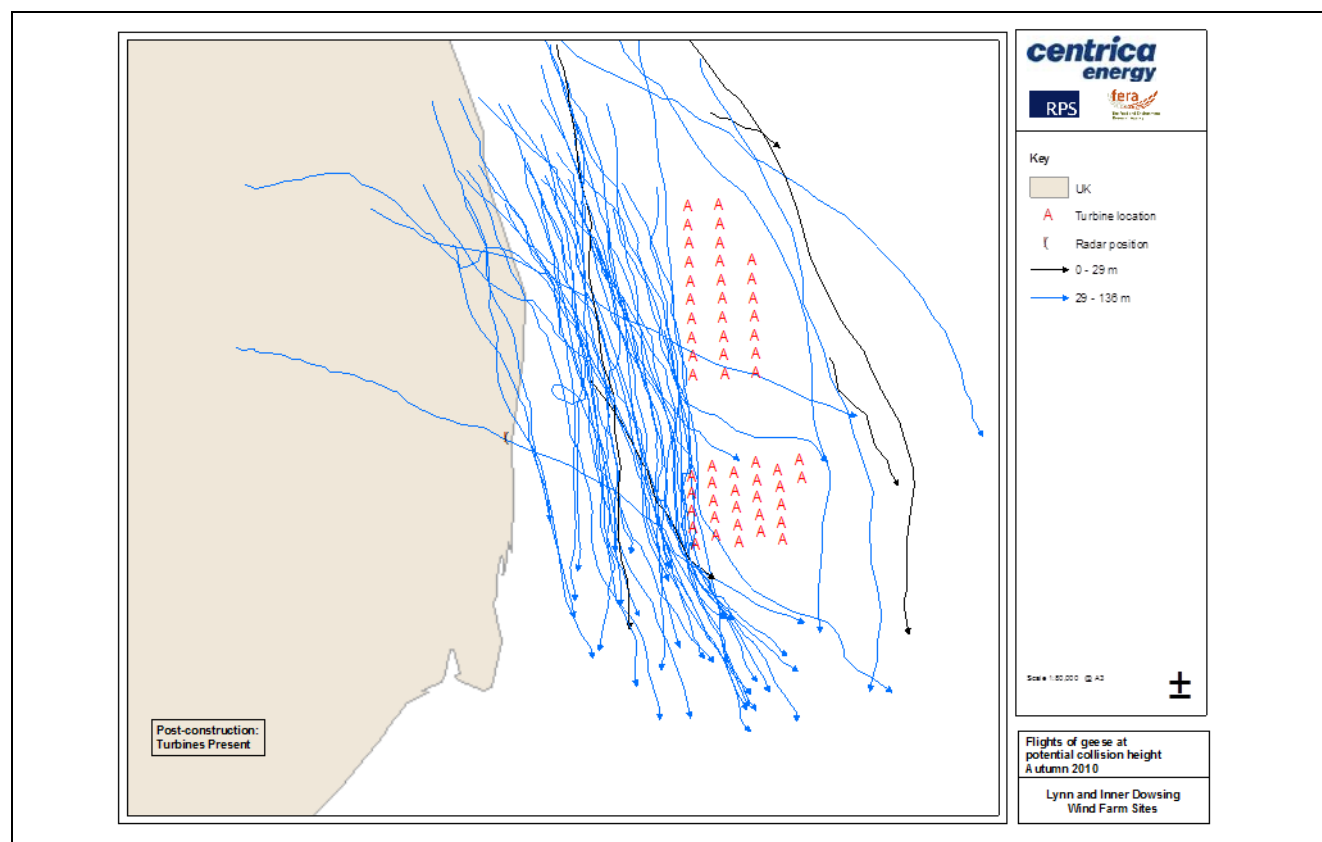


Figure 41: Observed goose flights at potential collision height, autumn 2010 (flight heights shown in key).

The estimated collision mortalities from all survey years for both turbine arrays combined are presented in Table 56. With a 99 % avoidance rate, and normalising the monitoring period to 60 days, there is an average post-construction mortality of one goose per autumn migration.

Table 56: Total predicted mortality of Pink-footed geese between the start and end dates of the radar survey for both arrays combined. Two avoidance rates (98 and 99 %) are presented; the onshore SNH recommended avoidance rate for Pink-footed goose is 99%.

Year	Predicted mortality during survey period (99 % avoidance rate)	Length of survey period (days)	Mortality normalised to 60 days (98 % avoidance)	Mortality normalised to 60 days (99 % avoidance)
2007	0.730	39	2.246	1.123
2008	0.497	42	1.420	0.710
2009	1.253	46	3.269	1.634
2010	0.468	44.25	1.269	0.635

Section 4.9.7 and Section 4.9.8 below further consider the results of the radar monitoring in combination with the results from the other ornithological surveys, in order to provide conclusions in relation to the ornithological interest of the LID sites as a whole.

4.9.7 Synthesis of Ornithological Monitoring Results

Table 57 provides a summary comparison of the impact assessments for the important bird species identified within the ESs with the results of ornithological monitoring (where possible). Table 58 provides a similar comparison for the remainder of the 13 key species selected for analysis from the boat-based bird survey report but which were not assessed within the ESs. Finally, Table 59 is provided specifically for Pink-footed goose.

The original baseline ornithological monitoring results were presented in the LID ESs and data were assessed as part of the EIA process with birds being classed in terms of their sensitivity to wind farm development. In summary, sensitive bird receptors were defined as those which fulfilled sensitivity criteria as defined in the ESs and which occurred in numbers of regional, national or international importance (AMEC, 2002; OWP, 2002). This process resulted in the identification of the sensitive receptors detailed in Table 57.

Results of the impact assessments presented within the ESs suggested the following:

- During construction the most likely impacts upon conservation interests were predicted to be from disturbance with special reference to divers and Gannet feeding in the wind farm areas. The magnitude of impacts were judged to be 'moderate to low'. It was suggested that tern species, feeding in areas to the south and west of the wind farm sites during the summer, may be affected behaviourally by service vessels on transit. However, terns were not witnessed feeding in the wind farm sites during the baseline surveys and evidence was also referenced with regards to feeding terns tolerating boat activity (NWP, 2001; in Amec 2002; OWP 2002);
- The potential impacts of the operation of the wind farms discussed within the ESs were mainly related to collision risk. However, collision risk modelling conducted at the time suggested very low collision rates for Gannet, terns and divers. The ESs also stated that there was no reason to believe that a direct loss of habitat during the operational phase, and thus displacement, would occur for divers and auks seen feeding in the wind farm areas. This statement was made with the caveat that their favoured food resources remained unchanged. The ESs also suggested that, as there was no evidence for seaducks, terns or any waterfowl species feeding within the wind farm sites, displacement of these species was unlikely; and
- With regards to the waterfowl species traversing the Inner Dowsing site, none were seen flying at rotor height from the EIA baseline surveys. In the Lynn site a small number of birds were seen at rotor height but it was concluded in the ESs that collision would be unlikely to have adverse effects on the species concerned. It was speculated that birds may avoid the Lynn site but that if this did occur it would not have adverse effects on the species concerned. Flight line disruption and avoidance was also considered in the ESs with respect to terns traversing the wind farm sites, with the conclusion that there was no reason to believe that this would affect breeding or migration success. Again, the ESs considered it highly unlikely the species would suffer from collision mortality.

The LID Year 3 Post-Construction Monitoring Report focuses on 13 key bird species at the site-specific level (boat-based surveys), within the context of the results from the regional aerial bird surveys, and includes a specific study on Pink-footed goose migration. Many of the 13 key species considered in the boat-based bird survey analysis were not subject to impact assessments in the ESs as they were not deemed to be at risk (see Table 58; a further summary of key points from the ESs and ES Ornithological Addendums for each of the 13 key species is provided in Appendix 7.2). However, there was no evidence that those species which were subject to impact assessments would be significantly affected by the construction and operation of the wind farms through disturbance effects or collision mortality (AMEC, 2002; OWP, 2002; ESS, 2002; ESS, 2004). Analysis of the boat-based bird survey data focused on changes in the abundance and distribution of the 13 key bird species in relation to the LID wind farms and found no conclusive evidence for statistically significant displacement of birds. However, Red-throated diver did provide some indication of disturbance and potentially displacement from the LID sites, though given the low numbers of birds which used the wind farm sites prior to construction and the availability of similar habitat nearby the effects are likely to be negligible. Furthermore, a number of species (Kittiwake, skuas and Guillemot) have shown an increase in numbers in the combined LID sites during the construction phase and in the third year of operation. In addition, Sandwich tern have increased in the LID sites (more so in the Lynn site) throughout the monitoring period. Although increased use of the sites may not increase collision risk for some species (e.g. Guillemot which are unlikely to spend much time at risk height >20 m³⁶) other species may be expected to have associated increases in collision risk depending on the percentage of time spent at risk height.

³⁶ Approximate risk height (lowest sweep of the blade at LID being 29.15 m above Chart Datum, or 25 m above Mean Sea Level).

Table 57: Important bird species identified within the ESs (and ES Addendums) for the LID wind farm sites and subject to impact assessment, compared with ornithological monitoring (aerial and boat-based) results (where appropriate), in relation to FEPA Licence Objective 1. When a question mark is present there was no evidence available for collision sensitivity (Amec, 2002; OWP, 2002). Cells shaded grey represent those species which were not the focus of monitoring, and therefore detailed comparison is not provided.

Environmental Statement Prediction (Amec, 2002; OWP, 2002)					Results of Monitoring		Observations on whether monitoring supports predictions regarding FEPA Licence Objective 1 (changes in usage of area (displacement))
Species	Protected?	Disturbance sensitive?	Collision sensitive?	Summary of ESs in relation to impacts on abundance and distribution	Current results for relevant species		
Red-throated diver	Y	Y	Y?	- The magnitude of construction impacts on diver was judged as being ‘moderate to low’ due to the ‘probable’ regional importance of the diver population recorded in the Inner Dowsing wind farm area. - Potential disturbance during construction. - Unlikely to be any displacement of divers from the wind farm sites, provided resources remained consistent.	Analysis of the boat-based surveys, despite the data limitations, suggested that Red-throated diver may have been displaced from the LID sites following construction, with the control site being preferentially inhabited.	Aerial survey results for diver spp. found nationally important numbers of divers in the wider study area, but not in the high interest area in winter 2011/12, and numbers fluctuated within the wider study area between years. Visual inspection of diver observations and possibly density surface models suggest that, even though not tested statistically, displacement of divers from the LID wind farms could have taken place.	- Prediction: low potential sensitivity to displacement. - Results from monitoring: some evidence of displacement from the LID sites (possibly to the control site). No statistically significant result was identified, likely due to the low numbers of observations and distribution of the data.
Black-throated diver (<i>Gavia arctica</i>)	Y	Y	Y?		N/A		N/A
Great Northern diver (<i>Gavia immer</i>)	Y		Y?		N/A		N/A
Manx shearwater (<i>Puffinus puffinus</i>)	Y	Y		See ESs – not considered here.	N/A		N/A
Northern Gannet			Y	- The Gannet population was found likely to be of regional importance. - Magnitude of impact of construction activity (disturbance of birds feeding in the sites) judged to be ‘moderate to low’. - Potential disturbance during construction. - Unlikely to be any displacement of Gannet feeding within the wind farm sites, provided their resources remained consistent.	- Analysis of the boat-based bird survey results indicated background variation in population estimates with no statistical changes in the use of the LID sites and buffers that could be linked to the construction and operation of the wind farms. - Aerial survey results showed that numbers of Gannets were very low in the study area at the time of year when digital aerial surveys were carried out (winter).		- Prediction: unlikely to be displacement. - Results from monitoring: no evidence of significant displacement of birds from the wind farms from the boat-based bird survey results.
Dark-bellied Brent goose (<i>Branta bernicla</i>)	Y	Y	Y?	See ESs – not considered here.	N/A		N/A
Shelduck (<i>Tadorna tadorna</i>)	Y	Y	Y?	See ESs – not considered here.	N/A		N/A
Eurasian Wigeon (<i>Anas Penelope</i>)	Y	Y	Y?	See ESs – not considered here.	N/A		N/A
Common Eider (<i>Somateria mollissima</i>)	Y	Y	Y	See ESs – not considered here.	N/A		N/A
Common Scoter (<i>Melanitta nigra</i>)	Y	Y		No evidence to suggest that seaducks are attracted to any particular feeding locations within the wind farm areas, therefore direct loss of habitat through birds avoiding the wind farm areas was not predicted to occur.	- Winter 2011/12 aerial bird surveys revealed nationally important numbers of Common scoters within the GW4 survey area, however none were found within the high interest area. - No evidence for any overall decline in numbers since aerial monitoring commenced in 2004/05. - Only very low numbers of seaduck recorded during aerial surveys within the high interest area prior to construction. - Not a key species of interest for the boat-based survey analysis.		- Prediction: no direct loss of habitat through birds avoiding the wind farms. - Results from monitoring: large numbers of Common scoter found during aerial surveys, however these all occurred outwith the high interest area during digital aerial surveys. No evidence for any overall decline of Common scoters since aerial monitoring commenced in 2004/05. Only very low numbers of seaduck recorded during aerial surveys within the high interest area prior to construction.
Dunlin (<i>Calidris alpine</i>)	Y			See ESs – not considered here.	N/A		N/A
Common Redshank (<i>Tringa tetanus</i>)	Y			See ESs – not considered here.	N/A		N/A
Ruddy Turnstone (<i>Arenaria interpres</i>)	Y			See ESs – not considered here.	N/A		N/A
Great skua (<i>Stercorarius skua</i>)	Y		Y?	- Great skua was the only skua species selected as a sensitive receptor within the LID ESs due to its conservation status and possible collision sensitivity. - Anecdotal evidence (observations) of skuas taking avoiding action when flying close to the Blyth Harbour wind turbines and that aerial kleptoparasites and predators such as skuas are likely to avoid the wind farm areas, which would effectively result in a loss of feeding habitat but with the benefits of a reduction in collision risk.	Analysis of the boat-based bird survey data indicated that Skuas have shown an increase in numbers in the combined LID sites during the construction phase and in the third year of operation.		- Prediction: skuas likely to avoid the installed wind farm sites. - Results from monitoring: increase in numbers of skuas in the wind farm sites during construction phase and in third year of operation, from the boat-based bird survey analysis. Low numbers of observations limited the power of the analyses.
Little gull (<i>Hydrocoloeus minutes</i>)	Y		Y	See ESs – not considered here.	The winter 2011/12 aerial bird survey analysis suggested that Little gull numbers were likely to have exceeded the 1% nationally important threshold in the GW4 survey region and in the high interest area (HiDef and WWT Consulting, 2012). Little gull was not one of the key species of interest selected for analysis from the site-specific boat-based bird surveys, with boat-based		N/A

	Environmental Statement Prediction (Amec, 2002; OWP, 2002)				Results of Monitoring	Observations on whether monitoring supports predictions regarding FEPA Licence Objective 1 (changes in usage of area (displacement))
Species	Protected?	Disturbance sensitive?	Collision sensitive?	Summary of ESs in relation to impacts on abundance and distribution	Current results for relevant species	
					surveys from 2007 to 2012 recording only 41 individuals (during 14 surveys) over the whole survey area.	
Common tern	Y	Y		- Construction impacts on tern species (as a group), in both the Lynn and Inner Dowsing sites, would likely be limited to possible behavioural responses, by feeding birds, to transiting service vessels. However, evidence was supplied which inferred that feeding terns can tolerate boat activity (NWP, 2001). - Disruptions of flight lines of terns transiting both the Lynn and Inner Dowsing sites during the operational phase were considered unlikely to affect breeding or migration success. - Displacement was considered unlikely as there was little evidence of terns feeding in the sites.	Common tern showed trends in population estimates over time that could not be clearly linked to the construction and operation of the LID sites. However, the low numbers of bird observations hindered the power and interpretation of the analyses.	- Prediction: displacement considered unlikely. - Results from monitoring: no evidence of significant displacement of birds from the wind farms from the boat-based bird survey results.
Sandwich tern	Y	Y			Sandwich tern showed an increase in numbers within the LID sites (particularly the Lynn site) throughout the boat-based bird survey monitoring.	- Prediction: displacement considered unlikely. - Results from monitoring: increase in numbers within the wind farms sites over the monitoring period, from the boat-based bird survey results.
Arctic tern (<i>Sterna paradisaea</i>)	Y	Y			N/A	N/A
Little tern (<i>Sternula albifrons</i>)	Y	Y			N/A	N/A

Table 58: Additional bird species considered in this Summary Report (although not identified as important species in the LID ESs), relevant text from the ESs, compared with ornithological monitoring (aerial, boat-based) results (where appropriate), in relation to FEPA Licence Objective 1.

