moray offshore renewables ltd

Environmental Statement

Technical Appendix 4.5 B - Aerial Ornithology Surveys for the Moray Firth Zone, Summer 2011

Telford, Stevenson, MacColl Wind Farms and associated Transmission Infrastructure Environmental Statement

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APPENDIX 4.5 B

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Contents

Executive Summary

- Six aerial surveys of Zone 1 (Moray Firth; Figure 1.1) of the UK Offshore development Round 3 were carried out between May 2011 and July 2011. This document reports the results of these surveys.

- The aim of these surveys was to collect bird distribution data and to provide data on flight directions in relation to SPA connectivity.

- All surveys used high resolution digital still imagery methods. An image was captured every 250 m on a 2 km survey grid. Images were collected at a 2 cm ground sampling distance (GSD) resolution.

- Eight grids were analysed and the data used to determine trends in flight direction and distribution across the survey area.

- General patterns of distribution highlighted that for most species, densities were highest close to breeding colonies. Many individuals were also located further offshore.

- Patterns of orientation suggested that guillemots within the wind farm area could be linked with all three SPAs. Peak abundance estimates for guillemots reached 50,049 (lower CL: 49,567, upper CL: 50,524, *CV* = 0.01) for the survey area and 3,135 (lower CL: 3,108, upper CL: 3,164, *CV* = 0.05) for the eastern development area.

- Many razorbills within the wind farm area (plus buffer) were heading in a south easterly direction, perhaps suggesting arrival at foraging grounds from northern SPAs or departure to breeding sites at Troup, Pennan and Lion's Heads SPA. The peak abundance estimate for razorbills was 40,381 (lower CL: 39,991, upper CL: 40,780, *CV* = 0.01) for the survey area, and 4,283 (lower CL: 4,219, upper CL: 4,348, *CV* = 0.04) for the eastern development area.

- No strong trend in orientation was apparent for puffins, although given the importance of the SPAs for this species it is likely that most of the puffins recorded offshore would be linked to these sites. Abundance estimates for puffins peaked at 6,217 (lower CL: 6,080, upper CL: 6,353, *CV* = 0.04) for the survey area, and 408 (lower CL: 400, upper CL: 415, *CV* = 0.14) for the eastern development area.

- Although fulmars were widespread throughout the wind farm area, their large foraging range may indicate that linkages between all three SPAs exist. Peak abundance estimates for fulmars were 14,492 (lower CL: 14,242, upper CL: 14,727, *CV* = 0.02) for the survey area, and 939 (lower CL: 931, upper CL: 948, *CV* = 0.09) for the eastern development area.

- There was a trend for kittiwakes located offshore to be orientated towards the south, perhaps reflecting birds flying away from the north on foraging trips or towards the south on return. Peak abundance estimates for kittiwakes reached 35,498 (lower CL: 34,286, upper CL: 36,739, *CV* = 0.02) for the survey area, and 2,307 (lower CL: 2,211, upper CL: 2,407, *CV* = 0.06) for the eastern development area.

- No strong trends in orientation were detected for great black-backed gulls. However, given the importance of the SPAs for this species it is likely that most individuals recorded offshore would be linked to these sites. Peak abundance for great black-backed gulls reached 609 (lower CL: 569, upper CL: 651, *CV* = 0.11) for the survey area, and 16 (lower CL: 14, upper CL: 18, *CV* = 0.73) for the eastern development area.

- Other bird species and groups recorded included cormorants / shags, herring gulls, terns, gannets and skuas.

- Several seals and cetaceans were also captured in digital images.

1. Introduction

Moray Offshore Renewables Ltd (MORL) contracted APEM Ltd to collect additional data on birds and marine mammals by digital aerial survey. These data will inform a site specific EIA and cumulative impact assessment, as well as future Appropriate Assessments under the Habitats Directive, for Zone 1 (Moray Firth; Figure 1.1) of the UK Offshore development Round 3.

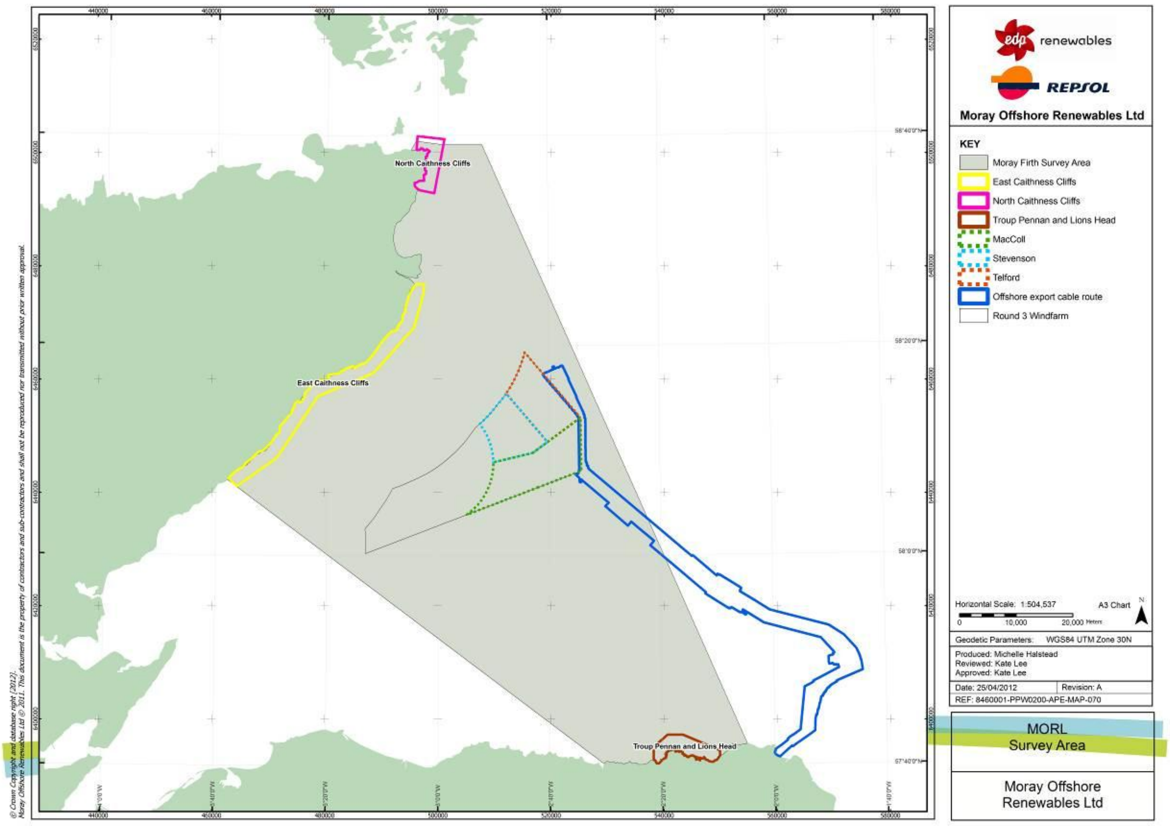


Figure 1.1 MORL survey area

The main objectives of the work are:

- Collect bird distribution data for a wider area than that covered by the boat-based surveys; and
- Provide data on flight directions for this wider area, in relation to SPA connectivity.
-

The data collected are intended to be suitable to provide additional context for EIA and to inform an Appropriate Assessment for all key species, and in particular for:

- Fulmar *Fulmarus glacialis*
- Kittiwake *Rissa tridactyla*
- Guillemot *Uria aalge*
- Razorbill *Alca torda*

- Puffin *Fratercula arctica*
- Great black-backed gull *Larus marinus*

A total of six aerial surveys of the Moray Firth zone were targeted, falling within the periods listed below with at least three days between each one.

1. 1st to 10th May;
2. 11th to 20th May;
3. 21st to 31st May;
4. 1st to 15th June;
5. 15th to 30th June; and
6. 10th to 20th July.

This report summarises the findings of all six surveys undertaken during May to July 2011.

1.1. Ornithology

The Moray Firth area supports internationally important numbers of breeding seabirds during the summer months. As a consequence, there are a number of areas designated for breeding seabirds in the Moray Firth area:

- East Caithness Cliffs SPA: designated for guillemot, herring gull, kittiwake, razorbill and shag, plus a seabird assemblage including puffin, great black-backed gull, cormorant and fulmar;
- North Caithness Cliffs SPA: designated for guillemot, plus a seabird assemblage including puffin, razorbill, kittiwake and fulmar;
- Cromarty Firth and Inner Moray Firth SPAs: designated for common tern; and
- Troup, Pennan and Lion's Heads SPA: designated for guillemot plus a seabird assemblage including razorbill, kittiwake, herring gull and fulmar.

Breeding seabirds typically commute offshore to feed, often over areas such as the Smith Bank, partially located within the location of the Moray Firth Zone.

It is understood from boat-based surveys undertaken to support the ornithology and marine mammal assessments for the Telford, Stevenson and McColl wind farms, that the principal species of interest in the breeding season are fulmars, kittiwakes, guillemots, razorbills and puffins, though other species will be routinely recorded and identified. Linkages to nearby SPAs can be investigated by examining flight direction data and the relationship between distance from SPAs and bird density.

2. Methods

The digital aerial surveys were undertaken using a Britten-Norman Islander twin engine survey aircraft and a Vulcanair P68 Observer survey aircraft. Surveys involved digital still image collection using a GPS-linked bespoke flight management system. A grid-based survey design was used, as set out in the Method Statement and approved by MORL.

2.1. Survey Design

APEM use a grid survey methodology to derive sufficient independent estimates of bird density (and distribution) to achieve a predefined level of confidence of population size estimation. This also allows an independent sample to be generated for other analyses, including directional analysis and flight height estimation. Importantly this approach also spreads survey effort evenly over the survey area, reducing the potential for bias.

A grid was randomly overlain on the survey area using flight planning software with intersections of the grid separated by 2 km. The aircraft flew along a flight line in a north-northwest to south-southeast orientation and an image was captured every 250 m along each flight line, generating a total of ~9,400 images (including those which fall over land), or 'samples', which equates to eight grids. Images were collected at a 2 cm GSD resolution, providing a much greater resolution than the 5 cm minimum accepted resolution (Thaxter & Burton 2009).

A schematic plan of the 2 km by 250 m survey design is shown (Figure 2.1.1) for the survey area covered in this project. Each black point on the Figure insert represents an image collected every 250 m on each survey transect.

Surveys were designed to begin soon after sunrise (weather permitting), to capture diurnal activity throughout the course of one day. Owing to the size of the area, on most occasions it was necessary to complete the survey soon after sunrise on the following day.

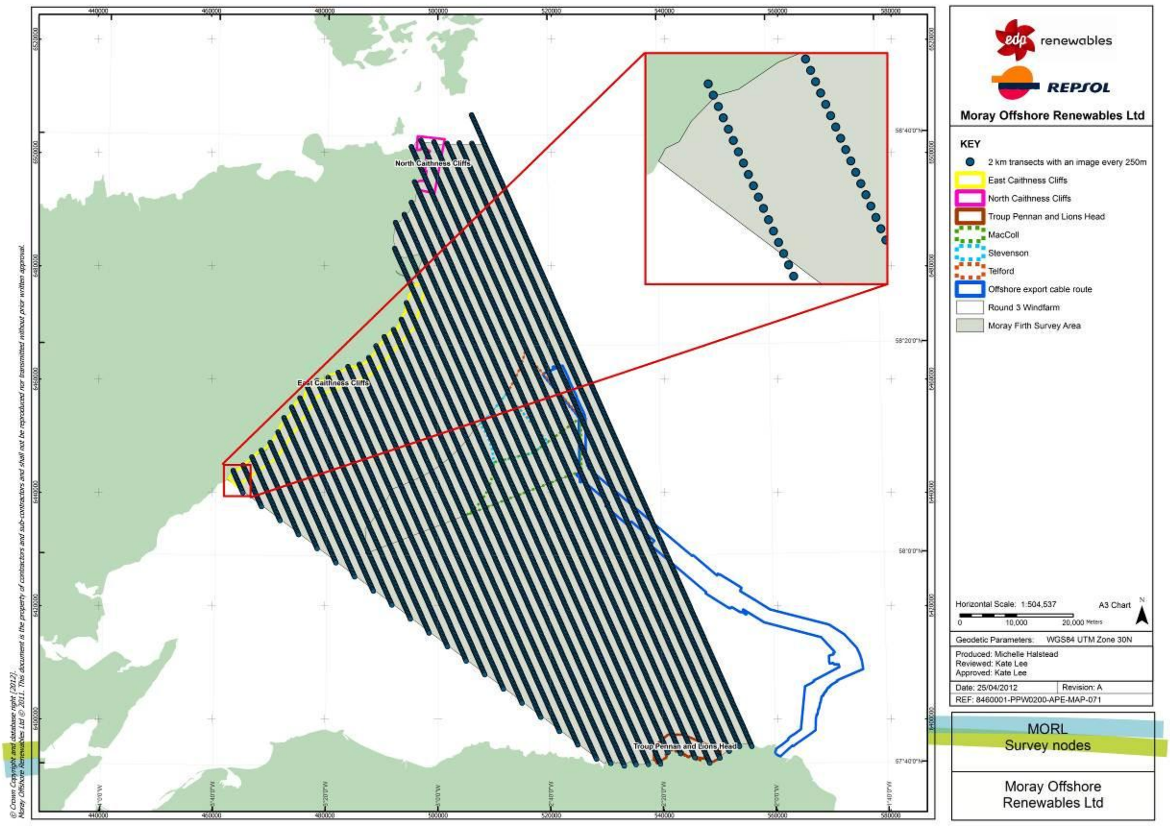


Figure 2.1.1 Gridded survey design based on 250 m in-transect spacing between image capture points for the survey area. Land areas are shown in green and the survey area is shown in blue. The overlap of transects with the coastline and the survey area boundary ensures the collection of images over the entire study area. Images over land are omitted from the bird count.

2.2. Survey information and weather conditions

The dates upon which the six surveys were undertaken, along with a breakdown of the weather conditions on each survey and any other significant information is presented (Table 2.2.1).

Table 2.2.1 Survey dates and weather conditions.

Survey No.	Date surveys undertaken	Time of day	State of seas	Wind speed/ direction	Cloud cover	Visibility	Other significant information
1	01/05/2011	AM	3	15 knots from the E	Scattered	>10 km	Start of survey delayed until fog cleared
		PM	3	15 knots from the E	Scattered	>10 km	
	02/05/2011	AM	3	15 knots from the E	Broken	>10 km	Start of survey delayed until fog cleared
		PM	3	15 knots from the E	Scattered, clearing	>10 km	Slightly hazy
2	16/05/2011	AM	2-3	20 knots from the W	Overcast at 1,500 ft	>10 km	
		PM	2-3	30 knots from the WNW	Scattered at 2,000 ft	>10 km	
	17/05/2011	AM	2-3	7 knots from the S	Scattered at 2,000 ft	>10 km	
3	27/05/2011	AM	2-3	20-30 knots from the WNW	Scattered at 2,000 ft	>10 km	
		PM	2-3	15-30 knots from the W	Scattered at 2,000 ft	>10 km	
	28/05/2011	AM	3-4	20-30 knots from the SW	Few/scattered at 1,800 ft	>10 km	
4	06/06/2011	AM	3-4	12-13 knots from the SE	Overcast at 1,200 ft	>8 km	Rain showers
		PM	1-2	10 knots from the SW	Few at 2,800 ft, broken at 4,500 ft	>50 km	Bright sunlight
	07/06/2011	AM	3	25 knots from the SW	Overcast at 1,000 – 1,200 ft	>10 km	Rain showers

Survey No.	Date surveys undertaken	Time of day	State of seas	Wind speed/ direction	Cloud cover	Visibility	Other significant information
5	17/06/2011	AM	0-1	10 knots from the SW	Clear	>10 km	
		PM	1-2	22 knots from the SE	Scattered	>10 km	
6	13/07/2011	AM	2	5-15 knots from the SE/SW	Scattered at 2,500 ft	>10 km	
		PM	1-2	0-10 knots from the NW	Clear	>10 km	
	14/07/2011	AM	2-3	15-20 knots from the S	Clear	>10 km	

Figure 2.2.1 to Figure 2.2.5 below show the survey flight lines and timings for each survey. Different parts of the survey area were surveyed at different times of day, ensuring a spread of temporal data collected from each location throughout the survey area.

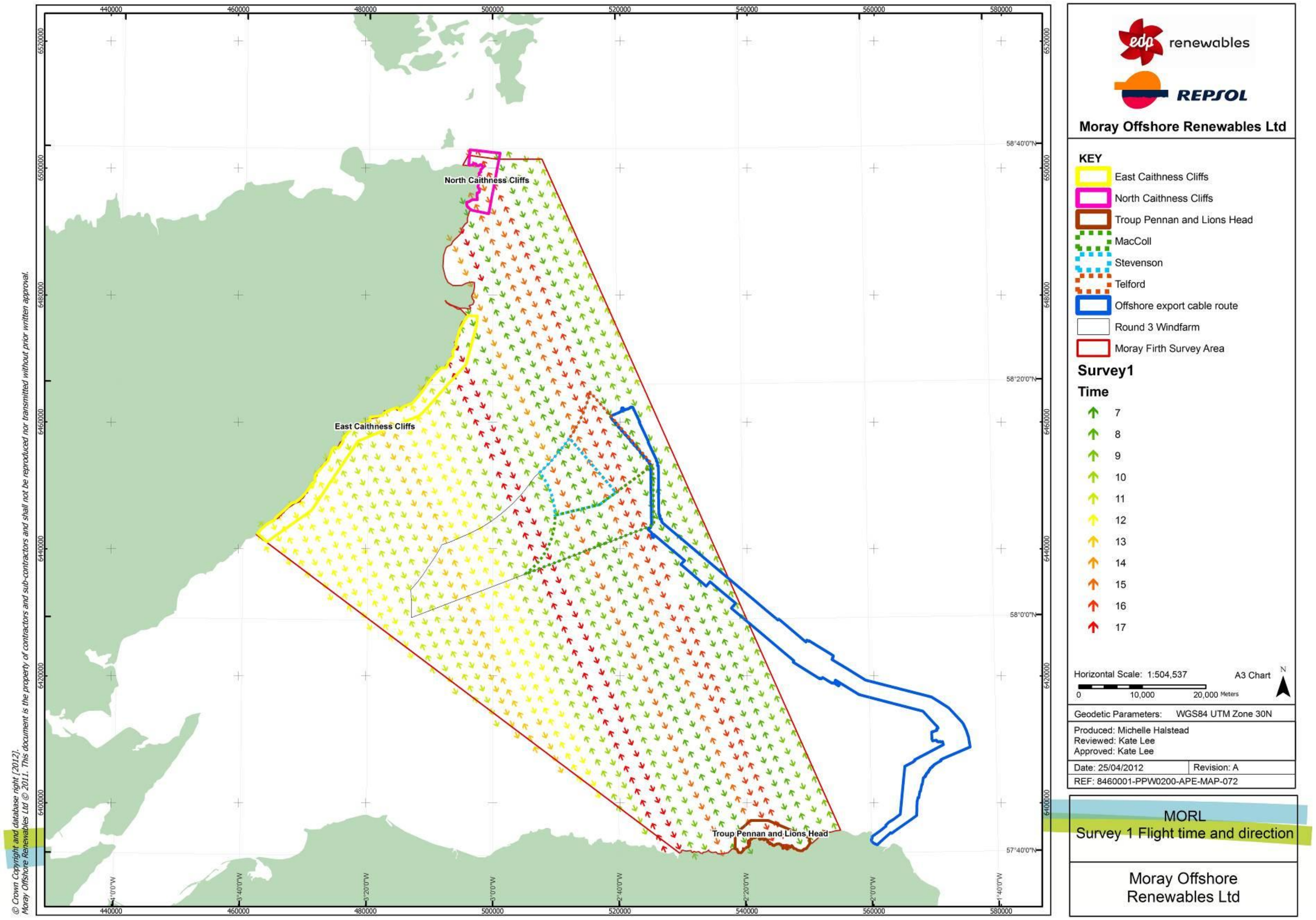


Figure 2.2.1 Survey 1 Flight lines and timing

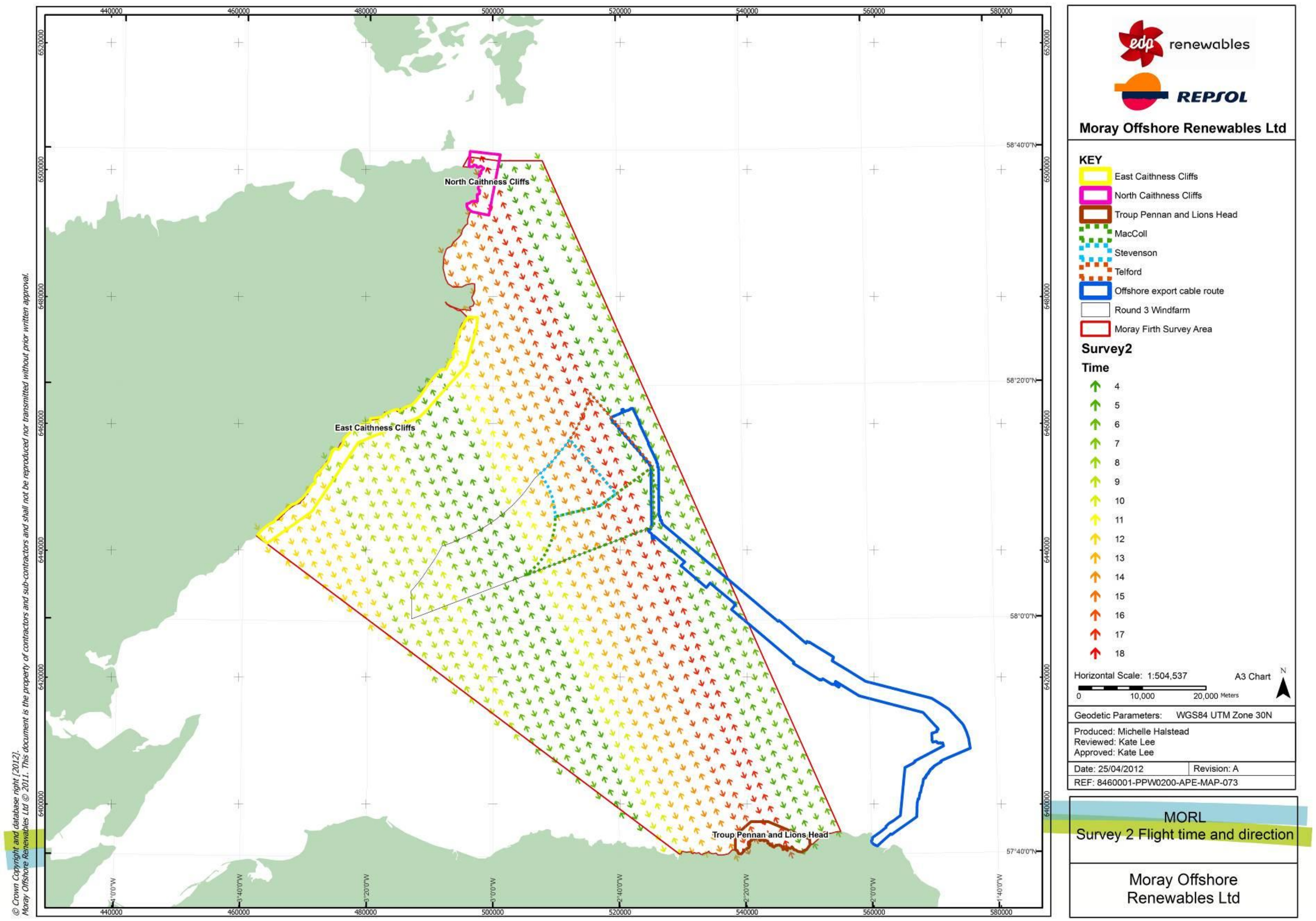


Figure 2.2.2 Survey 2 Flight lines and timing

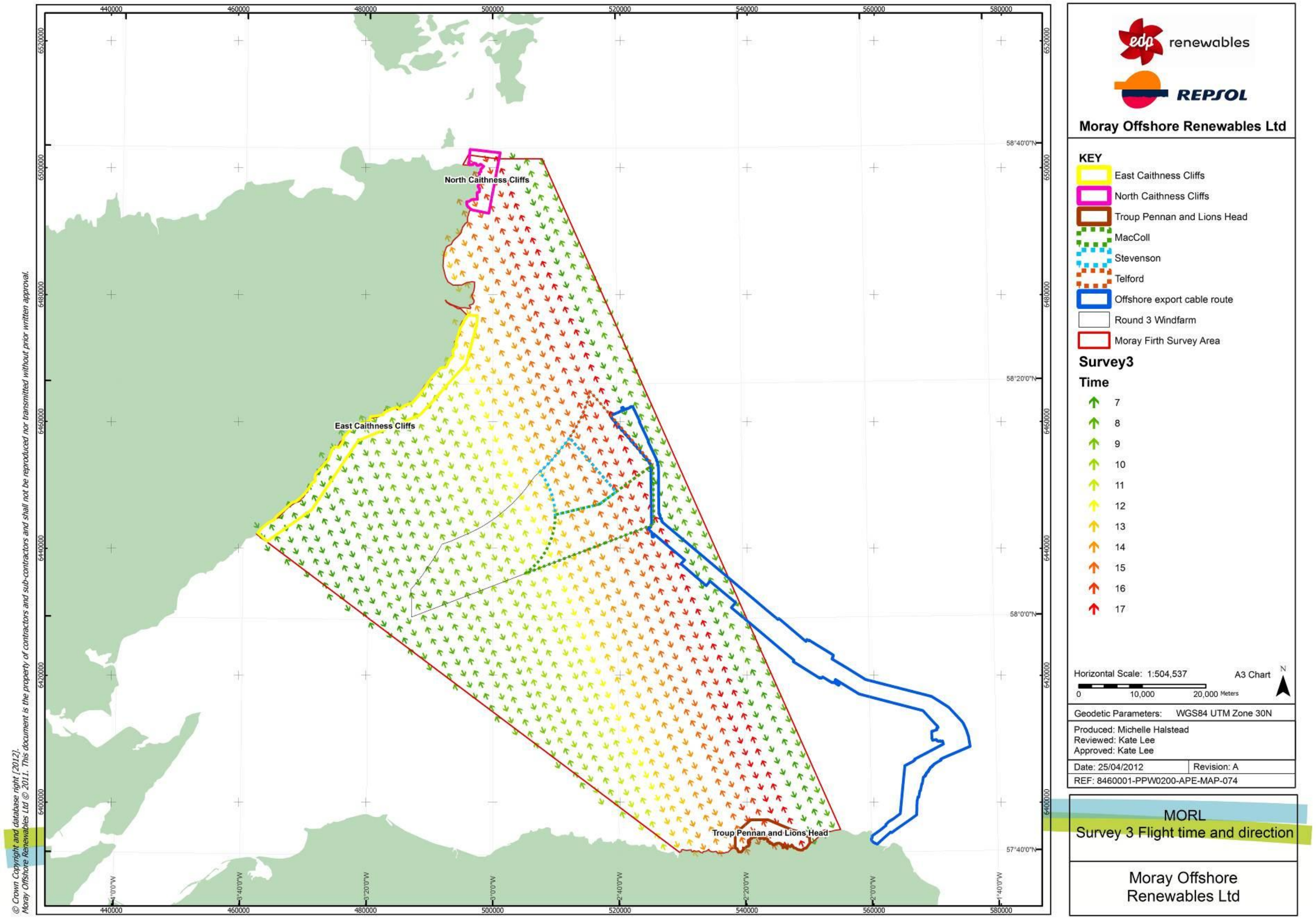


Figure 2.2.3 Survey 3 Flight lines and timings

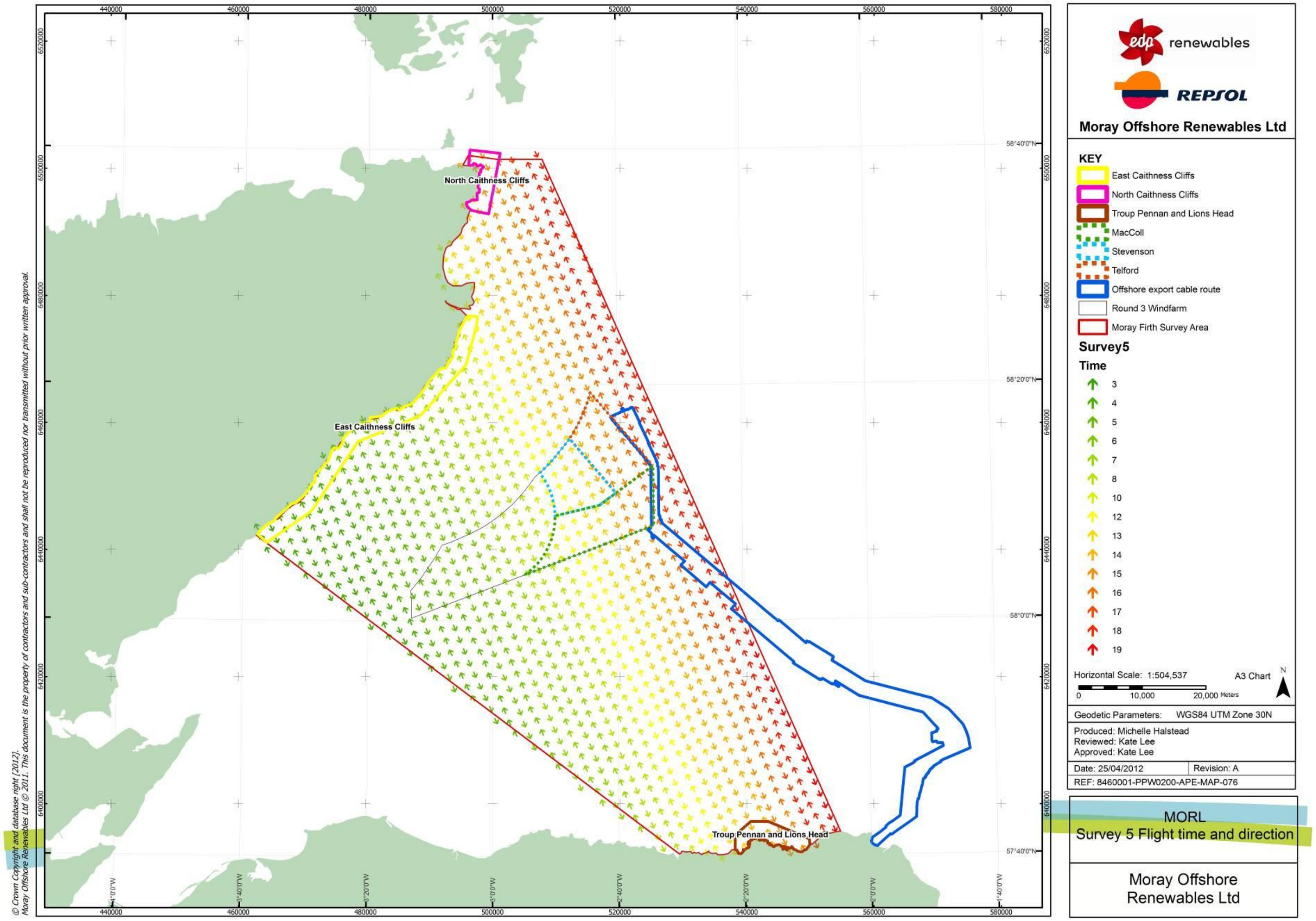


Figure 2.2.4 Survey 5 Flight lines and timings

2.3. Data Outputs

2.3.1. Data collation

Survey data were analysed to produce maps showing bird and cetacean distribution in a GIS format. Photographs were imported as georeferenced images (WGS 84 projection) into ArcView 9.2 (ESRI) and the following metadata were recorded:

a. Date;
b. Time;
c. GPS co-ordinate location;
d. Species (or group) ID;
e. Count (although as animals individually tagged always equals one);
f. Behaviour (in flight or on water);
g. Flight height;
h. Flight orientation.

Wherever possible, birds and marine mammals were identified to species level. Some auks were not separated and were identified to the group level 'guillemot / razorbill'.

2.3.2. QA procedure

Images are 100% internally Quality Assured by APEM ornithologists.. Images are assessed in batches with a different staff member responsible for each batch. Images containing no birds are removed and kept in a separate folder. Of these 'blank' images, 10% are randomly selected for QA by an independent reviewer. If there is less than 90% agreement, the entire batch is re-audited.

After this process only images containing birds remain. All birds and mammals are identified to the lowest taxonomic level possible (e.g. gull >> small gull >> kittiwake), georeferenced and tagged in GIS. Similarly 10% of the "blank" images are then selected randomly for external QA. A confusion matrix is created to show the degree of agreement and identify areas of potential misidentification.

The appointed external auditors for seabirds are the British Trust for Ornithology (BTO). The BTO provide up to three external auditors to provide independent assessments of survey images. The BTO auditors associated with this project have considerable experience in undertaking bird surveys and research. It is our aim that at least 90% agreement between in-house and external QA reviewer should be achieved. If agreement is less than 90%, the entire batch would be re-reviewed internally and the QA process repeated.

For this project, all marine mammals recorded in images were passed to MORL for treatment by staff at Aberdeen University.

2.4. Data Analysis

2.4.1. Directional Analysis

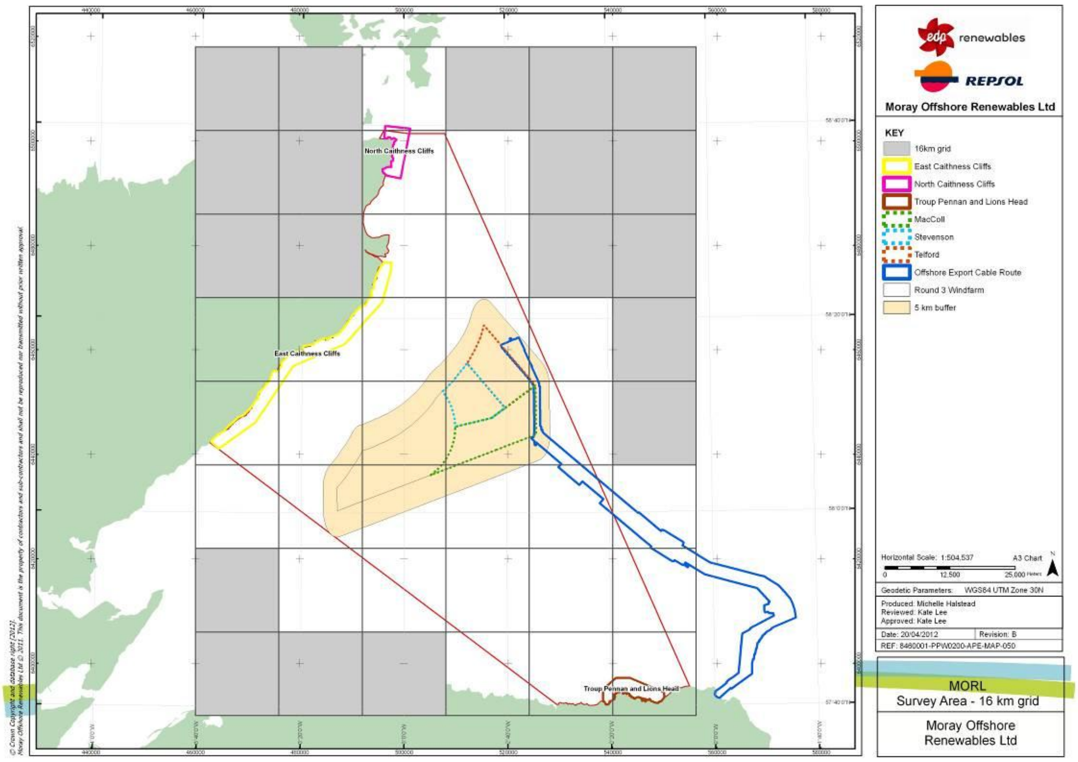
Each individual bird was geo-referenced using GIS; the analyst determined the head / tail axis and the bearing was determined automatically by in-house software. The actual bird position and bearing at the time of image capture were therefore known and these were extracted into the GIS layer. Data can then be used in various ways: for example, directions of individual birds can be plotted on a map to examine patterns of movement; also, general directional preferences of birds (either grouped or by species) can be investigated.

