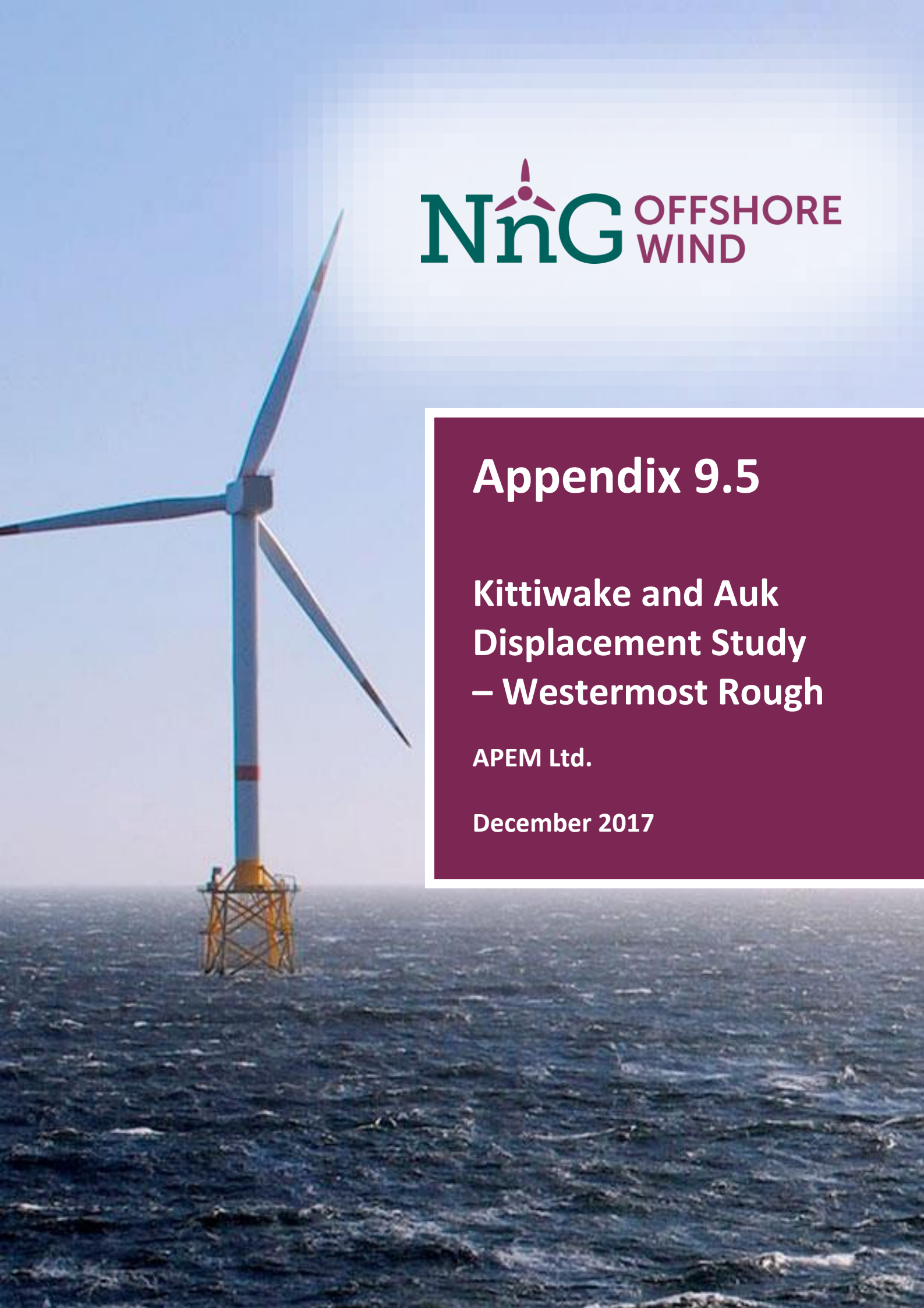

Appendix 9.5

Kittiwake and Auk Displacement Study – Westermost Rough

APEM Ltd.

December 2017

P00001836 Mainstream Kittiwake and Auk Displacement

Neart na Gaoithe Offshore Wind Limited

December 2017

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1. Executive Summary

Three high resolution digital still aerial surveys of the Westermost Rough Offshore Wind Farm (WROWF) and its surrounding 8 km buffer were carried out in July 2017. Surveys were conducted to compare distributions of kittiwakes and auks inside and outside the wind farm. Transects covering the wind farm footprint and its 8 km buffer were flown in both NW-SE and NE-SW directions. Surveys were flown at 2 cm resolution and *c*. 50% coverage was achieved for each survey.

Counts and distributions have been presented for both kittiwake and auks for each survey.

Design-based estimates of bird abundance with confidence limits were calculated for the wind farm and 1 km concentric bands stretching from the edge of the WROWF footprint to a distance of 9 km. Densities were also calculated for the landward and seaward halves of the wind farm and their corresponding 1 km buffers. Densities were then plotted against the distance from the wind farm. A quasi-Poisson Generalised Additive Model was used to determine the relationship between relative density estimates and distance to the WROWF. A Kruskal-Wallis test was undertaken on the relative density estimates to investigate if there was any significant difference in the densities between different buffers.

Overall mean densities calculated for the entire wind farm and its surrounding 1 km buffer zones indicates that there is no clear evidence of displacement for kittiwakes. There were variations in kittiwake densities between buffers but this was not statistically significant potentially due in part to the large between survey variability in kittiwake densities.

There is a lot of variability in overall mean auk densities calculated for the entire wind farm and its surrounding 1 km buffer zones suggesting no clear evidence of displacement. There were variations in mean densities of auks between buffers but these differences were not statistically significant.

Overall, although mean densities varied between the wind farm footprint and the buffers due to the large variation in between survey densities no statistically significant differences were found in density with distance to wind farm for both kittiwakes (GAM analysis: p=0.971, Kruskal-Wallis test: p=0.717) and auks (GAM analysis: p=0.528, Kruskal-Wallis test: p=*0.472*). Further analysis could be undertaken to determine whether other environmental variables (e.g. tide, bathymetry, weather and prey abundance / distribution) contribute to the distributions and variable densities observed during the July 2017 aerial surveys, and by so doing demonstrate clearly what appears to be a lack of any significant auk and kittiwake displacement.

2. Introduction

APEM Ltd was commissioned by Neart na Gaoithe (NnG) Offshore Wind Limited to undertake three digital aerial surveys of Westermost Rough Offshore Wind Farm (WROWF) and a surrounding 8 km buffer area (the survey area) to compare distributions of kittiwakes and auks during the breeding season to provide context for the NnG Environmental Impact Assessment.

Previously APEM successfully applied a novel survey design and statistical method using data from digital stills imagery to assess avoidance rates for gannets during the autumn passage at an offshore wind farm (APEM, 2014). This method has been adapted to investigate displacement of kittiwakes and auks at WROWF during the breeding season.

WROWF is located approximately 8 km north-east of Withernsea off the Yorkshire coast in the North Sea and approximately 35 km from the Flamborough Head and Bempton Cliffs breeding colony (Figure 1). It covers an area of 35 km^2 with a capacity of approximately 210 MW, and was fully commissioned in 2015. The wind farm comprises 35 turbines spaced approximately 1 km apart (Figure 2), each with a turbine height of 177 m, hub height of 102 m and rotor diameter of 154 m. For the purposes of this study APEM conducted aerial surveys of the WROWF and a surrounding 8 km buffer as shown in Figure 1. Transects extended slightly further than 8 km to ensure full coverage of the 8 km buffer, all data captured in the surveys was used in the analysis for this report. The total wind farm area surveyed was 35 km^2 and the buffer area surveyed was 390 km^2. The survey design enabled an assessment of the magnitude of any change in kittiwake and auk densities with increasing distance from the WROWF to be carried out, the results of which are presented in this report.

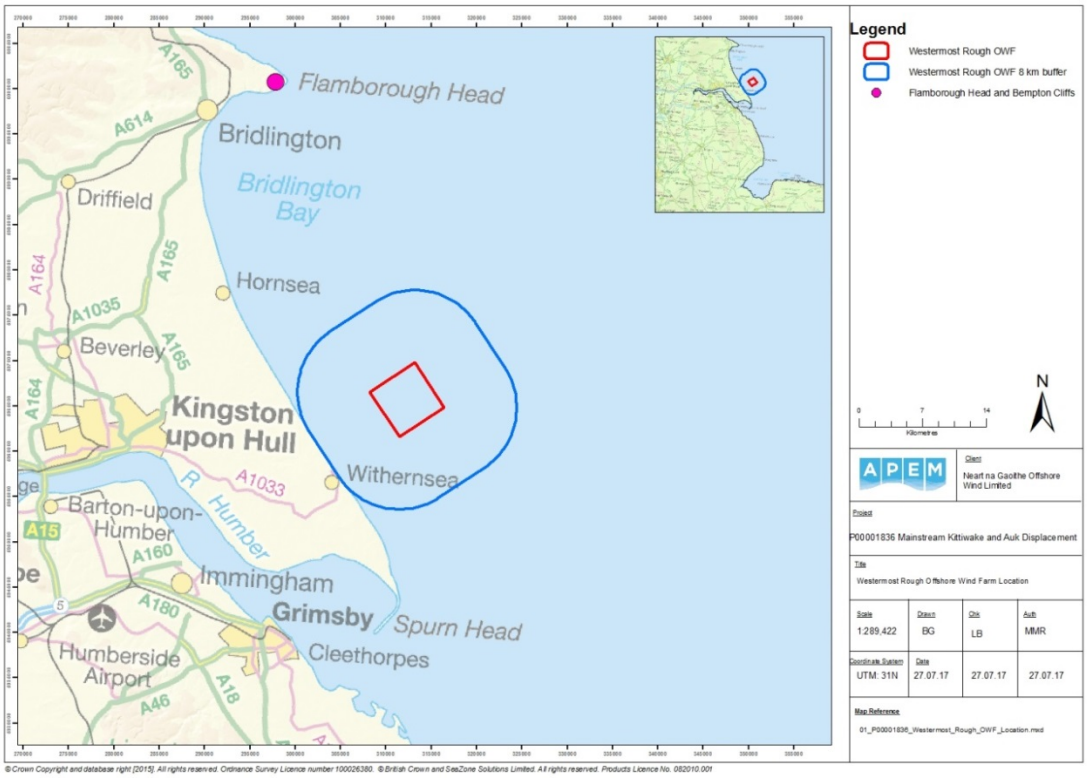

Figure 1 **Location of Westermost Rough Offshore Wind Farm survey area.**

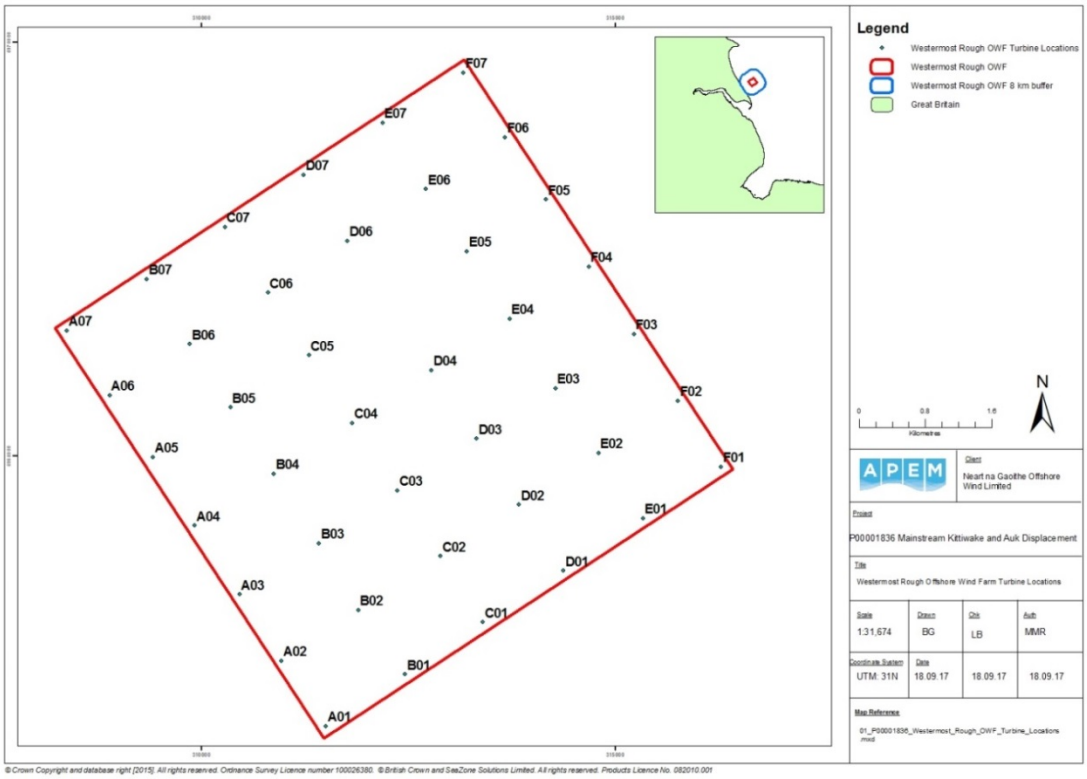

Figure 2 **WROWF Turbine locations and identification codes.**

The three digital aerial surveys at WROWF were carried out to deliver the data necessary to determine how kittiwake and auk numbers and distributions vary with distance to offshore wind farm.

This report details the results of the three aerial surveys conducted to compare distributions of kittiwakes and auks inside and outside the wind farm. The numbers and distribution of flying gannets recorded at WROWF was also collated and are presented in Appendix 4.

3. Methods

3.1 Aerial Survey

Three high resolution digital aerial surveys were conducted in July 2017, in the midst of the breeding season for the key species of interest (Table 1), to obtain count and distributional data for kittiwakes, auks and gannets. In July, breeding kittiwakes will commute between coastal breeding sites and offshore feeding areas (Cramp & Simmons, 1977) and are therefore expected to be present within the survey area during this time of the year.

Table 1 Biologically defined minimum population scales (BDMPS) bio-seasons for the key species of interest (Furness, 2015).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gannet			(Migration-free breeding season: Apr-Aug)									
Kittiwake			(Migration-free breeding season: May-Jul)									
Guillemot			(Migration-free breeding season: Mar-Jun)									
Razorbill				(Migration-free breeding season: Apr-Jun)								
Puffin				(Migration-free breeding season: Apr-Aug)								

Note: BDMPS non-breeding seasons are shown in blue and breeding seasons are shown in yellow.

Aerial surveys were conducted using Vulcanair P68 twin engine aircraft flying at an altitude of approximately 1,400 ft. Bespoke flight planning software was used to program the survey flight lines which extend slightly further than the extent of the 8 km buffer to ensure full coverage (Figure 3). The on-board GPS systems ensured that the survey tracks were flown to an accuracy of 45 m across track and 5-10 m along track.

Displacement of birds such as kittiwakes and auks might occur both from within the wind farm and also from an area around it. The survey design accounted for this by extending the survey transects a sufficient distance to cover an 8 km buffer area from the edge of the wind farm so that a sample was taken from areas of sea beyond any known displacement effect. Krijgsveld *et al*. (2011) have shown that birds in flight may show avoidance behaviour up to 5 km from the wind farm and Percival (2014) has shown that birds on the water may be displaced from a zone up to 3 km from the wind farm. To account for this each transect began at least 8 km away from the outermost turbine on one side of the WROWF, crossed the wind farm and continued at least 8 km beyond the other side of the WROWF.

The number of transects and area covered required to obtain sufficient data was determined from estimated encounter rates of kittiwakes, auks and gannets, devised from densities recorded during the breeding season. Peak densities of 0.65, 3.27, 6.76 and 3.09 / km^2 for gannets, kittiwakes, guillemots and razorbills respectively were recorded by boat survey in the area of the WROWF (RPS, 2009).

To determine in a statistically defensible manner any relationship between kittiwake and auk numbers and distance to an offshore wind farm during the breeding season the surveys aimed to record the location of a minimum of 350 individuals of each species (a number slightly greater than that found to be sufficient to assess gannet response to a wind farm:

APEM 2014). For example, assuming a peak density of 3.09 razorbills / km^2 we would have to gather at least 113 km^2 of images. Assuming a peak density of 0.65 for gannets / km^2 we would have to gather at least 540 km^2 of images. However as seabird densities can vary from day to day a total of three surveys were conducted at 2 cm resolution, each covering approximately 215 km^2 to ensure that in total 350 individuals of each species were recorded. Figure 3 displays the series of transects flown during each of the three surveys.

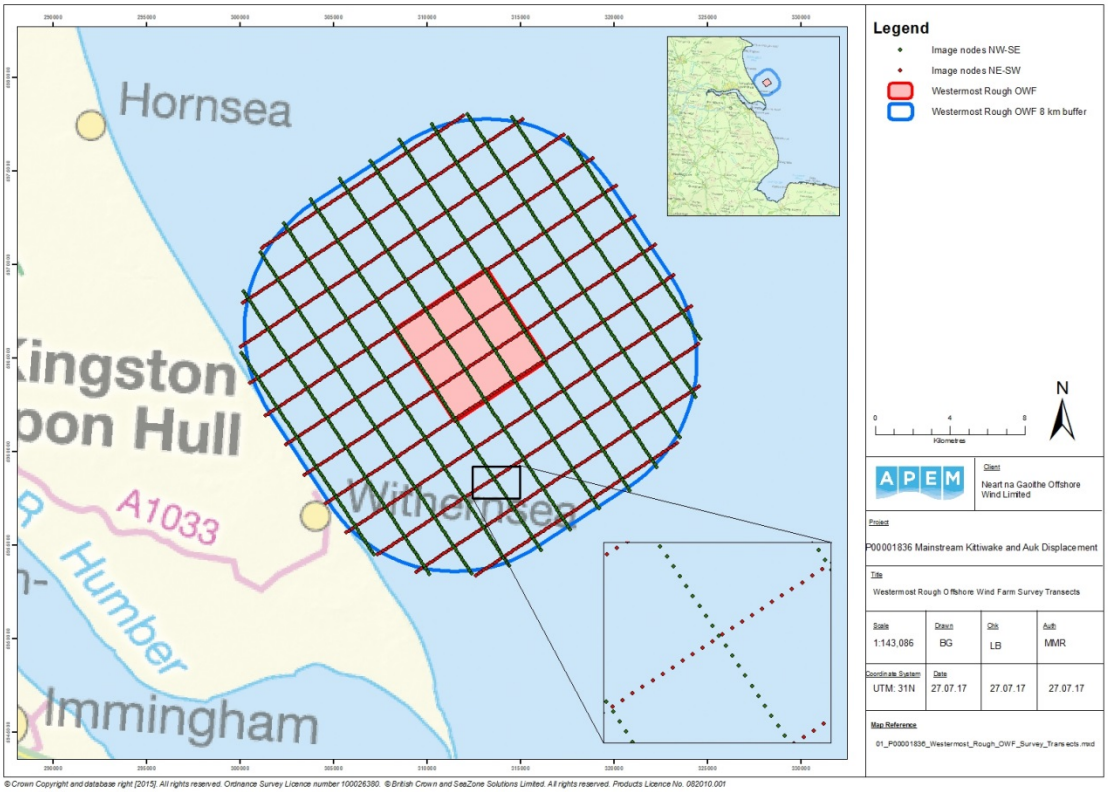

Figure 3 Westermost Rough aerial survey transects and survey area.

3.1.1 Survey Timings

Details of the survey timings and weather conditions during each survey are presented in Tables 2 and 3.

Table 2 Survey dates of the WROWF digital aerial surveys.

Survey Number	Date	Total number of images within survey area	Survey coverage
1	13/07/2017	2,630	48%
2	14/07/2017	2,630	48%
3	16/07/2017	2,631	48%

Table 3 Weather conditions during the WROWF digital aerial surveys.

Survey Number	Sea state	Wind speed / direction	Cloud cover*	Visibility
1	2	25 knots / SW	85 – 90 %	>10 km
2	2-4	20 knots / NW	75 – 95 %	>10 km
3	1-2	< 10 knots / NNW & E	15 – 99 %	>10 km

*0% Clear, 1-10% Few, 11-50% Scattered, 51-95% Broken, 96-100% Overcast.

3.1.2 Shipping Observations

During each survey the camera technician on-board the aircraft noted any shipping observations. Ships were not necessarily on the flight path of the aircraft, but are visual observations made in real-time by the camera operators. Such vessels would have either crossed or passed within one nautical mile of a transect, in front of the aircraft. Details of shipping observations made by the on-board camera technician can be found in Appendix 1.

In Survey 1 one container ship, eight fishing boats, one maintenance vessel, and three small vessels of unknown function were recorded. In Survey 2 nine fishing vessels and one vessel of an unknown function were recorded. In Survey 3 one rowing boat, five speed boats, one fishing boat and one small leisure boat were recorded.

Four fishing vessels were captured in the Survey 1 imagery, one was located to the east near to the buffer zone boundary, one was located south of the wind farm and two were located in the west of the buffer zone (Figure 4).

One sailing boat, three fishing vessels and one vessel of an unidentified function were captured in the Survey 2 imagery. The sailing boat was located in the western buffer zone, two of the three fishing vessels were located in the wind farm and one was located in the south-west buffer zone. The unidentified vessel was located to the west of the wind farm (Figure 5).

One fishing vessel, two supply vessels and three vessels of an unidentified function were captured in the Survey 3 imagery. The fishing vessel was located in the north-west corner of the buffer zone. The supply vessels were located in the north and south of the wind farm. The three unidentified vessels were located in the west, south-east and eastern regions of the buffer zone (Figure 6).

