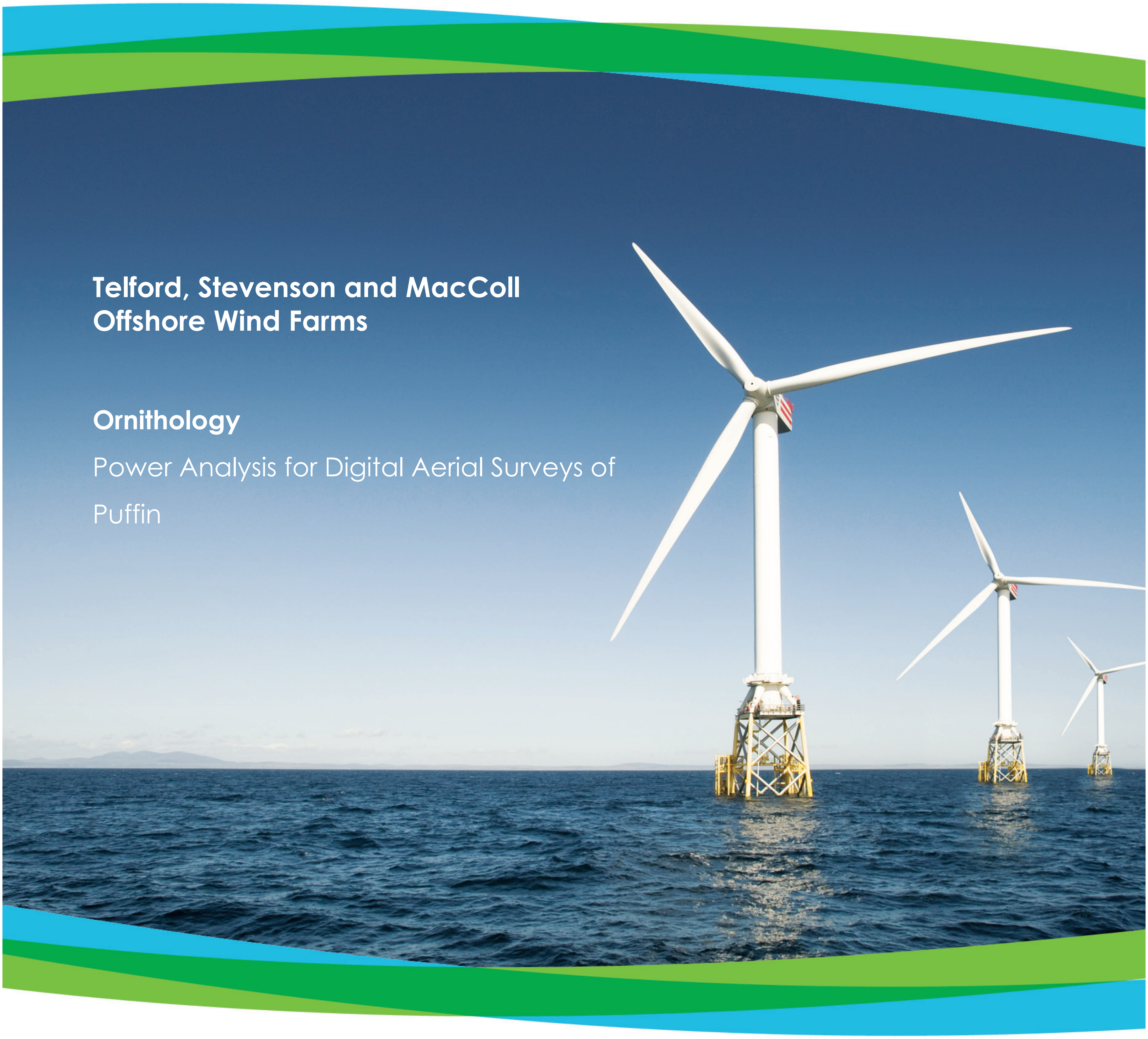
moray offshore renewables ltd

Developing Wind Energy In The Outer Moray Firth



Telford, Stevenson and MacColl Offshore Wind Farms

Ornithology

Power Analysis for Digital Aerial Surveys of Puffin

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1 Background

Offshore wind farms have the potential to displace birds from within the wind farm footprint during the operational phase. The most appropriate method to monitor for this change is to use Density Surface Models to predict changes in spatial distribution of birds on the water. Data can be collected using a variety of methods, including digital aerial video surveys. An important part of designing a survey programme is determining the number of surveys required to collect sufficient data for a suitable statistical analysis to have sufficient power to detect a difference (i.e. between pre- and post-construction or within and out with the wind farm post-construction) where one exists. This can be determined by undertaking a statistical power analysis. This report describes the statistical power analysis for the consented MORL offshore wind farms (henceforth referred to as MORL wind farms). Any *a priori* power analysis is used to determine the minimum sample size needed to detect a given effect size, for a given alpha value and power value. The aim of this power analysis was to determine if the statistical power to detect a change was a potential limitation to survey design. It is important to note that with this aim this report does not represent the final survey design, but indicates the survey design that would result in the minimum sample size needed to reach a certain level of statistical power for a given level of significance. It is likely that construction of the MORL wind farms will be progressed in phases and therefore future surveys may not follow the survey design analysed here. Should the pre-construction or post-construction surveys change in design due to a change in the build out of the wind farms a further power analysis will be undertaken to determine a suitable survey design that is not constrained by statistical power. This may involve surveying smaller areas, which would likely result in a change in the trade-off between the number of surveys, transect strip width and area surveyed (i.e. the number of transects). Part of this trade off may include determining the most cost effective way to achieve the necessary level of power (e.g. more frequent surveys *versus* larger survey area).

