



**London Array Offshore Wind Farm:
Ornithology Aerial Survey Report 2013 / 2014**

London Array

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EXECUTIVE SUMMARY

1. This report provides a summary of the aerial surveys conducted during 2013 / 14. Post-construction monitoring works are currently on-going and additional preliminary analysis of the effect of constructing and operating the London Array Wind Farm (OWF) on diver populations has been undertaken and will be presented as an addendum to this report.
2. The site of the London Array OWF plus a buffer around the wind farm (total = 'Zone 1') in the Outer Thames estuary was surveyed four times (once per month in November, December, January and February) during the winter of 2013 / 14, using digital high resolution still imagery.
3. A control zone ('Zone 2') was surveyed with the same frequency over the same period, to satisfy Marine Licence conditions.
4. Phase 1 of the London Array OWF construction started in March 2011 and the first turbine was in operation by October 2012. The wind farm was fully operational by April 2013 with inauguration of the wind farm in July 2013. Construction of Phase 2 was cancelled in February 2014.
5. The 2013 / 14 aerial surveys are the first winter post-construction surveys of the Phase 1 development site in the London Array OWF site. Pre-construction aerial surveys were carried out during the 2009 / 10 and 2010 / 11 winters, and during-construction surveys in the 2011 / 12 and 2012 / 13 winters.
6. Surveys were conducted on a systematic grid of 500 m separation, with images at 3 cm GSD resolution. An average zonal coverage of 15% was obtained.
7. The majority of divers recorded were red-throated divers (97.4%); the remainder were recorded as black-throated divers and great northern divers. The total diver population estimated across Zone 1 and Zone 2 was low in November 2013 with moderate numbers recorded in January and February 2014. Total diver numbers peaked in December 2013 with 5,748 (4,804 - 6,821) estimated to be present.
8. Diver distribution appeared to reflect shallow water areas that include the Margate and Long Sands sandbanks. Approximately 97% of all divers were in water depths of < 20 m.
9. The highest concentrations of divers were recorded in the north-eastern part of Zone 1 in December 2013. This distribution of divers in Zone 1 was broadly similar to that observed pre-construction.
10. Diver abundance and distribution between Zones 1 and 2 changed over the past four years of winter aerial surveys (2010 / 11 - 2013 / 14). Peak diver numbers in Zone 1 containing the Phase 1 London Array wind farm fell between the 2010 / 11 (pre-construction) and 2011 / 12 (first year of construction), before rising again from February 2013 (post-construction) and 2013 / 14 (Table Exec 1, Figure 4.3). Peak diver numbers in control Zone 2 increased in 2011 / 12 before reverting to broadly pre-construction levels in 2012 / 13 and 2013 / 14 (Figure 4.4). This suggests that divers may have been displaced by construction activity into adjacent control zone.

Table Exec 1 Monthly raw counts of red-throated divers in Zone 1. Diver numbers increased following the placement of the last turbine in early January 2013. However January and February have previously been identified as peak months for red-throated divers wintering in the Greater Thames estuary (Webb *et al.* 2009) and an increase of even greater magnitude between January and February was recorded in 2011 prior to windfarm construction. Pale green cells show periods when London Array was being built.

Date	2010 / 11	2011 / 12	2012 / 13	2013 / 14
November	18	2	27	15
December	184	2	9	1,023
January	144	181	193	261
February	1,257	155	665	279
Total	1,603	340	894	1,578

11. During the post-construction surveys in 2013 / 14 higher numbers of red-throated divers were observed in Zone 1 during the December 2013 survey than during the three previous December surveys. The total count of 1,578 red-throated divers recorded in 2013 / 14 was similar to the 1,603 observed pre-construction in 2010 / 11 (Table Exec 1). This suggests a continuing increase in diver numbers following the completion of the main body of work in December 2012. However, diver numbers are not equally distributed throughout Zone 1 and are low within the Phase 1 wind farm boundary and in the areas within at least 2 km of it. Further post-construction surveys should show whether divers continue to increase in Zone 1 and whether divers move closer to the active wind farm area.
12. Large inter-annual variation in recorded diver numbers is common. Aerial surveys of the London Array OWF conducted by APEM Ltd have recorded variation in peak population estimates between years (APEM, 2010; 2011a; 2011b; 2012; 2013a; 2014). This is in accordance with aerial surveys over the last 10 years in the Greater Thames area (Webb *et al.* 2009). Reasons for this variation could include effects of weather, natural variation, diurnal distribution, effects of construction etc.
13. Other bird species / groups recorded in the 2013 / 14 aerial survey included, fulmars, gannets, cormorants/shags, cormorants, grebes, pomarine skuas, small gulls (including kittiwakes, black-headed gulls and common gulls), large gulls (including lesser black-backed gulls, herring gulls and great black-backed gulls) and auks (all identified as guillemot / razorbill). Gulls were the most abundant species group after divers.
14. The majority of marine mammals recorded across all zones during the 2013 / 14 aerial survey were seals (64% of total marine mammals). The remaining individuals were recorded as dolphins / porpoises (27%) and harbour porpoises (9%). Seals were recorded in each survey, except January 2014 and were most abundant in Zone 1 in February 2014. Dolphins / porpoises and harbour porpoises were most abundant in Zone 1 in November 2013.

1. INTRODUCTION

1.1 Aerial surveys

This report summarises the findings of the first post-construction aerial surveys of the birds and marine mammals present in the London Array Limited Offshore Wind Farm (OWF) site (hereby referred to as London Array OWF site) containing Phase 1 development and the associated “control” Zone, surveys carried out during the 2013 / 14 winter.

Previously the London Array OWF site consisted of Phases 1 and 2 development areas as well as two other areas not currently under consideration for development (one to the south of Phase 1 and the other to the north of Phase 2, see Figure 2.1). In February 2014 the decision was made to not progress with the development of the Phase 2 area. Due to the cancellation of Phase 2 development, the boundaries of the London Array OWF site have since changed and the London Array OWF site refers to the Phase 1 development only (Figure 2.2).

Pre-construction aerial surveys were carried out over the winters of 2009 / 10 and 2010 / 11. Offshore construction for the Phase 1 area of the London Array OWF site commenced in March 2011 and the first of 175 turbines was installed in January 2012. The first year of during construction aerial surveys were carried out over the winter of 2011 / 12. The final turbine was installed in December during the winter 2012 / 13 surveys (Figure 2.3). Phase 1 was fully operational by spring 2013, although some residual construction works were undertaken over the summer / autumn of 2013 and 2014. At all times there will be a programme of turbine maintenance. A construction schedule can be found in Appendix I. This report describes the findings of the first year of post-construction surveys carried out over the winters of 2013 / 14.

DONG Energy, on behalf of London Array Ltd., has commissioned APEM Ltd. to collect high definition digital aerial images over London Array OWF site and associated control zones over the winter months (November, December, January and February) since 2009. During the winter of 2009 / 10 two control zones were surveyed as well as the London Array OWF. In the winter of 2010 / 11, 2011 / 12 and 2012 / 13 five control zones were surveyed as well as the London Array OWF site plus an extra buffer around the wind farm. During 2013 / 14 one control zone was surveyed as well as the London Array OWF plus buffer.

The aerial surveys were designed to meet the requirements of the Marine Licence¹ granted in respect of the wind farm, and to satisfy the wider Ornithological Review Panel (ORP) process. The ORP was set up prior to award of consent as an expert panel comprising representatives from London Array, Natural England and Royal Society for Protection of Birds. The aim of the ORP was to discuss and agree the scope of the ornithological monitoring required under the phased approach in the London Array Marine Licence, and to agree an interaction figure thought unlikely to have an adverse effect on the integrity of the Outer Thames Estuary SPA. In order to satisfy Marine Licence conditions, pre-, during and post-construction monitoring for phase 1 of the wind farm is required, necessitating aerial surveys of the London Array OWF site plus a buffer around the site (Zone 1) and a control zone (Zone 2). Aerial surveys designed to support a Phase 2 application covered additional control zones (Zone 3, 5, 6 & 7) in the Thames Estuary fulfilling the ORP process with regards to future (now redundant) phases of development.

¹ The Marine Licence, issued in August 2012 replaces and combines the previous FEPA and CPA licences.

1.2 Importance of the Outer Thames Estuary for red-throated divers

During the non-breeding season, red-throated divers aggregate in often large groups in offshore areas. The Outer Thames Estuary SPA (Special Protection Area) has been identified by Natural England using data collected from aerial surveys during the period from January 1989 to winters of 2005 / 06 and 2006 / 07 and analysed by the Joint Nature Conservation Committee (JNCC) Seabirds and Cetaceans Team. These data show that the Outer Thames Estuary SPA regularly supports numbers of wintering red-throated diver that are of European importance, exceeding 1% of the Great Britain (GB) population of 17,000 birds. The red-throated diver is listed under Annex I of the EU Birds Directive (79/409/EEC) as being a rare or vulnerable species, meaning that EU member states are obligated to identify and designate key areas of habitat used by the species as SPAs. Sites supporting 1% or more of the GB population of an Annex I species are automatically considered for SPA designation (Stroud *et al.* 2001). Visual aerial survey estimates for the Outer Thames SPA place the wintering total at 6,466 individuals or 38% of the GB estimate (O'Brien *et al.* 2008). The SPA covers over 379,268 ha of offshore habitat between Kent and Norfolk. Over the wider Greater Thames area, estimates of 8,130 red-throated divers have been made, representing 47% of the national estimate (O'Brien *et al.* 2008).

1.3 Aim and objectives

The aim of this project is to provide information about the response of and risks to bird species (predominantly, but not exclusively, red-throated diver *Gavia stellata*), arising from the construction and operation of the wind farm. The red-throated diver is listed under Annex I of the EU Birds Directive (79/409/EEC) as being a rare or vulnerable species, meaning that EU member states are obligated to identify and designate key areas of habitat used by the species as Special Protection Areas (SPAs). Sites supporting 1% or more of the Great Britain population of an Annex I species are automatically considered for SPA designation (Stroud *et al.* 2001).

The defined objectives of the project are to:

1. Provide baseline surveys of Phase 1 pre-, during and post-construction in the London Array OWF site;
2. Provide baseline surveys of the, now cancelled, Phase 2 and the rest of the OWF not currently under construction;
3. Provide pre-, during and post-construction baseline surveys of control zones for the OWF site;
4. Describe temporal and spatial variation in bird numbers across the OWF and control zones;
5. Produce population estimates, with a given level of precision, for birds across the OWF and control zones;
6. Produce updated estimates of red-throated diver abundance and distribution within the OWF and control zones, with respect to the Special Protection Area (SPA) in the Outer Thames Estuary.

2. METHODS

2.1 Survey design

High definition digital aerial surveys were conducted during the winter period between November 2013 and February 2014. Four surveys of two zones were completed in total, with one survey conducted each month.

Each survey was flown on a 500 m grid at a 3 cm ground sampling distance (GSD) resolution to ensure comparability with the 2010 / 11 pre-construction survey and 2011 / 12 and 2012 / 13 during construction surveys (for detailed rationale, see APEM 2010). The primary aim of APEM's grid survey methodology is to derive sufficient independent estimates of bird density (and distribution) to target a predefined level of precision around population estimates. The spacing of the grid (an image is collected at each grid internode) is determined by the predicted number of samples required to achieve the predefined level of confidence ($CV < 0.16$).

Aerial surveys were undertaken using either a Vulcanair P68 Observer twin engine survey aircraft or a Vulcanair P68C twin engine survey aircraft.

Surveys were flown in the following areas (Figures 2.1 & 2.2; for detailed rationale, see APEM 2011):

Marine Licence condition (environmental monitoring plan) areas

Zone 1: area encompassing the London Array Ltd OWF including the Phase 1 development site plus a buffer surrounding the OWF site.

After the 2009 / 10 aerial surveys, an additional area to the northeast of the London Array OWF footprint was added to Zone 1, encompassing an aggregate site and the whole of the Long Sand sandbar. A 1 km buffer surrounding Zone 1 was also added to examine bird density in surrounding shipping lanes after the 2009 / 10 surveys. During the winters of 2010 / 11, 2011 / 12, 2012 / 13 and 2013 / 14 surveys of Zone 1 included the, now cancelled, Phase 2 development site.

Zone 2: control zone to south west of London Array OWF site.

As per the 2010 / 11, 2011 / 12 and 2012 / 13 surveys. This zone was used to detect displacement of red-throated divers, as it contains sea bed mostly < 20 m deep and is largely devoid of shipping traffic, making it a likely suitable replacement habitat for any divers avoiding the wind farm area. An additional 1 km buffer surrounding Zone 2 was added to examine bird density in surrounding shipping lanes after the 2009 / 10 surveys.

Wider ORP process areas

In the previous winter surveys of 2011 / 2012 and 2012 / 13 Zones 3, 5, 6 and 7 were surveyed to provide a wider understanding of red throated diver populations in the Thames Estuary with the aim of supporting a Phase 2 development. It was agreed with the ORP that survey of these additional zones was not required as part of the post construction monitoring requirements related to the Phase 1 development and as such these zones are no longer required to be surveyed.

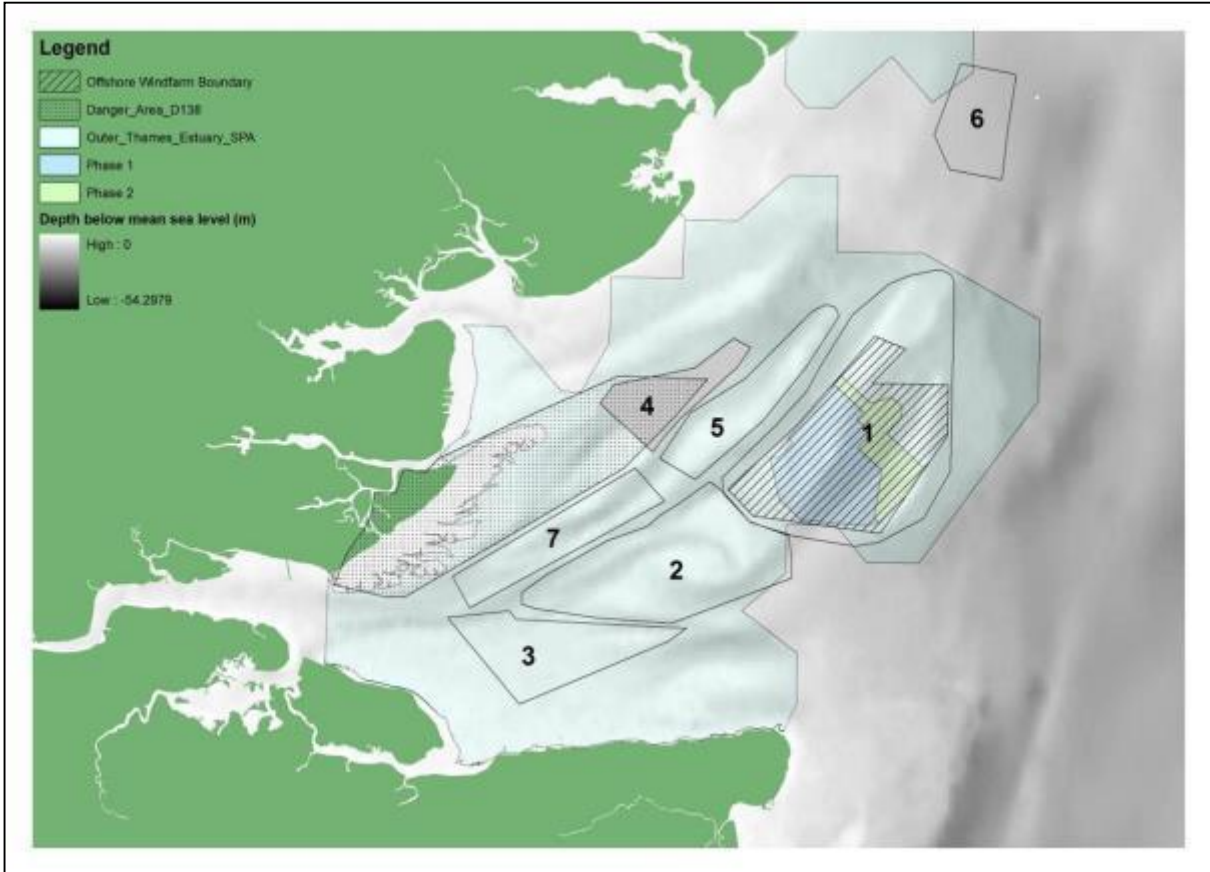


Figure 2.1: Layout of previous survey areas (Zones 1, 2, 3, 5, 6 and 7). Zone 1 contains the London Array OWF site (lined area). The London Array OWF site contains Phase 1 (lined blue area) and Phase 2 (lined green area) development sites as well as two uncoloured areas that are not currently being considered for development. Zone 2 is the Marine Licence control zone, while Zones 3, 5, 6 and 7 are the ORP Phase 2 additional zones. Zone 4 (grey) was not surveyed due to being part of MOD area D138 (dotted area). The Outer Thames Estuary SPA (light blue area), designated for wintering red-throated divers, is also shown.

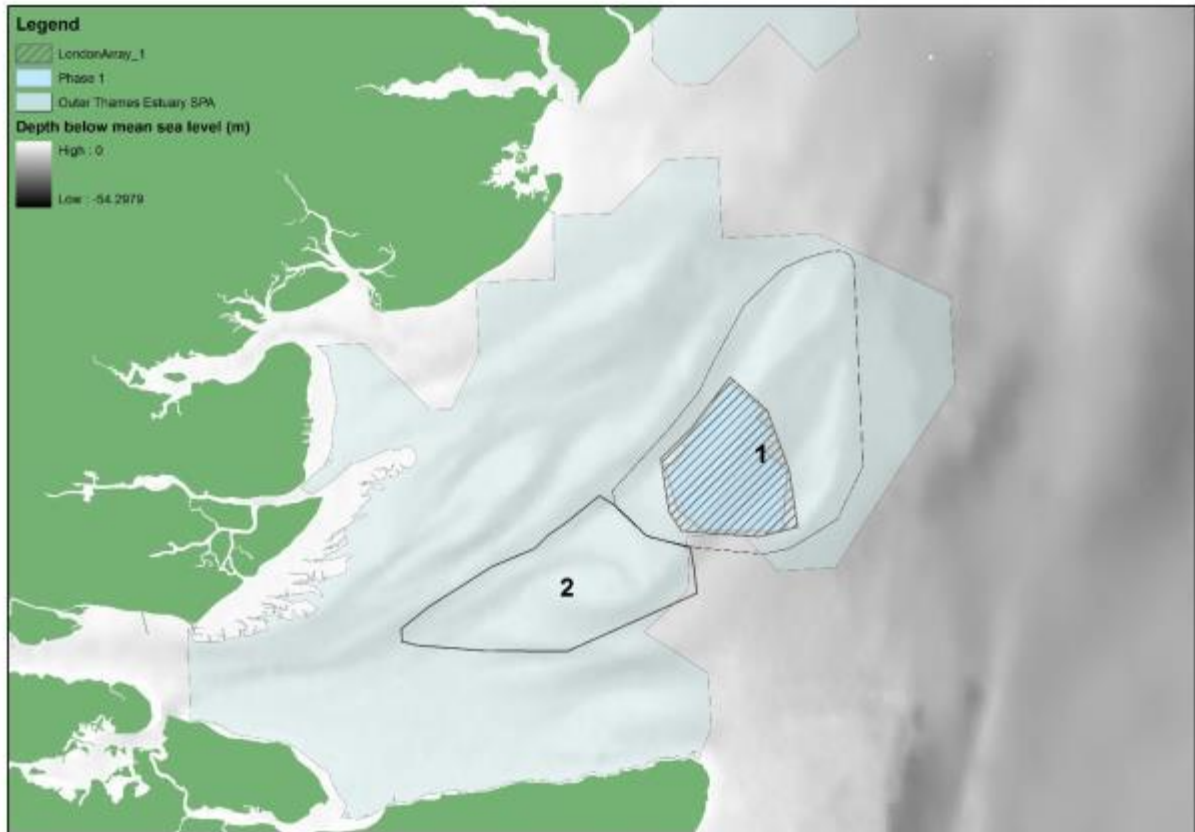


Figure 2.2: Layout of 2013 / 14 survey areas. Zone 1 contains the London Array OWF site (lined area). The London Array OWF site contains the Phase 1 (blue area) development site as well as two uncoloured areas that are not currently being considered for development. Zone 2 is the Marine Licence control zone. The Outer Thames Estuary SPA (light blue area), designated for wintering red-throated divers, is also shown.

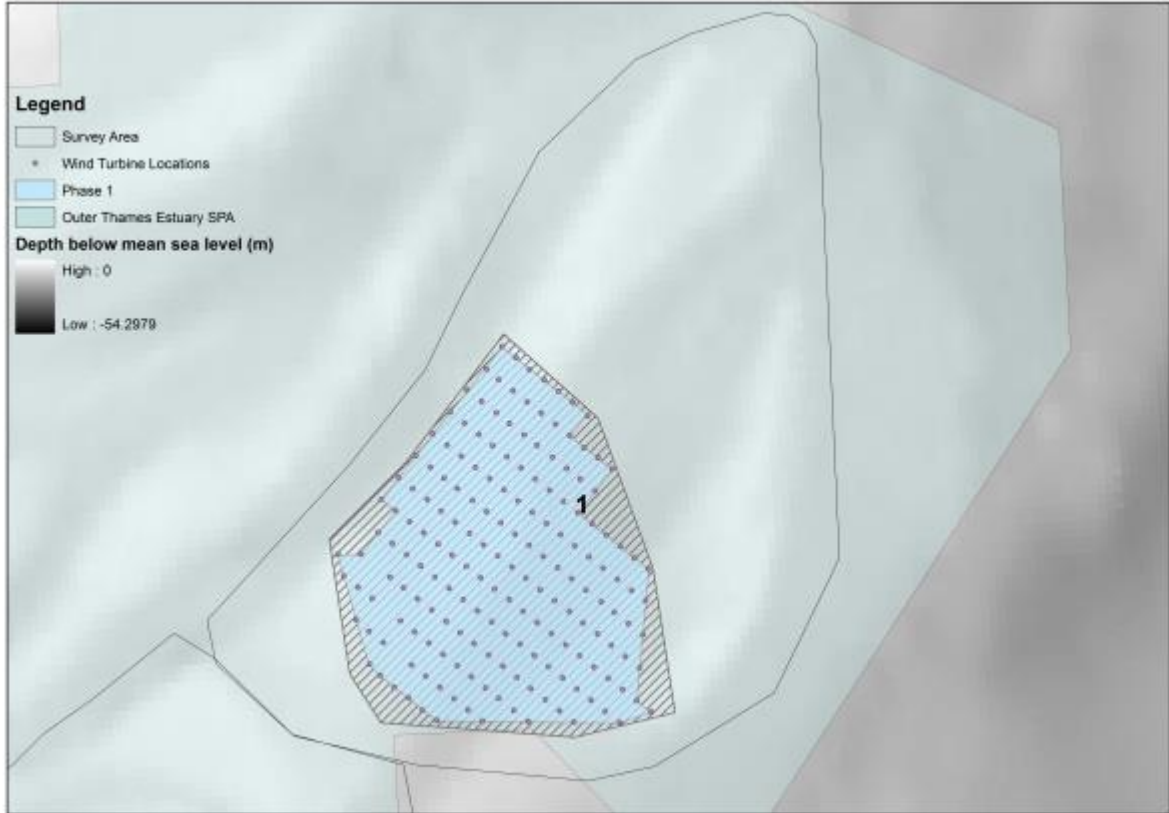


Figure 2.3: Layout of 175 turbines within Phase 1. Zone 1 contains the London Array OWF site (lined area). The London Array OWF site contains the Phase 1 (blue area) development site and each turbine is represented by a pink dot. The Outer Thames Estuary SPA (light blue area), designated for wintering red-throated divers, is also shown.

2.2 Survey information

Each survey zone was completed within a single day. Therefore, the order in which the zones were surveyed depended on the length of time available to complete each zone within a day.

Table 2.1: Survey dates of all four surveys conducted of Zone 1 and Zone 2 during winter 2013 / 14.