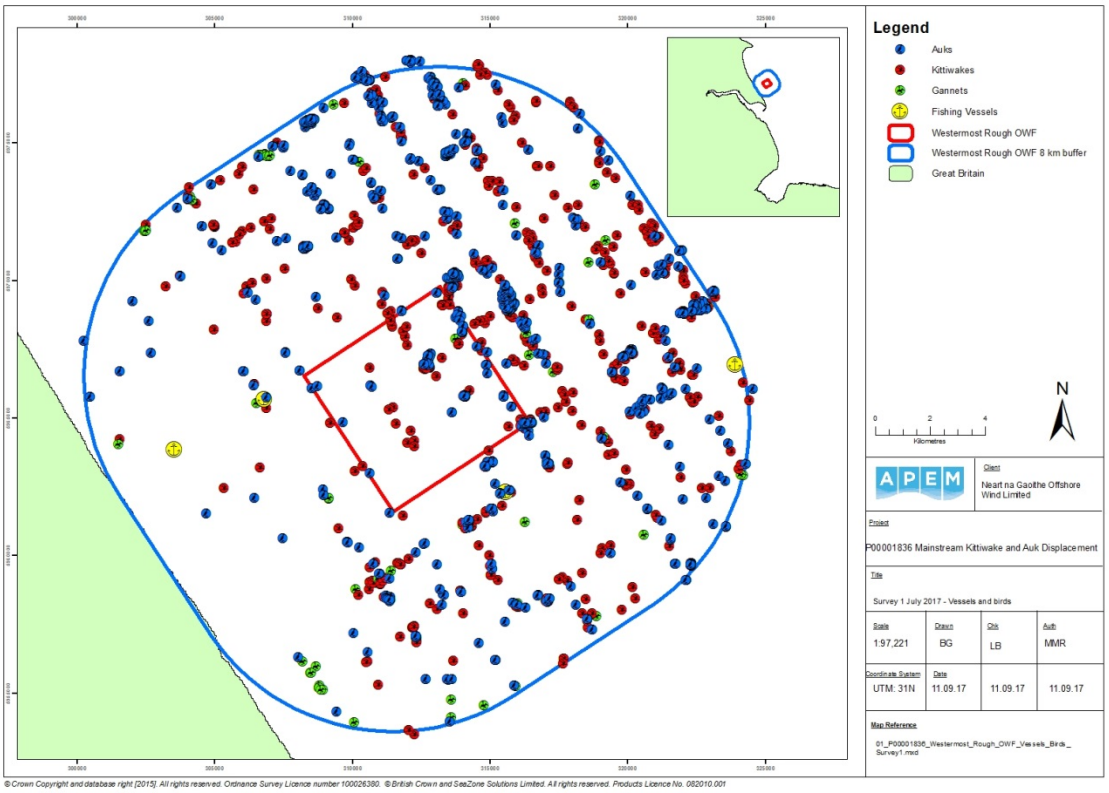

Figure 4 **Location of vessels and birds captured within the Survey 1 imagery.**

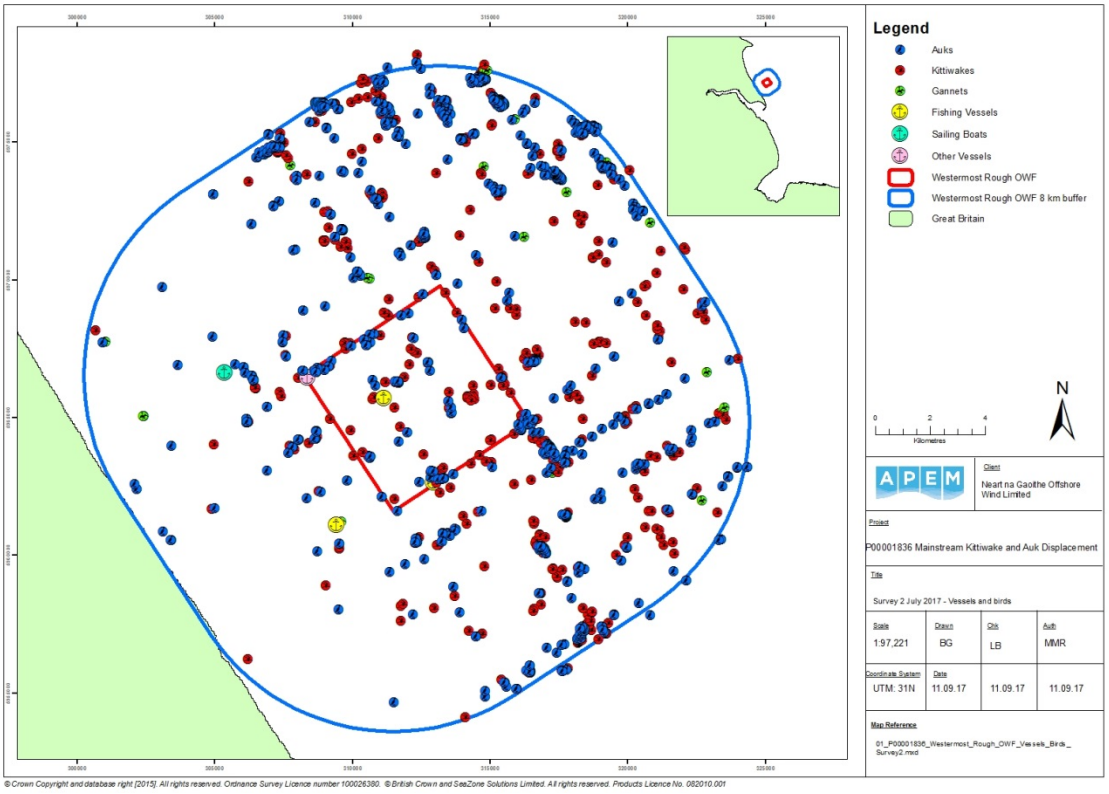

Figure 5 **Location of vessels and birds captured within the Survey 2 imagery.**

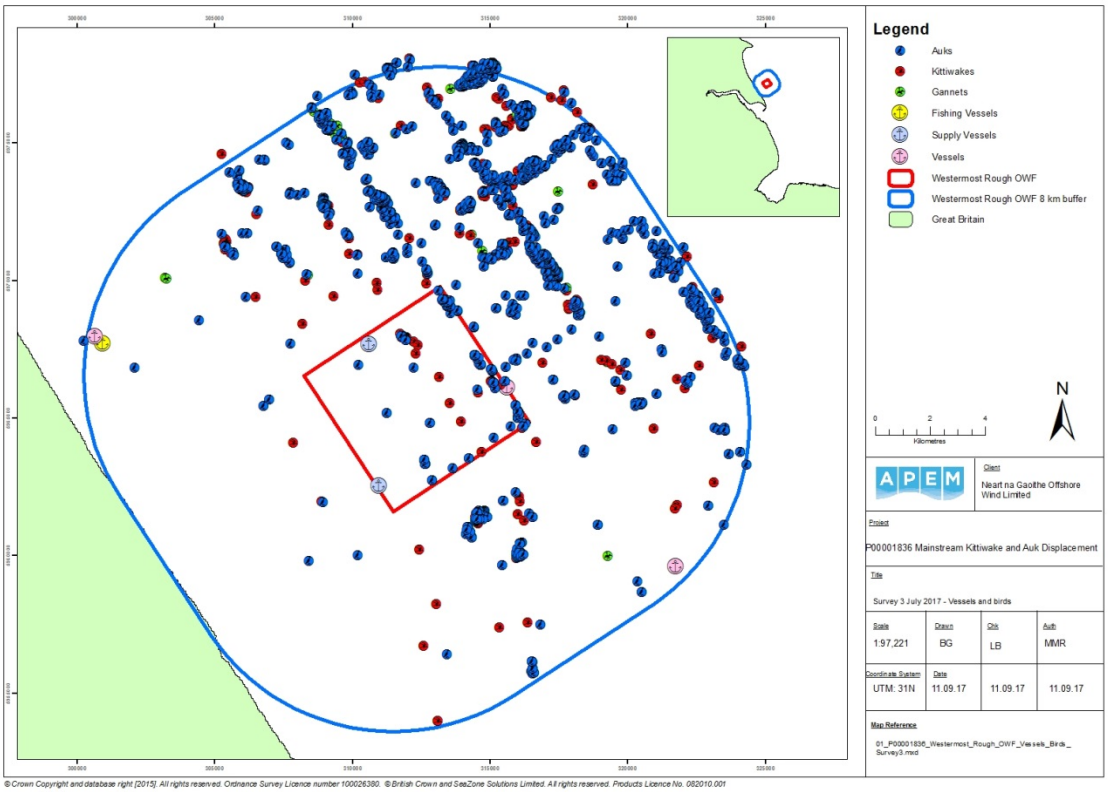

Figure 6 Location of vessels and birds captured within the Survey 3 imagery.

3.2 Image Analysis

Digital aerial images captured during each survey were imported as georeferenced images (WGS 84 projection) into ArcView 9.2 (ESRI) allowing the spatial location of birds to be accurately determined. The following data were recorded for each survey:

- Observation time;
- Position (eastings, northings);
- Species;
- Numbers;
- Age classes; and
- Behaviour.

The digital still imagery acquired by the aerial surveys was analysed by APEM staff using bespoke image analysis software to determine species identification, abundance, distribution and other information relevant to seabirds present within the survey area.

All birds detected were assigned to a species group and where possible, each of these was identified to species levels consistent with JNCC classified species groups (Appendix 2). Consequently, birds where identification to a particular species was not possible were assigned to taxonomic groups such as:

- 'Small gull species';
- 'Guillemot/razorbill'; and

- ‘Auk species’.

Not all auks could be identified to species level therefore displacement analysis was carried out at the species group level.

3.3 Data Analysis

3.3.1 Absolute Abundance Estimates

To assess the magnitude of any changes in kittiwake and auk density with increasing distance from the WROWF design-based estimates of bird abundance with confidence limits (CL) and associated precision of estimates were calculated for the WROWF and 1 km concentric buffer zones (Figure 7). All analysis and data manipulation were conducted in the R programming language (R Development Core Team, 2015) and non-parametric 95% confidence intervals were generated using the ‘boot’ library of functions (Canty & Ripley, 2010).

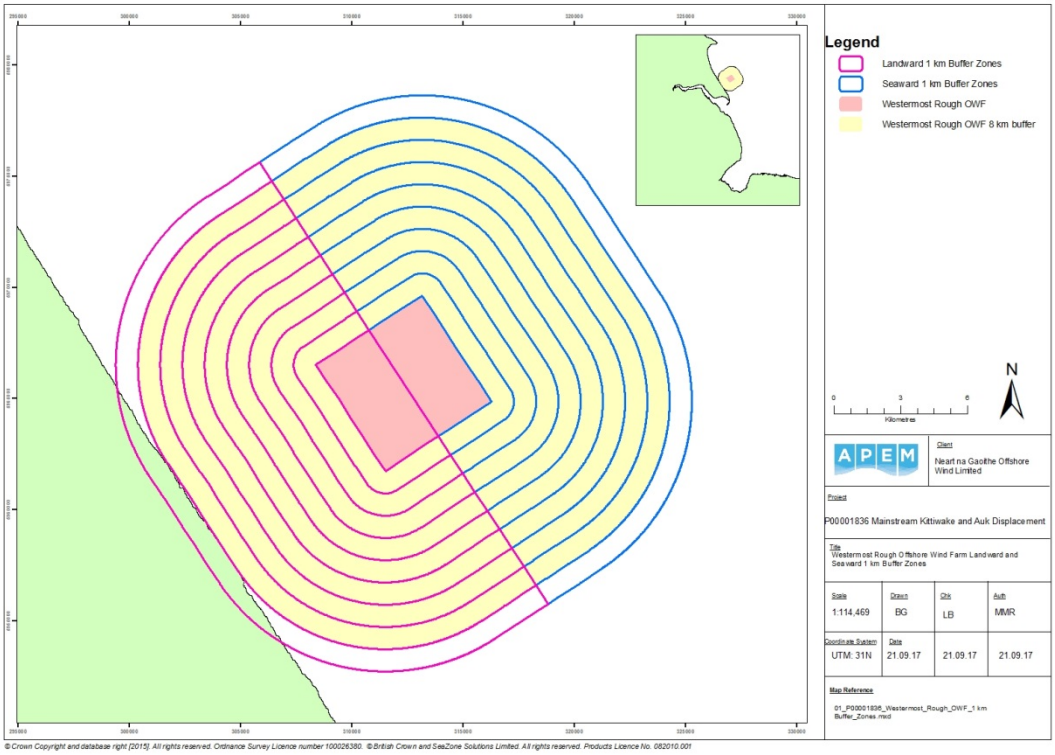

Figure 7 **Layout of 1 km buffer zones increasing to a distance of 9 km from the edge of the WROWF boundary and landward and seaward survey areas.** Note: 1 km buffer zones extend to a distance of 9 km as transects extended slightly further than the 8 km buffer zone, this allowed for all birds captured in the survey imagery to be included in the analysis, including those overlapping edge of 8 km buffer.

The distribution of kittiwakes and auks during the three aerial surveys showed lower numbers present between the wind farm footprint and the coastline. To determine whether there is any evidence for variation in densities with increasing distance away from the wind farm the analysis included calculating kittiwake and auk densities for the entire survey area

(the wind farm footprint and surrounding 1 km buffer zones) as well as densities split by landward and seaward halves (Figure 7).

3.3.2 Absolute Density Estimates

To calculate the absolute density estimates, it is necessary to know the total area encompassed by the WROWF and each concentric buffer area clipped to the survey area boundary. To calculate the absolute density estimates each abundance estimate and confidence interval is then divided by its corresponding area. This provides a density estimate of the number of birds per km^2 allowing the comparison between the WROWF and buffer areas, as density takes into account the varying areas of the buffers. Some buffers will be sampled by only a few images and therefore their density estimates are less reliable than larger areas.

3.3.3 Relative Density Estimates

Kittiwake and auk numbers may vary from day to day. For each of the three aerial surveys we determined how the relative density of each species varied with the factor of interest, in this case the WROWF footprint. Measuring this variation is important as it will affect the robustness of the results. To calculate the relative abundance estimates, it is necessary to know the total density of each species across each survey. This was done by summing the previously calculated absolute densities of the WROWF footprint and buffer areas for each survey. The relative density for each survey was then calculated by dividing each density value by the sum of the densities.

3.3.4 Displacement Effect Analysis

To investigate whether there is any displacement effect on kittiwakes and auks from the WROWF, analysis based on Generalised Additive Models (GAMs) was used. Distance to the edge of the WROWF was determined in ArcGIS using the modelling base grid and the modelled density numbers from the GAMs. A quasi-Poisson GAM was used to determine the relationship between relative density estimates and buffer distance. If the wind farm is having a negative effect on the distribution of birds it is expected that densities would increase with increasing distance away from the turbines at least up to a certain distance at which the birds would cease to be aware of the wind farm. GAM analysis was used to ensure that the relationship between distance to wind farm and density was not forced into a linear model, and to allow the relationship to take a smoothed non-linear relationship if the model determined that this was a better fit.

In addition to the GAM analysis, a Kruskal-Wallis test was undertaken on the relative density estimates to investigate if there was any significant difference in the densities between different buffers. This test could help identify, for example, increasing densities as a result of displacement up to a certain distance away from the turbines before densities revert to background at sea densities. A Kruskal-Wallis test allows for differences between populations to be investigated without requiring normally distributed data. If the Kruskal-Wallis test showed a significant result, further analysis was undertaken using Dunn's Test for multiple comparisons (using the FSA package in R).

The dataset consists of 7,891 images clipped to the survey area (Table 4), each representing an aerial photograph of the survey area. Of the 7,891 images only 2,157 contained either kittiwakes, auks and/or gannets (between 1 and 210 birds).

Table 4 Total number of images containing kittiwakes, auks and gannets.

	Survey 1	Survey 2	Survey 3
Kittiwakes	438	401	228
Auks	334	371	549
Gannets	51	22	29
Kittiwakes and/or auks and/or gannets	756	695	706
Total images captured within the survey area	2,630	2,630	2,631

4. Results

4.1 Kittiwakes

4.1.1 Abundance and behaviour

Table 5 presents the number of kittiwakes recorded during each of the three July 2017 digital aerial surveys. Our estimate of 703 kittiwakes likely to be present based on expected densities (3.27 birds per km^2: RPS, 2009) was much exceeded. Kittiwake numbers remained relatively constant across all of the three surveys with higher numbers observed during Survey 3 (n=1,865: Table 5b). Overall, higher numbers of kittiwakes were recorded in flight during Surveys 1 and 2, with higher numbers recorded sitting on the water during Survey 3 (Table 5b).

Table 5 Raw counts of kittiwakes recorded in a) the WROWF and b) the WROWF plus 8 km buffer in the three July 2017 digital aerial surveys.

a) WROWF			
Survey Number	**Flying**	**Sitting**	**Total Count**
1	86	94	180
2	81	58	139
3	14	35	49
b) WROWF plus 8 km buffer			
Survey Number	**Flying**	**Sitting**	**Total Count**
1	968	781	1,749
2	1,042	801	1,843
3	396	1,469	1,865

4.1.2 Distribution

Figures 8 to 10 present the distribution of kittiwakes recorded during the July 2017 digital aerial surveys. Overall, numbers were greater offshore and kittiwakes were present within the wind farm footprint in each survey. In Survey 1 kittiwakes were distributed across the survey area with lower numbers observed in the south-western region of the 8 km buffer zone (Figure 8). In Survey 2 kittiwakes were located across the survey area with lower numbers observed in the western half of the 8 km buffer zone (Figure 9). In Survey 3 kittiwakes were distributed across the survey area with lower numbers observed in the south-western region of the 8 km buffer zone, between the wind farm and the coast (Figure 10).

Note: The number of points visible on each figure is not necessarily equal to the total number of individuals recorded. This is because some animals are located in very close proximity to each other and at the scale required to display the whole survey area several of the points may overlay each other.

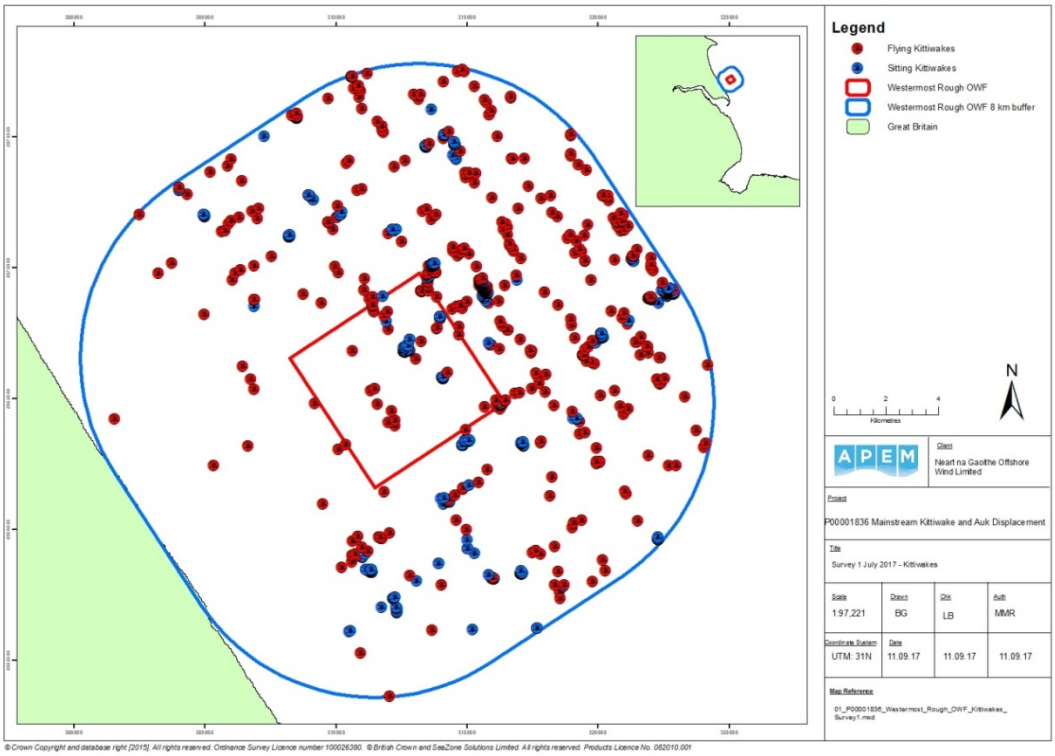

Figure 8 **Distribution of kittiwakes recorded in the WROWF and 8 km buffer during Survey 1.**