Plotting individual directions is a useful descriptive method of analysing directional behaviour, but APEM's experience from previous projects suggests that using circular statistics conveys more inferential power. Data can be treated in a variety of ways, analysing individual surveys and data for the entire season, at species / group level or for all SPA species.

It is important to note that birds are recorded at all stages of a foraging trip; outbound flight from nesting colonies, search flight (for plunge divers) and return flight. As central place foragers are known to typically make a bee-line to the nest once a prey load has been collected, it is expected that linkages between foraging areas and SPAs will emerge as directional preferences against a background of 'noise' or widely distributed flight directions – that is return journeys to the same nesting locations should stand out from foraging trips and search flights. This non-randomness in distribution can be tested to indicate significance of directional preferences. Close linkages between nest colonies and specific foraging areas may be reflected by bi-modality; that is, an axis of outward-inward directions may be apparent. This is especially pertinent to seabirds, as many are known to make 'commuting' flights – straight-line movements to predictable food resources.

The directional data of pooled data from all grids for all surveys were analysed by was dividing the survey area into a 16 km by 16 km grid in ArcGIS (this resolution chosen to ensure suitable numbers of encounters per grid cell over the entire survey area of 4,439 km^2 and equivalent to ~6% of the total area). Each flying bird record across the survey area for each of the key species was allocated to one of the grid cells and the data for each grid cell was analysed using a circular statistics software package to show the flight direction of the birds in each cell. This process was repeated for each survey. Not all cells overlain were surveyed (Figure 2.4.1.1).

Figure 2.4.1.1 Grid cells (16 km x 16 km) overlaying the entire survey area. Cells greyed out were not surveyed; extent of individual cell coverage is apparent from proportion within blue line boundary. Orange area shows 5 km buffer around Round 3 Zone.



2.4.2. Density Surface Modelling (DSM)

In order to achieve the goals of this report, Density Surface Modelling (DSM) was used to produce smoothed distribution maps representing animal abundance throughout the Moray Firth survey area. Bird population data were modelled in a Generalised Additive Model (GAM) framework using spatial and environmental covariates to generate predicted abundance estimates throughout the Moray Firth survey area. The advantage of this method over conventional design-based methods is that it provides a smooth density surface based on information about variables associated with high densities of key species (Borchers *et al.* 2002).

Based on the survey grid and environmental covariates, a complete grid of abutting cells was constructed covering the entire survey area (Figure 1.1). Site georeferenced locations of birds and marine mammals contained within each individual image were then used to generate raw counts of each species/group per image. These monthly bird and marine mammal data were then spatially joined to each survey month grid cell and each cell characterised by potentially important spatial and environmental covariates (Table 2.4.2.1. **Variables used in the models and associated with grid cells**).

Table 2.4.2.1. Variables used in the models and associated with grid cells

Variable	Abbreviation
Average water depth (m) per grid cell	*Depth*
Easting (X)	*X*
Northing (Y)	*Y*
Closest distance from cell centroid to coastline (m)	*Shoreline*
Closest distance from cell centroid to Troup. Penan and Lion's Head SPA	*Troup_SPA*
Closest distance from cell centroid to North Caithness SPA (m)	*North_SPA*
Closest distance from cell centroid to East Caithness SPA (m)	*East_SPA*

N.B Geology habitat was not included as a predictor variable within the modelling as it was unable to take a smoothing parameter.

To model animal abundance, raw counts were scaled from the study image footprint area to the grid cell area and rounded to provide adjusted count data. Animal abundance was modelled as a function of covariates using a GAM. Environmental covariates were assessed to determine which variables were collinear using Variance Inflation Factor (VIF) analysis carried out using the 'AED' library of functions (Zuur *et al.* 2007; Zuur *et al.* 2009). VIF leaves only the variable that contain unique information and excludes the variables that are collinear (Zuur *et al.* 2007; Zuur *et al.* 2009). A VIF of greater than ten suggests collinearity (Zuur *et al.* 2007) and environmental covariates displaying a VIF greater than this were therefore excluded from the GAM analysis. In order to cope with the non-parametric nature of counts, models were fitted with either a quasipoisson or Negative Binomial error distribution with a logarithmic link function. Models were chosen based on which provided the better fit and selection of those variables best describing the distribution of individuals was made in a stepwise procedure using Akaike's information Criterion (AIC) to select the most parsimonious model. Models were fitted using the 'mgcv' library of functions (Wood 2001; Wood *et al.* 2008) and all analysis conducted in the R programming language (R Development Core Team 2010). Models were run for all six surveys separately and also for individual bird species across surveys. Density surface maps of smoothed predicted abundance were then created by reloading predicted counts from the model into each georeferenced grid cell.

Non-parametric bootstrap methods were used for variance estimation. A variability statistic was generated by re-sampling 999 times with replacement from the modelled data. The statistic was evaluated from each of these 999 bootstrap samples and upper and lower 95% confidence intervals of these 999 values taken as the variability of the statistic over the population (Efron & Tibshirani 1993).

Measures of precision (i.e. how different sample counts are from one another) were calculated by extracting the number of grid cells originally sampled from the modelled data 999 times, and using a poisson estimator, suitable for a pseudo-Poisson zero-inflated distribution (Elliott 1977). This produced a CV (coefficient of variation) based on the relationship of the standard error to the mean.

All analysis and data manipulation was 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).

3. Results

3.1. Directional analysis

Trends in flight directions were investigated using the Oriana software package. The survey area was divided into a 16 km by 16 km grid and the headings of flying birds for each of the key species falling in to each grid square were analysed providing an overview of flight direction across the survey area. This process was undertaken for pooled data (surveys one to six) for each species.

3.1.1. Guillemot

3.1.1.1. Orientation by grid cell

The majority of guillemots were recorded to the north and west of the Round 3 Zone. Guillemots in the east of the survey area appear to be oriented more towards Troup, Pennan and Lion's Heads SPA. In the west of the survey area, and close to the SPA sites, there is a less apparent trend in flight direction. There was some evidence of orientational preferences along a north west – south east axis (Figure 3.1.1).

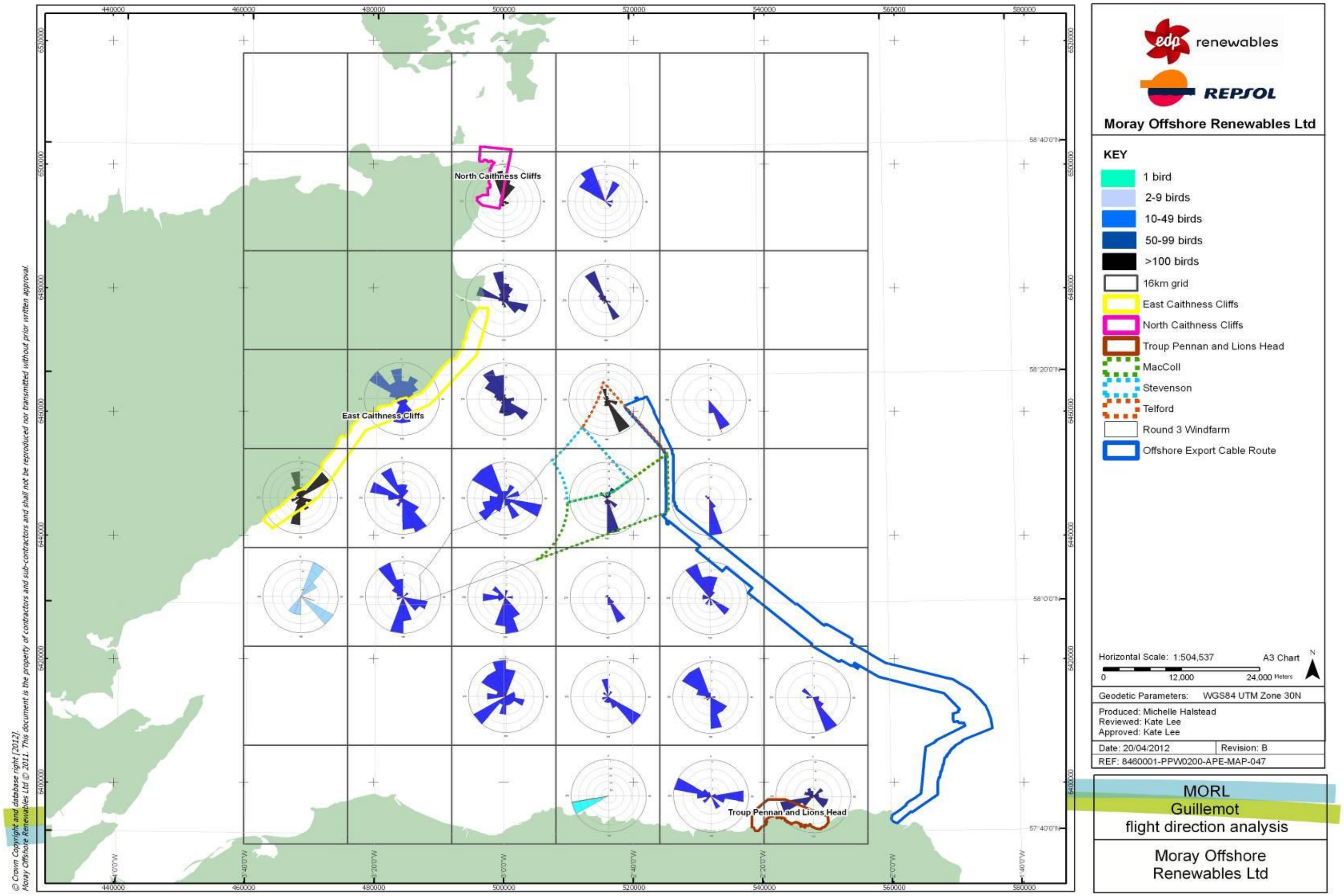


Figure 3.1.1 Pooled guillemot flight direction

3.1.2. Razorbill

3.1.2.1. Orientation by grid cell

The majority of razorbills recorded were in cells relatively close to the coast and within the Round 3 Zone. Within the Round 3 Zone razorbills were typically recorded heading towards Troup, Pennan and Lion's Heads SPA with some birds showing directional preferences along a north-south axis (Figure 3.1.2).

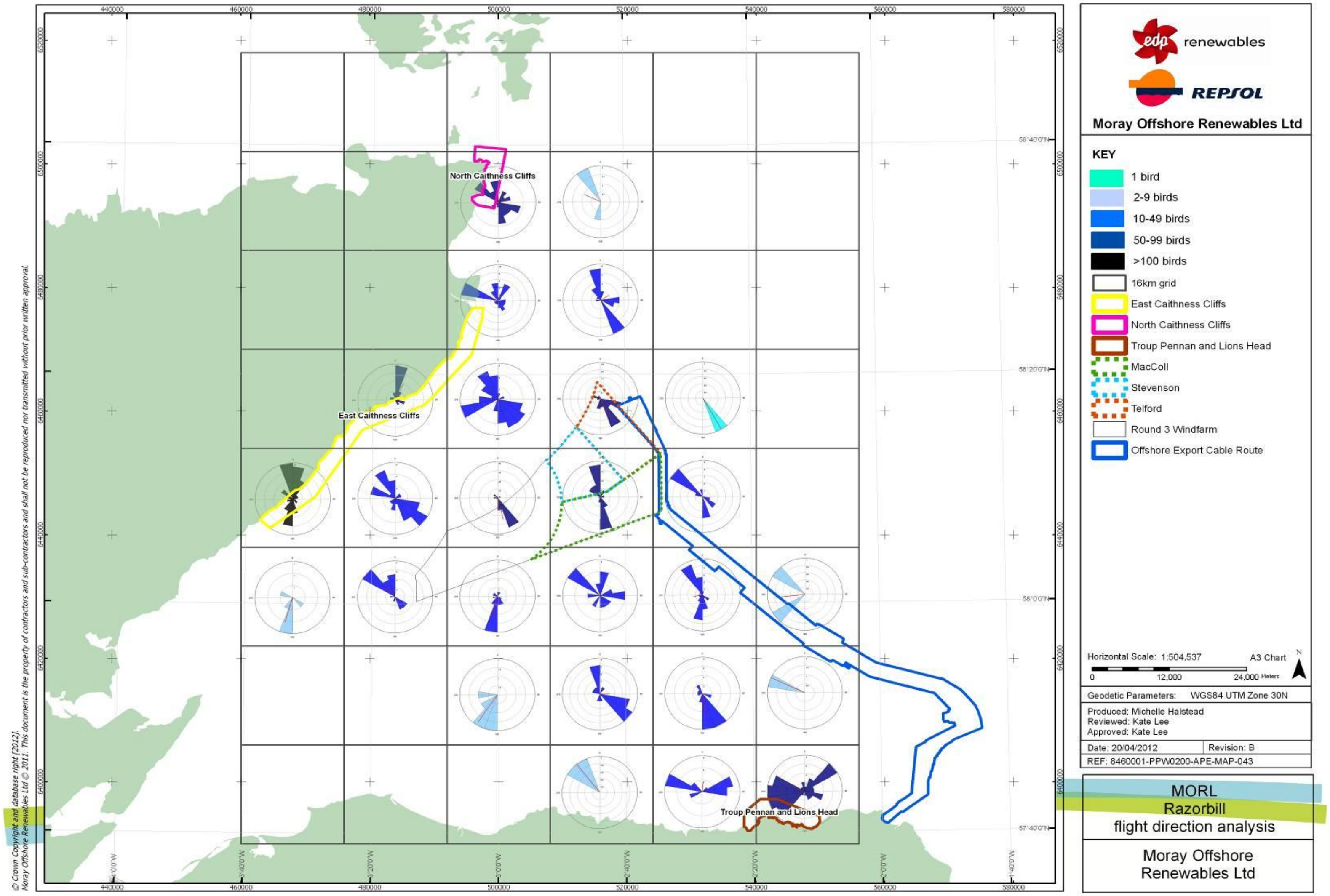


Figure 3.1.2 Pooled razorbill flight direction

3.1.3. Guillemot / Razorbill

3.1.3.1. Orientation by grid cells

Guillemots / razorbills were recorded across the survey area, with the majority recorded close to SPAs and in the north of the Round 3 Zone. Elsewhere, these auks were scattered, with birds recorded in the Telford wind farm apparently heading south east towards Troup, Pennan and Lion's Heads SPA (Figure 3.1.3).

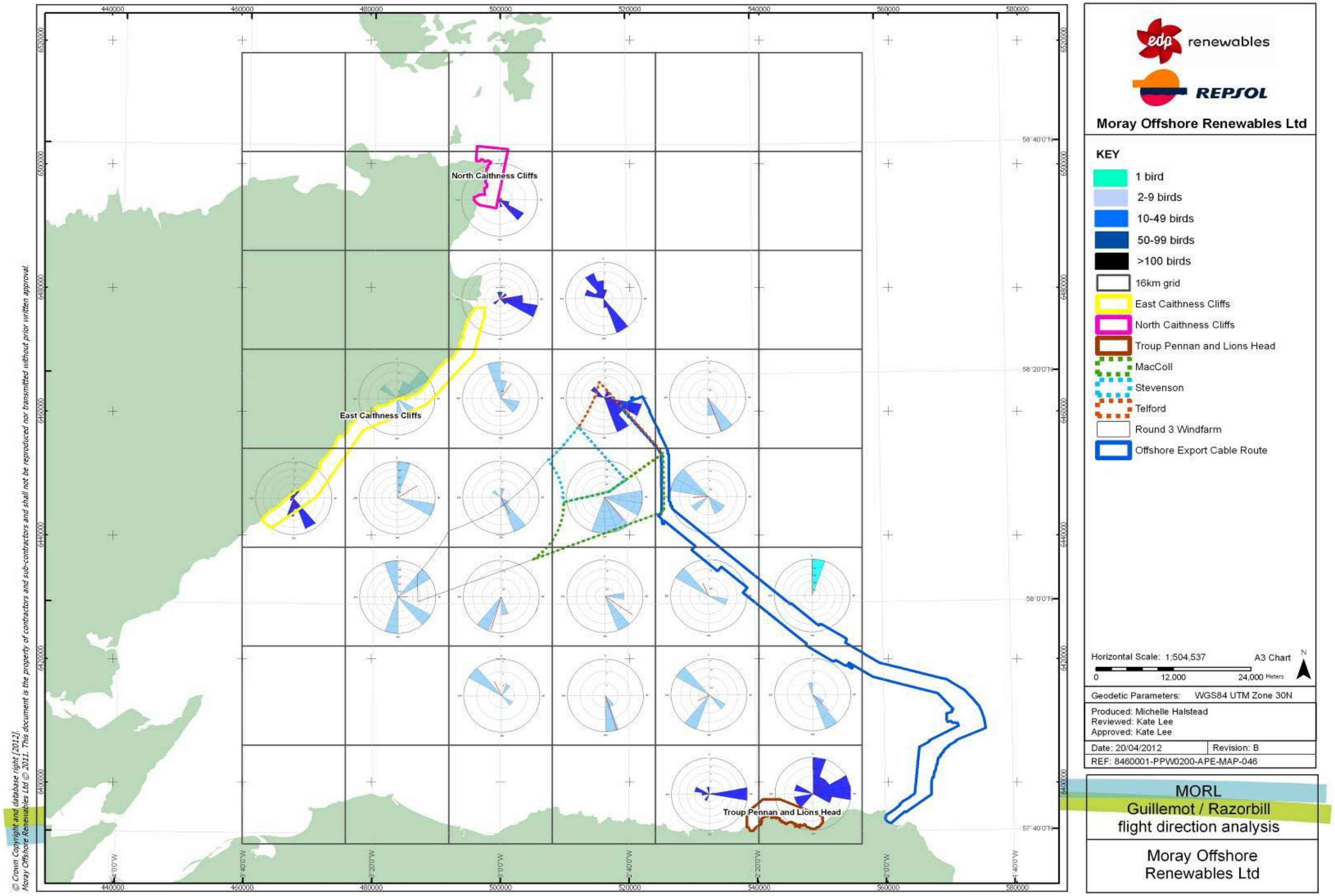


Figure 3.1.3 Pooled guillemot / razorbill flight direction

3.1.4. Puffin

3.1.4.1. Orientation by grid cells

Relatively few puffins were recorded in cells > 16 km from the coast (Figure 3.1.4). Puffins recorded in the Telford area however, showed an apparent southerly orientation, whilst puffins elsewhere in the Round 3 Zone showed no apparent trends in their orientation..

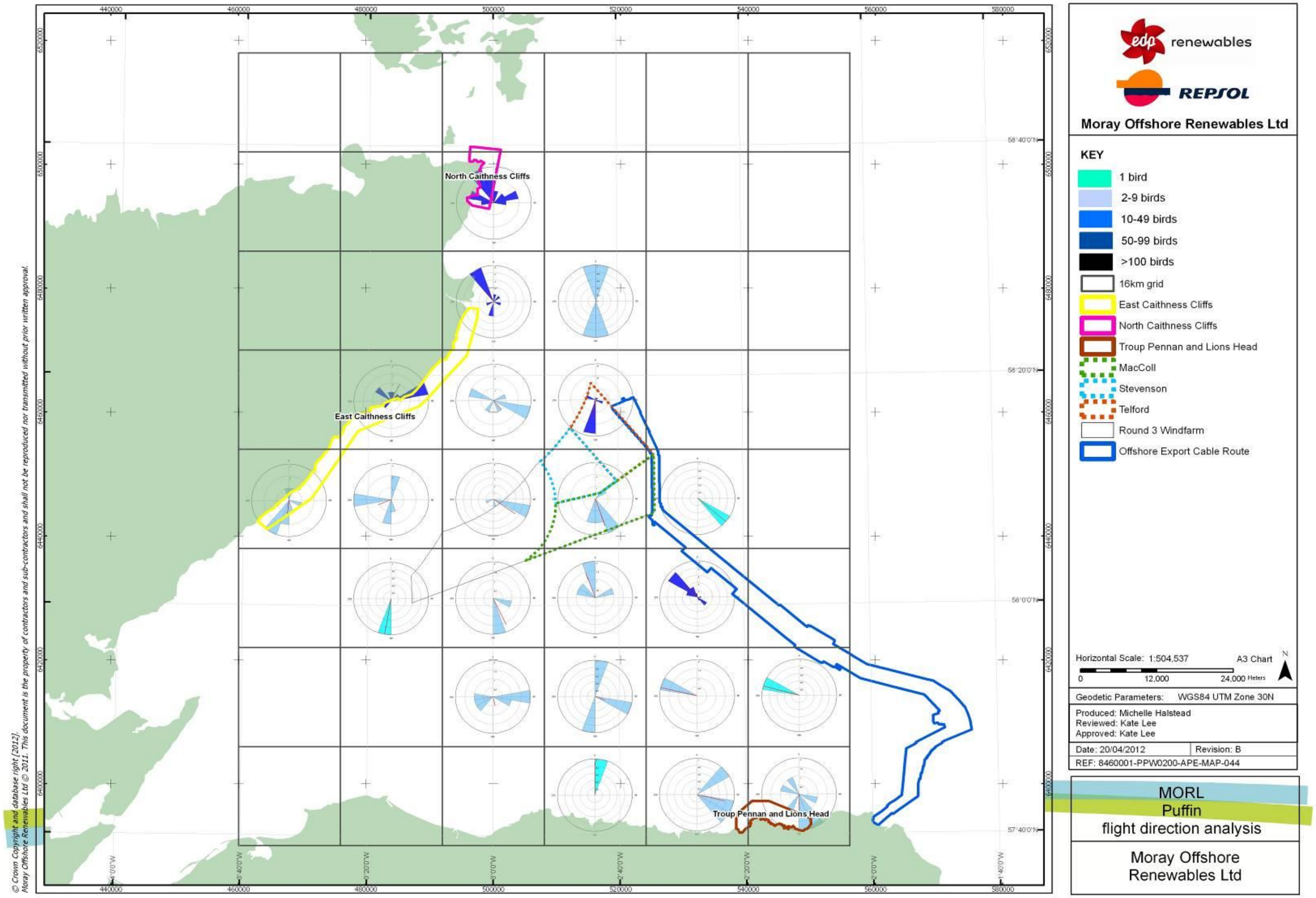


Figure 3.1.4 Pooled puffin flight direction

3.1.5. Fulmar

3.1.5.1. Orientation by grid cells

Fulmars were fairly widespread across the survey area (Figure 3.1.5). Distributional patterns are difficult to discern, with birds typically scattered in several directions. Unsurprisingly, many were recorded close to colonies along the coastlines.

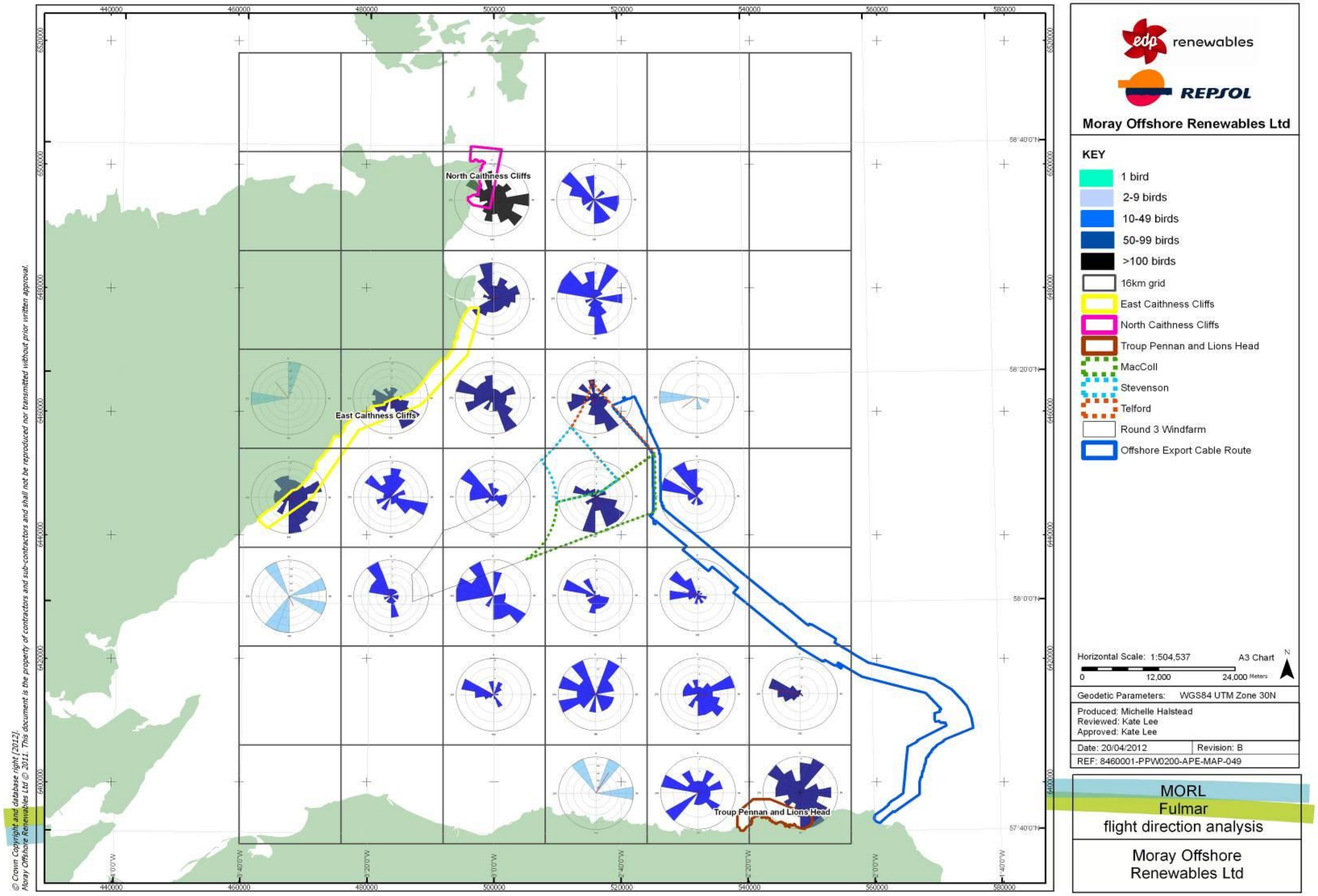


Figure 3.1.5 Pooled fulmar flight direction

3.1.6. Kittiwake

3.1.6.1. Orientation by grid cells

Kittiwakes were widespread across the survey area, often with greatest numbers close to the cliff colonies (Figure 3.1.6). Bearings are fairly scattered making distributional patterns difficult to discern.

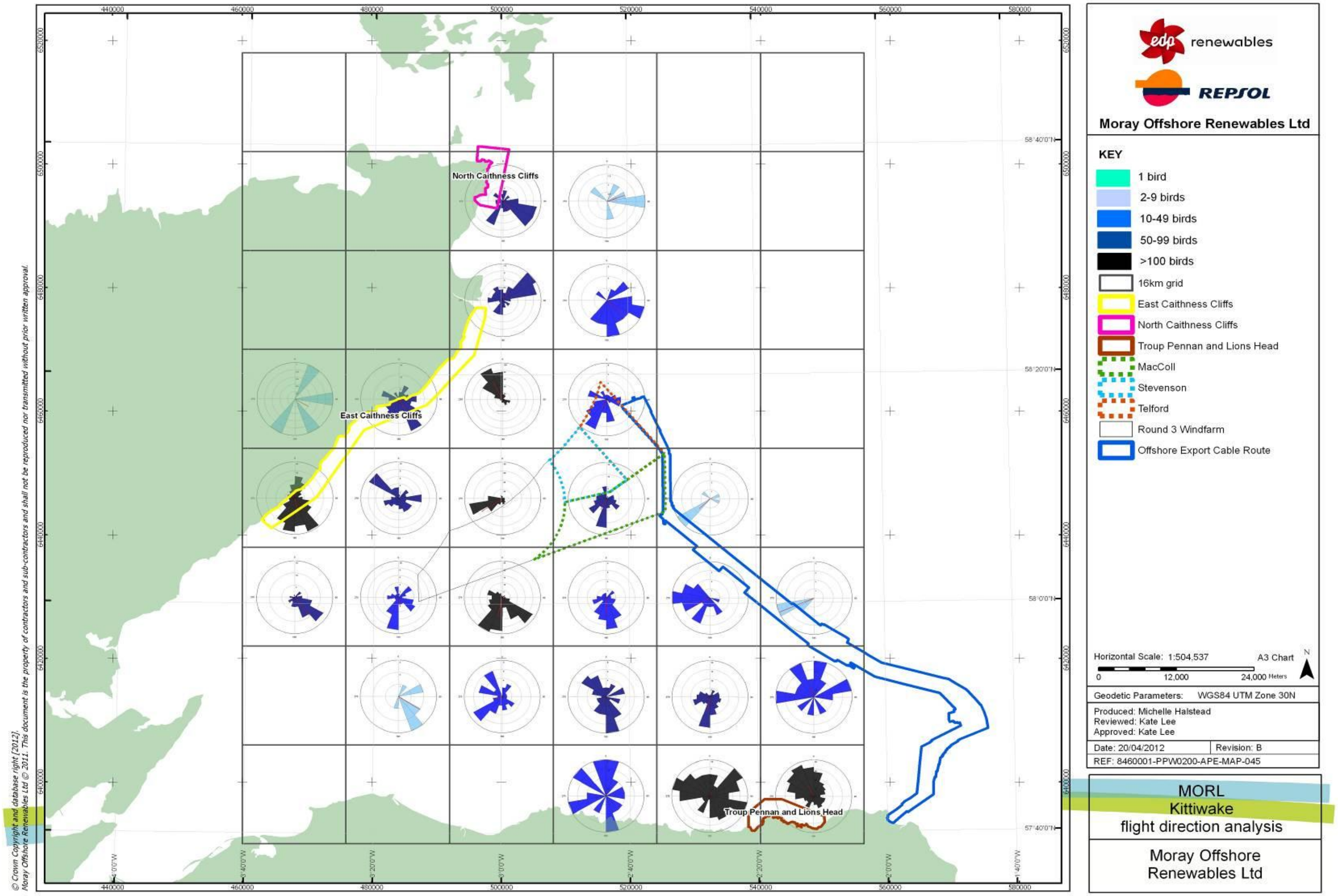


Figure 3.1.6 Pooled kittiwake flight direction

3.1.7. Great black-backed gulls

3.1.7.1. Orientation by grid cells

Few great black-backed gulls were recorded across the survey area > 16 km away from the coastlines (Figure 3.1.7). Great black-backed gulls recorded within the Round 3 Zone were oriented towards the west and south.

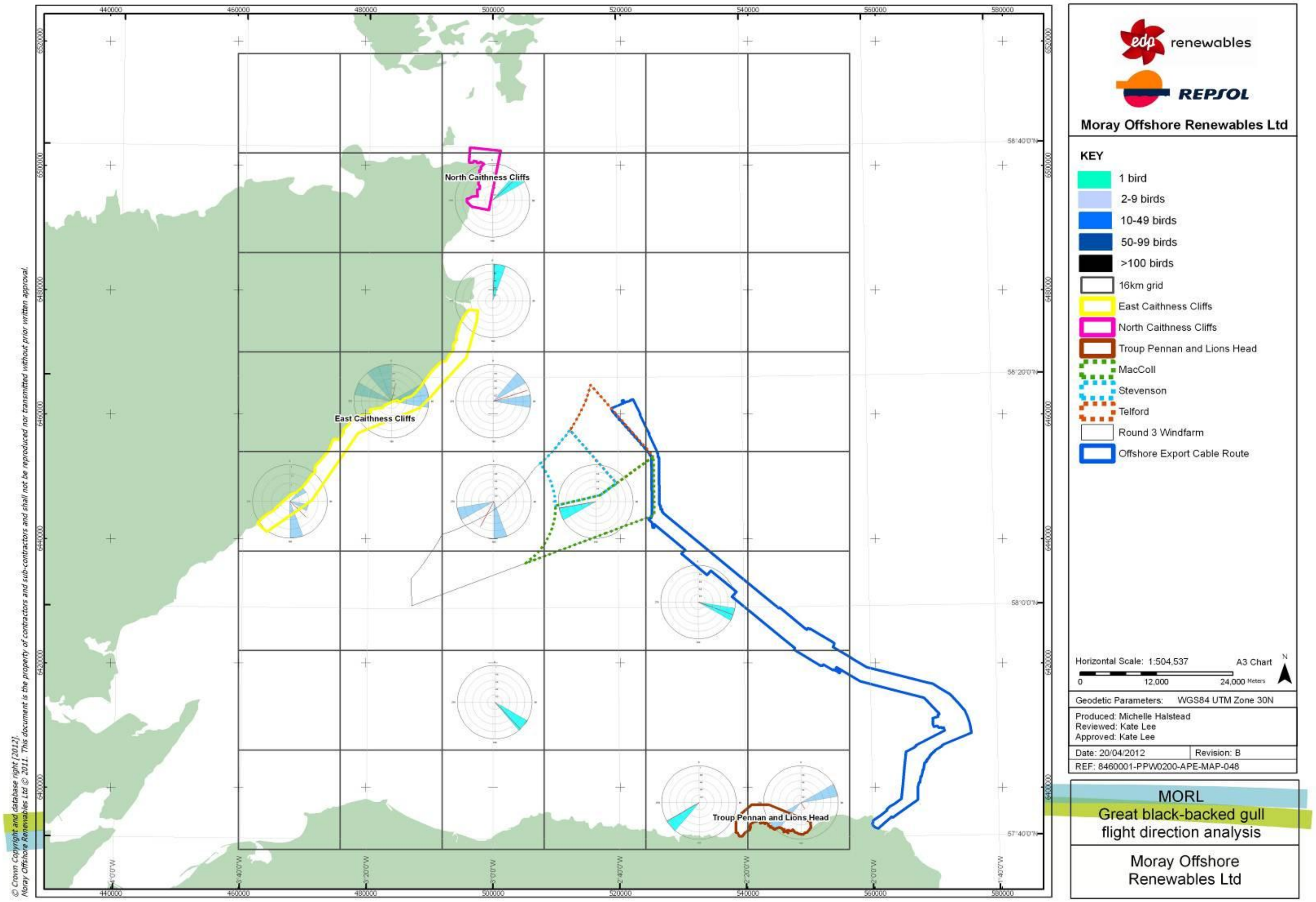


Figure 3.1.7 Pooled great black-backed gull flight direction

3.2. Raw Counts

Table 3.2.1 below shows the raw counts for each species and their behaviour during each survey.

