Report name: **Assessment of The Crown Estate Aerial survey marine mammal data for the Firth of Forth development areas**

Authors: Kelly Macleod and Carol Sparling

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Submitted by:
Carol Sparling
SMRU Limited
Scottish Oceans Institute
New Technology Centre
North Haugh
ST ANDREWS
Fife KY16 9SR

Tel: + 44 (0) 1334 479 100
Fax: + 44 (0) 1334 477 878
email: ces@smru.co.uk
website: http://www.smru.co.uk

VAT reg. No. GB 607 6064 48

SMRU LIMITED is a limited company registered in Scotland, Registered Number: 296937.
Registered Office: 5 Atholl Crescent, Edinburgh EH3 8EJ

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1. Introduction

The Crown Estate commissioned a series of aerial surveys of offshore wind farm sites during 2009-2010 around the UK. The Scottish territorial waters and Round 3 sites within the Firths of Forth and Tay were all surveyed during summer 2009 and winter 2009-2010. The surveys employed standard visual aerial survey methods to record seabirds and marine mammals with a view to these data contributing to the baseline information required to inform the Environmental Impact Assessments for each of the lease areas.

The purpose of this report is to provide a brief overview of how the marine mammal data collected on these surveys could be analysed. Legislation requires developers to assess the local density and abundance of marine mammals within the development sites as a minimum, and therefore, an assessment of whether the aerial data would support an analysis to generate such information is the primary goal of this note.

2. Data Files

Before analysis commences, all data files will need to be validated. This is outwith the current scope of work. The data were supplied as ESRI shapefiles and comprised observation and track files for every survey. The conversion from the original data files to shapefiles has corrupted the time field within some files and access to the raw data files would be preferable for any analysis in future.

The validation process would eliminate problems within the data such as multiple codes for the same species, missing values, erroneous codes etc.

No environmental data are contained within the observation or effort files; therefore there is currently no means of assessing the effects of varying sighting conditions on encounter rates of marine mammals. This is an important consideration when comparing differences in density estimates temporally or spatially where they may be real or artifacts of different sighting conditions.

2.1 Data summary

2.1.1 Survey effort

The transect design was based on parallel lines with equal spacing in both the inshore (<12mn, from the coast) and offshore (>12nm) areas. The transect design remained unchanged throughout the surveys and were covered on multiple occasion in each season. Inshore and offshore waters were surveyed between May-August 2009 (summer, Figure 1: Summer survey tracks flown within and out with the 12 nm boundary in 2009.Figure 1) and November 2009 – March 2010 (winter, Figure 2).

2.1.2 Marine mammal sightings

During surveys of inshore waters, seven species of marine mammal were positively identified (Table 1). Of these, the harbour porpoise was most common, especially during summer months. Other marine mammals were identified as far as possible; 'seals' were also commonly recorded particularly during summer. In offshore waters, five species were positively identified; harbour porpoise and 'seals' being the most common (Table 2).

3. Potential Analyses

3.2 Distribution maps

All observation and track files are supplied as shapefiles and presumed to be British National Grid projection with Eastings and Northings in metres. The files can be mapped in any GIS at the appropriate temporal scales i.e. per survey, per month, per season. Whilst distribution maps are useful for showing what species were recorded where at the time of survey, they should be interpreted with care as the amount of survey effort is an important factor in determining sightings distribution and can greatly influence 'apparent density'.

3.3 Encounter rates

Encounter rates can be used as a basic index to make comparisons between 'relative abundance' of different species within an area or between areas and/or time periods. They are not a measure of density and are simply calculated by dividing the number of observations by the amount of survey effort (length of transect). Encounter rates can be generated from the aerial data for each survey and species/species group. Encounter rates do not take into account the factors that affect the detectability of different species on different survey occasions.

3.4 Density estimation

The most common method used to estimate density of marine mammals is analysis of surveys using a line transect approach where exact measurements of distances to sightings are recorded in the field. This approach records all marine mammals from the transect line out to the edge of the observer field-of-view and relies on the fundamental assumption that all animals are recorded on the transect line, but some can be missed away from the line. The probability of missing animals increases with increasing distance from the transect line; this relationship can be modeled by fitting a 'detection function' to the perpendicular distances to the observations recorded in the field. The recommended sample size to fit a detection function is 60-80 observations; although it is often possible to fit an adequate detection function with fewer.