Survey	Month surveyed	Day surveyed	
		Zone 1	Zone 2
Survey 1	November	10 th	9 th
Survey 2	December	11 ^{th*}	9 th
Survey 3	January	10 th	11 th
Survey 4	February	3 rd	2 nd

* Due to poor weather conditions surveys were not completed on consecutive days

Weather Conditions

A breakdown of the weather conditions on each survey and any other significant information can be found in Appendix II.

2.3 Data collection

Flight planning software defines the required flying altitude and speed according to the camera, lens and required pixel resolution. Digital still images were collected with a 3 cm ground sampling distance (GSD) resolution.

Survey data are analysed to produce maps showing bird and marine mammal distribution and density in a GIS format. Photographs are imported as geo-referenced images (WGS 84 projection) into ArcView 9.2 (ESRI) and the following data are recorded:

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

Data on flight height are not considered essential, as the main species of interest are red-throated divers. Divers typically fly close to the sea surface (Blomdahl *et al.*, 2003), making collision with turbine rotors unlikely. However, such data can be derived from digital still images if subsequently required.

2.4 Quality Assurance procedure

A standard internal and external Quality Assurance (QA) procedure was carried out on each survey.

For the internal QA, images were assessed in batches with a different staff member responsible for each batch. Each bird image was reviewed and checked by APEM's own dedicated QA manager, ensuring that 100% of birds found in the images were subject to internal QA. The QA manager, an experienced ornithologist, is responsible for maintaining and updating the image library and also provides advice and guidance to the image processing staff. Images containing no birds were removed and kept separately for further QA. Of these 'blank' images, 20% were randomly selected for QA by the QA manager. If there was less than 90% agreement, the entire batch of images was re-analysed.

Upon completion of the internal QA, 20% of the birds located in each survey were subject to external QA by an independent organisation. The appointed auditors for seabirds are the British Trust for Ornithology (BTO). The images for external QA were selected at random using a random number generator. The selected images were provided to the BTO along with information on measured body lengths and wingspans of the birds. All identifications were conducted 'blind' by the external analyst. Upon completion, a matrix was created to show the proportion of agreement and identify areas of potential misidentification. It has been previously established that at least 90% agreement between BTO and APEM is required. Any disagreements were reviewed and if the 90% threshold was still not reached then a further 20% of images were assessed by the BTO. If 90% agreement was not achieved after secondary assessment, then the entire batch of images would be required to be reassessed and the QA process repeated.

For marine mammals, up to 100% of images from each survey containing such animals were sent for external identification. The appointed auditors for marine mammals are SMRU Marine Limited. Upon return of the SMRU identifications, the data was updated accordingly with any improvements on the level of identification already achieved by the image analysts and ornithologists at APEM.

2.5 Data analysis

Design-based abundance estimates

Design-based estimates of bird and marine mammal abundance with confidence limits (CL) and associated precision of estimates were calculated for each zone. All analysis and data manipulation were conducted in the R programming language (R Development Core Team 2010) and non-parametric 95% confidence intervals were generated using the 'boot' library of functions (Canty & Ripley, 2010).

Abundance estimates

To calculate abundance estimates, it is necessary to know the total number of images required to cover the survey area. This was done by calculating the average size of an image footprint. An average image footprint was calculated by dividing the sum of the image areas contained within the survey area by the number of images that were wholly or partially within the survey area. Average coverage was 15%, although coverage of the zones varied between months (lowest coverage 12.6%, highest coverage 21.88%). The variation in coverage was due to the use of camera systems with differing image footprint sizes, and variation in environmental conditions resulting in variation in the amount of partial images captured within the tolerance limits of the survey design. The same survey design was flown during each survey resulting in the same number of replicates. A greater coverage does not necessarily lead to an increased encounter rate. Nonetheless, if greater coverage leads to an increased uniform encounter rate, this will be reflected by an improved precision estimate. However, if the variance between images increases due to encountering larger flocks and thereby increasing the variability between images, this will be reflected by a poorer precision estimate. Therefore the encounter rate and variability are assessed within the calculation of the precision estimate. This provides a measure to use to compare between surveys to assess how well a change in abundance would be detected by each survey.

Population estimates were generated by adding up the raw counts from geo-referenced images and dividing this number by the total number of images to give the mean number of birds per image (i). Population estimates (N) for each survey month were then calculated by multiplying the mean number of birds per image by the total number of images required to cover the entire study area (A). This is analogous to abundance estimation outlined in Borchers *et al.* (2002).

$$N = i A$$

Population estimates were derived from the grid data for all the monthly surveys undertaken during the winter 2013 / 14 surveys. For each monthly aerial survey of each zone, geo-referenced locations of birds and marine mammals contained within each individual digital still image were used to generate raw counts. Bird and mammal locations contained within the boundaries of each zone were then extracted using ArcGIS, leaving raw count data for images obtained from each zone. Where an image fell across the survey boundary, only the part of the image that fell within the survey area was included in the analysis.

Confidence limits

Confidence limits (CL) showing the extent of variability surrounding the relative population estimate were calculated using a non-parametric bootstrap method. APEM routinely use bootstrap methods to calculate CL as this statistical method is considered to be a very robust

way of assigning measures of accuracy (Borchers *et al.* 2002). For the bootstrap simulation, a sub-sample of images within stratum were re-sampled 999 times with replacement from image data (i.e. 999 subsamples of the raw counts were used to produce 999 new 'total raw count' values). Each of the 999 bootstrap values were then used to produce relative population estimates within each stratum as described in section 4.6.1.1. The upper and lower 95% confidence intervals (+CL and -CL respectively) of all the bootstrapped population estimates was taken as the variability of the statistic over the population (Efron & Tibshirani, 1993).

Precision

For every population estimate, APEM calculates a CV' (coefficient of variation) to provide a measure of precision about the mean population estimate, i.e. to provide a measure of how good the estimates are of the relative population. As aerial survey grid data normally contain a high proportion of images with zero counts (as animals are not normally evenly distributed across the survey area), measures of precision were calculated from the raw count data using a negative binomial estimator which is suitable for data that have a pseudo-Poisson over-dispersed distribution caused by a large number of zero counts (Elliott 1977). This produced a CV' based on the relationship of the standard error (SE) to the mean (μ).

$$CV' = SE / \mu$$

Effectively, this statistic is used to determine whether the sampling regime is sufficient to estimate the population with a given level of precision. A $CV' \leq 0.16$ relates to a precision level able to detect a doubling or halving of the population (Bohlin, 1990), although at very low densities, it is not always mathematically possible to obtain a CV' of 0.16, even if 99% of the area is covered.

2.5.2 Relative density distribution maps for divers

Bird and mammal observations comprised individual points for each recorded individual, geo-referenced to actual spatial location at the time of survey. Relative density distribution maps were produced for total divers using ArcGIS (version 9.2) by summing the number of divers recorded in each image and then representing this sum of divers as a dot on a map that was proportional to the number of divers in that image; i.e. large numbers of divers per image were represented by larger dots than smaller numbers of divers per image.

3 RESULTS

3.1 Abundance estimates

Table 3.1: Peak counts, estimates, confidence limits and precision for all bird species recorded across the survey area during winter 2013 / 14. Estimates with a precision of 0.16 or better are in red italic text.

Species / group	Zone	Month	Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
Total diver species	1	December	<i>1,023</i>	<i>4,698</i>	<i>3,742</i>	<i>5,749</i>	<i>0.03</i>
Red-throated diver	1	December	<i>974</i>	<i>4,473</i>	<i>3,559</i>	<i>5,520</i>	<i>0.03</i>
Black-throated diver	1	December	27	124	60	197	0.19
Great northern diver	1	December	22	101	55	147	0.21
Fulmar	1	January	1	7	1	22	>1.00
Gannet	1	November	10	72	36	123	0.32
Total cormorant & shag	2	December	<i>99</i>	<i>452</i>	<i>99</i>	<i>1,357</i>	<i>0.10</i>
Grebe species	1	February	1	7	1	22	>1.00
Pomarine skua	1	November	1	7	1	22	>1.00
Total small gull species	1	January	<i>78</i>	<i>562</i>	<i>338</i>	<i>871</i>	<i>0.11</i>
Kittiwake	1	January	<i>76</i>	<i>547</i>	<i>324</i>	<i>857</i>	<i>0.11</i>
Black-headed gull	2	November	7	51	7	124	0.38
Common gull	1	December	11	51	14	96	0.30
Total large gull species	1	December	<i>120</i>	<i>551</i>	<i>197</i>	<i>1,084</i>	<i>0.09</i>
Lesser black-backed gull	1	December	19	87	19	174	0.23
Herring gull	2	November	<i>43</i>	<i>314</i>	<i>58</i>	<i>665</i>	<i>0.15</i>
Great black-backed gull	1	December	<i>79</i>	<i>363</i>	<i>147</i>	<i>730</i>	<i>0.11</i>
Total auk species	2	February	<i>147</i>	<i>1,161</i>	<i>790</i>	<i>1,556</i>	<i>0.08</i>
Total dolphin & porpoise	1	November	10	72	29	123	0.32
Harbour porpoise	1	November	5	36	7	72	0.45
Seal	1	February	<i>60</i>	<i>433</i>	<i>60</i>	<i>1,112</i>	<i>0.13</i>

3.1.1 Divers

3.1.1.1 Total diver species

Data presented in Table 3.2 refer to total divers recorded during the winter 2013 / 14 surveys. All divers were identified to species level including; red-throated divers, black-throated divers and great northern divers. Divers were recorded in both zones in all survey months with peak numbers recorded during December. The highest peak count was recorded in Zone 1 at an estimated 4,698 (3,742 – 5,749) individuals. The proportions of divers identified to species level are presented in Table 3.3. All divers were identified to species level with the majority identified as red-throated divers (97.4% of total divers). Population estimates for divers that were identified to species are provided in subsequent sections.

Table 3.2: Monthly counts, estimates, confidence limits and precision for total divers in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	15	108	58	166	0.26
	Zone 2	11	80	37	139	0.30
December 2013	Zone 1	1,023	4,698	3,742	5,749	0.03
	Zone 2	231	1,056	850	1,275	0.07
January 2014	Zone 1	261	1,879	1,310	2,549	0.06
	Zone 2	136	982	758	1,228	0.09
February 2014	Zone 1	279	2,015	1,661	2,354	0.06
	Zone 2	128	1,011	774	1,272	0.09

Table 3.3: Percentages of diver species recorded in each survey month between November 2013 and February 2014.

Survey	Red-throated divers	Black-throated divers	Great northern divers
November 2013	92.3	0.0	7.7
December 2013	96.1	2.1	1.8
January 2014	99.5	0.25	0.25
February 2014	99.5	0.25	0.25

3.1.1.2 *Red-throated divers*

Data presented in Table 3.4 refer to red-throated divers recorded during the winter 2013 / 14 surveys. The majority of divers recorded were red-throated divers and these were recorded in both zones in all survey months. The peak abundance of red-throated divers was recorded in Zone 1 during the December survey at an estimated 4,473 (3,559 – 5,520) individuals.

Table 3.4: Monthly counts, estimates, confidence limits and precision for red-throated divers in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	13	94	50	151	0.28
	Zone 2	11	80	37	139	0.30
December 2013	Zone 1	974	<i>4,473</i>	<i>3,559</i>	<i>5,520</i>	<i>0.03</i>
	Zone 2	231	<i>1,056</i>	<i>850</i>	<i>1,275</i>	<i>0.07</i>
January 2014	Zone 1	259	<i>1,865</i>	<i>1,296</i>	<i>2,592</i>	<i>0.06</i>
	Zone 2	136	<i>982</i>	<i>766</i>	<i>1,242</i>	<i>0.09</i>
February 2014	Zone 1	278	<i>2,007</i>	<i>1,661</i>	<i>2,376</i>	<i>0.06</i>
	Zone 2	127	<i>1,003</i>	<i>766</i>	<i>1,288</i>	<i>0.09</i>

3.1.1.3 *Black-throated divers*

Data presented in Table 3.5 refer to black-throated divers recorded during the winter 2013 / 14 surveys. Small numbers of black-throated divers were recorded in Zone 1 during the December 2013 and January and February 2014 surveys with a single black-throated diver recorded in Zone 2 in February 2014. The peak black-throated diver abundance was recorded in Zone 1 in December 2013 at an estimated 124 (60 – 197) birds.

Table 3.5: Monthly counts, estimates, confidence limits and precision for black-throated divers in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A
December 2013	Zone 1	27	124	60	197	0.19
	Zone 2	0	0	0	0	N/A
January 2014	Zone 1	1	7	1	22	>1.00
	Zone 2	0	0	0	0	N/A
February 2014	Zone 1	1	7	1	22	>1.00
	Zone 2	1	8	1	24	>1.00

3.1.1.4 *Great northern divers*

Data presented in Table 3.6 refer to great northern divers recorded during the winter 2013 / 14 surveys. Small numbers of great northern divers were recorded in Zone 1 during the November and December 2013 and January 2014 surveys. The peak great northern diver abundance was recorded in December 2013 in Zone 1 at an estimated 101 (55 – 147) birds.

Table 3.6: Monthly counts, estimates, confidence limits and precision for great northern divers in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	2	14	2	36	0.71
	Zone 2	0	0	0	0	N/A
December 2013	Zone 1	22	101	55	147	0.21
	Zone 2	0	0	0	0	N/A
January 2014	Zone 1	1	7	1	22	>1.00
	Zone 2	0	0	0	0	N/A
February 2014	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A

3.1.2 Other bird species (excluding divers)

3.1.2.1 Fulmars

Data presented in Table 3.7 refer to fulmars recorded during the winter 2013 / 14 surveys. Fulmars were recorded in each survey month, except February 2014. Peak numbers of fulmars were present within Zone 1 in November 2013 and January 2014 with an estimated 7 (1 – 22) birds.

Table 3.7: Monthly counts, estimates, confidence limits and precision for great northern divers in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	1	7	1	22	>1.00
	Zone 2	0	0	0	0	N/A
December 2013	Zone 1	1	5	1	14	>1.00
	Zone 2	0	0	0	0	N/A
January 2014	Zone 1	1	7	1	22	>1.00
	Zone 2	0	0	0	0	N/A
February 2014	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A

3.1.2.2 Gannets

Data presented in Table 3.8 refer to gannets recorded during the winter 2013 / 14 surveys. Gannets were recorded in each survey month, except January 2014. Peak numbers of gannets were present within Zone 1 in November 2014 with an estimated 72 (36 – 123) birds.

Table 3.8: Monthly counts, estimates, confidence limits and precision for gannets in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	10	72	36	123	0.32
	Zone 2	0	0	0	0	N/A
December 2013	Zone 1	6	28	6	55	0.41
	Zone 2	0	0	0	0	N/A
January 2014	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A
February 2014	Zone 1	1	7	1	22	>1.00
	Zone 2	0	0	0	0	N/A

3.1.2.3 Total cormorants & shags

The data presented in Table 3.9 refer to all cormorants and shags recorded, including those not identified to species. Cormorants and shags were present in all survey months, except February 2014. The peak number of cormorants and shags was present within Zone 2 in December 2014, with an estimated 452 (99 – 1,357) birds.

Table 3.9: Monthly counts, estimates, confidence limits and precision for total cormorants & shags in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	2	14	2	36	0.71
	Zone 2	0	0	0	0	N/A
December 2013	Zone 1	0	0	0	0	N/A
	Zone 2	99	452	99	1,357	0.10
January 2014	Zone 1	1	7	1	29	>1.00
	Zone 2	0	0	0	0	N/A
February 2014	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A

3.1.2.4 Cormorants

The data presented in Table 3.10 refer to cormorants. Cormorants were present in Zone 1 during the November 2013 and January 2014 surveys. The peak number of cormorants was present in November 2013, with an estimated 14 (2 – 36) birds.

Table 3.10: Monthly counts, estimates, confidence limits and precision for in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	2	14	2	36	0.71
	Zone 2	0	0	0	0	N/A
December 2013	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A
January 2014	Zone 1	1	7	1	29	>1.00
	Zone 2	0	0	0	0	N/A
February 2014	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A

3.1.2.5 Total grebes

Data presented in Table 3.11 refer to grebes not identified to species recorded during the winter 2013 / 14 surveys. Grebe species were present in February 2014 with a single individual recorded in each zone with the peak number of grebes observed in Zone 2 with an estimated 8 (1 – 24) individuals.

Table 3.11: Monthly counts, estimates, confidence limits and precision for total grebes in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A
December 2013	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A
January 2014	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A
February 2014	Zone 1	1	7	1	22	>1.00
	Zone 2	1	8	1	24	>1.00

3.1.2.6 *Pomarine skuas*

Data presented in Table 3.12 refer to pomarine skuas recorded during the winter 2013 / 14 surveys. A single pomarine skua was recorded in Zone 1 during the November 2013 survey when an estimated 7 (1 – 22) birds were estimated to be present. Pomarine skuas were not recorded in any other survey month.

Table 3.12: Monthly counts, estimates, confidence limits and precision for pomarine skuas in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	1	7	1	22	>1.00
	Zone 2	0	0	0	0	N/A
December 2013	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A
January 2014	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A
February 2014	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A

3.1.2.7 Total small gulls

Data presented in Table 3.13 refer to total small gulls (including kittiwakes, black-headed gulls, common gulls and gulls not identified to species) recorded during the winter 2013 / 14 survey. Small gulls were recorded in all zones with peak numbers recorded in Zone 1 in January 2014 which held an estimated 562 (338 – 871) birds. The proportions of small gulls identified to species level are presented in Table 3.14. The majority of small gulls (75% of total small gulls) were identified as kittiwakes. Unidentified small gulls were likely to have been either kittiwakes or common gulls. Population estimates for small gulls that were identified to species are provided in subsequent sections.

Table 3.13: Monthly counts, estimates, confidence limits and precision for all total small gull species (identified to group and species levels) in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	23	166	72	303	0.21
	Zone 2	14	102	22	226	0.27
December 2013	Zone 1	50	230	156	303	0.14
	Zone 2	19	87	46	137	0.23
January 2014	Zone 1	78	562	338	871	0.11
	Zone 2	41	296	188	419	0.16
February 2014	Zone 1	21	152	94	217	0.22
	Zone 2	12	95	32	166	0.29

Table 3.14: Percentages of small gull species recorded in each survey month between November 2013 and February 2014.

Survey	Kittiwakes	Black-headed gulls	Common gulls	Unidentified small gulls
November 2013	35.0	32.5	32.5	0.0
*December 2013	61.0	0.0	24.5	14.5
January 2014	92.0	0.0	8.0	0.0
February 2014	91.0	0.0	3.0	6.0

* Light conditions in December sub-optimal

3.1.2.8 *Kittiwakes*

Data presented in Table 3.15 refer to kittiwakes recorded during the winter 2013 / 14 surveys. The highest number of kittiwakes was recorded in the January 2014 survey, when estimates peaked in both zones. Kittiwake numbers peaked at an estimated 547 (324 – 857) individuals in Zone 1 during the January 2014 survey.

Table 3.15: Monthly counts, estimates, confidence limits and precision for kittiwake in each zone at 500 m resolution...

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	12	87	36	159	0.29
	Zone 2	1	7	1	22	>1.00
December 2013	Zone 1	33	152	96	202	0.17
	Zone 2	9	41	14	78	0.33
January 2014	Zone 1	76	547	324	857	0.11
	Zone 2	34	246	159	347	0.18
February 2014	Zone 1	18	130	72	195	0.23
	Zone 2	12	95	32	166	0.29

3.1.2.9 *Black-headed gulls*

Data presented in Table 3.16 refer to black-headed gulls recorded during the winter 2013 / 14 surveys. Small numbers of black-headed gulls were recorded in November 2013 in both zones. The peak number of black-headed gulls was recorded in Zone 2 at an estimated 51 (7 – 124) birds.

Table 3.16: Monthly counts, estimates, confidence limits and precision for black-headed gulls in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	5	36	7	72	0.45
	Zone 2	7	51	7	124	0.38
December 2013	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A
January 2014	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A
February 2014	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A

3.1.2.10 Common gulls

The data presented in Table 3.17 refer to common gulls recorded during the winter 2013 / 14 surveys. Common gulls were recorded in all survey months, with peak numbers recorded during December 2013 when an estimated 51 (14 – 96) birds were recorded in Zone 1.

Table 3.17: Monthly counts, estimates, confidence limits and precision for common gull in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	6	43	6	108	0.41
	Zone 2	6	44	7	102	0.41
December 2013	Zone 1	11	51	14	96	0.30
	Zone 2	6	27	6	50	0.41
January 2014	Zone 1	2	14	2	36	0.71
	Zone 2	7	51	14	101	0.41
February 2014	Zone 1	1	7	1	22	>1.00
	Zone 2	0	0	0	0	N/A

3.1.2.11 Total large gulls

Data presented in Table 3.18 refer to total large gulls (including lesser black-backed gulls, herring gulls, great black-backed gulls and large gulls not identified to species) recorded during the winter 2013 / 14 surveys. Large gulls were recorded in all zones with peak numbers recorded in Zone 2 in the November 2013 survey at an estimated 679 (153 – 1,395) birds. The proportions of large gulls identified to species level are presented in Table 3.19. The majority of large gulls (62% of total large gulls) were identified as great black-backed gulls. Population estimates for large gulls that were identified to species are provided in subsequent sections.

Table 3.18: Monthly counts, estimates, confidence limits and precision for total large gull species (identified to group and species levels) in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	26	187	65	346	0.20
	Zone 2	93	679	153	1,395	0.10
December 2013	Zone 1	120	551	197	1,084	0.09
	Zone 2	73	334	206	539	0.12
January 2014	Zone 1	15	108	43	194	0.26
	Zone 2	19	137	58	238	0.66
February 2014	Zone 1	16	116	29	231	0.25
	Zone 2	4	32	8	63	0.50

Table 3.19: Percentages of large gull species recorded in each survey month between November 2013 and February 2014.

	Lesser black-backed gulls	Herring gulls	Great black-backed gulls	Unidentified large gulls
November 2013	5.0	40.0	55.0	0.0
December 2013	11.0	22.0	64.0	3.0
January 2014	15.0	17.5	67.5	0.0
February 2014	15.0	10.0	70.0	5.0

3.1.2.12 *Lesser black-backed gulls*

Data presented in Table 3.20 refer to lesser black-backed gulls recorded during the winter 2013 / 14 surveys. Small numbers of lesser black-backed gulls were recorded in both zones in all survey months with the exception of Zone 2 in February 2014. Peak numbers of lesser black-backed gulls were recorded in December 2013 when an estimated 87 (19 – 174) birds were recorded in Zone 1.

Table 3.20: Monthly counts, estimates, confidence limits and precision for lesser black-backed gulls in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	4	29	4	79	0.50
	Zone 2	2	15	2	37	0.71
December 2013	Zone 1	19	87	19	174	0.23
	Zone 2	3	14	3	37	0.58
January 2014	Zone 1	2	14	2	36	0.71
	Zone 2	3	22	3	58	0.58
February 2014	Zone 1	3	22	3	65	0.58
	Zone 2	0	0	0	0	N/A

3.1.2.13 Herring gulls

The data presented in Table 3.21 refer to herring gulls recorded during the winter 2013 / 14 surveys. Herring gulls were recorded in both zones in all survey months with the exception of Zone 2 in February 2014. Peak numbers of herring gulls were recorded in Zone 2 during the November 2013 survey, when an estimated 314 (58 – 665) birds were present.

Table 3.21: Monthly counts, estimates, confidence limits and precision for herring gulls in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	5	36	7	72	0.45
	Zone 2	43	314	58	665	0.15
December 2013	Zone 1	22	101	22	225	0.21
	Zone 2	21	96	21	238	0.22
January 2014	Zone 1	1	7	1	22	>1.00
	Zone 2	5	36	5	108	0.45
February 2014	Zone 1	2	14	2	36	0.71
	Zone 2	0	0	0	0	N/A

3.1.2.14 *Great black-backed gulls*

Data presented in Table 3.22 refer to great black-backed gulls recorded during the winter 2013 / 14 surveys. Great black-backed gulls were recorded in both zones in all survey months with peak numbers recorded in Zone 1 during December 2013, with an estimated 363 (147 – 730) individuals present.