Table 3.2.1 Raw counts and behaviour for each survey for each species recorded. Key species are shaded in light blue.

		Survey						
Taxon	**Behaviour**	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
Common eider	Flying	-	-	-	-	-	-	8
	Sitting	7	-	-	-	1	-	
Long-tailed duck	Flying	-	-	-	-	-	-	5
	Sitting	5	-	-	-	-	-	
Scoter species	Flying	-	-	-	-	1	-	1
	Sitting	-	-	-	-	-	-	
Seaduck species	Flying	-	-	-	-	-	-	2
	Sitting	-	-	-	-	-	2	
Red-throated diver	Flying	-	-	-	-	-	1	2
	Sitting	1	-	-	-	-	-	
Diver species	Flying	-	-	-	-	-	-	1
	Sitting	-	1	-	-	-	-	
Fulmar	Flying	169	311	210	187	138	154	1,862
	Sitting	73	229	94	176	56	65	
Manx shearwater	Flying	1	-	-	-	-	-	1
	Sitting	-	-	-	-	-	-	
Gannet	Flying	67	44	51	54	53	58	445
	Sitting	8	16	12	25	23	34	
Cormorant	Flying	-	-	-	-	-	3	3
	Sitting	-	-	-	-	-	-	
Cormorant / shag	Flying	2	-	-	-	-	2	55
	Sitting	50*	-	-	-	1	-	
Shag	Flying	1	-	1	-	1	-	10
	Sitting	2	-	3	-	2	-	
Great skua	Flying	6	27	20	2	6	4	69
	Sitting	-	2	1	-	-	1	

Skua species	Flying	5	-	-	-	1	-	6
	Sitting	-	-	-	-	-	-	
Kittiwake	Flying	674	1,024	358	910	406	303	4,375
	Sitting	9	62	29	133	329	138	
Black-headed gull	Flying	-	-	-	1	-	1	13
	Sitting	-	11	-	-	-	-	
Common gull	Flying	12	25	1	7	4	-	57
	Sitting	-	8	-	-	-	-	
Small gull species	Flying	13	12	12	6	16	13	743
	Sitting	203	57	91	137	107	76	
Lesser black-backed gull	Flying	-	6	-	2	-	-	27
	Sitting	3	4	2	2	2	6	
Herring gull	Flying	58	57	16	69	58	29	1,050
	Sitting	114	80	105	53	155	256	
Great black-backed gull	Flying	-	6	5	9	4	9	93
	Sitting	13	22	10	1	4	10	
Black-backed gull species	Flying	-	-	-	1	1	1	21
	Sitting	6	4	2	-	3	3	
Large gull species	Flying	2	1	3	2	3	7	221
	Sitting	78	12	7	30	18	58	
Sandwich tern	Flying	-	-	-	-	1	-	1
	Sitting	-	-	-	-	-	-	
Arctic tern	Flying	-	4	8	2	4	1	19
	Sitting	-	-	-	-	-	-	
Tern species	Flying	60	270	150	95	32	14	622
	Sitting	-	-	-	1	-	-	
Black guillemot	Flying	-	-	-	1	6	-	47
	Sitting	10	7	4	3	10	6	
Guillemot	Flying	401	341	149	298	322	66	5,698
	Sitting	1,236	720	493	555	639	478	
Guillemot / razorbill	Flying	50	21	55	312	54	17	1,487
	Sitting	301	60	66	234	134	183	
Puffin	Flying	26	51	38	26	46	1	977
	Sitting	150	142	161	114	182	40	
Razorbill	Flying	161	282	123	199	218	91	4,689
	Sitting	660	998	520	712	501	224	
Auk species	Flying	-	-	3	-	-	-	6
	Sitting	-	-	3	-	-	-	
							Grand Total:	22,616

* Cormorant / shag records relate to an aggregation of birds on rocky outcrops close to the coast in the north and north west of the survey area.

3.3. Model Outputs

Figure 3.3.1 to Figure 3.3.7 (Section 3.3.1.8) show the outputs of the GAMs model produced for each species for each survey. Figure 3.3.8 shows the model outputs for all surveys combined for each species. Summaries of the models, including model fit, are provided in Appendix III. It was not possible to run models for every species / survey combination. This was due either to low numbers of the species being recorded or counts being highly correlated with an environmental variable leading to overestimation and unreliability of the population abundance predictions.

3.3.1.1. Guillemots

Figure 3.3.1 shows the modelled distribution of guillemots for each survey with the associated population estimates, confidence intervals and precision reported in Table 3.3.1(Section 3.3.1.9). Population estimates for the whole survey area for guillemots ranged from 17,006 in survey 6 to 50,049 in survey 1. The peak estimate, recorded in survey 1 had upper and lower confidence limits of 50,524 and 49,567 respectively and a precision of 0.01.

For the three wind farm sites, the peak estimate was recorded in survey 2 (population estimate of 3,135) and the lowest estimate was 297, recorded in survey 6. The peak estimate for areas MacColl and Telford were recorded in survey 2 (1,055 and 1,308 respectively) and the peak estimate for the Stevenson area was recorded in survey 1.

Table 3.3.8 (Section 3.3.1.9) shows the population estimate for guillemots based on data from all six surveys combined. The model estimated 69,485 guillemots across the whole survey area (upper CL: 70,247; lower CL: 68,801 and precision: 0.01) with 9.8% of these birds estimated to be within the three wind farm sites, 3.8% in MacColl, 3.1% in Stevenson and 2.9% in Telford.

3.3.1.2. Razorbills

Figure 3.3.2 (Section 3.3.1.8)shows the modelled distribution of razorbills for each survey with the associated population estimates, confidence intervals and precision reported in Table 3.3.2 (Section 3.3.1.9)

The peak population estimate for the survey area was recorded during survey 2 with 40,381 birds estimated, upper and lower confidence limits of 40,780 and 39,991 respectively, and a precision of 0.01. The lowest population of razorbills was recorded during survey 6 (population estimate of 9,400; upper CL: 9,543; lower CL: 9,269; precision: 0.03).

For the three wind farm sites, the peak estimate was also recorded in survey 2 (population estimate of 4,283) where 10.6% of the razorbills predicted for the whole survey area were estimated within the three wind farm sites. The lowest estimate was 85, recorded in survey 6, which represented <1% of the estimated razorbills across the whole survey area. The peak estimate for areas MacColl, Stevenson and Telford were recorded in survey 2 (2,356, 1,060, and 867 respectively).

Table 3.3.8 (Section 3.3.1.9) shows the population estimate for razorbills based on data from all six surveys combined. The model estimated 59,846 razorbills across the whole survey area (upper CL: 60,861; lower CL: 58,936 and precision: 0.01) with 4.2% of these birds estimated to be within the eastern development area, 1.8% in MacColl, 1.25% in Stevenson and 1.14% in Telford.

3.3.1.3. Guillemots / Razorbills

Figure 3.3.3 (Section 3.3.1.8) shows the modelled distribution of all guillemots and razorbills (i.e. all those identified to species and group level) for each survey with the associated population estimates, confidence intervals and precision reported in Table 3.3.3 (Section 3.3.1.9). The model outputs for all guillemots and razorbills for the whole survey area peaked during survey 1 (population estimate of 86,882; upper CL: 87,810; lower CL: 86,023; precision: 0.01). The lowest population estimate was recorded during survey 6 (population estimate of 33,846; upper CL: 34,256; lower CL: 33,442; precision: 0.02).

For the three wind farm sites, the peak estimate was recorded in survey 2 (population estimate of 7,490) and the lowest estimate was 560, recorded in survey 6. 10.2% of the guillemots and razorbills estimated for the whole survey area were calculated to be within the three wind farm sites during survey 2. The peak estimate for areas MacColl, Stevenson and Telford were recorded in survey 2 (3,381, 1,872, and 2,238 respectively).

Table 3.3.8 (Section 3.3.1.9) shows the population estimate for all guillemots and razorbills based on data from all six surveys combined. The model estimated 149,353 birds across the whole survey area (upper CL: 151,610; lower CL: 147,161 and precision: 0.0045) with 4.6% of these birds estimated to be within the three wind farm sites, 1.78% in MacColl, 1.45% in Stevenson and 1.34% in Telford.

3.3.1.4. Puffins

Figure **3.3.4** (Section 3.3.1.8) shows the modelled distribution of puffins for each survey with the associated population estimates, confidence intervals and precision reported in Table 3.3.4 (Section 3.3.1.9). The model outputs for puffins for the whole survey area peaked during survey 3 (population estimate of 6,217; upper CL: 6,353; lower CL: 6,080; precision: 0.04). The lowest population estimate was recorded during survey 6 (population estimate of 1,480; upper CL: 1,552; lower CL: 1,411; precision: 0.07).

For the three wind farm sites, the peak estimate was recorded in survey 2 (population estimate of 408) where 6.8% of the puffins modelled for the whole survey area were estimated within the area. The lowest estimate was 3, recorded in survey 6, which represented 0.2% of the estimated puffins across the whole survey area. The peak estimates for MacColl were recorded in survey 3 (178), in survey 1 for Telford and survey 2 for Stevenson.

Table 3.3.8 (Section 3.3.1.9) shows the population estimate for puffins based on data from all six surveys combined. The model estimated 11,780 puffins across the whole survey area (upper CL: 11,874; lower CL; 11,686 and precision: 0.02) with 4.6% of these birds estimated to be within the eastern development area, 2.1% in MacColl, 1.33% in Stevenson and 1.16% in Telford.

3.3.1.5. Fulmars

Figure 3.3.5 (section 3.3.1.8) shows the modelled distribution of fulmars for each survey with the associated population estimates, confidence intervals and precision reported in Table 3.3.5 (Section 3.3.1.9).

Population estimates for the whole survey area for fulmars ranged from 6,101 in survey 5 to 14,492 in survey 2. The peak estimate, recorded in survey 2, had upper and lower confidence limits of 14,727 and 14,242 respectively and a precision of 0.02.

For the three wind farm sites, the peak estimate was also recorded in survey 2 (population estimate of 939) and the lowest estimate was 60, recorded in survey 4. Only 6.5% of the fulmars estimated for the whole survey area were calculated to be within the eastern development area during the peak month. The peak estimates for areas MacColl, Stevenson and Telford were recorded in survey 2 (331, 247, and 361 respectively).

Table 3.3.8 (Section 3.3.1.9) shows the population estimate for fulmars based on data from all six surveys combined. The model estimated 21,241 fulmars across the whole survey area (upper CL: 21,541; lower CL: 20,973 and precision: 0.01) with 4.14% of these birds estimated to be within the three wind farm sites, 1.37 % in MacColl, 1.15% in Stevenson and 1.62% in Telford.

3.3.1.6. Kittiwakes

Figure 3.3.6 (Section 3.3.1.8) shows the modelled distribution of kittiwakes for each survey with the associated population estimates, confidence intervals and precision reported in Table 3.3.6 (Section 3.3.1.9). The peak population estimate for the survey area was recorded during survey 2 with 35,498 birds estimated, upper and lower confidence limits of 36,739 and 34,286 respectively, and a precision of 0.02. The lowest population of kittiwakes was recorded during survey 3 (population estimate of 12,471; upper CL: 12,746; lower CL: 12,180; precision: 0.03).

For the three wind farm sites, the peak estimate was also recorded in survey 2 (population estimate of 2,307) where 6.5% of the kittiwakes predicted for the whole survey area were estimated within the three wind farm sites. The lowest estimate was 61, recorded in survey 4, which was 0.3% of the estimated kittiwakes across the whole survey area. The peak estimates for areas MacColl, Stevenson and Telford were recorded in survey 2 (1,379, 747, and 181 respectively).

Table 3.3.8 (Section 3.3.1.9) shows the population estimate for kittiwakes based on data from all six surveys combined. The model estimated 47,765 kittiwakes across the whole survey area (upper CL: 48,993; lower CL: 46,484 and precision: 0.01) with 2.56% of these birds estimated to be within the three wind farm sites, 1.08 % in MacColl, 1.03% in Stevenson and 0.45% in Telford.

3.3.1.7. Great black-backed gulls

Figure 3.3.7 (Section 3.3.1.8) shows the modelled distribution of great black-backed gulls for each survey with the associated population estimates, confidence intervals and precision reported in Table 3.3.7. The peak population estimate for the survey area was recorded during survey 6 with 609 birds estimated, upper and lower confidence limits of 651 and 569 respectively, and a precision of 0.11. The lowest population of great black-backed gulls was recorded during survey 5 (population estimate of 267; upper CL: 301; lower CL: 236; precision: 0.17).

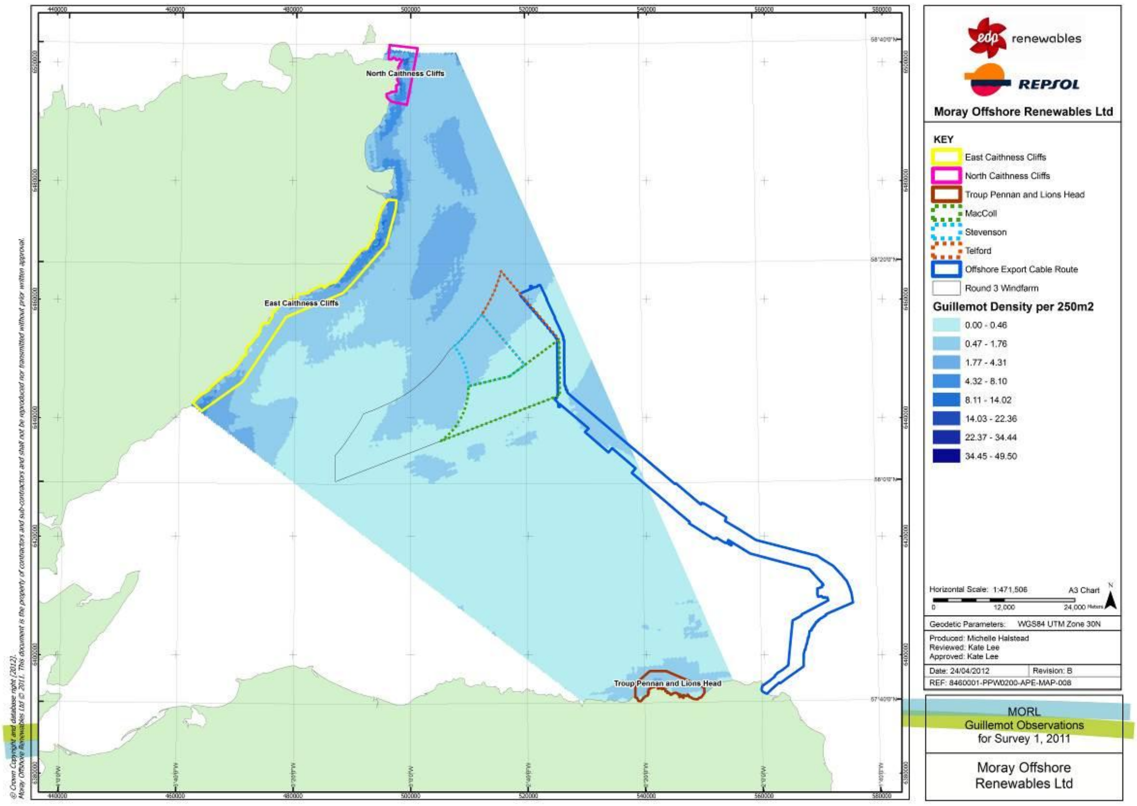
For the three wind farm sites, the peak estimate was also recorded in survey 6 (population estimate of 16) where 2.6% of the great black-backed gulls predicted for the whole survey area were estimated within the Telford, Stevenson and MacColl wind farms. The peak estimates for areas MacColl, Stevenson and Telford were recorded in survey 6 (1, 3, and 12 respectively). No great black-backed gulls were recorded in the three wind farm sites during survey 5, and data from surveys 1 to 4 could not be modelled.

Table 3.3.8 (Section 3.3.1.9) shows the population estimate for great black-backed gulls based on data from all six surveys combined. The model estimated 950 great black-backed gulls across the whole survey area (upper CL: 1,000; lower CL: 903 and precision: 0.06) with 0.5% of these birds estimated to be within the three wind farm sites, 0.1 % in MacColl, 0.32% in Stevenson and 0.21% in Telford.

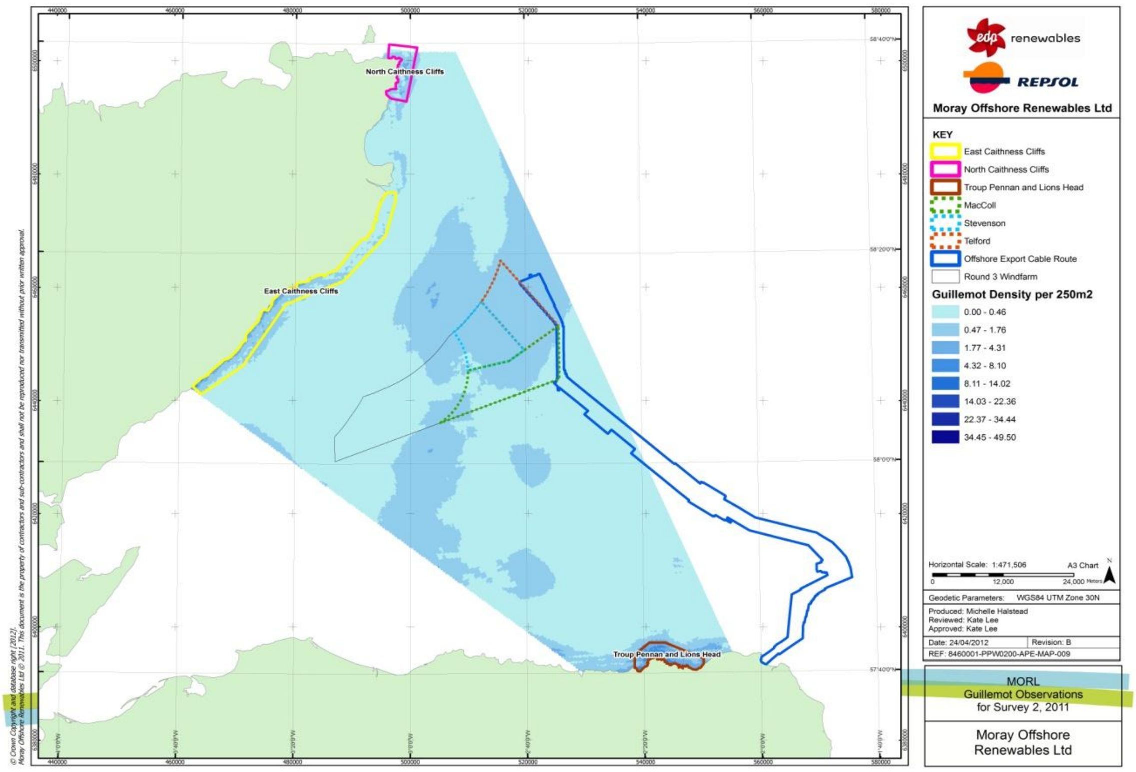
3.3.1.8. Distribution of key species for all surveys

Figure 3.3.8 (Section 3.3.1.8) shows the modelled distribution of each species for all surveys combined with the associated population estimates, confidence intervals and precision reported in Table 3.3.8 (Section 3.3.1.9).

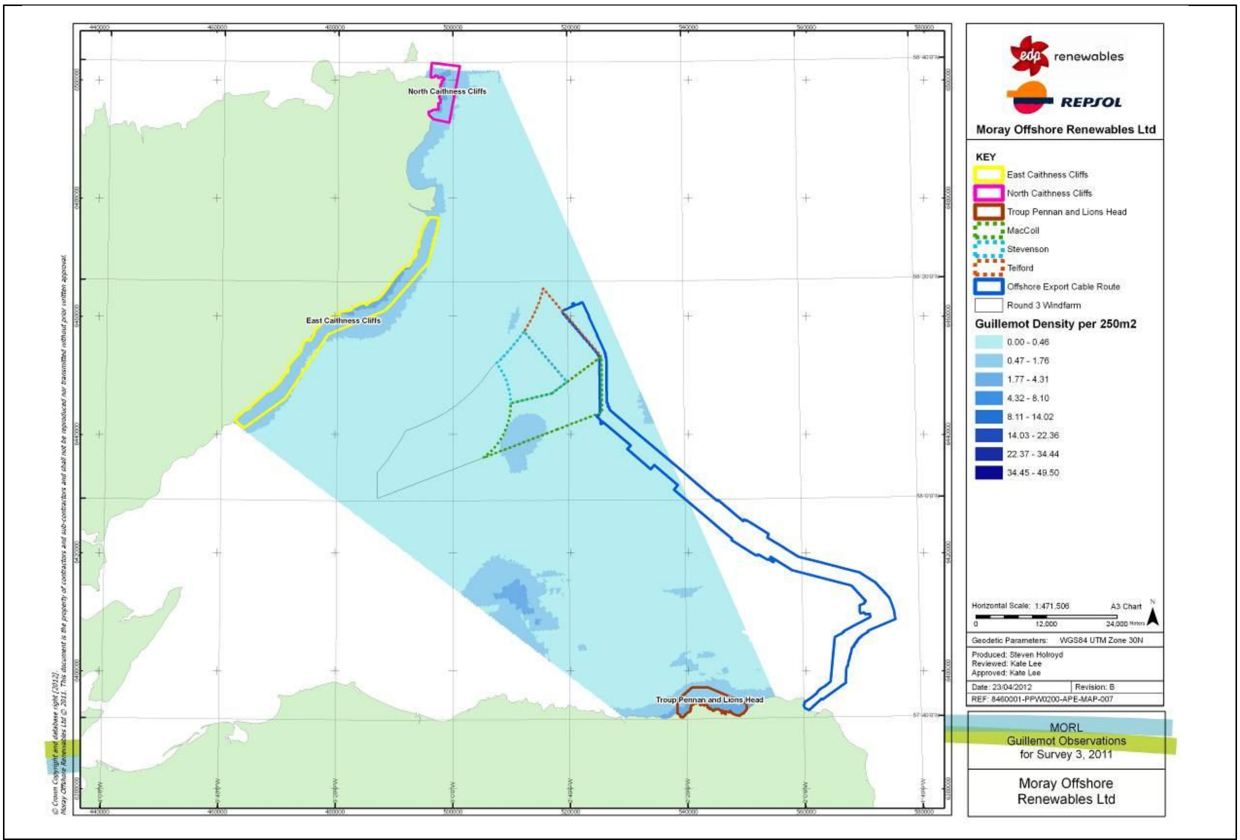
Figure 3.3.1 Distribution of guillemots recorded in the Moray Firth survey area in each survey