As the key target species for displacement studies in the Moray Firth is Atlantic puffin (*Fratercula arctica*) this species was used as the model for this power analysis.

2 Methods

2.1 Survey design

In order to undertake the power analysis it was necessary to start with some assumptions about survey type and design. It was assumed that data would be collected in strip transects across the wind farms footprint, and a buffer area around the wind farms, using high definition digital video cameras to record the location and species of each bird. These surveys have not been contracted. These results, or any necessary future power analysis, will be used to determine the scope of works for future survey tenders.

The number of strip transects was based on the time required to fly over the area in a single day across the period of the surveys (May to July). Transects were aligned to match up with existing digital aerial transects being undertaken in the BOWL wind farm, which also provided the transect spacing at 2.53 km (Figure 2.1). The transects used in this power analysis included only the length within the MORL study area (pale green shaded area in Figure 2.1) and not the full length of the combined MORL and BOWL transects. The survey area consists of a 2009 km^2 rectangle which buffers the wind farm footprint by at least 10 km on all sides of the MORL wind farms.

A total of 18 transects, each approximately 41.3 km in length and separated from one another by 2.53 km, were created covering the aerial survey area. Transects were assigned numbers from 1 to 18 running from north to south. It was assumed that strip transect width would be 250 m or 500 m and that there would be no decline in detectability with increasing distance from the line.

The survey regime consisted of three hypothetical aerial surveys carried out in May, June and July of a year in the pre-construction phase and three further hypothetical aerial surveys carried out in the May, June and July of a year in the operational phase (six surveys in total).