Environmental Statement Prediction (Amec, 2002; OWP, 2002)		Results of Monitoring		Observations on whether monitoring supports predictions regarding FEPA Licence Objective 1 (changes in usage of area (displacement))
Species	Summary of points from the ESs	Current results for relevant species		
Fulmar	Fulmars were not found in large numbers during the baseline surveys and were not selected as a key receptor species within the LID ESs. Thus, no impact assessment was carried out for this species and no predictions were made about how Fulmar may respond to the construction and operation of the wind farms.	Fulmar showed trends in population estimates over time that could not be clearly linked to the construction and operation of the LID sites. However, the low numbers of bird observations hindered the power and interpretation of the analyses.		N/A – no prediction
Kittiwake	Kittiwake were not selected as a key receptor species within the LID ESs as they were not deemed to be sensitive to disturbance or collision and were not a conservation sensitive species. Thus they were not subject to impact assessment and no predictions about how the species may respond to the construction and operation of the LID wind farms were made.	The boat-based bird survey results indicated that Kittiwake showed a significant increase in numbers in the combined LID sites during the construction phase and in the third year of operation relative to the baseline.	Density surface modelling results from previous visual and digital aerial surveys showed no obvious increasing or decreasing trends between years for the species groups investigated, and there was no significant difference in pooled population estimates for gulls (as a group) in winter 2011/12 compared to the pooled estimates in any previous winter seasons, suggesting that overall numbers have stayed the same in the study area.	N/A – no prediction
Common gull	Common gull were the most frequently encountered gull during the baseline surveys but with the smallest local breeding population. They were shown as Amber listed for RSPB criteria but it was stated that this was not applicable to the population in the wind farm area. It was also suggested that they may be sensitive to collision but that there was no evidence available. Thus, the species was not included in the receptors taken through to the desk study and impact assessments within the ESs.	Analysis of the boat-based bird survey data indicated background variation in population estimates with no statistical changes in the use of the LID sites and buffers that could be linked to the construction and operation of the wind farms.		N/A – no prediction
Lesser black-backed gull	Lesser black-backed gull were not included as a receptor species within the LID ESs. This is despite being a conservation sensitive species (although this was deemed not applicable to the population found in the wind farm sites) and potentially at risk of collision. Lesser black-backed gull were discussed with reference to potential collision risk as the wind farm sites were within foraging range of breeding sites and known collision sensitivity. The likelihood of any significant population effects arising through collision mortality was discounted. No reference was made with regards to disturbance or displacement effects.	Results of the boat-based bird surveys suggested Lesser black-backed gull did show some significant differences in population size in the LID sites and control site over time, and general observations based on the raw population data indicated that there was an increase during the construction phase followed by an initial decrease and later increase during the three years of operational monitoring.		N/A – no prediction
Herring gull	Herring gull were not included as a receptor species within the LID ESs. This is despite being a conservation sensitive species (although this was deemed not applicable to the population found in the wind farm sites) and potentially at risk of collision. Herring gull are however mentioned in relation to collision risk assessments as the wind farm sites were within foraging range of breeding sites and known collision sensitivity. The likelihood of any significant population effects arising through collision mortality was discounted. Disturbance or displacement effects were not discussed.	Analysis of the boat-based bird survey results indicated background variation in population estimates with no statistical changes in the use of the LID sites and buffers that could be linked to the construction and operation of the wind farms.		N/A – no prediction
Great black-backed gull	Although being frequently recorded during the baseline surveys, and acknowledged as being potentially at risk from collision, Great black-backed gull were not chosen as a receptor species within the LID ESs. This was because they were deemed not to breed locally and were not of high conservation concern.	Analysis of the boat-based bird survey results indicated background variation in population estimates with no statistical changes in the use of the LID sites and buffers that could be linked to the construction and operation of the wind farms.		N/A – no prediction
Guillemot	The LID ESs did not consider Guillemot as a sensitive receptor. However, the ESs do note that Guillemot was a common feature of surveys and populations may have been of local importance. The species is also mentioned with regards to displacement, and it is concluded that they are not expected to be displaced from the wind farm sites once they were built and therefore no mitigation measures were proposed.	The boat-based bird survey analyses indicated that Guillemot have shown an increase in numbers in the combined LID sites during the construction phase and in the third year of operation. The boat-based survey control site and buffer presented similar trends to those seen in the wind farm sites. This could illustrate a more widespread wind farm effect or a more general increase in the use of the wider region.	The aerial survey results indicated that the numbers of auks fluctuated within the wider study area between years, although numbers appeared to be significantly higher during winter 2011/12 (end of the third year of operation as defined for the boat-based bird survey analyses) than in most previous winters.	Prediction: no displacement from installed wind farm sites expected. Results from monitoring: increase in numbers of Guillemot in the wind farm sites and control site during the construction phase and the third year of operation, from the boat-based bird survey analysis. Winter aerial surveys also indicated that the number of auks was higher in the wider study area at the end of the third year of operation. Thus, the increases in the third year of operation suggested by the boat-based surveys may indeed represent a non-wind farm specific increase in Guillemot numbers. Nevertheless, as the wind farm sites demonstrate similar trends to the wider area this suggests that birds are not avoiding the sites.
Razorbill	Razorbill were not strictly considered within the LID ESs. However, the ESs did suggest that auks were unlikely to be sensitive to displacement, and therefore would be unlikely to be excluded from the wind farm sites once they were built.	Razorbill exhibited a strong selection for the control site and buffer during the operational boat-based bird survey monitoring. The species was not present in the LID sites and buffers during the first and second years of operation. However, Razorbill were only seen in relatively low numbers which hindered the power of the analyses carried out. Notwithstanding this, the statistical modelling indicated that Razorbill numbers showed no significant trend over time, and thus seemed unlikely to have been affected by the construction and operation of the wind farms.		Prediction: displacement unlikely. Results from monitoring: despite there being an apparent preference for the boat-based survey control site and buffer during the operational phase, there was no evidence of significant displacement of birds from the wind farms from the analysis of boat-based bird survey results.

Table 59: Additional bird species (Pink-footed goose) considered in this Summary Report (although not identified as an important species in the LID ESs), predicted impact, compared with ornithological monitoring (radar) results, in relation to FEPA Licence Objective 1 (changes in usage of area by birds on passage) and Objective 2 (assess collision risk prior to construction of the wind farms and investigate techniques/methodologies for collecting data on actual collisions during and post construction).

Species	Prediction	Results of Monitoring	Observations on whether monitoring supports predictions in relation to FEPA Licence Objectives 1 and 2
	Summary of points from the ESs / pre-construction ornithology report	Current results for relevant species	
Pink-footed goose	There were no predictions of Pink-footed goose mortality in the Lynn or Inner Dowsing ESs. Predictions of goose <i>spp.</i> mortality from collision are presented in the pre-construction ornithology report (ESS, 2004), which predicted eight goose <i>spp.</i> collisions annually at 95 % avoidance (thus 1.6 collisions at 99 % and 3.2 at 98 %). The more recent Lincs Appropriate Assessment (BERR, 2008) presented predicted mortalities for LID of between 20 and 33 Pink-footed geese per annum (99% avoidance rate) based on theoretical modelling of the known population size.	The data presented in RPS (2011) provides strong evidence for near-scale horizontal avoidance of the LID wind farm sites by Pink-footed geese during the post-construction years. The pre-construction ornithology report (ESS, 2004) predicted eight goose <i>spp.</i> collisions annually at 95 % avoidance (thus 1.6 collisions at 99 % and 3.2 at 98 %) which is similar to, but slightly higher than predictions from radar monitoring data of one goose per autumn migration (99% avoidance rate) (see Section 4.9.6). The prediction in the pre-construction report was based on observations of eight goose flocks observed from boat surveys, all but one of which were identified as Pink-footed geese. As Pink-footed goose migration is episodic in nature, predicting collisions from the ‘snapshots’ that boat surveys provide is somewhat less reliable than predictions based on the continuous survey that radar provides, thus comparisons between the two methodologies should be made with caution. The pre-construction collision estimates would have been significantly higher had a peak of goose activity been sampled; in such cases where continuous monitoring is not possible it is more appropriate to use population level data in collision analysis. The more recent Lincs Appropriate Assessment (BERR, 2008) presented predicted mortalities for LID of between 20 and 33 Pink-footed geese per annum (99% avoidance rate) based on theoretical modelling of the known population size. These are an order of magnitude higher than the values estimated with empirical radar data (see Appendix 7.3).	Pre-construction collision mortality predictions higher than predictions from radar monitoring.

4.9.8 Conclusions

4.9.8.1 Addressing the ornithological monitoring questions

The specific questions to be addressed as listed in Section 4.9.1, are considered here in turn, based on the results of the aerial, boat-based and radar surveys presented above.

Q19: Has the post-construction monitoring revealed any significant changes in the abundance and distribution of the key species and species groups?

The aerial bird survey results were used to assess any changes in the numbers of seabirds and seaduck within the wider GW4 study area. The winter 2011/12 surveys revealed that nationally important numbers of Common scoters and diver species (most likely Red-throated divers) were found within the GW4 survey area, which is consistent with results of previous surveys. Lower numbers of these species were recorded within the high interest area around the LID offshore wind farms; the numbers of divers were below the threshold of national importance, and no Common scoters were found within this area. Little gull numbers were however likely to have exceeded the 1% nationally important threshold in the GW4 area and in the high interest region from the winter 2011/12 survey analyses³⁷. It should be noted that the high interest region covers a large area around the LID sites. Little gull was not one of the key species of interest selected for analysis from the site-specific boat-based bird surveys, with the boat-based surveys carried out from 2007 to 2012 recording only 41 individuals (during 14 surveys) over the whole survey area.

Density surface modelling results from previous visual and digital aerial surveys have shown no obvious increasing or decreasing trends between years for the species groups investigated, though numbers in each species group have fluctuated between years. Some significant differences in numbers of divers and auks were found in comparison between winter 2011/12 and previous years: the pooled abundance estimate of divers for all winter surveys in 2011/12 (latter stage of the third year of operation, as defined by the boat-based bird survey analysis) was significantly lower than the pooled estimate in winter 2010/11 (latter stage of the second year of operation, as above). **Some visual patterns also suggested that some displacement of divers might have taken place during and following construction of the LID wind farms.** Auk numbers in the pooled estimate for winter 2011/12 (latter stage of the third year of operation, as above) were significantly higher than the pooled estimates for all other winters with the exception of winter 2009/10 (latter stage of the first year of operation, as above). There was no significant difference in pooled population estimates for gulls in winter 2011/12 compared to the pooled estimates in any previous winter seasons, suggesting that overall numbers have stayed the same in the study area. **Density surface models for all gulls did not reveal a strong association with the proposed site of the wind farms prior to construction in 2004 to 2006. The same pattern was apparent in surveys carried out following construction, suggesting that overall gull distribution was not affected by operation of the LID offshore wind farms.** Although not statistically assessed, there was no evidence from the aerial monitoring results for any overall change in Common scoter numbers since 2004/05.

At the site-specific level, statistical modelling of the boat-based bird survey data revealed that at least nine of the 13 key receptors showed **statistically** significant changes in abundance over time. These species were Gannet, skuas, Kittiwake, Common gull, Lesser black-backed gull, Herring gull, Great black-backed gull, Sandwich tern and Guillemot. However, only four of these species (Kittiwake, skuas, Guillemot and Sandwich tern) demonstrated trends which could be linked with the construction and operation of the wind farms. **The power of models to detect statistically significant effects was limited by the low numbers of observations and distribution of data for a number of species (Red-throated diver, Fulmar, skuas, Common tern and Razorbill). Thus, the results for these species remain somewhat inconclusive.** Models examining spatial distribution were inconclusive and did not perform well due to the generally low numbers of bird observations. **Red-throated diver exhibited some evidence of displacement, being more abundant in the control site relative to the LID sites following construction, although given the lack of data in the control site prior to construction this was not conclusive. Nevertheless the species was encountered less within the wind farm sites following construction and aerial survey data also suggested birds were avoiding the sites.** Jacob's selectivity index, supported by distribution plots, suggested that some areas were preferred by some species. The Lynn site and buffer was favoured by skuas, Kittiwake, Sandwich tern and Guillemot.

Therefore, although the aerial bird survey analysis revealed no obvious increasing or decreasing trends between years for the species groups investigated in the wider study area, analysis of the boat-based bird survey data did identify trends at the site-specific level.

³⁷ While there is no UK population estimate to compare with, a new threshold of about 160 is likely to be established by the Avian Population Estimates Panel at its next revision (J. Reid, in HiDef and WWT Consulting, 2012).

Q20: Are the changes observed attributable to the wind farms?