Table 3.22: Monthly counts, estimates, confidence limits and precision for great black-backed gulls in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	17	123	50	231	0.24
	Zone 2	48	351	51	804	0.14
December 2013	Zone 1	79	363	147	730	0.11
	Zone 2	44	201	137	265	0.15
January 2014	Zone 1	12	86	29	166	0.29
	Zone 2	11	79	36	137	0.30
February 2014	Zone 1	10	72	29	130	0.32
	Zone 2	4	32	8	63	0.50

3.1.2.15 Total auks

Data presented in Table 3.23 refer to total auks. All auks were identified as guillemots / razorbills during the winter 2013 / 14 surveys. Auks were recorded in both zones in all survey months with the exception of Zone 2 in November 2013. Peak numbers of guillemots or razorbills were recorded during the February 2014 survey in both zones, with peak numbers recorded at an estimated 1,161 (790 – 1,556) birds in Zone 2.

Table 3.23: Monthly counts, estimates, confidence limits and precision for total auks (identified to group and species levels) in each zone at 500 m resolution. Estimates with a precision of 0.16 or better are in red italic text.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	5	36	7	72	0.45
	Zone 2	0	0	0	0	N/A
December 2013	Zone 1	51	<i>234</i>	<i>161</i>	<i>321</i>	<i>0.14</i>
	Zone 2	83	<i>379</i>	<i>242</i>	<i>544</i>	<i>0.11</i>
January 2014	Zone 1	63	<i>454</i>	<i>338</i>	<i>576</i>	<i>0.13</i>
	Zone 2	52	<i>376</i>	<i>246</i>	<i>520</i>	<i>0.14</i>
February 2014	Zone 1	113	<i>816</i>	<i>607</i>	<i>1,069</i>	<i>0.09</i>
	Zone 2	147	<i>1,161</i>	<i>790</i>	<i>1,556</i>	<i>0.08</i>

3.1.3 *Marine mammals*

3.1.3.1. *Total dolphins & porpoises*

Data presented in Table 3.25 refer to total dolphins and / or porpoises (including positively identified harbour porpoises (see 3.1.3.2) and dolphins not identified to species) recorded during the winter 2013 / 14 surveys. Total dolphins / porpoises were recorded in all survey months with peak numbers observed in Zone 1 during the November 2013 survey, with an estimated 72 (29 – 123) individuals present.

Table 3.25: Monthly counts, estimates, confidence limits and precision for total dolphin / porpoises in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	10	72	29	123	0.32
	Zone 2	3	22	3	66	0.58
December 2013	Zone 1	2	9	2	23	0.71
	Zone 2	1	5	1	14	>1.00
January 2014	Zone 1	4	29	7	58	0.50
	Zone 2	0	0	0	0	N/A
February 2014	Zone 1	8	58	22	101	0.35
	Zone 2	2	16	2	39	0.71

3.1.3.2. *Harbour porpoises*

Data presented in Table 3.26 refer to harbour porpoises recorded during the winter 2013 / 14 surveys. Harbour porpoises were recorded in all survey months except December 2013. The peak number of harbour porpoises was recorded in Zone 1 during the November 2013 survey when an estimated 36 (7 – 72) individuals were recorded.

Table 3.26: Monthly counts, estimates, confidence limits and precision for harbour porpoises in each zone at 500 m resolution.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	5	36	7	72	0.45
	Zone 2	2	15	2	44	0.71
December 2013	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A
January 2014	Zone 1	1	7	1	22	>1.00
	Zone 2	0	0	0	0	N/A
February 2014	Zone 1	2	14	2	36	0.71
	Zone 2	0	0	0	0	N/A

3.1.3.3 Seals

Data presented in Table 3.27 refer to seals recorded during the winter 2013 / 14 surveys. Seals were recorded in each survey month except January 2014. The peak number of seals was recorded in Zone 1 during the February 2014 survey when an estimated 433 (60 – 1,112) individuals were recorded.

Table 3.27: Monthly counts, estimates, confidence limits and precision for seals in each zone at 500 m resolution. Estimates with a precision of 0.16 or better are in red italic text.

		Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
November 2013	Zone 1	4	29	7	58	0.50
	Zone 2	6	44	6	139	0.41
December 2013	Zone 1	2	9	2	23	0.71
	Zone 2	0	0	0	0	N/A
January 2014	Zone 1	0	0	0	0	N/A
	Zone 2	0	0	0	0	N/A
*February 2014	Zone 1	60	<i>433</i>	<i>60</i>	<i>1,112</i>	<i>0.13</i>
	Zone 2	0	0	0	0	N/A

*Large number of seals recorded hauled out on transient sandbank during February 2014 survey of Zone 1

3.2 Distribution

3.2.1 Distribution of divers

3.2.1.1 November 2013

The relative distribution of divers recorded in both zones during November 2013 is shown in Figure 3.1: A. The distribution of each individual diver recorded in this survey is also shown in Figure 3.2: A and B.

Relatively few divers were recorded in images taken across both zones during the November 2013 survey.

In Zone 1, 15 divers were thinly distributed across the site with four (27%) individuals located within the London Array OWF area containing the Phase 1 site. Of the remaining divers recorded nine divers were recorded to the north of the London Array OWF site with a single individual observed south of the London Array OWF within the Zone 1 boundary. The bathymetry data indicate that the majority of individuals were located in areas of approximately 5-20 m water depth and were generally located around the edges of the shallowest areas (i.e. sand banks; Figure 3.1: A). Tide height data at the nearest point to the London Array OWF site (Whitaker Beacon) indicate that the tide was incoming at the time of the survey (Appendix III).

A total of 11 divers were located within Zone 2 during the November 2013 survey. The majority of divers were recorded in the centre of the site located close to the edges of shallow sand bank areas. The remaining individuals were recorded in the north east of the site over shallow water areas of approximately 0-10 m water depth (Figure 3.1: A). Tide height data indicate that the tide was outgoing then incoming for the last hour of the survey (Appendix III).

3.2.1.2 December 2013

The relative distribution of divers recorded in both zones during the December 2013 survey is shown in Figure 3.1: B. The distribution of each individual diver recorded in this survey is also shown in Figure 3.3: A and B.

Large numbers of divers were recorded in images taken during the December 2013 survey, with the highest number of divers located in Zone 1 (n =1,023 ; 82%).

In Zone 1, the majority of divers were recorded along the eastern boundary in a band running north to south, and in the north of the survey area above the London Array OWF site. Low numbers of divers were recorded within the London Array OWF site. Birds were largely recorded in clusters of four to 25 individuals with a larger cluster of over 50 individuals recorded to the east of the centre of the Zone 1 survey area. These individuals were largely recorded near to the edge of shallow sand bank areas, approximately 5-20 m water depth (Figure 3.1: B). Tide height data at the nearest point to the London Array OWF site (Whitaker Beacon) indicate that the tide was outgoing until half way through the survey then incoming (Appendix III).

A total of 231 divers were recorded in Zone 2, during the December 2013 survey. These individuals were mainly recorded towards the centre of the zone distributed near the edge of shallow sand bank areas of 5-20 m water depth running parallel to northern boundary of Zone 2 (Figure 3.1:B). Tide height data indicate that the tide was incoming during the survey (Appendix III).

3.2.1.3 *January 2014*

The relative distribution of divers recorded in both zones during the January 2014 survey is shown in Figure 3.1: C. The distribution of each individual diver recorded in this survey is also shown in Figure 3.4: A and B.

Moderate numbers of divers were recorded in images taken during the January 2014 survey with the highest number of divers located in Zone 1 (n=261; 69%).

In Zone 1, aggregations of divers were recorded in the northern half of the survey area, above the London Array OWF site, with individuals also present in the south-western corner of Zone 1. A single diver was recorded within the London Array OWF with low numbers of divers recorded in close proximity to the London Array OWF. Birds were largely recorded in clusters of four to 25 individuals. These individuals were largely recorded over shallow sand bank areas, approximately 5-20 m water depth (Figure 3.1: C). Tide height data at the nearest point to the London Array OWF site (Whitaker Beacon) indicate that the tide was outgoing until the last hour of the survey when it was then incoming (Appendix III).

A total of 136 divers were recorded in Zone 2, during the January 2014 survey. These individuals were recorded throughout the survey area with fewer individuals recorded along the northern and southern boundaries. Birds were largely recorded as individuals, however small clusters of two, three and four to 25 individuals were also present. The majority of birds were distributed across the shallow sand bank areas of 5-20 m water depth in the north and south west areas of Zone 2 (Figure 3.1:D). Tide height data indicate that the tide was outgoing during the survey (Appendix III).

3.2.1.4 *February 2014*

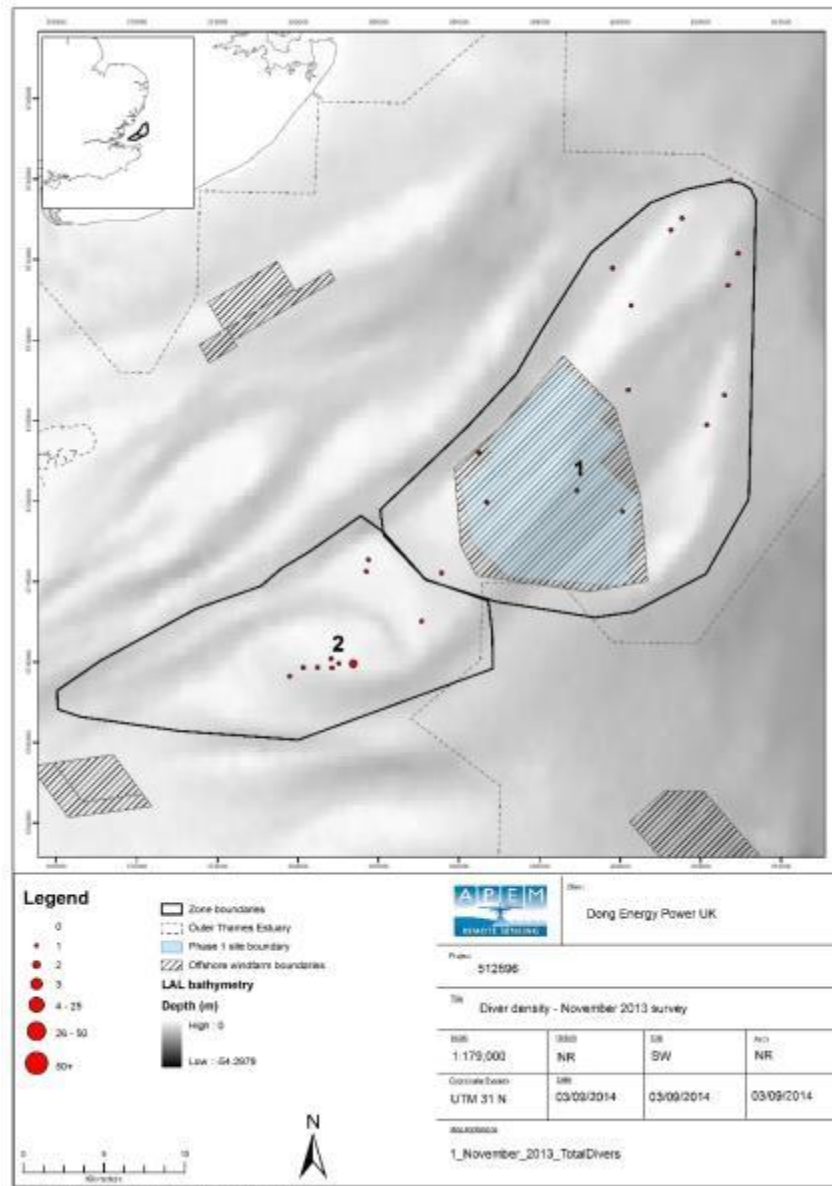
The relative distribution of divers recorded in both zones during the February 2014 survey is shown in Figure 3.1: D. The distribution of each individual diver recorded in this survey is also shown in Figure 3.5: A and B).

Moderate numbers of divers were recorded in images taken during the February 2014 survey, with the highest number of divers located in Zone 1 (n =279 ; 68.5%).

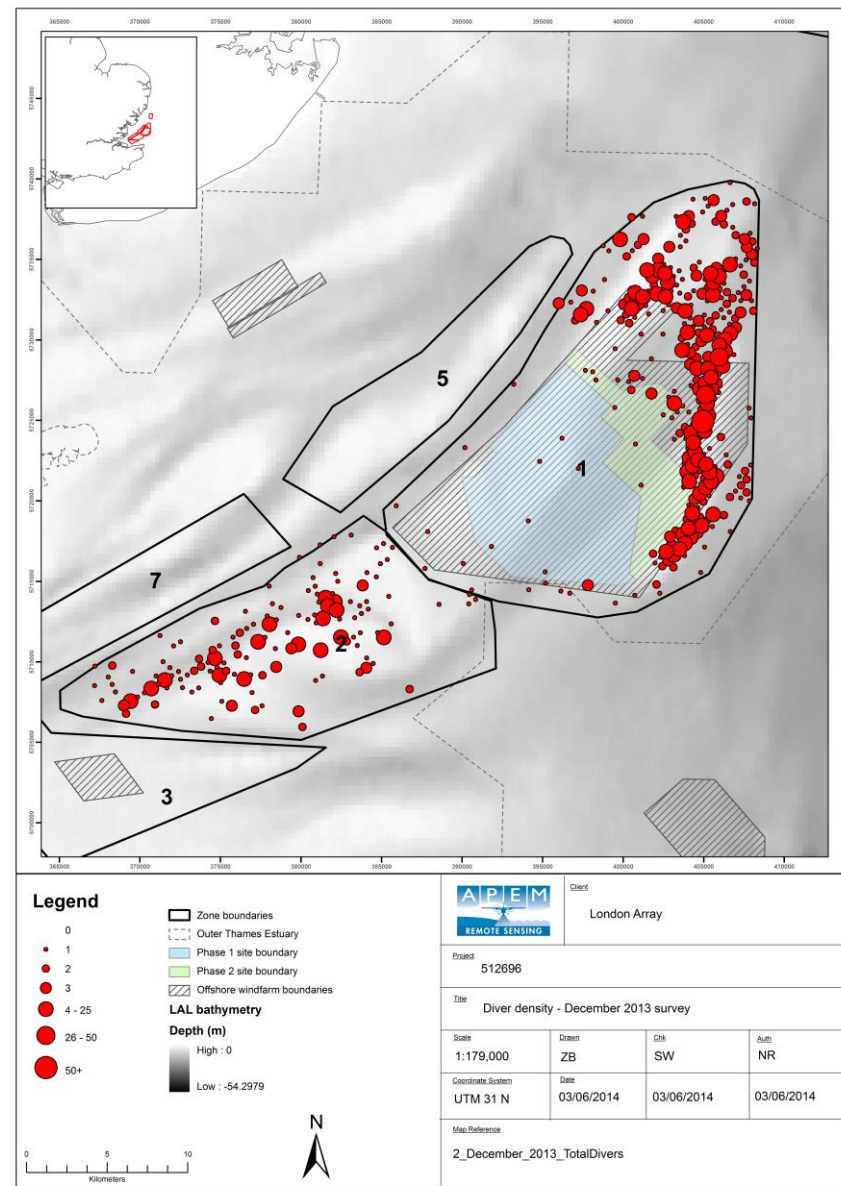
In Zone 1, larger numbers of divers were recorded in the northern half of the survey area. Divers were recorded along the northern boundary, above the London Array OWF site, and in a large aggregation next to the northern boundary of the London Array OWF site. Birds were largely recorded as individuals and in clusters of four to 25 individuals. These individuals were largely recorded near to the edge of shallow sand bank areas, approximately 5-20 m water depth (Figure 3.1: D). Data on tide height at the nearest point to the London Array OWF site (Whitaker Beacon) indicate that the tide was incoming during the survey (Appendix III).

A total of 128 divers were recorded in Zone 2, during the February 2014 survey. All birds were recorded in the north and north-western areas of the zone, evenly distributed in a band running parallel to the northern boundary. No birds were recorded in the southern half of the zone. The majority of individuals were distributed near the edge of shallow sand bank areas of 5-20 m water depth (Figure 3.1: D). Tide height data indicate that the tide was incoming during the survey (Appendix III).

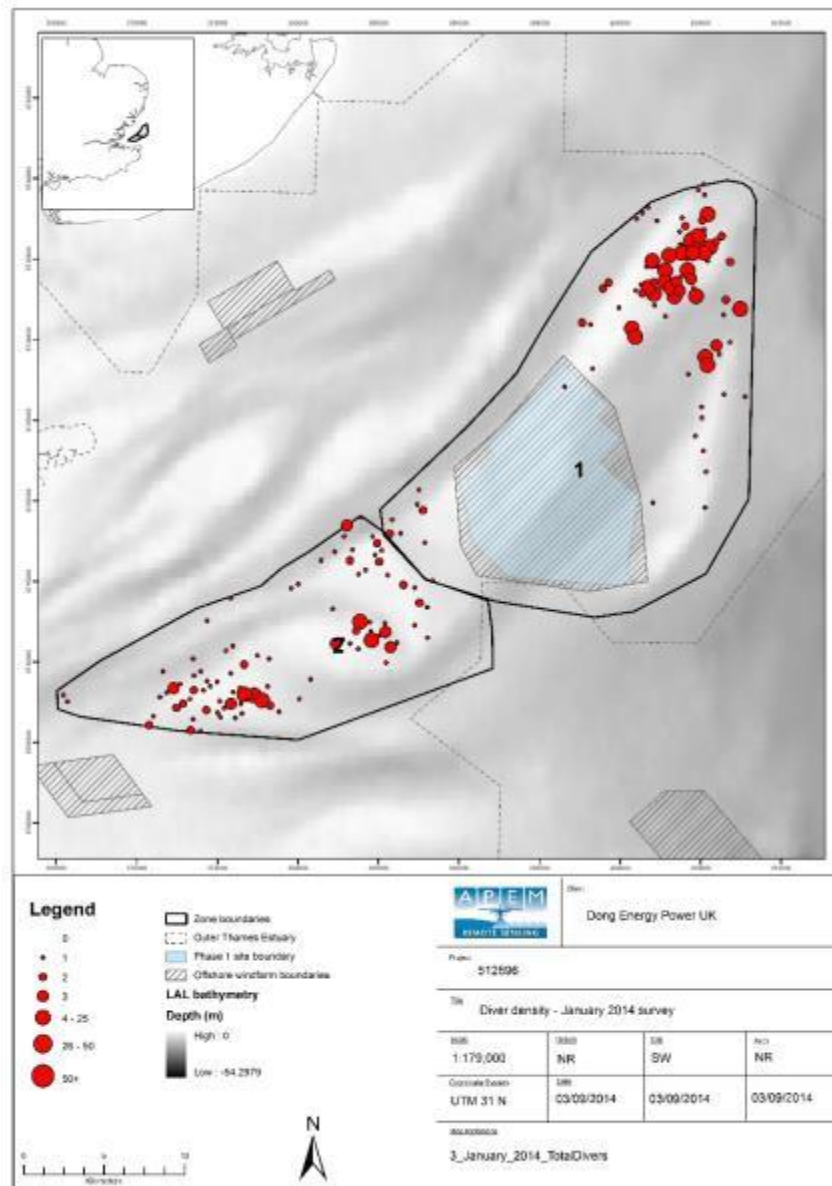
Figure 3.1: Relative distribution of divers recorded in both zones in each survey month during 2013-14 post-construction winter. London Array Phase 1 (hatched blue area) is shown inside the hatched area of London Array OWF. Other hatched areas also show the Kentish Flats OWF (inside Zone 3), Gunfleet Sands OWF (north-west of Zone 5) and Thanet OWF (south of Zone 1). Location of Zone 1 and Zone 2 is shown in the inclusion.



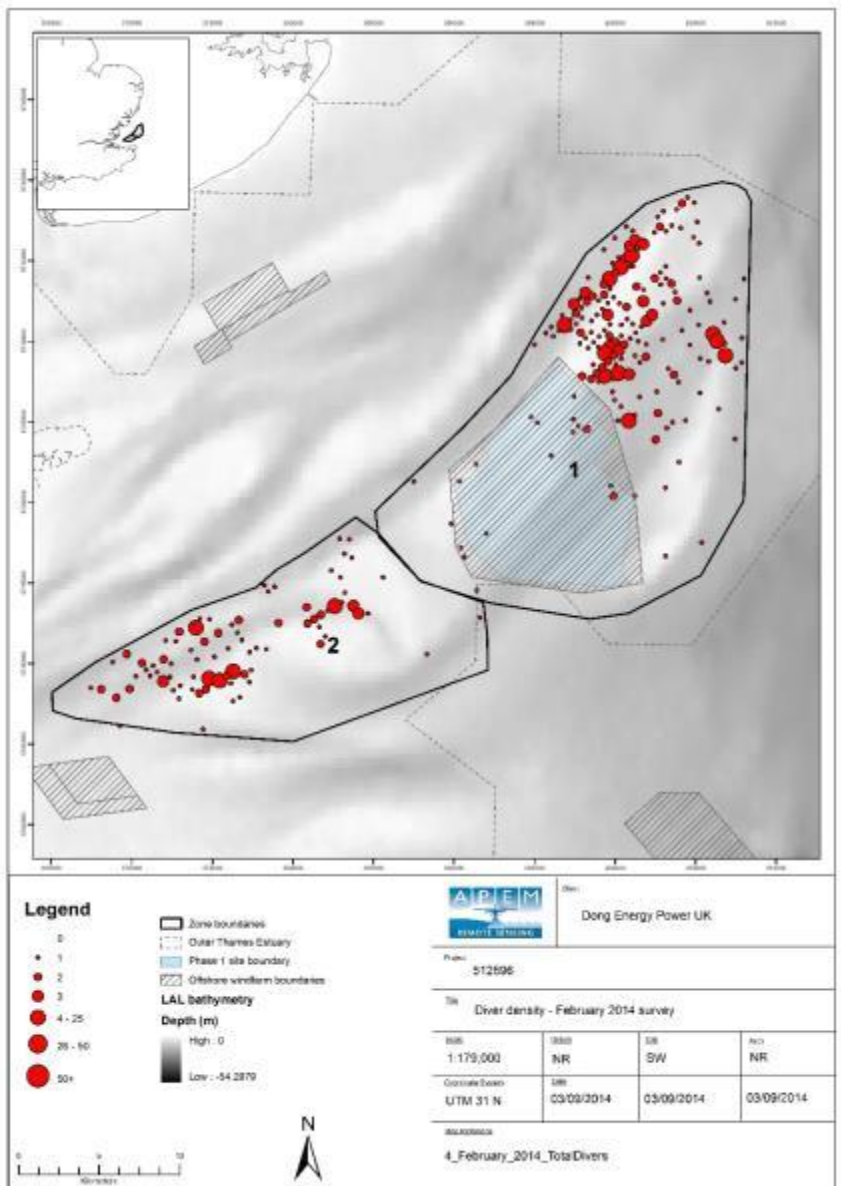
A. November 2013



B. December 2013



C. January 2014



D. February 2014

3.2.2 *Distribution of other bird species and marine mammals*

3.2.2.1 *November 2013*

The distribution of each individual bird (including divers) and marine mammal recorded by the November 2013 survey is shown in Figure 3.2: A and B. This section describes the distribution of all species / groups other than divers recorded by the November 2013 survey.

In Zone 1, bird species / groups recorded during the November 2013 survey were distributed throughout the site. During the survey, a single fulmar was recorded within the London Array OWF site on the south eastern boundary. Gannets were mainly recorded in the north of Zone 1 with two individuals recorded south of the London Array OWF site. Individual gannets were also recorded to the north east and south west of the London Array OWF site. No gannets were observed within the Phase 1 site boundary. The three cormorants recorded during the survey were located in three separate locations; in the south east of the Phase 1 site area, to the north of the London Array OWF site and close to the outer eastern boundary of the Zone 1 survey area. A single pomarine skua was recorded above the London Array OWF site towards the eastern Zone 1 survey area boundary. Small gulls and large gulls were largely located throughout the southern half of Zone 1, with a cluster of gulls recorded to the south west of the London Array OWF site. Although individual small gulls were observed on the north west boundary of the Zone 1 survey area and in the north west of the London Array OWF site with individual large gulls located in the north west of the survey area and towards the eastern boundary above the London Array OWF site. Auks were located in the south of Zone 1, within the Phase 1 site boundary with individuals located in the centre and above the eastern boundary of the London Array OWF site (Figure 3.2: A).