Having carried out a preliminary assessment of the data, the following analyses to derive density and abundance estimates could be undertaken:

3.4.1 Strip transect analysis

a. Seasonal density of harbour porpoise and 'seals' in surveys covering inshore waters (inside 12nm)

For the observations recorded during summer and winter surveys of the inshore waters, there are only sufficient observations for harbour porpoise (50) and seals (72) to fit a detection function. However, the methodology employed during the aerial surveys is optimized for recording bird data and is essentially a modified strip transect approach, where a detection function is fitted to observations allocated to four distance bands (44-163m (A), 163-282m (B), 282 -426m (C) and 426-1000 m (D)). However, the search protocol and corresponding behaviour of observers has seriously affected the ability to fit a detection function to the marine mammal data. One would expect detections in all distance bands but they should be greatest in Band A before progressively declining to Band D – the function is fitted with a wide shoulder at Band A and then a slope and tail out to the furthest distance. However, as an example, for harbour porpoises recorded in inshore waters pooled over summer and winter, there are 41 observations in Band A, 9 observations in Band B and none in Bands C and D (Table 3). A detection function cannot be fitted to these data. Therefore, the recommended approach would be to treat the data as a strip transect of width 44-163m (Band A). The strip transect approach assumes that you observe all animals present within the strip. This assumption will be seriously violated because marine mammals spend a proportion of their time underwater and also are easily missed by observers. The consequence of this approach is that density will be considerably underestimated.

The analysis of the 'seal' data (include those classified as 'seal' and 'grey seal') would have to take the same approach. In the inshore waters, data pooled across summer and winter, there were 52 observations in Band A, 19 in Band B and none in Bands C and D. This would make no distinction between the two different species of seal, which may be important in terms of assessing impacts given the very different conservation status of the two species.

For both harbour porpoise and seals, density estimates could be derived for winter and summer for the inshore waters survey area. However, these would be minimum estimates and would need to be caveated with reference to the inherent negative bias.

b. Seasonal density of 'harbour porpoises', 'seals' and white-beaked dolphin in surveys covering the waters beyond the 12nm territorial waters limit.

The data for the most numerous species/species categories from surveys conducted beyond the 12 nm limit also show a predominance of sightings in the Band A (Table 4). There are more sightings of harbour porpoise, seals and white-beaked dolphin compared to the inshore waters surveys but the 'spiked' nature of the data is similar therefore it is unlikely that a detection function can be fitted to these data. The total area surveyed is larger in the offshore area so these differences in numbers of sightings cannot be used to infer any differences in relative abundance without first taking survey effort into account. Similar to the inshore area, these data could be used to estimate the density of the most commonly sighted marine mammal species using a strip transect approach in the survey area that assumes a strip width equivalent to Band A for summer and for winter, but would represent a minimum estimate.

3.4.2 Spatial modeling

Density estimates could also be derived by modeling the counts of animals against a suite of environmental covariates. The relationship between the response and explanatory variables can then be used to predict density throughout the survey area and mapped as a continuous density surface. The model used in this approach would be a Generalized Additive Model.

For this approach, environmental covariate data (e.g. depth, seabed sediment type etc) need to be available throughout the area of interest at an appropriate resolution. Also, the transect data need to be divided into short segments of effort. Considering the scale of the development areas, 1km segments would probably be most appropriate. Within each season, this process would result in >1000 segments over the surveyed inshore and offshore area. Each sighting is then assigned to the corresponding segment and the count per segment used as the response variable. With such small sample sizes, the number of segments with no sightings will be extremely high and there is a risk that it will be impossible to fit a satisfactory GAM to the data. Given the lower number of sightings in the winter sample, it is possible that only the summer data can be modeled in this way.

4. Conclusions

The assumptions of line transect methods are more permissive compared to strip transects and do allow for animals to be missed away from the transect line (although assumes all are seen directly on the transect line) and still generate robust density estimates. However, the aerial survey data in the Firths of Forth and Tay will not support a line transect analysis; sample sizes are small and observations are restricted primarily to the first distance Band (referred to as spiked data). Therefore, a standard strip transect analysis is recommended using only observations recorded in Band A to generate a density and abundance estimate for the survey area within each season, the total numbers of sightings that can be used in such an analysis are presented in table 5. The limitation of this approach is that it relies on the very strict assumption that **all** animals are recorded in the survey strip and this clearly is violated. Therefore, whilst density estimates can be generated they will be seriously negatively biased. This approach will generate a single mean estimate of density for the survey area (i.e. inshore or offshore) for the survey period considered (i.e. summer or winter). By spatially modeling density using a GAM, a density surface can be generated for the entire region (inshore and offshore) which can then be sub-set retrospectively to generate density and abundance estimates for smaller areas within it, such as any of the development sites. Normally, this process has two principle stages; fitting the detection function to the distance data so that counts of sightings can be corrected and then fitting a GAM to the corrected counts. As the aerial data will not support the first stage (fitting detection functions) the modeling will be based on counts that are not adjusted for detectability and therefore the resulting density estimates will also be underestimated. Aerial surveys using teams of observers have been carried out in many locations throughout Europe and it may be appropriate to apply a ‘correction factor’ to the density based on existing literature. However, how appropriate this is will need to be assessed.