Some of the changes observed at the site-specific level have been attributed to background variation, however certain observations may be associated with the construction and operation of the wind farms. Many of the 13 key species of interest from the boat-based bird surveys did not appear to be influenced by the construction and operation of the LID wind farms, with Common gull, Herring gull, Great black-backed gull and Gannet all demonstrating population trends consistent with background variability. However, Kittiwake, skuas and Guillemot increased in the LID sites during the construction phase, declined in the first two years of operation (to approximately baseline levels) then increased again in the third year. In relation to Guillemot, the aerial survey results indicated that the numbers of auks appeared to be significantly higher during winter 2011/12 (end of the third year of operation as defined for the boat-based bird survey analyses) than in most previous winters. Thus, the increase in Guillemot in the wind farm sites in the third year of operation (boat-based surveys) may have represented an increase in the wider area and not a specific attraction to the LID sites³⁸. In the construction phase, attraction may have resulted from the provision of structures acting as perches or from an increase in prey availability which might have been associated with construction activity. The numbers of observations of birds on turbine structures was found to be seasonal during the construction phase and the availability of structures (prior to the addition of the wind turbine blades and operation) will also influence the magnitude of the effect. Foraging observations within the LID sites were also highly seasonal but were generally more frequent and numerous during the construction phase, supporting the influence of construction on prey availability. However, increases in prey associated with construction (piling activity influencing fish) are likely to be relatively isolated and short lived. The attraction in the third year of operation may be explained by increases in prey resulting from 'reef effects' or may have been associated with construction activity at the adjacent Lincs wind farm. The increase in Sandwich tern numbers using the LID sites (specifically the Lynn site) throughout the monitoring may also be linked to indirect reef effects associated with the presence of the wind farms. However, there is no strong evidence which links prey availability, reef effects and bird abundance in relation to the LID sites, due to the lack of data at suitable scales sampling bird prey resources.

Q21: Has the monitoring confirmed the predictions in relation to impact on bird species?

Abundance and distribution

Table 57, Table 58 and Table 59 above have provided summary comparisons of the predicted impacts for the bird species considered within the ESs, the pre-construction ornithology report, and the key species which have formed the focus of monitoring, with the results of ornithological monitoring (where possible).

The boat-based bird survey monitoring suggested that there was little **statistical** evidence for any significant disturbance or displacement from the LID sites **for the 13 key species investigated. However, Red-throated diver presented some evidence of disturbance and potentially displacement to the control site. Visual inspection of the aerial bird survey results also suggested that displacement of divers from the LID wind farm sites could have taken place. The ESs predicted that divers feeding within the wind farm area would be sensitive to disturbance during construction, however it was considered that divers would not be permanently displaced during operation, provided their prey remained within the sites. Despite this prediction, it is widely known from research that diver species are sensitive to disturbance and displacement impacts, see Garthe and Huppopp (2004), McCluskie *et al.*, (2013) and Shwemmer *et al.*, (2011). The prediction that displacement would be unlikely for Gannet appears to have been supported. In relation to the prediction that displacement of Common tern and Razorbill would be unlikely, the results of the monitoring remain inconclusive.** The increases in the number of skuas, Kittiwake, Sandwich tern and Guillemot in the wind farm sites, which may indicate attraction effects, were not predicted in the ESs.

Pink-footed goose

Predictions of collision mortality of Pink-footed goose from the radar monitoring results are below the predictions made at the pre-construction stage (noting these were based on quite different and less appropriate methods), and more recently (BERR, 2008).

The more recent Lincs Appropriate Assessment (BERR, 2008) presented predicted mortalities for LID of between 20 and 33 Pink-footed geese per annum (99% avoidance rate) based on theoretical modelling of the known population size, which are an order of magnitude higher than the values estimated with empirical radar data.

The data presented in RPS (2011) provides strong evidence for near-scale horizontal avoidance during the post-construction years. Given this evidence it is likely that Pink-footed geese also exhibit vertical avoidance. Such behaviour is discounted in the collision models as there is limited confidence in the accuracy of the height estimations. Assuming geese are capable of vertical avoidance of structures, the collision mortalities presented in Section 4.9.6 will be overestimates.

³⁸ It should be noted however that the aerial surveys were carried out in the winter of 2011/12, whereas the boat-based bird surveys recorded peak Guillemot numbers in the autumn.

The predicted number of annual Pink-footed goose collisions with LID turbines, determined from the radar monitoring (Table 56), is unlikely to have any significant impact on the North Norfolk Coast SPA wintering population (site total of 23, 802 individuals³⁹), given that the UK population of this species is expanding (Trinder *et al.*, 2005).

4.9.8.2 Addressing the objectives of the FEPA Licences for ornithological monitoring

The ornithology section of the Summary Report (and associated Appendices) has addressed the three ornithological monitoring objectives outlined in the LID FEPA Licences as follows:

1. Assess changes in usage of area by feeding birds and birds on passage.

Within the boat-based bird survey section of this Summary Report, 13 key ornithological receptors have been examined to assess whether there have been any changes in their abundance and distribution in relation to the construction and operation of the wind farm sites. Various analytical methods have been employed to help disentangle what is a complex response by birds from background variation. *Analytical power in relation to some of the species (Fulmar, skua species, Common tern and Razorbill) was limited due to the low numbers of bird observations and distribution of the data, and in these cases the effects of construction and operation remain inconclusive. Red-throated diver provided some evidence for displacement, which was supported by observations from the aerial bird surveys, although data limitations inhibited the power of the statistical analysis to confirm suggested trends. For the other species there was no particular evidence of significant or sustained displacement of birds from the wind farms.* However, there was some indication that certain species may have been attracted to the wind farm sites during their construction and later during operation (third year of operation) which may be related to temporary construction activity at the adjacent Lincs wind farm or indirect 'reef effects'. *There is however no evidence to support this due to the lack of available prey data at relevant spatial and temporal scales.*

There was evidence for changes in usage of the area by Pink-footed geese, through near-scale horizontal avoidance of the installed wind farms during autumn migration.

2. Assess collision risk prior to construction of the wind farm and investigate techniques/methodologies for collecting data on actual collisions during and post construction.

Collision risk modelling was carried out where deemed necessary during the EIA stage and updated prior to construction (AMEC, 2002; OWP, 2002; ESS, 2002; ESS, 2004). Section 4.9.5 of this Summary Report provided an account of techniques/methodologies for collecting data on actual collisions. No system for the direct measurement of bird collisions with offshore wind turbines is currently commercially available. The radar studies that have taken place at LID (see Section 4.9.6) during the construction and post-construction phases, whilst primarily for use in monitoring Pink-footed goose, have provided a beneficial method for observing bird avoidance behaviour of the wind farm. Although not a technique for monitoring actual collisions, this has used some of the most reliable technology that is available to date for determining flight activity around the wind turbines, both during daytime and night periods.

3. Survey benthos to inform reasons for possible changes in bird distribution and density on site.

Results of the benthic ecology surveys (EGS Ltd, 2012) suggested that there was little evidence of significant change in the benthic habitat and communities over the monitoring period which might influence birds through prey availability. Efforts were made to further investigate the observed distributions of birds from the boat-based survey data in relation to available explanatory covariates using spatially explicit statistical models. However, these models did not perform well due to the very low numbers of bird observations available for assessing relationships with covariates.

³⁹ "Calculated using totals from the WWT/JNCC November Grey Goose census (Hearn 1998) for the period 1992/93 to 1996/97"
<http://jncc.defra.gov.uk/pdf/UKSPA/UKSPA-A6-18.pdf>

4.10 Archaeology

4.10.1 FEPA Requirements

The FEPA requirements for archaeology are set out in Table 60 below.

Table 60: FEPA Requirements – Archaeology.

Ref	FEPA Condition
9.31	The Licence Holder shall not permit any development to commence as authorised by this Licence until a protocol has been submitted to the Licensing Authority which has been formally agreed with an archaeologist representing the County Council adjacent to the site of the works. This shall detail what action must be taken to protect any archaeological and shipwreck remains that were identified in the Environmental Statement submitted in support of the application for consent for the works or any such artifacts which may be discovered during the course of progressing the development.

The status and history of reporting for this parameter is summarised in Table 61.

Table 61: Status – Archaeology.

Phase	Requirement	Complete	LID Report
Pre-construction	Submission of Protocol	✓	Submitted pre-construction, submission dates not known.
Phase	Additional Items	Complete	LID Report
During-construction	Updated Protocol provided	✓	Construction Monitoring Report (CREL, 2009)
Year 2 Post-Construction	Update provided	✓	Year 2 Post-Construction Monitoring Report (CREL, 2012)
Year 3 Post-Construction	Updated Protocol provided	✓	Year 3 Post-Construction Monitoring Report

This section of the Summary Report provides a short update on the status of, and compliance with, the Archaeological Protocol.

4.10.2 Update on FEPA compliance

4.10.2.1 Overview

The Lynn and Inner Dowsing Offshore Wind Farms Archaeological Protocol currently in place (Wessex Archaeology, 2006b) has been updated to focus on the LID O&M phase (Wessex Archaeology, 2012b). This updated Protocol is provided in Appendix 8 and is now subject to consultation. Once approved by English Heritage, this updated Protocol will continue to be in place throughout the lifetime of the wind farms.

The Archaeological Protocol applies to the sub-tidal and intertidal (to Mean High Water Springs mark) aspects of the projects. The Protocol makes provision for the establishment of Archaeological Exclusion Zones to protect identified sites of interest, including the creation of new exclusion zones if new finds are discovered, and also for altering existing exclusion zones as a result of further evaluation.

Nine Archaeological Exclusion Zones were initially identified in the original Protocol (Wessex Archaeology, 2006a; 2006b), of which it is now proposed that four remain in place (Wessex Archaeology, 2012b; see Section 4.10.2.2 below). During the construction stage of the wind farms, there were no instances of the installation jack-up vessels breaching any of the Archaeological Exclusion Zones, and all cables were installed in the pre-determined locations (CREL, 2009).

The Archaeological Protocol was initially submitted to the Licensing Authority prior to construction, with an update submitted as part of the Construction Monitoring Report (CREL, 2009). Part of this Protocol was subsequently updated following a review of recent (2010) geophysical data for a small study area within the LID sites, and this update was provided to the Licensing Authority as Appendix A9 to the LID Year 2 Post-Construction Monitoring Report (CREL, 2012).

The updated Archaeological Protocol presented in Appendix 8 incorporates the following:

- A further review of recent (2011) geophysical data for a small study area (Wessex Archaeology, 2012a);
- A general reassessment of the status of the existing Archaeological Exclusion Zones;
- Information relevant to the operations and maintenance (O&M) phase rather than construction phase; and

- The Protocol for Archaeological Discoveries: Offshore Renewables Projects (The Crown Estate, 2010).

GLID would like to consult with English Heritage on this update and seek approval of the recommendations.

4.10.2.2 Ongoing Compliance

The updated Protocol will be in place for the lifetime of the wind farms, and GLID will continue to communicate the requirements of the Protocol to the LID O&M team, as required.

A recent example of ongoing compliance includes further investigation of geophysical data, by an archaeologist, prior to maintenance works which had potential to impact the seabed in close proximity to existing archaeological features. Samples of the more recent geophysical datasets from the EGS Ltd 2010 and 2011 surveys were examined by Wessex Archaeology (Wessex Archaeology, 2011 and Wessex Archaeology, 2012a) ahead of jack-up activities at wind turbine ID29. As a result of the investigation reported in Wessex Archaeology (2011), it was recommended that the Archaeological Exclusion Zone around site 2072 was removed (although impact to this area should still be avoided), and this recommendation was accepted by English Heritage (Appendix 10; ref 10.54).

Figure 42 shows the archaeological sites in the LID study area, including the proposed four remaining Archaeological Exclusion Zones.

4.10.3 Conclusions

The FEPA Licence requirements for archaeology have been fulfilled, but it is worth noting that the Archaeological Protocol remains in place for the LID sites during the operational phase. GLID seek approval for the updated Protocol and the proposed revisions to the Archaeological Exclusion Zones presented in Appendix 8, from the Licensing Authority and English Heritage.

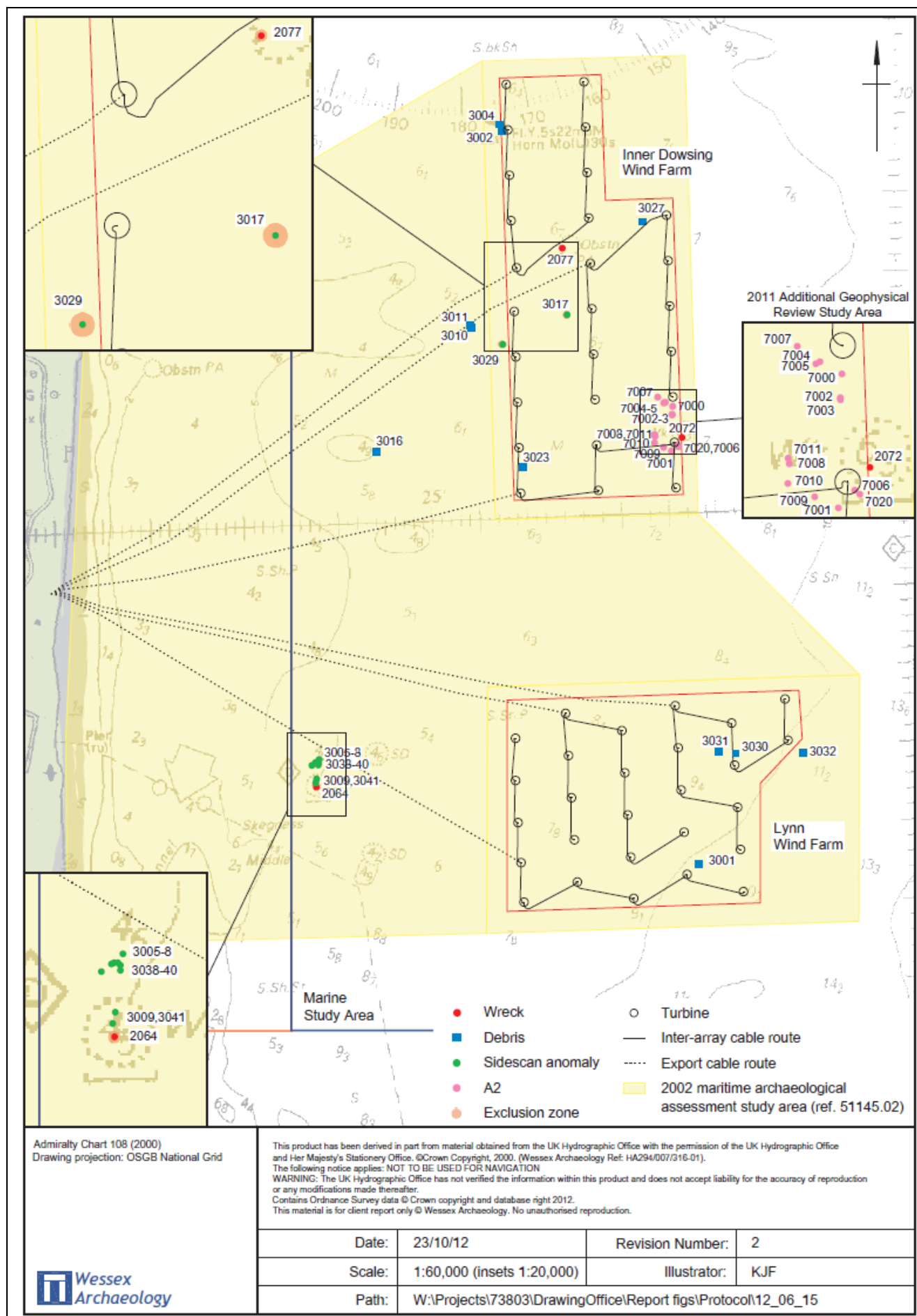


Figure 42: Maritime Archaeology in the LID Offshore Wind Farms, including new features (A2) identified from 2011 additional geophysical review (from Wessex Archaeology 2012b).