Of the 10 cetaceans recorded during the November 2013 survey, three dolphins / porpoises and four harbour porpoises were recorded in the north west and south east of the survey area outside the London Array OWF site. The remaining harbour porpoise and dolphin / porpoise were observed in the south of the survey area within the London Array OWF site, with a single dolphin / porpoise recorded south of the London Array OWF within the Zone 1 survey area (Figure 3.2:A).

Additionally, four seals were recorded close to the north east and south west boundaries of the Zone 1 survey area, with a single individual recorded to the south east of Zone 1 (Figure 3.2: A).

Birds recorded within Zone 2 during the November 2013 survey were generally located towards the centre and in the eastern half of the zone, with birds recorded along the south west boundary of the site. The majority of large gulls and small gulls were recorded together in the centre of the site with individual small gulls thinly dispersed across the survey area, with the exception of the south east of the site. Although large gulls were mainly located in the centre of the site high numbers were recorded along the south west boundary of Zone 2 with individual large gulls recorded in the south east of the zone and along the northern border in the centre of the survey area (Figure 3.2: B).

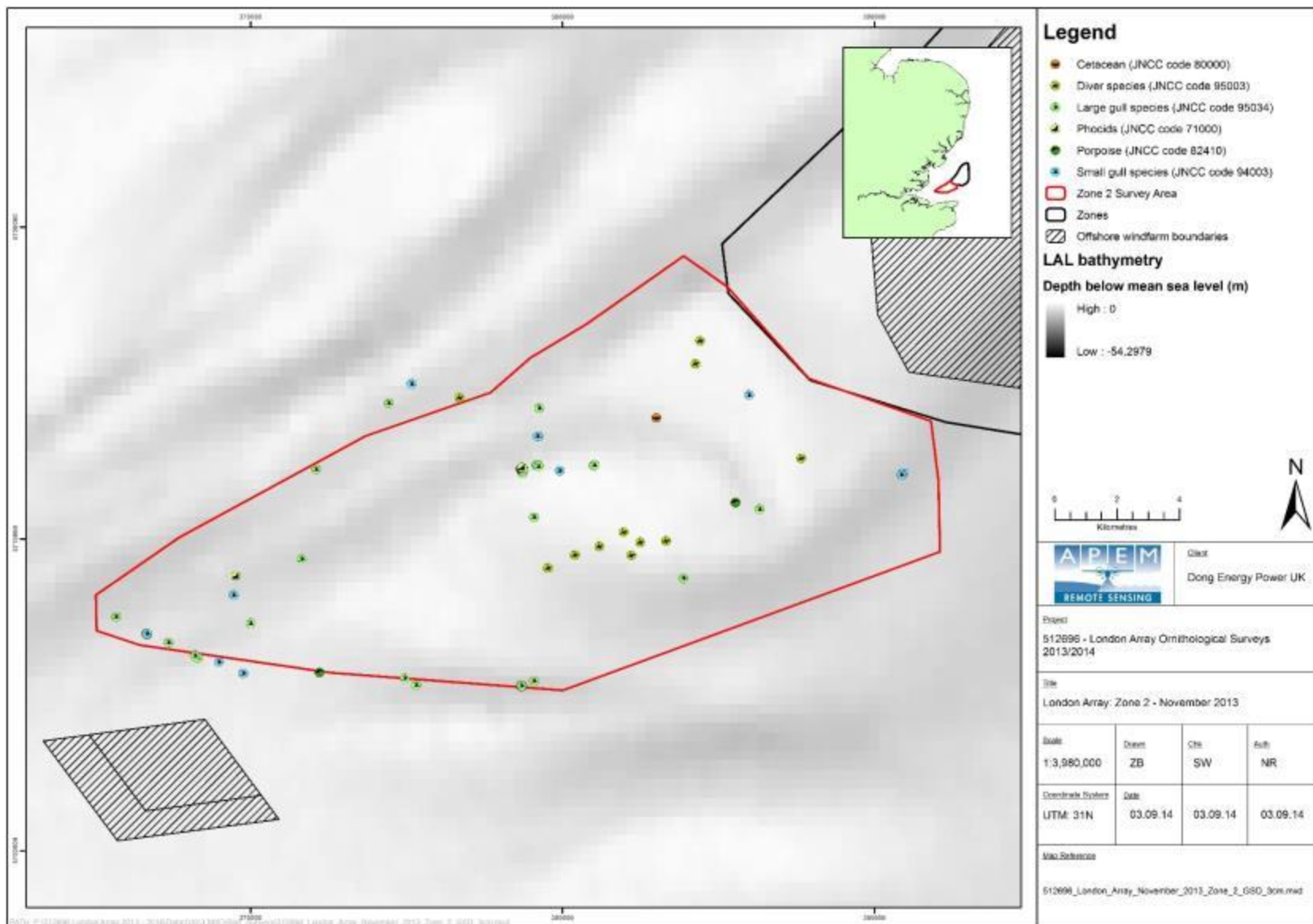
Of the four cetaceans recorded during the November 2013 survey, one dolphin / porpoise was observed to the north of the centre of Zone 2. Of the remaining cetaceans (all identified as harbour porpoise) two were recorded together to the east of the centre of Zone 2 with one individual recorded in the south west of the survey area along the southern boundary.

Additionally, five seals were recorded together in the centre of the site with one individual located to the west of the centre of the site (Figure 3.2: B).

Figure 3.2: Distribution of bird and marine mammal species / groups recorded in each zone during the November 2013 survey at 500 m resolution.



A: Zone 1



B: Zone 2

3.2.2.2 *December 2013*

The distribution of each individual bird and marine mammal (including divers) recorded in this survey is shown in Figure 3.3: A and B. This section describes the distribution of all species / groups apart from divers recorded during the December 2013 survey.

Of the other birds recorded within Zone 1, a single fulmar was observed in the centre of the London Array OWF site, within the Phase 1 site boundary. Of the six gannets observed, four were located in the north of the survey area and two were observed to the east and south east of the site. No gannets were observed within the London Array OWF site.

In total 33% of small gulls were recorded within the London Array OWF site, with further individuals observed north of the London Array OWF site and in the south east and south west of the Zone 1 survey area. Large gulls were also recorded throughout the London Array OWF site, with groups of birds recorded to the west of the centre and south east of the London Array OWF site. Further individual large gulls were recorded north of the site, in the south east and in the south west outside the London Array OWF site. Auks were thinly distributed throughout much of the zone, excluding the south west corner of the survey area. The majority of individuals were recorded in the northern half of the survey area and towards the south east of the survey area (Figure 3.3: A)

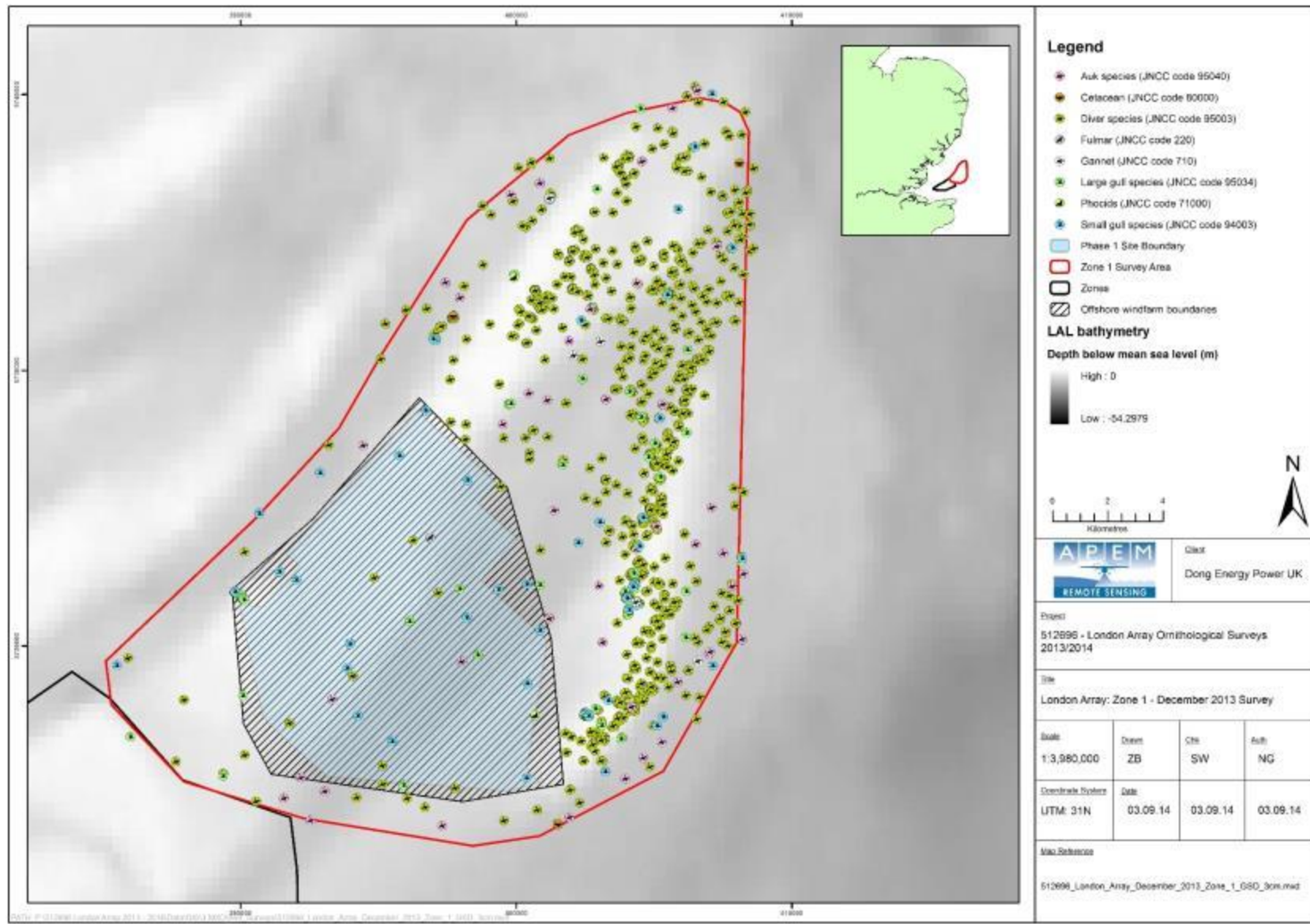
The three dolphins / porpoises recorded during the December 2013 survey were located in three separate locations outside of the London Array OWF site; one was located in the north of the zone towards the eastern boundary, one was recorded in the north west of the survey area with the remaining individual located on the Zone 1 survey area boundary in the south east of the survey area. Of the two seals recorded during the survey, one was recorded in the north of the survey area outside the London Array OWF site with the remaining individual located in the south east of the London Array OWF site (Figure 3.3: A).

Within Zone 2 many cormorants / shags were recorded sitting on fixed structures including wind farm platforms in the south west corner of the survey area. Small gulls were generally recorded along the southern and western and eastern Zone 2 area boundaries although individual small gulls were located in the centre of the survey area and south of the survey area. Large gulls were thinly dispersed across much of the site, with the majority recorded in the western corner of Zone 2.

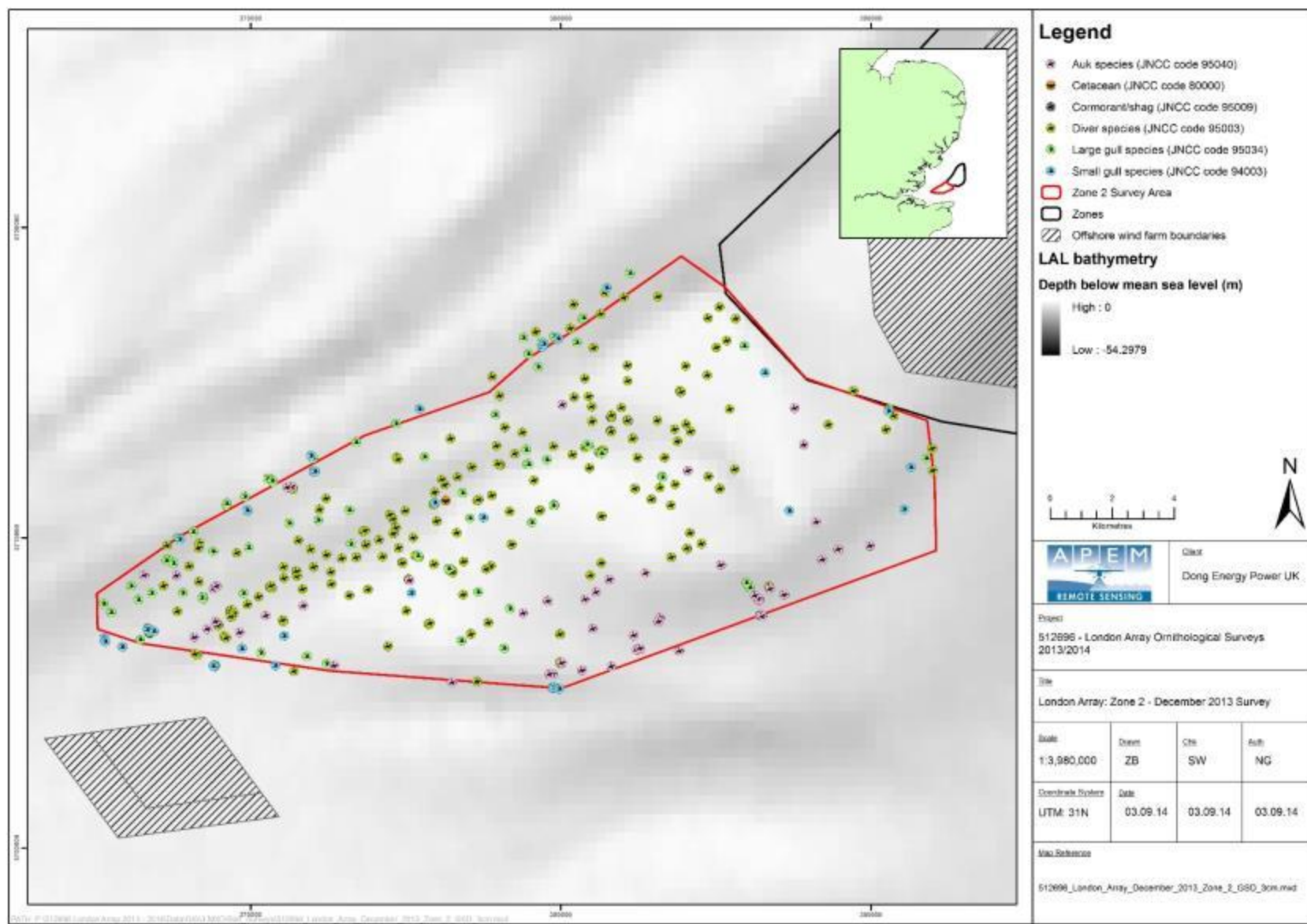
Auks were generally recorded in the southern half of the zone towards the southern and south eastern boundaries with individual auks thinly dispersed in the northern half of the survey area (Figure 3.3: A).

During the December 2013 survey, a single dolphin / porpoise was recorded in the centre of the Zone 2 survey area (Figure 3.3: A).

Figure 3.3: Distribution of bird and marine mammal species / groups and marine mammals recorded in each zone during the December 2013 survey at 500 m resolution.



A: Zone 1



B: Zone 2

3.2.2.3 *January 2014*

The distribution of each individual bird (including divers) and marine mammal recorded during this survey is shown in Figure 3.4: A and B. This section describes the distribution of all the species / groups apart from divers recorded during the January 2014 survey.

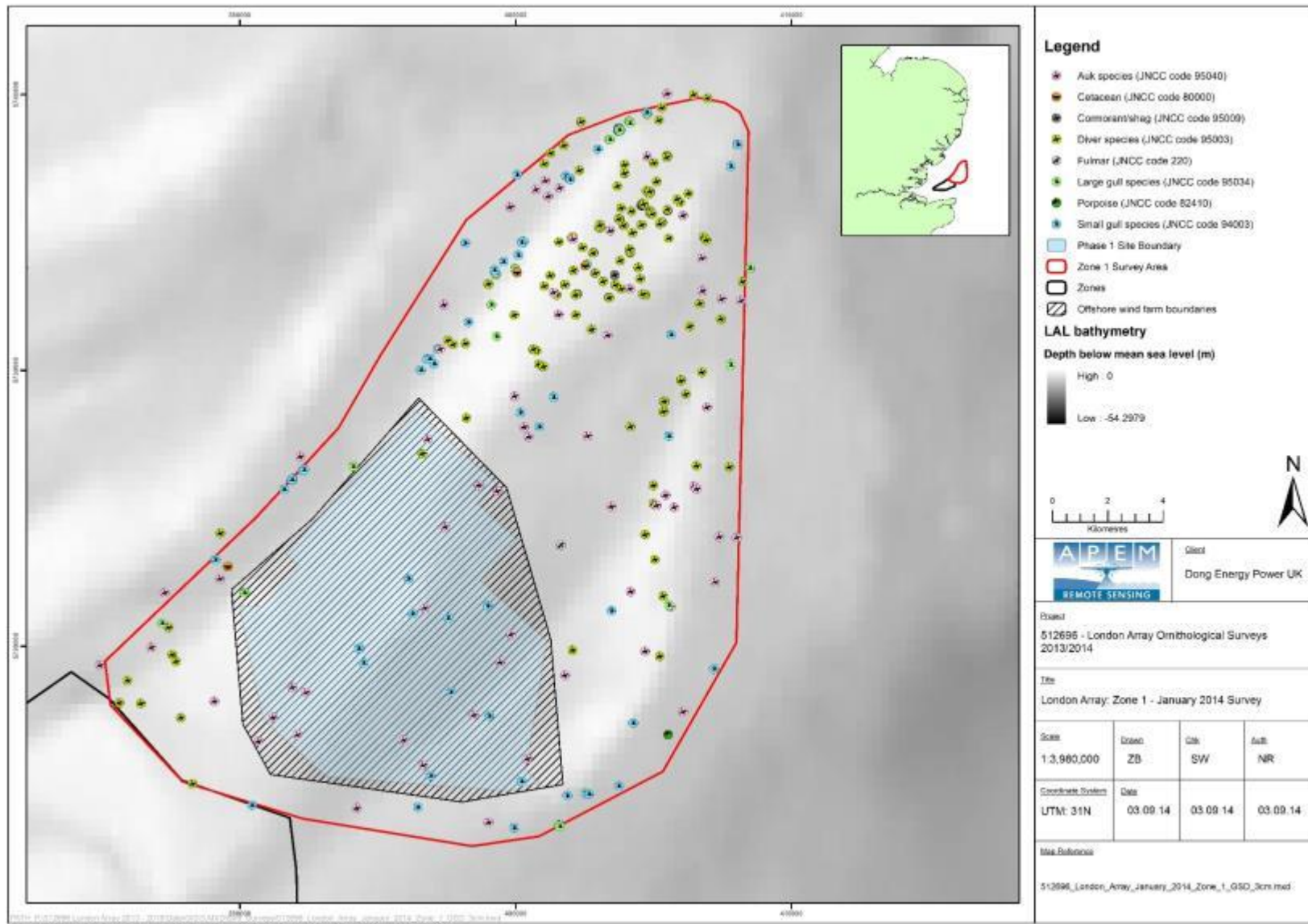
In Zone 1, most individuals were located along the north western boundary of Zone 1 above the London Array OWF site and to the east of the Phase 1 site. Some individual birds were distributed throughout the survey area.

A single fulmar was recorded in the centre of Zone 1 and a single cormorant was recorded in the north of the zone above the London Array OWF site. Small gulls were loosely distributed throughout much of Zone 1, with the clusters recorded along the north west boundary of the site. Large gulls were loosely distributed around the periphery of Zone 1, with the majority recorded in the north west of the site above the London Array OWF site. A single large gull was recorded in the south west of the London Array OWF site. Auks were observed across Zone 1 with the majority recorded in the north of the site and towards the eastern boundary of the survey area (Figure 3.4: A).

Of the four cetaceans recorded during the January 2014 survey, one harbour porpoise was recorded in the south east corner of the zone towards the eastern zonal boundary. The remaining three cetaceans (all identified as being either dolphins or porpoises) were recorded outside of the London Array OWF in the north west and south west of the survey area (Figure 3.4: A).

In Zone 2, small gulls were mainly distributed in the south west of the survey area and along the northern boundary of the site, with individuals located to the east of the centre of the site. Similar to small gulls, large gulls were mainly distributed in the south west of the zone, with clusters of large gulls recorded along the north western boundary of the site. Individual large gulls were also recorded towards the centre of the survey area and in the north east of the site. Auks were also recorded within Zone 2 and were dispersed across much of the area, with fewer individuals in the far eastern end of the zone (Figure 3.4: B).

Figure 3.4: Distribution of bird and marine mammal species / groups and marine mammals recorded in each zone during the January 2014 survey at 500 m resolution.



A: Zone 1



B: Zone 2

3.2.2.4 February 2014

The distribution of each individual bird (including divers) recorded in this survey is shown in Figure 3.5: A and B. This section describes the distribution of all species / groups apart from divers recorded in the February 2014 survey.

The other bird species / groups recorded within Zone 1 were distributed throughout Zone 1 with larger numbers located in the northern half of the zone. In Zone 2, the majority were located in the southern half of the zone.

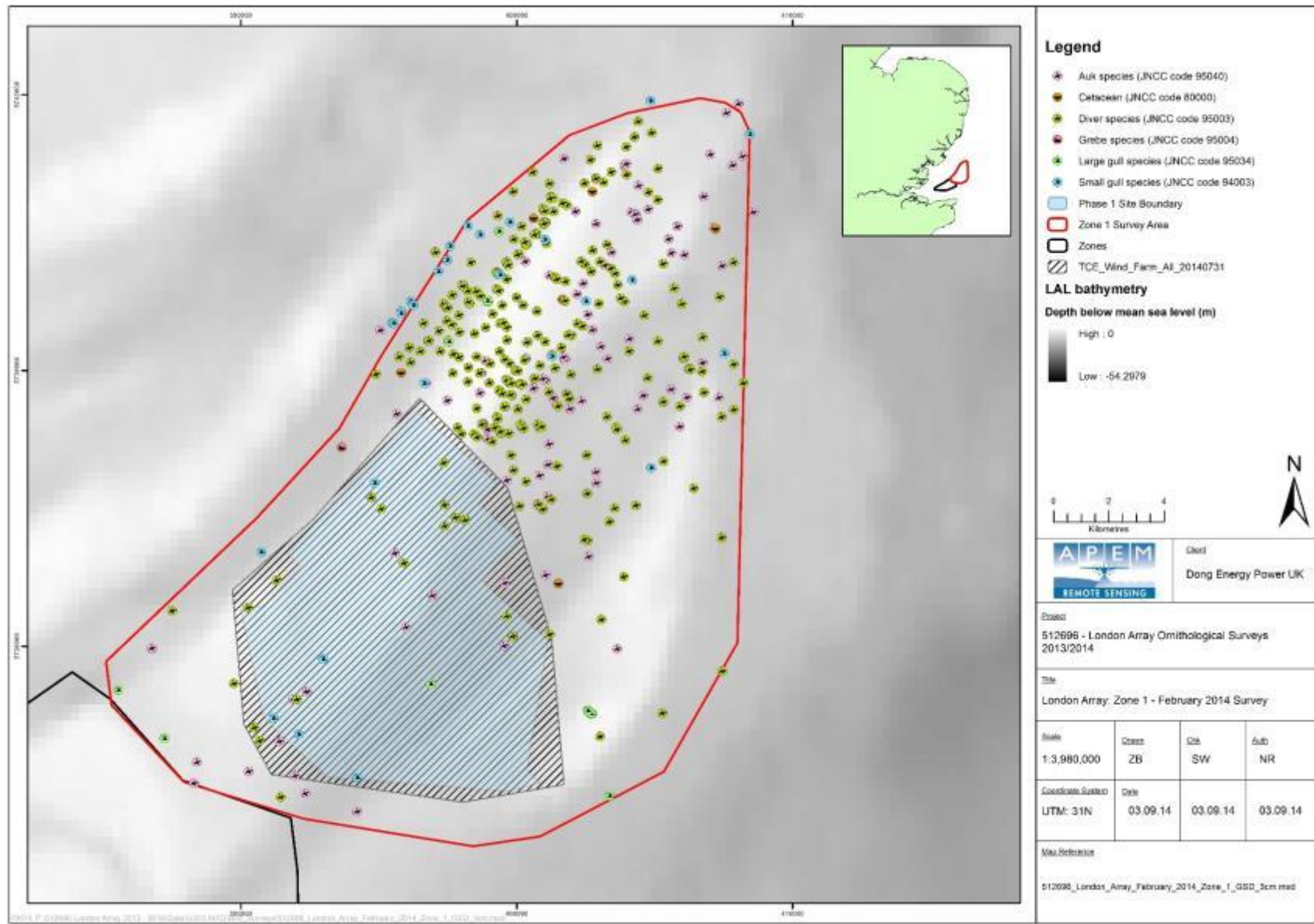
A single cormorant/shag was recorded outside of the Zone 1 boundary in the south west. Of the two gannets recorded, one was located outside of the Zone 1 northern boundary and one was located in the north east of the Zone 1 survey area, above the London Array OWF site. A single grebe species was recorded in the central-western part of the zone. The majority of small gulls were located in the northern half of Zone 1 with individuals also present in the south-western half of the Zone 1 survey area. Large gulls were distributed throughout Zone 1 with the majority recorded in the northern half around the periphery of the zone. Auks were observed across Zone 1 with the majority recorded in the north of the zone (Figure 3.5: A).