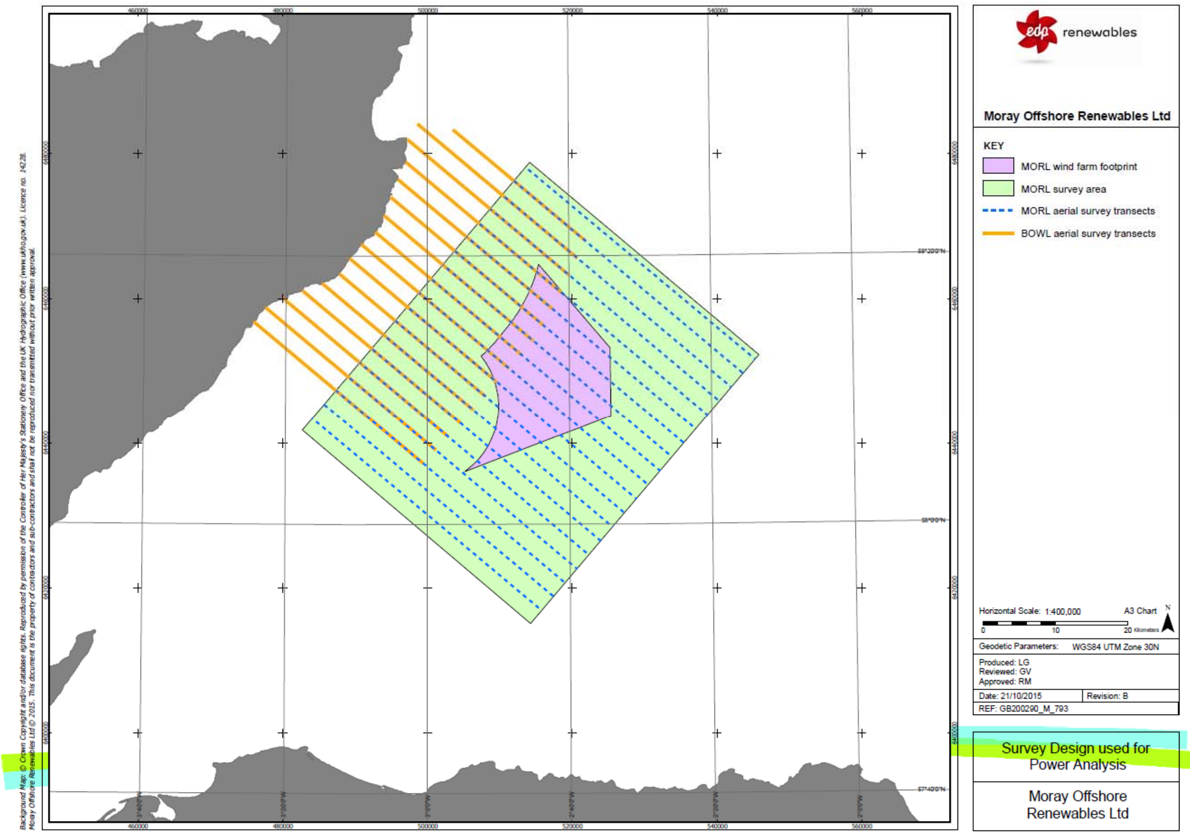

Figure 2.1: Digital aerial strip transects used in statistical power analysis of the MORL wind farms. Orange transect lines show the existing BOWL transects, blue lines show the proposed MORL transects. Power analysis is based on blue transects within the pale green shaded study area

2.2 Data simulation

For each simulated survey, points representing individual puffins were generated using a Poisson process for which the intensity was calculated as a function of sea depth and location (within the wind farm versus in the remainder of the survey area), on a 300 x 300 m 'covariate grid'. This was implemented using a modified version of the simPts function from the DSpat package in R. A relationship with sea depth was only incorporated to create a non-uniform density of birds across the survey area. It does not serve any other purpose, and was not intended to suggest that this would or would not be an explanatory variable in any future modelling.
Each simulated puffin was randomly assigned as either available for detection or unavailable for detection according to a Bernoulli distribution, with the probability of detection being the correction factor supplied by HiDef (see below for details).

2.2.1 Simulation parameters

Expected number of puffins: The minimum estimated density of puffins from the baseline boat-based bird survey data was used to represent the expected density of puffins at the time of each simulated pre-construction survey (see Table 2.1 below). The minimum estimated density was taken as the Density Surface Model estimate for May and the conventional distance sampling estimate for June and July. This is the most precautionary approach since power would be lowest when fewer birds are available to be detected. These density estimates were then used to calculate the expected numbers using the aerial survey area shown in green in Figure 2.1 (2009 km^2). It should be noted that densities used were estimated from the baseline boat-based survey area. This is smaller than the indicative aerial survey area used for simulation, so the densities were extrapolated to a wider area than they were collected from. Densities used may therefore not represent the situation across the whole aerial survey area.

Table 2.1: Estimated puffin densities and numbers used in the power analysis.

Month	Minimum estimate over the two years		Number estimated to be using aerial survey area
	Number	Density per km^2	
May	2121	3.25	6528
June	470	0.72	1446
July	970	1.49	2985

Model parameters used to calculate intensity: The parameter for sea depth was taken from analyses of boat-based puffin data collected as part of the baseline for the wind farm. For simulations of surveys conducted during the operational phase of the wind farm, the parameter for in *versus* out of the wind farm was calculated based on 30% of the puffins having been displaced from within the wind farm into the remainder of the survey area during the operational phase. The expected number of puffin in each month used for simulations was based on the expected density described above. It should be noted that the parameter used for depth is based on a very simplified model of puffin occurring within the boat-based survey area, and has been extrapolated to fill the indicative aerial survey area which includes sea depths not represented by the boat-based survey area.