4.11 Drill arisings

4.11.1 FEPA Requirements

The LID drill arisings deposits were permitted under FEPA Licence 33553/07/0, which is separate to the main wind farm FEPA Licences. The FEPA Licence requirements are set out in Table 62 below.

Table 62: FEPA Monitoring Requirements – Drill Arisings.

Ref	FEPA Condition
9.2	The Licence Holder must forward results from the Suspended Sediment and Deposition monitoring (as mentioned in the Annex attached to this licence) to the Licensing Authority, CEFAS and Natural England as soon as the results are available.
Annex	This Annex summarises the minimum physical and biological monitoring requirements that must be undertaken to comply with condition 9.2 of licence 33553/07/0. Full details of the proposed survey specifications to meet these requirements are to be set out in a separate report to be agreed by the Licensing Authority, in consultation with Natural England, prior to the commencement of any drive-drill-drive construction activity. All monitoring surveys should be based on a clear and reported rationale and robust hypotheses should be erected for each survey. Benthos The Licence Holder must monitor the drill arising depositions to assess the area of direct benthic habitat loss. The monitoring is required to commence from the time of the first drill operation. The methodology is to be determined between the License Holder and Natural England, subject to agreement by the Licensing Authority, prior to commencement of the drive-drill-drive activity.

Six of the LID monopile locations required drilling during installation due to a hard underlying chalk formation. Monitoring of potential elevations in suspended sediment concentrations was undertaken during construction (including a separate monitoring study to the SSC monitoring reported in Section 4.2) and diver surveys were carried out on one of the spoil mounds (LN29) in August and December 2007. This monitoring was reported to the Regulator in the LID Construction Monitoring Report (CREL, 2009).

Further investigation of the mounds, at LN02 and LN29, was reported in the LID Year 1 Post-Construction Monitoring Report (CREL, 2010), using the hydrographic survey data collected by DeepOcean in May/June 2009. The Year 1 Post-Construction Monitoring Report provided an assessment of the dimension of the soil mounds through a comparison of the 2007 and 2009 data.

In response to the Year 1 Post-Construction Monitoring Report, the Licensing Authority queried why the mounds had not continued to winnow away, as previously predicted, and GLID provided a response in the Year 2 Post-Construction Monitoring Report (CREL, 2012). The drill arising mounds at LN02 and LN29 were surveyed again in October 2011 via geophysical survey along with grab samples and drop down video / still photography across the mounds. In addition to this Year 3 post-construction survey, bathymetric survey data is also available from 2010 (during the second post-construction monitoring year). These data have also be analysed as part of the Year 3 assessment of drill arisings, the results of which are summarised in this section of the Summary Report. Collectively these datasets (4 datasets in total⁴⁰ covering the period from construction in 2007 through to 2011) enable GLID to provide an evidence-based update to the Licensing Authority on the development of the mounds over time in terms of the size (dimensions), composition and biological characteristics. The status and history of reporting for this parameter is also summarised in Table 63.

Table 63: Status – Drill Arisings.

Phase	Requirement	Complete	LID Report
During-construction	Monitoring (diver survey, 2007)	✓	Construction Monitoring Report (CREL, 2009)
Year 1 Post-Construction	Monitoring (hydrographic, 2009)	✓	Year 1 Post-Construction Monitoring Report (CREL, 2010)
Phase	Additional Items	Complete	LID Report
Year 2 Post-Construction	Monitoring (hydrographic, 2010)	✓	Year 3 Post-Construction Monitoring Report
Year 3 Post-Construction	Monitoring (hydrographic, sampling, DDV, 2011)	✓	Year 3 Post-Construction Monitoring Report

⁴⁰ 5 datasets including the DeepOcean dataset however this is not considered further in this Summary Report.

This section of the Summary Report provides an update on the monitoring of the drill arising mounds at LN02 and LN29, drawing on the survey contractor Technical Report presented in Appendix 9, and addresses the following specific questions, in order to close out this FEPA requirement:

Q22	<i>How have the recorded dimensions of the drill arising mounds changed over the course of the monitoring period?</i>
Q23	<i>What are the implications of these results for benthic habitats?</i>
Q24	<i>What are predictions going forward?</i>

4.11.2 Methodology and Results of the Year 3 survey

4.11.2.1 Methodology

A survey was carried out by EGS (International) Ltd and Benthic Solutions Limited in October and November 2011, on two drill arising mounds within the LID sites. Full details of the survey and results are presented in Appendix 9.

The two LID mounds selected for survey were the mounds at LN02 (labelled as Mound A, within EGS Ltd (2012d) but referred to within this Summary Report as LN02, for ease of comparison with previous survey data) and LN29 (labelled as Mound B within EGS Ltd (2012d) but referred to as LN29 here, as above). The location of LN02 and LN29 is illustrated in Figure 43 below. The aim of the survey was to assess the size of these mounds, their composition (sediment characteristics) and biological characteristics (EGS Ltd, 2012d).

Three methods were used to acquire data on the mounds:

3. High resolution multibeam bathymetry;
4. Grab samples (LN02 and LN29); and
5. Drop down video (DDV) / still photography (LN29 only).

The bathymetric survey was carried out in October 2011 using the survey vessel the “EGS Pioneer”, as part of the main LID Year 3 post-construction geophysical survey. The benthic sampling survey was also carried out in October 2011, using the “Wessex Explorer”, however re-sampling at the correct position of LN02 using only grab samples took place in November 2011 (EGS Ltd 2012d). Full details of the vessel and survey equipment specifications are provided in Appendix 9.

Grab sampling and the DDV/still photography was carried out on the centre of the drill arisings mounds, and at sites located 50 m to the north, south, east and west. Grab sampling was carried out using a 0.1 m² Hamon grab, and the DDV was deployed in transects which crossed the mound (EGS Ltd, 2012d).

PSA and benthic infaunal analysis was carried out on the grab samples, and assessment of the epifaunal communities was made from the DDV and stills imagery (EGS Ltd, 2012d).

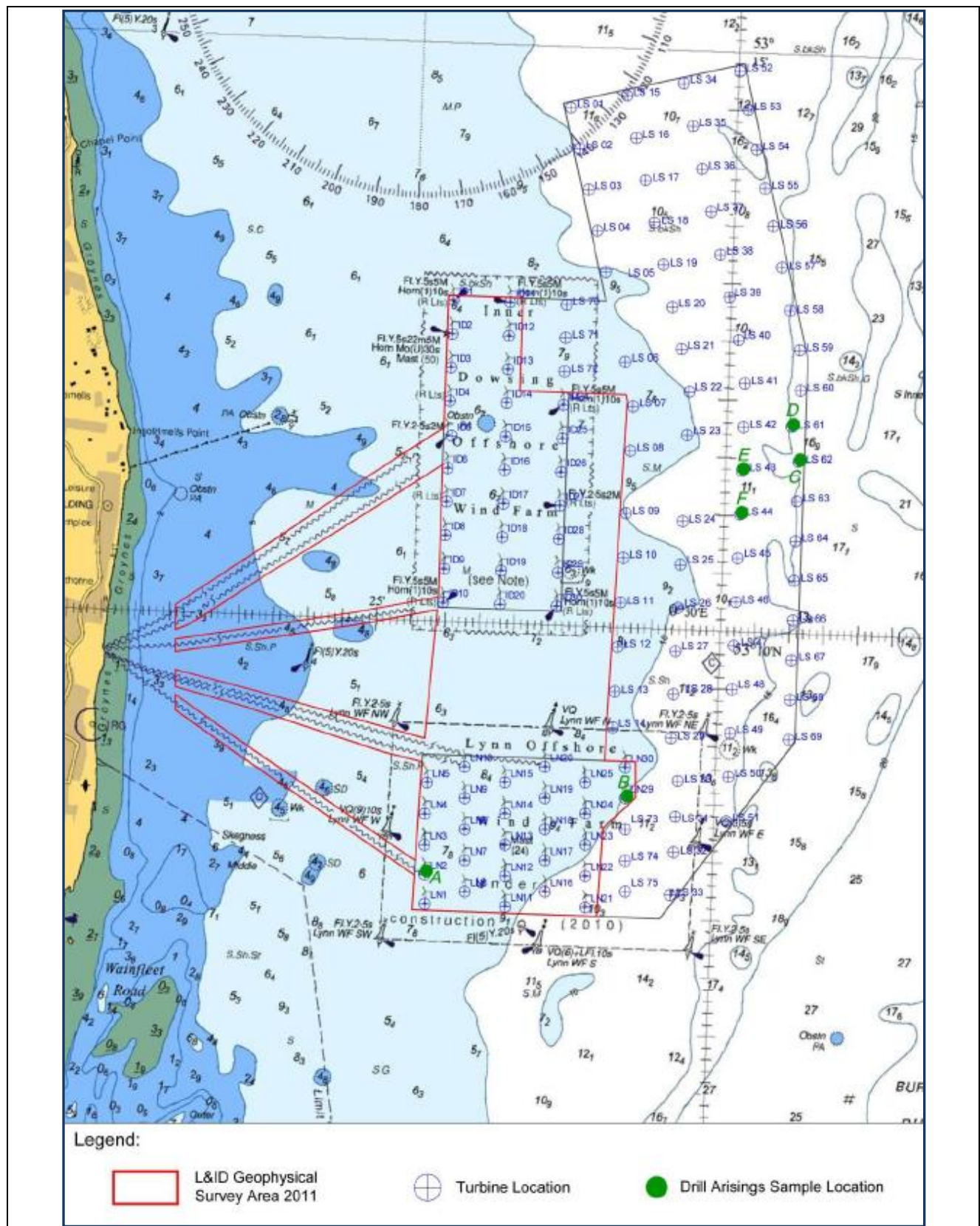


Figure 43: LID (and Lincs) Drill Arisings Survey Area; Mound A: LN02; Mound B: LN29 (from EGS Ltd, 2012d).

4.11.2.2 Results

The bathymetric data (Year 3, 2011) collected allows quantification of the physical dimensions of spoil mounds LN02 and LN29. Data is presented in Figure 44 and Figure 45 below (Note: these figures also include survey data from previous years – a comparison of the development of the spoil mounds over time in terms of physical size is provided in Section 4.11.3). LN02 is approximately 1 m in height above the surrounding seabed, whilst LN29 is approximately 0.75 m above the surrounding seabed.

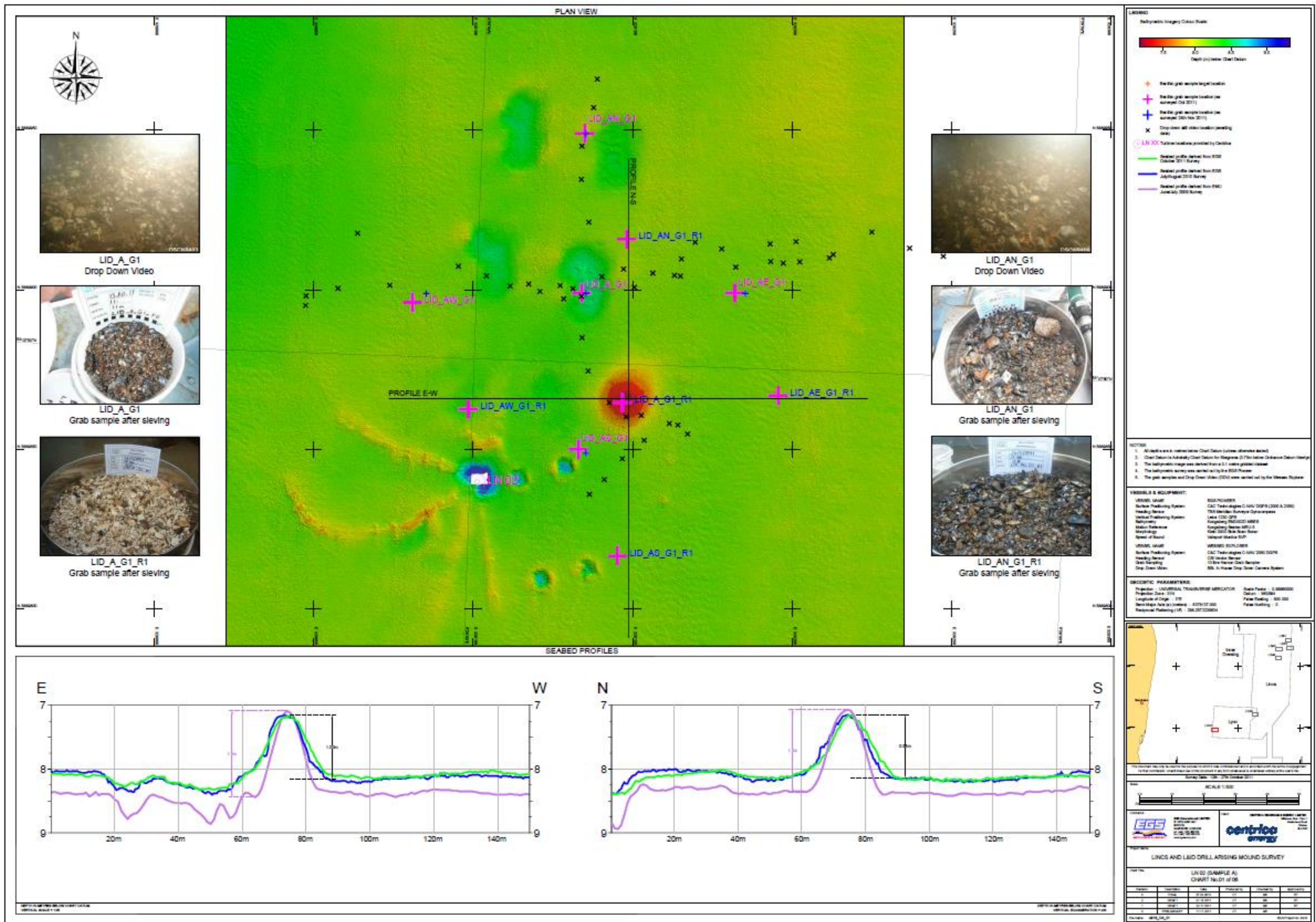


Figure 44: LN02 (Mound A) Chart 1 (from EGS Ltd, 2012d).