In Zone 1 a total of 68 marine mammals were recorded during the February 2014 survey. Of the two harbour porpoises recorded, one was observed in the centre of the London Array OWF site, with the remaining individual recorded in the north of the zone. Of the six dolphin / porpoises recorded during the February 2014 survey, one was recorded in the centre of the zone close to the boundary of the London Array OWF site. The remaining individuals were recorded in the north of Zone 1 above the London Array OWF site. Sixty seals were recorded throughout the Zone 1 survey area with larger numbers observed to the north of the zone (Figure 3.5: A).

In Zone 2, a single grebe species was located to the west of the centre of the survey area. Small gulls were mainly distributed in the north, north east and along the southern boundary of the site. Large gulls were located in the north, along the southern boundary and in the centre of the zone. Auks were mainly distributed across the southern half of the site with individuals also recorded in the north and central-northern parts of the zone. (Figure 3.5: B).

A total of two cetaceans, identified as being either dolphins or porpoises, were recorded within Zone 2, located north of the centre of the site and in the north east corner of the site (Figure 3.5: B).

Figure 3.5: Distribution of bird and marine mammal species / groups and marine mammals recorded in each zone during the February 2014 survey at 500 m resolution.



A: Zone 1



B: Zone 2

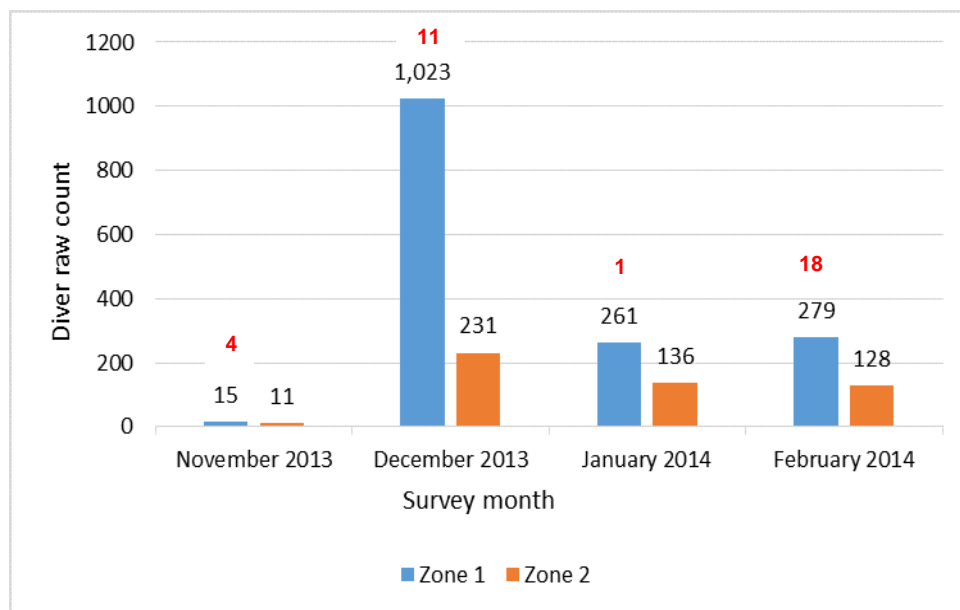
4 DISCUSSION

4.1. Diver abundance and distribution during the winter 2013 / 14

The total number of divers recorded in Zone 1 and Zone 2 in each month during the 2013 / 14 aerial surveys peaked during December 2013 (Figure 4.1). Relatively low numbers of divers were recorded in November (total raw count = 26), whilst the highest numbers of divers were observed during December (total raw count = 1,254). Similar numbers of divers were recorded during the January and February surveys (total raw count = 397 and 407 respectively). The highest numbers of divers were recorded in Zone 1 during December 2013. The majority of divers were located both to the north and east of the Phase 1 London Array OWF along the eastern boundary of Zone 1.

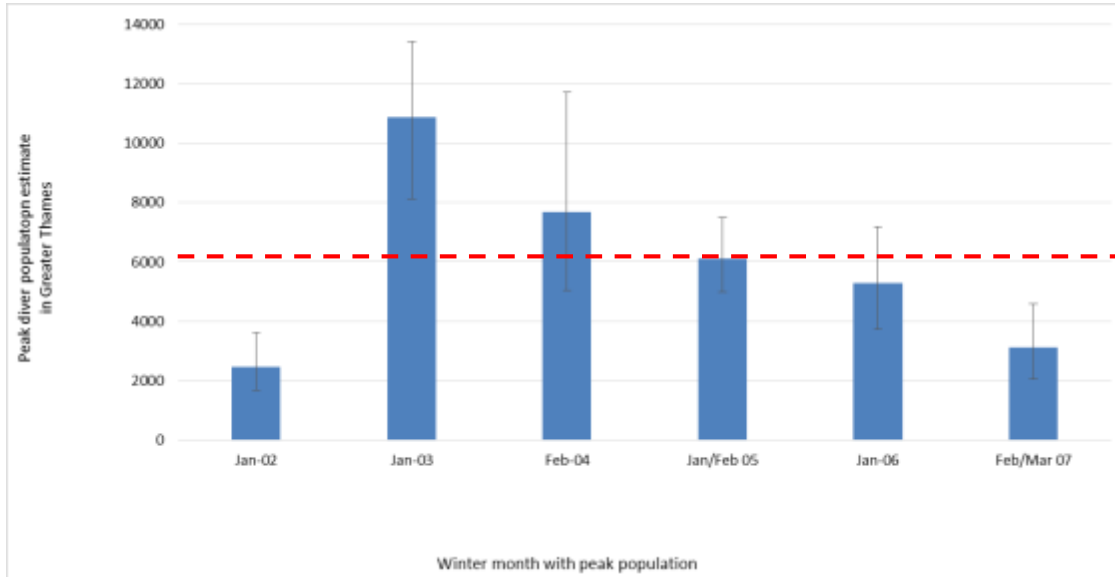
There are a range of factors that may explain the inter-annual variation of diver abundance and distribution in the Outer Thames Estuary, with January and February previously identified as peak months for red-throated divers wintering in the Greater Thames estuary (Webb *et al.* 2009). The large numbers of divers observed during February may represent pre-migration aggregations of birds; pairs return to territories from the UK typically in March and April (Wernham *et al.* 2002).

Figure 4.1: Total raw count of divers recorded in each zone in each month during the 2013 / 14 surveys. Numbers of divers recorded within the London Array OWF are indicated in red.



The Outer Thames Estuary SPA has been designated for a total of 6,466 divers with a total of 8,130 individuals estimated across the wider Greater Thames estuary (O'Brien *et al.* 2008; Webb *et al.* 2009). During the December 2014 aerial survey diver abundance across both zones peaked at a total of 5,748 (4,804 – 6,821) individuals; which is 89% of the designated SPA population (though note the December 2013 population estimate may include some temporal variation as the survey spanned two days). Aerial surveys over the past 10 years in the Greater Thames area (Figure 4.2) have shown a wide variation in peak population estimates for divers, ranging from 2,460 divers in January 2002 to 10,884 in January 2003 (Webb *et al.* 2009). Although the peak diver numbers recorded during the December 2013 survey falls within the range of these recent past surveys, it is slightly unusual for the peak count to be in December.

Figure 4.2: Peak seasonal population estimates for divers recorded by aerial surveys in the Greater Thames area between January 2002 – February / March 2007 (Webb et al. 2009). It should be noted that numbers are not comparable in all months due to differing levels of coverage. The red dashed line shows the SPA designated total of 6,466 individuals. Error bars represent confidence limits.



There are a range of factors that may help explain the inter-annual variation of diver abundance and distribution in the Outer Thames Estuary over the last decade. These factors include changes in weather patterns (e.g. varying conditions on the wintering grounds and summer breeding sites), diurnal variation in diver movements affecting the numbers of divers recorded by each survey (Skov *et al.* 2010), disturbance or habitat change related to developments including the wind farm in the area, changes in boat traffic intensity (Camphuysen *et al.* 2004, Schwemmer *et al.* 2011), or a possible combination of all of these factors.

Across all zones, diver distribution was generally indicative of habitat preferences; approximately 97% of all divers were recorded in water depths of less than 20 m that are associated with sand bank regions (Skov & Prins 2001).

Diver abundance and distribution are influenced on a diurnal basis according to the state of the tide. Tide data from the nearest available point to the London Array site (Whitaker Beacon: Appendix III) suggest that on the majority of occasions, divers appeared to be distributed over sand bank areas when the tide was at or near its highest level (i.e. sand banks fully submerged). At times where the tide was at or near its lowest, the birds appeared to be distributed around the edges of the now exposed sand bank areas; at these times (ebb tide) modelling predicts the lowest availability of suitable habitat (Skov *et al.* 2010). Sand banks may provide feeding habitat for divers since herring and sprat are known to use sand banks as nursery and feeding grounds (Natural England & JNCC 2010). In addition, diver distribution may be related to hydrographic variables since eddies and current speed are significant response variables explaining diver density at London Array (Skov *et al.* 2010).

4.2. Comparison of diver abundance and distribution during the pre-, during- and post-construction surveys (2012 / 13 to 2013 / 14)

By comparing peak diver abundance (i.e. the highest diver abundance recorded in any one survey month between November to February) over the winter surveys of 2010 / 11, 2011 / 12, 2012 / 13 and 2013 / 14 (Figures 4.3 and 4.4 & Table 4.1), it can be seen that there have been changes in diver abundance and distribution over the last four years. (For the comparison of peak diver abundance in Zones 3, 5, 6 & 7 see Appendix VI).

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

Diver distributions within Zone 1 have also changed over the last four years (Figure 4.5). In all winters large numbers of divers were concentrated in the northern area and eastern edge of Zone 1. Large numbers were also recorded in the Phase 1 and 2 areas during the 2010 / 11 winter. However, during 2011 / 12 very few divers were located in these wind farm areas and the northern area and eastern edge of Zone 1 held lower diver densities. During the 2012 / 13 aerial survey, the majority of divers were concentrated in the northern area and eastern edge of Zone 1, with a small number of divers distributed throughout the Phase 1 construction area. During the 2013 / 14 post-construction survey the majority of divers were recorded in the north of Zone 1 close to the eastern boundary of Phase 2, a pattern broadly similar to that recorded pre-construction. A small number of divers have also been distributed throughout the Phase 1 OWF area during the 2012 / 13 and 2013 / 14 winters.

Interestingly the pattern (but not the scale) of the numerical change in diver numbers observed in Zone 2 appears to be the inverse of that of Zone 1, (Figure 4.4), especially during the 2011 / 12 winter that witnessed a large proportional decline in diver numbers in Zone 1 accompanied by a large proportional increase in Zone 2. In Zone 2, diver abundance rose by 46% between the peak pre-construction survey of 2010 / 11 and the peak 2011 / 12 construction survey (a change from 909 to 1,980), before falling by 42% to the peak construction survey 2012 / 13 (1,144 divers). Post-construction peak diver abundance in Zone 2 fell by a further 8% to 1,056 during the 2013 / 14 winter.

Diver distribution also changed notably in Zone 2 over the last four years (Figure 4.5). In 2010 / 11 the majority of divers were located down the centre of Zone 2 in a broadly east-west orientation, while in 2011 / 12 a far larger number of divers were situated in the north-eastern part of Zone 2 on the boundary of Zone 1. In 2012 / 13, divers were again located down the centre and in the eastern part of Zone 2 but few divers were located along the boundary of Zone 1. During the 2013 / 14 post-construction survey divers were located in most of Zone 2 apart from the south-eastern corner. Generally, over all four winter surveys the majority of divers occurred mainly in areas of less than 20 m water depth which were associated with sand bank regions (Skov & Prins 2001). (For bird distribution during the winters 2012 / 13, 2011 / 12 and 2010 / 11 see Appendices V, VI and VII).

Such changes in abundance and distribution within Zones 1 and 2 indicate that something has affected diver occurrence between Zone 1, containing the Phase 1 development, and Zone 2, the control zone, over the last four years. One possible cause may be the result of shipping activity around the Phase 1 site due to the London Array OWF construction and operation. Offshore construction of Phase 1 commenced in March 2011 after completion of the 2010 /

11 winter surveys. The first turbine was in operation in October 2012, with the main body of construction completed by December 2012. As there is some evidence that divers may be sensitive to shipping disturbance (Camphuysen *et al.* 2004, Schwemmer *et al.* 2011), it is possible that the increased level of shipping activity inside Phase 1 during construction disturbed some divers in the area. The peak diver estimate in Zone 1 fell between the pre-construction surveys in 2010 / 11 and the first year of during-construction surveys in 2011 / 12, while at the same time the number of divers present in control Zone 2 increased. Although the observed increase within Zone 2 does not equate to the decrease in Zone 1 this may indicate that some divers shifted their distribution out of Zone 1 and into Zone 2 during the construction of the wind farm, as indicated by the distribution of divers close to the northern boundary of Zone 2 (Figure 4.5 B).

However, it is important to note that the peak diver abundance increased in Zone 1 in the second year of construction in 2012 / 13 while in control Zone 2 diver numbers fell (Table 4.1). This former observation may be due to the many divers present on the Thames rapidly recolonizing the area in January and February 2013 after the main body of the works was completed in December 2012. Boat traffic levels associated with the works decreased compared to levels during construction, although commissioning of all the turbines was not completed until April 2013 with inauguration of the wind farm in July 2013. Therefore it would appear that if the construction of the wind farm did initially have an effect on the diver distribution in 2011 / 12, with decreased levels of boat traffic from 2012 / 13 onwards divers may have started moving back into Zone 1 from the nearby control zone and elsewhere.

Additionally, a continued program of turbine maintenance is undertaken, with similar levels of activity associated with the works throughout most of the year. However, work can be weather dependent and may be concentrated during the summer months. Residual construction works related to array cables and scour protection on offshore substation was also carried out during the summer and autumn of 2013 and 2014 before the winter surveys.

The first post-construction survey was conducted during the winter of 2013 / 14 with the peak diver estimate continuing to rise in Zone 1 compared to the previous winter, while in control Zone 2 peak diver numbers stabilised (Figure 4.4) and cumulative numbers increased slightly (Figure 4.5 D). This suggests that divers may be moving back into Zone 1 post-construction, perhaps largely as a result of larger numbers being present on The Thames. It is also important to note that some of the divers have been recorded within the wind farm footprint, and that quite high numbers are within 1-2 kilometres of the turbines. The concentration of divers recorded in the north-eastern corner of Zone 1 during the 2010 / 11, 2012 / 13 and 2013 / 14 aerial surveys was similar to previous historical aerial surveys in 2003 / 04 and 2004 / 05 (see APEM 2011 for review). Further winter aerial surveys over London Array between 2014 / 15 and 2015 / 16 will provide more information on whether diver numbers continue to rise in Zone 1 which includes the London Array OWF, Phase 1.

Disturbance caused by the construction of the Phase 1 London Array wind farm is certainly not the only possible cause of changes in diver abundance and distribution in the London Array area. Fluctuations in abundance and distribution may reflect inter-annual variation in environmental conditions. For example, the winter of 2010 / 11 was exceptionally cold throughout much of northern Europe and these weather patterns may have led to inflated numbers of divers utilising the Outer Thames estuary during this time. In contrast the winters of 2011 / 12, 2012 / 13 and 2013 / 14 were milder and may have given rise to a wider dispersion of divers outside of the study zones. As previously mentioned, diurnal variation between surveys in different years may have influenced the number of divers recorded. It is also possible that patterns of distribution were also partly determined by hydrodynamic variables that varied between surveys (Skov *et al.* 2010). It is likely that a combination of all these environmental variables as well as the possible displacement effects of construction

have influenced diver distribution over the last four years, which is why it is important to gather long term datasets to be able to understand historical trends.

Figure 4.3: Peak population estimates for total divers recorded by the London Array aerial surveys in Zone 1 in winters between 2010 / 11 and 2013 / 14. Error bars represent confidence limits.

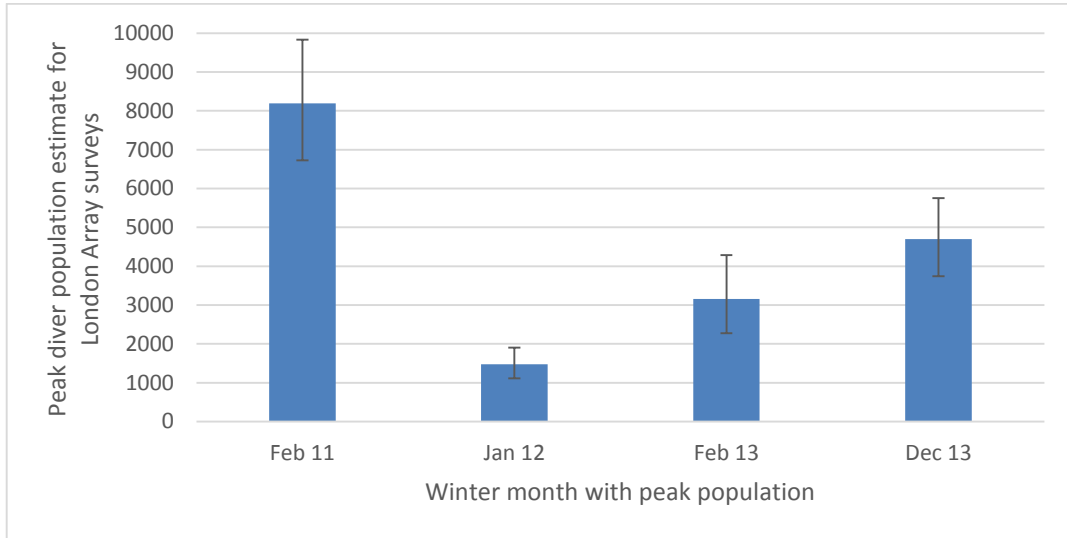


Figure 4.4: Peak population estimates for total divers recorded by the London Array aerial surveys in Zone 2 in winters between 2010 / 11 and 2013 / 14. Error bars represent confidence limits.

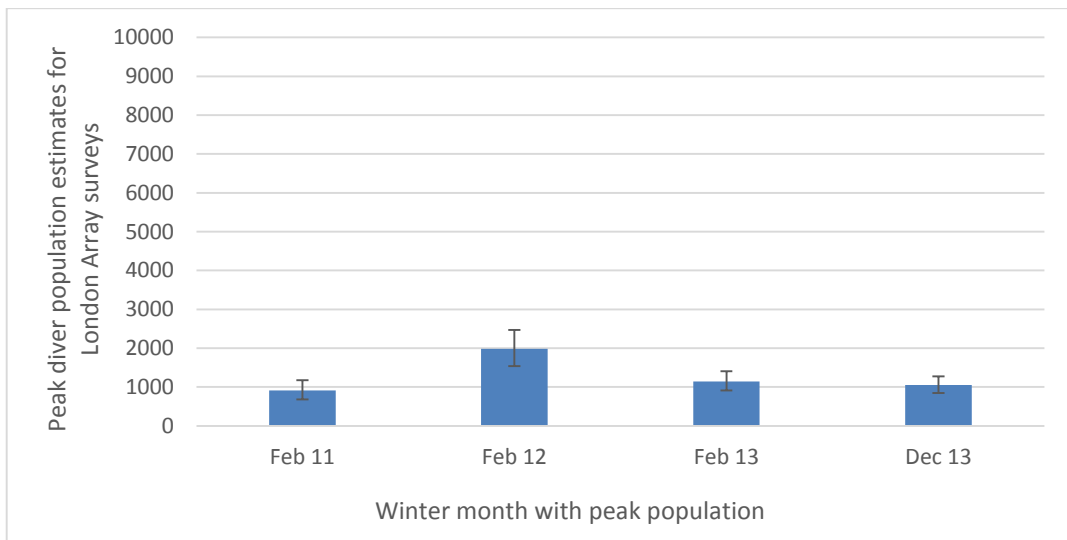
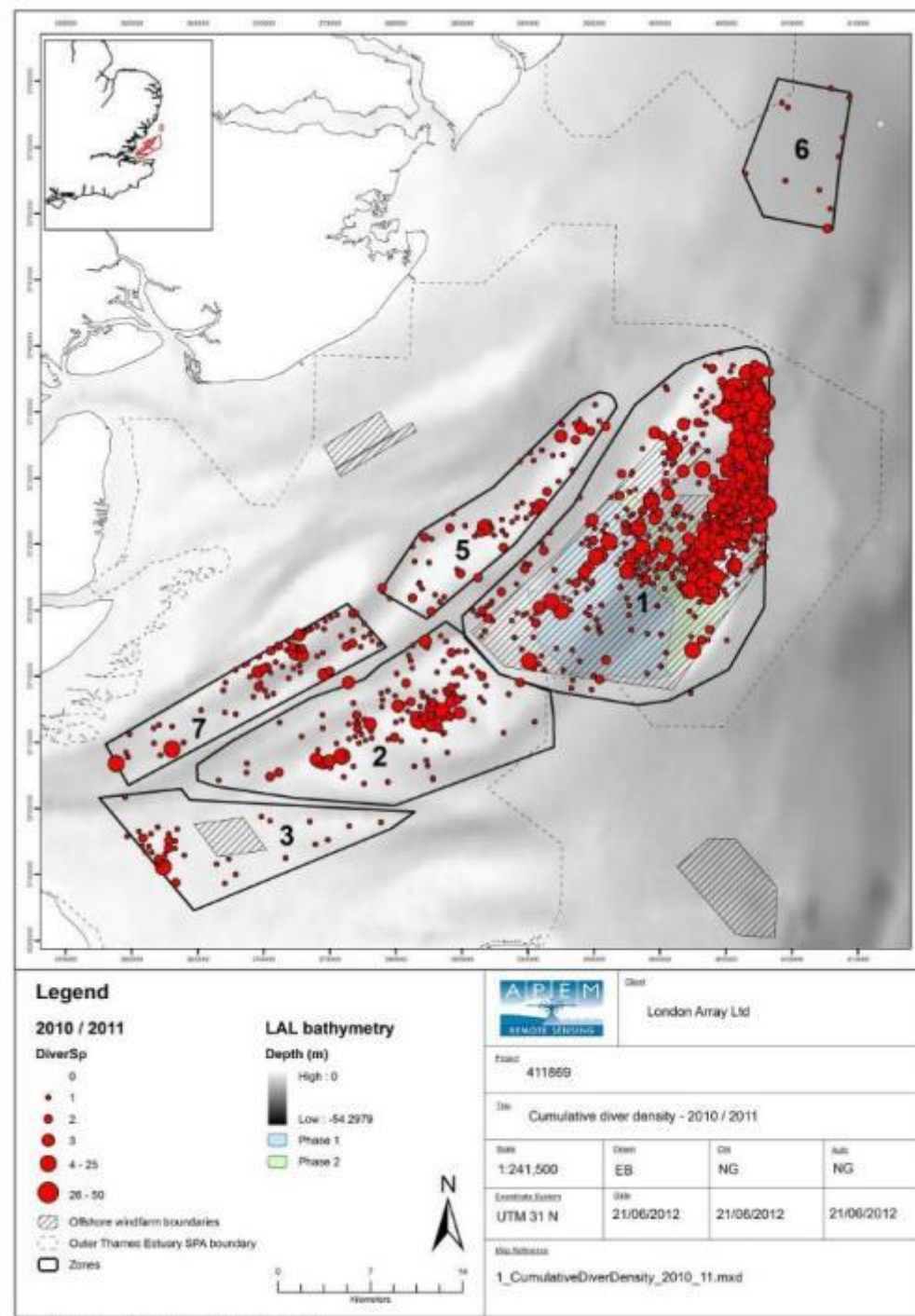