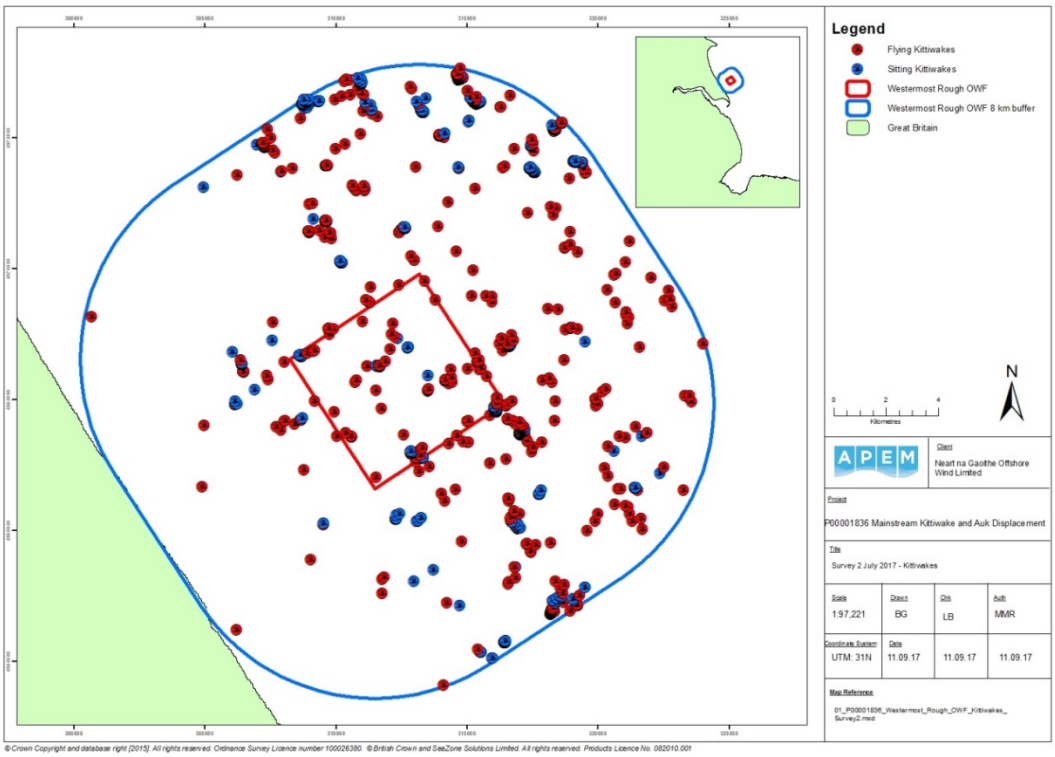

Figure 9 **Distribution of kittiwakes recorded in the WROWF and 8 km buffer during Survey 2.**

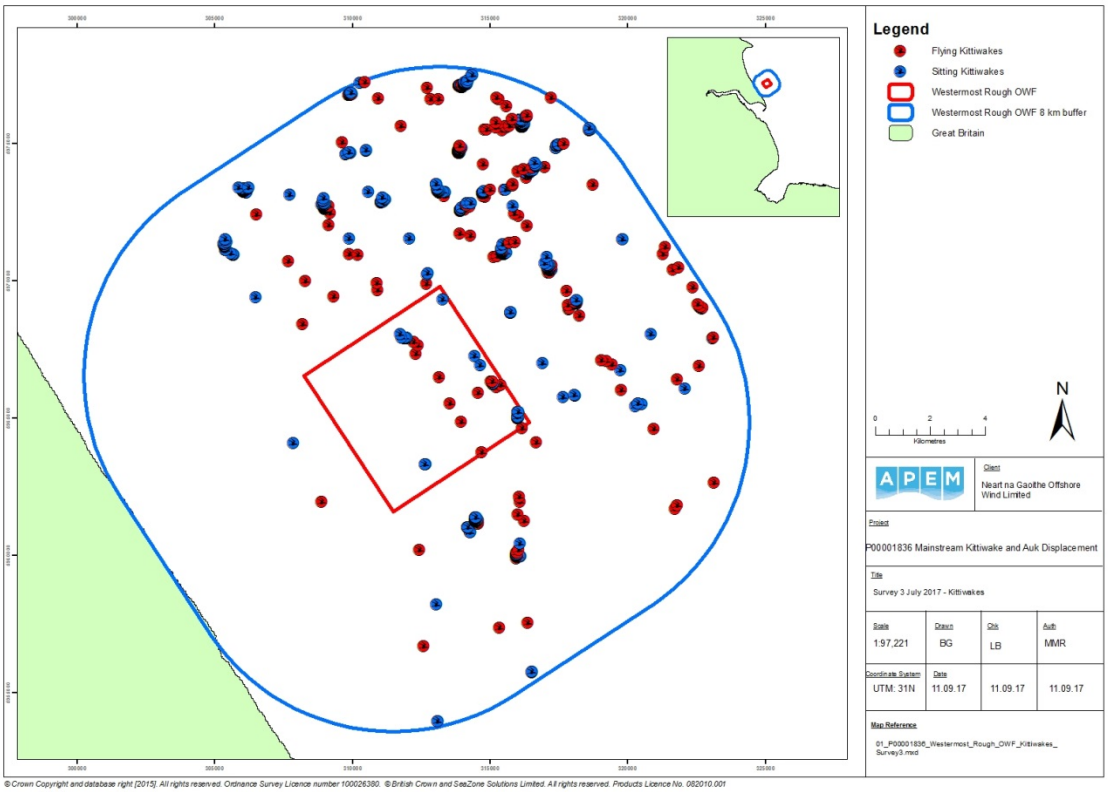

Figure 10 Distribution of kittiwakes recorded in the WROWF and 8 km buffer during Survey 3.

4.1.3 Displacement effects

Kittiwake densities were calculated for the wind farm footprint and 1 km surrounding buffer zones up to a distance of 9 km (8 km + 1 km to ensure all birds on edge of outermost buffer recorded) from the wind farm boundary. Additionally, the 1 km buffer zones and wind farm footprint were halved to calculate landward and seaward densities as distributions showed numbers to be lower between the wind farm and coastline. Landward and seaward sections used in the analyses are shown in Figure 7.

Mean kittiwake densities were lower for the landward half of the survey area compared to the seaward half (Figure 14). Although densities of kittiwake are low in the landward half of the wind farm footprint and 0 – 1 km buffer, there is no evidence of displacement of kittiwakes occurring landward due to the large variability in densities across the survey area. No significant effect of distance on density was found within the GAM analysis (p=0.165*),* nor the Kruskal-Wallis test (p=0.377*).* The latter test, here and elsewhere in this report, found no significant difference between any of the buffer and wind farm footprint densities. Although this may appear surprising following a visual appraisal of the counts this is due to the large variation (heterogeneity) in seabird counts / densities between surveys.

Higher mean densities occurred within the seaward half of the survey area (Figure 14). As for the landward survey area, due to the heterogeneity in counts between surveys there is no strong evidence of displacement from the wind farm. No significant effect of distance on density was found within the GAM analysis (p=0.817*),* nor the Kruskal-Wallis test (p=0.558*).*

Although not significantly different to the other buffer densities mean densities of kittiwakes were higher between 0 – 2 km outside the wind farm.

The mean densities for the entire wind farm footprint and its surrounding 1 km buffer zones also indicate that there is no evidence of displacement for kittiwakes, again due to the large variability in densities between surveys (Figure 15). No significant effect of distance on density was found within the GAM analysis (*p*=0.0.971*),* nor the Kruskal-Wallis test (*p*=0.717*).* Although not significantly different to the other buffer densities mean densities of kittiwakes were higher between 0 – 2 km outside the windfarm.

The large variations in densities recorded for the wind farm and each 1 km buffer zone across the three aerial surveys (Figures 11 to 13) account for the large standard error bars shown in Figures 14 and 15.

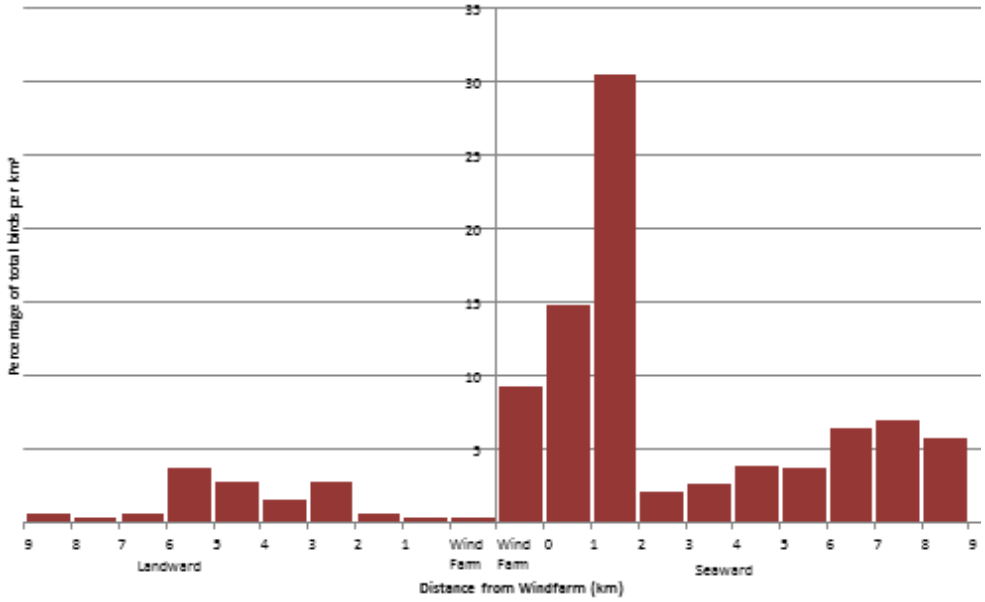

Figure 11 Percentage of kittiwakes recorded during Survey 1 in the landward and seaward wind farm and 1 km buffer zones.

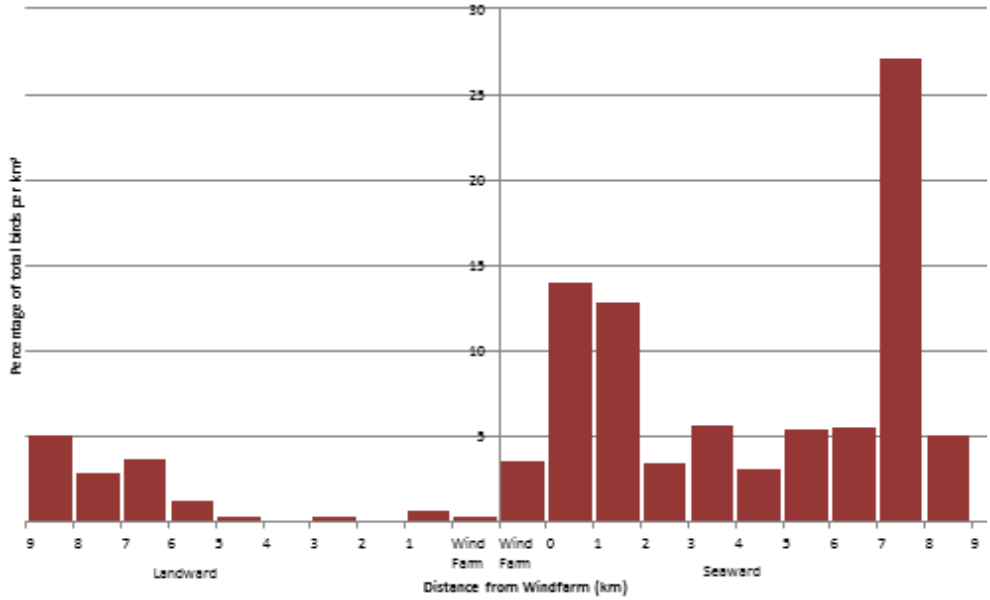

Figure 12 **Percentage of kittiwakes recorded during Survey 2 in the landward and seaward wind farm and 1 km buffer zones.**

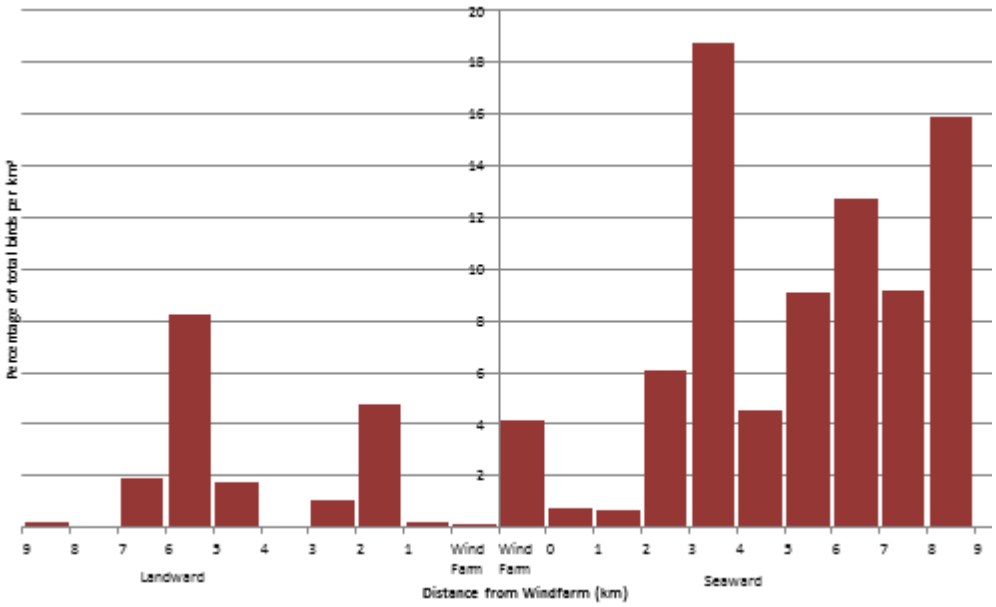

Figure 13 **Percentage of kittiwakes recorded during Survey 3 in the landward and seaward wind farm and 1 km buffer zones.**

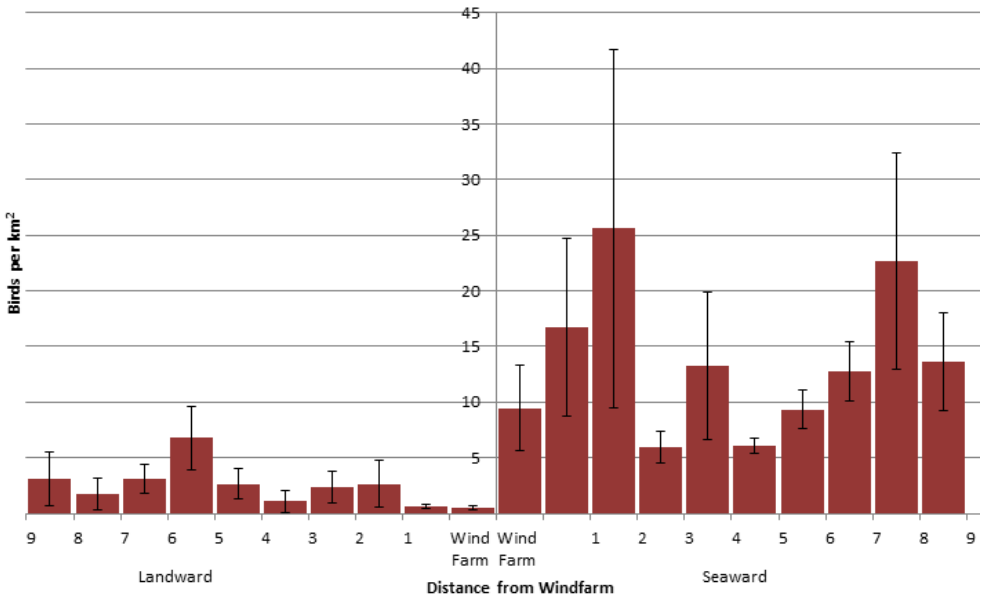

Figure 14 **Mean densities and standard error of kittiwakes recorded in the landward and seaward wind farm and 1 km buffer zones.**

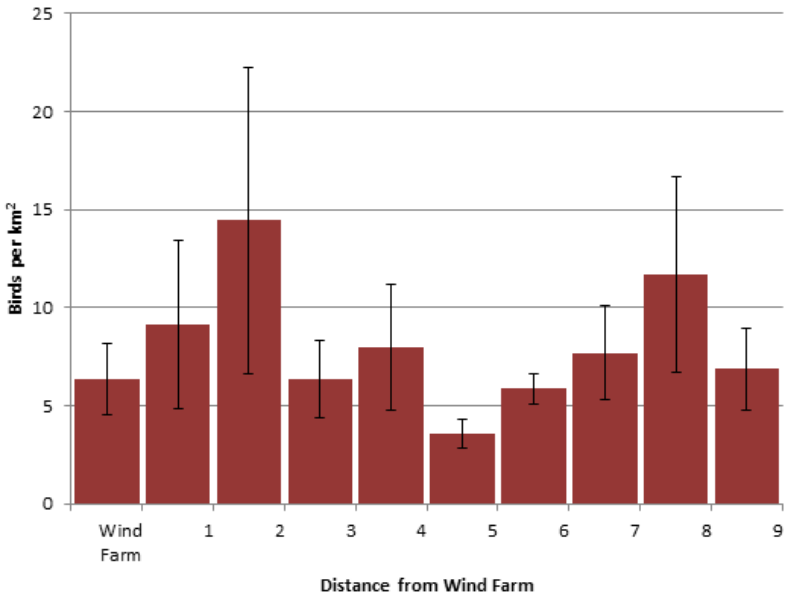

Figure 15 **Mean densities and standard error of kittiwakes recorded in the entire wind farm and 1 km buffer zones.**

4.2 Auks

4.2.1 Abundance and behaviour

Table 6 presents the number of total auks recorded during each of the three July 2017 digital aerial surveys. Auk numbers increased from Survey 1 to Survey 3 (Table 6b). The majority

of auks were recorded sitting on the water during each of the three surveys (Table 6). Raw counts and distribution maps for guillemot, razorbill and puffin are presented in Appendix 3.

Table 6 Raw counts of auks recorded in a) the WROWF and b) the WROWF plus 8 km buffer in the three July 2017 digital aerial surveys.

a) WROWF			
Survey Number	**Flying**	**Sitting**	**Total Count**
1	0	147	147
2	2	136	138
3	1	332	333
b) WROWF plus 8 km buffer			
Survey Number	**Flying**	**Sitting**	**Total Count**
1	15	2,033	2,048
2	17	2,651	2,668
3	17	5,588	5,605

4.2.2 Distribution

Figures 16 to 18 present the distribution of all auks recorded during the July 2017 digital aerial surveys. In Survey 1 auks were loosely distributed across the survey area (Figure 16). In Survey 2 auks were distributed across the survey area with lower numbers recorded in the south of the 8 km buffer zone (Figure 17). In Survey 3 auks were recorded in higher numbers in the north and north-east of the survey area (Figure 18).

Note: The number of points visible on each figure is not necessarily equal to the total number of individuals recorded. This is because some animals are located in very close proximity to each other and at the scale required to display the whole survey area several of the points may overlay each other.

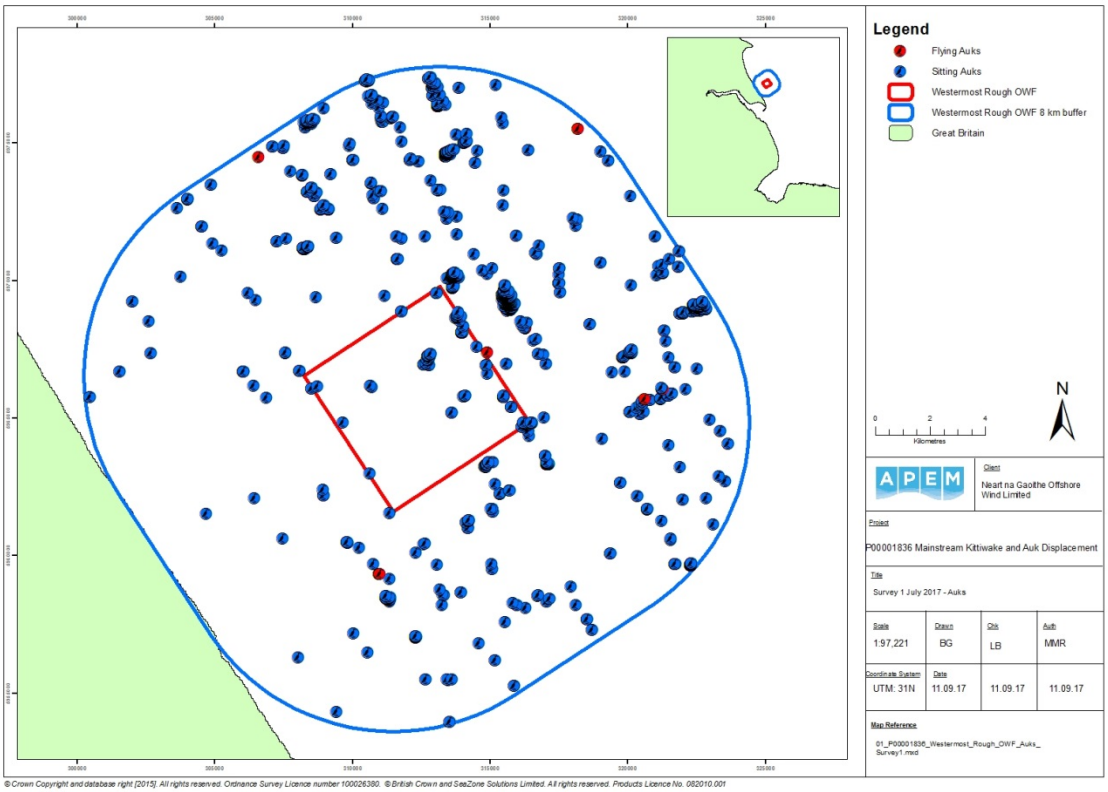

Figure 16 **Distribution of auks recorded in the WROWF and 8 km buffer during Survey 1.**