Incorporation of additional noise: In order to represent additional noise due to unmodelled covariates (e.g. prey abundance), the intensity used for generating the Poisson process was calculated as above but with the addition of a random noise component. This random noise component varied according to a normal distribution, with a mean of zero and a standard deviation equal to a proportion of the mean value of the original intensity. Results associated with different standard deviations are reported in order to demonstrate the effect of increasing noise upon power.

Availability bias: HiDef provided information regarding their adjustment for availability bias (the same approach was applied to the data for the Dogger Bank ES) which is based on the assumption that puffins spend approximately 20.2% of their time at sea underwater. Time at sea includes time spent flying, on the water and diving. Puffins do not dive from flight, but from the sea surface. As this analysis is concerned with birds on the water (and not birds in flight), there is a requirement to remove the component of ‘unavailability’ from the proportion of birds in flight.

From the baseline data from the MORL wind farm, 95.7% of predicted puffins were assumed to be 'on the water' versus 'in flight'. From the unavailability figure provided by HiDef, 0.9%[1] would have been attributable to birds in flight. However, all of the birds underwater must be attributable to the proportion of birds on the water, as birds dive from the surface of the water. Therefore it was calculated that approximately 21.1%[2] of birds on the water would be unavailable for detection as a result of diving for food.

2.2.2 Data analysis

Transect lines were segmented to give 41 segments per transect line, each of 500 m x approximately 1,008 m. The coordinates of the mid-point of each segment were calculated and the sea depth at that point was assigned to each segment. Sampling was simulated by extracting observations that fell within each survey segment to give a response variable of number of simulated puffins falling within a survey segment.

The MRSea package in R was used to model the data as a function of month, phase (pre-construction and operational), depth, a two-dimensional spatial smooth and an interaction among phase and the two-dimensional smooth.

2.2.3 Evaluation

Data were simulated 100 times and each simulated dataset was analysed as described above. For each analysis, the success or otherwise of the model in identifying the displacement of puffins assumed during the simulation stage was recorded. A success was defined as a simulation for which the model reported an interaction among the two-dimensional spatial smooth and phase with a probability of greater than 95%. Predictions were made from a subset of the models detecting a significant change to ensure that interaction effects identified reflected the underlying process rather than resulting from overfit of the model. In all cases, a decline in numbers of puffin within the wind farm footprint was clearly detectable from density surface plots generated.

[1] 20.2% of the 4.3% of birds assumed to be in flight.

[2] 20.2% + 0.9%

3 Results

Power was estimated based on one survey per month in each month (May, June and July) with a 30% reduction in numbers of birds within the wind farm boundary (under the assumption that these birds were displaced to the buffer zone) during the operational phase (see Figure 3.1). Results of the power analysis for different strip widths and levels of noise are provided in Table 3.1.