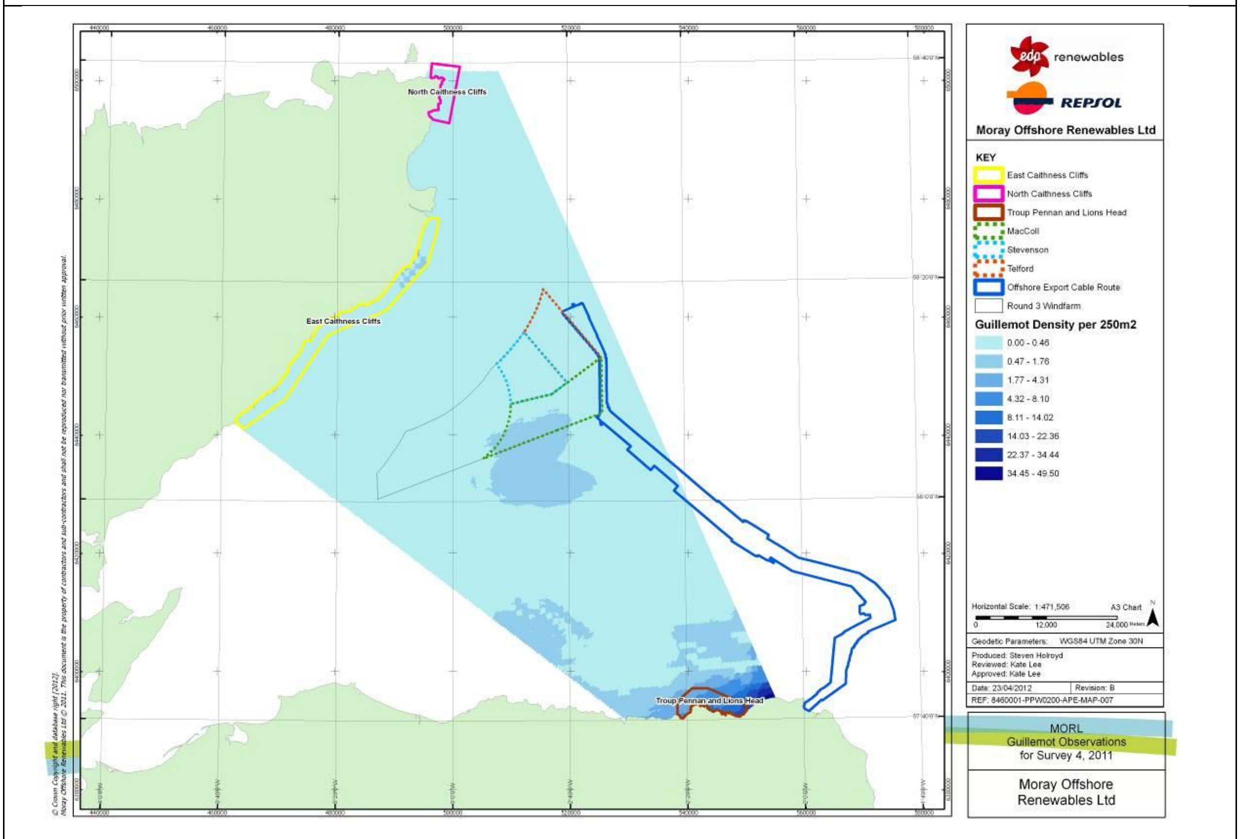
A: Survey 1



B: Survey 2

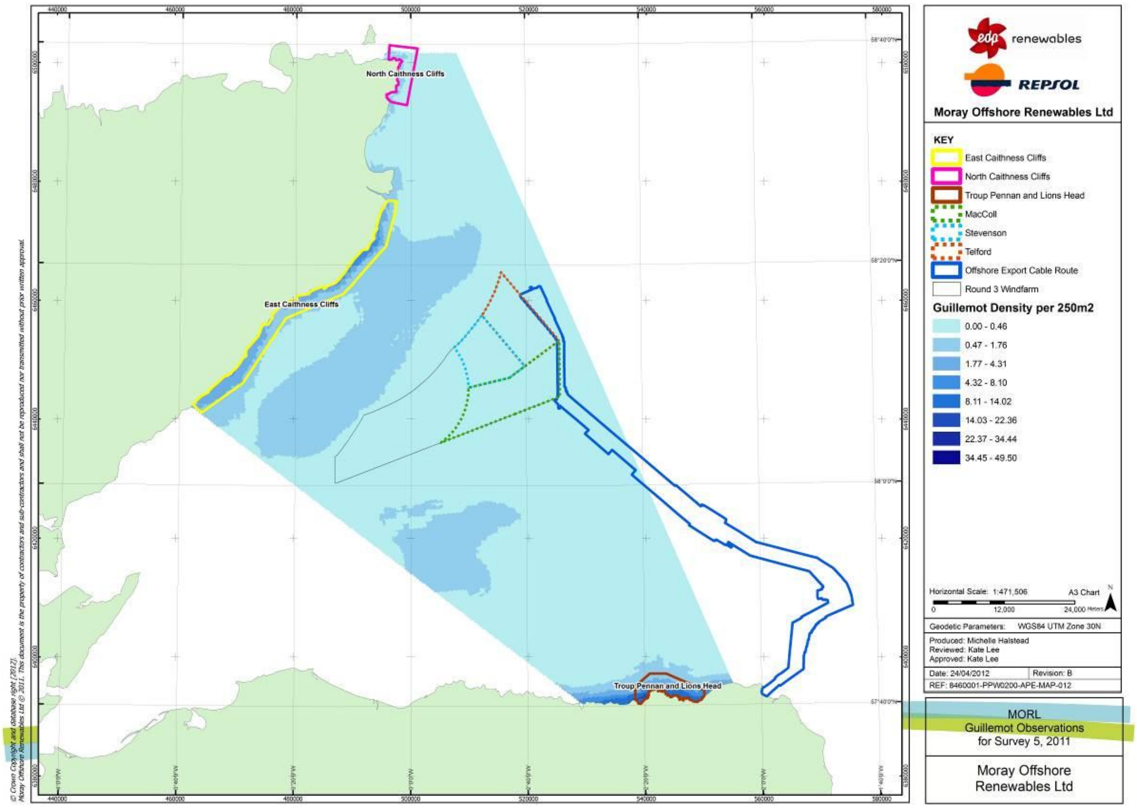


C: Survey 3

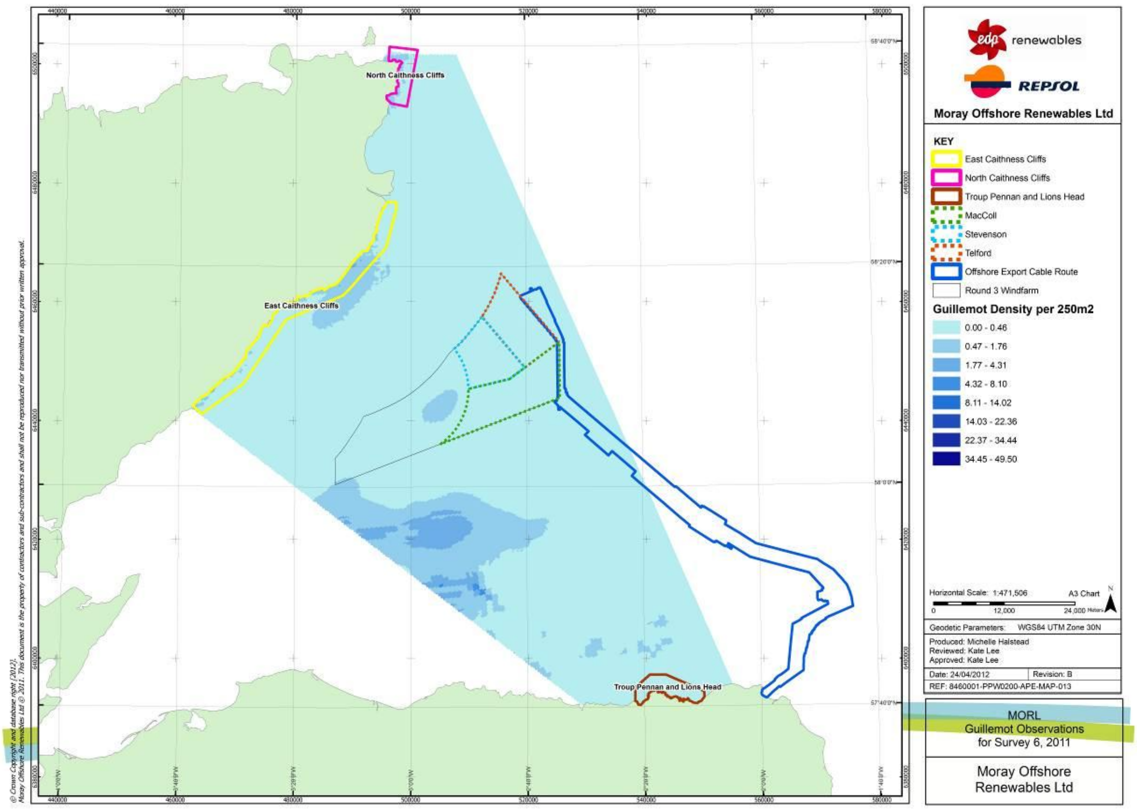


D: Survey 4

APPENDIX 4.5 B

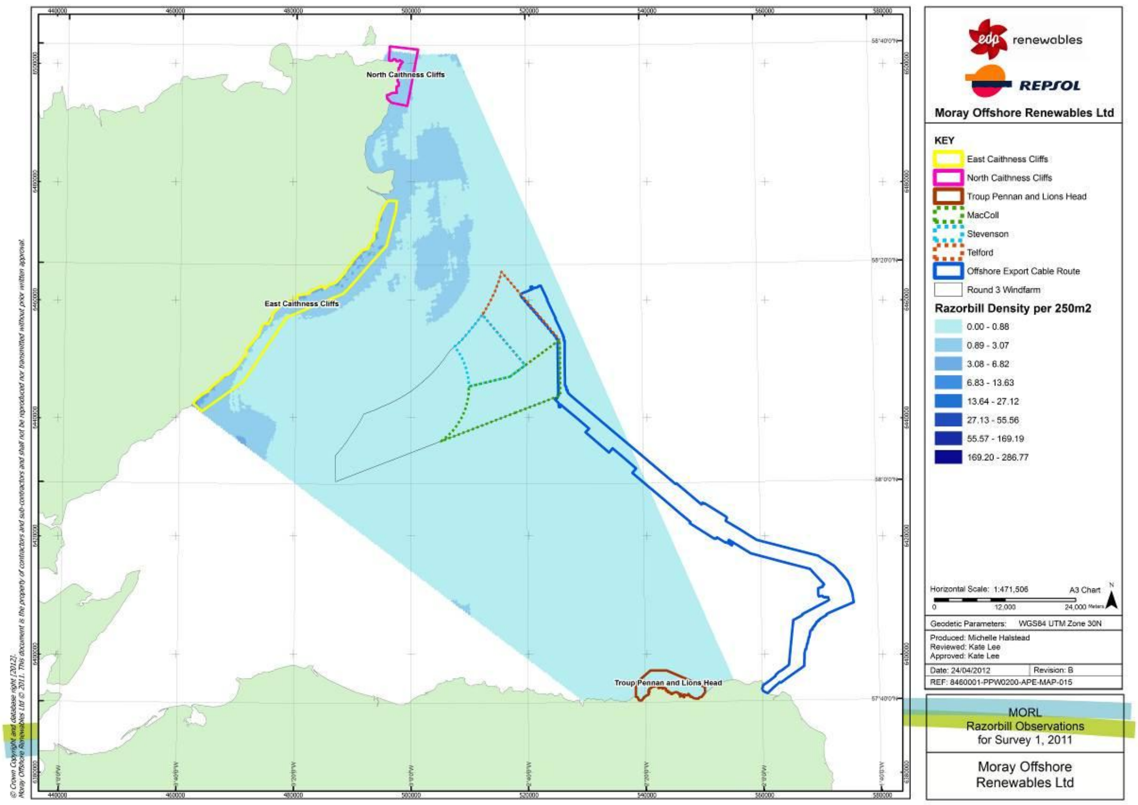


E: Survey 5

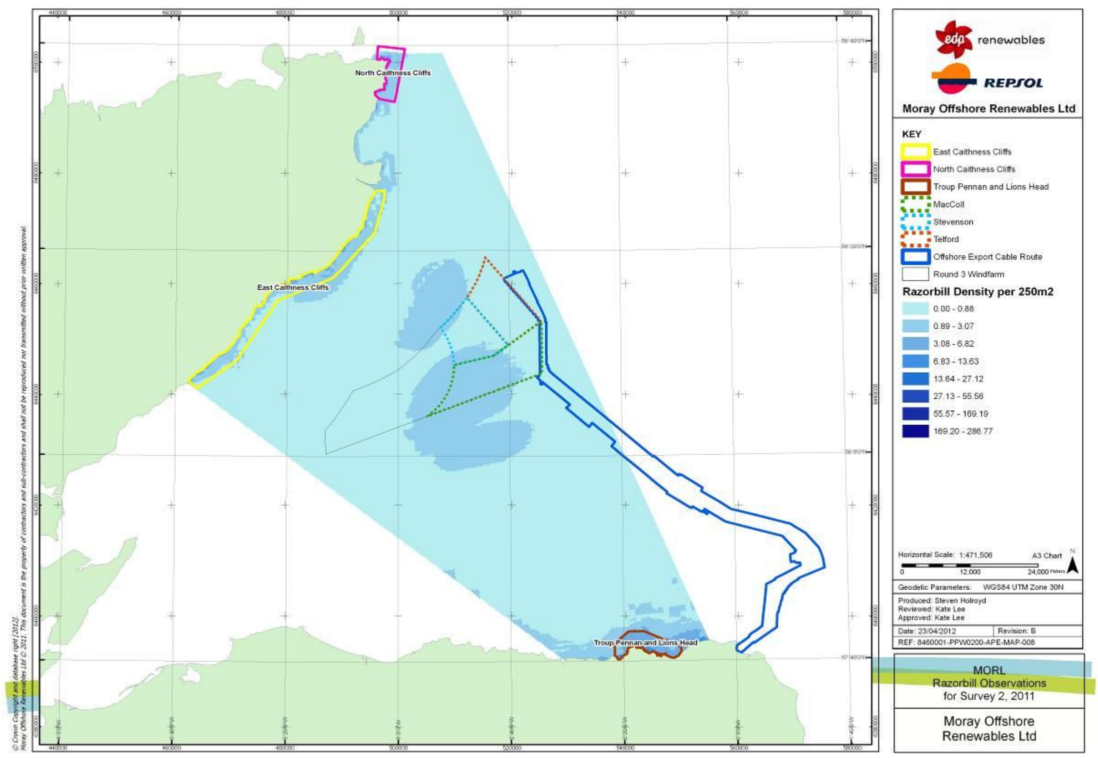


F: Survey 6

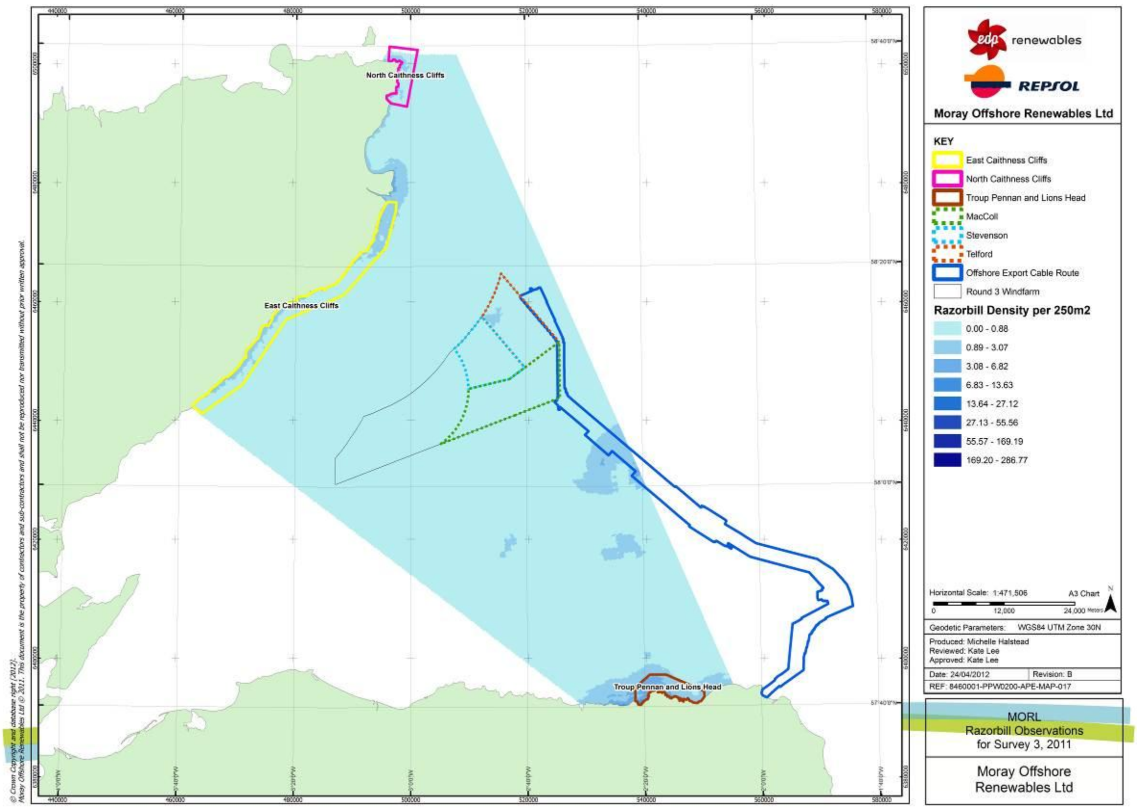
Figure 3.3.2 Distribution of razorbills recorded in the Moray Firth survey area in each survey



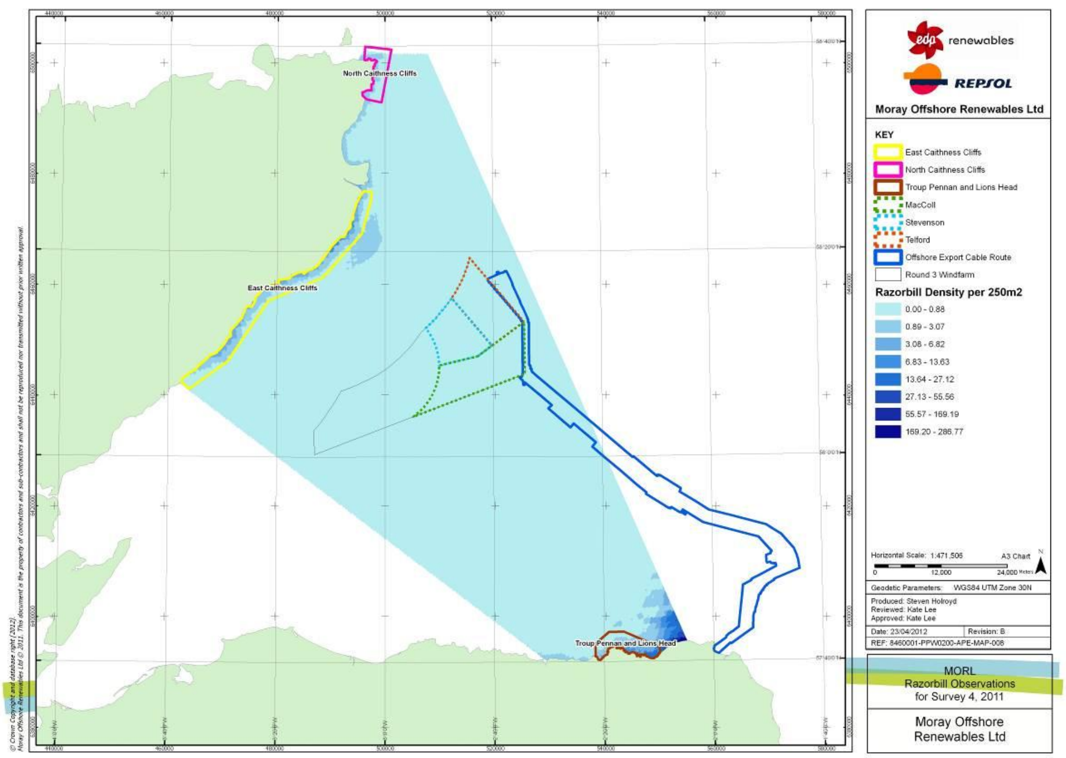
A: Survey 1



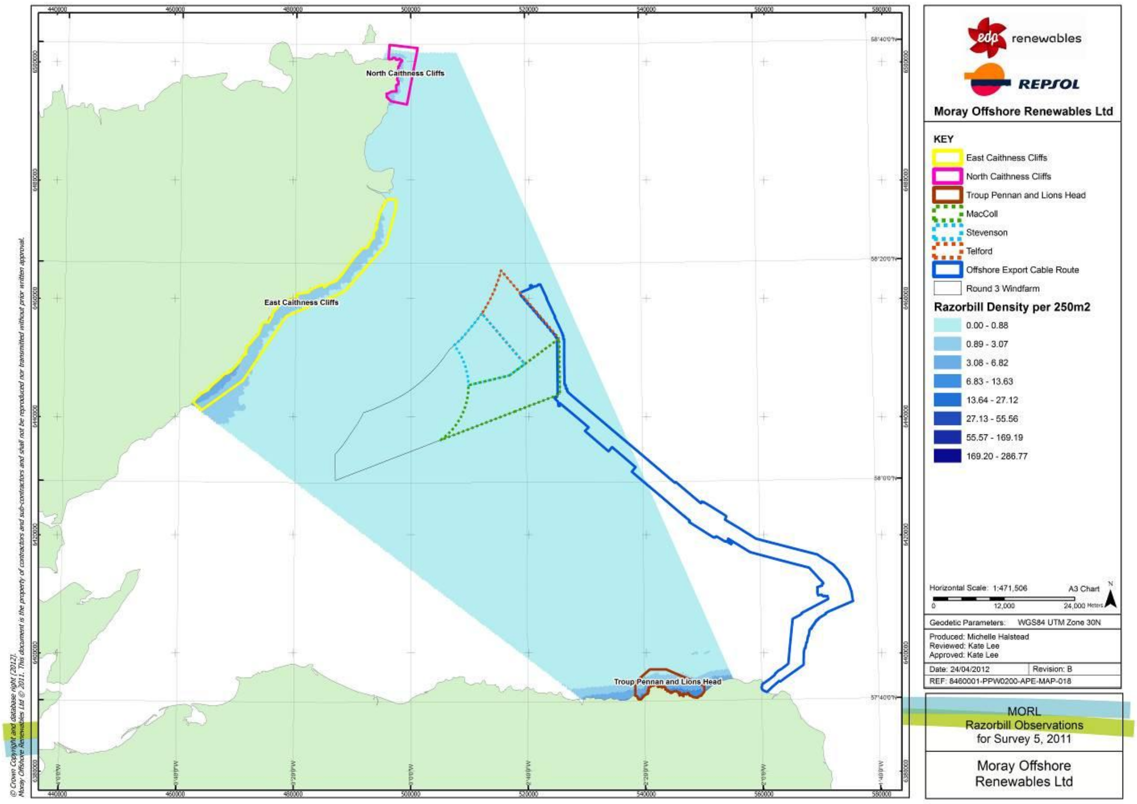
B: Survey 2



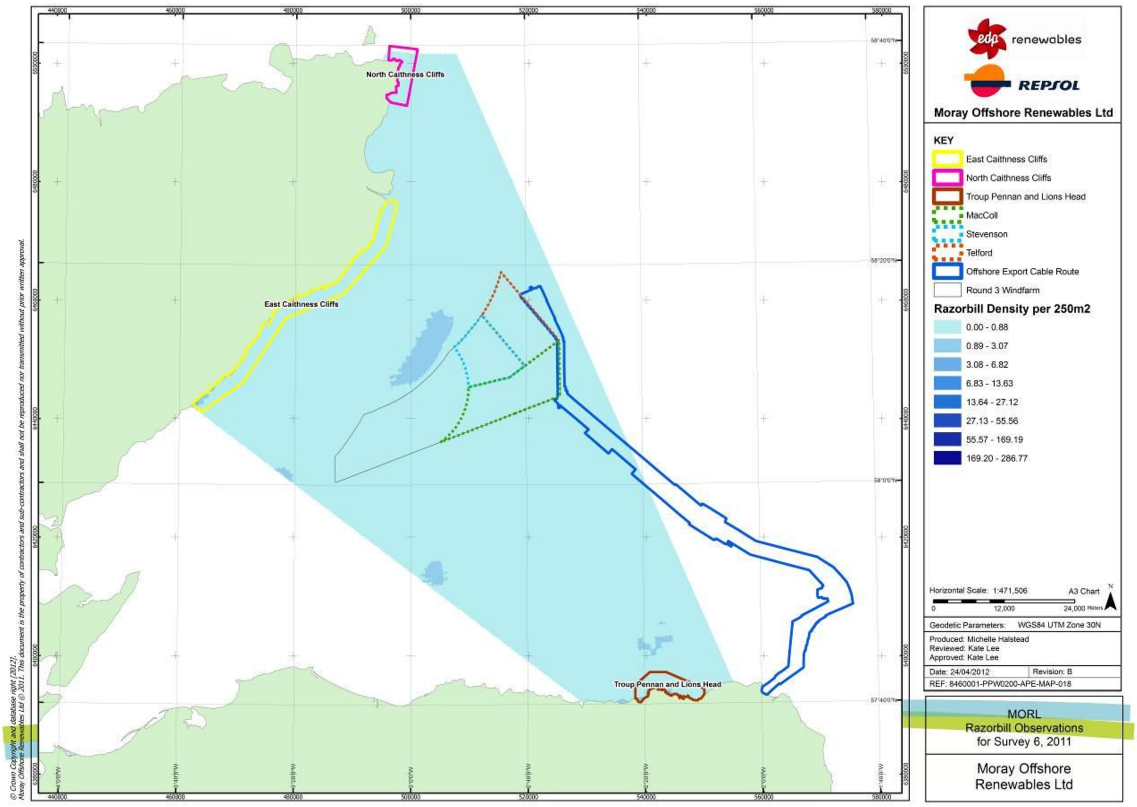
C: Survey 3



D: Survey 4

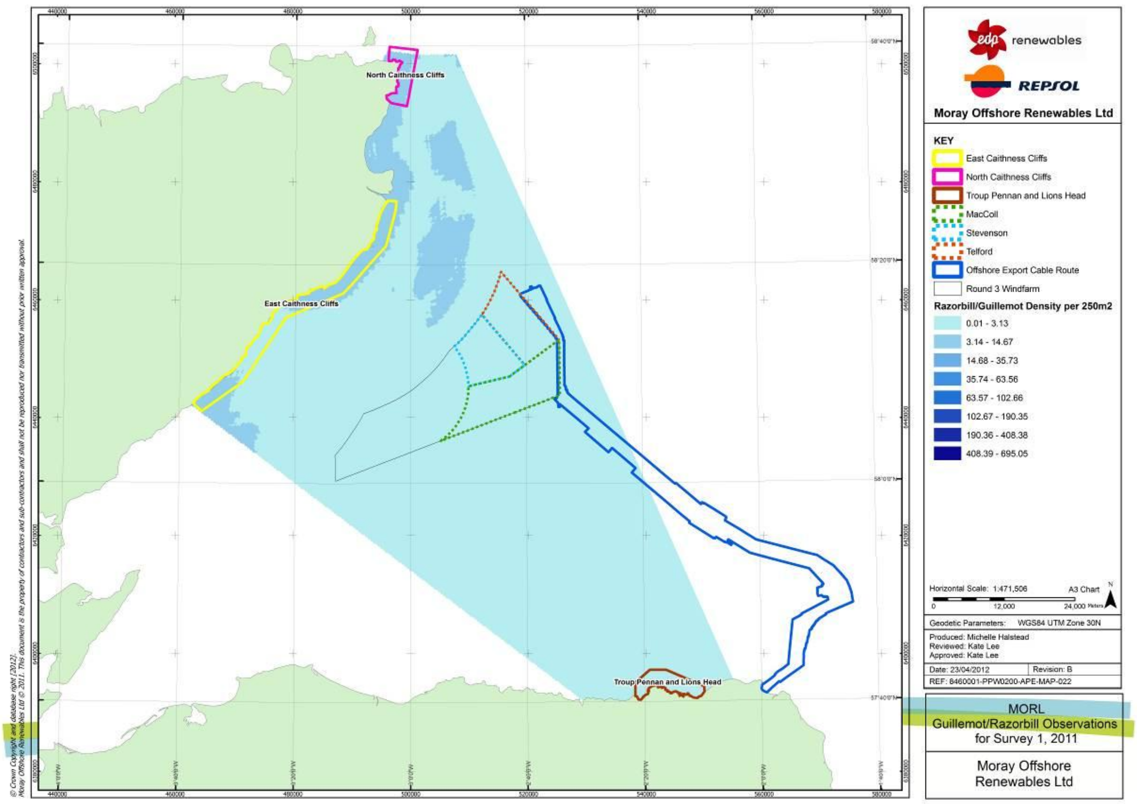


E: Survey 5

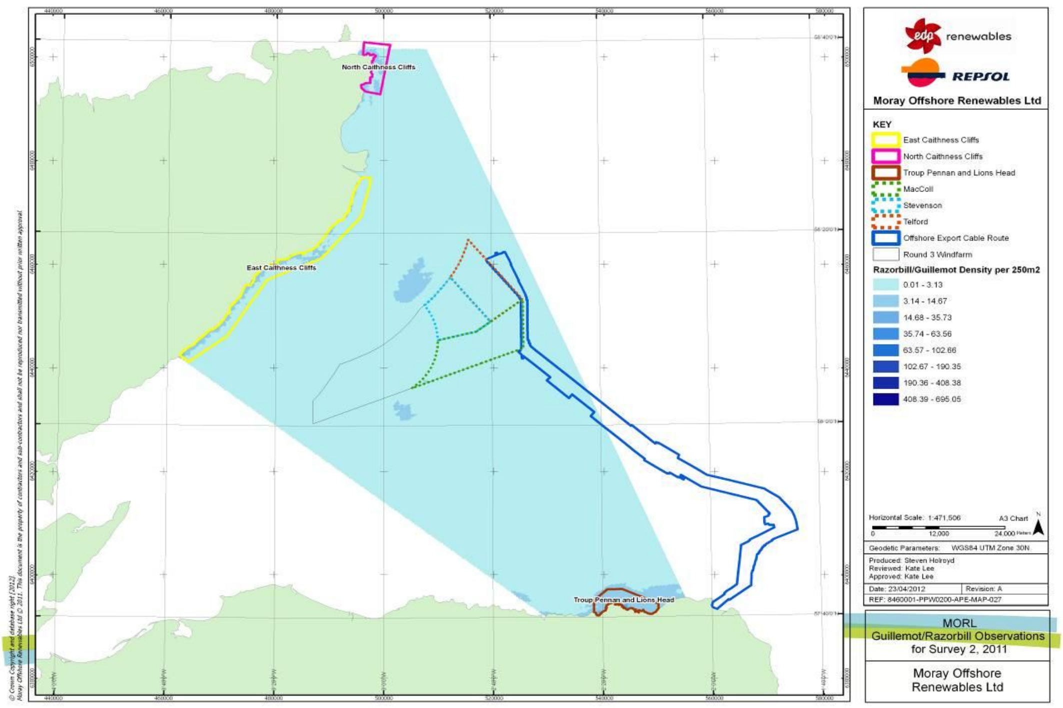


F: Survey 6

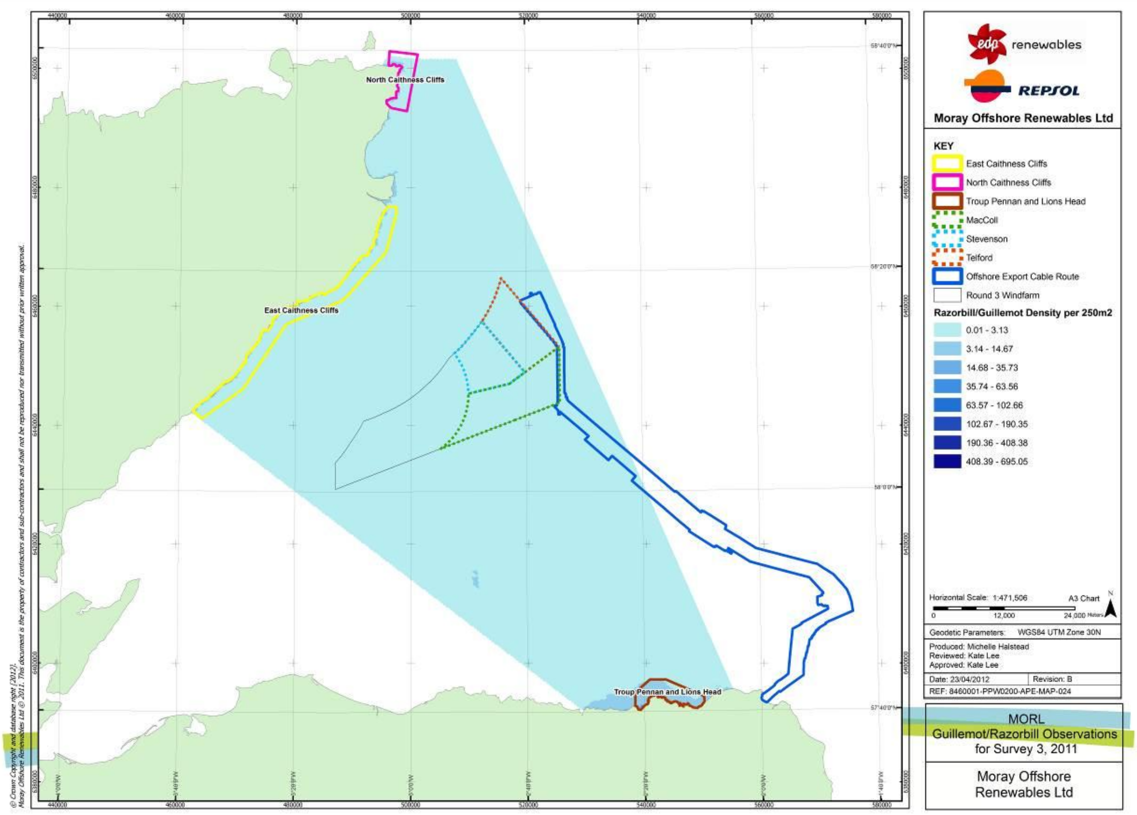
Figure 3.3.3 Distribution of all guillemots / razorbills recorded in the Moray Firth survey area in each survey