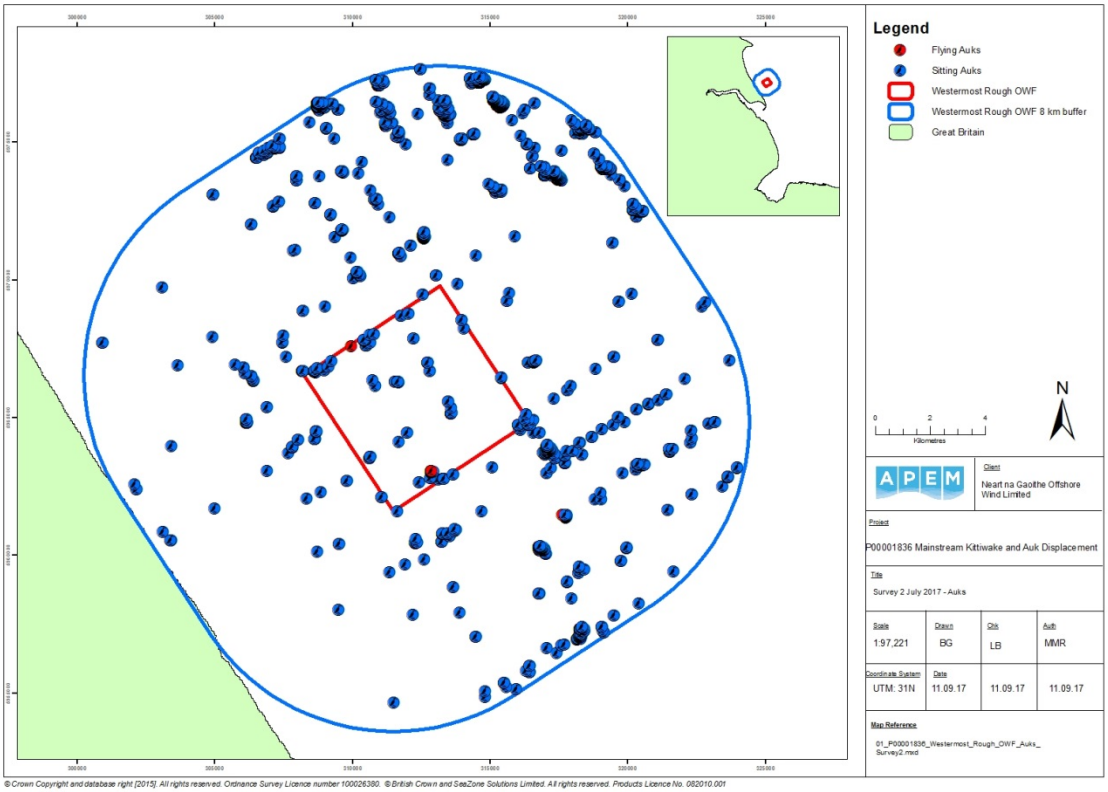

Figure 17 **Distribution of auks recorded in the WROWF and 8 km buffer during Survey 2.**

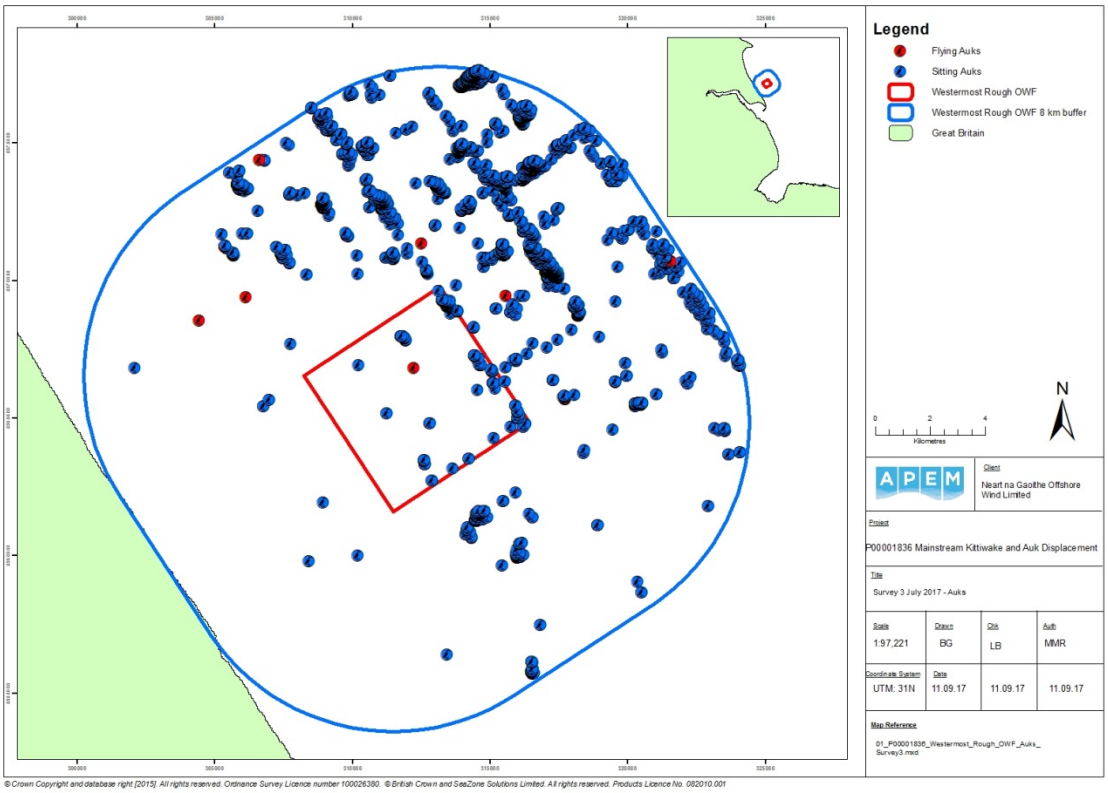

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Figure 18 Distribution of auks recorded in the WROWF and 8 km buffer during Survey 3.

4.2.3 Displacement effects

Auk densities were calculated for the wind farm footprint and 1 km surrounding buffer zones up to a distance of 9 km (8 km + 1 km to ensure all birds on edge of outermost buffer recorded) from the wind farm boundary. Additionally, the 1 km buffer zones and wind farm footprint were halved to calculate landward and seaward densities as distributions showed numbers to be lower between the wind farm and coastline. Landward and seaward sections used in the analyses are shown in Figure 7.

Mean auk densities were lower for the landward half of the survey area compared to the seaward half (Figure 22). Although densities of auks are low in the landward half of the wind farm footprint, there is no evidence of displacement of auks occurring in the landward section due to the large variability in densities across the survey area. No significant effect of distance on density was found within the GAM analysis (*p=0.144),* nor the Kruskal-Wallis test (*p=0.287).* The latter test, here and elsewhere in this report, found no significant difference between any of the buffer and wind farm footprint densities. Although this may appear surprising following a visual appraisal of the counts this is due to the large variation (heterogeneity) in seabird counts / densities between surveys.

Higher mean densities occurred within the seaward half of the survey area (Figure 22). As for the landward survey area, due to the heterogeneity in counts between surveys there is no evidence of displacement from the wind farm. No significant effect of distance on density was found within the GAM analysis (*p=0.27),* nor the Kruskal-Wallis test (*p=0.453).* Although

not significantly different to the other buffer densities mean densities of auks were higher between 3 – 4 km outside the wind farm.

The mean densities for the entire wind farm footprint and its surrounding 1 km buffer zones also indicate that there is no evidence of displacement for auks, again due to the large variability in densities between surveys (Figure 23). No significant effect of distance on density was found within the GAM analysis (*p=0.528),* nor the Kruskal-Wallis test (*p=0.472).* Although not significantly different to the other buffer densities mean densities of auks were higher between 3 – 4 km outside the windfarm.

The large variations in densities recorded for the wind farm and each 1 km buffer zone across the three aerial surveys (Figures 19 to 21) account for the large standard error bars shown in Figures 22 and 23.

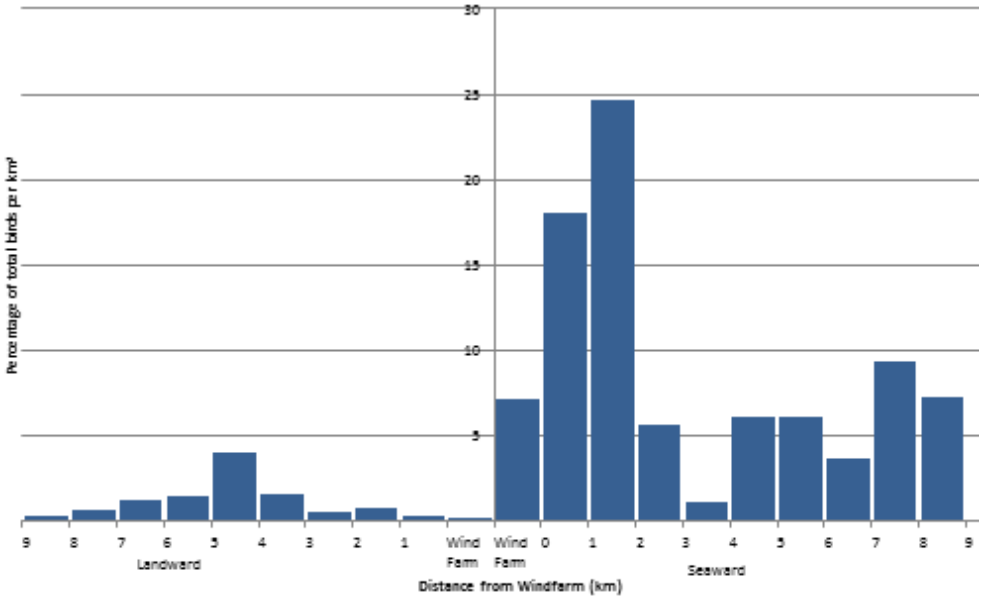

Figure 19 **Percentage of auks recorded during Survey 1 in the landward and seaward wind farm and 1 km buffer zones.**

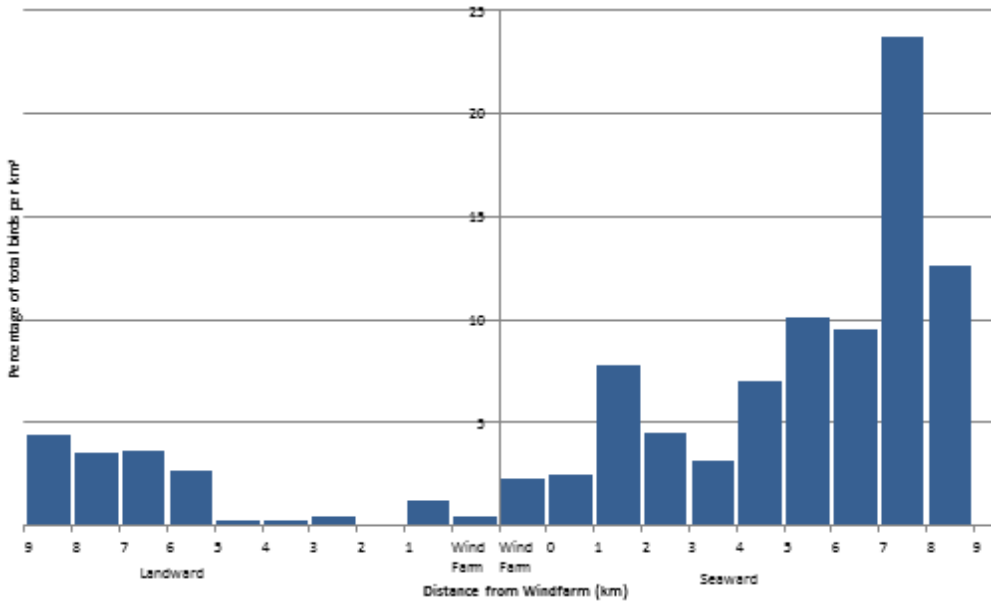

Figure 20 **Percentage of auks recorded during Survey 2 in the landward and seaward wind farm and 1 km buffer zones.**

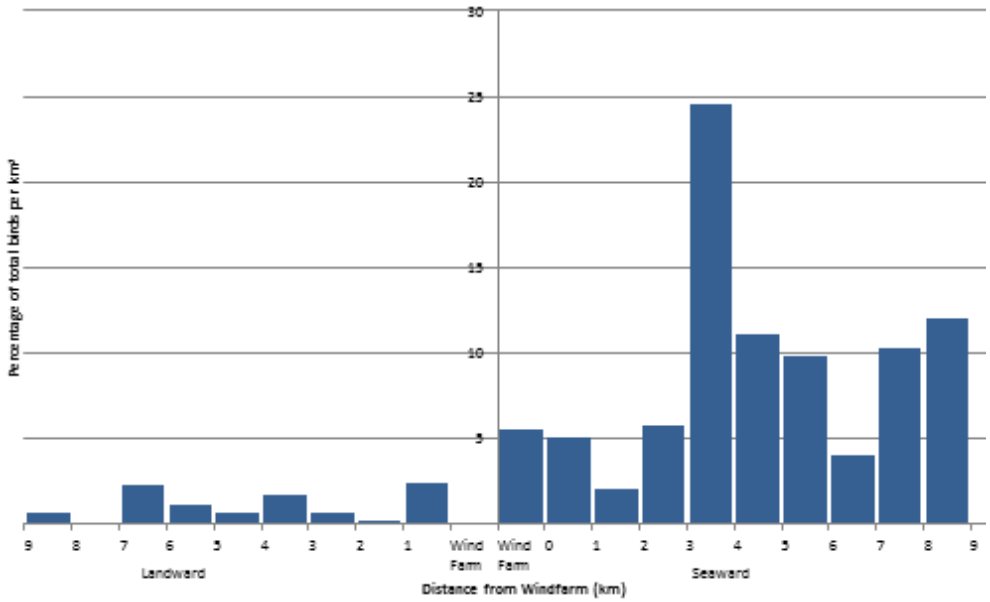

Figure 21 **Percentage of auks recorded during Survey 3 in the landward and seaward wind farm and 1 km buffer zones.**

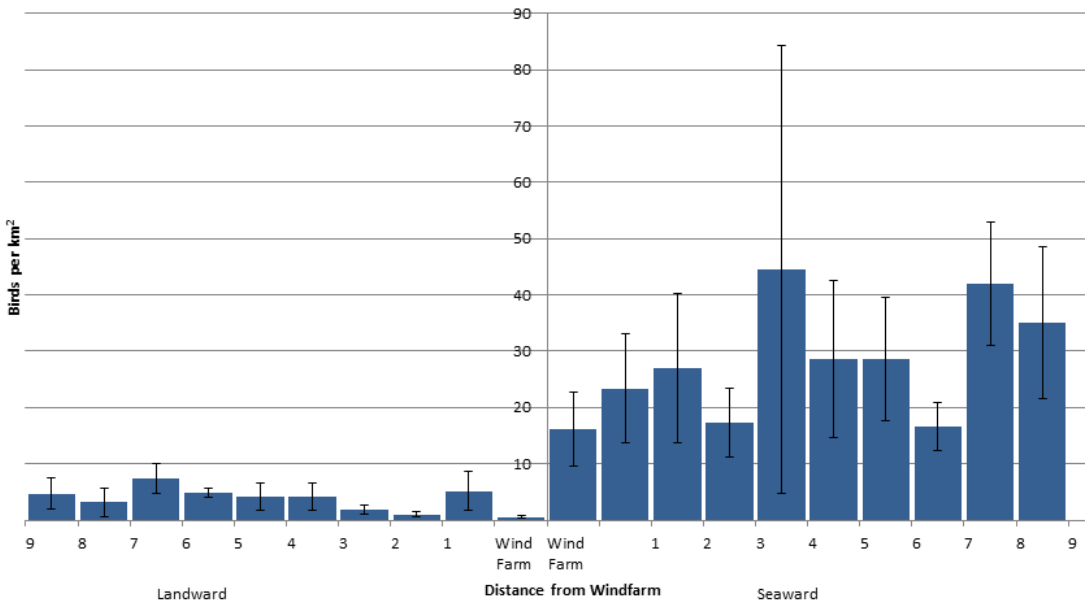

Figure 22 **Mean densities and standard error of auks recorded in the landward and seaward wind farm and 1 km buffer zones.**

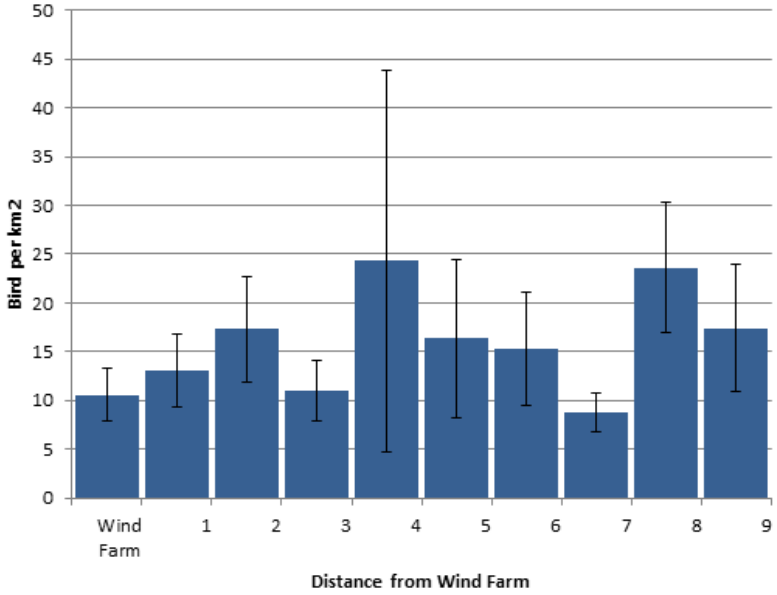

Figure 23 **Mean densities and standard error of auks recorded in the entire wind farm and 1 km buffer zones.**

5. Discussion

Kittiwakes and auks were present in high numbers across the WROWF and its surrounding 8 km buffer during the three July 2017 digital aerial surveys. Overall, kittiwakes and auks were present both in the wind farm footprint and the 8 km buffer. Lower numbers were recorded between the wind farm boundary and the coastline, with large numbers of birds observed offshore including large aggregations in the northern region of the 8 km buffer.

During the breeding season, breeding kittiwakes are concentrated at coastal colonies. In July, breeding kittiwakes will commute between coastal breeding sites and offshore feeding areas (Cramp & Simmons, 1977). Furthermore non-breeding individuals such as first-year birds range widely throughout the North Sea at this time of year (Olsen & Larsen, 2003).

The majority of auks recorded during the July 2017 surveys were sitting on the water. At this time of year many adults begin their post-breeding moult (Stone *et al*. 1995) and are therefore flightless. Auk chicks and adults begin to fledge and leave their breeding colony from late June and throughout July (Stone *et al*. 1995) reflecting the increases in auks recorded from Survey 1 to Survey 3.

5.1 Displacement

There is a considerable degree of uncertainty regarding the extent to which seabirds may be displaced (Furness, 2013). Current figures indicate that auks may be displaced at some wind farms, and displacement is partial and can be negligible at some wind farms, and kittiwakes are generally not displaced (Table 7; Furness, 2013). Displacement impacts are more likely to occur if the wind farm is within foraging range of the breeding colonies as birds may be required to travel further to obtain food (Searle *et al*. 2014; Furness 2013). However, there is lack of evidence on species-specific displacement as most studies are from non-breeding seabirds outside of the UK (Searle *et al*. 2014).

Table 7 Classification of evidence of the impact (displacement, no effect, or attraction) of foraging seabirds by offshore wind farms (Furness, 2013).

Species	Horns Rev OWF	Egmond aan Zee OWF & Princess Amalia Windpark	Thornton Bank OWF	Bligh Bank OWF
Kittiwake				
Guillemot		18%		70%
Razorbill		17%		

Note: Red = strongly displaced, or displaced in 80-100% of data sets (none in the table); Orange = mildly but significantly displaced, or displaced significantly in 40-70% of data sets; Yellow = slight evidence of displacement, or displaced significantly in 10-30% of data sets; Green = Not displaced; Blue = significantly attracted into wind farm area. Values in cells indicate the proportion of relevant results reported.

5.1.1 Kittiwake Displacement

Kittiwake densities were lower within the landward half of the survey area compared to the seaward half. There was no statistically defensible evidence of displacement of kittiwakes occurring landward as there was a lot of variability in densities across the survey area. Similarly for the seaward half of the survey area there was no statistically defensible evidence of displacement due to the large variations in mean densities between surveys. The higher mean densities of kittiwakes between 0 – 2 km outside of the wind farm footprint are not statistically different to those within the wind farm footprint or further out from it.

Overall mean densities calculated for the entire wind farm and its surrounding 1 km buffer zones indicated that there was no statistically defensible evidence of kittiwake displacement as densities varied greatly between surveys. The higher mean densities of kittiwakes occurring between 0 – 2 km outside of the wind farm footprint are again not statistically different to the densities elsewhere.

If the wind farm is a negative determinant of kittiwake densities and distribution low densities would be expected to occur near the wind farm. This was not the case for the July 2017 surveys at WROWF. Overall mean densities of kittiwakes showed moderate densities present within the wind farm (6.36 birds per km^2) with densities fluctuating with increasing distance to the wind farm. Daunt *et al*. (2002) suggest that kittiwakes exhibit highly flexible foraging strategies at sea, probably reflecting the patchy and unpredictable distribution and availability of its prey. Kittiwakes would therefore forage in areas of high prey abundance which by fluctuating markedly from one day to the next with weather and tidal conditions would drive the varied distributions and densities observed during the July 2017 aerial surveys. Additionally, Chivers *et al*. (2013) identified that kittiwake feeding activity was strongly influenced by distance from colony, and to a lesser extent, distance from land and bathymetry. Further analysis could be undertaken to assess whether other environmental variables are influencing kittiwake distribution and densities in the wind farm and its surrounding area. Allowing for environmental variation could help confirm the lack of observed displacement.

Overall, due to the high variation in kittiwake densities between surveys, no significant effect of distance on kittiwake density was observed at the WROWF (GAM analysis: p=0.971, Kruskal-Wallis test: p=0.717).