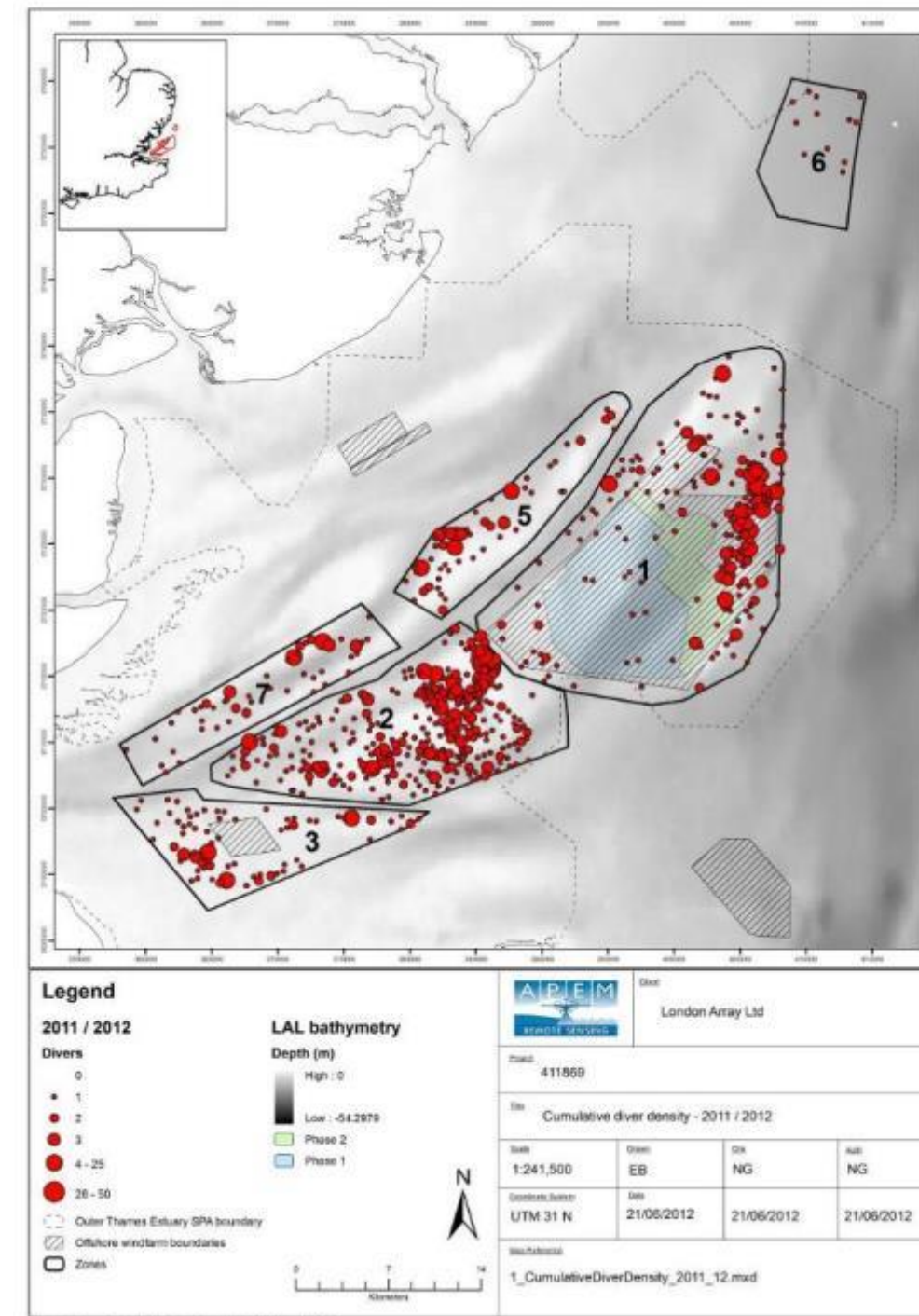
Table 4.1: Peak population estimates for divers recorded by the London Array aerial surveys in Zones 1 & 2 over four winters between 2010 / 11 and 2013 / 14.

Zone	Year	Month	Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
1	2011	February	1,257	8,194	6,727	9,830	0.03
	2012	January	181	1,474	1,108	1,906	0.07
	2013	February	665	3,153	2,276	4,281	0.04
	2014	December	1,023	4,698	3,742	5,749	0.03
2	2011	February	144	909	682	1,174	0.08
	2012	February	433	1,980	1,536	2,469	0.05
	2013	February	241	1,144	912	1,410	0.07
	2014	December	231	1,056	850	1,275	0.07

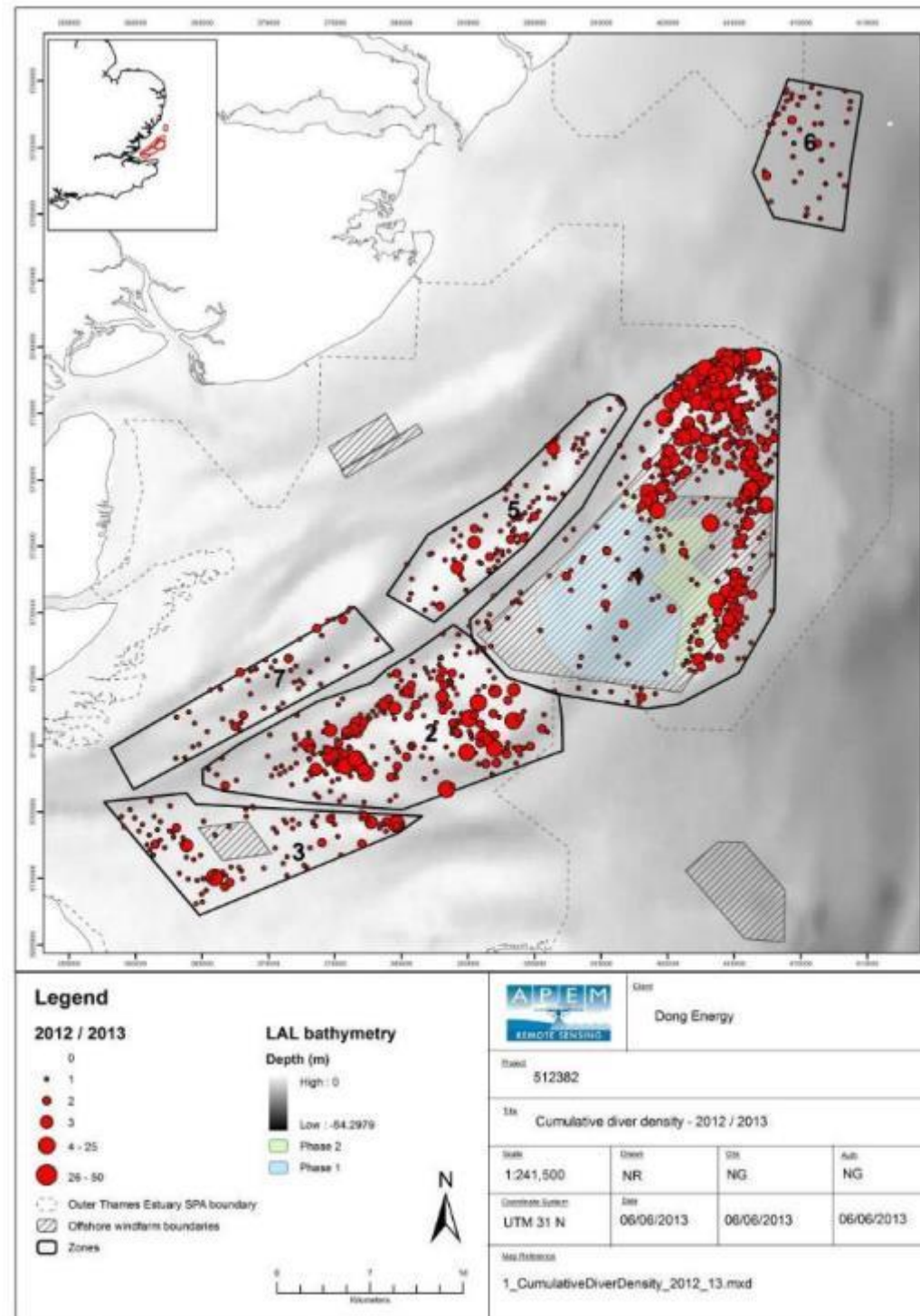
Figure 4.5: Cumulative distribution of divers in all zones during the winter of A) 2010 / 11 pre-construction, B) 2011 / 12 (during construction), C) 2012 / 13 (end of construction in December 2012) & D) 2013 / 14 (post-construction). These maps illustrate that there were generally fewer divers across all zones in 2011-12 compared with the previous year. Please note that the size of the dots is directly comparable across the figures.



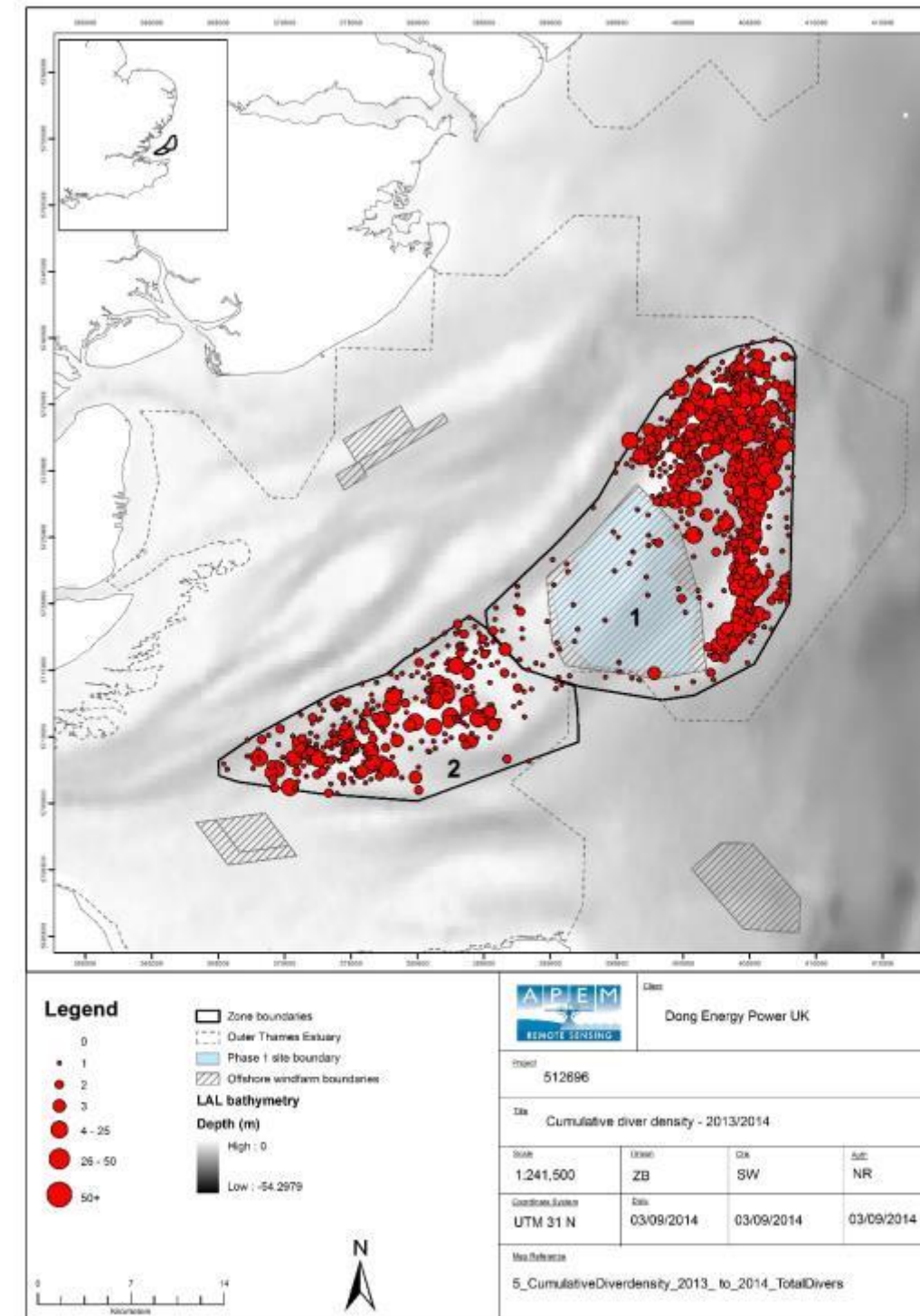
A: Winter survey 2010 / 11 pre-construction



B: Winter survey 2011 / 12 construction from January 2012



C: Winter survey 2012 / 13 construction to January 2013



D: Winter survey 2013 / 14 post-construction

4.3. Comparison of other bird species abundance and distribution during the pre-, during- and post-construction surveys (2012 / 13 to 2013 / 14)

In addition to divers, a range of bird species were recorded during the winter of 2013 / 14 during the aerial surveys of Zone 1 and Zone 2. Future aerial surveys of Zone 1 and Zone 2 will help interpret any change in the number of bird species post-construction, especially as samples of some bird species recorded are small.

Low numbers of fulmars were recorded during the winter 2013 / 14 surveys, with numbers peaking at an estimated eight individuals during January 2014 within Zone 1. Fulmars are known to be widely distributed throughout the North Sea following dispersal from their breeding colonies during September (Stone *et al.* 1995). Therefore, low numbers of this species within the Outer Thames estuary are to be expected. Indeed, low numbers of fulmars were also recorded across Zone 1 during the winters of 2012 / 13, 2011 / 12 and 2010 / 11 where peak estimates of 47, 49 and six individuals were recorded respectively.

Gannets peaked in November 2013 in Zone 1 at an estimated 72 individuals. Fledging occurs from August to October with European birds migrating southwards at the end of the breeding season (Wernham *et al.* 2002). Gannets are known to be widely dispersed throughout the North Sea during winter (Stone *et al.* 1995), and timing may reflect the passage of gannets through the North Sea from wintering quarters to more northerly breeding grounds (Wernham *et al.* 2002). During the first year of post-construction monitoring lower numbers of gannets were observed than during the 2010 / 11 and 2012 / 13 surveys, when peak estimates of 749 and 593 individuals were present in Zone 1 in February. Subsequent post-construction data may indicate whether this is due to gannets avoiding the vicinity of built wind farms (Krijgsveld *et al.* 2011).

Relatively high numbers of cormorants and shags were present in Zone 2 with numbers peaking at 425 during the December 2013 survey, an increase from the 2012 / 13 peak count of 325 individuals. Since cormorants and shags show a coastal distribution year-round (Cramp & Simmons 2004), and Zone 2 lies less than 20 km from land, high numbers in this area are to be expected. Cormorant numbers can increase in the vicinity of built wind farms using the infrastructure as a roost that provides opportunities for the birds to dry their wings out after foraging (Krijgsveld *et al.* 2011). However, further post-construction survey data will aid interpretation.

A slight decrease in peak grebe numbers was observed between the 2012 / 13 and 2013 / 14 winters from eight grebes present within Zones 1 and 2 during February 2014 to 31 grebes present in December 2013 in Zone 1. These were most likely great crested grebes as this species is known to shift to coastal areas during the non-breeding period, particularly shallow coastal areas and estuaries along the east coast (Lack 1986). There is no obvious explanation for the observed change in numbers.

During November 2013, an estimated seven pomarine skuas were located within Zone 1, similar to that recorded in November 2012 (peak estimate=8). These individuals are likely to reflect late autumn passage to wintering grounds off West Africa as their principal movements through the North Sea occur from September to October (Tasker *et al.* 1987; Cramp & Simmons 2004).

The majority of small gulls (75% of the total small gulls) were identified as kittiwakes. Kittiwake numbers peaked at an estimated 617 individuals across Zone 1 in January 2014; a higher

number than that observed during the previous winter surveys when peak estimates of 376, 229 and 196 in 2012 / 13, 2011 / 12 and 2010 / 11 were recorded, respectively. As with other bird species, kittiwakes are known to move in response to atmospheric depressions at sea (Wernham *et al.* 2002), which may have caused an influx of kittiwakes into the estuary at this time. Smaller numbers of black-headed gulls were recorded in November 2013 in Zones 1 and 2, with a peak of 51 individuals recorded in Zone 2. Black-headed gulls spend much of their time over land as well as tidal inshore waters showing a preference for inlets or estuaries with sandy or muddy beaches (Snow & Perrins 1998). Common gull numbers peaked at an estimated 51 individuals in Zone 1 during December 2013, a slight decrease in number from the previous winter survey peak estimate of 85 individuals during February 2013 in Zone 2. Common gulls are found in high densities around coastal parts of estuaries and bays in winter (Stone *et al.* 1995), and there is some evidence of movement of common gulls between Denmark and the UK during winter, sometimes peaking in January and suggesting a gradual westwards shift through the winter (Wernham *et al.* 2002). Further post-construction survey data will confirm whether numbers of small gulls continue to fluctuate.

Total large gulls peaked in November 2013 when an estimated 679 individuals were recorded in Zone 2. Lesser black-backed gull numbers remained relatively constant during the 2013 / 2014 winter with a peak of 87 individuals recorded in December 2013 in Zone 1. The corresponding peak estimates during the 2012 / 13, 2011 / 12 and 2010 / 11 winters were 80, 27 and 84 individuals, respectively. Herring gulls were recorded by all surveys with the exception of the Zone 2 February 2014 survey. Herring gull numbers peaked in November 2013 when 314 individuals were estimated to be present. Great black-backed gulls were the most numerous large gull recorded in 2013 / 14, with a peak of 363 individuals recorded during December 2013 in Zone 1. This was an increase from the maximum count of 220 recorded during the 2012 / 13 surveys. Great black-backed gulls are known to be numerous in the North Sea while on passage to their wintering grounds (Coulsen *et al.* 1984). The distribution of great black-backed gulls is known to extend further out to sea following the end of their breeding season (Stone *et al.* 1995), and like many other gulls and seabirds that feed on discards can be attracted by the presence of fishing vessels (Camphuysen 1993). Further post-construction survey data will allow interpretation of the effect of the London Array OWF, however large gulls are not known to be much affected by the presence of offshore wind farms (Krijgsveld *et al.* 2011).

Large numbers of auks were recorded during the winter 2013 / 14 surveys, with a peak estimate of 1,165 individuals during February 2014 in Zone 2. Auks are generally widespread in marine areas in winter, and numbers can fluctuate at a given site (Stone *et al.* 1995). Guillemot and razorbill adults are known to be dispersive, remaining in seas close to colonies, whilst young birds disperse over longer distances (Cramp & Simmons 2004). Adult auks return to breeding colonies from February to May (Cramp & Simmons 2004). The large numbers of auks recorded in 2013 / 14 may just be a chance event and further post-construction surveys are needed to interpret the data.

4.4 Marine mammals 2013 / 14

The majority of marine mammals recorded during the post-construction winter 2013 / 14 surveys were seals (64%) with a peak estimate of 433 recorded in Zone 1 during the February 2014 survey. The high number recorded was due to a congregation of seals hauled out together on a transient sandbank. These seals may have been either common or grey seals as both species are frequently recorded in the Thames Estuary (Kowalik *et al.* 2008). The remaining marine mammals were identified as dolphin / porpoises (27%) and harbour porpoises (9%). It is likely that the majority of individuals recorded as dolphins & porpoises were also harbour porpoises since this species is most often seen between January and April in the south-eastern North Sea (Reid *et al.* 2003). Other species of

cetacean, such as bottlenose and white-beaked dolphins, have been recorded in the Thames Estuary, but sightings occur largely in the summer, between June and October (Kowalik *et al.* 2008).

5 CONCLUSIONS

Only 188 divers were estimated to be present across Zones 1 and 2 in November 2013, in contrast to December when 5,754 divers were present across both zones. Moderate diver numbers were recorded in January (2,861) and February 2014 (3,026).

The majority of divers were red-throated divers (97.4%) with the remainder being black-throated (1.4%) and great northern divers (1.2%). All divers were identified to species level.

Diver distribution appeared to reflect shallow water areas over sand banks. Approximately 97% of divers were in water depths of < 20 m.

The majority of divers were concentrated in the north-eastern edge of Zone 1 during the December 2013 aerial survey. This distribution was broadly similar to the pre-construction surveys of the area in 2003 / 04 and 2004 / 05 and 2010 / 11.

Diver abundance and distribution has changed between Zones 1 and 2 over the past four years of winter aerial survey (Figure 4.5). Peak diver population estimates in Zone 1 containing the Phase 1 London Array wind farm fell between the 2010 / 11 pre-construction winter and 2011 / 12 first construction winter (Figure 4.3). Numbers started to rise in 2012 / 13 coinciding with the completion of the main body of work in December 2012, although commissioning of all turbines was not completed until April 2013. This increase suggests that some of the divers that used the area pre-construction in 2010 / 11 may have moved back into Zone 1 after initial displacement. As the drop in diver numbers in Zone 1 in 2011 / 12 coincided with the construction of the Phase 1 wind farm, it is possible that disturbance linked to the construction, perhaps in the form of increased shipping traffic (it is known that divers are affected by shipping disturbance) resulted in some divers redistributing themselves out of Zone 1 into the nearby control Zone 2. However, it is important to note that January and February have previously been identified as peak months for red-throated divers wintering in the Greater Thames estuary (Webb *et al.* 2009) and that an increase of even greater magnitude between January and February was recorded in 2011 prior to windfarm construction. The first year of post-construction surveys in 2013 / 14 recorded an increase in diver abundance in Zone 1. Post-construction there was some boat traffic associated with maintenance activities albeit at a much lower level than during construction.

In control Zone 2, peak diver numbers increased in 2011 / 12 when diver numbers had much declined in Zone 1, before reverting in 2012 / 13 and 2013 / 14 to broadly similar numbers to those recorded before construction in 2010 / 11.

Future aerial surveys of the Zone 1 and Zone 2 will show whether diver numbers continue to rise in Zone 1 during the post-construction years.

The construction of the Phase 1 wind farm will not have been the only driver of changing diver abundance and distribution over the last three years. Historic data from the Greater Thames area have shown that diver numbers fluctuate widely, perhaps due to a combination of effects including changes in environmental conditions near and far, diurnal movements, hydrodynamic variables as well local developments.

Several other bird species / groups were recorded on the surveys, the most abundant of which were gulls (including kittiwakes, black-headed gulls, common gulls, lesser black-backed gulls, herring gulls and great black-backed gulls). The observed increase in cormorant numbers may be related to the wind farm as may be the decline in gannet numbers (Krijgsveld *et al.* 2011).

Seals were the most commonly recorded marine mammals across all zones (64% of total marine mammals) and were most abundant in Zone 1 in February 2014 when observed hauled out on a transient sandbank. The remaining individuals were identified as dolphins / porpoises (27%) and harbour porpoises (9%).

Further, more quantitative analysis of the data collected to date and commissioned by London Array Limited will be provided as an addendum to this report. London Array Limited in partnership with Natural England have pooled their respective aerial survey data from the Outer Thames Estuary SPA and, on the basis of that pooled resource, Natural England commissioned the application of spatially adaptive statistical modelling tools to these joint data-holdings. This work will be published in due course as a Natural England report. This pilot partnership work was undertaken with a view to the further development and application of that modelling approach by London Array Limited to provide the most statistically robust analysis of the results of its ongoing monitoring in its future post-consent monitoring reports.