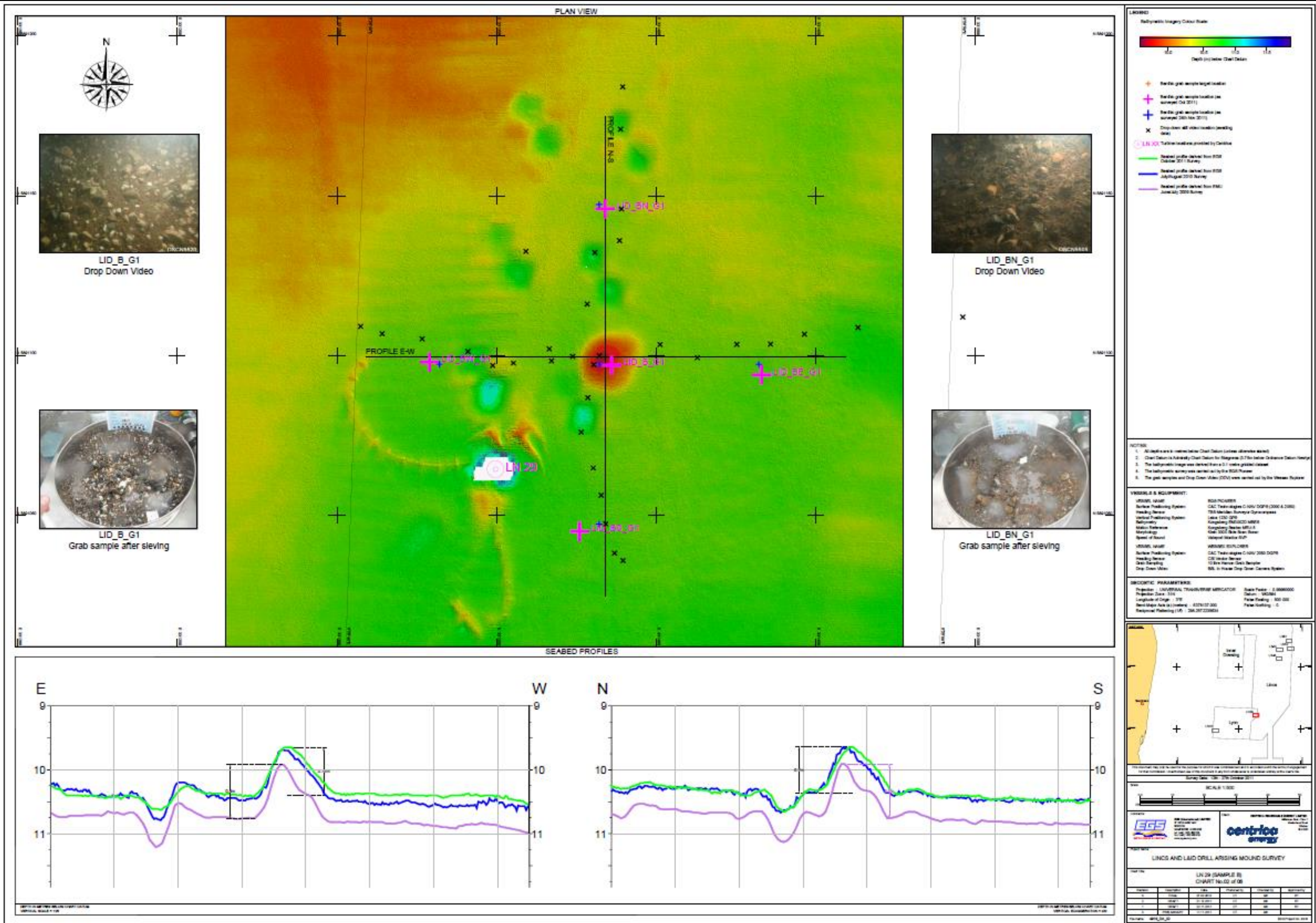


Figure 45: LN29 (Mound B) Chart 2 (from EGS Ltd, 2012d).

The characteristics of the sediments at the sites surrounding the monitored spoil mounds were identified from the quadrant of samples taken around each mound, allowing identification of the baseline particle sizes to allow comparison against the sediments on the mounds. These data allowed the surrounding seabed to be categorised as varying from slightly gravelly silty SAND to slightly silty sandy GRAVEL based on the Folk classification (EGS Ltd, 2012d).

At LN02, sediments across the central mound were found to differ from the surrounding seabed, with the mound having a higher proportion of gravels. Specifically, the mound contained 30% greater gravel proportion relative to the surrounding seabed, at the expense of the sand fraction, with fines remaining at a consistent (and low) proportion. At LN02, chalk comprised 80% of the volume of the sample.

At LN29, the central mound also showed some differences in particle size distribution relative to the surrounding seabed (as defined by the four quadrant samples). As at LN02, the proportion of gravels was higher (in this case by 20%) in the central mound, at the expense of both fines and sands. In terms of the evidence for chalk presence / absence, LN29 reveals a considerably lower chalk content, relative to LN02 above. In the case of LN29, chalk comprised 15% of the volume of the sample and only 40% seabed coverage (as determined from the camera work).

The macro-invertebrate population (infaunal and epifaunal) was investigated from a single replicate from each survey station. Table 64 below provides a summary of the mound centre values compared with the mean of the surrounding sites, and shows that the mound centres display a poorer biological community than those of the surrounding sediments. However, LN29 illustrated a species recovery of 91%, whilst the equivalent figure for LN02 was 75%. EGS Ltd (2012d) state that the biomass and biological community parameters calculated at these two spoil mounds are indicative of a recovering population, with the establishment of niche species in low numbers and the absence of opportunistic species. The greater recovery at LN29 relative to LN02 is likely to be related to lower chalk composition within the surface of the mound and related lower seabed coverage of the chalk, as described above.

It should also be noted that individuals (5) of the polychaete worm *Sabellaria spinulosa* were recorded from the centre of the drill arising mound at LN29, with greater abundances of this species recorded at the 50 m east grab (105 ind.), 50 m south grab (29 ind.) and 50 m west grab (4 ind.) (Appendix G of EGS, 2012d), although it is accepted that no reef features themselves were recorded in this survey.

Table 64: Summary of Mound Centre Values Compared with Mean from the Surrounding Sites (from EGS Ltd, 2012d).

Mound	Species Richness	Species Abundance	Sample Diversity (H(s))	Evenness 1-Lambda'	Total Biomass (g)
Mound A*	75.0%	55.1%	100.0%	105.9%	65.5%
Mound B	90.8%	35.2%	125.4%	115.5%	24.3%
*Excludes changed site LID-AW-R1 (see Appendix 9 for further details)					

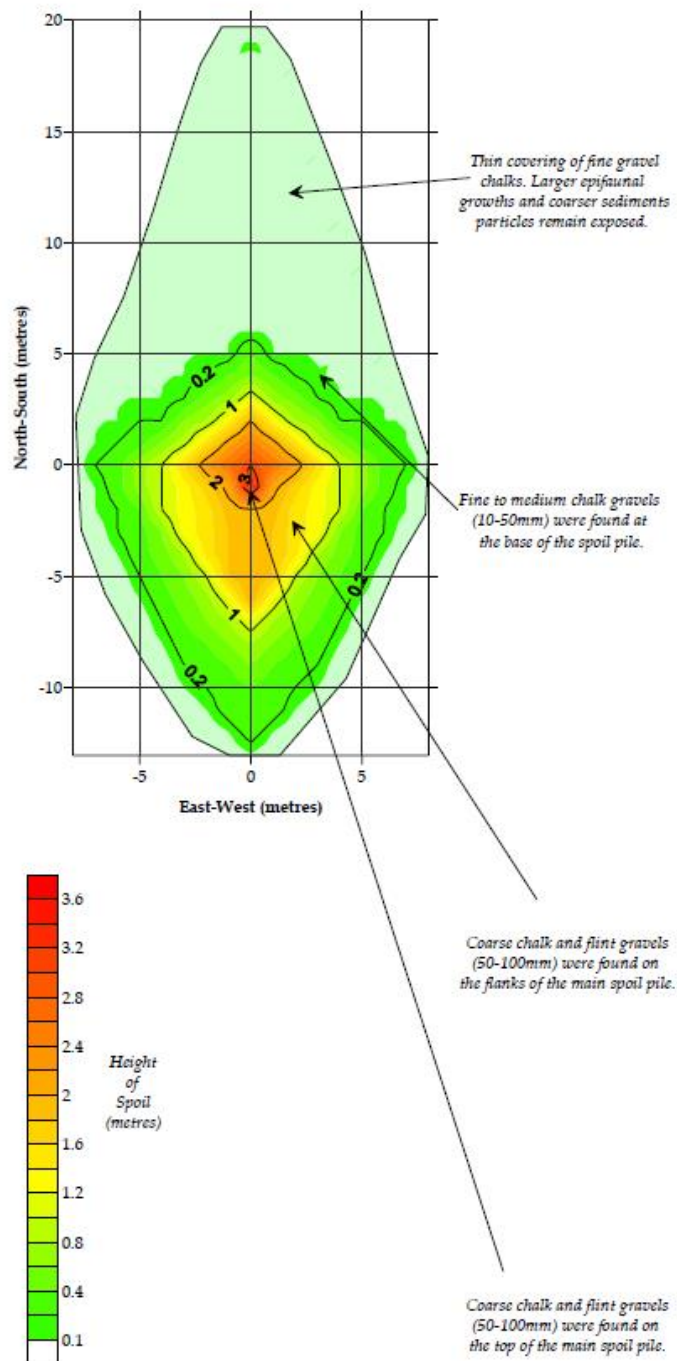
Overall, the collected and analysed data demonstrates a component of finer sediments becoming incorporated into the spoil mounds. The data also illustrates that whilst a degraded biological community exists on the spoil mounds, recovery is an advanced state (EGS Ltd, 2012d) with some spatial variability in the rate of recovery, as noted above.

4.11.3 Methodology and Results for inter-year comparisons

As noted in the introduction to this section, surveys have been completed across a number of years. These data allow evaluation of the change to the size of the monitored spoil mounds over time. These surveys extend from surveys following the disposal of the drill arisings in 2007, to the third year of post-construction monitoring in 2011. Specifically the available datasets are:

- 2007 (August and December): Diver surveys (CREL, 2007; CREL, 2009);
- 2009: Bathymetric survey (first year of post-construction monitoring) (EMU, 2009);
- 2010: Bathymetric survey (second year of post-construction monitoring) (EGS Ltd, 2011a); and
- 2011: Bathymetric survey (third year of post-construction monitoring) (EGS Ltd, 2012a).

The results from the 2007 diver surveys were reported in a specific report documenting the monitoring of the disposal of drill arisings (CREL, 2007) and the key data is summarised within the Construction Monitoring Report (CREL, 2009). During August 2007, the monitoring involved data collection at location LN29. An assessment of the height of the spoil mound was undertaken via a diver using a depth sensor. This was used to create a contour map showing elevations across the spoil mound (Figure 46). The mound was recorded as having a height of around 3 m. A re-survey of LN29 completed in December 2007 indicated a reduction had occurred in the spoil mound height in the intervening 4 months, with a height of 1.2 m recorded.



Area & Volume Calculations

Spoil Depth (m)	Area (m ²)	Volume (m ³)
0 - 0.1	450.6	152.3
0.1	174.7	99.5
1	53.8	36.9
2	10.0	4.3

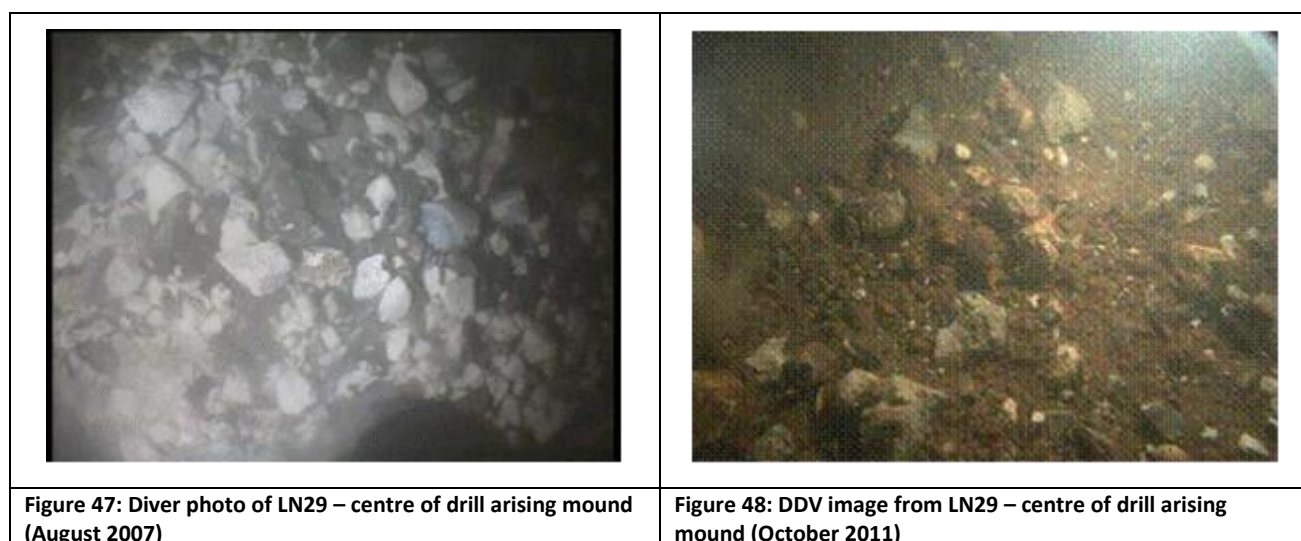


Figure 46: Approximate Representation of the Drill Arisings Mound at LN29 together with Surface Area and Volumetric Calculations (from CREL, 2007).

The Year 1 Post-Construction Monitoring Report (CREL, 2010) presented both the 2007 data described above and the 2009 bathymetric survey dataset. Whilst a quantitative comparison between the 2007 diver surveys and the full bathymetric survey of 2009 is not possible due to the differing levels of accuracy of the datasets, the data was used to conclude that no significant changes had been recorded across the spoil mound during this period.

The 2009, 2010 and 2011 bathymetry surveys all allow a quantified assessment of the development of the mounds across this period. This analysis is presented in detail in EGS Ltd (2012d). Comparison of the datasets has allowed the difference in level across soil mounds LN02 and LN29 to be determined. At LN02, the height of the mound above the surrounding seabed had decreased by 0.35 m (± 0.05 m) between June / July 2009 and July / August 2010. The same spoil mound demonstrated no noticeable change between July / August 2010 and October 2011 (EGS Ltd, 2012d). At LN29 a decrease in height between June / July 2009 and July / August 2010 of 0.25 m (± 0.05 m) was recorded, whilst again no change was recorded from July / August 2010 to October 2011 (EGS Ltd, 2012d). In addition, the data recorded some spreading of material within the mounds between 2009 and 2010 (i.e. corresponding to the period of reducing mound height).

In addition to the recording of mound size over time, it is also possible to compare sediment composition over time based on images taken during the 2007 surveys (i.e. immediately after spoil disposal) and the 2011 surveys (i.e. most recent survey). Figure 47 (below) shows the sediment composition at the centre of LN29 in 2007, with the newly deposited chalk arisings clearly visible. Figure 48 shows an image from the centre of the mound at LN29 obtained via DDV in October 2011. These images provide further support to the observation above (Section 4.11.2.2) that a finer component of sediment is becoming incorporated into the mounds.