5.1.2 Auk Displacement

Auk densities were lower within the landward half of the survey area compared to the seaward half. There was no statistically defensible evidence of displacement of auks occurring landward as there was a lot of variability in densities across the survey area. Similarly for the seaward half of the survey area there was no statistically defensible evidence of displacement due to the large variations in mean densities between surveys. The higher mean densities of auks between 3 – 4 km outside of the wind farm footprint are not statistically different to those within the wind farm footprint or further out from it.

Overall mean densities calculated for the entire wind farm and its surrounding 1 km buffer zones indicated that there was no statistically defensible evidence of auk displacement as densities varied greatly between surveys. The higher mean densities of auks occurring between 3 – 4 km outside of the wind farm footprint are again not statistically different to the densities elsewhere.

If the wind farm is a negative determinant of auk densities and distribution low densities would be expected to occur near the wind farm. This was not the case for the July 2017 surveys at WROWF. Overall mean densities showed moderate densities present within the wind farm (10.55 birds per km^2) with densities fluctuating with increasing distances to the wind farm. The observed peak density of auks observed between 3 – 4 km outside the wind farm may therefore be a result of other contributing environmental variables. During the breeding season and periods of high bird abundance, when competition for prey items is greater, prey availability may become the key determinant of bird distributions. Auks are known to dive to depths of up to 190 m (Piatt & Nettleship, 1985) with an average depth of 36 – 49 m (Burger & Simpson, 1986; Harris *et al*. 1990; Barrett & Furness, 1990). It is possible that the shallow waters (<20 m) between the wind farm and coast may not contain sufficient abundances of prey items, thus ensuring that the auks distribute across deeper waters to the north and west of the survey area across more suitable feeding habitat. In addition, razorbills are known to feed in shallow, inshore areas more than guillemots and puffins, and have a more selective feeding preference as they are less able to exploit different prey types as a result of making shorter, shallower dives (Dall'Antonia, 2001; Furness & Tasker, 2000; Thaxter *et al*. 2010). If preferred prey items are not available razorbills may therefore travel greater distances to feed and show higher densities at greater distances. Seabird numbers are known to fluctuate depending on season and prey abundance. Consequently, their foraging locations change (Searle *et al.* 2014). Furthermore, if auk distribution is driven by gradient away from the coast this may affect the distribution and be contributing to the higher densities observed in the seaward half of the survey area. Further analysis could be undertaken to assess whether other environmental variables are influencing auk distribution and densities in the wind farm and its surrounding area. Allowing for environmental variation could help confirm the lack of observed displacement.

Overall, due to the high variation in auk densities between surveys, no significant effect of distance on auk density was observed at the WROWF (GAM analysis: p=0.528, Kruskal-Wallis test: p=0.472).

6. References

APEM (2014). Assessing Northern Gannet Avoidance of Offshore Windfarms. APEM Scientific Report 512775, East Anglia Offshore Wind Ltd. April 2014.

Barrett, R. T. and Furness, R. W. (1990). The prey and diving depths of seabirds on Hornoy, North Norway after a decrease in the Barents Sea capelin stocks. Ornis Scand. 21, 179-186.

Bradbury, G., Trinder, M., Furness, B., Banks, A., Caldow, R. and Hume, D. (2014). Mapping Seabird Sensitivity to Offshore Wind Fams. PLoS ONE 9(9): e103366. Doi:10.1371/journal.pone.0106366.

Burger, A. E. and Simpson, M. (1986). Diving depths of Atlantic puffins and common murres. Auk 103, 828-830.

Canty, A. and Ripley, B. (2010). Boot: Bootstrap R (S-Plus) Functions. R package version 1. 2-43.

Chivers L.S., Lundy, M.G., Colhoun, K., Newton, K.C., Houghton, J.D.R. and Reid, N. (2013). Identifying optimal feeding habitat and proposed marine protected areas (pMPAs) for the black-legged kittiwake (Rissa tridactyla) suggests a need for complementary management approaches. Biological Conservation 164:73–81.

Cramp, S. and Simmons, K.E.L. (1977). The Birds of the Western Palearctic, Vol. I. Oxford University Press, Oxford.

Daunt, F., Benvenuti, S., Harris, M.P., Dall'Antonia, L., Elston, D.A. and Wanless, S. (2002). Foraging strategies of the Black-legged Kittiwake Rissa tridactyla at a North Sea colony: evidence for a maximum foraging range. Marine Ecology-progress Series - MAR ECOL-PROGR SER. 245. 239-247. 10.3354/meps245239.

Dall'Antonia, L., Gudmundsson, G.A. and Benvenuti, S. (2001). Time allocation and foraging pattern of chick-rearing Razorbills in north-western Iceland. Condor 103: 469–480.

Furness, R.W. and Tasker, M.L. (2000). Seabird-fishery interactions: quantifying the sensitivity of seabirds to reductions in sandeel abundance, and identification of key areas for sensitive seabirds in the North Sea. Mar Ecol Prog Ser 202: 354–364.

Furness, B. (2013). Extent of displacement and mortality implications of displacement by seabirds by offshore windfarms. Draft Environmental Statement Chapter 11 Appendix B: Seabird Displacement Review.

Furness, R.W. (2015) *Non-breeding season populations of seabirds in UK waters: Population sizes for Biologically Defined Minimum Population Scales (BDMPS)*. Natural England Commissioned Reports, Number 164.

Harris, M. P., Towll, H., Russell, A. F. and Wanless, S. (1990). Maximum dive depth attained by auks feeding young on the Isle of May, Scotland. Scot. Birds 16, 25-28.

Krijgsveld, K.L., Fijn, R.C., Japink, M., van Horssen, P.W., Heunks, C., Collier, M.P., Poot, M.J.M., Beuker, D. and Dirksen, S. (2011). Effect studies Offshore Wind Farm Egmond aan Zee. Final report on fluxes, flight altitudes and behaviour of flying birds. NoordzeeWind report nr OWEZ_R_231_T1_20111114_flux&flight.

Nelson, E.J., Vallejo, G., Canning, S., Kerr, D., Caryl, F., McGregor, R., Rutherford, V. and Lancaster, J. (2014) Analysis of Marine Environmental Monitoring Plan Data from the Robin Rigg Offshore Wind Farm, Scotland (Operational Year 4). Natural Power report to E.ON Climate and Renewables.

Nelson, E., Caryl, F., Vallejo, G., McGregor, R. and Lancaster, J. (2015). Analysis of Marine Ecology Monitoring Plan Data – Robin Rigg Offshore Wind Farm, Operational Five Year Technical Report – Ornithological Monitoring. Natural Power Report to E.ON Climate and Renewables.

Olsen, K. M. and Larsson, H. (2003). Gulls of Europe, Asia and North America. London: Christopher Helm.

Percival, S. (2014). Kentish Flats Offshore Wind Farm: Diver Surveys 2011-12 and 2012-13. Ecology Consulting report to Vattenfall Wind Power.

R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna.

RPS Planning & Development Ltd. (2009). Westermost Rough Offshore Wind Farm Ornithological Technical EIA Report, DONG Energy.

Searle, K., Mobbs, D., Butler, A., Bogdanova, M., Freeman, S., Wanless, S. and Daunt, F. (2014). Population consequences of displacement from proposed offshore wind energy developments for seabirds breeding a Scottish SPAs (CR/2012/03). Marine Scotland Report.

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

Thaxter, C.B.,Wanless, S.,Daunt, F., Harris, M.P., Benvenuti, S., Watanuki, Y., Gremillet, D. and Hamer, K.C. (2010). Influence of wing loading on trade-off between pursuit-diving and flight in common guillemot and razorbills. J. Exp. Biol. 213: 1018–1025.

Walls, R., Canning, S., Lye, G., Givens, L., Garrett, C. and Lancaster, J. (2013a) Analysis of Marine Environmental Monitoring Plan Data from the Robin Rigg Offshore Wind Farm, Scotland (Operational Year 1). Natural Power report to E.ON Climate and Renewables.

Walls, R., Pendlebury, C., Lancaster, J., Lye, G., Canning, S., Malcom, F., Rutherford, V., Givens., L. and Walker, A. (2013b) Analysis of Marine Environmental Monitoring Plan Data from the Robin Rigg Offshore Wind Farm, Scotland (Operational Year 2). Natural Power report to E.ON Climate and Renewables.

Appendix 1 Shipping Observations

Details of the shipping observations made by the on-board camera technician for each aerial survey are shown in Table 1. The locations of vessels observed in each survey are presented in Figure 1.

Survey Number	Boat type	Easting	Northing	Bearing
1	Container ship	323619.9347	5961318.118	-
	Fishing boat	321779.1305	5961109.443	SE
	Fishing boat	313654.0478	5852985.565	SW
	Fishing boat	304838.5579	5970295.769	Stationary
	Fishing boat	308876.6698	5970592.721	NW
	Maintenance vessel	321481.9179	6023807.265	Stationary
	Fishing boat	309364.8037	5848821.216	SW
	Small vessel x2	307200.7162	5969888.073	W
	Fishing boat	312327.0391	5958539.571	NE
	Small vessel	306388.3607	5965744.067	-
	Fishing boat	318867.1747	5973442.783	-
	Fishing boat	318534.1672	5960151.292	W
2	Fishing boat	311248.8084	5961367.791	Stationary
	Fishing boat	312495.741	5965030.774	Stationary
	Fishing boat	309569.5187	5969636.045	SW
	Fishing boat x2	306654.3861	5967744.499	N
	Fishing boat x2	304622.1517	5973863.689	Stationary
	Unknown	309876.0975	5977143.05	-
	Fishing boat	313958.0672	5962651.648	Stationary
	Fishing boat	308658.6891	5967507.188	Stationary
3	Rowing	317813.6127	5976887.415	NW
	Speedboat x2	311683.1365	5969859.679	NW
	Fishing boat	308504.9863	5970453.244	E
	Leisure boat	313522.9415	5956325.848	S
	Speed boat	310728.7592	5959841.639	n/a
	Speed boat	305433.7228	5958202.061	SW
	Speedboat	307496.7522	5959292.687	SW

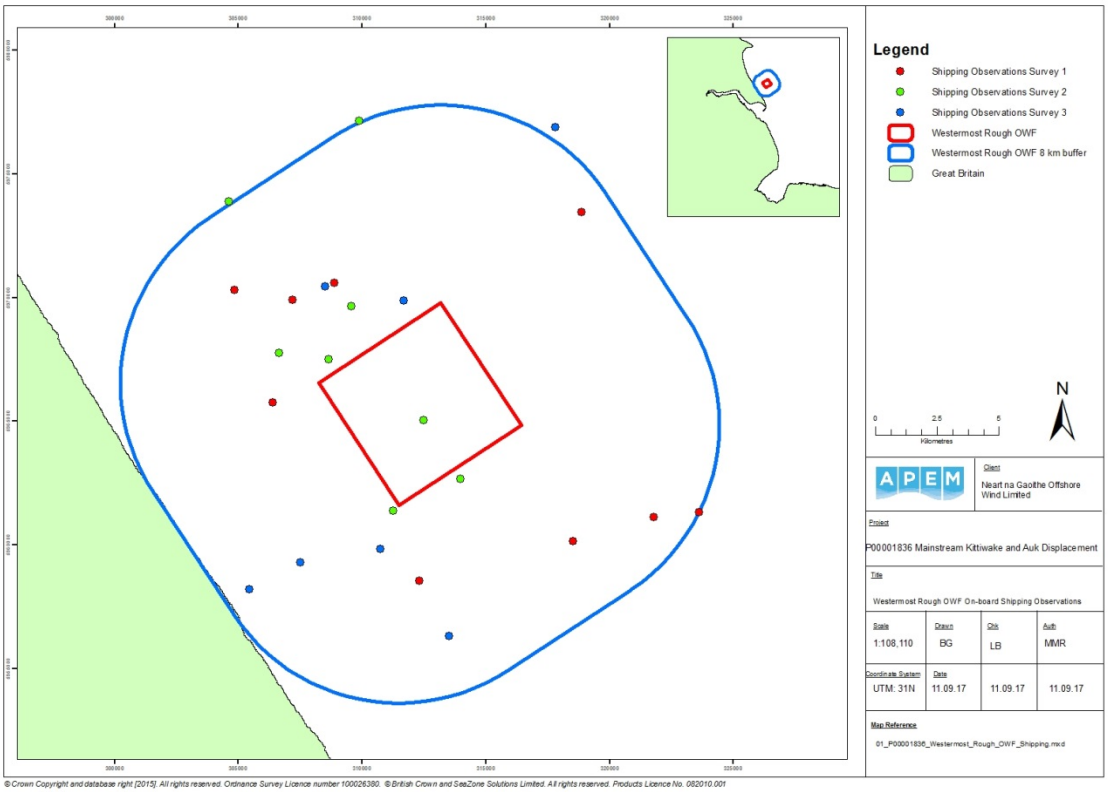

Figure 1 **Location of observed vessels recorded in each July 2017 aerial survey by the on-board camera technician.**

Appendix 2 JNCC Bird Groups

JNCC Code	Grouping	Species Code	Species
N/A	N/A	710	Gannet
94003	Small gull species	6020	Kittiwake
		5820	Black-headed gull
		5900	Common gull
95040	Auk species	6340	Guillemot
		6360	Razorbill
		6540	Puffin

Appendix 3 Species Specific Auk Counts and Distribution

Species specific auk counts and behaviour

Auks were identified to species level where possible. Where species could not be identified birds were categorised into the following groups:

- Guillemot/razorbill
- Auk species

Tables 1 to 5 present the raw counts and behaviour of each auk species recorded during the three surveys conducted in July 2017.

Our estimate of 1,453 guillemots likely to be present based on expected densities (6.76 birds per km^2: RPS, 2009) was much exceeded in Survey 3 when 2,049 individuals were recorded (Table 1). The majority of guillemots were observed siting on the water at the time of the survey (Table 1). Our estimate of 664 razorbills based on expected densities (3.09 birds per km^2: RPS, 2009) was exceeded in Surveys 1 and 3 Razorbill numbers remained relatively similar across Survey 1 and 2 and peaked in Survey 3 (n=766: Table 2). Low numbers of puffins were recorded during the three aerial surveys, with a peak count of 83 individuals recorded in Survey 1 (Table 3). Guillemot/razorbill numbers peaked during Survey 3 when 2,718 individuals were recorded (Table 4). Relatively low numbers of auk species were recorded across the three aerial surveys, with a peak count recorded during Survey 2 (n=104: Table 5).

Table 1 Raw counts of guillemots recorded in a) the WROWF and b) WROWF plus 8 km buffer in the three July 2017 surveys.

a) WROWF			
Survey Number	**Flying**	**Sitting**	**Total Count**
1	0	38	38
2	2	22	24
3	1	196	197
b) WROWF plus 8 km buffer			
Survey Number	**Flying**	**Sitting**	**Total Count**
1	10	744	754
2	7	525	532
3	14	2,035	2,049

Table 2 **Raw counts of razorbills recorded in a) the WROWF and b) WROWF plus 8 km buffer in the three July 2017 surveys.**

a) WROWF			
Survey Number	Flying	Sitting	Total Count
1	0	18	18
2	0	33	33
3	0	45	45
b) WROWF plus 8 km buffer			
Survey Number	Flying	Sitting	Total Count
1	2	644	646
2	1	401	402
3	0	766	766

Table 3 **Raw counts of puffins recorded in a) the WROWF and b) WROWF plus 8 km buffer in the three July 2017 surveys.**

a) WROWF			
Survey Number	Flying	Sitting	Total Count
1	0	2	2
2	0	4	4
3	0	5	5
b) WROWF plus 8 km buffer			
Survey Number	Flying	Sitting	Total Count
1	1	82	83
2	0	79	79
3	0	61	61

Table 4 **Raw counts of guillemots/razorbills recorded in a) the WROWF and b) WROWF plus 8 km buffer in the three July 2017 surveys.**

a) WROWF			
Survey Number	Flying	Sitting	Total Count
1	0	81	81
2	0	65	65
3	0	86	86
b) WROWF plus 8 km buffer			
Survey Number	Flying	Sitting	Total Count
1	0	537	537
2	9	1,542	1,551
3	3	2,715	2,718

Table 5 **Raw counts of unidentified auk species recorded in a) the WROWF and b) WROWF plus 8 km buffer in the three July 2017 surveys.**

a) WROWF			
Survey Number	**Flying**	**Sitting**	**Total Count**
1	0	8	8
2	0	12	12
3	0	0	0
b) WROWF plus 8 km buffer			
Survey Number	**Flying**	**Sitting**	**Total Count**
1	2	26	28
2	0	104	104
3	0	11	11

Species specific auk distribution

Figures 1 to 15 present the distribution of auks recorded in the three digital aerial surveys conducted in July 2017.

Guillemots were loosely distributed across the survey area during Survey 1 with lower numbers recorded in the west (Figure 1). In Survey 2 guillemots were distributed across the survey area (Figure 2). In Survey 3 guillemots were largely distributed in the northern half of the survey area (Figure 3).

Razorbills showed similar distribution patterns to that of guillemots, with individuals located across the site with lower numbers recorded in the south-west in Surveys 1 and 2 (Figures 4 and 5), and predominantly in the northern half of the survey area in Survey 3 (Figure 6).

In Surveys 1 and 2 puffins were distributed across central and eastern half of the survey area, with low numbers present within the wind farm footprint area (Figures 7 and 8). In Survey 3 puffins were largely distributed in the northern half of the survey area (Figure 9).

Guillemot/razorbills were distributed across the survey area in Survey 1 (Figure 10). IN Surveys 2 and 3 higher numbers of guillemot/razorbills were recorded in the central, northern and eastern regions of the survey area (Figures 11 and 12).

Auk species were recorded in the northern half of the survey area in Survey 1 (Figure 13). In Survey 2 auk species were distributed in the eastern and northern regions of the survey area (Figure 14). In Survey 3 auk species were predominantly recorded in the north with no individuals present within the wind farm footprint (Figure 15).

Note: The number of points visible on each figure is not necessarily equal to the total number of individuals recorded. This is because some animals are located in very close proximity to each other and at the scale required to display the whole survey area several of the points may overlay each other.

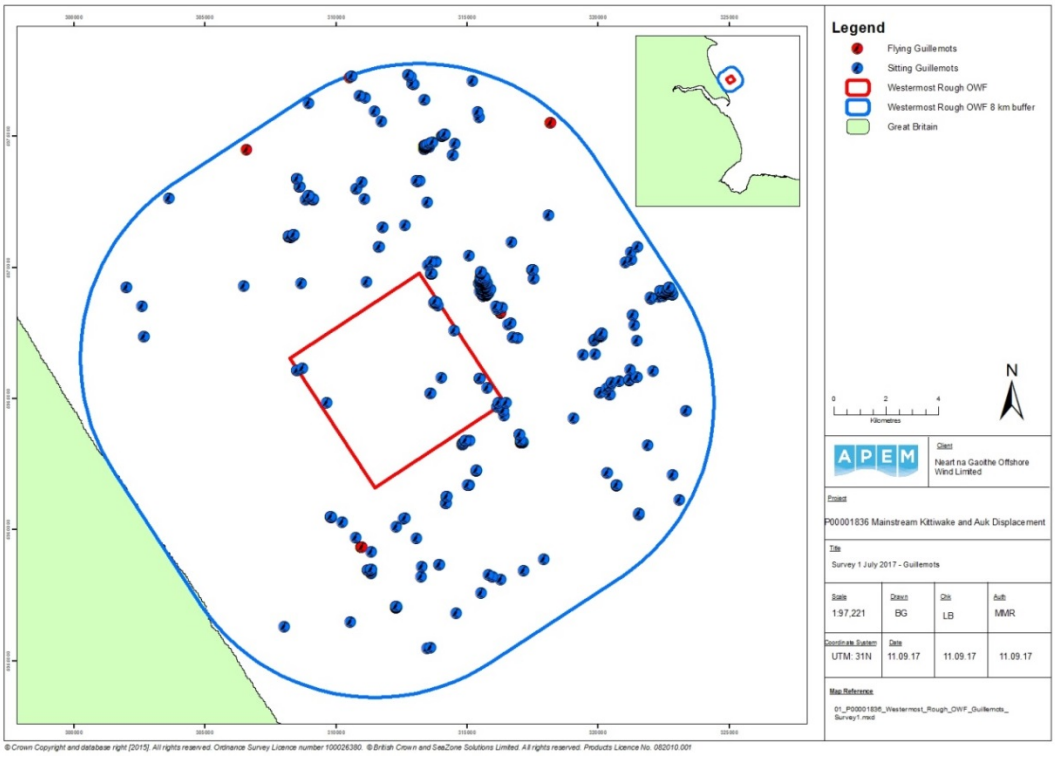

Figure 1 **Distribution of guillemots recorded in the WROWF and 8 km buffer during Survey 1.**