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APPENDIX I CONSTRUCTION SCHEDULE

Date	Work Summary	Notes
March 2011	START OF OFFSHORE CONSTRUCTION	
	Installation of monopole foundations	
July 2011	Installation of offshore substations	
August 2011 – November 2012	Inter-array cable installation linking turbines to substations	
Autumn 2011 – Autumn 2012	Installation of four export cables between substations and the landfall at Seasalter in the Swale	
October 2012	First turbine in operation	
December 2012	MAIN BODY OF CONSTRUCTION COMPLETED	Continuous program of maintenance
April 2013	Commissioning of all turbines complete	
July 2013	Wind farm inaugurated	
Summer / Autumn 2013 and 2014	Residential construction works related to array cables and scour protection on offshore substation	

APPENDIX II SURVEY WEATHER CONDITIONS

Date surveys undertaken	Zone(s) surveyed	State of seas*	Wind speed / direction	Visibility
November 9th 2013	2	1	20 knots / SW	Cloud cover was broken to overcast with > 10 km visibility
November 10th 2013	1	1 - 2	20 knots / NNW	Cloud cover scattered with > 10 km visibility
December 9th 2013	2	1	18 knots / SW	Cloud cover scattered with > 10 km visibility
December 11th 2013	1	1	15 - 25 knots / SSW	No cloud cover with >10 km visibility
January 10th 2014	1	1	20 knots / SW	No cloud cover with > 10 km visibility
January 11th 2014	2	2 - 3	25 knots / NW	No cloud cover with > 10 km visibility
February 2nd 2014	2	1 - 2	AM 24 knots / SW PM 15 – 20 knots / S	No cloud cover AM with cloud cover becoming scattered at 2,000 feet by early PM. Visibility was >10 km throughout the day
February 3rd 2014	1	2 - 3	30 knots / SE	No cloud cover with > 10 km visibility all day

APPENDIX III TIDE INFORMATION FROM WHITAKER BEACON



Figure II.1 Location of Whitaker Beacon tide monitoring site

Table II.1 Information on survey times and tide height and state during surveys at Whitaker Beacon site

Survey	Date	Zone	Survey time	Tide height at Whitaker Beacon	State of tide
November 2013	10/11/2013	1	08:11 – 13:20	11:01: 0.7m 17:27: 4.19m	Incoming
	09/11/2013	2	07:52 – 10:49	03:48: 4.64m 10:01: 0.46m	Outgoing then incoming for last hour
December 2013	11/12/2013	1	09:40 – 14:43	12:51: 0.95m 19:19: 3.99m	Outgoing until half way through survey then incoming
	09/12/2013	2	12:02 – 14:49	10:45: 0.5m 17:10: 4.38m	Incoming
January 2014	10/01/2014	1	09:19 – 14:14	06:57: 3.79m 13:14: 1.21m	Outgoing then incoming for last hour
	11/01/2014	2	09:49 – 12:34	08:07: 3.66m 14:21: 1.31m	Outgoing
February 2014	03/02/2014	1	09:35 – 14:13	08:29: -0.26m 14:45: 5.36m	Incoming
	02/02/2013	2	10:56 – 14:11	07:46: -0.36m 14:02: 5.52m	Incoming

APPENDIX IV PEAK POPULATION ESTIMATES OF DIVERS RECORDED BY THE LONDON ARRAY AERIAL SURVEYS IN ZONES 1, 2, 3, 5, 6 & 7 OVER THREE WINTERS IN 2010 / 11, 2011 / 12 AND 2012 / 13.

Zone	Year	Month	Count	Population Estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
1	2011	February	1,257	8,194	6,727	9,830	0.03
	2012	January	181	1,474	1,108	1,906	0.07
	2013	February	665	3,153	2,276	4,281	0.04
2	2011	February	144	909	682	1,174	0.08
	2012	February	433	1,980	1,536	2,469	0.05
	2013	February	241	1,144	912	1,410	0.07
3	2011	January	30	175	93	274	0.18
	2012	January	63	534	364	720	0.13
	2013	January	63	294	201	411	0.13
5	2011	February	53	312	200	448	0.14
	2012	February	83	391	255	575	0.11
	2013	February	63	288	215	370	0.13
6	2010	December	9	68	23	121	0.33
	2011	November	5	23	5	42	0.44
	2013	February	18	82	46	128	0.24
7	2011	February	61	367	253	499	0.13
	2012	February	63	286	163	444	0.13
	2013	January	25	202	121	291	0.20

APPENDIX V BIRD DISTRIBUTION IN WINTER 2012 / 13

Figure III.1 Distribution of birds and marine mammals during November 2012

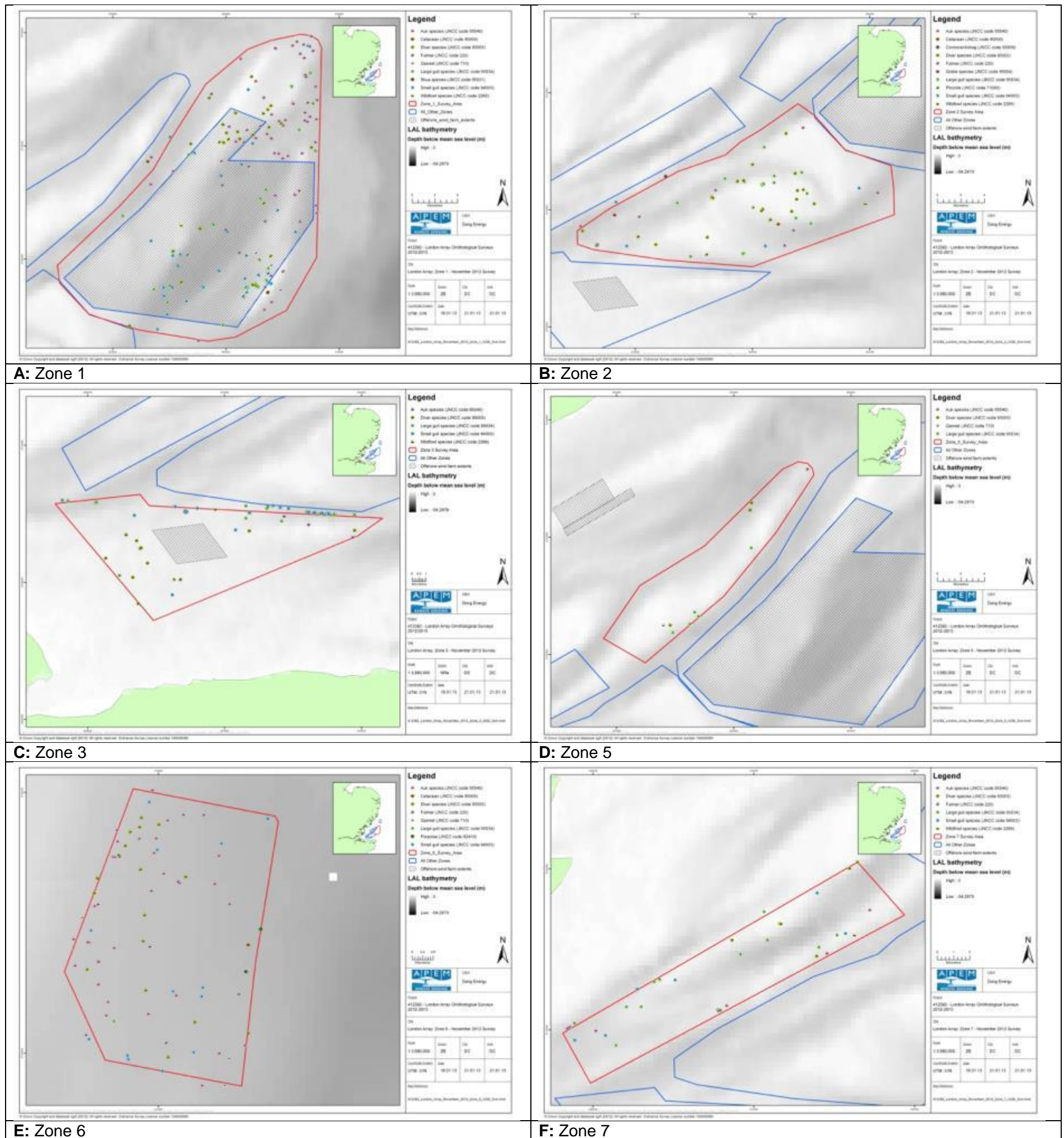


Figure III.2 Distribution of birds and marine mammals during December 2012

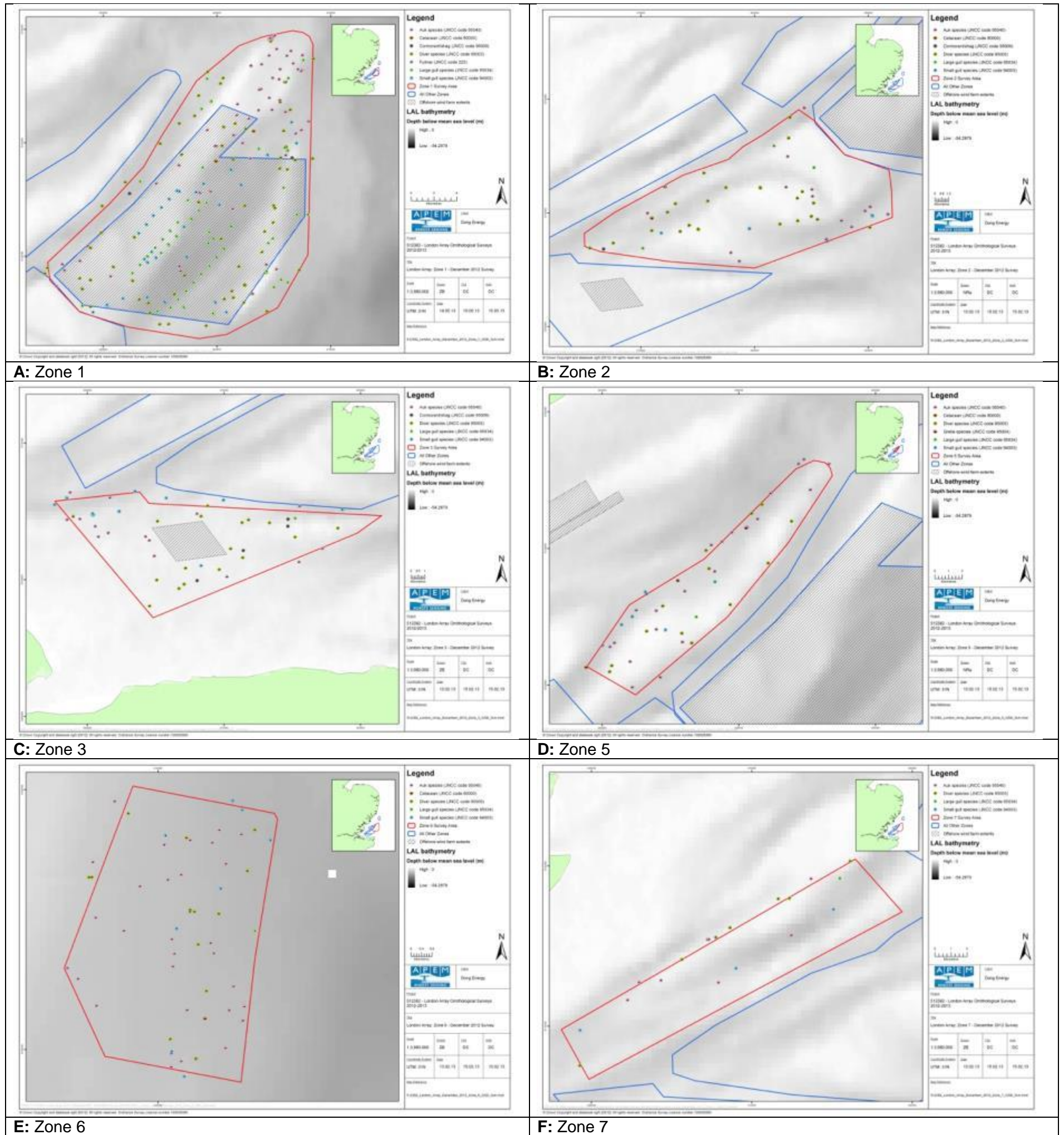


Figure III.3 Distribution of birds and marine mammals during January 2013

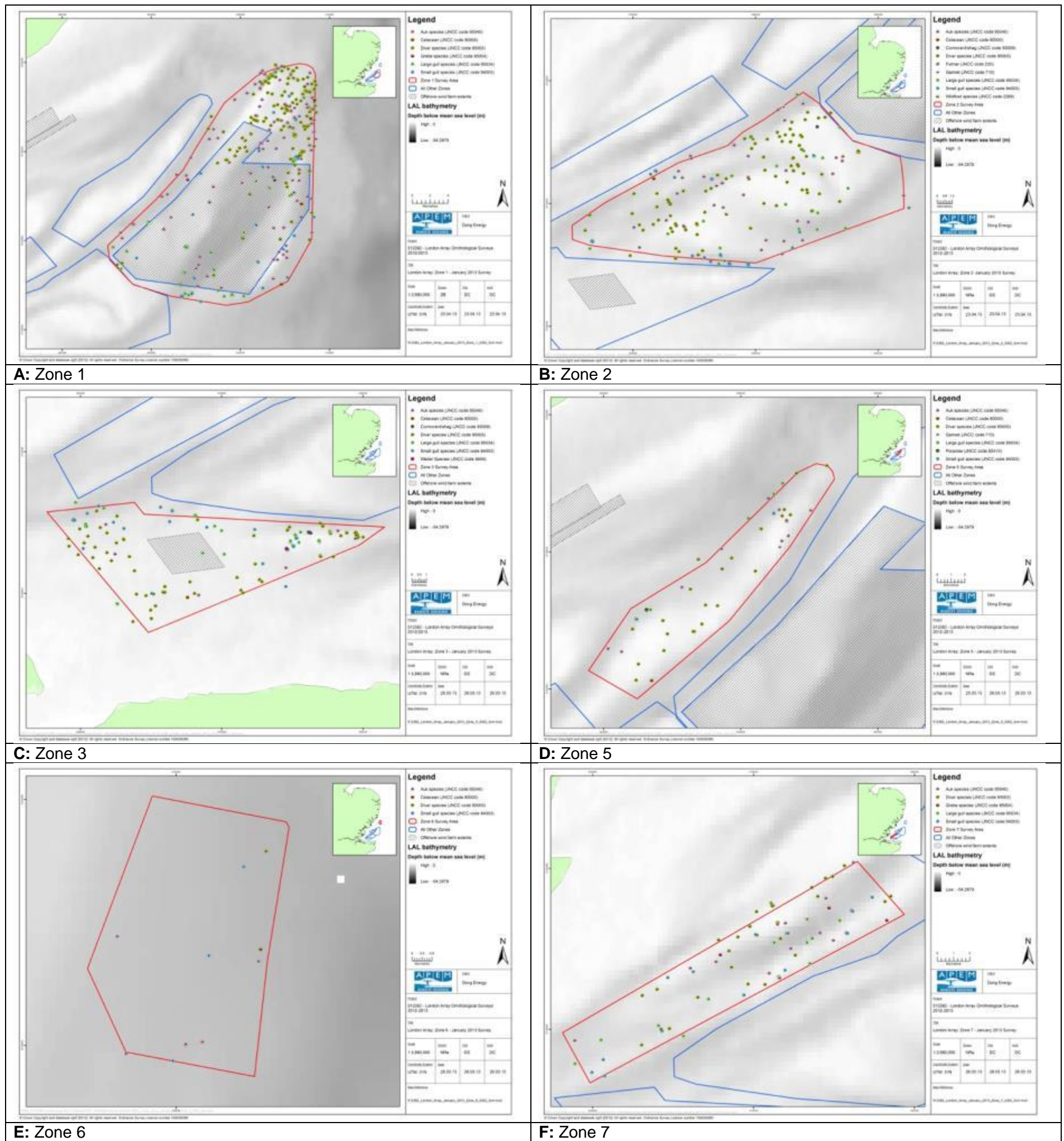
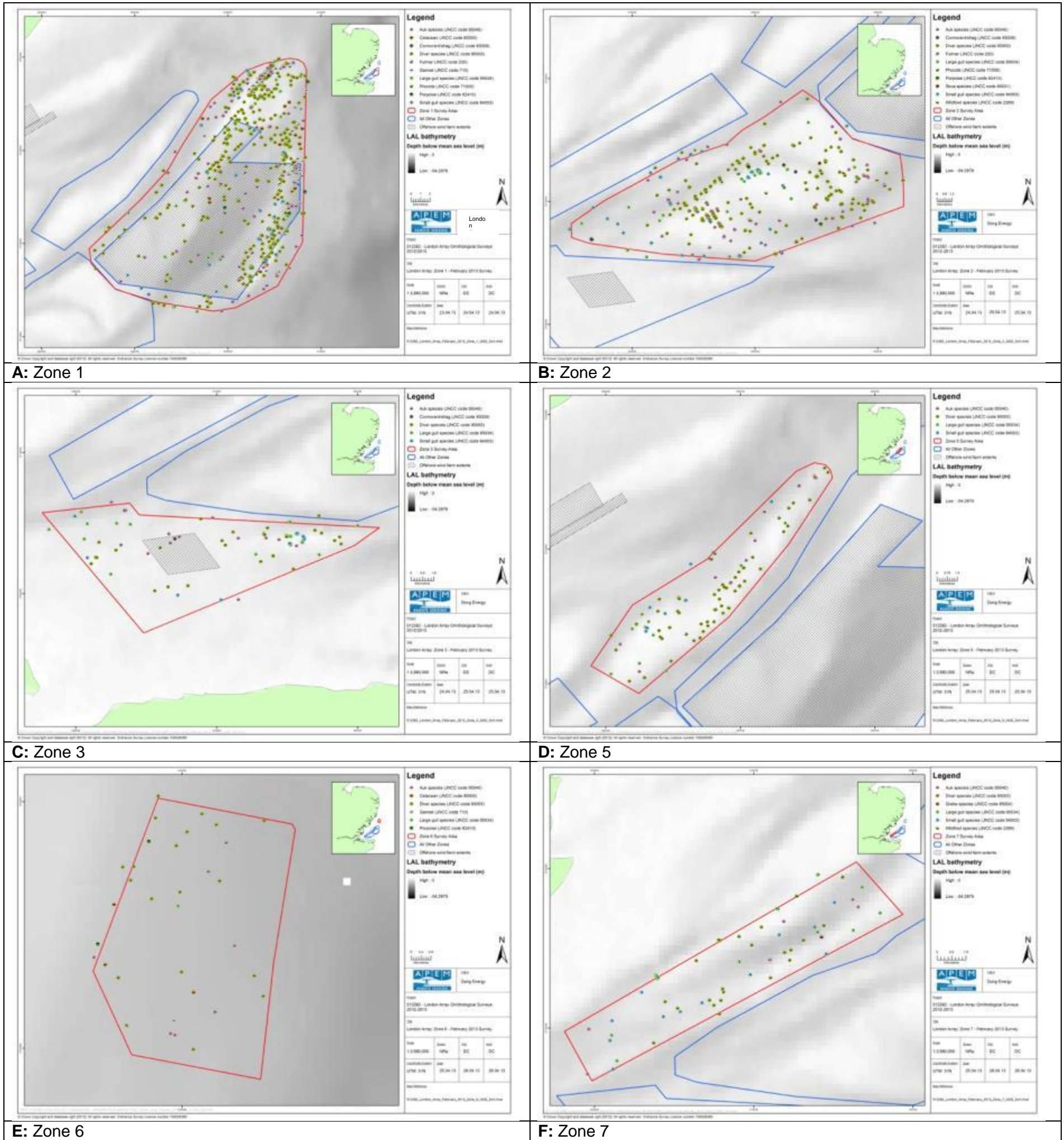