The analytical approach has been restricted by poor field protocol in relation to marine mammal data collection. The developers will need to carefully consider whether the analyses of these data are important in the context of gaining consent. Future data collection efforts that aim to collect sufficient data to allow estimates of density for marine mammals to be derived need to be carefully considered. However, minimum density estimates at an appropriate spatial and temporal scale to the developments are likely more valuable than the large scale abundance data that currently exist (for example from SCANS surveys).

5. Tables and Figures

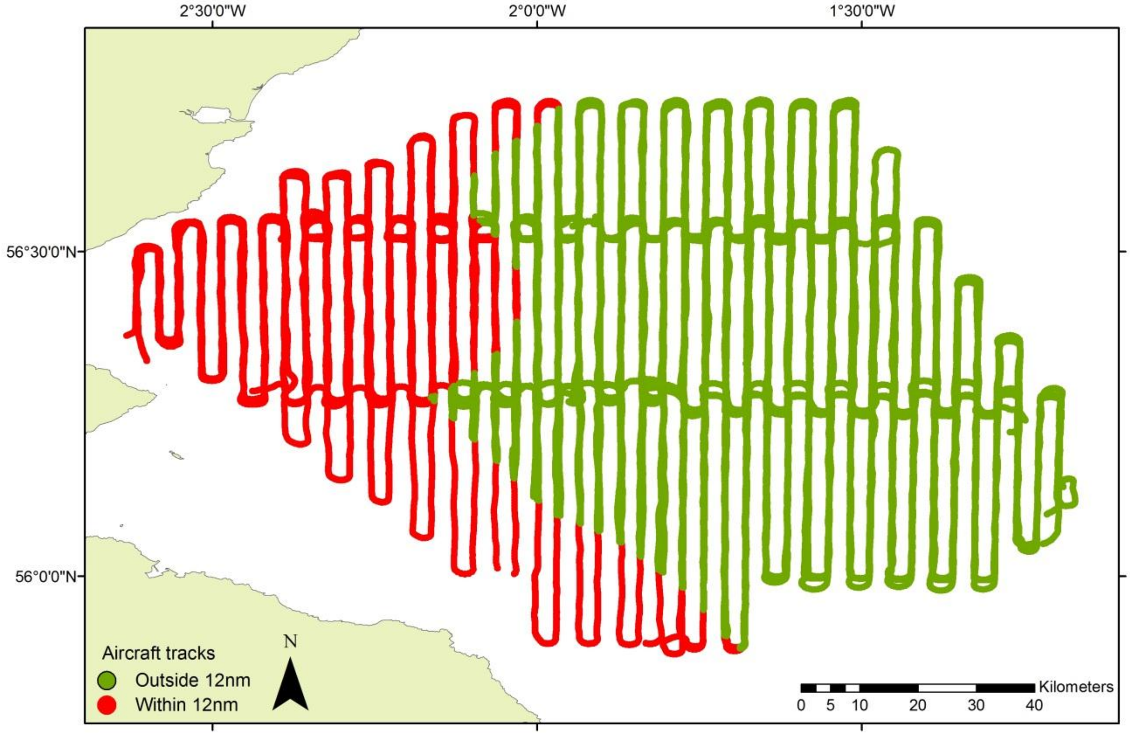

Figure 1: Summer survey tracks flown within and out with the 12 nm boundary in 2009.