4.11.4 Conclusions

From the results reported above, it is possible to address the three questions posed at the beginning of this section:

Q22: How have the recorded dimensions of the drill arising mounds changed over the course of the monitoring period?

When the data and trends described above (Section 4.11.2 and Section 4.11.3) are combined, overall trends across the data period can be summarised. The surveys directly following spoil disposal indicate an initial (over 4 months) significant reduction in the height of the mounds (of the order of a 50% reduction in mound height, relative to the surrounding seabed). Following this initial trend, monitoring across the three post-construction years illustrated a trend of reducing mound height but at a much reduced rate (relative to the short period immediately following disposal), followed by stability in mound height in the more recent surveys. This can be interpreted as an initial period of rapid erosion as the finer material within the spoil mound is winnowed by prevailing tidal currents. The winnowing process left the coarser, immobile, component of the spoil and this has now stabilised with no net trend illustrated between 2010 and 2011. Some reductions in height are recorded between 2009 and 2010, although there is a suggestion in the data that this may be potentially due to the spreading of coarser material within the mound.

Given the number of mounds (6 across LID) and the dimensions of the monitored mounds (around 1 m above the height of the surrounding seabed), the mounds will not have a significant effect on the flow regime across the area. Whilst any protrusion on the seabed will result in an alteration to tidal flows, in this case these will be localised to the immediate vicinity of the mounds.

Q23: What are the implications of these results for benthic habitats?

Benthic ecology data collected at mound centres and surrounding areas during 2011 indicate that there are similarities between benthic communities at mound centres and those of surrounding areas. Many of the species recorded were common to both mound centres and surrounding areas and were also recorded throughout the LID sites during other benthic monitoring studies. Abundances of these species were, however, lower at mound centres, which may be evidence of a historical, though localised, impact of drill arisings on benthic communities. The results provide evidence of recovery of benthic habitats and communities at the mounds and in close proximity to the mounds and that this is occurring even though the mounds are still evident.

Given the small number of drill arising mounds in the LID sites (i.e. 6), the highly localised area affected and the evidence of recovery of biological communities at the two mounds monitored, it is considered that there are no long term implications for the benthic environment of the LID sites from the presence of these mounds.

Q24: What are predictions going forward?

As noted in previous reporting on the drill arisings monitoring, it is not possible to quantitatively predict the rate of change across the mounds with a high degree of confidence. An understanding of this process has been developed based on monitoring of the spoil mounds and this can be used to provide an indication of potential future trends.

The trends observed and described here, illustrate an initial period of winnowing of the spoil mounds and lowering of mound height (in the months following deposition in 2007). Following this the mounds have been recorded to be relatively stable in terms of their height compared to the height of the surrounding seabed. Some lowering has been observed during this period (specifically 2009 to 2010), however this has been of relatively small magnitude (0.35 m and 0.25 m at the monitored mounds).

Based on these trends, it would be expected that the mounds will continue to remain relatively stable over the coming years, although some degree of lowering may occur. In terms of composition, the finer (baseline) sediments surrounding the mounds would be expected to continue to be incorporated into the surface of the mound centres. Whilst the evidence base for these processes from the monitoring is good, there will remain some uncertainty in the rate of the processes, and spatial variability will occur across the sites.

Benthic ecology monitoring provided evidence of recovery of the benthic communities on the drill arising mounds, with similar species compositions to those of surrounding benthic habitats and the wider area (Section 4.11.2.2). At present, it is unclear whether these communities will recover completely, i.e. no significant differences between the communities on the mounds and the surrounding benthic habitats, as the mounds are likely to remain stable in the medium term. The benthic monitoring data does provide strong evidence, however, to support the conclusion that the presence of these low mounds does not equate to sterilization of benthic communities, with both infaunal and epifaunal species (including the reef forming polychaete *S. spinulosa*) recorded on drill arising mounds in post-construction surveys.

5 Discussion of inter-relationships

5.1 Overview

This section summarises the more detailed discussions presented in Section 4 of this report, and considers the interrelationships between the different monitoring results in order to provide a holistic appreciation of impacts across the wind farm sites.

5.2 Subsea Noise and Marine Fish

As discussed in Section 4.4, a series of underwater acoustic measurements in and around the LID wind farm sites were taken on 16, 17 and 18 February 2011 (Subacoustech Environmental Ltd, 2012), to characterise the ambient subsea noise due to the presence of the operational wind farms, and to assess the range over which any increase in noise occurred. The underwater noise data indicated that there was an overall increase in noise (tidal flow, wind and waves interacting with the turbine structures), compared to the measured background, in and around the turbine array for frequencies from 2 to 200 Hz with the perceived noise levels (within 100 m) for fish marginally higher than measured in nearby waters. The noise was of a sufficiently low level that there was considered to be no likelihood of direct physical injury to marine species in the form of lethal injury, or hearing impairment from long term exposure. The results from measurements taken at ranges to 10 m from an operational wind turbine indicated that the underwater noise was unlikely to cause a significant behavioural (avoidance) response, however fish may be able to perceive sound from the wind farms up to a maximum of 10 km. Within the limits of the site-specific fish survey data collected (i.e. lack of data collection with the LID wind farm sites post-construction; the only wind farm based site sampled in Year 3 being shrimp trawl ST04), no discernible effects of the wind farms on the fish community composition were observed, although no effects would be anticipated based on the acoustic measures undertaken for the LID operational turbines.

Subacoustech (Subacoustech Environmental Ltd, 2011) also undertook a series of underwater acoustic measurements during impact piling operations at the adjacent Lincs wind farm on 16 and 22 March 2011 (substation jacket) and 14, 16, 18 and 28 May 2011 (4 turbine foundation monopiles). The study showed that noise specialist species such as herring (*C. harengus*) would probably have exhibited strong behavioural avoidance out to 9.5 (3 piles) to 15 km (1 pile) during piling of the monopiles and 4 km during piling of the smaller jacket piles, and at much smaller distances for noise generalists. The effect of piling noise during construction at Lincs has been incidentally assessed on fish populations through a limited number of the LID monitoring surveys, which were undertaken during Lincs piling (see Section 4.5.5).

None of the impact piles for which Subacoustech (Subacoustech Environmental Ltd, 2011) undertook underwater acoustic measurements coincided directly with these fish survey events, although anticipated effects would be of a similar magnitude i.e. strong behavioural avoidance up to 15 km, although in most cases only to 9.5 km. For the fish survey events that coincided (e.g. survey undertaken on the same date) with piling at the Lincs wind farm, survey sites were located within the possible behavioural effects distances of the Lincs piles (shrimp trawls were undertaken between 2 and 5 km from the Lincs wind farm site boundary and approximately 8 to 10 km from the centre of the Lincs site). However, no effects were discernible in the communities composition measured, although the surveys that coincided with Lincs piling events were targeting motile crustaceans (shrimp trawling and potting) which are not considered to be noise sensitive.

Further review of the shrimp trawls, and specifically the by-catch data, showed that *C. harengus* were found in all of the shrimp surveys undertaken during the Lincs piling activity, and in abundances within the range of surveys undertaken for Year 2 and Year 3 post-construction (range of 0 to 93 individuals); SS17 (June 2011; 1 individual), SS19 (Sept 2011; 9 individuals) and SS21 (Feb 2012; 76 individuals). The same was true for other noise specialists such as *S. sprattus*. **However as the shrimp surveys were not designed to sample clupeid species it is not possible to draw conclusions from these observations.**

5.3 Benthic Communities and Sediment Distribution

As discussed in Section 4.7 and Section 4.8, no large scale changes in sediment composition or benthic communities were detected within the LID survey area between the pre-construction and post-construction surveys. The sediments across the survey area were found to be consistent during pre-construction and post-construction surveys, with featureless sandy GRAVEL to gravelly SAND characterising the seabed during all surveys. Similarly, the benthic infaunal community composition was found to be typical of the sediment types recorded within the survey area and for this region of the southern North Sea in all surveys. The post-construction benthic ecology data validated the predictions made in the LID ESs regarding construction effects,

whereby localised effects on benthic ecology were observed with evidence of high recovery rates, and no evidence of broad scale effects.

Evidence of impacts on benthic sediments and associated communities were, however, evident in the jack-up and drill arisings datasets. The jack-up footprint survey data, from both geophysical and benthic ecology surveys, indicated historic localised disturbance to benthic habitats and communities, though there was clear evidence of recovery. Bathymetry data showed infilling of jack-up footprints, and benthic ecology data showed recovery of benthic infaunal and epifaunal communities within the footprints (see Section 4.8.2.2.3).

Surveys of drill arising mounds also showed highly localised effects on benthic communities within the LID offshore wind farm sites. Although the PSA data did not show considerable differences in the sediment composition at drill arising mounds, lumps of chalk were recorded within the mound centres (though not at surrounding sampling sites, 50 m from the mound centre). As discussed in Section 4.11.2, the benthic infauna at the mound centres had lower abundances compared to those recorded at surrounding areas suggesting a highly localised effect on benthic communities from the drill arisings. However, the results provided evidence of recovery of benthic habitats and communities at the mounds and in close proximity to the mounds and that this was occurring even though the mounds are still evident.

5.4 Benthic Communities and Marine Fish

As discussed in Section 4.8, no large scale changes in sediment composition or benthic communities were detected within the LID survey area between pre-construction and post-construction surveys. The post-construction benthic ecology data validated the predictions made in the LID ESs regarding construction effects, whereby localised effects on benthic ecology were observed with evidence of high recoverability, and no evidence of broad scale effects. Small scale changes were noted for jack-up footprints and in proximity to drill arisings, with both showing evidence of recovery.

In contrast to the benthic data, inter-annual variations in fish populations were noted from the site-specific pre-construction and post-construction monitoring. However, these site-specific trends were generally also noted to be part of a broader inter-annual (and seasonal) variation of fish populations from examination of fish landing data. Strong seasonal trends were also noted for most of the fish surveys, again, this was not reflected in the benthic data which was limited to a single annual survey, given that benthic species composition are generally less seasonally affected. Seasonally influenced epibenthic species were also collected and assessed as part of the fisheries data, and key motile invertebrate species such as *P. montagui*, *C. crangon* (higher abundances in autumn), *C. pagurus* and *C. maenas* (higher abundances in summer) were all seasonally influenced. Inter-annual (and seasonal) differences could therefore not be attributed to the presence of the LID wind farms.

In the LID ESs, the localised changes in benthic ecology, as a result of the wind farms, were not predicted to have any discernible effect on fish stocks. Within the limitations of the paucity of post-construction surveys undertaken within the LID wind farms, these predictions have been validated by the fish monitoring surveys.

5.5 Ornithology

Density surface modelling results from previous visual and digital aerial surveys showed no obvious increasing or decreasing trends between years for the species groups investigated, though numbers in each species group fluctuated between years. At the site-specific level, statistical modelling of the boat-based bird survey data revealed that at least nine of the 13 key receptors showed **statistically** significant changes in abundance over time, with four of these **receptors** (Kittiwake, skuas, Guillemot and Sandwich tern) demonstrating trends which could be linked with the construction and operation of the wind farms (**however low numbers of skua species reduce confidence in these results**). Kittiwake, skuas and Guillemot increased in the LID sites during the construction phase, declined in the first two years of operation then increased again in the third year. In relation to Guillemot, it is of note that the aerial survey results indicated that the numbers of auks appeared to be significantly higher during winter 2011/12 (end of the third year of operation as defined for the boat-based bird survey analyses) than in most previous winters. The Sandwich tern population using the LID sites (specifically the Lynn site) increased throughout the monitoring period.

Despite the data limitations and lack of significant model results from the boat-based bird survey analysis, Red-throated diver appeared to provide some evidence of disturbance and potentially displacement following the construction of the LID sites, and this was supported by visual observations from the aerial bird survey results. Disturbance of Red-throated diver during the construction phase was predicted in the LID ESs, however it was considered that permanent displacement during operation would not occur, provided that prey resources remained within the sites. As noted above, despite this prediction, it is widely known from research that diver species are sensitive to disturbance and displacement impacts, see Garthe and Huppopp (2004), McCluskie *et al.*,

(2013) and Shwemmer *et al.*, (2011). The boat-based bird survey monitoring suggested that there was **no particular** evidence for any significant or **sustained** displacement of the **remaining** key species investigated from the LID sites, confirming the predictions that displacement would be unlikely for Gannet, Common tern and Razorbill (although the low numbers of Common tern and Razorbill limited the robustness of data analysis). However, the increase in number of skuas, Kittiwake, Sandwich tern and Guillemot as noted above, may indicate attraction effects related to construction activity or indirect 'reef effects', that were not predicted. Predictions of collision mortality of Pink-footed goose from the radar monitoring results are below the predictions made at the pre-construction stage, and more recently (BERR, 2008).

Collision risk modelling was carried out where deemed necessary during the Environmental Impact Assessment stage and updated prior to construction. The radar studies that have taken place at LID during the construction and post-construction phases have provided a beneficial method for observing bird avoidance behaviour of the wind farms and have used some of the most reliable technology that is available to date for determining flight activity around the wind turbines, both during daytime and night periods.

There was little evidence of significant change in the benthic habitat and communities within the wind farm sites over the monitoring period which might influence birds through prey availability.

5.6 Physical Processes

The conclusions reported in this Summary Report with respect to suspended sediments, currents, seabed morphology, scour and drill arisings have been examined in order to consider the physical environmental processes at the wind farm sites as a whole.

Monitoring of currents suggested that there are likely to be turbulent wakes in the lee of the monopiles, extending at least 400 m downstream during a flood tide. The LID ESs suggested that turbulence around the monopiles would cause local scour pits, and make sediment readily available for suspension and transport by waves and currents. The geophysical surveys have shown that localised scour is occurring around the majority of the LID wind turbine foundation locations, with the latest survey (2011) recording the continuing development of scour at the turbines, although with a larger proportion of the total scour recorded prior to, and up to, the 2009 survey. Regarding the predicted effects of turbulence and scour on suspended sediment levels, post-construction suspended sediment monitoring showed generally low suspended sediment levels, which varied only with the spring and neap tide cycle, although it was noted that no storm events occurred during the post-construction deployment period. The impact to the suspension of material off the seabed was found to be local to the wind farm sites during construction and of a short term duration.

The dominant sediment type of featureless gravelly sand to sandy gravel has been consistent since the first geophysical survey in 2002 to the most recent survey in 2011. Some differences in seabed features were noted however, including an increase in the number of clay patches over the post-construction surveys, and differences in the location of megaripples across survey years, indicating a degree of sediment mobility across the seabed. The presence of some linear seabed features, also showed an erosion trend over the post-construction surveys. No notable trends in seabed elevation were revealed in terms of either erosion or accretion, with any observed changes being localised and generally related to features associated with construction or infrastructure.

The majority of the jack-up footprints, created in 2007 and 2008 by the MPI Resolution, are still visible in the most recent dataset (2011), up to 4 years after their creation, which indicates a relatively benign sedimentary environment. However, all MPI Resolution footprints have experienced accumulation in the centre of the depression and scour around the edges, with the rate of infilling being spatially variable across the sites. In addition, the MPI Resolution footprints are not observed at all turbine locations in 2011, indicating that these footprints have infilled. Surveys of the drill arisings mounds illustrated that in the 4 months after deposition the mounds significantly reduced in height, following which the mounds have been recorded to be relatively stable in terms of their height above the surrounding seabed.