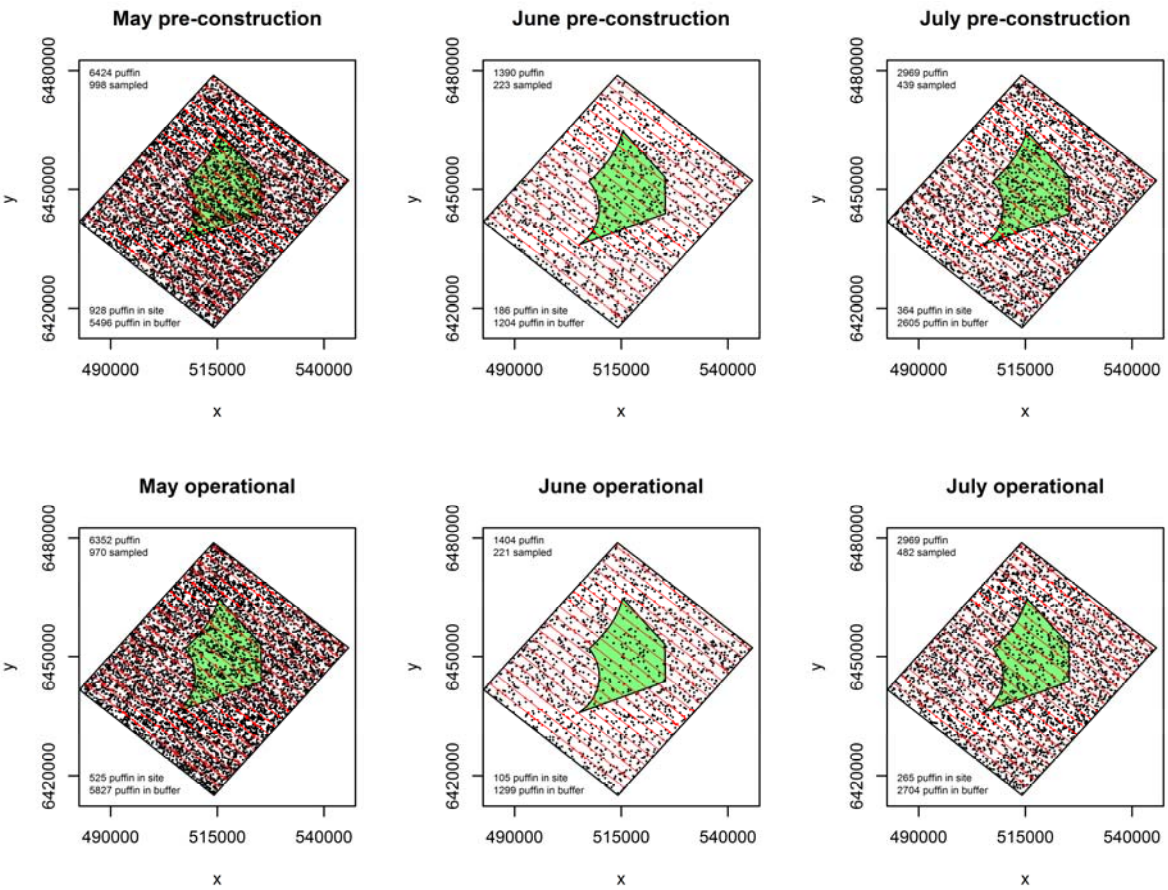

Figure 3.1: Simulated distribution of puffins in each month between a pre-construction (or baseline) and post-construction scenario. A displacement rate of 30% was modelled. This figure is based on a CV (simulated noise) of 0. Black dots represent birds present but not "observed" and red dots represent birds that were "observed".

The results of the power analysis for different strip widths and levels of noise (CV) are provided in Table 3.1. With a 250 m strip width there was a high level of statistical power (80% or more) to detect a 30% change in puffin distribution up to a CV level of 0.6. This was achieved with only three surveys before and three surveys after construction. With a 500 m strip with there was a sufficient level of power across all the levels of simulated noise in the data.

Table 3.1: Results of the power analysis of simulated puffin spatial abundance between a pre-construction (no displacement) and operational (30% displacement) scenario. Additional noise in the data was simulated by incorporating a noise term of varying co-efficients of variation (CV).

Strip width	250 m	500 m
Noise (CV)	**Power**	**Power**
0	86%	93%
0.2	86%	90%
0.4	82%	91%
0.6	79%	91%
0.8	66%	83%
1	64%	80%

Since there was sufficient power to detect a 30% change with only three surveys, using either a 250 m or 500 m strip width, across the three month survey window, further surveys were not analysed. If more than three surveys were undertaken within this survey window there would be an increase in statistical power.

4 Conclusions

The power analysis suggests current statistical methods would not be a limiting factor in the ability to detect a 30% or higher change in puffin densities within the wind farm. The power analysis alone would suggest that three pre-construction and three operational phase surveys in May to July would be enough to detect a level of displacement of 30% or higher. However, it is important to note that the final decision on the number, frequency and strip width of surveys may need to take other factors in to account (such as temporal variation in bird abundance, habituation, etc.). If the decision is made to undertake more surveys than modelled here, there would be sufficient power to use a 250 m strip width and still be able to detect a 30% or higher displacement rate.

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