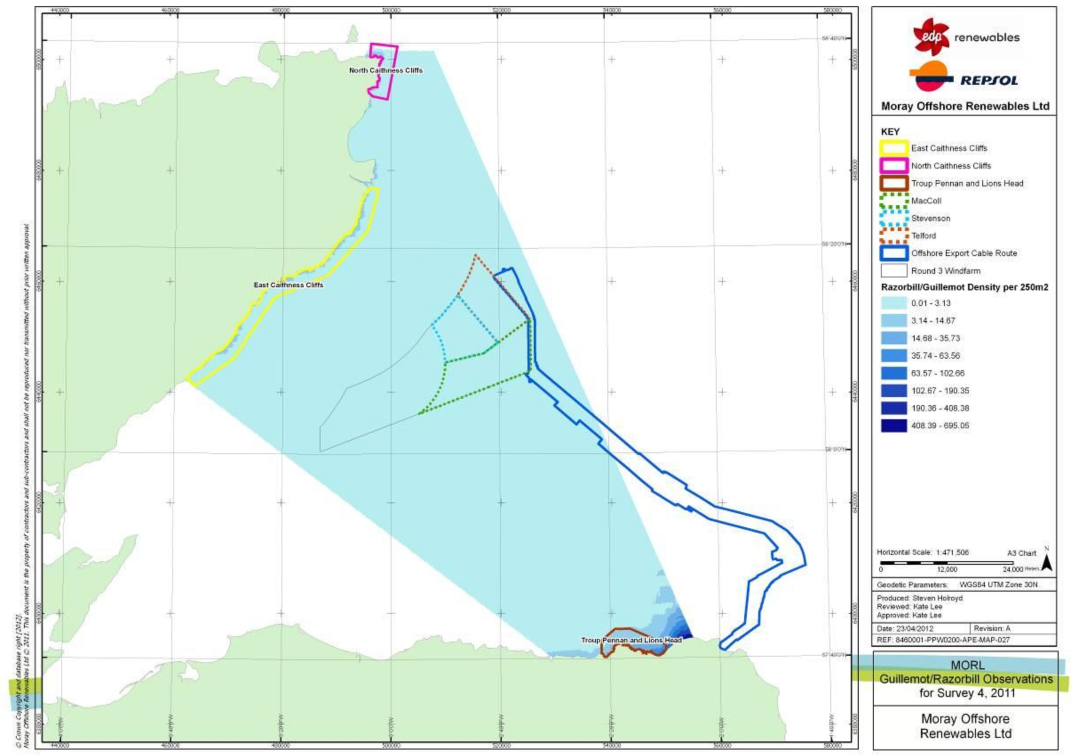
A: Survey 1



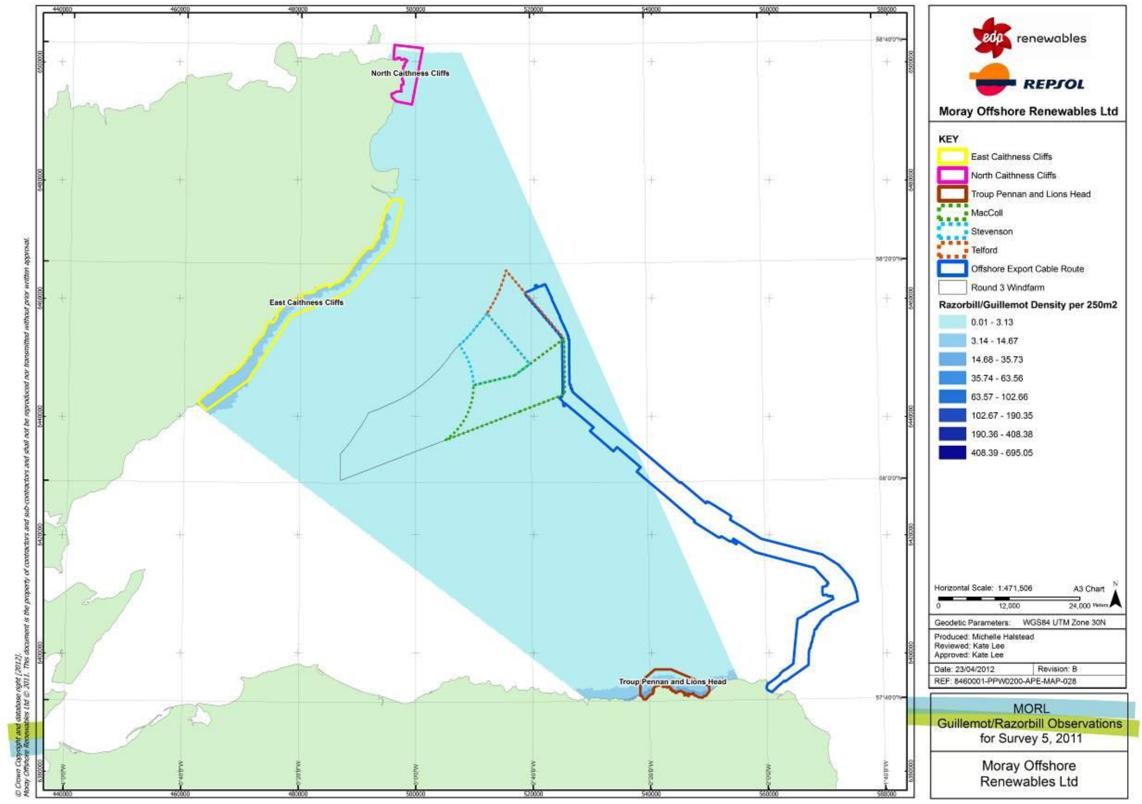
B: Survey 2



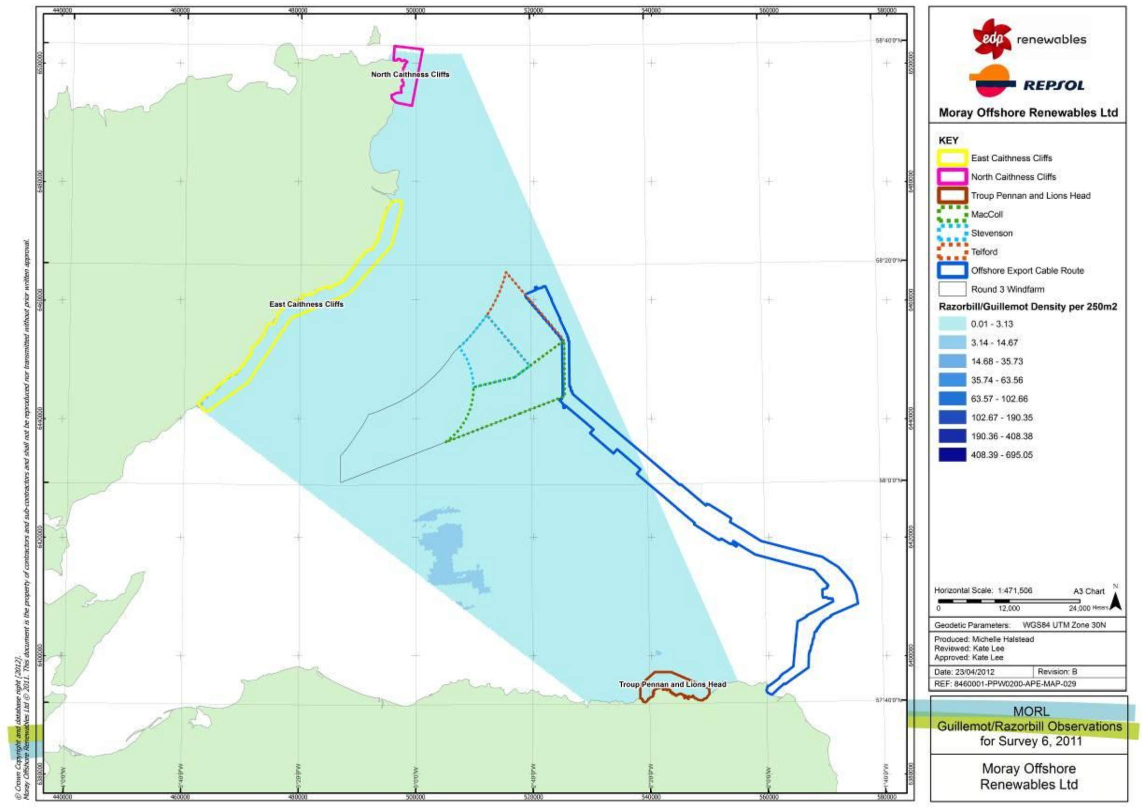
C: Survey 3



D: Survey 4

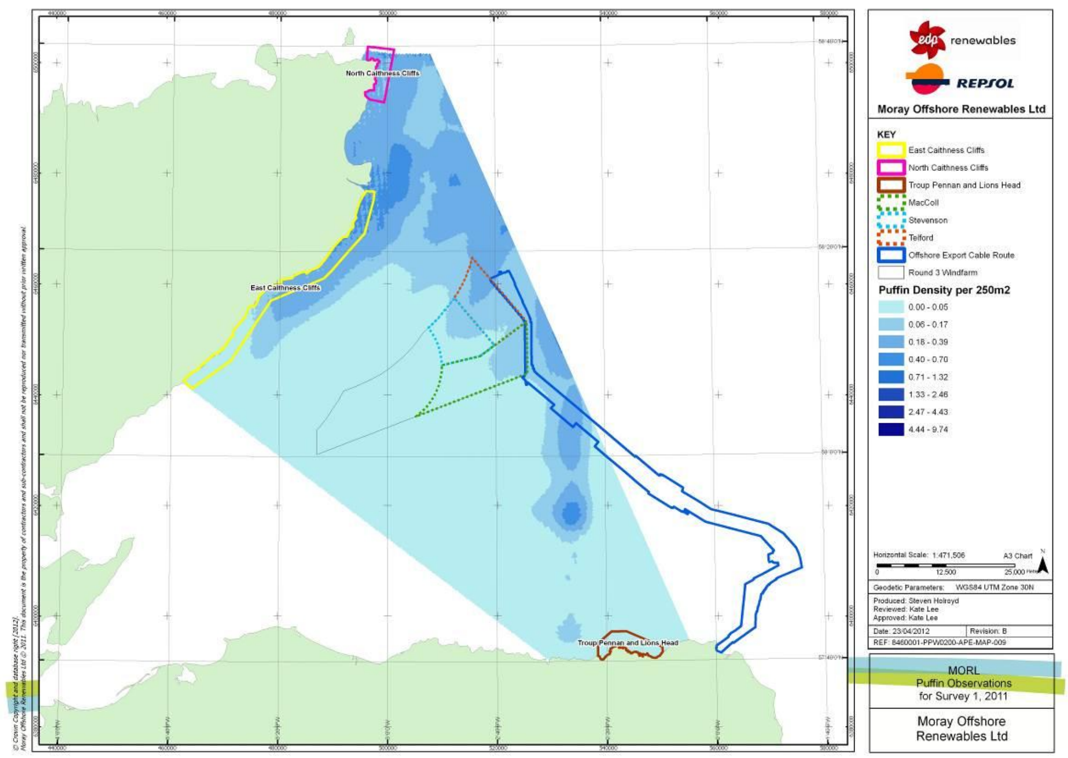


E: Survey 5

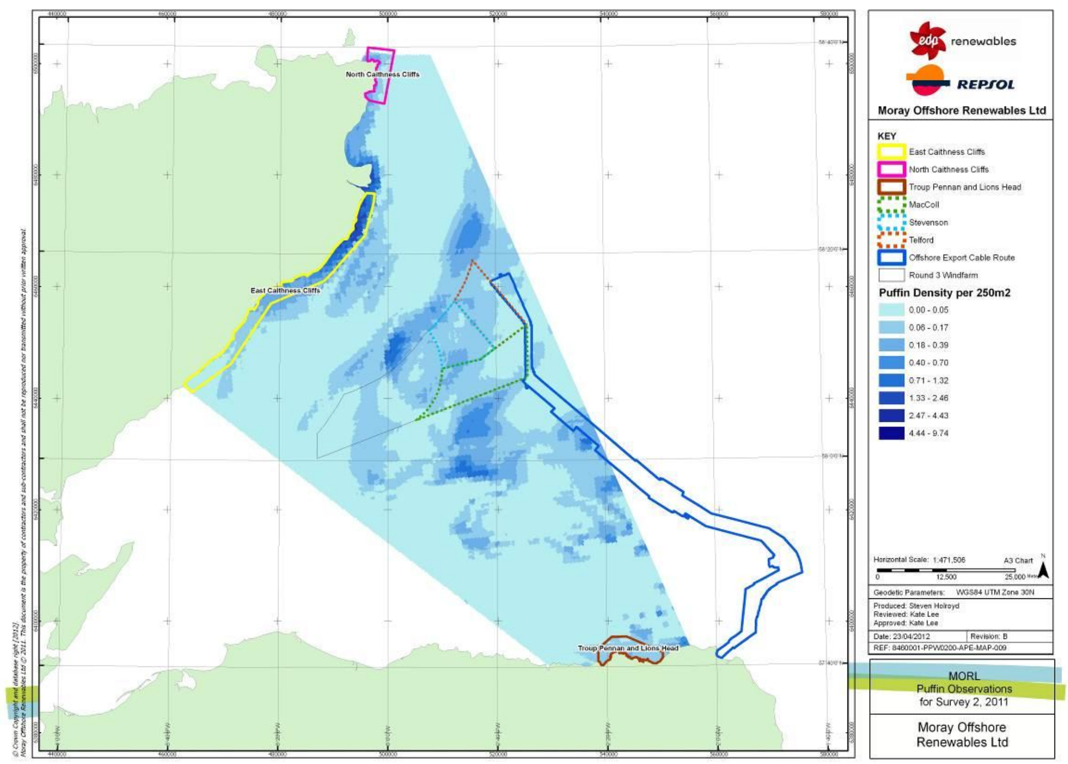


F: Survey 6

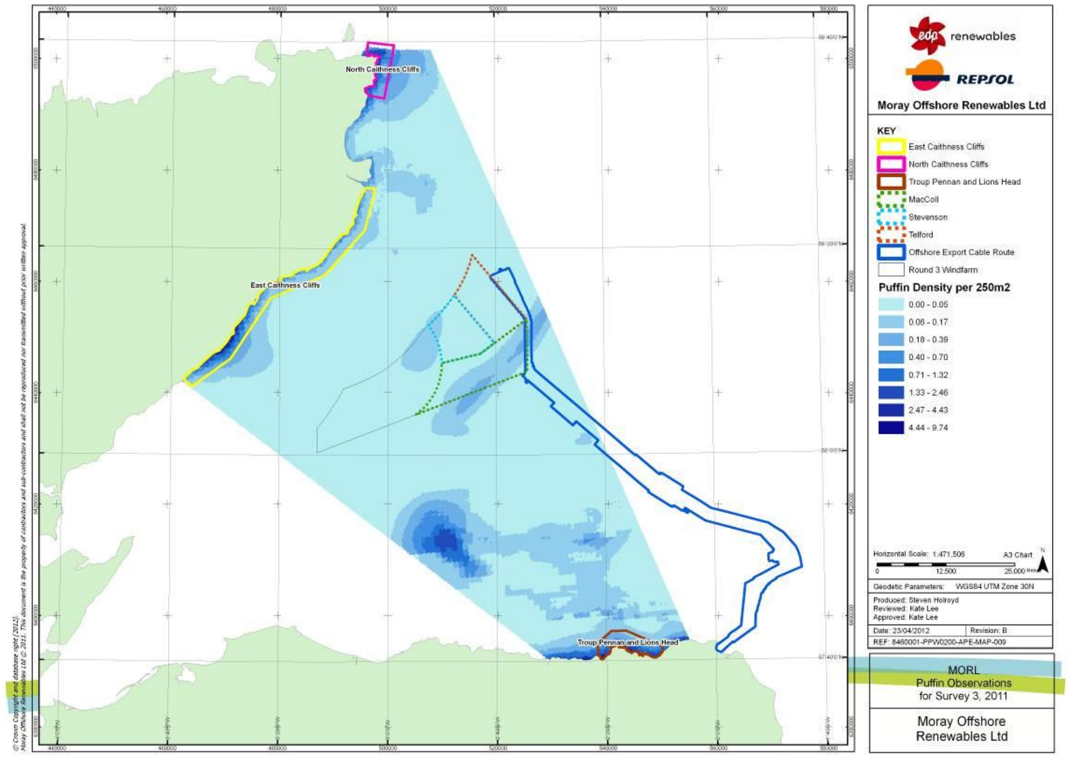
Figure 3.3.4 Distribution of puffins recorded in the Moray Firth survey area in each survey



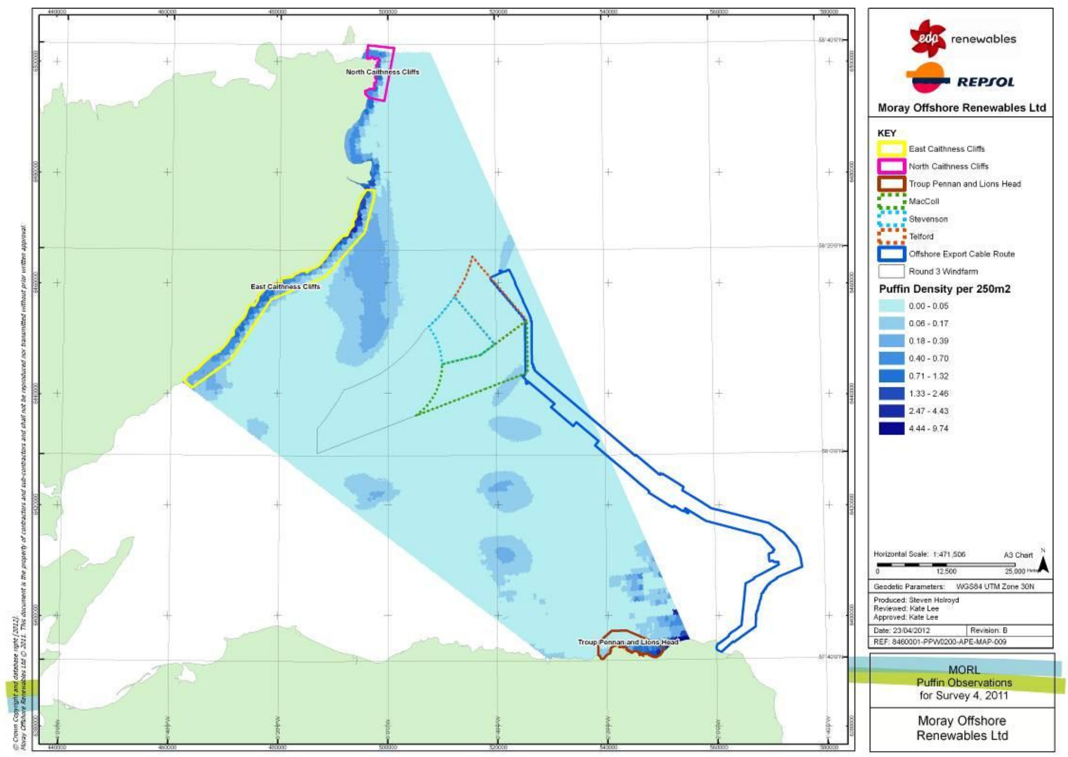
A: Survey 1



B: Survey 2



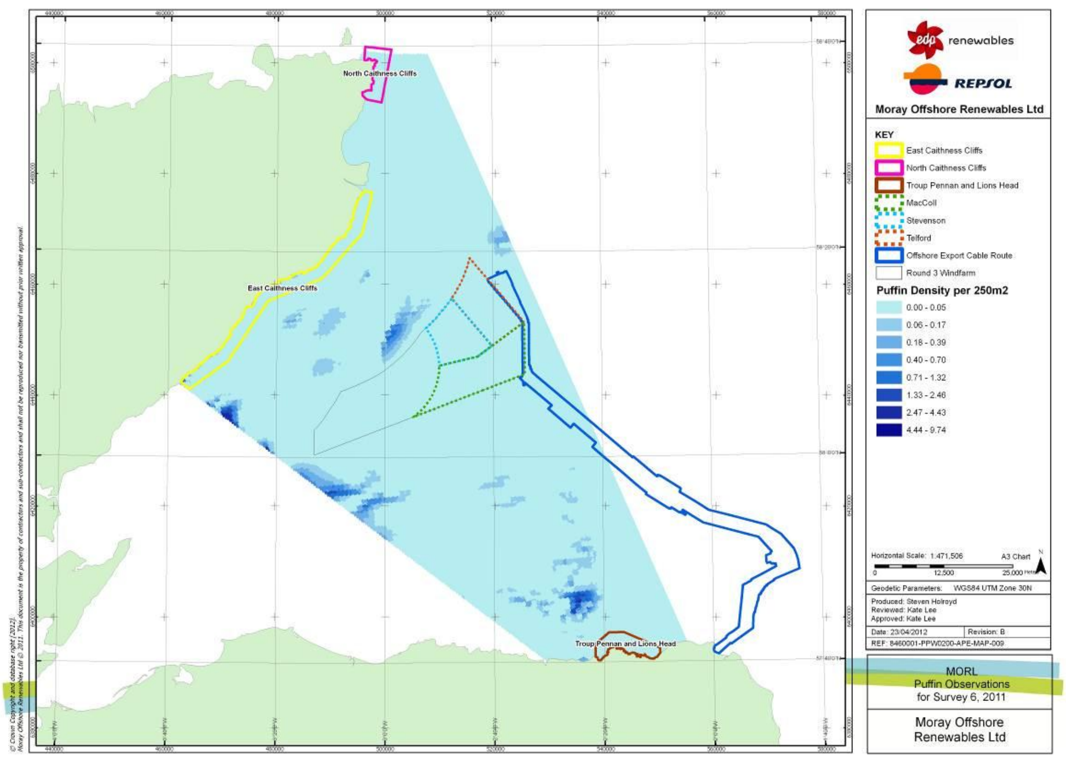
C: Survey 3



D: Survey 4

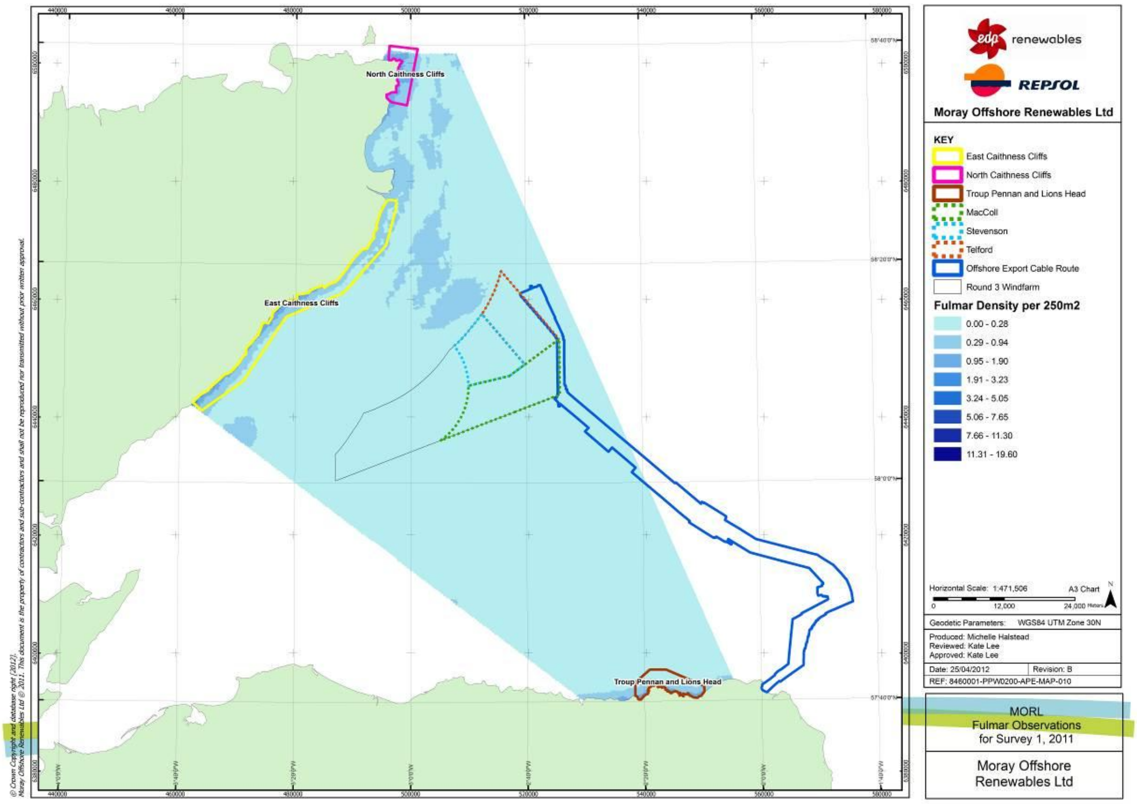
No Model Possible

E: Survey 5

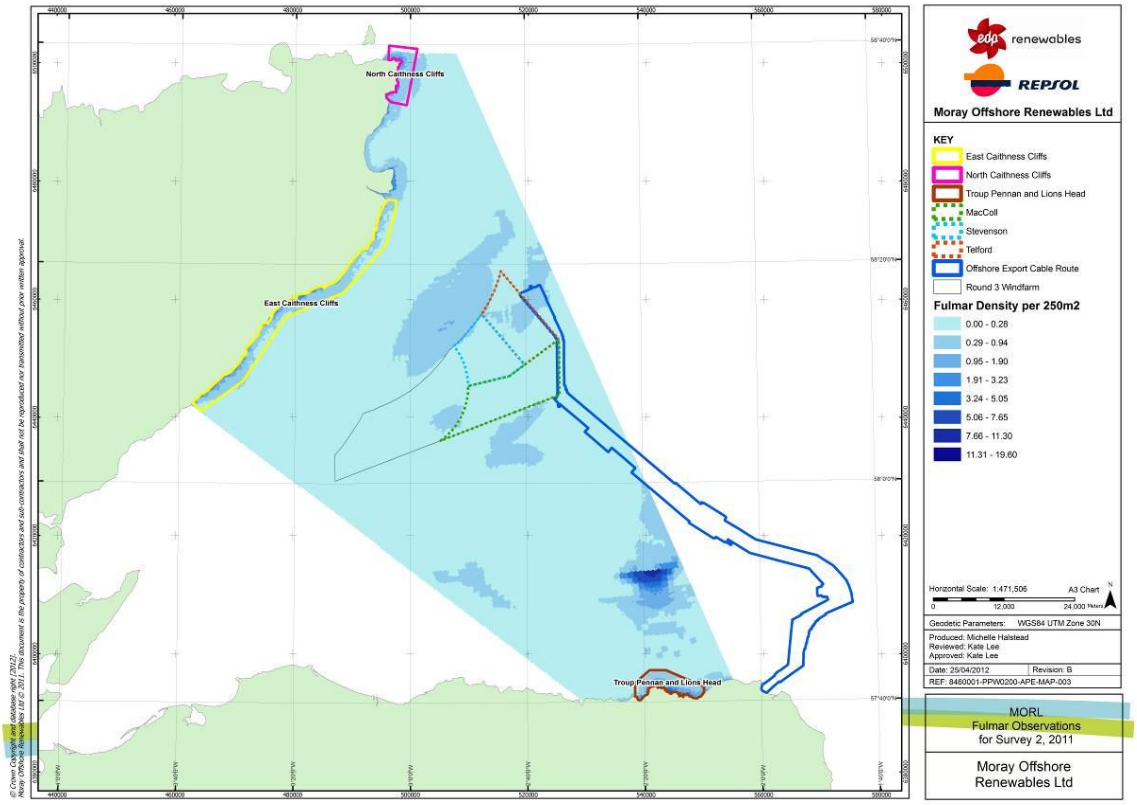


F: Survey 6

Figure 3.3.5 Distribution of fulmars recorded in the Moray Firth survey area in each survey



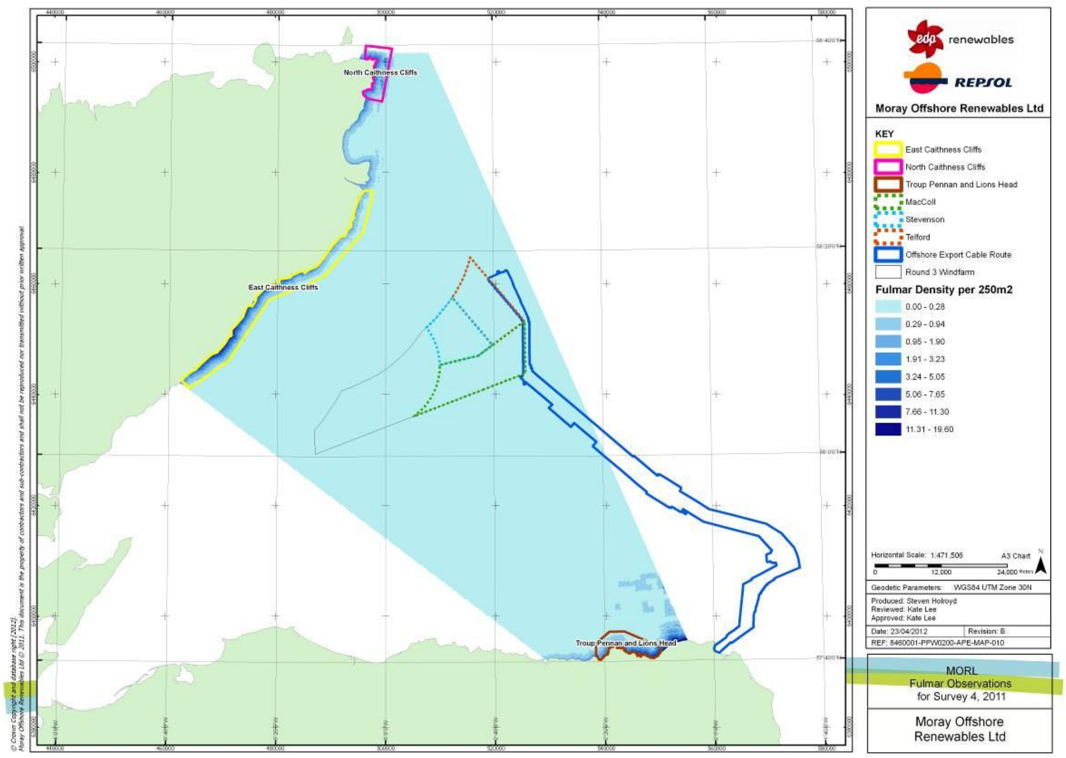
A: Survey 1



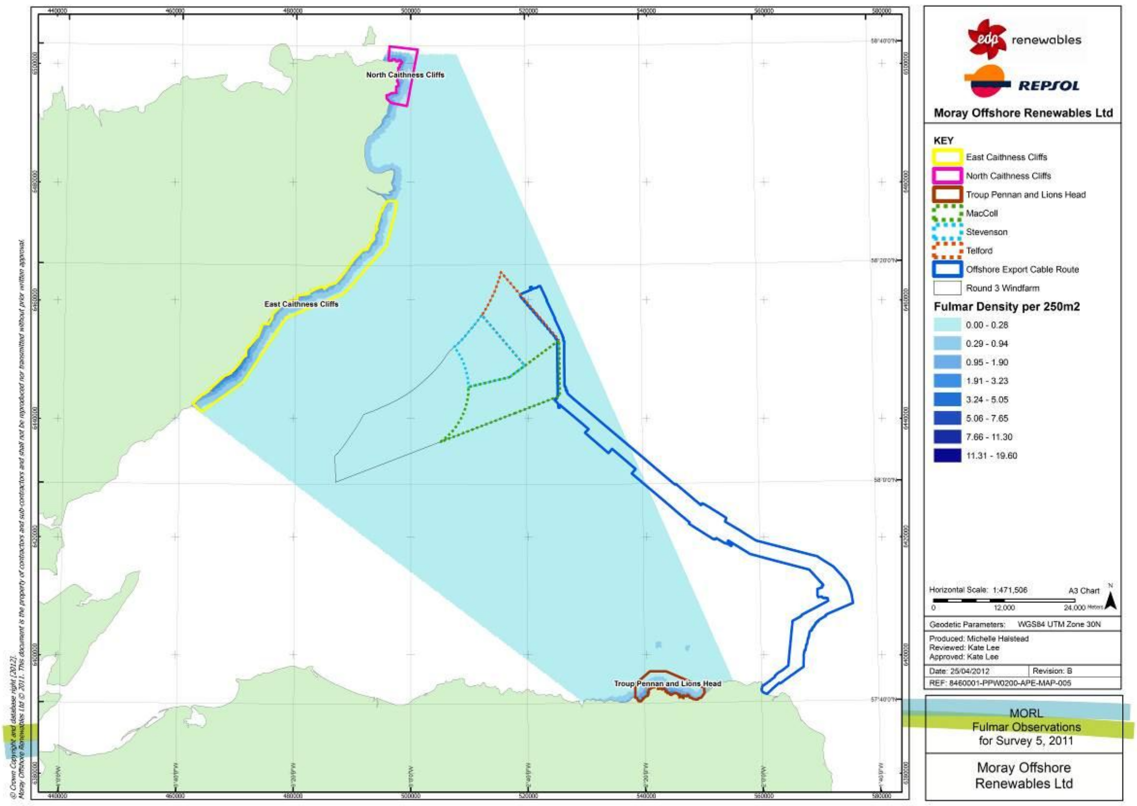
B: Survey 2

No Model Possible

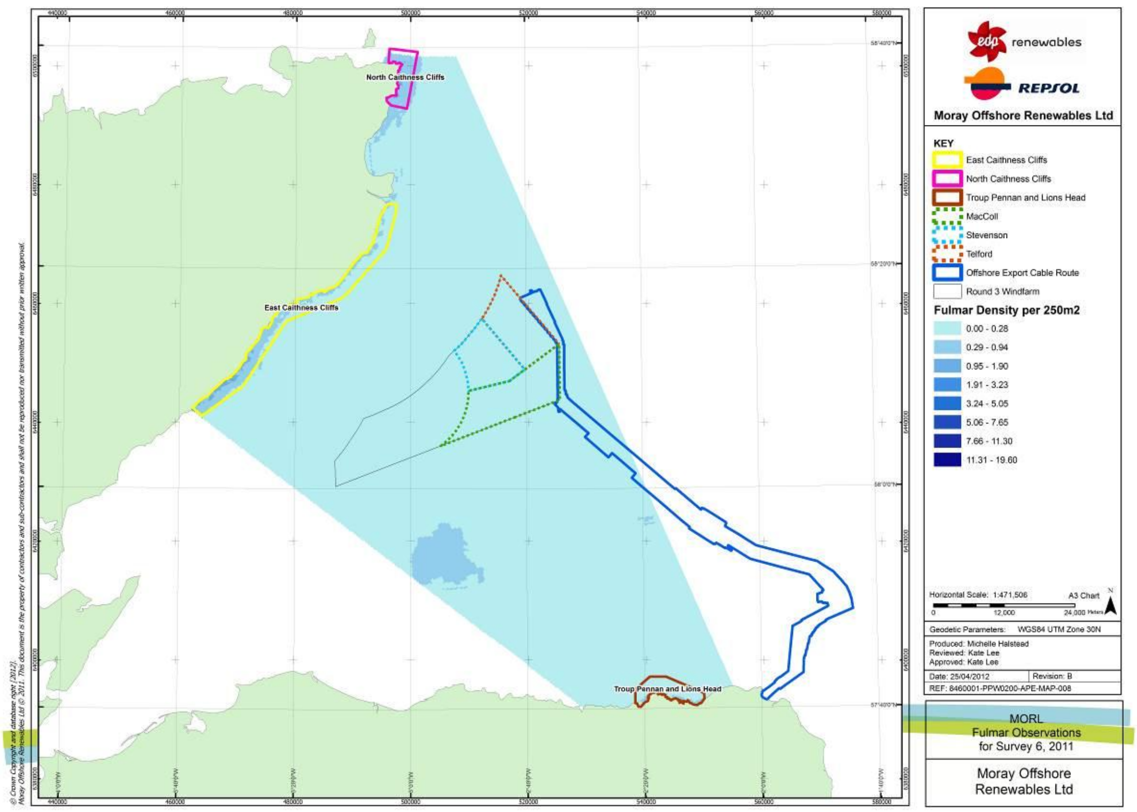
C: Survey 3



D: Survey 4



E: Survey 5

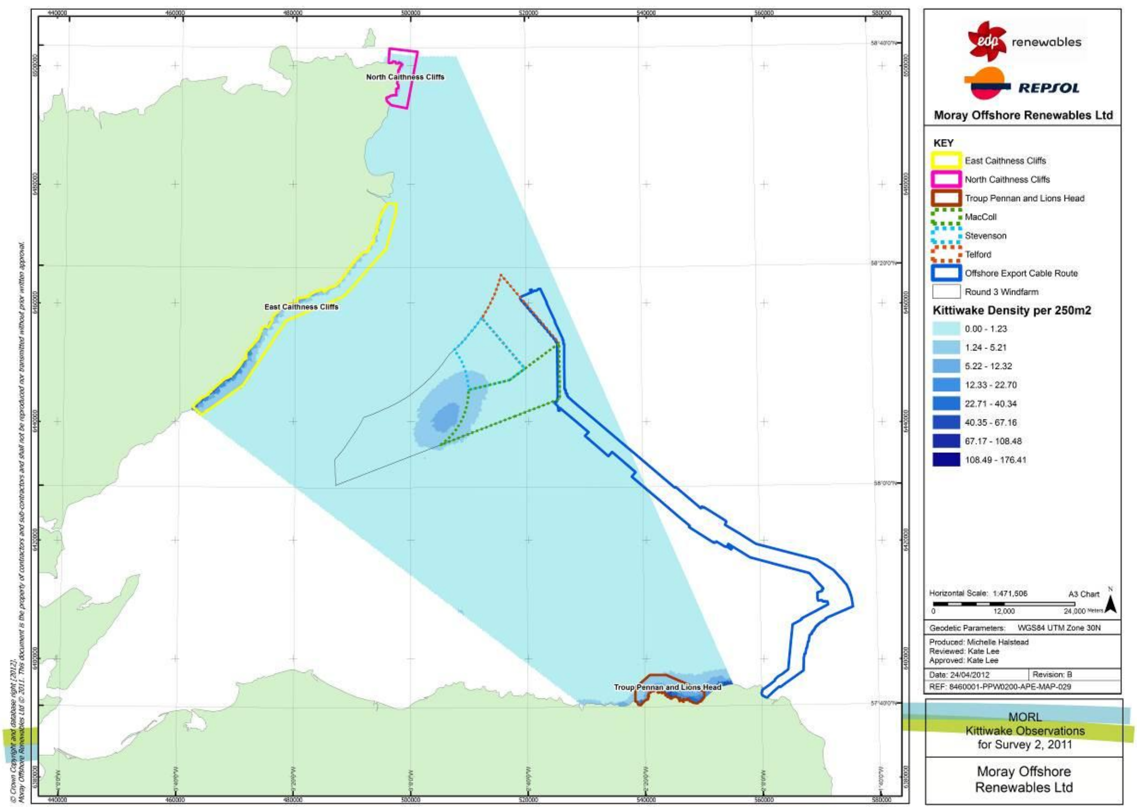


F: Survey 6

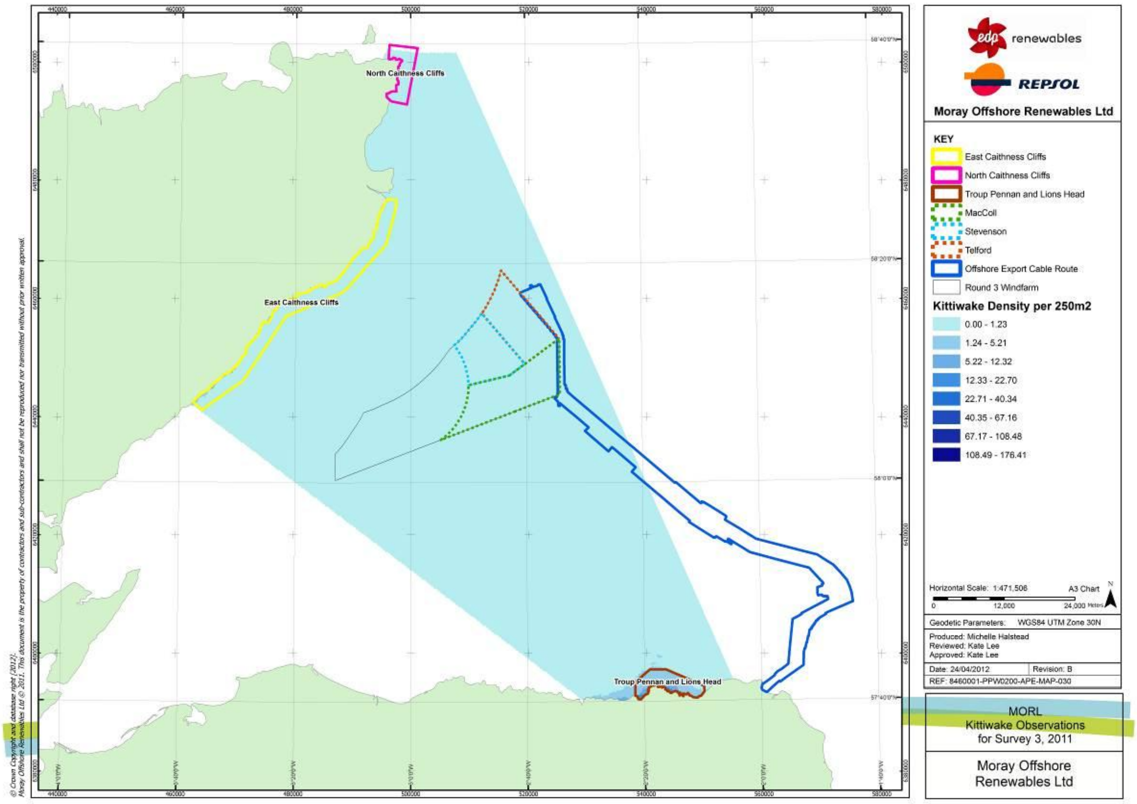
Figure 3.3.6 Distribution of kittiwakes recorded in the Moray Firth survey area in each survey