Therefore these surveys have illustrated that the seabed in the vicinity of the LID sites is subject to gradual changes during the post-construction survey years.

6 Conclusions

6.1 Key observations from the monitoring programme

This section reviews the conclusions provided for each of the monitoring parameters in Section 4, in relation to the FEPA Licence conditions and the questions addressed by the monitoring programme. A summary of the conclusions is provided in Table 65. Section 4 should be consulted for each relevant monitoring parameter for full details of the relevant surveys, methods, analysis and results, including limitations.

Potential wind farm related changes have been indicated for certain environmental parameters from the monitoring data, however no wind farm related changes have also been noted for other parameters. In addition, there are parameters for which potential wind farm related changes were observed at the construction stage, where evidence now suggests recovery towards previous conditions. These observations are explored below. The observation of a wind farm related change does not necessarily mean a negative change for that particular parameter in the wider context.

6.1.1 Potential temporary changes from construction

Some of the monitoring data has indicated that localised changes were detected during construction, with subsequent surveys suggesting a return or recovery towards previous conditions.

This appears to be the case for suspended sediments, whereby elevated concentrations were measured over the construction period, in contrast to generally low levels recorded post-construction (although noting baseline SSC conditions during construction may have been influenced by wave conditions relative to the post-construction monitoring period). It was concluded that the elevations in SSC recorded during construction were local to the wind farm sites during construction and of a short term duration.

Regarding the impact of the jack-up vessel footprints created during construction (2007 and 2008), the benthic sampling data collected from within the jack-up footprints and at associated reference locations in 2011 showed that the benthic communities were broadly similar within and outside the jack-up footprints, and provided evidence of almost complete recovery of the communities within the jack-up footprints. The geophysical surveys also indicated that many of these footprints are gradually infilling. The majority of the jack-up footprints were still visible, however the rate of infilling was found to be spatially variable across the sites with some of the footprints no longer observed at all turbine locations approximately 4 years after construction. This trend of infilling is expected to continue over time and the more recent jack-up footprints created by the MS Wind vessel during wind farm operations and maintenance work are expected to follow a similar trend of gradual infilling over time.

The benthic ecology surveys also indicated that cable laying operations affected a limited area, and that recolonisation by benthic species occurred quickly following disturbance. This confirmed the ESs prediction that the impact of temporary habitat loss due to cable laying would be “low level” and “medium term”. Effects on benthic communities from increases in SSCs and sediment deposition were found to be limited and if adverse effects occurred then full recovery has taken place since offshore wind farm construction.

In relation to the effects on benthic ecology of the drill arising mounds, given the small number of drill arising mounds in the LID sites (i.e. 6), the highly localised area affected and the evidence of recovery of biological communities at the two mounds monitored, it was considered that there are no long term implications for the benthic environment of the LID sites from the presence of these mounds.

6.1.2 Potential changes recorded post-construction

The monitoring data have also indicated potential wind farm related changes which have continued to be recorded during the post-construction surveys.

The presence of turbulent wakes downstream of the wind turbine structures was recorded in the monitoring data. Although scour continues to develop at the sites as noted from the 2011 survey, a greater proportion of the total scour recorded occurred prior to and up to 2009.

In terms of ornithology, the aerial bird survey **analysis for** the wider Greater Wash region showed no obvious increasing or decreasing trends between years for the species groups investigated, however at the site-specific level, statistical modelling of the boat-based bird survey data revealed that four of the 13 key species (Kittiwake, skuas, Guillemot and Sandwich tern) demonstrated trends which could be linked with the construction and operation of the wind farms **(however low numbers of skua species reduce confidence in these results).**

Kittiwake, skuas and Guillemot increased in the LID sites during the construction phase, declined in the first two years of operation then increased again in the third year. Potential reasons for the observed effects have been suggested in order to provide a considered discussion of the results, with the above trends attributed to attraction effects during construction (at both LID and at the adjacent Lincs site) and potential attraction effects from increases in prey resulting from 'reef effects' associated with the presence of the wind farms. The increase in Sandwich tern population throughout the monitoring years may also be linked to the indirect reef effects associated with the presence of the wind farms. However it is noted that there is no evidence to support this reasoning from the available data.

Despite the lack of statistically significant results from the boat-based bird survey data analysis for Red-throated diver, this species appeared to provide some evidence of disturbance and potentially displacement following the construction of the LID sites, and this was supported by visual observations from the aerial bird survey results. It was considered that the implications are likely to be limited given the low numbers of Red-throated diver originally using the LID sites and availability of similar habitat in close proximity to the wind farms.

The bird detection radar data provided evidence for near-scale horizontal avoidance of the wind turbines by Pink-footed geese on autumn migration.

6.1.3 Evidence for no wind farm related changes

Results from other monitoring surveys provided no evidence for wind farm related changes. There is no evidence from the available data considered in this Summary Report for a wind farm related effect on the Lincolnshire beach profiles. The Lincolnshire shoreline behaviour remains dominated by the re-nourishment activities, and the analysis undertaken by the EA did not demonstrate that the presence of the wind farms has altered this behaviour.

The subsea operational noise from the wind farms is unlikely to cause a significant behavioural response in the marine animals found in the region, with the increase in the species perceived noise levels at LID considered to be within the typical variation expected for shallow water regions.

The presence of the wind farms has not caused any notable changes or trends in sediment type or seabed elevation across the sites, with the possible exception of the increased observation of clay patches post-construction. The geophysical surveys have illustrated that the seabed in the vicinity of the LID sites is subject to gradual changes during the post-construction survey years.

In general, both seasonal and annual variations in the fish populations were noted from the LID monitoring surveys. These variations largely agreed with the wider patterns noted in the fisheries landings data, and therefore could not be attributed to the LID wind farms. No gross changes in species composition occurred between the pre-construction and post-construction surveys. Regarding the potential effects of EMF, whilst *Raja clavata* did appear to have higher catch rates in the vicinity of the LID wind farm sites (the wind farms and along the export cables) post-construction compared with pre-construction, this apparent difference in catch rates was within the natural fluctuation recorded for the species across the survey sites and years. For other species of elasmobranchs, catch rates were sporadic across the survey sites and years and no general patterns could be observed. Therefore, no discernible EMF effect could be measured, within the known limitations of the paucity of sampling sites within the LID wind farm sites post-construction. In general, the fish monitoring surveys supported the predictions made within the LID ESSs, with localised changes not shown to have had an impact on fish stocks over the wider area and in the longer term.

Regarding benthic ecology, the results of the monitoring surveys have indicated that the construction of the LID offshore wind farms has not had a significant effect on the benthic habitats or communities present in the vicinity. Furthermore, the data indicated that the presence of the LID offshore wind farms has not affected the ability of reef building species to form reef habitats, with Annex I reef habitats recorded post-construction within the offshore wind farm sites and outside the offshore wind farm boundaries.

In addition to the observations reported above regarding potential effects on ornithological receptors, with the possible exception of Red-throated diver the boat-based bird survey monitoring suggested that there was no particular evidence for any significant or sustained displacement from the LID sites based on the remaining key species investigated, and confirmed the predictions in the ESSs that displacement would be unlikely for Gannet, Common tern and Razorbill (although the low numbers of Common tern and Razorbill limited the robustness of the analyses). No statistical changes in the use of the LID sites and buffers that could be linked to the construction and operation of the wind farms were identified for Common gull, Herring gull, Great black-backed gull and Gannet.

6.2 Overall Conclusion

A series of surveys have been carried out at the LID sites and wider survey area for a range of environmental parameters, to fulfil the requirements of the monitoring programme set out in the LID FEPA Licences. Data have been collected over a 10 year period, with the first survey taking place in 2002 and the final survey being carried out in 2012. During this timeframe, scientific understanding has evolved and new guidelines and standards for surveys and approaches to monitoring programmes have been produced, as would be expected. In analysing the data collected during the LID monitoring period, such limitations need to be understood and taken into account where possible, as is the case in this report. Despite these limitations, the data collected during the LID monitoring programme have been explored to the best extent possible through use of various analyses. This has enabled trends to be revealed in the data, and interpretation of these trends in terms of possible wind farm related changes and comparisons with the ESs.

GLID have therefore complied with the requirements of the FEPA Licences with respects to environmental monitoring and it is considered that these requirements are now closed.

Table 65: Monitoring outcomes with respect to FEPA Conditions and monitoring questions.

Monitoring Parameter	FEPA Conditions	Monitoring Question	Monitoring Outcome
Suspended Sediment Concentrations and Currents	9.26, Annex 1 (1), Annex 1 (3)	Q1: Do the results from the suspended sediment concentration monitoring and current monitoring validate and confirm the predictions made in the Lynn and Inner Dowsing ESs?	Elevated suspended sediment concentration levels were measured over the construction period during storm events, with construction activities on the seabed thought to be responsible for increasing the supply of sediment available for suspension within the vicinity of the wind farms. The ABPmer (2006) study investigating the disposal of drill arisings associated with monopile installation provided a more useful reference point to compare with the monitoring results than the LID ESs, and predictions made within this study compared favourably with the field measurements of elevated SSC. Wave conditions during the construction phase were likely to have contributed to the elevations in SSC observed in the field. Both the predicted SSC and the measured concentrations illustrated levels above background concentrations, however, these elevations were short lived. The measured currents at the LID sites matched the modelled results presented in the ESs. The wake study confirmed the presence of a turbulent wake in the lee of a monopile extending 400 m downstream (the measurement distance limit) at maximum tidal streaming during flood and in the direction of the prevailing tidal current. The current modelling in the ESs also suggested that turbulence generated around the monopiles following construction would cause local scour pits at the seabed and make sediment readily available for suspension and transport by the waves and tidal currents. The suspended sediment levels recorded by the monitoring sites during the post-construction period showed that SSC levels were generally low and varied only with the spring and neap tide cycle (noting there were no storm events during the post-construction monitoring period). It was concluded from the field measurements of waves, currents and sediment concentration that the far-field effect on the movement and distribution of seabed sediment was insignificant and that the impact to the suspension of material off the seabed was local to the wind farm sites during construction, and of a short term duration.
Beach Profiles	9.6, Annex 1 (4)	Q2: Within the limitations and constraints of the data, to what extent can the beach profile monitoring be used to validate the predicted changes to long-shore transport as provided in the ESs and ES Addendum, and the conclusions of the ESs and ES Addendum?	The scale of the installed development is smaller than the consented scheme, whereby the installed scheme provides less blockage to the tides and waves. Therefore any potential effects which may result from the installed wind farms are likely to be less than as concluded in the ESs and the Coastal Processes Addendum. A consideration of beach profile behaviour along the Lincolnshire coast, as reported by the Environment Agency, concluded that the current behavioural tendencies remain as reported historically. The shoreline behaviour remains dominated by the re-nourishment activities, and the analysis undertaken by the Environment Agency does not demonstrate that the presence of the wind farms has altered this behaviour. The conservative UNIBEST predictions show that the only area with a potential for longshore transport to be influenced by the wind farms is between Skegness and Gibraltar Point. This prediction was made on the basis that the wind farms will have a minor effect on waves passing to the coast. It was considered that the scale of any variation in beach profiles along the Lincolnshire frontage will remain dominated by the variation in re-nourishment volumes and annual and seasonal variation in the wave regime.
Subsea Noise	9.7, Annex 1 (8)	Q3: Do the post-construction subsea noise survey results suggest that marine mammals and fish species will be impacted by any detected increase in subsea noise?	The post-construction subsea noise survey results do not suggest that marine mammals and fish species will be significantly impacted by the detected operational noise, based on the perceived levels of sound for the marine species considered.
		Q4: How do these results compare with the predictions made in the Environmental Statements regarding the effects of operational subsea noise on fish and marine mammals?	The LID post-construction subsea noise survey detected an overall increase in noise, compared to background noise, in and around the wind turbine array for frequencies from 2 to 200 Hz. However, the increase in the species perceived noise levels at LID are considered to be within the typical variation expected for shallow water regions. It was concluded that the operational noise from the wind farms is unlikely to cause a significant behavioural response in the marine animals found in the region. The Lynn ES acoustics and vibration chapter concluded that no adverse impacts were expected from the operational phase. This prediction is supported by the results of the operational subsea noise monitoring.
Fish Communities	9.8, Annex 1 (6), Annex 1 (7)	Q5: To what extent does the post-construction monitoring validate the predictions made in the ESs, particularly in regard to electro-sensitive species?	The predictions made in the LID ESs of localised effects (from suspended sediment and turbidity, sediment redistribution, loss of habitat and creation of new habitat) that would not be discernible, are borne out by the site-specific monitoring data, with the general annual variations noted also occurring in the wider fisheries data, and not attributable to the wind farm construction activities. However, the paucity of surveys undertaken within the wind farm development areas post-construction limits the assessment of any localised effects of seabed disturbance from the construction activities on fish and shellfish populations. Regarding operational noise and vibration, within the limits of the site-specific fish survey data collected (i.e. lack of data collection with the LID wind farm sites post-construction), no discernible effects of the wind farms on the fish community composition were observed, including effects of operational noise. There was opportunity to appraise the effects of construction noise given the Lincs piling events coinciding (e.g. on the same date) with a limited number of LID site-specific shrimp and potting surveys, with no discernible adverse effects of construction noise on the fish community composition and specifically on shellfish populations noted. Regarding the effects of EMF, no discernible adverse effects on fish populations were noted, with possible effects on shellfish populations more likely to be attributable to geographic variations rather than as a result of the presence of the LID export cables. General observations of catches in electro-sensitive species such as skates and rays in site-specific longlining and otter trawl surveys gave lower catch rates of these species pre-construction compared with post-construction, which could suggest attraction of these species to the general area of the LID wind farms, however this also followed the general annual variation trend observed for the wider landings data, and therefore is unlikely to be attributable to the LID wind farms.
		Q6: Are the same species assemblages represented in the post-construction surveys compared with the pre-construction surveys, including electro-sensitive species?	The general changes between the LID pre-construction and post-construction surveys were of abundances in species, rather than reflecting a change in the species composition between these survey years. No gross change in species composition between pre-construction and post-construction surveys was observed for any of the site-specific survey types.
		Q7: Is there evidence for any increasing or decreasing trends in species abundance and whether this could be attributable to the wind farms?	Site-specific inter-annual variations were generally reflective of variations in the wider fish community (based on landings data as a proxy), therefore there is no evidence to link cause and effect with the construction of the LID wind farms. However, there was a general lack of sampling within the LID sites post-construction, which meant that any effects local to the wind farm development sites, as predicted in the LID ESs, would be undetectable.
		Q8: Is there evidence for changes in species distribution within and around the wind farm sites and whether this could be attributable to the wind farms?	No geographic changes in community composition were noted for any of the trawl surveys (otter, beam and shrimp) or the longlining survey. The only survey for which geographic differences were noted was for potting, with differences between the cable route sampling sites and sites to the south. Whilst the potential for EMF from LID export cables was considered, it was thought that this change was more likely to be attributable to the shallow coastal locations of these survey sites, compared to the offshore, deeper water southern sites.
Marine Mammals	9.12, 9.13, 9.14, 9.15, 9.16, 9.17	N/A	Marine mammal monitoring was carried out during the construction phase of the LID projects, with the results submitted to the Licensing Authority in the Construction Monitoring Report (CREL, 2009). No post-construction monitoring was required for marine mammals.
Seabed Morphology and Scour	9.23, 9.24, 9.27, 9.28, 9.29, 9.33, Annex 1 (2)	Q9: Has the third post-construction geophysical survey carried out in 2011 revealed similar or different sediment types and distributions across the survey area compared with the surveys of 2002, 2009 and 2010?	The 2011 survey revealed that the dominant sediment type within the survey area is featureless gravelly SAND to sandy GRAVEL, which is consistent with the results from the previous surveys. However it was found that the number of clay patches within the survey area was greater in the 2011 survey results than in the previous survey results, which could be attributed to decreased sediment input or increased erosion over the sites.