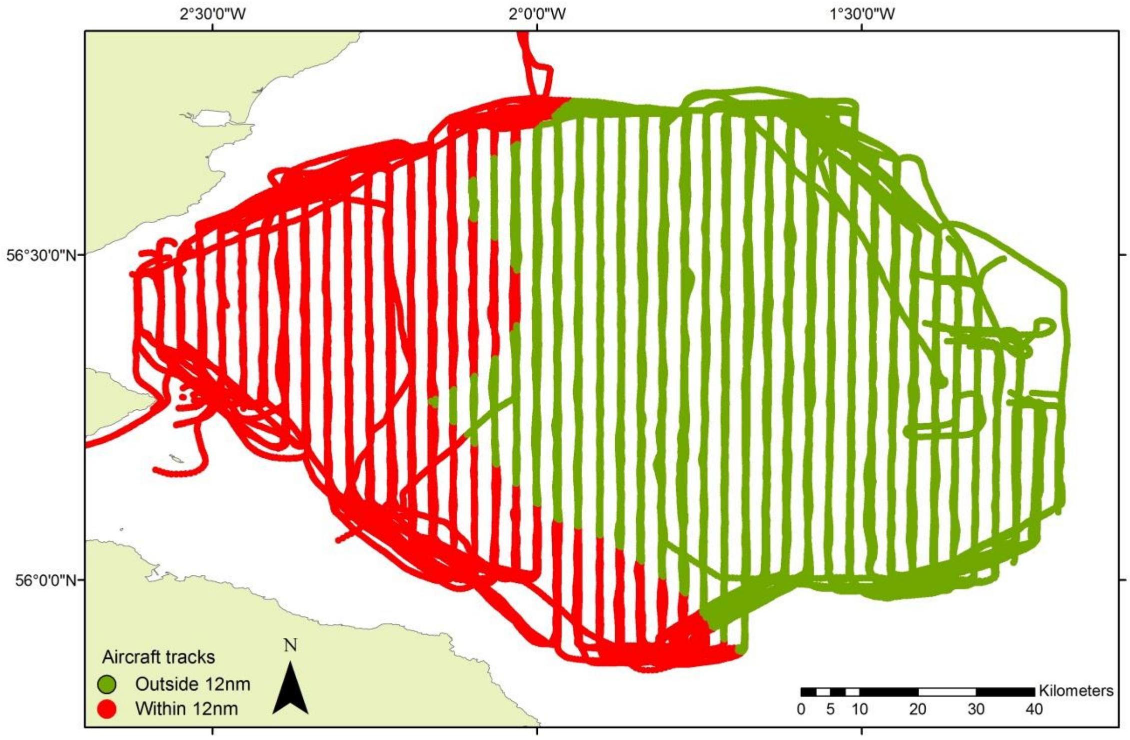

Figure 2. Winter survey tracks flown within and out with the 12 nm boundary in 2009-2010.

Table 1. Summary of all marine mammal records from aerial surveys within 12 nm.

	Inside 12 nm		
Species	**Summer**	**Winter**	**Sightings Totals**
Bottlenose dolphin		2	2
Common dolphin		1	1
Harbour porpoise	31	19	50
White-beaked dolphin	8		8
Minke whale	1		1
Killer whale	1		1
Grey seal		3	3
Large cetacean	3	1	4
Small cetacean	18	4	22
Dolphin	2	1	3
Seal	29	39	68
Cetacean	3		3
Total	**96**	**70**	**166**

Table 2. Summary of all marine mammal records from aerial surveys outside 12 nm.

	Outside 12 nm		
Species	**Summer**	**Winter**	**Sightings totals**
Bottlenose dolphin	1		1
Harbour porpoise	130	50	180
Long-finned pilot whale		2	2
Minke whale	6	1	7
White-beaked dolphin	41	15	56
Large cetacean	4	1	5
Small cetacean	53	17	70
Cetacean	15	3	18
Grey seal	5	6	11
Harbour seal		4	4
Seal	194	68	262
Total	**462**	**172**	**634**

Table 3. Distribution of sightings of the most numerous species/groups in distance Bands A – D recording during flights within the 12 nm limit.

Species	Area	Season	A	B	C	D	Total
Harbour Porpoise	Inside	Summer	25	6			31
	Inside	Winter	16	3			19
Seal	Inside	Summer	19	10			29
	Inside	Winter	30	9			39
Grey Seal	Inside	Winter	3				3

Table 4. Distribution of sightings of the most numerous species/groups in distance Bands A-D recorded during flights beyond the 12 nm limit.

Species	Area	Season	A	B	C	D	Total
Harbour Porpoise	Outside	Summer	107	23			130
	Outside	Winter	44	6			50
Small cetacean	Outside	Summer	34	19			52
	Outside	Winter	8	9			17
White-beaked dolphin	Outside	Summer	20	16	5		41
	Outside	Winter	9	6			15
Seal	Outside	Summer	139	54	1		194
	Outside	Winter	60	7	1		68
Grey seal	Outside	Summer	4	1			5
	Outside	Winter	4	2			6
Harbour seal	Outside	Summer					
	Outside	Winter	4				4

Table 5. Total sightings of the most numerous species/groups in distance band A according to area and season

Species	Area	Season		Total
Harbour Porpoise		Summer	Winter	
	Outside	107	44	**151**
	Inside	25	16	**41**
	Total	**132**	**60**	**192**
All Seal sp.	Outside	143	68	211
	Inside	19	33	52
	Total	162	101	263
White-beaked dolphin	Outside	20	9	29
	Inside	7		7
	Total	27	9	36

6. Appendix

Track files with corrupt time stamps:

20091204 ffc tracks Outside 12

20091204 ffc tracks Inside 12 n

20090716 ff4 tracks Outside 12

20090621 ff4 tracks Outside 12

20090529 ff3 tracks Outside 12

20090621_ff4_tracks_Inside_12_n

20090716_ff4_tracks_Inside_12_n