No Model Possible

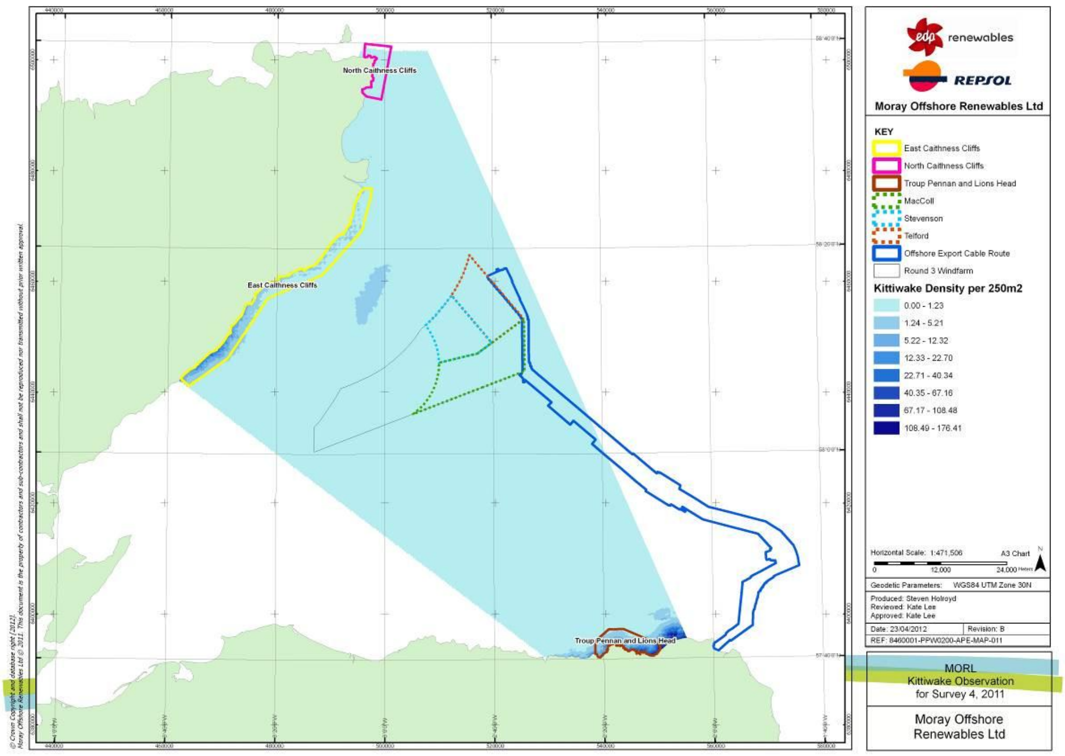
A: Survey 1



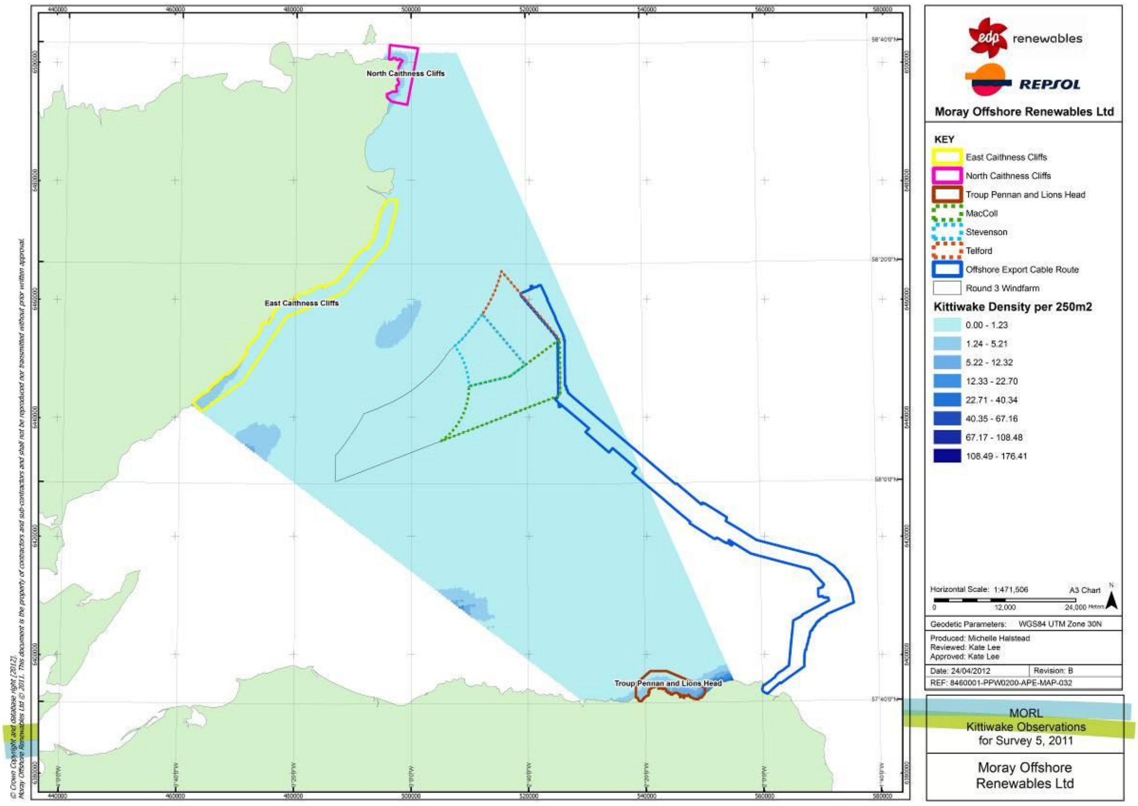
B: Survey 2



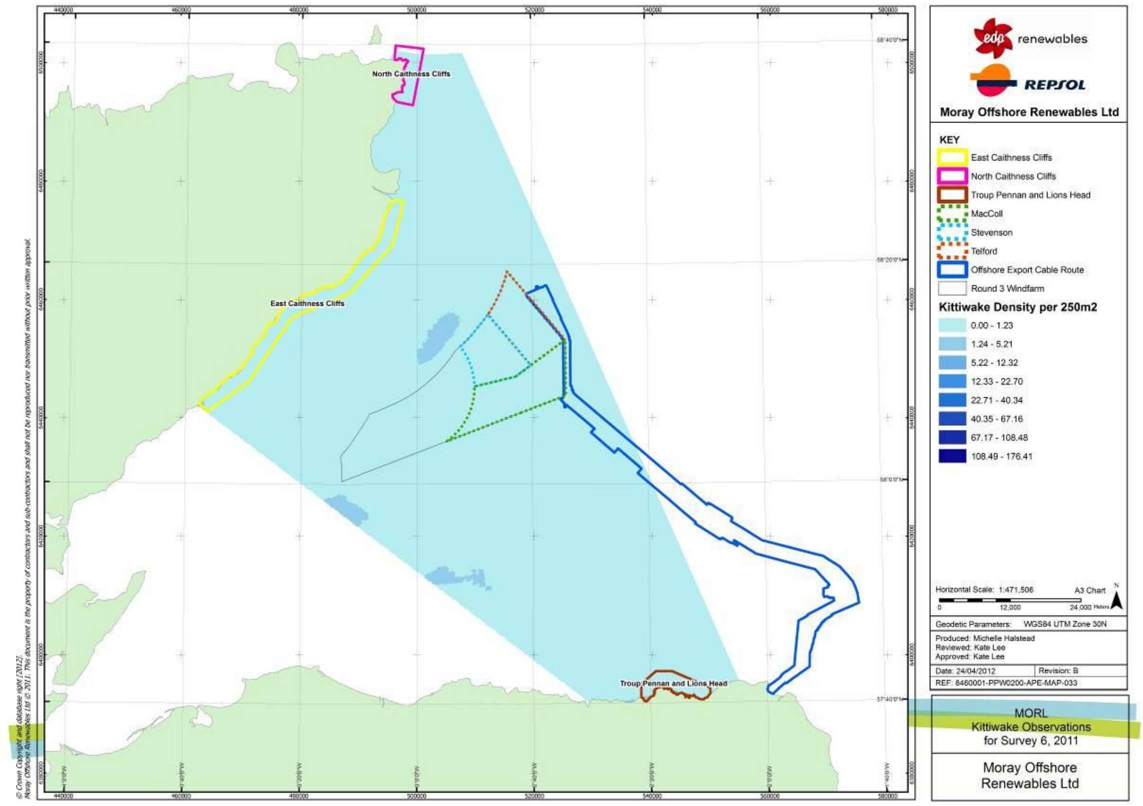
C: Survey 3



D: Survey 4



Survey 5

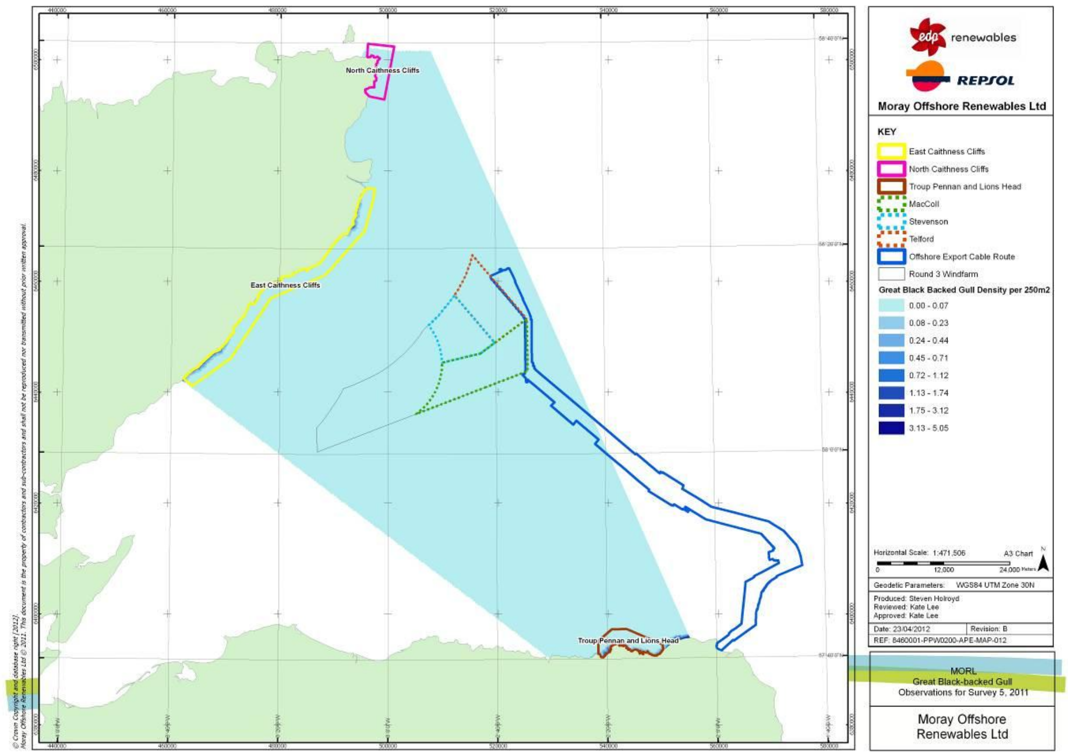


Survey 6

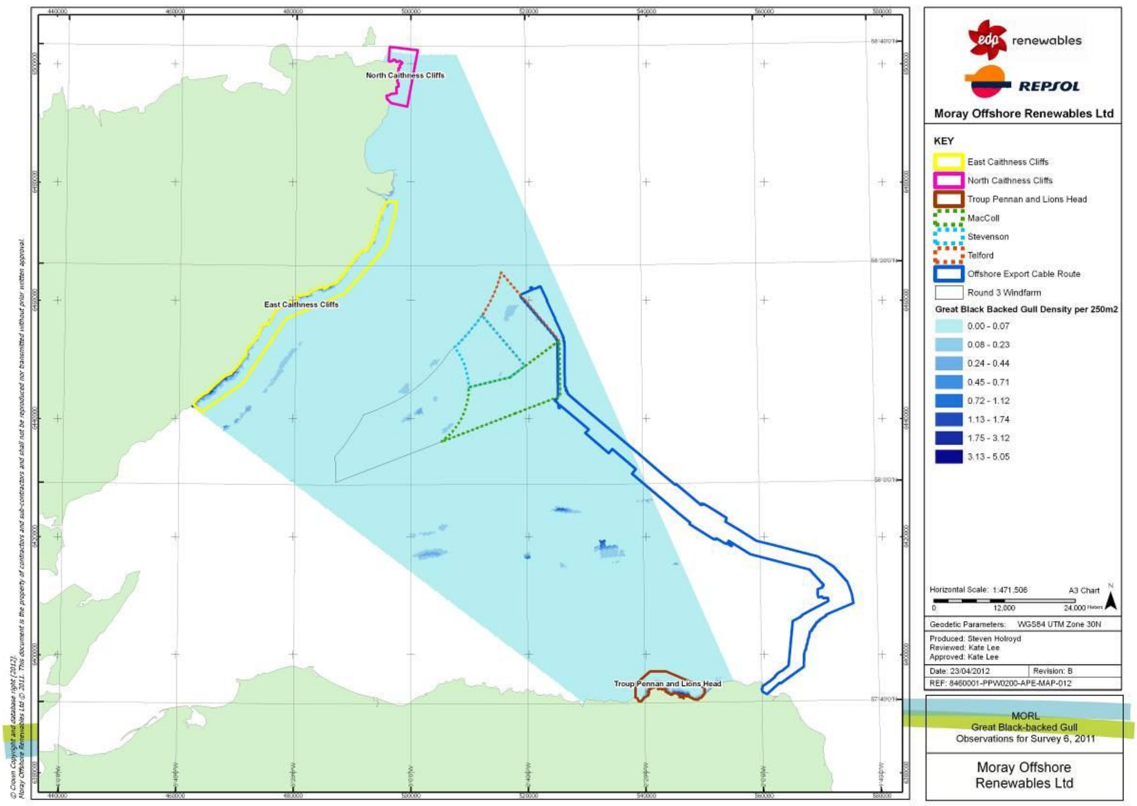
Figure 3.3.7 Distribution of great black-backed gulls recorded in the Moray Firth survey area in each survey

No Model Possible
A: Survey 1
No Model Possible
B: Survey 2

No Model Possible
C: Survey 3
No Model Possible
D: Survey 4

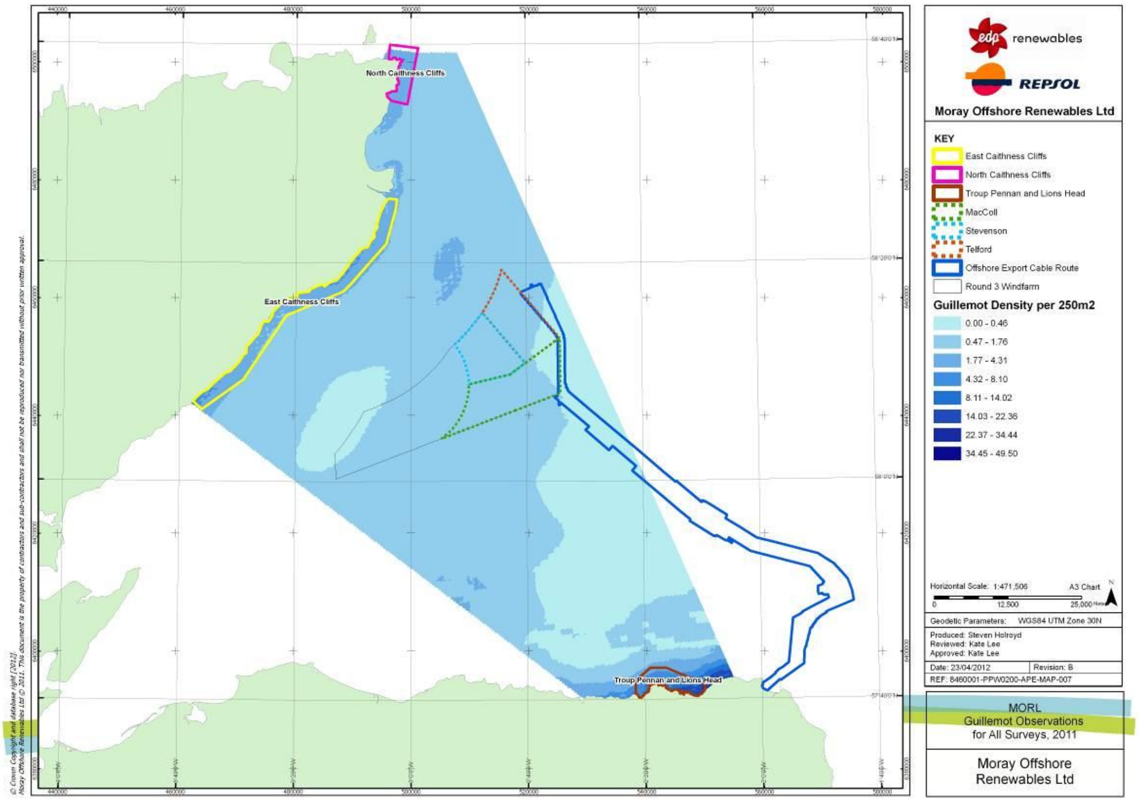


E: Survey 5

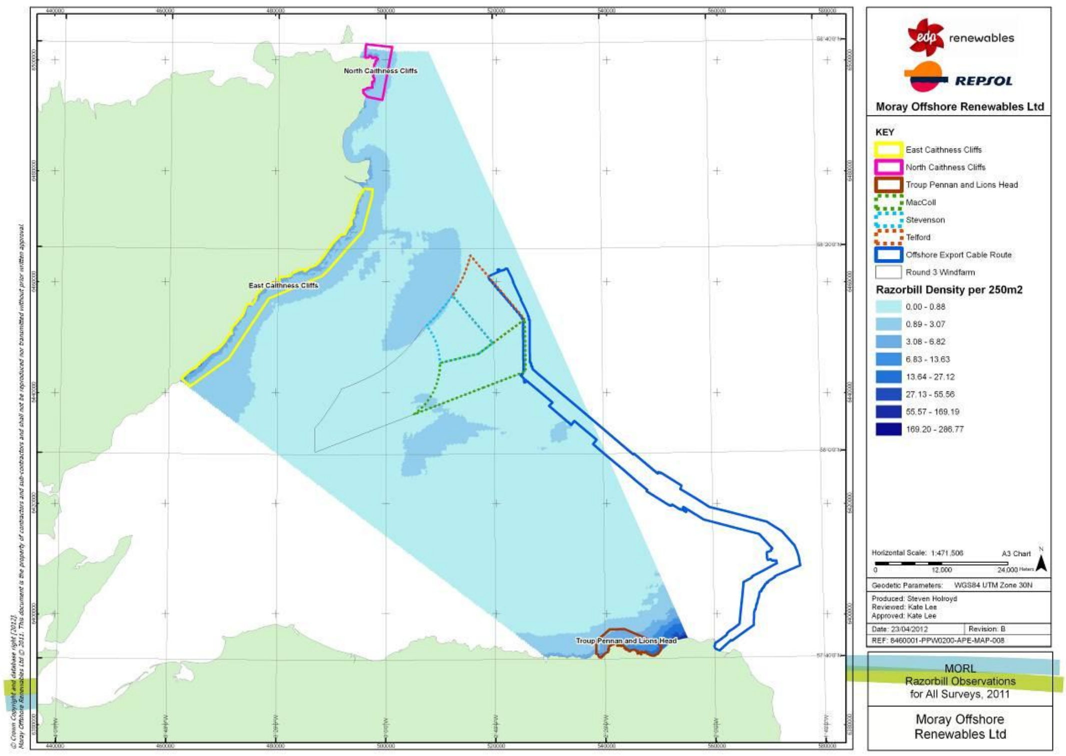


F: Survey 6

Figure 3.3.8 Distribution of each of the key species for all surveys combined

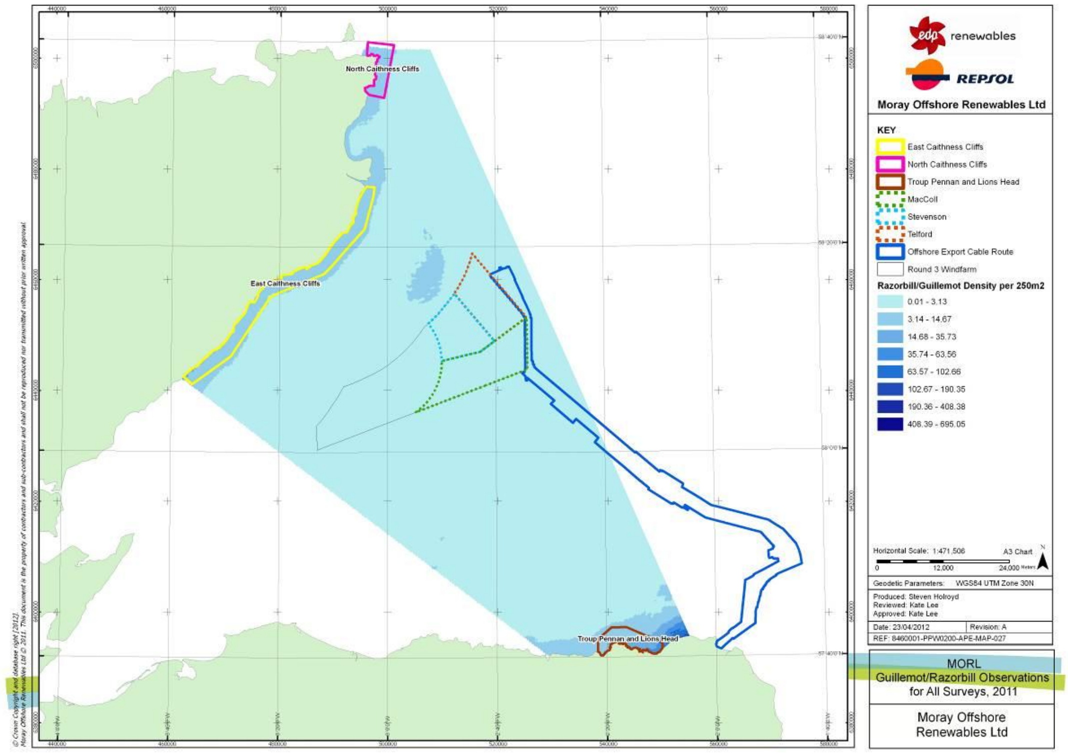


A: Guillemots

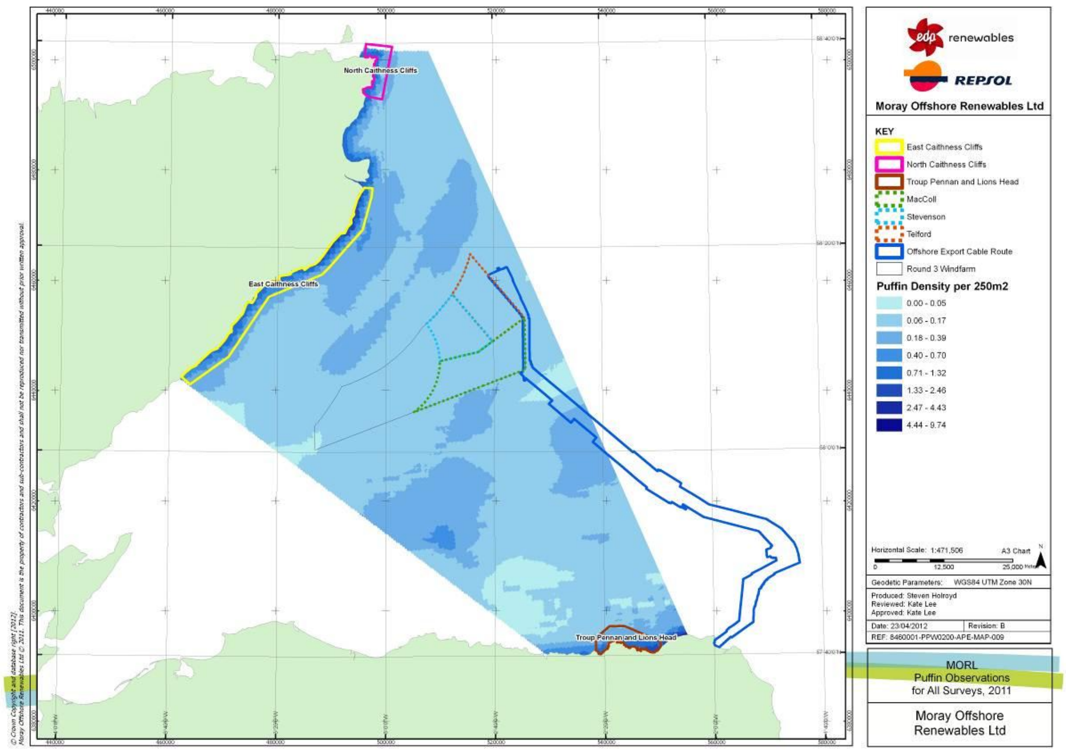


B: Razorbills

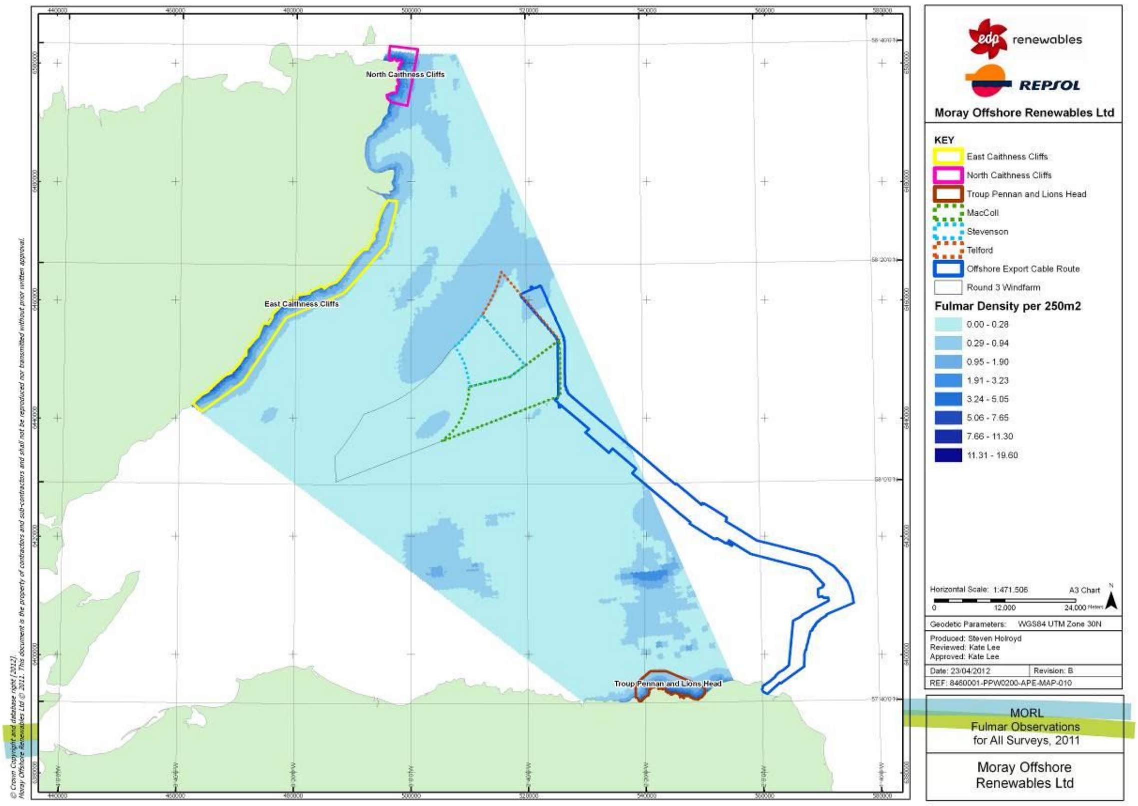
APPENDIX 4.5 B



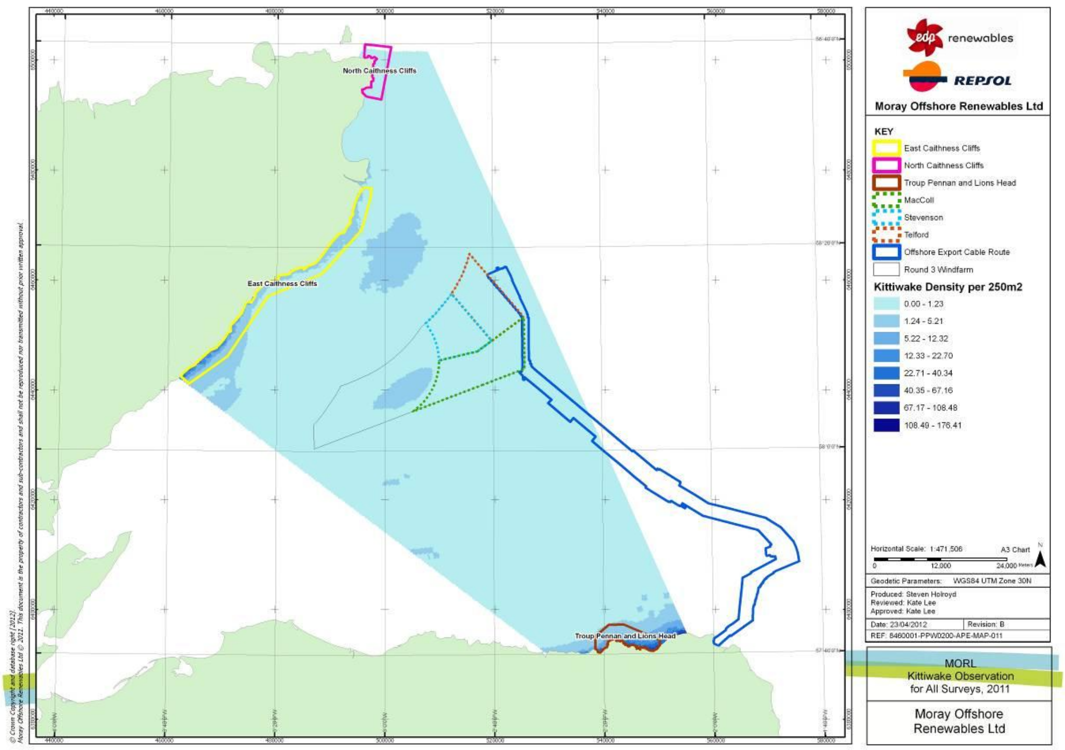
C: All Guillemots / Razorbills



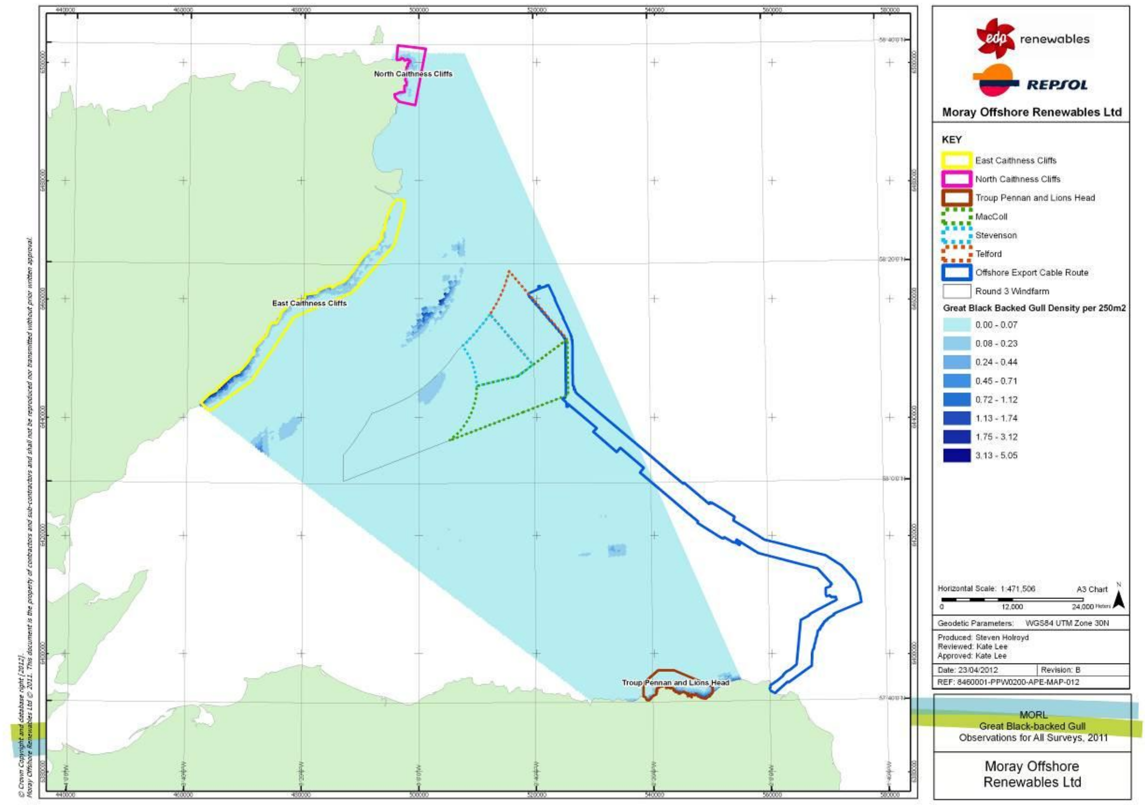
D: Puffins



E: Fulmars



F: Kittiwakes



G: Great black-backed gulls

3.3.1.9. Population Estimates

Population estimates were calculated for each of the key species using the model outputs. Table 3.3.1 to Table 3.3.8 below shows the population estimates and associated confidence limits for the whole survey area, the three wind farm sites combined and the MacColl, Stevenson and Telford areas individually.