Monitoring Parameter	FEPA Conditions	Monitoring Question	Monitoring Outcome
		Q10: Are there any similarities or differences in the presence or location of seabed features between 2011, 2010, 2009 and 2002?	Megaripples were recorded across the sites in both the pre-construction and post-construction surveys, and although these features were of a similar magnitude in terms of size across both the pre- and post-construction surveys, their location varied across surveys. This is indicative of a degree of sediment mobility across the surveyed area of seabed. A number of areas of low relief, linear seabed features, were observed in the first year of post-construction (2009), however the subsequent surveys illustrated erosion of these features, with the features not recorded in the most recent (2011) dataset.
		Q11: Are there any changes in seabed elevation and topography between survey years and if so, how has this affected inter-array and export cable burial depth?	A comparison of the successive years of bathymetric surveys across the wind farm sites did not reveal any notable trends in seabed elevation (in terms of either erosion or accretion). Any observed changes were localised and generally related to features associated with construction or infrastructure (noting the above discussion of bedform variability over time). Therefore any changes observed around inter-array cables are related more to the localised processes of scouring associated with the presence of the cables (or relic plough features) themselves, as opposed to changes to burial depths as part of a wider net trend in seabed levels. Some inter-array cables have been noted as illustrating some scour (and corresponding accumulation). This process is more commonly recorded for east – west orientated cables (as opposed to north – south), which is potentially related to the east – west aligned cables being perpendicular to the predominant north – south orientated flows. A trend of sediment accumulation was recorded for the export cables across the post-construction surveys.
		Q12: Is there evidence of scour around the wind turbine foundations?	Scour is occurring around the majority of the LID wind turbine foundation locations, with the greatest amount of scour observed at location LN21 from both the 2009 and 2011 datasets.
		Q13: Are any new obstructions apparent between the 2002 and post-construction surveys which may be debris left from the construction of the wind farms?	A larger number of sonar contacts were detected during the 2011 survey analysis compared with all previous survey years, attributed to the different identification parameters used for each survey, and due to the higher resolution and quality of the 2011 survey compared with previous years. Two contacts were identified as obstructions from the 2011 analysis, and it was considered by EGS Ltd (2012a) that these were first detected in the 2002 pre-construction survey. It would therefore appear that these two obstructions are not related to the construction of the wind farms.
		Q14: Has the monitoring confirmed the predictions in the ESs in relation to scour?	The results of the monitoring survey in 2011 have revealed that the overall average horizontal scour extent was interpreted to be 15.1 m, with the overall average vertical scour extent interpreted to be 1.7 m, confirming the predictions in the ESs that the scour is localised. The magnitude of scour recorded in the post-construction monitoring surveys confirms that scour pits from individual turbines will not interact with scour pits from adjacent turbines. The ESs considered that the rate of scour would be most rapid immediately following construction, and then would decrease towards an equilibrium. The datasets suggest that scour processes are ongoing, as recorded by the increased vertical scour extents between the Year 1 and Year 3 post-construction surveys. This relatively slow development of scour is likely to be related to the nature of the underlying clay substrate. While the Year 3 survey records the continuing development of scour at turbines, a larger proportion of the total scour recorded occurred prior, and up to, the Year 1 survey, therefore the observations to date broadly support the qualitative predictions regarding rate of scour.
Benthic communities	Annex 2 (5)	Q15: Do the results of the annual post-construction monitoring surveys provide evidence that the construction of the wind farms has had an effect (positive or negative) on the benthic communities present in the vicinity of the wind farms? If the findings of the monitoring surveys have shown negative effects of wind farm construction, is there evidence of recovery of the communities present?	The results of the pre-construction and post-construction monitoring surveys indicate that the construction of the LID offshore wind farms has not had a significant effect on the benthic habitats or communities present in the vicinity of the offshore wind farms. The communities recorded are typical for this region of the southern North Sea and are naturally variable, with changes in the communities recorded annually. Furthermore, many of the species recorded during post-construction surveys are indicative of habitats which have not been recently exposed to large scale disturbance or sediment deposition. The benthic survey results relating to individual features (e.g. drill arising mounds and jack-up footprints) are discussed below.
		Q16: Do the results of the three annual post-construction monitoring surveys provide evidence that the construction of the wind farms have had an effect (positive or negative) on Annex I biogenic reef communities (specifically <i>Sabellaria spinulosa</i> and mussel reefs)? Do the results of the monitoring surveys provide information on the changes in locations, distribution and extents of Annex I reef features between pre-construction (2005) and post-construction (Year 1, 2 and 3)?	The data collected on Annex I reef habitats during the pre-construction and post-construction surveys provided further evidence of the high natural variability expected for habitats dominated by these three reef forming species. During pre-construction surveys, the only potential reef habitats were recorded at far field sites to the south of the LID offshore wind farm sites and at a reference location to the east, with no reef habitats recorded within the offshore wind farm boundaries. During post-construction surveys, reef habitats were recorded within and around the LID offshore wind farm sites, with most of the potential reef habitats identified as being ephemeral in nature (i.e. recorded during one survey only). Although some areas of reef were identified as being more long lived, the presence, distribution and extents of these habitats in the future is likely to be heavily influenced by the dynamic nature of the environment and the natural variability of these reef building species. The pre-construction and post-construction data indicate that the presence of the LID offshore wind farms has not affected the ability of reef building species to form reef habitats, with Annex I reef habitats recorded post-construction within the offshore wind farm sites and outside the offshore wind farm boundaries.
		Q17: Do the results of the Year 3 post-construction monitoring survey provide evidence that benthic (epifaunal and infaunal) communities within jack-up footprints are significantly different from those outside the jack up footprints?	The findings of the jack-up footprint survey carried out in 2011 showed that the benthic communities were broadly similar within and outside the jack-up footprints. PSA data within and outside jack-up footprints were similar, though a slightly lower proportion of fine sediments was recorded within the two surveyed footprints compared to the respective jack-up ‘reference’ sites. Evidence from the geophysical surveys indicated that many of these footprints are gradually infilling due to sediment accumulation (noting that some footprints were no longer visible in the 2011 dataset). Infaunal communities within the jack-up footprints were also found to be similar to those at the ‘reference’ locations. There were, however, slight differences between the communities when replicate samples were compared, with mollusc species, recorded at lower abundances within jack-up footprints than at adjacent reference locations, largely accounting for the differences observed. This was also reflected in the biomass data. For other taxonomic groups, the community composition was similar between the footprints and reference locations, and DDV footage and grab data also showed that epifaunal communities were similar between jack-up footprints and adjacent ‘reference’ locations. The reduced abundances of the mollusc species within the footprints may be due to the slower recovery rates associated with these species, though it may equally be because of natural variability in the distribution of these species. Due to the small size of the dataset, it is not possible to draw conclusions about the reasons for the differences in abundances of these species, however the survey shows clear evidence of almost complete recovery of the communities within the jack-up footprints.
		Q18: Has the monitoring confirmed the predictions of the ESs in relation to impact on benthic communities?	The pre-construction and post-construction benthic ecology surveys indicated that cable laying operations affected a limited area (in terms of direct habitat loss), and that recolonisation by benthic species occurred quickly following disturbance, confirming the ESs prediction that the impact of temporary habitat loss due to cable laying would be “low level” and “medium term”. Regarding seabed sediment disturbance, the monitoring surveys indicated that effects on benthic communities from increases in SSCs and sediment deposition were limited and if adverse effects occurred, then full recovery has taken place since offshore wind farm construction. The results of the monitoring surveys therefore validate the predictions made in the LID ESs of very low impacts on benthic communities from raised suspended sediment levels, and no adverse impacts from sediment deposition. In terms of impacts from construction vessels on the seabed, the jack-up footprint survey confirmed (as noted in the table entry above) the predictions made in the ESs of rapid recolonisation, with almost full recovery of the benthic infaunal and epifaunal communities within the footprints within approximately 3 years of construction.

Monitoring Parameter	FEPA Conditions	Monitoring Question	Monitoring Outcome
Ornithology		Q19: Has the post-construction monitoring revealed any significant changes in the abundance and distribution of the key species and species groups?	Density surface modelling results from aerial surveys of the wider Greater Wash region showed no obvious increasing or decreasing trends between years for the species groups investigated, though numbers in each species group fluctuated between years. At the site-specific level, statistical modelling of the boat-based bird survey data revealed that at least nine of the 13 key receptors showed statistically significant changes in abundance over time, however, only four of these receptors (Kittiwake, skuas, Guillemot and Sandwich tern) demonstrated trends which could be linked with the construction and operation of the wind farms (the low numbers of skua species reduces confidence in this result however). Red-throated diver exhibited some evidence of displacement although this was not statistically significant, and visual inspection of the aerial bird survey results also suggested that displacement of divers from the LID wind farms could have taken place . The boat-based bird survey monitoring revealed no particular evidence for substantial or sustained displacement of the remaining key bird species considered from the wind farm sites.
		Q20: Are the changes observed attributable to the wind farms?	Some of the changes observed at the site-specific level may be associated with the construction and operation of the wind farms. Kittiwake, skuas and Guillemot increased in the LID sites during the construction phase, declined in the first two years of operation then increased again in the third year. Attraction during the construction phase may have resulted from the provision of structures acting as perches, or from an increase in prey availability, and attraction in the third year of operation may be explained by increases in prey resulting from ‘reef effects’ or may have been associated with construction activity at the adjacent Lincs wind farm. The increase in Sandwich tern population using the LID sites (specifically the Lynn site) throughout the monitoring years may also be linked to the indirect reef effects associated with the presence of the wind farms. However, there is no strong evidence which links prey availability, reef effects and bird abundance in relation to the LID sites, due to the lack of data at suitable scales sampling bird prey resources . In relation to Guillemot, the aerial survey results indicated that the numbers of auks appeared to be significantly higher during winter 2011/12 (end of the third year of operation as defined for the boat-based bird survey analyses) than in most previous winters. Thus, the increase in Guillemot in the wind farm sites in the third year of operation (boat-based surveys) may have represented an increase in the wider area and not a specific attraction to the LID sites. Divers are known to be disturbance sensitive (Garthe and Huppopp, 2004; McCluskie <i>et al.</i>, 2013; Shwemmer <i>et al.</i>, 2011). The implications of displacement at LID are likely to be limited given the low numbers of Red-throated diver originally using the LID sites and availability of similar habitat in close proximity to the wind farms.
		Q21: Has the monitoring confirmed the predictions in relation to impact on bird species?	The boat-based bird survey monitoring suggested that there was little statistical evidence for any significant disturbance or displacement from the LID sites, confirming the predictions that displacement would be unlikely for Gannet, Common tern and Razorbill (although the low numbers of Common tern and Razorbill limited the robustness of data analysis). However, Red-throated diver presented some evidence of disturbance and potentially displacement. The ESs predicted that divers feeding within the wind farm area would be sensitive to disturbance during construction, however it was considered that divers would not be permanently displaced during operation, provided their prey remained within the sites. Despite this prediction, it is widely known from research that diver species are sensitive to disturbance and displacement impacts (Garthe and Huppopp, 2004; McCluskie <i>et al.</i>, 2013; Shwemmer <i>et al.</i>, 2011). The increase in number of skuas, Kittiwake, Sandwich tern and Guillemot which may indicate attraction effects, were not predicted. Predictions of collision mortality of Pink-footed goose from the radar monitoring results are below the predictions made at the pre-construction stage, and more recently (BERR, 2008).
Archaeology	9.31	N/A	The FEPA Licence requirements for archaeology have been fulfilled, but it is worth noting that the Archaeological Protocol remains in place for the LID sites during the operational phase. GLID seek approval for the updated Protocol and the proposed revisions to the Archaeological Exclusion Zones presented in Appendix 8, from the Licensing Authority and English Heritage.
Drill Arisings	9.2, Annex (FEPA Licence 3553/07/0)	Q22: How have the recorded dimensions of the drill arising mounds changed over the course of the monitoring period?	The surveys directly following spoil disposal indicated an initial significant reduction in the height of the mounds. Following this initial trend, monitoring across the three post-construction years illustrated a trend of reducing mound height but at a much reduced rate, followed by stability in mound height in the more recent surveys. Given the number of mounds (6 across LID) and the dimensions of the monitored mounds (around 1 m above the height of the surrounding seabed), the mounds will not have a significant effect on the flow regime across the area.
		Q23: What are the implications of these results for benthic habitats?	Benthic ecology data collected at mound centres and surrounding areas during 2011 indicated that there are similarities between benthic communities at mound centres and those of surrounding areas. Abundances of the recorded species were lower at the mound centres, however the results provided evidence of recovery of benthic habitats and communities at the mounds and in close proximity to the mounds and that this is occurring even though the mounds are still evident. Given the small number of drill arising mounds in the LID sites (i.e. 6), the highly localised area affected and the evidence of recovery of biological communities at the two mounds monitored, it is considered that there are no long term implications for the benthic environment of the LID sites from the presence of these mounds.
		Q24: What are predictions going forward?	It is not possible to quantitatively predict the rate of change across the mounds with a high degree of confidence. Based on the trends observed and described in this report, it would be expected that the mounds will continue to remain relatively stable over the coming years, although some degree of lowering may occur. In terms of surface sediment composition, the finer (baseline) sediments surrounding the mounds would be expected to continue to be incorporated into the surface of the mound centres through background sediment transport. Whilst the evidence base for these processes from the monitoring is good, there will remain some uncertainty in the rate of the processes, and spatial variability will occur across the sites.

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8 Appendices

Appendix 1: LID FEPA Licences

Appendix 2: Beach Profiles

Appendix 3: Subsea Noise

Appendix 4: Fish Community

Appendix 5: Seabed Morphology and Scour

Appendix 6: Benthic Ecology

Appendix 7: Ornithology

Appendix 8: Archaeology

Appendix 9: Drill Arisings

Appendix 10: Table of Project Correspondence

Appendix 11: Response to Licensing Authority Comments