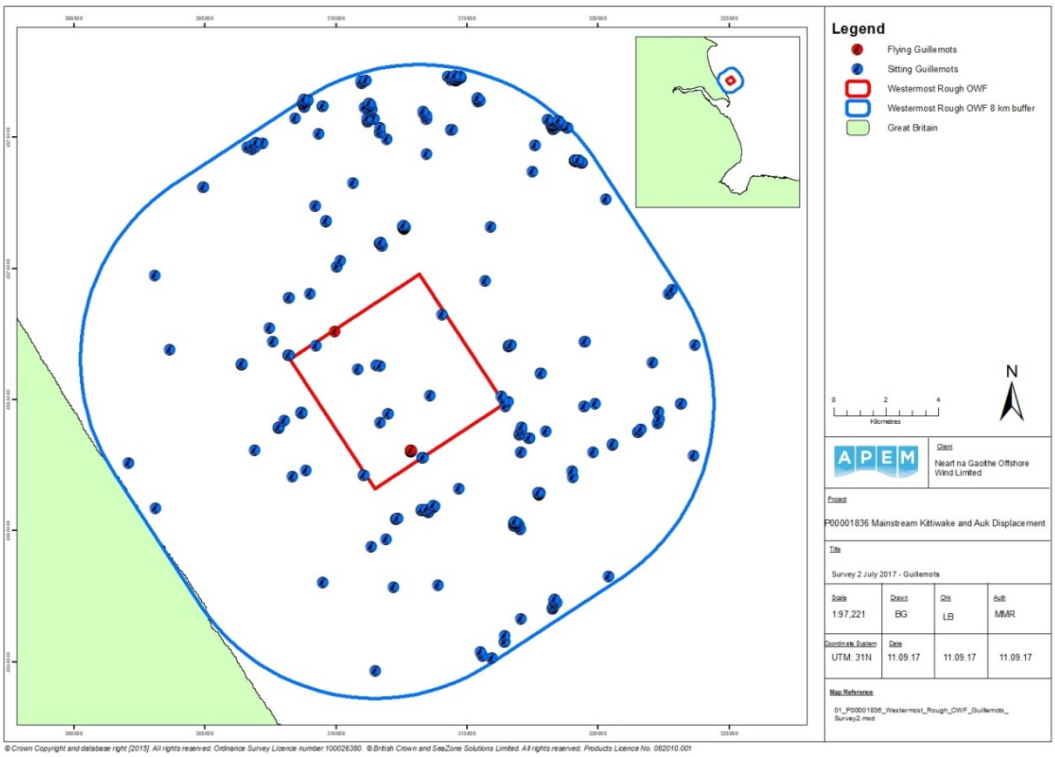

Figure 2 **Distribution of guillemots recorded in the WROWF and 8 km buffer during Survey 2.**

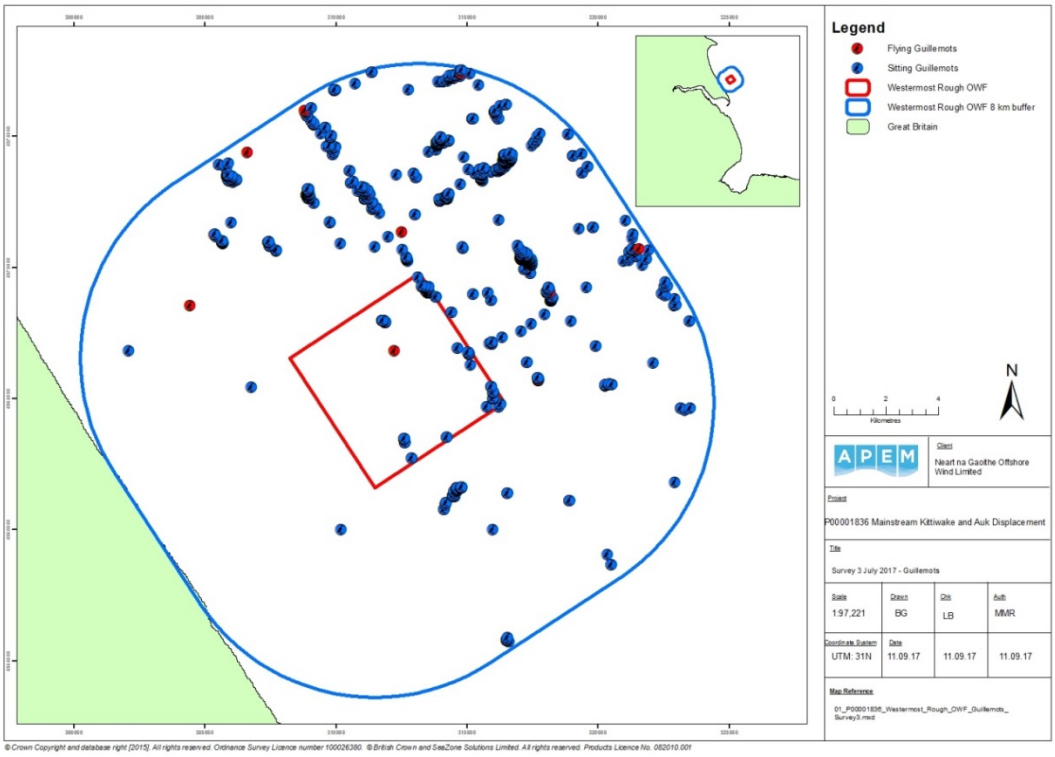

Figure 3 **Distribution of guillemots recorded in the WROWF and 8 km buffer during Survey 3.**

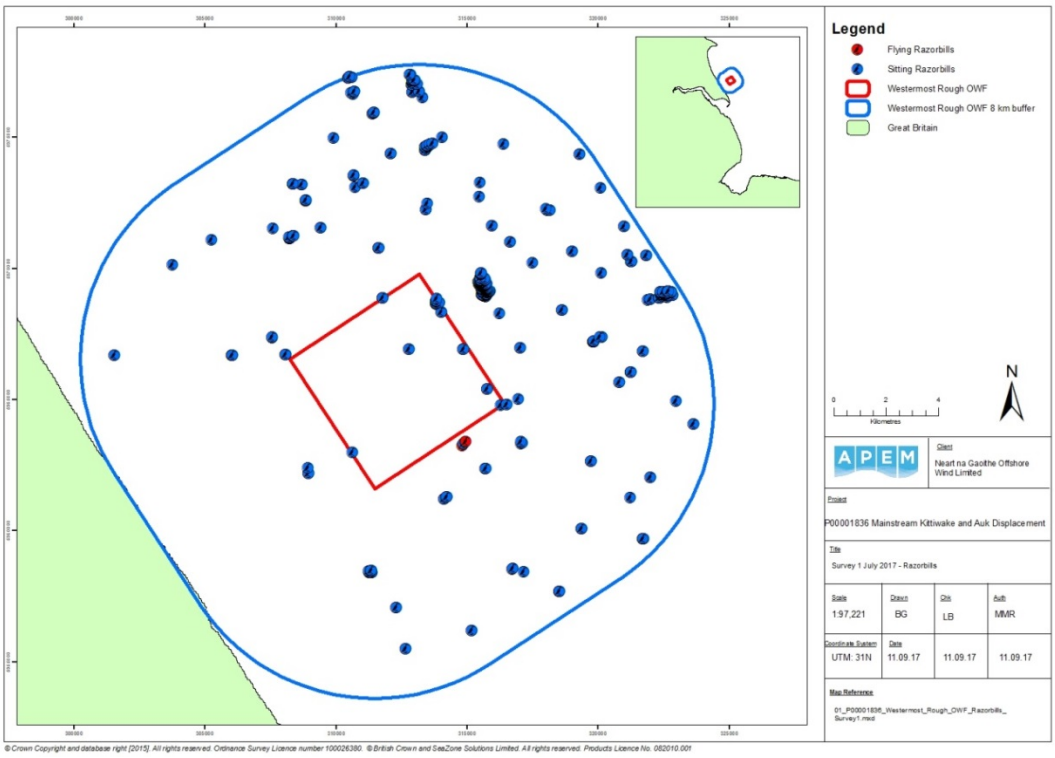

Figure 4 **Distribution of razorbills recorded in the WROWF and 8 km buffer during Survey 1.**

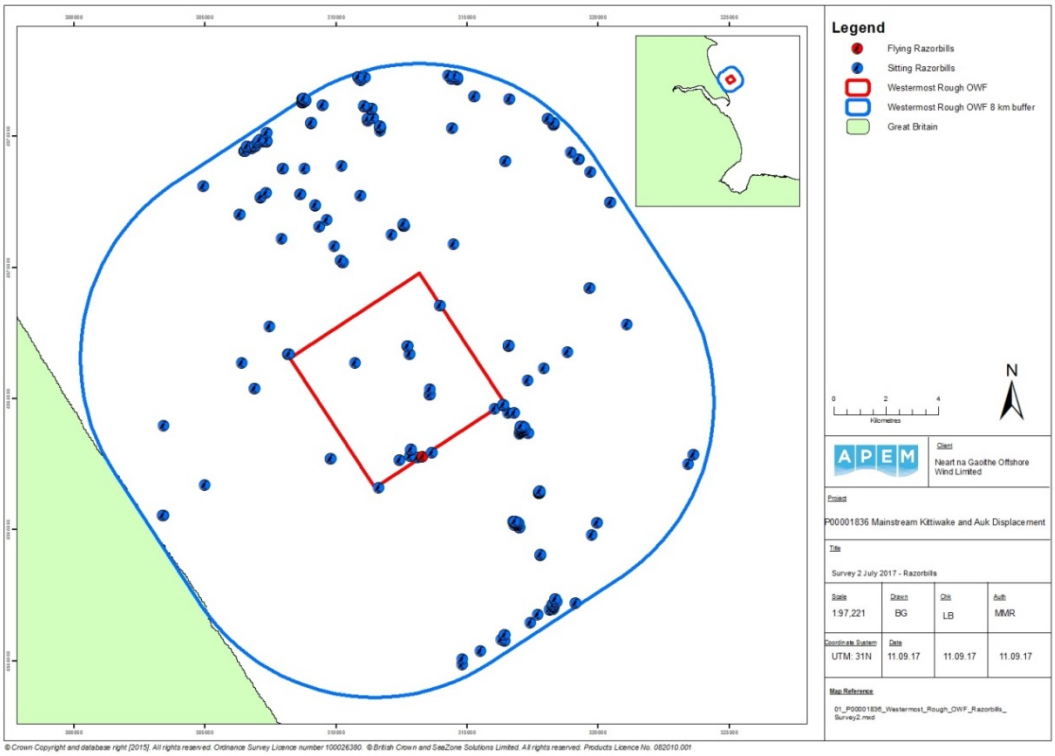

Figure 5 **Distribution of razorbills recorded in the WROWF and 8 km buffer during Survey 2.**

Figure 6 **Distribution of razorbills recorded in the WROWF and 8 km buffer during Survey 3.**

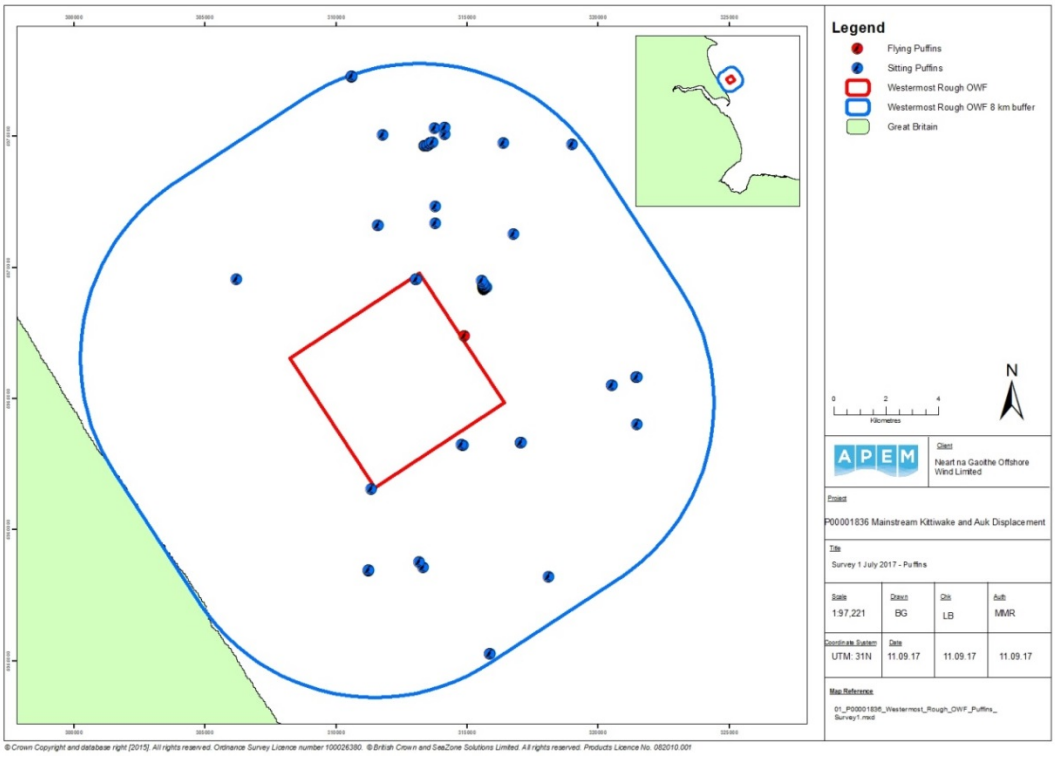

Figure 7 **Distribution of puffins recorded in the WROWF and 8 km buffer during Survey 1.**

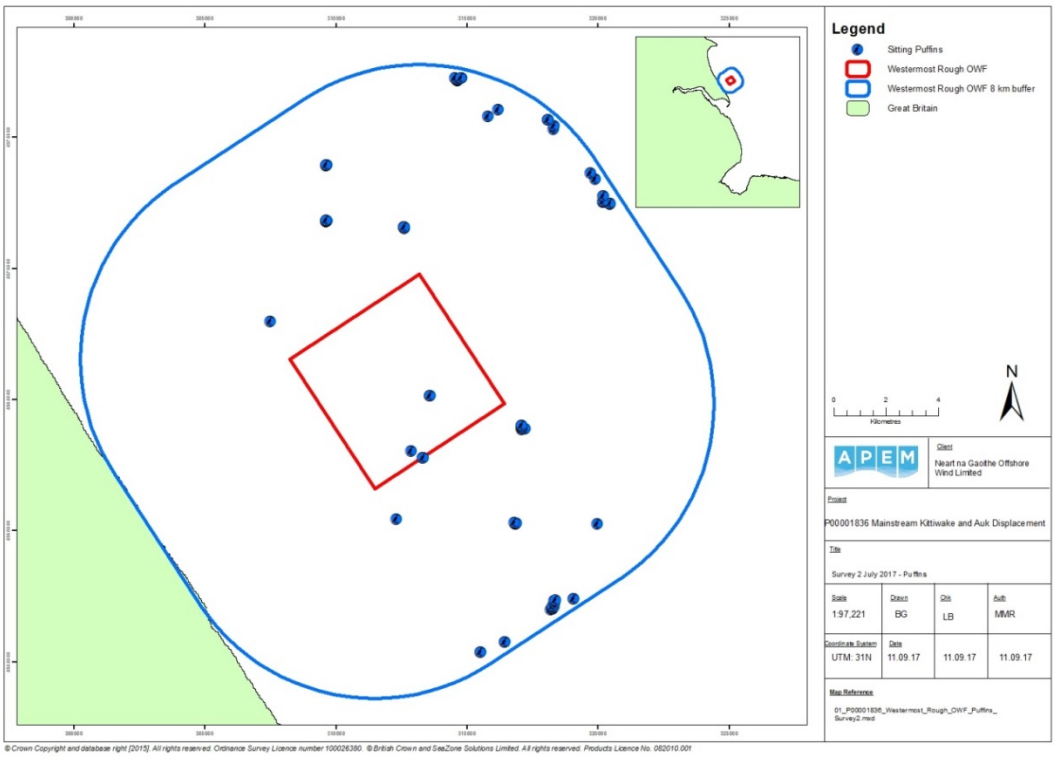

Figure 8 **Distribution of puffins recorded in the WROWF and 8 km buffer during Survey 2.**

Figure 9 **Distribution of puffins recorded in the WROWF and 8 km buffer during Survey 3.**

Figure 10 **Distribution of guillemot/razorbills recorded in the WROWF and 8 km buffer during Survey 1.**

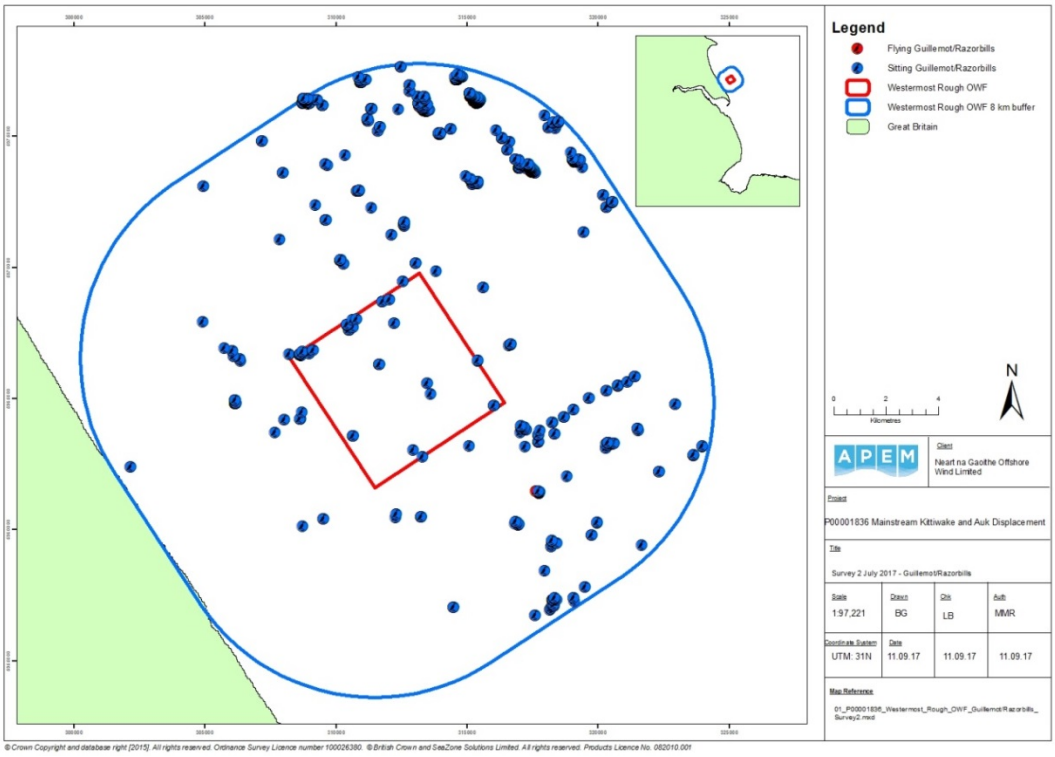

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Figure 11 **Distribution of guillemot/razorbills recorded in the WROWF and 8 km buffer during Survey 2.**

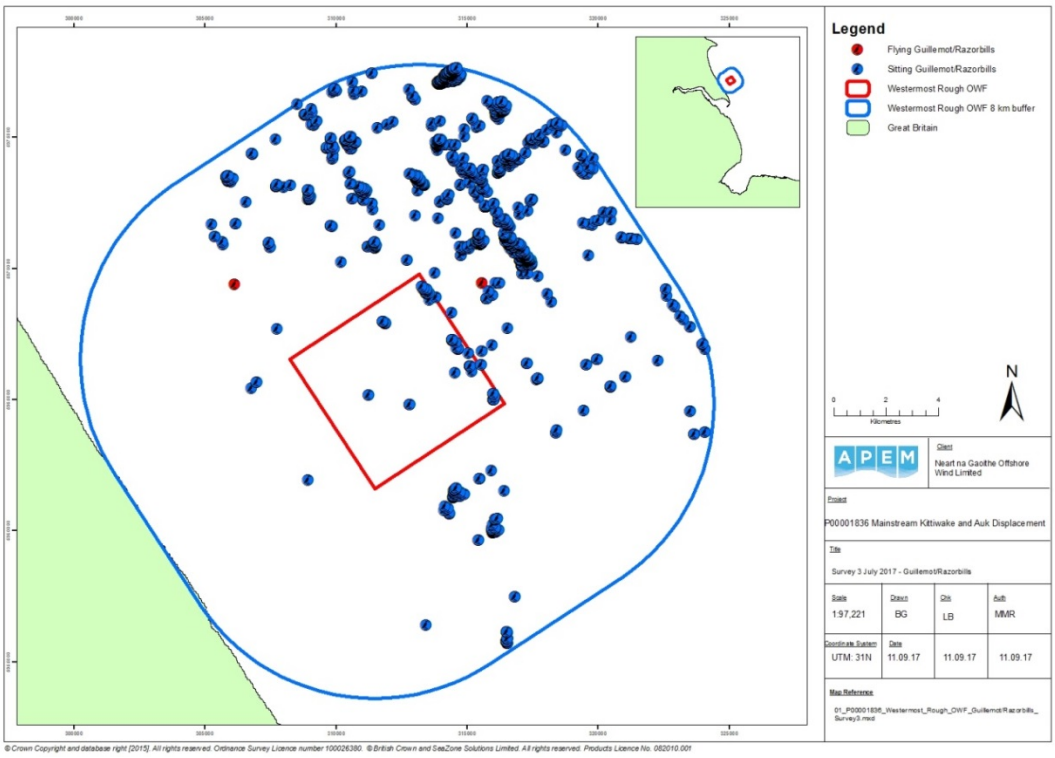

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Figure 12 **Distribution of guillemot/razorbills recorded in the WROWF and 8 km buffer during Survey 3.**

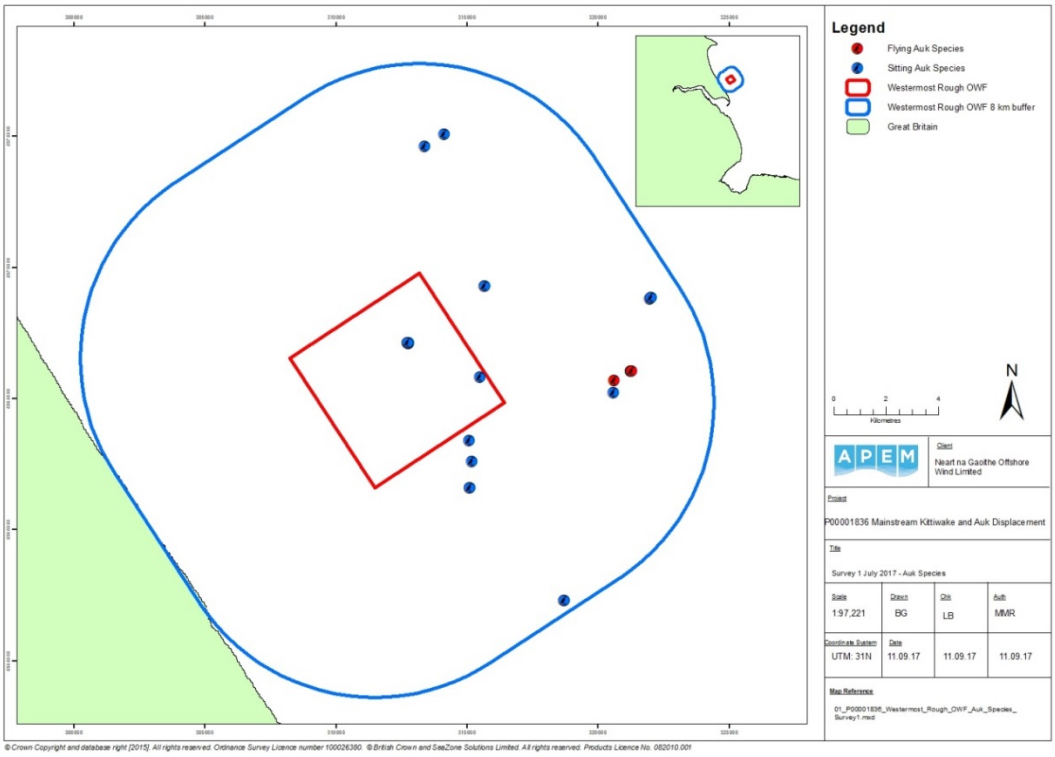

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Figure 13 Distribution of unidentified auk species recorded in the WROWF and 8 km buffer during Survey 1.