Table 3.3.1 Guillemot population estimates

	Area	Population estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
Survey 1	Survey Area	50,049	49,567	50,524	0.01
	Three wind farms	2,501	2,459	2,542	0.06
	MacColl	649	643	654	0.11
	Stevenson	795	777	813	0.1
	Telford	1,057	1,026	1,086	0.09
Survey 2	Survey Area	28,661	28,369	28,973	0.02
	Three wind farms	3,135	3,108	3,164	0.05
	MacColl	1,055	1,042	1,068	0.09
	Stevenson	772	766	779	0.11
	Telford	1,308	1,294	1,323	0.08
Survey 3	Survey Area	19,493	19,290	19,700	0.02
	Three wind farms	1,319	1,302	1,337	0.08
	MacColl	721	711	732	0.11
	Stevenson	345	341	349	0.16
	Telford	253	249	258	0.18
Survey 4	Survey Area	28,957	28,126	29,822	0.02
	Three wind farms	1,436	1,414	1,457	0.08
	MacColl	819	804	834	0.1
	Stevenson	333	329	338	0.16
	Telford	284	277	292	0.17
Survey 5	Survey Area	30,070	29,548	30,584	0.02
	Three wind farms	620	613	627	0.12
	MacColl	331	327	336	0.16
	Stevenson	160	158	163	0.23
	Telford	128	127	130	0.26
Survey 6	Survey Area	17,006	16,783	17,239	0.02
	Three wind farms	297	288	306	0.17
	MacColl	140	134	147	0.24
	Stevenson	124	119	128	0.26
	Telford	33	32	34	0.52

Table 3.3.2 Razorbill population estimates

	Area	Population estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
Survey 1	Survey Area	24,921	24,623	25,218	0.02
	Three wind farms	523	513	533	0.13
	MacColl	142	139	145	0.24
	Stevenson	162	157	167	0.23
	Telford	219	211	227	0.19
Survey 2	Survey Area	40,381	39,991	40,780	0.01
	Three wind farms	4,283	4,219	4,348	0.04
	MacColl	2,356	2,299	2,407	0.06
	Stevenson	1,060	1,047	1,073	0.09
	Telford	867	859	875	0.1
Survey 3	Survey Area	19,143	18,871	19,425	0.02
	Three wind farms	1,157	1,124	1,188	0.09
	MacColl	261	257	266	0.18
	Stevenson	422	406	439	0.14
	Telford	473	450	496	0.13
Survey 4	Survey Area	33,705	31,615	36,294	0.02
	Three wind farms	525	515	535	0.13
	MacColl	369	363	374	0.15
	Stevenson	78	77	79	0.33
	Telford	78	77	80	0.33
Survey 5	Survey Area	21,212	20,850	21,547	0.02
	Three wind farms	408	404	411	0.14
	MacColl	176	173	178	0.21
	Stevenson	92	90	93	0.31
	Telford	140	139	142	0.25
Survey 6	Survey Area	9,400	9,269	9,543	0.03
	Three wind farms	85	82	88	0.32
	MacColl	26	25	27	0.56
	Stevenson	44	42	46	0.44
	Telford	14	14	15	0.78

Table 3.3.3 All guillemots / razorbills population estimates

	Area	Population estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
Survey 1	Survey Area	86,882	86,023	87,810	0.01
	Three wind farms	3,469	3,413	3,533	0.05
	MacColl	904	891	918	0.1
	Stevenson	1,118	1,087	1,150	0.09
	Telford	1,448	1,403	1,493	0.08
Survey 2	Survey Area	73,142	72,477	73,809	0.01
	Three wind farms	7,490	7,441	7,541	0.03
	MacColl	3,381	3,343	3,421	0.05
	Stevenson	1,872	1,857	1,887	0.07
	Telford	2,238	2,220	2,256	0.06
Survey 3	Survey Area	43,291	42,830	43,769	0.01
	Three wind farms	2,556	2,520	2,591	0.06
	MacColl	1,011	1,001	1,022	0.09
	Stevenson	835	816	854	0.1
	Telford	709	684	733	0.11
Survey 4	Survey Area	85,059	79,626	90,846	0.01
	Three wind farms	2,340	2,304	2,375	0.06
	MacColl	1,468	1,449	1,487	0.08
	Stevenson	484	479	489	0.13
	Telford	388	384	392	0.15
Survey 5	Survey Area	55,856	55,056	56,678	0.01
	Three wind farms	1,172	1,161	1,185	0.08
	MacColl	575	566	584	0.12
	Stevenson	300	296	304	0.17
	Telford	297	293	300	0.17
Survey 6	Survey Area	33,846	33,442	34,256	0.02
	Three wind farms	560	544	577	0.12
	MacColl	198	189	208	0.2
	Stevenson	286	277	295	0.17
	Telford	77	74	79	0.34

Table 3.3.4 Puffin population estimates

	Area	Population estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
Survey 1	Survey Area	5,563	5,508	5,619	0.04
	Three wind farms	337	331	344	0.16
	MacColl	89	86	91	0.3
	Stevenson	67	65	68	0.36
	Telford	182	178	186	0.21
Survey 2	Survey Area	6,004	5,911	6,093	0.04
	Three wind farms	408	400	415	0.14
	MacColl	141	137	146	0.24
	Stevenson	149	144	153	0.24
	Telford	118	114	122	0.27
Survey 3	Survey Area	6,217	6,080	6,353	0.04
	Three wind farms	231	224	238	0.19
	MacColl	178	174	183	0.21
	Stevenson	37	36	38	0.49
	Telford	16	15	17	0.73
Survey 4	Survey Area	4,178	4,058	4,308	0.04
	Three wind farms	28	27	30	0.55
	MacColl	18	16	19	0.69
	Stevenson	1	1	1	2.94
	Telford	10	9	10	0.93
Survey 5	Survey Area	-	-	-	-
	Three wind farms	-	-	-	-
	MacColl	-	-	-	-
	Stevenson	-	-	-	-
	Telford	-	-	-	-
Survey 6	Survey Area	1,480	1,411	1,552	0.07
	Three wind farms	3	3	3	1.61
	MacColl	0	0	0	-
	Stevenson	1	1	1	2.7
	Telford	2	2	2	2.18

Table 3.3.5 Fulmar population estimates

	Area	Population estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
Survey 1	Survey Area	7,789	7,689	7,896	0.03
	Three wind farms	262	255	269	0.18
	MacColl	37	36	38	0.47
	Stevenson	84	81	86	0.32
	Telford	141	136	146	0.24
Survey 2	Survey Area	14,492	14,242	14,727	0.02
	Three wind farms	939	931	948	0.09
	MacColl	331	326	336	0.16
	Stevenson	247	244	250	0.19
	Telford	361	356	366	0.15
Survey 3	Survey Area	-	-	-	-
	Three wind farms	-	-	-	-
	MacColl	-	-	-	-
	Stevenson	-	-	-	-
	Telford	-	-	-	-
Survey 4	Survey Area	10,785	10,433	11,171	0.03
	Three wind farms	60	59	61	0.37
	MacColl	60	59	61	0.37
	Stevenson	74	72	75	0.34
	Telford	96	95	98	0.3
Survey 5	Survey Area	6,101	5,975	6,257	0.04
	Three wind farms	149	146	151	0.24
	MacColl	53	51	55	0.39
	Stevenson	40	39	41	0.47
	Telford	56	55	58	0.39
Survey 6	Survey Area	6,827	6,772	6,879	0.03
	Three wind farms	404	399	409	0.15
	MacColl	137	134	140	0.25
	Stevenson	152	149	154	0.24
	Telford	115	114	117	0.28

Table 3.3.6 Kittiwake population estimates

	Area	Population estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
Survey 1	Survey Area	-	-	-	-
	Three wind farms	-	-	-	-
	MacColl	-	-	-	-
	Stevenson	-	-	-	-
	Telford	-	-	-	-
Survey 2	Survey Area	35,498	34,286	36,739	0.02
	Three wind farms	2,307	2,211	2,407	0.06
	MacColl	1,379	1,300	1,465	0.08
	Stevenson	747	715	781	0.11
	Telford	181	177	185	0.22
Survey 3	Survey Area	12,471	12,180	12,746	0.03
	Three wind farms	432	429	435	0.14
	MacColl	201	199	202	0.2
	Stevenson	95	94	96	0.3
	Telford	136	134	138	0.25
Survey 4	Survey Area	34,697	32,394	36,767	0.02
	Three wind farms	132	130	133	0.25
	MacColl	40	39	40	0.45
	Stevenson	45	44	45	0.44
	Telford	47	46	48	0.42
Survey 5	Survey Area	17,640	17,076	18,247	0.02
	Three wind farms	61	59	63	0.37
	MacColl	14	14	15	0.75
	Stevenson	31	30	31	0.54
	Telford	16	15	17	0.73
Survey 6	Survey Area	13,731	13,589	13,881	0.02
	Three wind farms	411	400	423	0.14
	MacColl	37	36	39	0.47
	Stevenson	214	206	221	0.2
	Telford	160	156	165	0.23

Table 3.3.7 Great black-backed gull population estimates

	Area	Population estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
Survey 1	Survey Area	-	-	-	-
	Three wind farms	-	-	-	-
	MacColl	-	-	-	-
	Stevenson	-	-	-	-
	Telford	-	-	-	-
Survey 2	Survey Area	-	-	-	-
	Three wind farms	-	-	-	-
	MacColl	-	-	-	-
	Stevenson	-	-	-	-
	Telford	-	-	-	-
Survey 3	Survey Area	-	-	-	-
	Three wind farms	-	-	-	-
	MacColl	-	-	-	-
	Stevenson	-	-	-	-
	Telford	-	-	-	-
Survey 4	Survey Area	-	-	-	-
	Three wind farms	-	-	-	-
	MacColl	-	-	-	-
	Stevenson	-	-	-	-
	Telford	-	-	-	-
Survey 5	Survey Area	267	236	301	0.17
	Three wind farms	0	0	0	-
	MacColl	0	0	0	-
	Stevenson	0	0	0	-
	Telford	0	0	0	-
Survey 6	Survey Area	609	569	651	0.11
	Three wind farms	16	14	18	0.73
	MacColl	1	1	1	2.73
	Stevenson	3	2	3	1.83
	Telford	12	11	14	0.86

Table 3.3.8 All surveys population estimates

Species	Area	Population estimate	Lower Confidence Limit	Upper Confidence Limit	Precision
Guillemot	Survey Area	69,485	68,801	70,247	0.01
	Three wind farms	6,832	6,774	6,893	0.02
	MacColl	2,653	2,620	2,689	0.03
	Stevenson	2,175	2,150	2,199	0.04
	Telford	2,004	1,970	2,039	0.04
Razorbill	Survey Area	59,846	58,936	60,861	0.01
	Three wind farms	2,517	2,495	2,538	0.04
	MacColl	1,085	1,070	1,097	0.05
	Stevenson	751	740	762	0.07
	Telford	681	670	692	0.07
All Guillemot / Razorbill	Survey Area	149,353	147,161	151,610	0
	Three wind farms	6,832	6,774	6,893	0.02
	MacColl	2,653	2,620	2,689	0.03
	Stevenson	2,175	2,150	2,199	0.04
	Telford	2,004	1,970	2,039	0.04
Puffin	Survey Area	11,780	11,686	11,874	0.02
	Three wind farms	5,41	537	544	0.08
	MacColl	247	245	249	0.11
	Stevenson	157	156	158	0.15
	Telford	137	136	138	0.16
Fulmar	Survey Area	21,241	20,973	21,541	0.01
	Three wind farms	880	872	887	0.06
	MacColl	290	287	293	0.1
	Stevenson	245	243	247	0.12
	Telford	345	341	349	0.1
Kittiwake	Survey Area	47,765	46,484	48,993	0.01
	Three wind farms	1,225	1,197	1,256	0.05
	MacColl	514	493	534	0.08
	Stevenson	494	482	506	0.09
	Telford	217	212	222	0.13
Great black-backed gull	Survey Area	950	903	1,000	0.06
	Three wind farms	5	5	5	0.82
	MacColl	1	1	1	2.28
	Stevenson	3	2	3	1.14
	Telford	2	2	2	1.46

3.4. Marine Mammals

3.4.1. Abundance

3.4.1.1. Cetaceans

These data relate to cetaceans at group level (i.e. whales, dolphins, porpoises) and do not include those identified beyond group level, which appear separately below. Cetaceans were recorded in surveys 1, 3, 4, 5 and 6, with no cetaceans recorded during survey 2 (Table 3.4.1.1.1).

Table 3.4.1.1 Counts of cetaceans in each survey of the Moray Firth survey area.

Survey No.	Count
1	1
2	0
3	3
4	1
5	7
6	3

3.4.1.2. Dolphin / porpoise

Dolphins / porpoises were recorded in all surveys except survey 2. Numbers were highest during survey 1 when 31 individuals were recorded (Table 3.4.1.2.1).

Table 3.4.1.2 Counts of dolphins / porpoises in each survey of the Moray Firth survey area.

Survey No.	Count
1	31
2	0
3	3
4	15
5	19
6	29

3.4.1.3. Phocids

Phocids were recorded in surveys 1, 2, 5 and 6. No phocids (seals) were recorded during surveys 3 and 4 (Table 3.4.1.3.1). Numbers were highest during survey 5 when seven individuals were recorded (Table 3.4.1.3.1).

Table 3.4.1.3 Counts of phocids in each survey of the Moray Firth survey area

Survey No.	Count
1	2
2	1
3	0
4	0
5	7
6	1

3.4.2. Distribution

3.4.2.1. Cetaceans

Cetaceans, all of which were identified as dolphins / porpoises, were distributed evenly throughout the survey area during survey 1 (Figure 3.4.2.1). No cetaceans were observed during survey 2. During survey 3, six cetaceans, including three dolphins / porpoises and one whale, were recorded in the centre of the Moray Firth survey area (Figure 3.4.2.3). Sixteen cetaceans were recorded during survey 4 including nine dolphin species and a common dolphin in the south west of the Moray Firth survey area, and a whale towards the south of the North Caithness Cliffs SPA (Figure 3.4.2.4). In Survey 5, cetaceans were distributed throughout the survey area, with a concentration close to the Troup Pennan and Lion's Head SPA (Figure 3.4.2.2.5). Nineteen of the cetaceans recorded during Survey 5 were recorded as dolphins / porpoises and a whale was recorded in the centre of the Moray Firth survey area (Figure 3.4.2.2.5). Thirty-two cetaceans were recorded during survey 6 (Figure 3.4.2.2.6), including 29 identified as dolphin / porpoises. These were distributed throughout the survey area. A whale was also observed during survey 6 close to the coast, north of the East Caithness Cliffs SPA.

3.4.2.2. Phocids

During survey 1, phocids were observed on the coast close to Wick in the north east of the survey area (Figure 3.4.2.1). In survey 2, phocids were observed on the opposite side of the Moray Firth, within the Troup, Pennan and Lion's Heads SPA (Figure 3.4.2.2). No phocids were observed during surveys 3 and 4. During survey 5, seven phocids, including one grey seal, were observed close to the North Caithness Cliffs SPA and a small group of common seals (n=5) were observed within the Troup, Pennan and Lioness's Heads SPA (Figure 3.4.2.2.5). During survey 6, phocids were observed on the coast in the north east of the survey area (Figure 3.4.2.2.6).

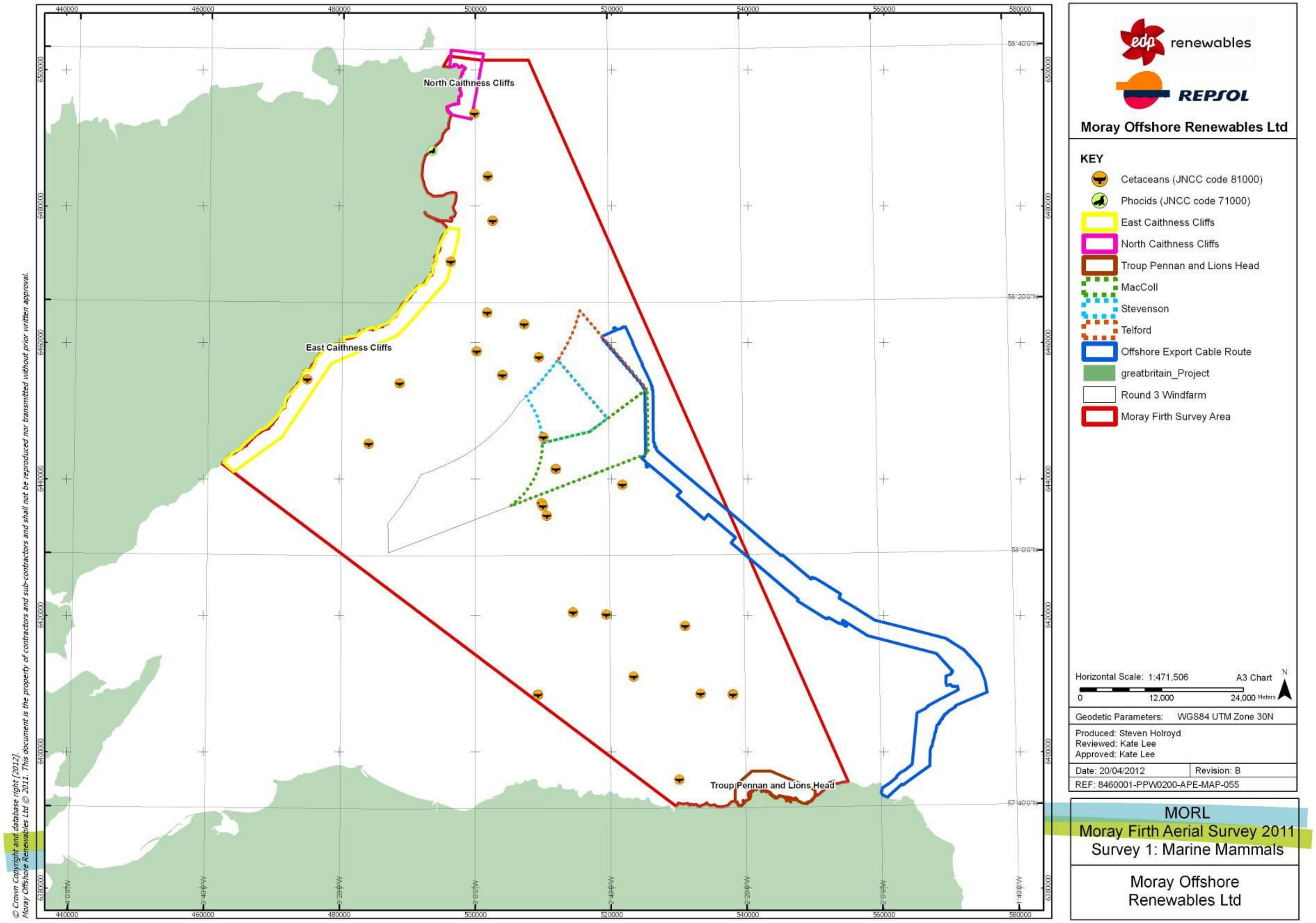


Figure 3.4.2.1 Distribution of marine mammals recorded in the Moray Firth in Survey

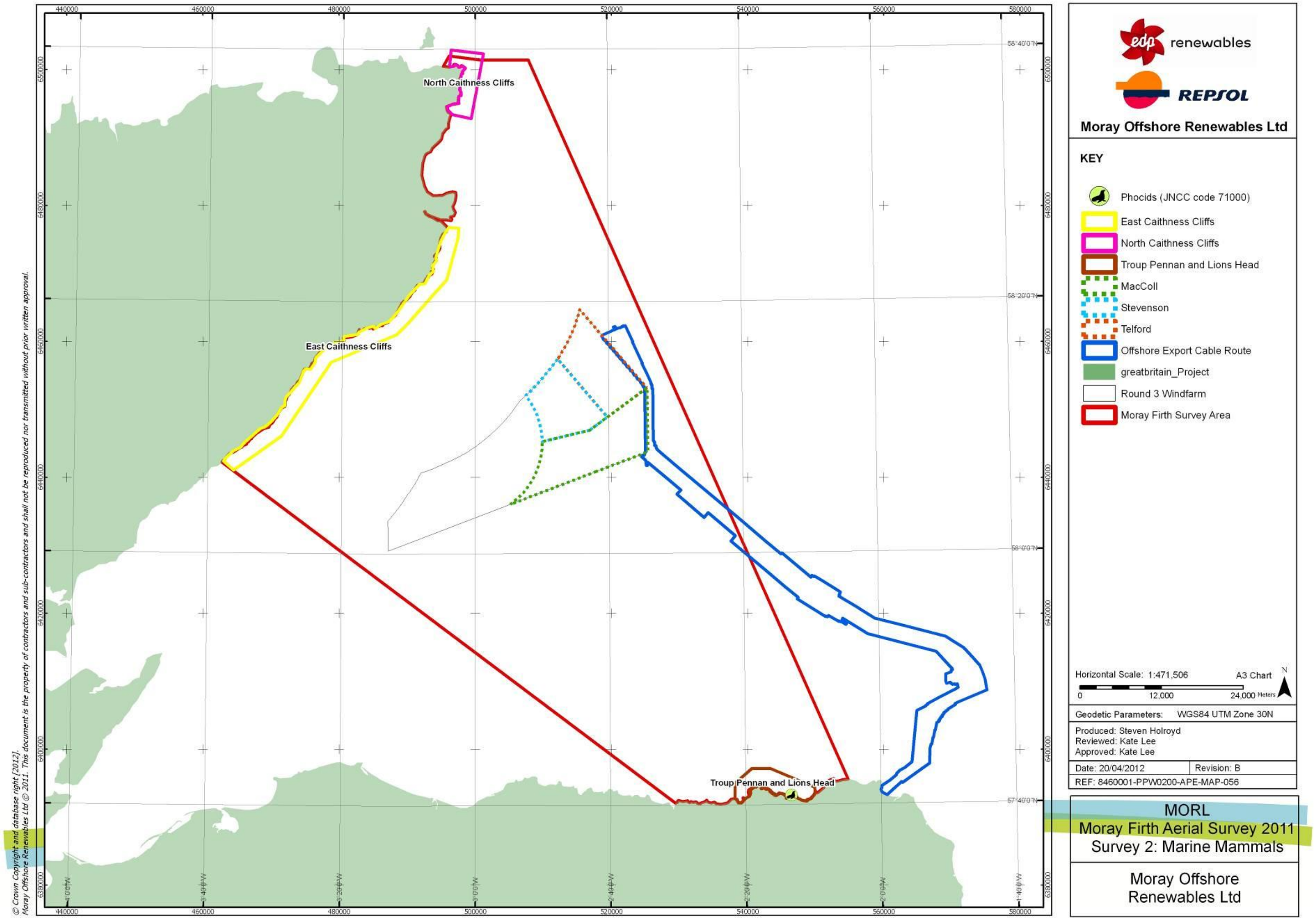


Figure 3.4.2.2 Distribution of marine mammals recorded in the Moray Firth in Survey 2

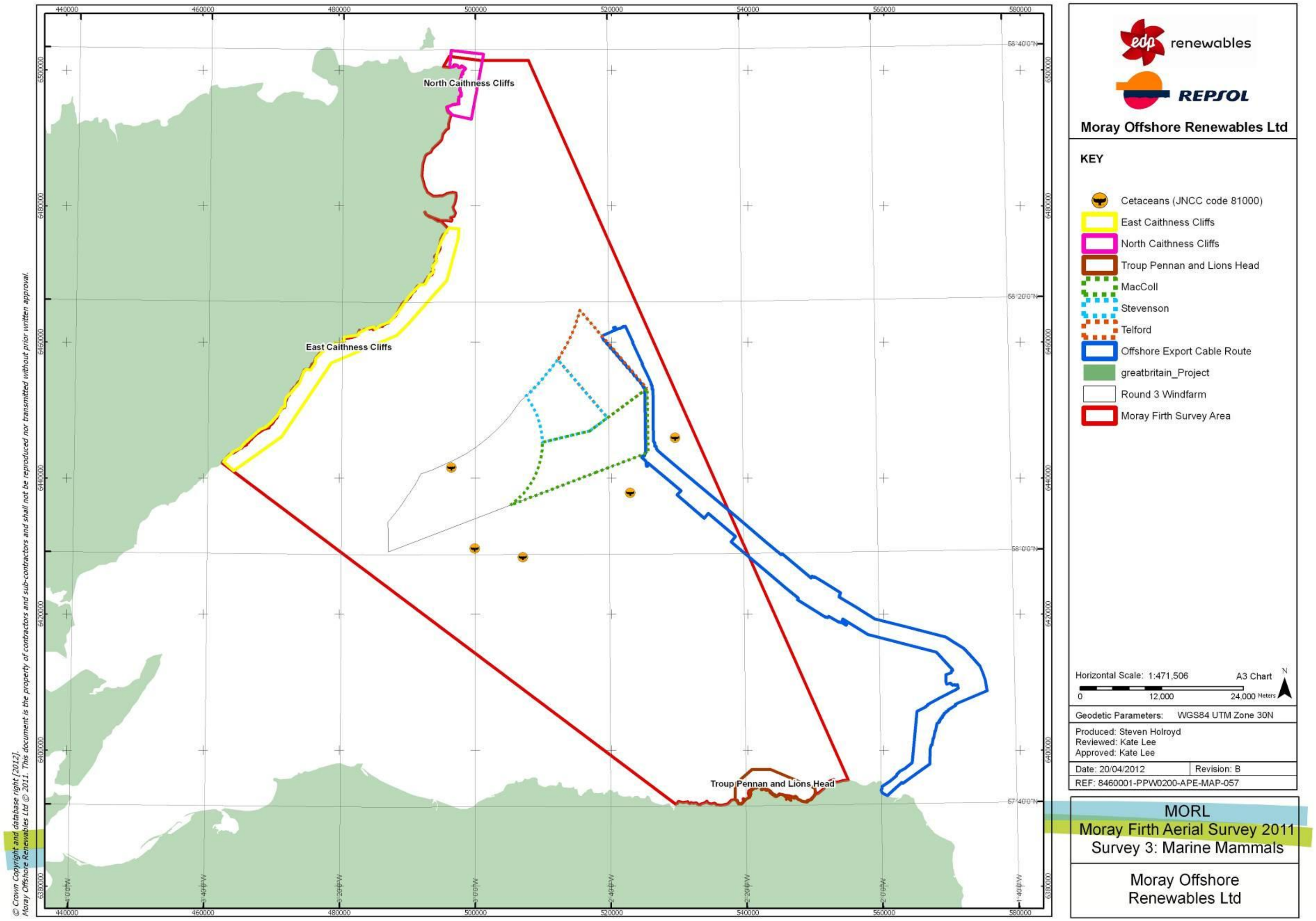


Figure 3.4.2.3 Distribution of marine mammals recorded in the Moray Firth in Survey 3

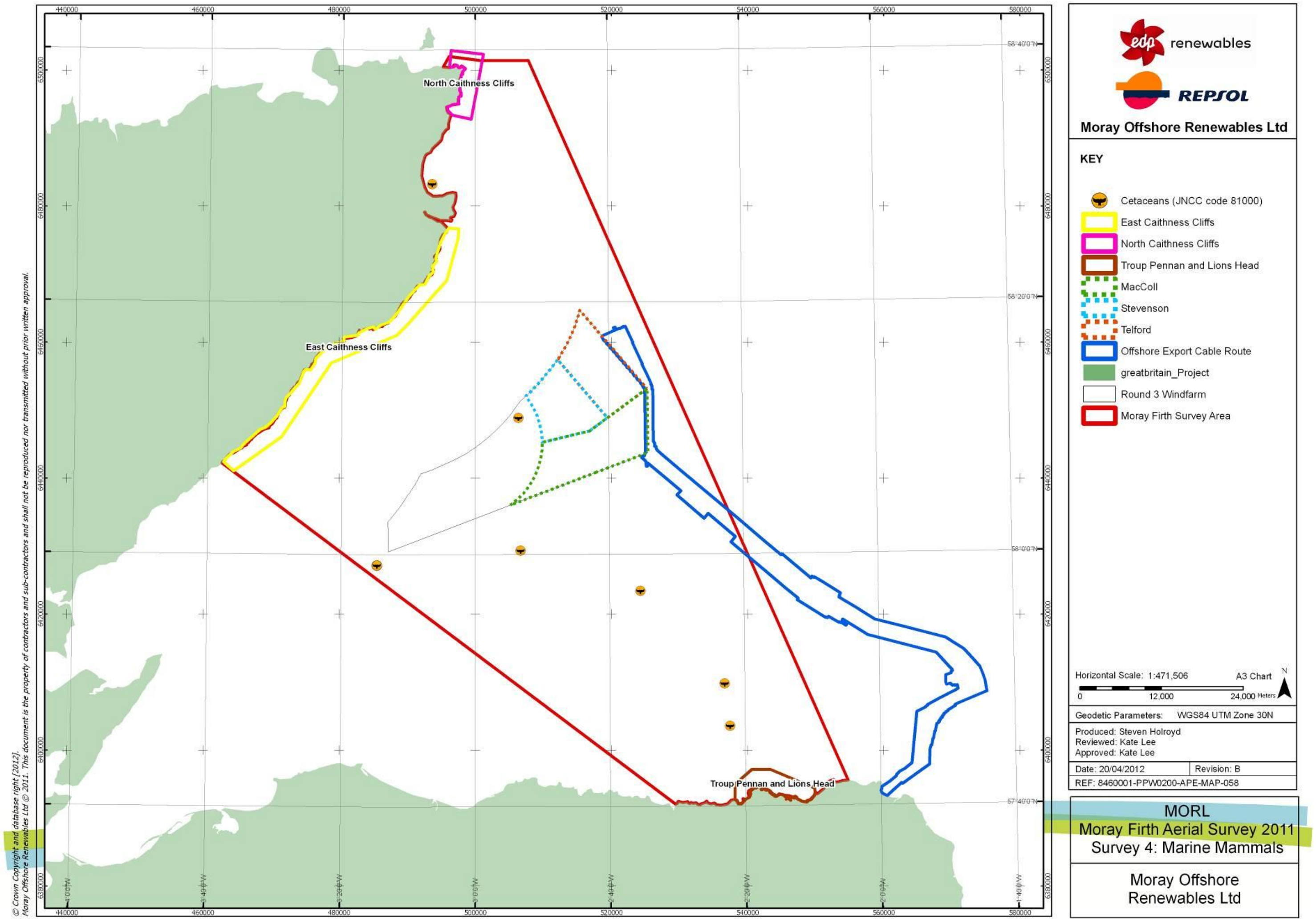


Figure 3.4.2.4 Distribution of marine mammals recorded in the Moray Firth in Survey 4

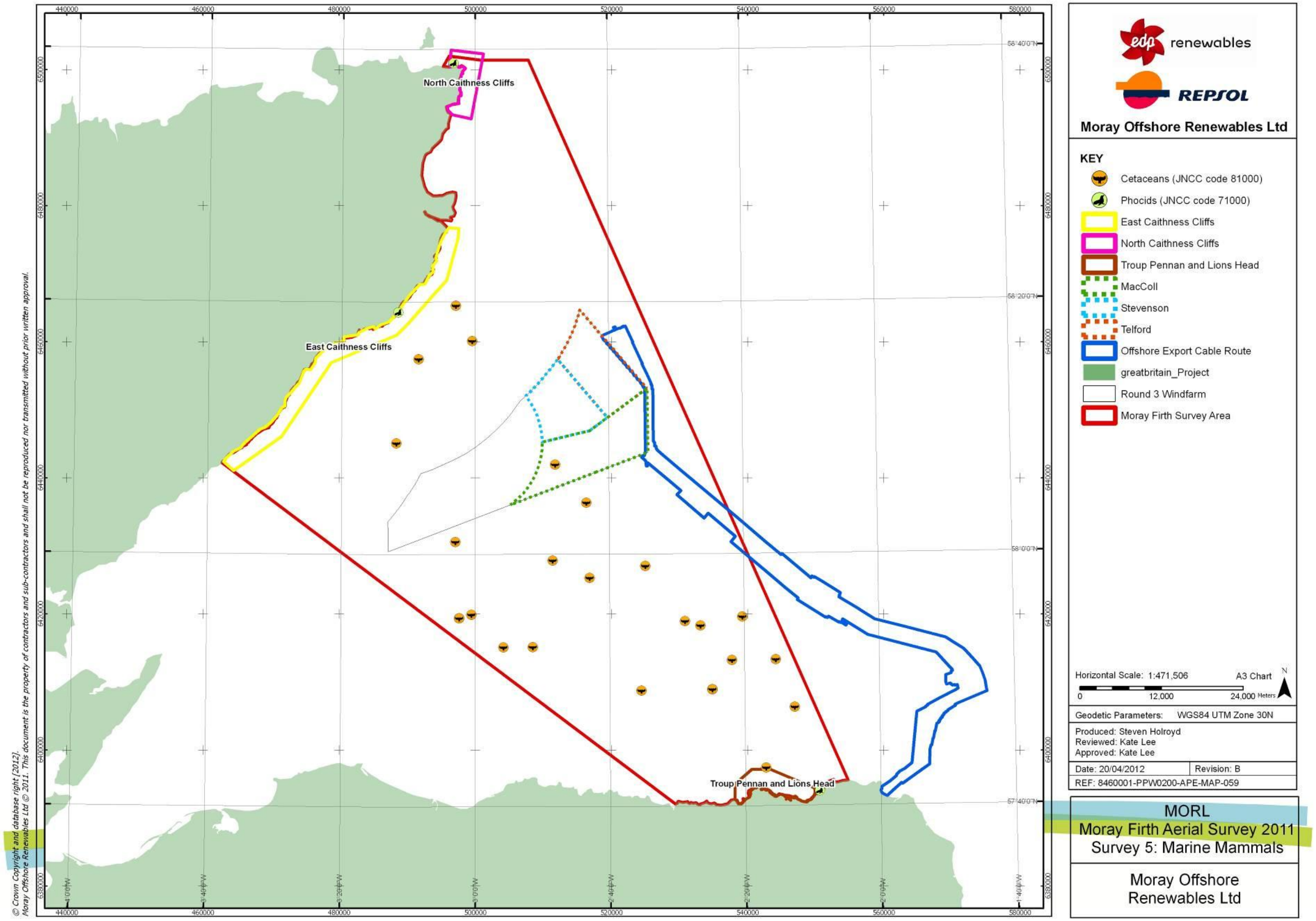


Figure 3.4.2.5 Distribution of marine mammals recorded in the Moray Firth in Survey 5

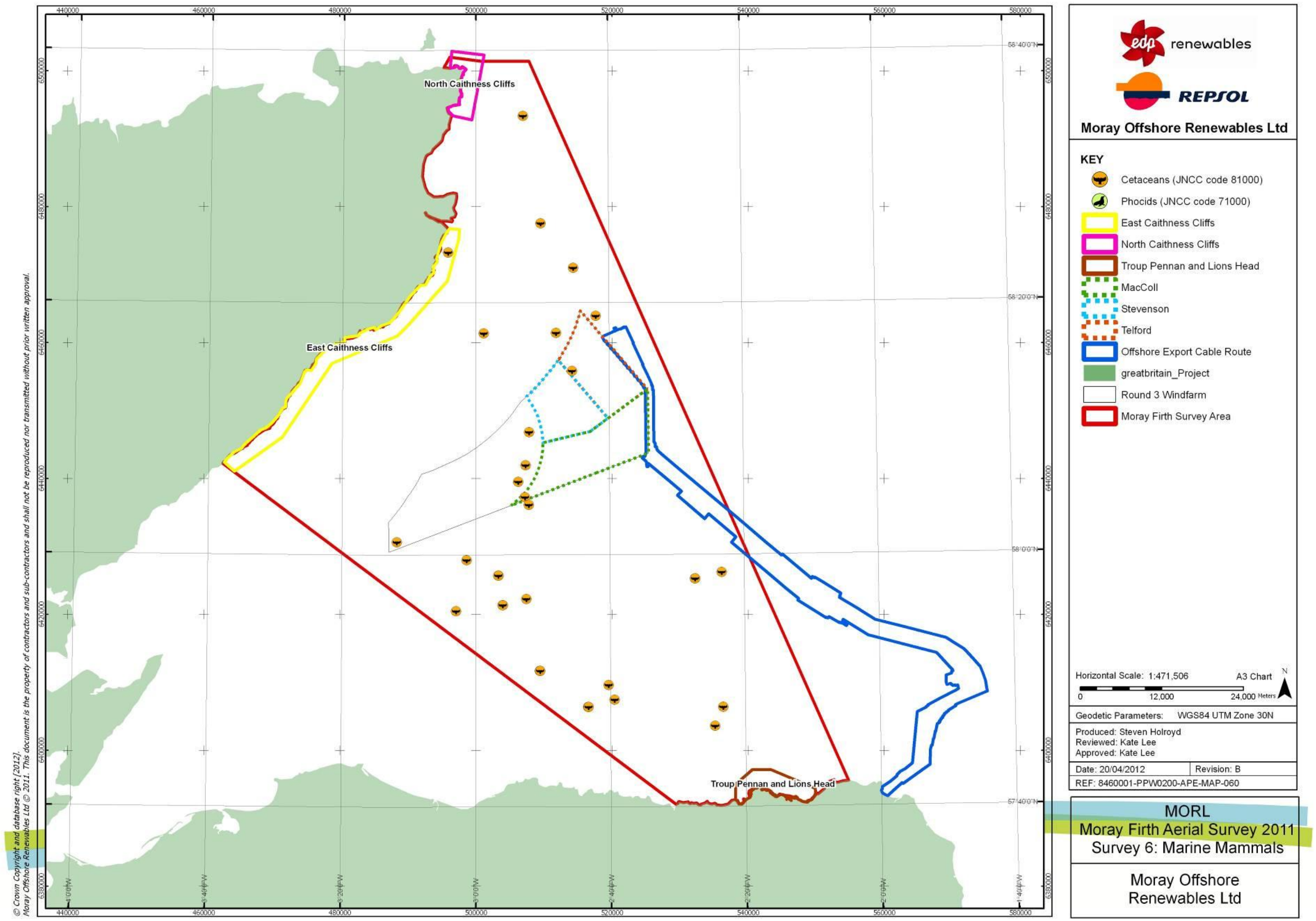


Figure 3.4.2.6 Distribution of marine mammals recorded in the Moray Firth in Survey 6

3.5. Beatrice Demonstrator Wind Farm Aerial Survey

A dedicated survey, designed to collect information regarding the population and distribution of bird and marine mammals observed within the vicinity of the Beatrice Demonstrator Wind Farm site, was undertaken during surveys 4, 5 and 6. No birds were recorded during survey 4 and marine mammals were absent from all surveys. The results of surveys 5 and 6 are summarised in Table 3.5.1and Table 3.5.2, and shown in Figure 3.5.1and Figure 3.5.2 respectively.