Figure III.4 Distribution of birds and marine mammals during February 2013



APPENDIX VI BIRD DISTRIBUTION IN WINTER 2011 / 12

Figure IV.1 Distribution of birds and marine mammals during November 2011

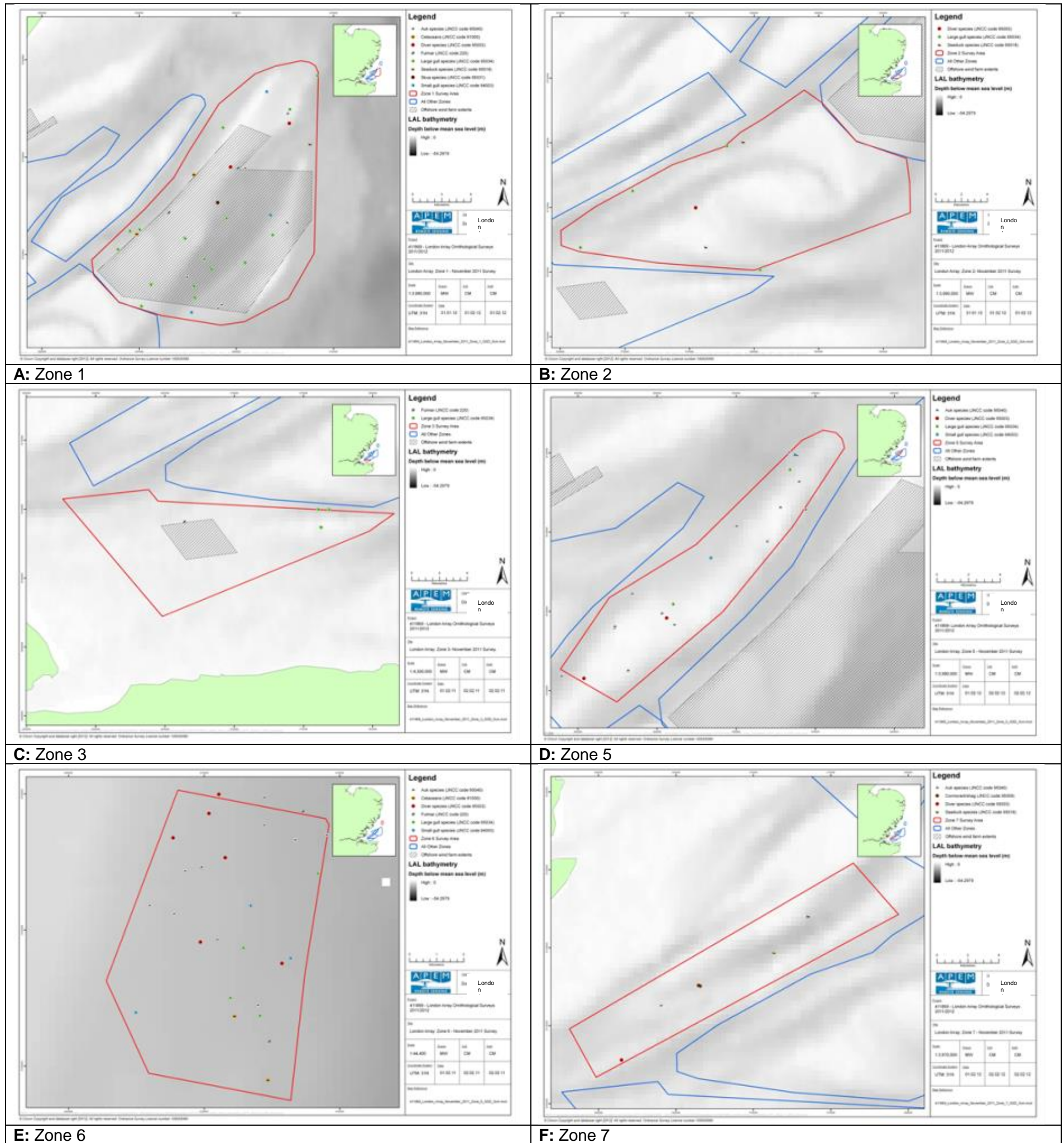


Figure IV.2 Distribution of birds and marine mammals during December 2011

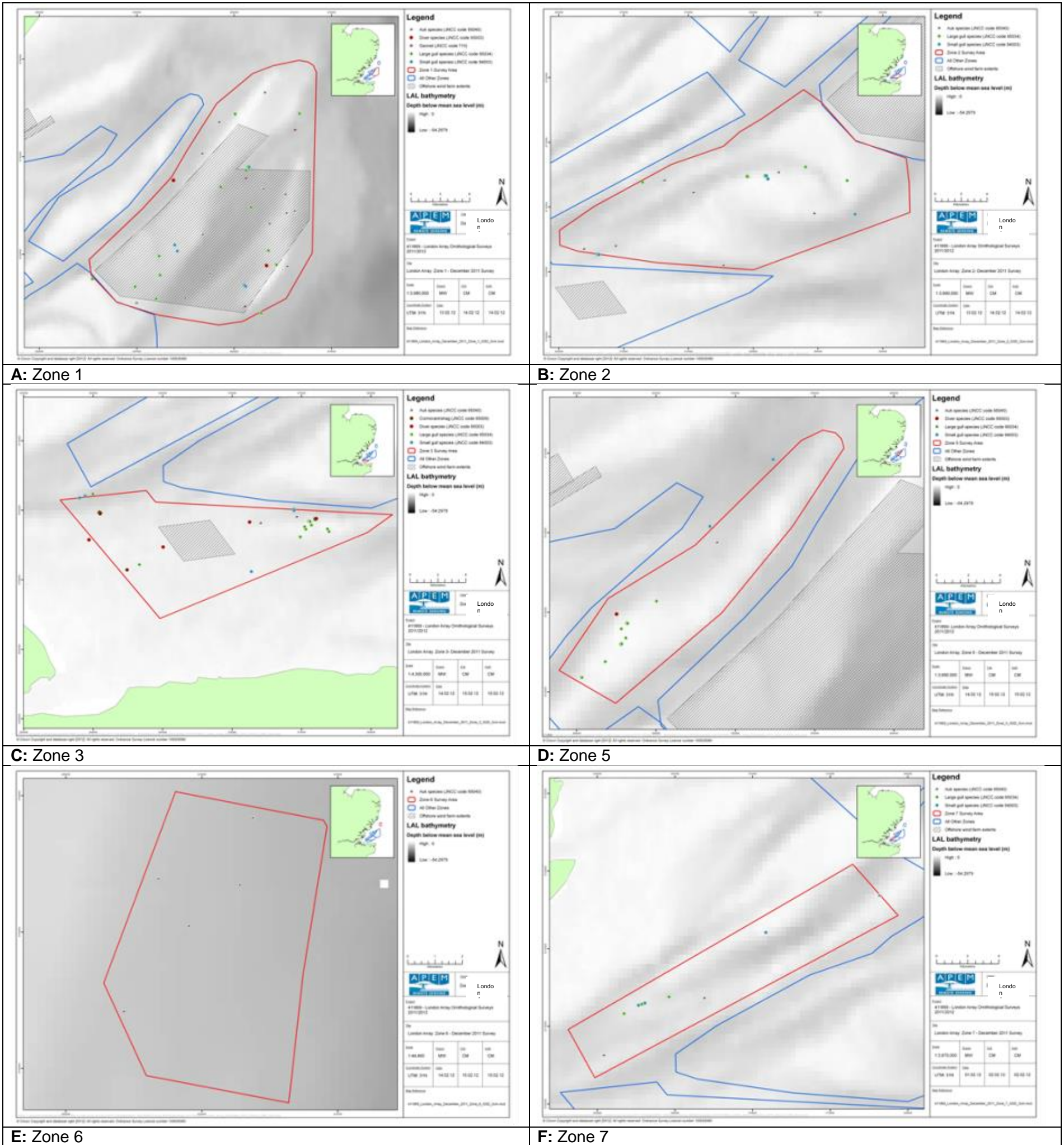


Figure IV.3 Distribution of birds and marine mammals during January 2012

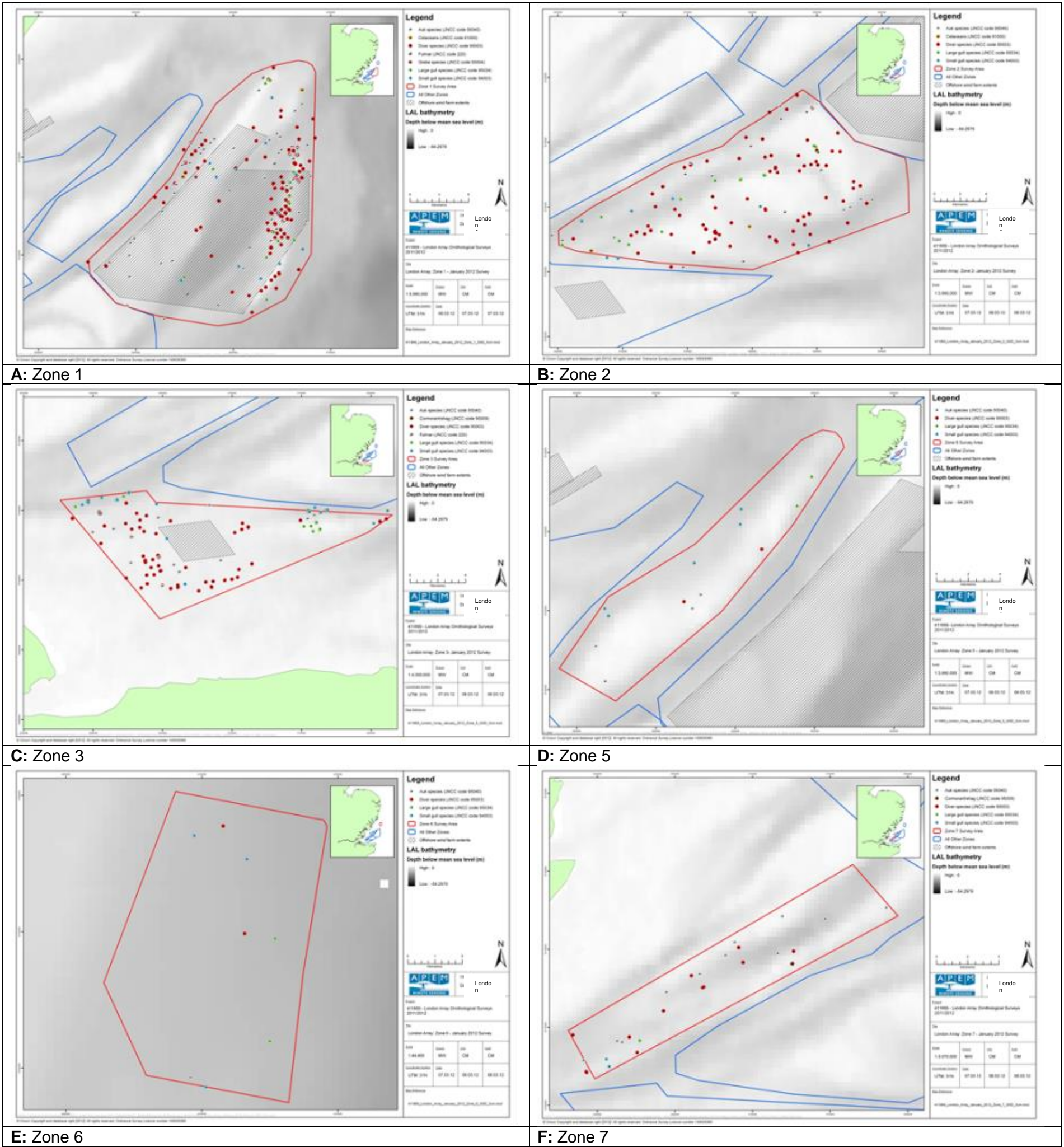
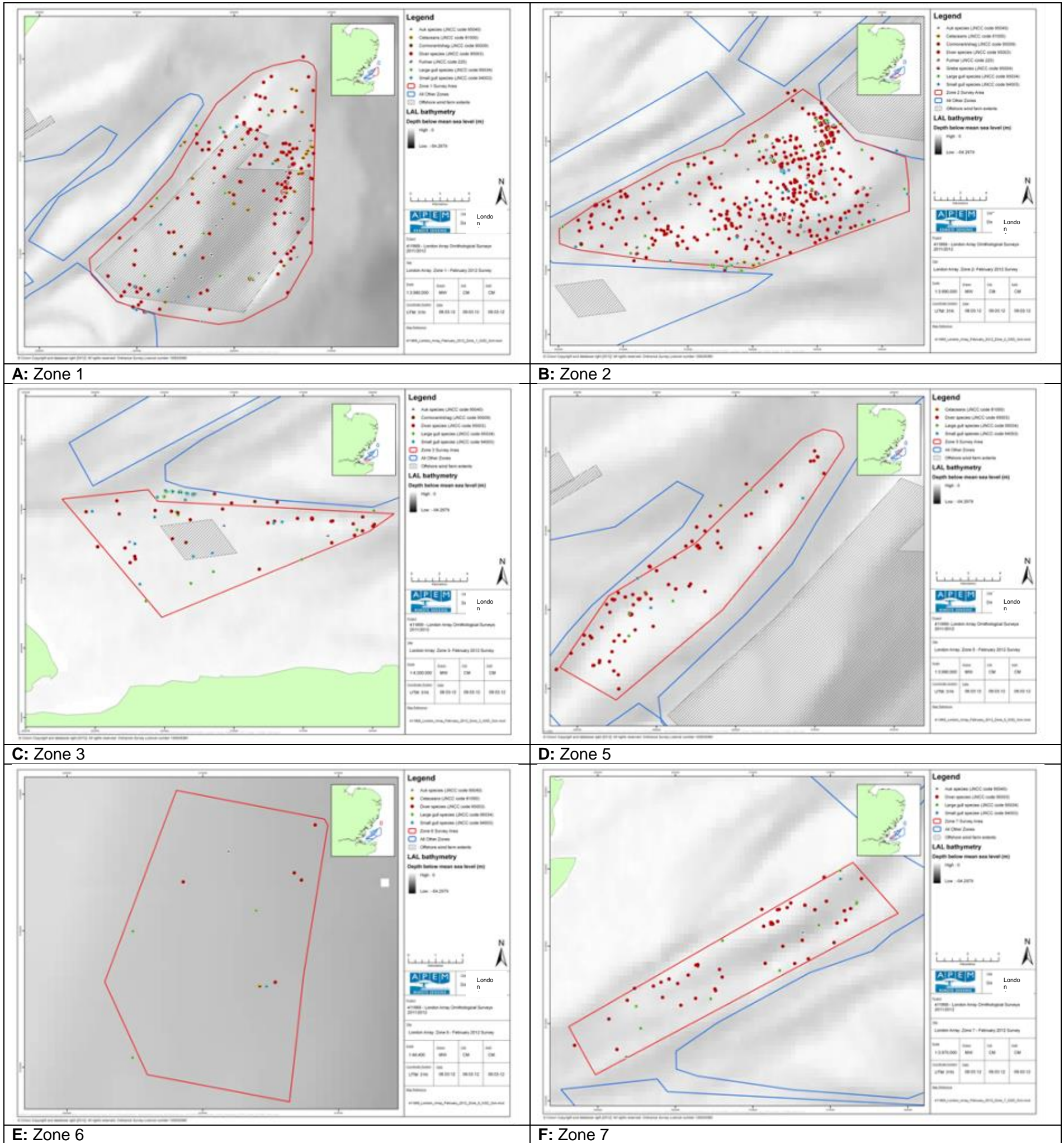


Figure IV.4 Distribution of birds and marine mammals during February 2012



APPENDIX VII BIRD DISTRIBUTION IN WINTER 2010 / 11

Figure V.1 Distribution of birds and marine mammals during November 2010

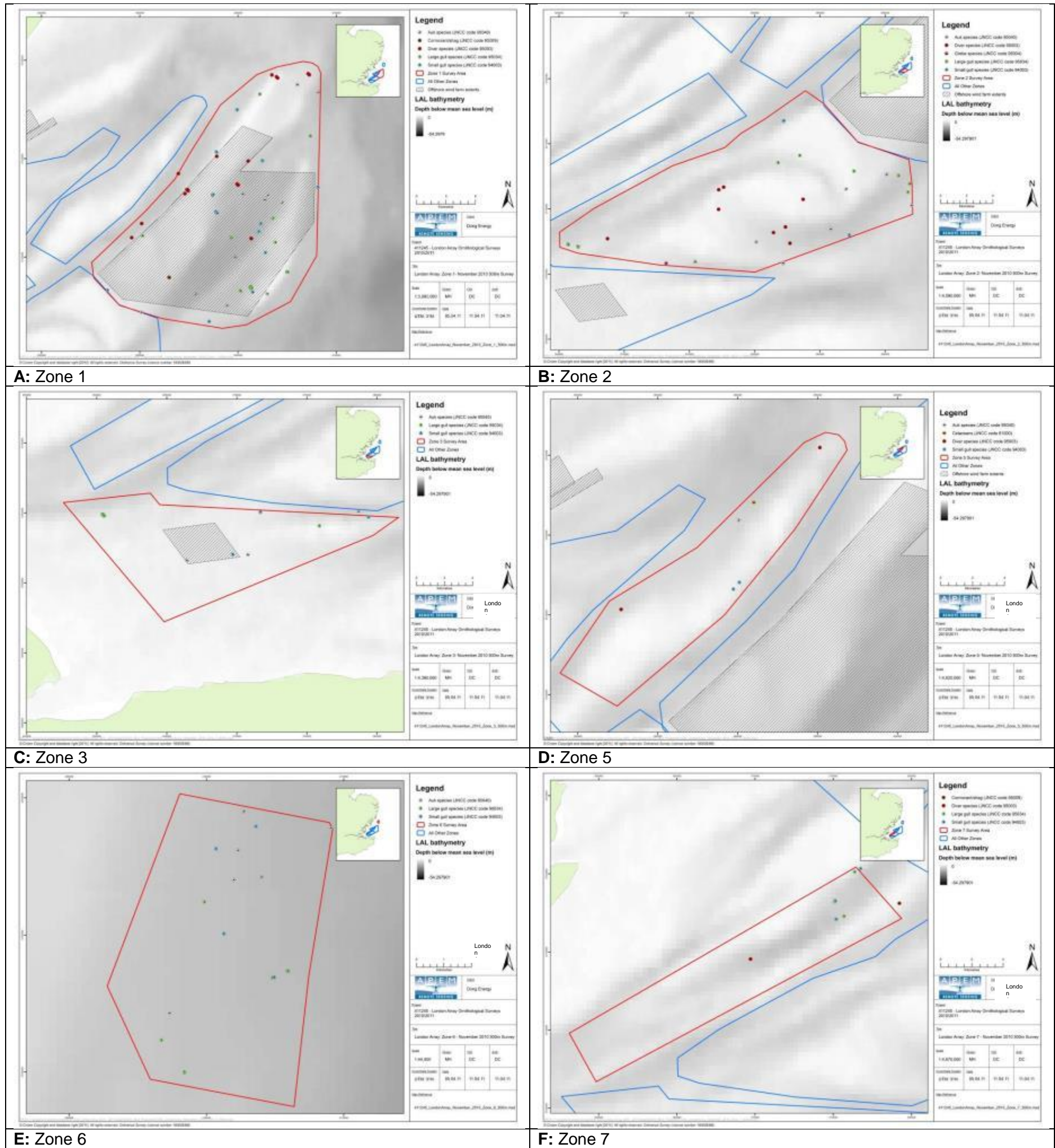


Figure V.2 Distribution of birds and marine mammals during December 2010

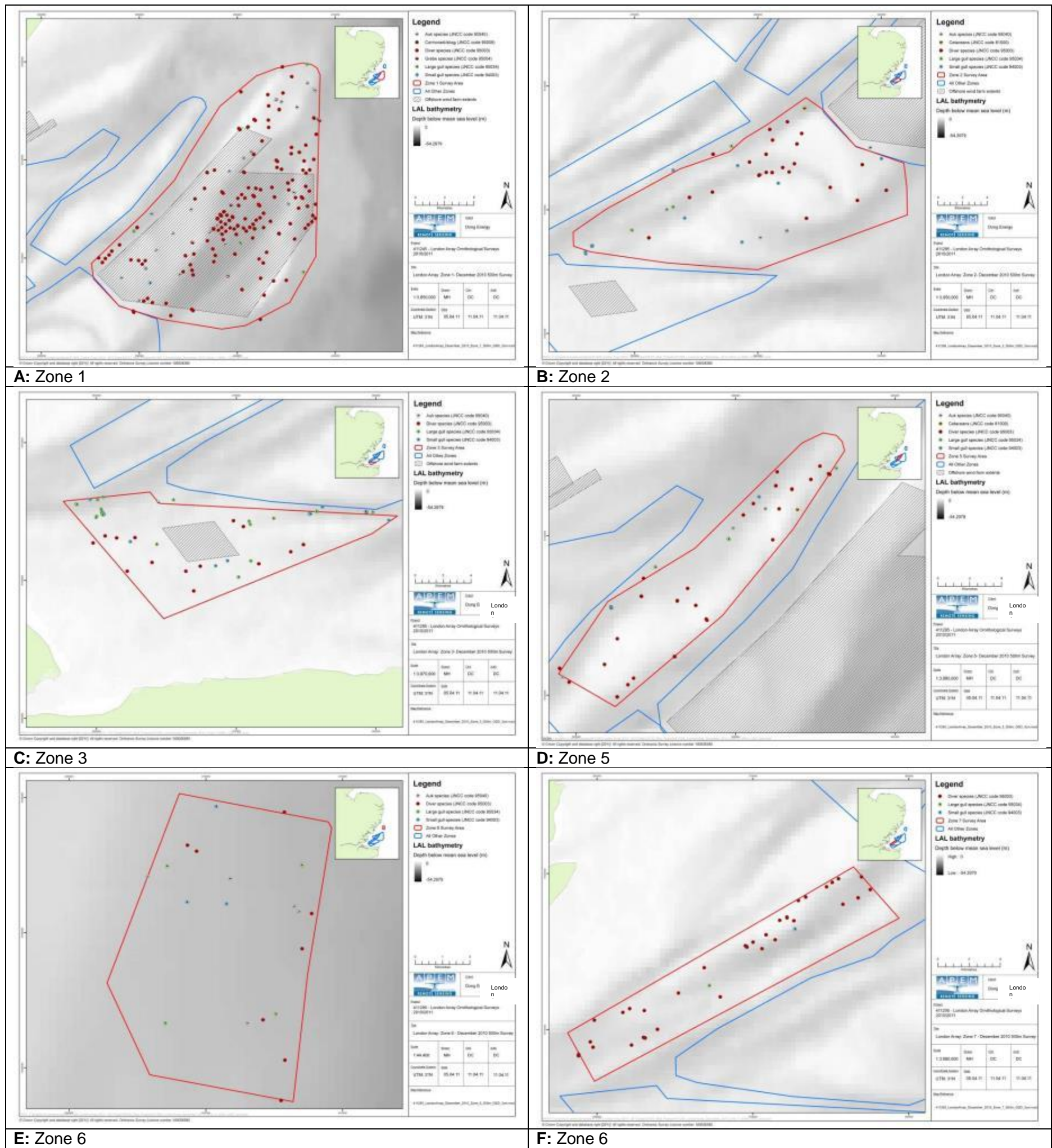
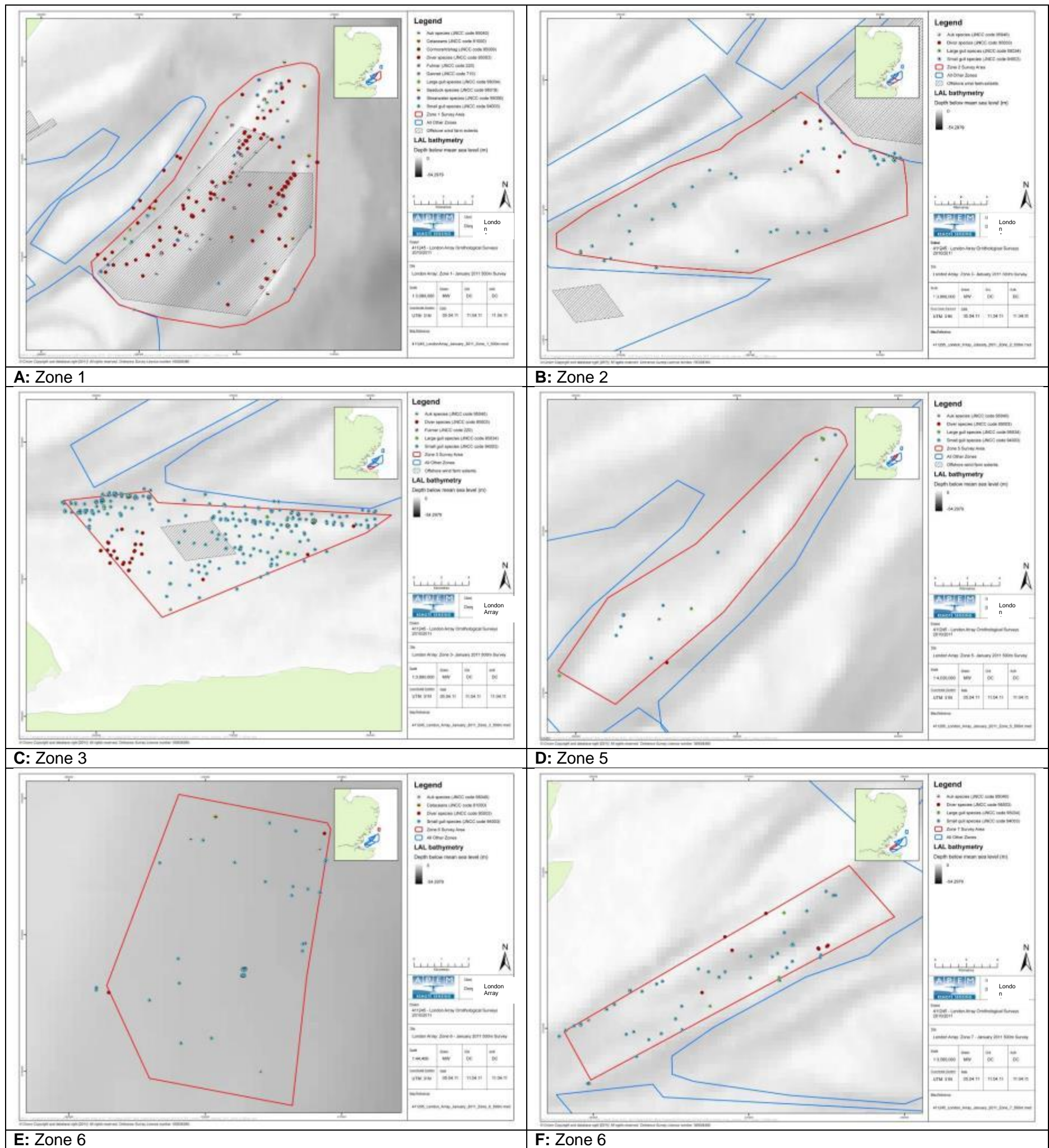


Figure V.3 Distribution of birds and marine mammals during January 2011



APPENDIX VIII JNCC BIRD & MARINE MAMMAL GROUPS

JNCC Code	Grouping	Species Code	Species
95003	Diver species	20	Red-throated diver
		30	Black-throated diver
		40	Great Northern diver
220	Fulmar	220	Fulmar
710	Gannet	710	Gannet
95009	Cormorant / shag	720	Cormorant
		800	Shag
95004	Grebe species		
95031	Skua species		Pomarine skua
94003	Small Gull species	6020	Kittiwake
		5820	Black headed gull
		5780 5900	Little gull Common gull
95034	Large Gull species	5910	Lesser black-backed gull
		5920	Herring gull
		6000	Great black-backed gull
95040	Auk species	6340	Guillemot
		6360	Razorbill
71000	All Phocids (e.g. seals)	n/a	
80000	All Cetaceans (whales, dolphins)	82410	Harbour porpoise

APPENDIX IX LATIN NAMES OF BIRD SPECIES

Common name	Latin name
Red-throated diver	<i>Gavia stellata</i>
Black-throated diver	<i>Gavia arctica</i>
Great northern diver	<i>Gavia immer</i>
Fulmar	<i>Fulmarus glacialis</i>
Gannet	<i>Morus bassanus</i>
Cormorant	<i>Phalacrocorax carbo</i>
Shag	<i>Phalacrocorax aristotelis</i>
Grebe species	Podicipediformes
Pomarine skua	<i>Stercorarius pomarinus</i>
Kittiwake	<i>Rissa tridactyla</i>
Black-headed gull	<i>Chroicocephalus ridibundus</i>
Common gull	<i>Larus canus</i>
Lesser black-backed gull	<i>Larus fuscus</i>
Herring gull	<i>Larus argentatus</i>
Great black-backed gull	<i>Larus marinus</i>
Guillemot	<i>Uria aalge</i>
Razorbill	<i>Alca torda</i>