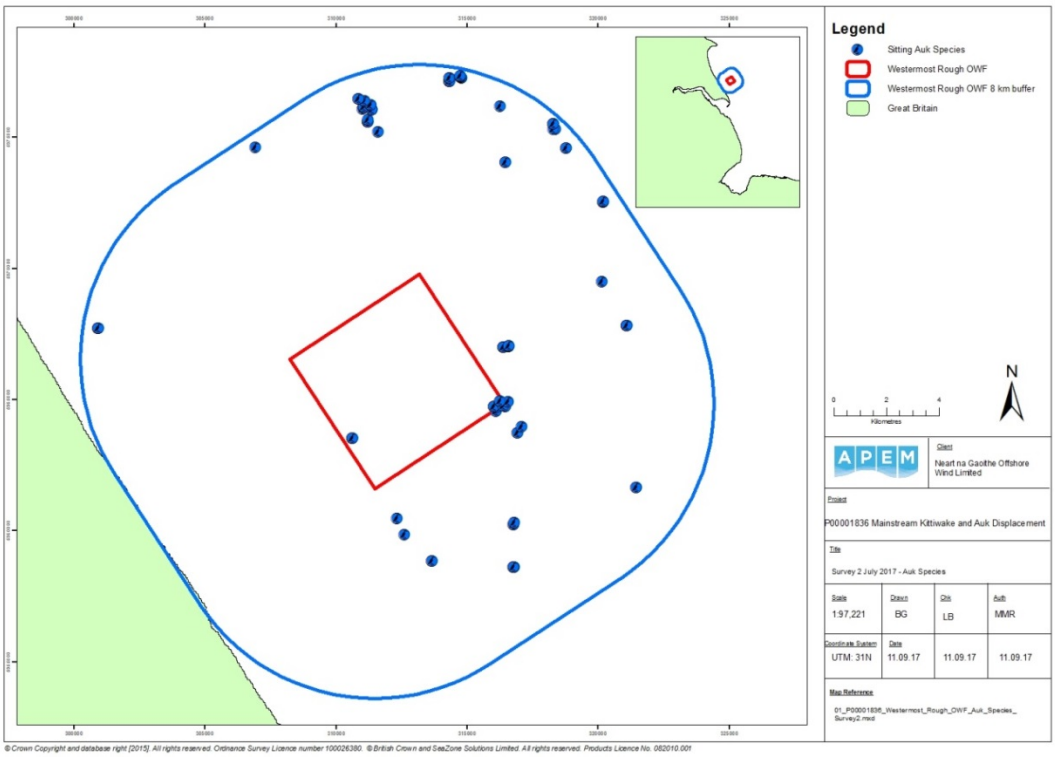

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Figure 14 Distribution of unidentified auk species recorded in the WROWF and 8 km buffer during Survey 2.

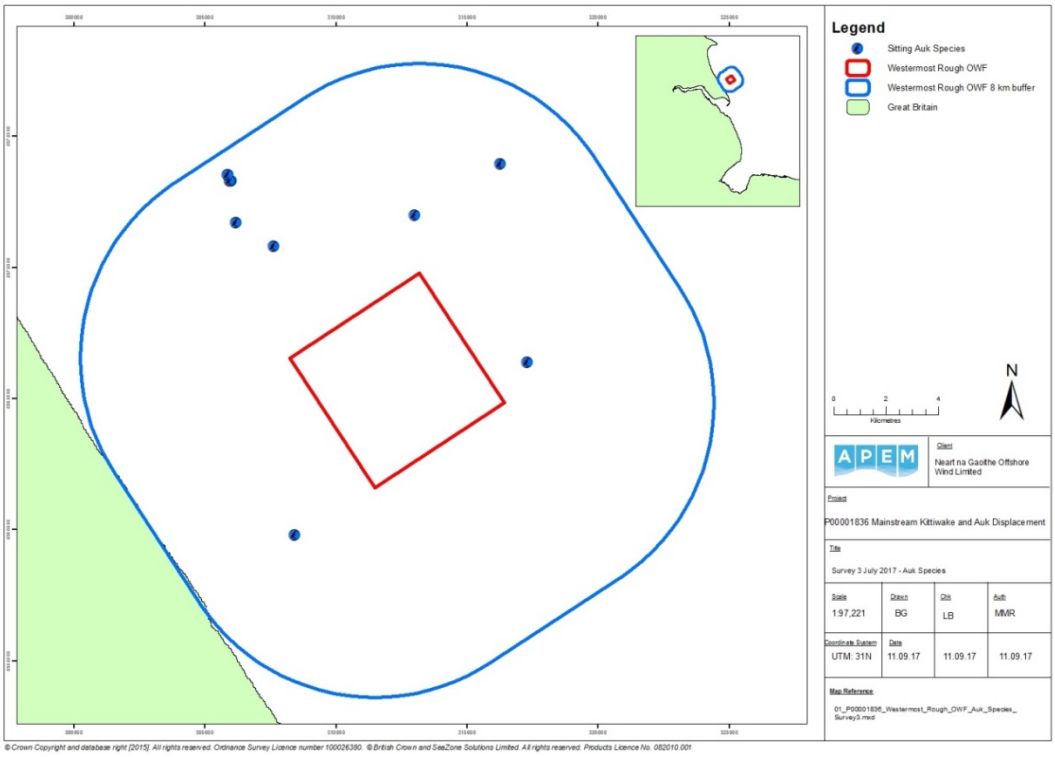

Figure 15 Distribution of unidentified auk species recorded in the WROWF and 8 km buffer during Survey 3.

Appendix 4 Gannet Counts and Distribution

The three digital aerial surveys were also conducted to collate data for flying gannet numbers and distribution.

The following results present flying gannet counts and distributions recorded from the three surveys conducted in July 2017 of the WROWF and its surrounding 8 km buffer area.

Gannet Counts

Table 1 presents the number of flying gannets recorded within the WROWF plus 8 km buffer in July 2017. For the purposes of assessing gannet avoidance only flying gannets were recorded.

A total of 164 gannets were recorded across the three surveys (Table 1). Gannets were recorded during all three digital aerial surveys and numbers peaked during Survey 1 when a total of 93 flying gannets were observed (Table 1).

Table 1 Raw counts of flying gannets recorded in a) the WROWF and b) the WROWF plus 8 km buffer in the three July 2017 surveys.

a) WROWF	
Survey Number	**Total Flying**
1	1
2	0
3	0
b) WROWF plus 8 km buffer	
Survey Number	**Total Flying**
1	93
2	24
3	47
Grand total	**164**

Gannet Distribution

Figures 1 to 3 present the distribution of gannets recorded in the three digital aerial surveys conducted in July 2017. In Survey 1 gannets were loosely distributed across the survey area with one individual recorded within the wind farm footprint (Figure 1). In Survey 2 gannets were distributed across the survey area with no flying birds recorded within the wind farm footprint (Figure 2). In Survey the majority of gannets were recorded in the northern half of the 8 km buffer zone (Figure 3).

Note: The number of points visible on each figure is not necessarily equal to the total number of individuals recorded. This is because some animals are located in very close proximity to each other and at the scale required to display the whole survey area several of the points may overlay each other.

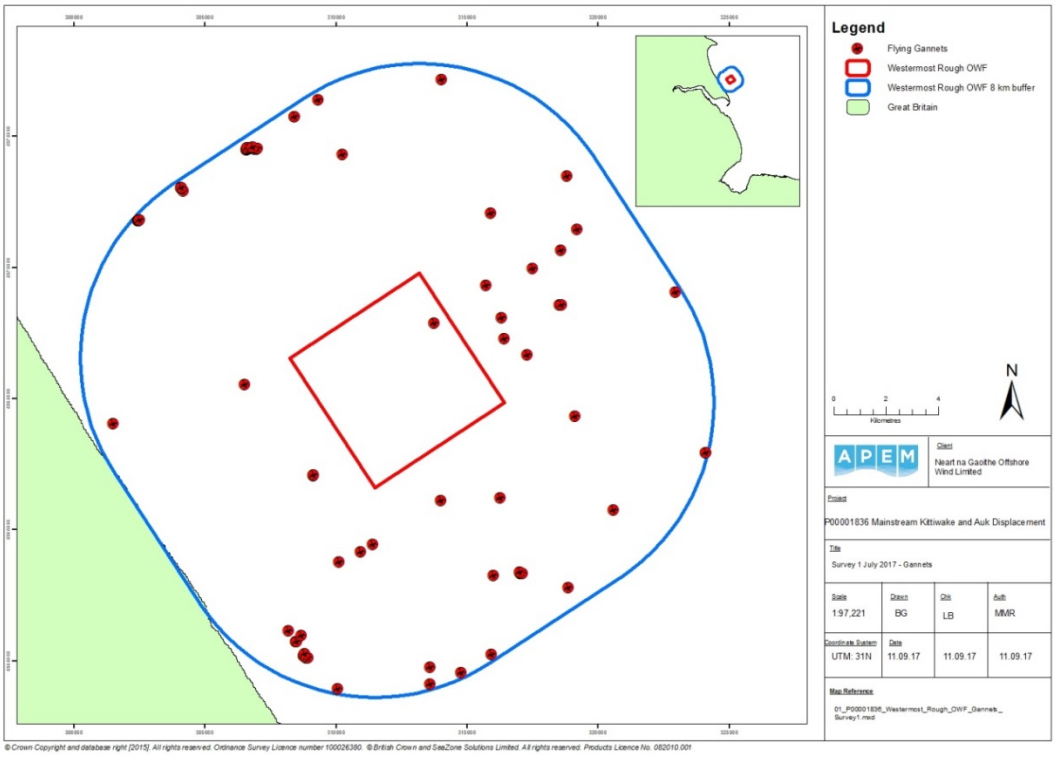

Figure 1 **Distribution of flying gannets recorded in the WROWF and 8 km buffer during Survey 1.**

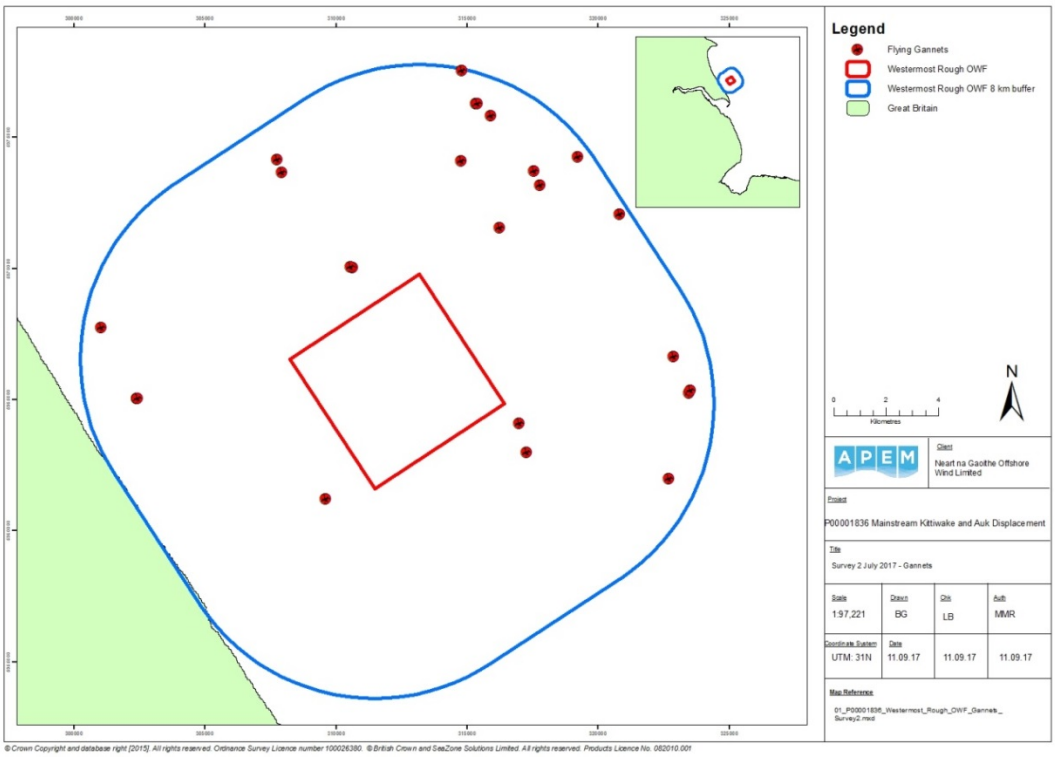

Figure 2 **Distribution of flying gannets recorded in the WROWF and 8 km buffer during Survey 2.**

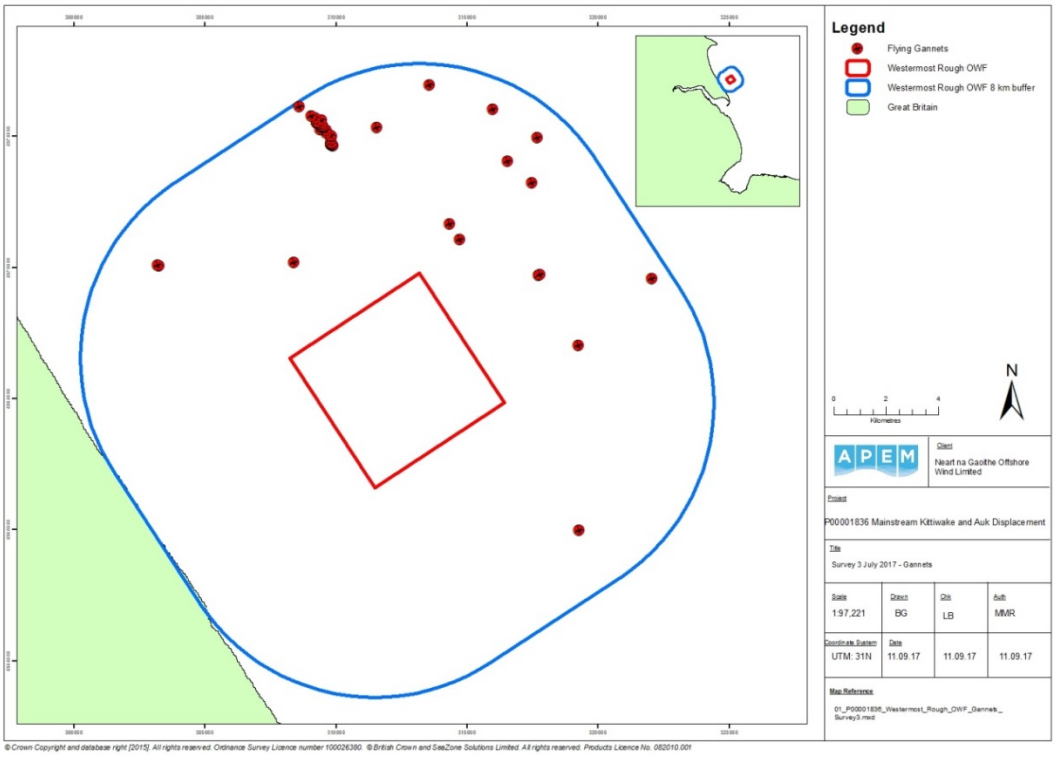

Figure 3 **Distribution of flying gannets recorded in the WROWF and 8 km buffer during Survey 3.**

Appendix 5 GAM and Kruskal-Wallis outputs

Table 1 presents the GAM details including model specification, degrees of freedom, significance and deviance explained by the model for both kittiwakes and auks. Table 2 presents the Kruskal-Wallis test details including Chi-squared value, degrees of freedom and significance values for both kittiwakes and auks. Figures 1 to 7 present the proportion of birds per km^2 for the wind farm and 1 km buffer zones.

Table 1 GAM results and specification.

Species	Area	Model Specification (including smooth function, covariates and estimated degrees of freedom)	Deviance explained (%)	Significance
Kittiwakes	Land	S(Distance,1.626)	17.1	0.165
	Sea	S(Distance,1)	0.662	0.817
	All	S(Distance, 1)	0.006	0.971
Auks	Land	S(Distance, 1.383)	14.9	0.144
	Sea	S(Distance, 1)	5.13	0.27
	All	S(Distance,1)	1.72	0.528

Table 2 Kruskal-Wallis test results.

Species	Area	Kruskal-Wallis Chi-squared	Degrees of freedom	Significance
Kittiwakes	Land	9.68	9	0.377
	Sea	7.77	9	0.558
	All	6.230	9	0.717
Auks	Land	10.841	9	0.287
	Sea	8.837	9	0.453
	All	8.630	9	0.472

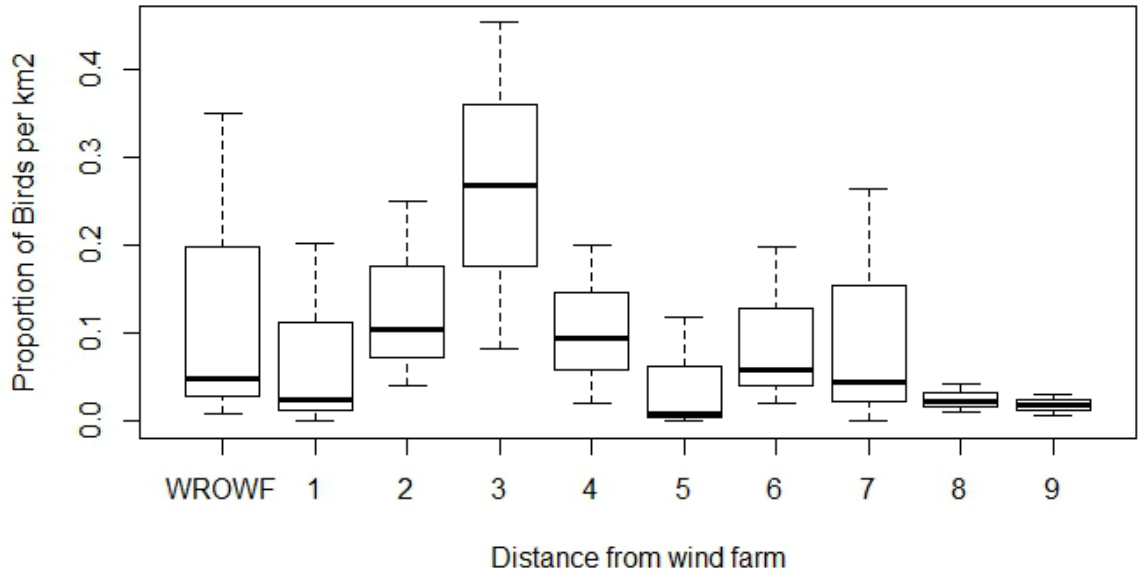

Figure 1 **Boxplot of kittiwake values across buffers for the landward half of the survey area.**

Note: The bottom and top of each box are the first and third quartiles, and the band inside the box is the second quartile (the median). The end of the top whisker represents the maximum value recorded.