Table 3.5.1 Survey 5 observations

Common name	Observations
Guillemot / razorbill	1
Small gull	1
Kittiwake	5
Total	**7**

Table 3.5.2 Survey 6 observations

Common name	Observations
Kittiwake	1
Total	**1**

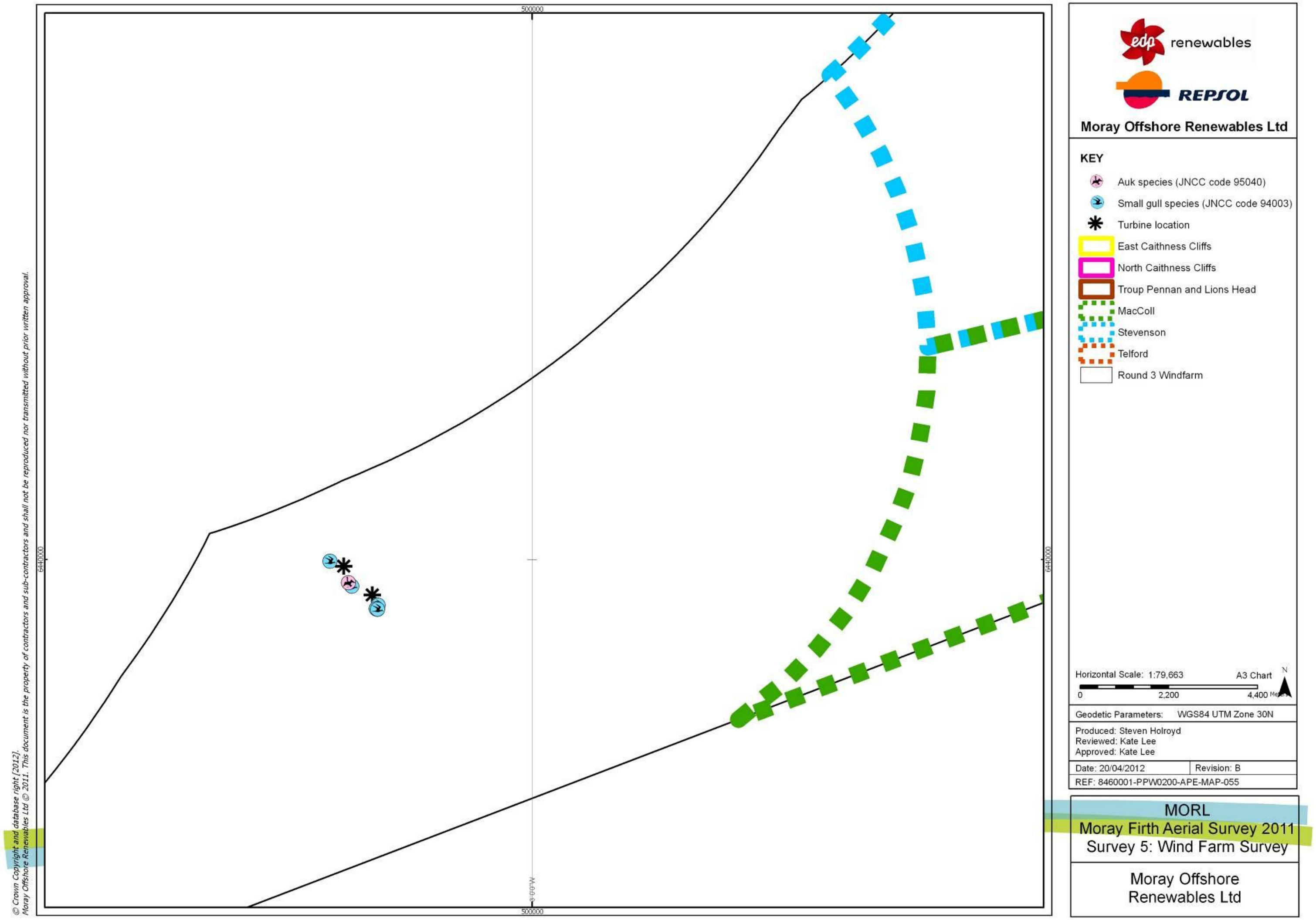


Figure 3.5.1 Distribution of bird species around the Beatrice wind turbines during survey 5

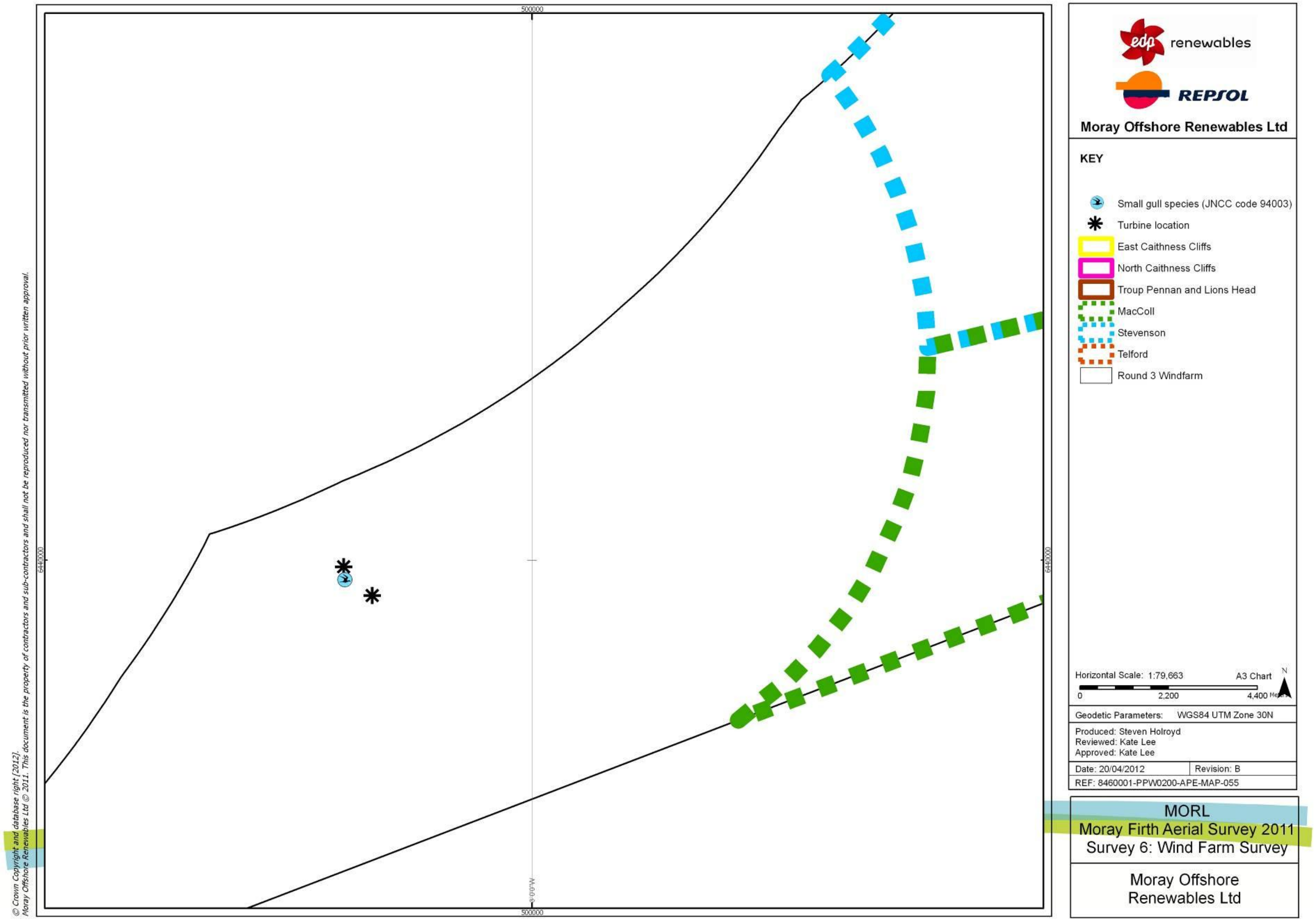


Figure 3.5.2 Distribution of bird species around the Beatrice wind turbines during survey 6

Of the seven birds observed during survey 5, all were in flight apart from the small gull, which was observed sitting on the water at the time of survey. The kittiwake observed in survey 6 was recorded in flight at the time of survey. All of the birds (both surveys) were observed within 0.5 km of the turbines.

3.6. External QA Results

Of the images analysed from the first grid for each survey, 10% of the birds identified were then selected randomly for external QA by BTO. A confusion matrix is created to show the degree of agreement and identify areas of potential misidentification. Table 3.6.1 below shows the external QA results which passed for all six surveys.

Table 3.6.1 External QA results

Survey	Agreement	Images QA'd	Overall
1	44	45	98%
2	70	76	92%
3	41	42	98%
4	86	88	98%
5	53	58	91%
6	24	24	100%

4. Discussion

4.1. Overview

Digital aerial surveys have generated a wealth of data on distribution and orientation of key species (guillemots, razorbills, puffins, fulmars, kittiwakes and great black-backed gulls). These data have been analysed to estimate the population of birds using the proposed development area (Round 3 Zone and Telford, Stevenson and MacColl wind farms) and to make inferences about connectivity between the proposed wind farm area and nearby SPAs (predominantly East Caithness Cliffs, North Caithness Cliffs and Troup, Pennan and Lion's Heads SPAs).

4.2. General distribution

It was usual for all key species to show highest densities closest to coastal colonies, at least in some surveys; this pattern was also reflected by the 'all surveys' models for the key species. This is perhaps unsurprising, as non-foraging birds are likely to be captured in flight around the colonies, as well as departing and arriving individuals. However, the relationship between distance from the colony and bird density is far from clear, and can be dependent on many factors including species (BirdLife International 2012 and references therein), prey availability (Monaghan *et al*. 1994; Suryan *et al*. 2000) and time of day (Webb *et al*. 1985). All of the key species considered here are capable of undertaking foraging trips many kilometres offshore.

Away from SPAs, relative density differed by species. The guillemot model for all surveys predicted highest densities in the northern and western areas of the survey area, with high concentration close to the Troup, Pennan and Lion's Heads SPA. Razorbill and all guillemot and razorbill models show a more even distribution, with higher densities along the coastlines and patches of higher density close to the Round 3 Zone. Puffins showed some tendency to a distribution weighted to the north and south of the Round 3 Zone, consistent with associations with SPAs, with a lower density across the wind farm area. Fulmars were distributed evenly with the exception of higher densities north of the Round 3 Zone and in the south east of the survey area; this perhaps reflects wider foraging ranges of this species (BirdLife International 2012 and references therein). Similarly, both kittiwakes and great black-backed gulls were fairly evenly spread away from the coast, with occasional areas of higher density extending into the wind farm area.

4.3. Flight directions

Orientation of birds within this area was analysed to examine linkages with SPAs. Pooling orientation preferences over all six surveys provided some insight, although some caution needs to be exercised. Headings of birds reveal direction of flight, and this can be used to infer linkages with sites on land. However, it should be considered that nesting seabirds frequently make 'commuting' flights (Weimerskirch 2007) when foraging offshore. Based on prior knowledge of profitable feeding grounds, these outward flights manifest themselves as predictable and straight-line orientations (e.g.

Weimerskirch 2007; Pettex *et al*. 2010), such that there may be beeline orientation both on the outward and return journeys. Suggested bimodality therefore may reflect birds arriving from and departing to the same SPAs (i.e. bimodal orientation along the axis between the Round 3 Zone and a SPA); alternatively it may reflect birds heading for SPAs in opposing directions. It is unclear whether the former possibility is supported by predictable and consistent feeding areas for birds within the Moray Firth area, resulting in beeline orientation ('commuting') on the outward journey, or whether birds do indeed take an array of directions on the foraging leg depending on individual knowledge and unpredictability of prey resources.

Accepting these caveats, guillemots recorded in the north and west of the Round 3 Zone showed some evidence of an orientation preference along a north west – south east axis. For those individuals located towards the north of the area, this orientation pattern suggests return flights to and from both North and East Caithness Cliffs SPAs, whilst those individuals further west may reflect linkages to all three SPAs, with those flying away from one SPA possibly orientating towards another. Guillemots located in the east of the survey area did not show a bimodal orientation and appeared to be orientated towards the Troup, Pennan and Lion's Head SPA.

Pooled razorbill orientation revealed that many individuals in the Round 3 Zone were heading in a south easterly direction, perhaps indicating birds arriving from northern SPAs or heading to Troup, Pennan and Lion's Heads SPA in the south. However, since razorbills are capable of foraging up to 95 km from breeding colonies (Thaxter *et al*. 2012) the possibility of linkages to northerly SPAs cannot be ruled out and it is likely that razorbills present within the survey area represent individuals breeding at all three SPAs. This was also the case for guillemots / razorbills identified to group level.

Relatively few puffins were recorded in coastal areas of the survey site, possibly reflecting their wide foraging range (Thaxter *et al.* 2012). Those individuals recorded in the Telford wind farm showed a southerly orientation trend, possibly reflecting departure from the north on foraging trips. No strong trend in orientation was apparent elsewhere within the survey area, making it difficult to convincingly argue for direct evidence of linkages between the SPAs and the Round 3 Zone, although given the importance of the SPAs for the species, it is likely that most of the puffins recorded offshore would be linked to these sites.

Fulmars were widespread throughout the survey area, and were scattered in their orientations. This lack of any directional trends may be reflective of fulmar flight behaviour; fulmars are known to change direction and wheel around in order to extend their gliding flight (Pennycuik 1959; BirdLife International 2012). However, the Round 3 Zone is well within the mean foraging range of fulmars (70 km: BirdLife International 2012), meaning linkages to all SPAs are feasible.

Although kittiwakes were widespread across the survey area, the greatest concentrations of these birds were in close proximity to cliff colonies within the SPAs. Directional patterns were particularly difficult to discern for individuals located close to colonies, which may be reflective of individuals departing from and arriving at breeding sites. Further offshore, there was a trend for individuals to be orientated towards southerly directions. Again, this could reflect birds flying away from the north on foraging trips or towards the south on return. Kittiwakes have been shown to forage up to 74 km from their breeding colony (Daunt *et al*. 2002), indicating that the Round 3 Zone would fall within range of all three SPAs and that linkages between each of them cannot be ruled out.

Pooled great black-backed gull orientation showed individuals recorded within the Round 3 Zone were flying towards the south and west. However, these directions were based on low numbers of individuals since most great black-backed gulls were located within 16 km of the coastline. Since great black-backed gulls are generalist feeders (BirdLife International 2012 and references therein), it is likely that this species may change direction frequently during a foraging trip rather than undertaking straight-line flights. It is therefore difficult to infer linkages between the SPAs and the Round 3 Zone for great black-backed gulls. Given the importance of the SPAs for the species it is likely that a proportion of individuals recorded offshore would be linked to these sites.

4.4. Population estimates

Estimates were produced for each of the six key species, in addition to combined guillemots / razorbills.

Guillemots were the most abundant of the speciated auks within the survey area, with a peak abundance estimate of 50,049 (lower CL: 49,567, upper CL: 50,524) for the survey area. This is to be expected since East and North Caithness Cliffs SPAs, together with the SPA at Troup, Pennan and Lion's Heads are designated for 5.7% of the East Atlantic breeding populations of guillemots (Stroud *et al*. 2001. Within the three wind farm sites, a peak estimate of 3,135 (lower CL: 3,108, upper CL: 3,164) individuals were present. Precision was high for both estimates (*CV* = 0.01 and 0.05 respectively), equating to a Class 1 and Class 2 level of precision respectively (Bohlin, 1990). Precision of estimates across the whole survey area was high throughout (*CV* < 0.02), and for most of the estimates for the three wind farm sites (*CV* < 0.16 on five of six surveys).

Across the six surveys, the peak abundance estimate for razorbills was slightly lower than for guillemots at 40,381 individuals (lower CL: 39,991, upper CL: 40,780). However, a greater number of razorbills were estimated within the three wind farm sites in comparison to guillemots, with a peak estimate of 4,283 individuals (lower CL: 4,219, upper CL: 4,348). Razorbill population estimates for both of the areas had a high level of precision (*CV* = 0.01 and 0.04 respectively), equating to a Class 1 and Class 2 level of precision respectively (Bohlin, 1990). Precision of estimates across the whole survey area was high throughout (*CV* < 0.03), and for the majority of the estimates for the three wind farm sites (*CV* < 0.16 on five of six surveys).

Abundance of all guillemots and razorbills combined peaked at 86,882 (lower CL: 86,023, upper CL: 87,810) for the survey area, and 7,490 (lower CL: 7,441, upper CL: 7,541) for the three wind farm sites. Guillemots and razorbills combined were therefore the most abundant group of all of the six key species within the Moray Firth survey area. Class 1 and Class 2 levels of precision were reached for each area respectively (*CV* = 0.01 and 0.03), reflecting the high abudance. Precision of estimates across the whole survey area and for the three wind farm sites were high throughout (*CV* < 0.02 and < 0.13 respectively).

Abundance estimates for puffins peaked at 6,217 (lower CL: 6,080, upper CL: 6,353) for the survey area, and 408 (lower CL: 400, upper CL: 415) for the three wind farm sites. Puffins were therefore the least abundant of all three auk species present during the surveys. Precision was still high for both areas (*CV* = 0.04 and 0.14 respectively), equating to a Class 1 level of precision across the survey area and Class 3 for the three wind farm sites (Bohlin, 1990). Precision of estimates across the whole survey area was high throughout (*CV* < 0.07), but only reached < 0.16 for one of the six surveys of the three wind farm sites, due to low puffin abundance in this area.

Peak abundance estimates for fulmars were 14,492 (lower CL: 14,242, upper CL: 14,727) for the survey area, and 939 (lower CL: 931, upper CL: 948) for the three wind farm sites. Fulmars were therefore abundant within the Moray Firth area. Since fulmars have a mean foraging range of 47.5 km and are capable of much greater movements (up to 580 km; Thaxter *et al*. 2012), a more widespread and pelagic distribution in comparison to other species such as auks, is to be expected. Class 1 and Class 2 levels of precision (Bohlin, 1990) were reached for each area respectively (*CV* = 0.02 and 0.09 respectively). Precision of estimates across the whole survey area was high throughout (*CV* < 0.04), and for two of the estimates for the three wind farm sites (*CV* < 0.15).

Peak abundance estimates for kittiwakes reached 35,498 (lower CL: 34,286, upper CL: 36,739) for the survey area, and 2,307 (lower CL: 2,211, upper CL: 2,407) for the three wind farm sites. Kittiwakes were therefore the second most abundant species group within the survey area, after auks, both across the whole survey area and within the three wind farm sites. High numbers of kittiwakes in the Moray Firth are to be expected since all three SPAs list kittiwakes as part of a breeding seabird assemblage (Stroud *et al*. 2001). Precision was again high (*CV* = 0.02 and 0.06 respectively), equating to a Class 1 and Class 2 level of precision respectively (Bohlin, 1990). Precision of estimates across the whole survey area was high throughout (*CV* < 0.04), and for three of the estimates for the three wind farm sites (*CV* < 0.15).

Great black-backed gull abundance peaked at 609 (lower CL: 569, upper CL: 651) for the survey area. Abundance within the three wind farm sites was only available for survey 6 with an estimate of 16 individuals (lower CL: 14, upper CL: 18). Great black-backed gulls were therefore the least abundant of the six key species of interest within the survey area. This is to be expected since only East Caithness Cliffs SPA is designated for great black-backed gulls as part of a breeding seabird assemblage. Precision was high for the whole survey area (*CV* = 0.11) equating to a Class 3 level of precision (Bohlin, 1990), but not for the three wind farm sites, due to the extremely low great black-backed gull abundance in this area.

4.5. Other SPA features

Other qualifying features of the three SPAs (shags, cormorants, common terns and herring gulls) are discussed with other species recorded on surveys below.

4.6. Other species

A number of shags / cormorants (n = 68) were recorded loafing on rocky outcrops to the north and north west of the survey area, adjacent to the East Caithness Cliffs SPA. All six surveys were conducted at a time when these birds were likely to have been closely associated with breeding colonies. It has been shown that adult shags in particular reduce their foraging range and spend a greater proportion of their time at sea foraging, in order to meet higher energetic demands during the breeding season (Wanless *et al.* 1991). Therefore, a proportion of individuals may have been foraging under water at the time of the survey, perhaps contributing to the low number of shags / cormorants observed. Furthermore, those adult shags / cormorants not foraging at the time of the survey are likely to have been on land, attending the nest site and therefore not recorded in the survey images.

In contrast, relatively high numbers of herring gulls (n = 1,050) were recorded which is to be expected since large numbers of this species breed along the area's coastline (e.g. at the Troup, Pennan and Lion's Head SPA).

A total of 642 terns were recorded across the six surveys. Since both Cromarty Firth and Inner Moray Firth SPAs have been designated for breeding common terns (Stroud *et al*. 2001), it is likely that the majority of tern species observed were common terns. Nineteen terns were identified as Arctic terns which are likely to have originated from breeding grounds within the Pentland Firth Islands SPA since the maximum foraging range for this species is approximately 24 km (Thaxter *et al*. 2012). A single sandwich tern was also identified which may have been breeding at the Loch of Strathbeg SPA to the south east, as sandwich terns are capable of longer foraging trips during the breeding season (ca.50 km; Thaxter *et al*. 2012).

Other species or groups recorded included red-throated divers, seaducks (including common eider, scoter and long-tailed duck), a manx shearwater, gannets, skuas (including great skuas), gulls (including black-headed gulls and common gulls) and black guillemots.

4.7. Marine mammals

Low numbers of seals were captured within images at haul-out sites near Wick and within the Troup, Pennan and Lion's Heads SPA.

A total of 112 cetaceans (of which 97 were identified as dolphins / porpoises and four were identified as whales) were recorded across the six surveys, with the majority on the first survey. Data was submitted to Aberdeen University for further treatment.

5. Conclusions

- Six high resolution digital still imagery aerial surveys yielded substantial data on distribution and directional preferences of six key species, in relation to key SPAs.
- General patterns of distribution highlighted that for most species, densities were highest close to breeding colonies. Many individuals were also located further offshore.
- Patterns of orientation suggested that guillemots within the Round 3 Zone could be linked with all three SPAs. Peak abundance estimates for guillemots reached 50,049 (lower CL: 49,567, upper CL: 50,524, *CV* = 0.01) for the survey area and 3,135 (lower CL: 3,108, upper CL: 3,164, *CV* = 0.05) for the three wind farm sites.
- Many razorbills within the Round 3 Zone (plus buffer) were heading in a south easterly direction, perhaps suggesting arrival at foraging grounds from northern SPAs or departure to breeding sites at Troup, Pennan and Lion's Heads SPA. The peak abundance estimate for razorbills was 40,381 (lower CL: 39,991, upper CL: 40,780, *CV* = 0.01) for the survey area, and 4,283 (lower CL: 4,219, upper CL: 4,348, *CV* = 0.04) for the three wind farm sites.
- No strong trend in orientation was apparent for puffins, although given the importance of the SPAs for this species it is likely that most of the puffins recorded offshore would be linked to these sites. Abundance estimates for puffins peaked at 6,217 (lower CL: 6,080, upper CL: 6,353, *CV* = 0.04) for the survey area, and 408 (lower CL: 400, upper CL: 415, *CV* = 0.14) for the three wind farm sites.
- Although fulmars were widespread throughout the Round 3 Zone, their large foraging range may indicate that linkages between all three SPAs exist. Peak abundance estimates for fulmars were 14,492 (lower CL: 14,242, upper CL: 14,727, *CV* = 0.02) for the survey area, and 939 (lower CL: 931, upper CL: 948, *CV* = 0.09) for the three wind farm sites.
- There was a trend for kittiwakes located offshore to be orientated towards the south, perhaps reflecting birds flying away from the north on foraging trips or towards the south on return. Peak abundance estimates for kittiwakes reached 35,498 (lower CL: 34,286, upper CL: 36,739, *CV* = 0.02) for the survey area, and 2,307 (lower CL: 2,211, upper CL: 2,407, *CV* = 0.06) for the three wind farm sites.
- No strong trends in orientation were detected for great black-backed gulls. However, given the importance of the SPAs for this species it is likely that most individuals recorded offshore would be linked to these sites. Peak abundance for great black-backed gulls reached 609 (lower CL: 569, upper CL: 651, *CV* = 0.11) for the survey area, and 16 (lower CL: 14, upper CL: 18, *CV* = 0.73) for the three wind farm sites.
- Other bird species and groups recorded included cormorants / shags, herring gulls, terns, gannets and skuas.
- Several seals and cetaceans were also captured in digital images.

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APPENDIX I: JNCC BIRD GROUPS

No.	JNCC Code	Grouping	Species Code	Species
1	95003	Diver species	20	Red-throated Diver
2		Diver species	30	Black-throated Diver
3		Diver species	40	Great Northern Diver
4	95004	Grebe species	90	Great Crested Grebe
5		Grebe species	100	Red-necked Grebe
6		Grebe species	110	Slavonian Grebe
7		Grebe species	120	Black-necked Grebe
8	220	Fulmar	220	Fulmar spp.
9	95006	Shearwater spp.	360 - 480	Shearwater spp.
10	95008	Petrel spp.	500 - 550	Storm-petrel spp.
11	710	Gannet	710	Gannet spp.
12	95009	Cormorant/Shag	720	Cormorant
13			800	Shag
14	95018	Seaduck species	2130	Common Scoter
15		Seaduck species	2150	Velvet Scoter
16	94003	Small Gull species	5900	Common Gull
17	95034	Large Gull species	5910	Lesser Black-backed Gull
18			5920	Herring Gull
19			6000	Great Black-backed Gull
20	95037	Tern species		Tern sp.
21	95040	Auk species	6470	Little Auk
22			6380	Black Guillemot
23			6340	Guillemot
24			6540	Puffin
25			6360	Razorbill
26	71000	All Phocids (e.g. seals)	n/a	
27	80000	All Cetaceans (whales, dolphins)	n/a	

APPENDIX II: LATIN NAMES OF SPECIES OF INTEREST

Common name	**Latin name**
Fulmar	*Fulmarus glacialis*
Gannet	*Morus bassanus*
Cormorant	*Phalacrocorax carbo*
Shag	*Phalacrocorax aristotelis*
Arctic Skua	*Stercorarius parasiticus*
Great Skua	*Stercorarius skua*
Kittiwake	*Rissa tridactyla*
Black-headed gull	*Chroicocephalus ridibundus*
Common gull	*Larus canus*
Lesser black-backed gull	*Larus fuscus*
Herring gull	*Larus argentatus*
Great black-backed gull	*Larus marinus*
Sandwich Tern	*Sterna sandvicensis*
Arctic Tern	*Sterna paradisaea*
Guillemot	*Uria aalge*
Razorbill	*Alca torda*
Black guillemot	*Cepphus grille*
Puffin	*Fratercula arctica*

APPENDIX III: MODEL SUMMARIES

Survey	Species	Modelled abundance	Max	Model	Deviance
Survey 1	Guillemot	50,049	10.30	S(Shoreline, 8.868) + s(X, 8.856) + s(Depth, 8.767) + s(North Caithness SPA, 8.884)	23.6
Survey 1	Razorbill	24,921	8.98	S(Shoreline, 8.805) + s(X, 8.395) + s(Depth, 8.893) + s(North Caithness SPA, 8.647)	26.2
Survey 1	Puffin	5,563	0.66	S(Shoreline, 8.849) + s(X, 8.953) + s(Depth, 1.002) + s(North Caithness SPA, 6.625)	22
Survey 1	Fulmar	7,789	2.96	S(Shoreline, 8.839) + s(X, 8.449) + s(Depth, 8.368) + s(North Caithness SPA, 8.802)	23.9
Survey 1	Kittiwake	-	-	-	-
Survey 1	Great Black-backed Gull	-	-	-	-
Survey 1	Guillemot + Razorbill	86,882	15.30	S(Shoreline, 8.874) + s(X, 8.868) + s(Depth, 8.951) + s(North Caithness SPA, 8.842)	25.5
Survey 2	Guillemot	28,661	23.41	S(Shoreline, 8.937) + s(X, 8.976) + s(Depth, 7.161) + s(North Caithness SPA, 8.891)	19.3
Survey 2	Razorbill	40,381	14.37	S(Shoreline, 8.737) + s(X, 8.923) + s(Depth, 8.800) + s(North Caithness SPA, 8.924)	19
Survey 2	Puffin	6,004	2.90	S(Shoreline, 8.902) + s(X, 8.949) + s(Depth, 8.993) + s(North Caithness SPA, 8.701)	25
Survey 2	Fulmar	14,492	9.16	S(Shoreline, 8.915) + s(X, 8.923) + s(Depth, 8.961) + s(North Caithness SPA, 8.979)	33.1
Survey	Kittiwake	35,498	89.88	S(Shoreline, 8.911) + s(X,	47.2

Survey	Species	Modelled abundance	Max	Model	Deviance
2				8.958) + s(Depth, 8.874) + s(North Caithness SPA, 8.874)	
Survey 2	Great Black-backed Gull	-	-	-	-
Survey 2	Guillemot + Razorbill	73,142	35.11	S(Shoreline, 8.672) + s(X, 8.974) + s(Depth, 8.961) + s(North Caithness SPA, 8.703)	17.6
Survey 3	Guillemot	19,493	4.88	S(Shoreline, 8.491) + s(X, 8.900) + s(Depth, 7.957) + s(North Caithness SPA, 8.927)	19.1
Survey 3	Razorbill	19,143	10.80	S(Shoreline, 8.871) + s(X, 8.946) + s(Depth, 8.840) + s(North Caithness SPA, 8.607)	29.2
Survey 3	Puffin	6,217	5.63	S(Shoreline, 8.886) + s(X, 8.642) + s(Depth, 8.481) + s(North Caithness SPA, 8.890)	32.3
Survey 3	Fulmar	-	-	-	-
Survey 3	Kittiwake	12,471	17.99	S(Shoreline, 8.062) + s(X, 8.899) + s(Depth, 8.968) + s(North Caithness SPA, 8.437)	21.5
Survey 3	Great Black-backed Gull	-	-	-	-
Survey 3	Guillemot + Razorbill	43,291	18.69	S(Shoreline, 8.750) + s(X, 8.910) + s(Depth, 8.894) + s(North Caithness SPA, 8.894)	19.8
Survey 4	Guillemot	28,957	49.50	S(Shoreline, 8.566) + s(X, 7.996) + s(Depth, 8.801) + s(North Caithness SPA, 8.882)	29.8
Survey 4	Razorbill	33,705	286.77	S(Shoreline, 8.650) + s(X, 8.623) + s(Depth, 8.500) + s(North Caithness SPA, 8.871)	36.4
Survey	Puffin	4,178	9.74	S(Shoreline, 8.925) + s(X,	35.9

Survey	Species	Modelled abundance	Max	Model	Deviance
4				8.956) + s(Depth, 8.919) + s(North Caithness SPA, 8.191)	
Survey 4	Fulmar	10,785	19.60	S(Shoreline, 8.903) + s(X, 7.587) + s(Depth, 8.736) + s(North Caithness SPA, 7.740)	50.4
Survey 4	Kittiwake	34,697	176.41	S(Shoreline, 8.854) + s(X, 8.896) + s(Depth, 8.867) + s(North Caithness SPA, 8.469)	63
Survey 4	Great Black-backed Gull	-	-	-	-
Survey 4	Guillemot + Razorbill	85,059	695.05	S(Shoreline, 8.736) + s(X, 8.783) + s(Depth, 8.771) + s(North Caithness SPA, 8.919)	32.9
Survey 5	Guillemot	30,070	20.00	S(Shoreline, 8.756) + s(X, 8.698) + s(Depth, 8.648) + s(North Caithness SPA, 8.906)	26.1
Survey 5	Razorbill	21,212	13.25	S(Shoreline, 8.529) + s(X, 8.589) + s(Depth, 8.913) + s(North Caithness SPA, 8.870)	25.2
Survey 5	Puffin	-	-	-	-
Survey 5	Fulmar	6,101	4.13	S(Shoreline, 8.874) + s(X, 8.844) + s(Depth, 8.255) + s(North Caithness SPA, 8.483)	31.1
Survey 5	Kittiwake	17,640	41.77	S(Shoreline, 8.959) + s(X, 8.895) + s(Depth, 8.295) + s(North Caithness SPA, 8.796)	47.5
Survey 5	Great Black-backed Gull	267	5.05	S(Shoreline, 1.000) + s(X, 7.306) + s(Depth, 1.805) + s(North Caithness SPA, 1.000)	74.3
Survey 5	Guillemot + Razorbill	55,856	24.12	S(Shoreline, 8.644) + s(X, 8.726) + s(Depth, 8.871) + s(North Caithness SPA, 8.920)	27.1
Survey	Guillemot	17,006	5.77	S(Shoreline, 8.746) + s(X,	25.9

Survey	Species	Modelled abundance	Max	Model	Deviance
6				8.860) + s(Depth, 8.935) + s(North Caithness SPA, 8.977)	
Survey 6	Razorbill	9,400	5.64	S(Shoreline, 8.931) + s(X, 8.928) + s(Depth, 8.910) + s(North Caithness SPA, 8.952)	25.2
Survey 6	Puffin	1,480	8.36	S(Shoreline, 8.983) + s(X, 9.000) + s(Depth, 8.997) + s(North Caithness SPA, 8.899)	37.3
Survey 6	Fulmar	6,827	1.53	S(Shoreline, 8.795) + s(X, 8.561) + s(Depth, 8.937) + s(North Caithness SPA, 8.799)	13
Survey 6	Kittiwake	13,731	3.85	S(Shoreline, 8.964) + s(X, 8.939) + s(Depth, 8.755) + s(North Caithness SPA, 8.945)	20.7
Survey 6	Great Black-backed Gull	609	4.12	S(Shoreline, 8.942) + s(X, 8.997) + s(Depth, 8.837) + s(North Caithness SPA, 6.476)	61.5
Survey 6	Guillemot + Razorbill	33,846	10.12	S(Shoreline, 8.667) + s(X, 8.939) + s(Depth, 8.995) + s(North Caithness SPA, 8.984)	24.8
All	Guillemot	69,485	28.91	S(Shoreline, 8.850) + s(X, 8.837) + s(Depth, 7.994) + s(North Caithness SPA, 8.997)	12.8
All	Razorbill	59,846	76.99	S(Shoreline, 8.953) + s(X, 8.654) + s(Depth, 8.909) + s(North Caithness SPA, 8.888)	16.4
All	Puffin	11,780	2.77	S(Shoreline, 8.683) + s(X, 8.814) + s(Depth, 8.504) + s(North Caithness SPA, 8.609)	7.54
All	Fulmar	21,241	8.80	S(Shoreline, 8.980) + s(X, 8.949) + s(Depth, 8.961) + s(North Caithness SPA, 8.969)	25
All	Kittiwake	47,765	77.64	S(Shoreline, 8.978) + s(X, 8.769) + s(Depth, 8.975) + s(North Caithness SPA, 8.965)	35.1

Survey	Species	Modelled abundance	Max	Model	Deviance
All	Great Black-backed Gull	950	3.42	S(Shoreline, 7.985) + s(X, 8.779) + s(Depth, 8.973) + s(North Caithness SPA, 8.841)	52.6
All	Guillemot + Razorbill	149,353	138.85	S(Shoreline, 8.967) + s(X, 8.648) + s(Depth, 8.861) + s(North Caithness SPA, 8.860)	14.8

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