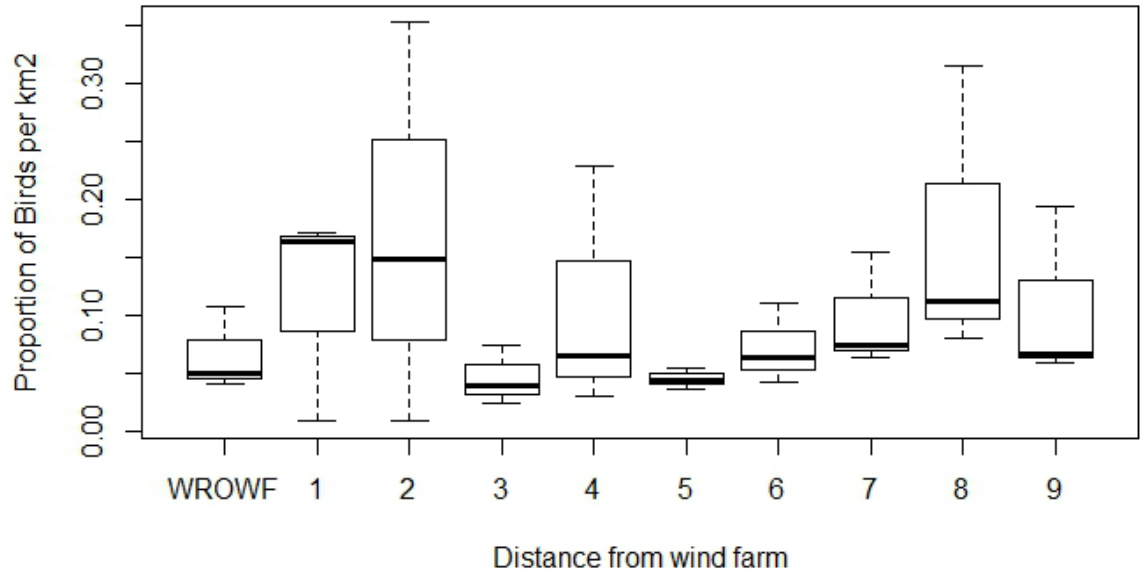

Figure 2 **Boxplot of kittiwake values across buffers for the seaward half of the survey area.**

Note: The bottom and top of each box are the first and third quartiles, and the band inside the box is the second quartile (the median). The end of the top whisker represents the maximum value recorded.

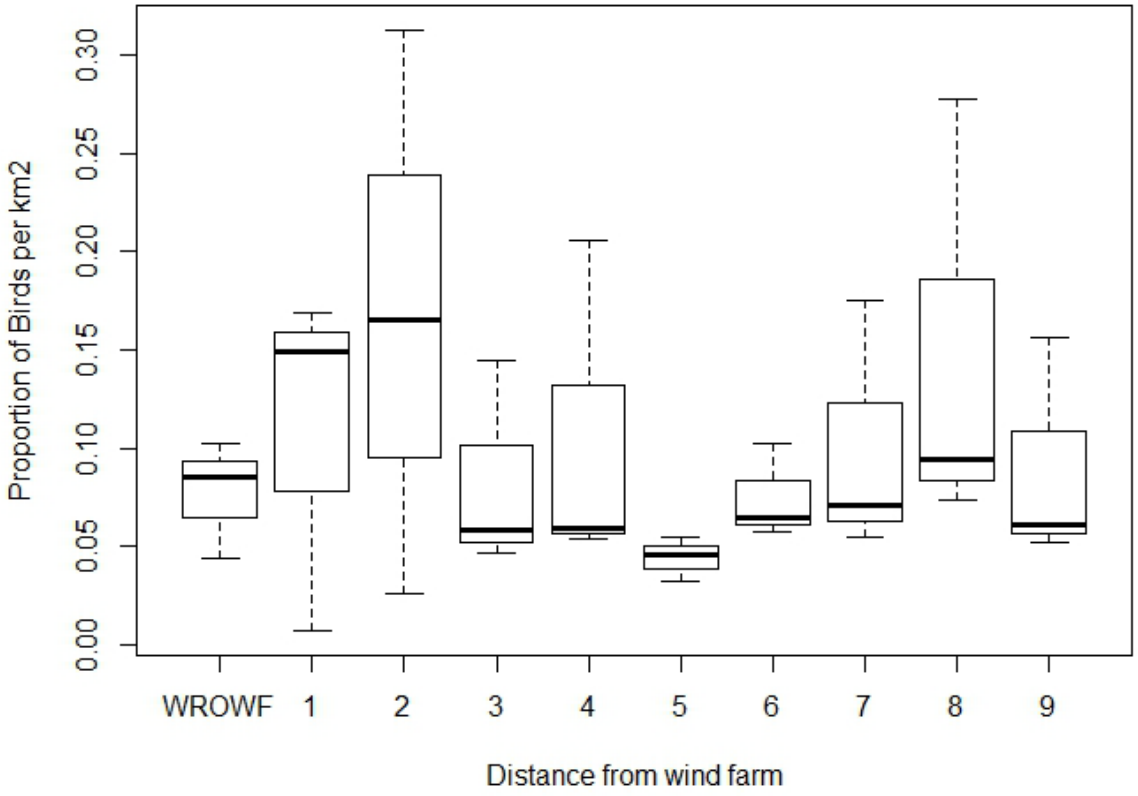

Figure 3 **Boxplot of kittiwake values for the entire wind farm and surrounding 1 km buffer zones.**

Note: The bottom and top of each box are the first and third quartiles, and the band inside the box is the second quartile (the median). The end of the top whisker represents the maximum value recorded.

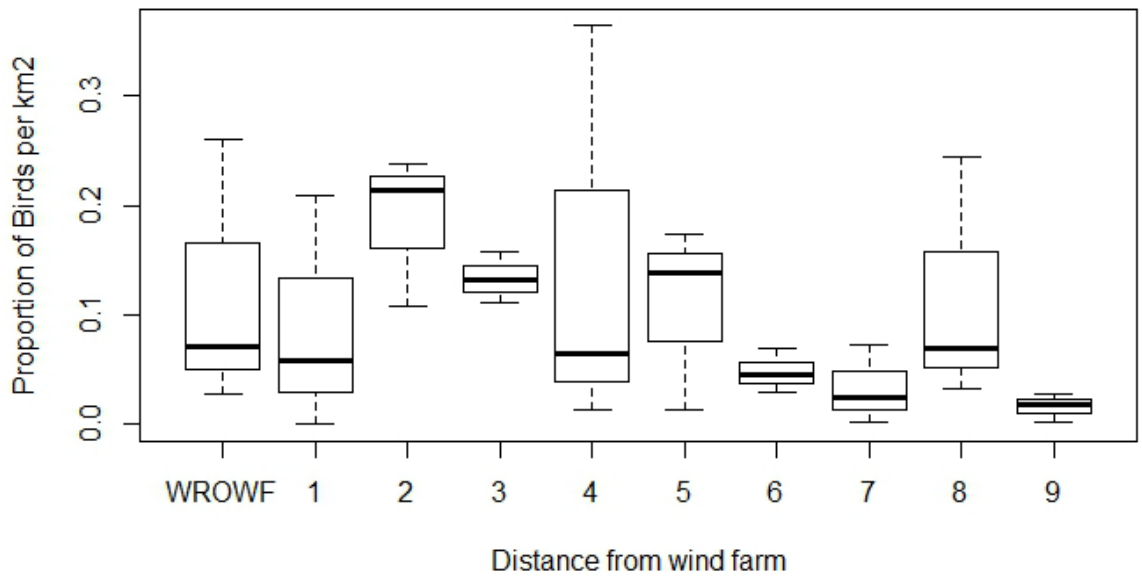

Figure 4 **Boxplot of auk values across buffers for the landward half of the survey area.**

Note: The bottom and top of each box are the first and third quartiles, and the band inside the box is the second quartile (the median). The end of the top whisker represents the maximum value recorded.

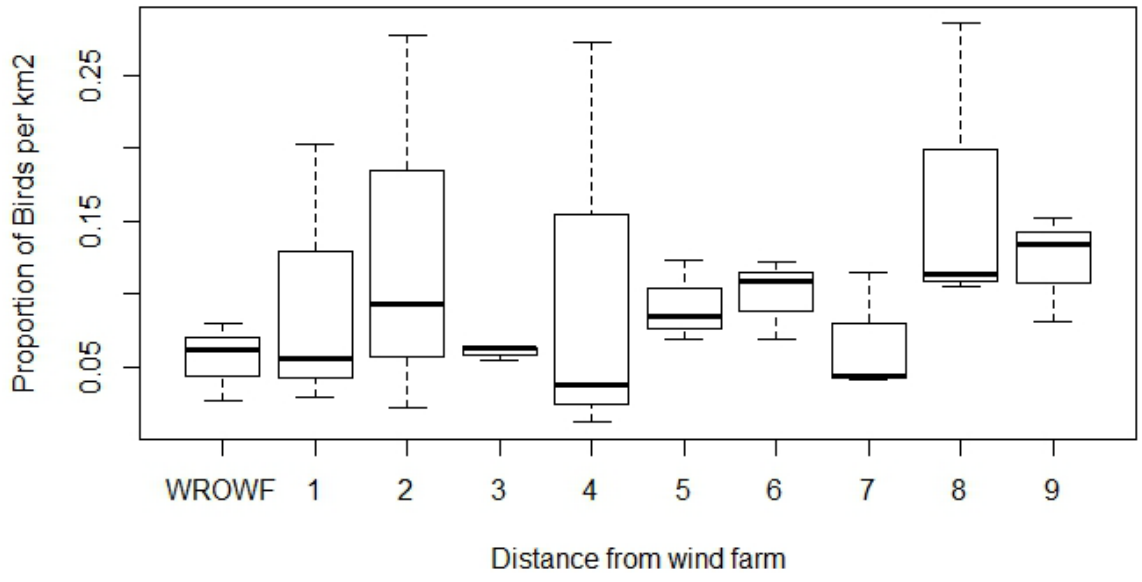

Figure 5 **Boxplot of auk values across buffers for the seaward half of the survey area.**

Note: The bottom and top of each box are the first and third quartiles, and the band inside the box is the second quartile (the median). The end of the top whisker represents the maximum value recorded.

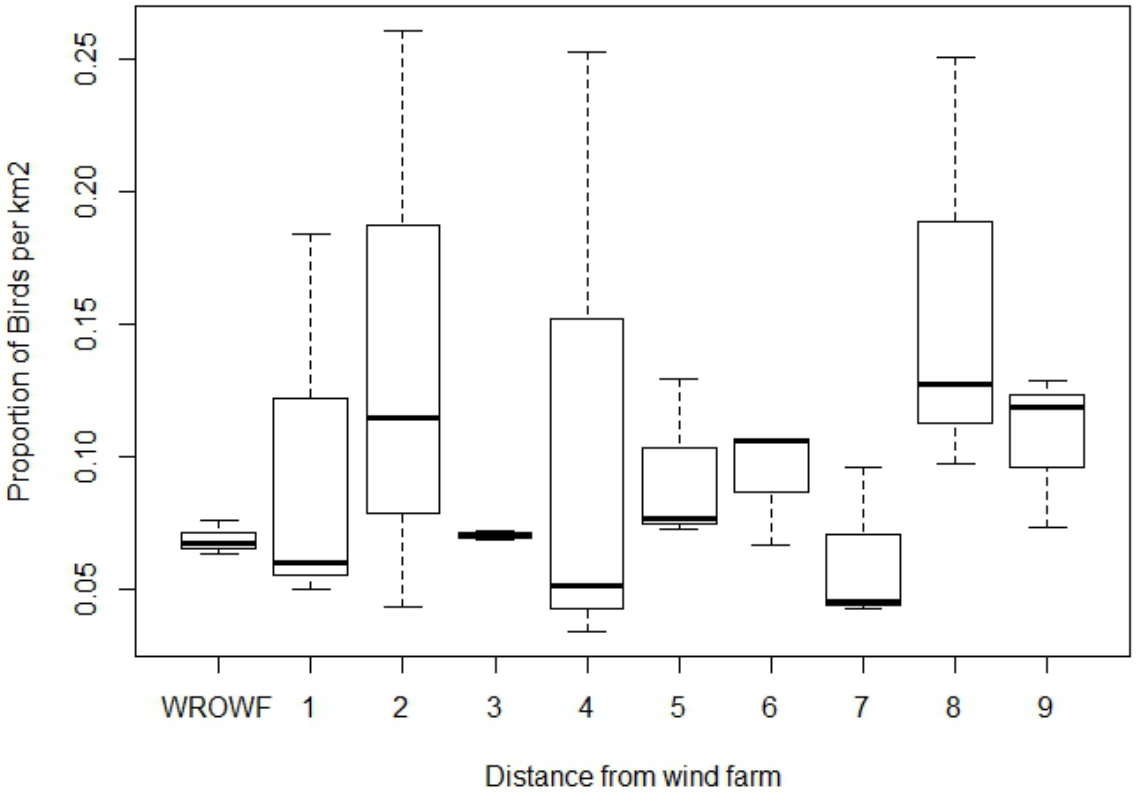

Figure 6 **Boxplot of auk values for the entire wind farm and surrounding 1 km buffer zones.**

Note: The bottom and top of each box are the first and third quartiles, and the band inside the box is the second quartile (the median). The end of the top whisker represents the maximum value recorded.

Appendix 6 Seabird Densities Within Study Site

Kittiwake and Auk densities – landward and seaward

Tables 1 and 2 present the kittiwake and auk densities calculated for landward and seaward wind farm and 1 km buffer zones per survey.

Table 1 Kittiwake densities per survey for landward and seaward wind farm and 1 km buffer zones.

	Buffer distance landward (km)										Buffer distance seaward (km)									
Survey Number	9	8	7	6	5	4	3	2	1	Wind farm	Wind farm	1	2	3	4	5	6	7	8	9
	Birds per km^2 (landward)										Birds per km^2 (seaward)									
1	1.23	0.62	1.05	6.80	5.09	3.01	5.05	1.13	0.60	0.76	17.14	27.22	55.93	3.84	4.82	7.09	6.80	11.88	12.87	10.71
2	7.87	4.54	5.64	1.87	0.49	0.20	0.49	0.00	0.97	0.45	5.47	21.90	19.99	5.40	8.71	4.86	8.47	8.64	42.19	7.90
3	0.25	0.00	2.67	11.62	2.41	0.00	1.53	6.75	0.26	0.16	5.84	1.00	0.99	8.57	26.39	6.38	12.76	17.85	12.93	22.34

Table 2 Auk densities per survey for landward and seaward wind farm and 1 km buffer zones.

	Buffer distance landward (km)										Buffer distance seaward (km)									
Survey Number	9	8	7	6	5	4	3	2	1	Wind farm	Wind farm	1	2	3	4	5	6	7	8	9
	Birds per km^2 (landward)										Birds per km^2 (seaward)									
1	0.68	1.39	2.60	3.16	8.70	3.33	1.08	1.73	0.77	0.45	15.30	38.87	53.14	12.05	2.32	13.24	13.18	7.98	20.14	15.67
2	9.96	8.00	8.18	6.02	0.49	0.51	1.12	0.09	2.69	1.08	5.16	5.63	17.63	10.29	7.10	16.06	23.02	21.75	54.01	28.74
3	3.51	0.00	11.71	5.45	3.17	8.57	3.45	1.19	12.01	0.16	28.08	25.53	10.12	29.40	124.15	56.32	49.80	20.18	52.03	61.08

Tables 3 and 4 present the percentages of the total densities for landward and seaward wind farm and 1 km buffer zones per survey.

Table 3 **Percentages of total kittiwake densities per survey for landward and seaward wind farm and 1 km buffer zones.**

	Buffer distance landward (km)										Buffer distance seaward (km)									
Survey Number	9	8	7	6	5	4	3	2	1	Wind farm	Wind farm	1	2	3	4	5	6	7	8	9
	Birds per km^2 (landward)										Birds per km^2 (seaward)									
1	0.67	0.34	0.57	3.70	2.77	1.64	2.75	0.62	0.33	0.41	9.33	14.82	30.46	2.09	2.63	3.86	3.70	6.47	7.01	5.83
2	5.05	2.91	3.61	1.20	0.31	0.13	0.31	0.00	0.62	0.29	3.50	14.03	12.81	3.46	5.58	3.11	5.43	5.54	27.04	5.06
3	0.17	0.00	1.89	8.26	1.71	0.00	1.09	4.80	0.18	0.11	4.15	0.71	0.71	6.09	18.76	4.54	9.07	12.69	9.19	15.87

Table 4 **Percentages of total auk densities per survey for landward and seaward wind farm and 1 km buffer zones.**

	Buffer distance landward (km)										Buffer distance seaward (km)									
Survey Number	9	8	7	6	5	4	3	2	1	Wind farm	Wind farm	1	2	3	4	5	6	7	8	9
	Birds per km^2 (landward)										Birds per km^2 (seaward)									
1	0.31	0.64	1.21	1.47	4.03	1.54	0.50	0.80	0.36	0.21	7.09	18.01	24.63	5.59	1.08	6.14	6.11	3.70	9.33	7.26
2	4.38	3.52	3.60	2.65	0.22	0.22	0.49	0.04	1.18	0.47	2.27	2.47	7.75	4.52	3.12	7.06	10.12	9.56	23.74	12.63
3	0.69	0.00	2.32	1.08	0.63	1.69	0.68	0.24	2.37	0.03	5.55	5.05	2.00	5.81	24.54	11.13	9.84	3.99	10.29	12.07

Tables 5 and 6 present the overall mean densities of kittiwakes and auks per survey for landward and seaward wind farm and 1 km buffer zones and their associated standard errors.

Table 5 **Mean kittiwake densities and standard errors for landward and seaward wind farm and 1 km buffer zones.**

		Buffer distance landward (km)										Buffer distance seaward (km)									
		9	8	7	6	5	4	3	2	1	Wind farm	Wind farm	1	2	3	4	5	6	7	8	9
		Birds per km^2 (landward)										Birds per km^2 (seaward)									
Survey Number	1	0.31	0.64	1.21	1.47	4.03	1.54	0.50	0.80	0.36	0.21	7.09	18.01	24.63	5.59	1.08	6.14	6.11	3.70	9.33	7.26
	2	4.38	3.52	3.60	2.65	0.22	0.22	0.49	0.04	1.18	0.47	2.27	2.47	7.75	4.52	3.12	7.06	10.12	9.56	23.74	12.63
	3	0.69	0.00	2.32	1.08	0.63	1.69	0.68	0.24	2.37	0.03	5.55	5.05	2.00	5.81	24.54	11.13	9.84	3.99	10.29	12.07
Mean Density		3.12	1.72	3.12	6.76	2.66	1.07	2.36	2.63	0.61	0.45	9.48	16.71	25.64	5.94	13.31	6.11	9.35	12.79	22.67	13.65
Standard Error		2.40	1.42	1.34	2.82	1.33	0.97	1.38	2.09	0.21	0.17	3.83	8.00	16.11	1.39	6.64	0.66	1.78	2.70	9.76	4.42

Table 6 **Mean auk densities and standard errors for landward and seaward wind farm and 1 km buffer zones.**

		Buffer distance landward (km)										Buffer distance seaward (km)									
		9	8	7	6	5	4	3	2	1	Wind farm	Wind farm	1	2	3	4	5	6	7	8	9
		Birds per km^2 (landward)										Birds per km^2 (seaward)									
Survey Number	1	0.31	0.64	1.21	1.47	4.03	1.54	0.50	0.80	0.36	0.21	7.09	18.01	24.63	5.59	1.08	6.14	6.11	3.70	9.33	7.26
	2	4.38	3.52	3.60	2.65	0.22	0.22	0.49	0.04	1.18	0.47	2.27	2.47	7.75	4.52	3.12	7.06	10.12	9.56	23.74	12.63
	3	0.69	0.00	2.32	1.08	0.63	1.69	0.68	0.24	2.37	0.03	5.55	5.05	2.00	5.81	24.54	11.13	9.84	3.99	10.29	12.07
Mean Density		4.72	3.13	7.50	4.88	4.12	4.13	1.88	1.00	5.15	0.56	16.18	23.34	26.96	17.25	44.53	28.54	28.67	16.64	42.06	35.16
Standard Error		2.75	2.47	2.65	0.87	2.42	2.36	0.78	0.48	3.47	0.27	6.63	9.66	13.27	6.10	39.84	13.91	10.94	4.35	10.98	13.50

Overall Kittiwake and Auk densities

Tables 7 and 8 show the overall densities calculated for kittiwakes and auks for the wind farm footprint and surrounding 1 km buffer zones.

Table 7 Mean kittiwake densities and standard errors for the entire wind farm and surrounding 1 km buffer zones.

		Buffer distance (km)									
		Wind farm	1	2	3	4	5	6	7	8	9
		Birds per km^2									
Survey Number	1	9.37	13.67	28.72	5.35	4.95	5.03	5.93	6.49	6.75	5.60
	2	6.64	13.17	12.87	3.61	4.62	2.53	4.50	4.29	21.62	4.08
	3	3.07	0.50	1.80	10.12	14.37	3.19	7.15	12.28	6.59	10.94
Mean Density		6.36	9.12	14.46	6.36	7.98	3.58	5.86	7.69	11.65	6.87
Standard Error		1.82	4.31	7.81	1.95	3.20	0.75	0.77	2.38	4.98	2.08

Table 8 Mean auk densities and standard errors for the entire wind farm and surrounding 1 km buffer zones.

		Buffer distance (km)									
		Wind farm	1	2	3	4	5	6	7	8	9
		Birds per km^2									
Survey Number	1	8.15	19.80	28.07	7.55	5.49	8.24	7.15	4.84	10.47	7.87
	2	7.56	6.78	12.93	8.12	3.82	8.24	12.06	10.87	28.40	14.52
	3	15.95	12.56	10.89	17.21	63.54	32.51	26.63	10.65	32.03	29.79
Mean Density		10.55	13.05	17.30	10.96	24.28	16.33	15.28	8.79	23.63	17.40
Standard Error		2.70	3.77	5.42	3.13	19.63	8.09	5.85	1.98	6.66	6.49