MORAY EAST
OFFSHORE WINDFARM

POWER ANALYSIS FOR PRE-CONSTRUCTION AERIAL SURVEYS

Telford, Stevenson and MacColl Offshore Windfarms

May 2018

Moray Offshore Windfarm (East) Limited

Produced by Apem Ltd on behalf of Moray Offshore Windfarm (East) Limited	
Produced by	Dr. Stephanie McGovern and Bethany Goddard
Reviewed by	Dr. Mark Rehfisch
Document Status	Final [version 3.1]
File Name [Moray East]	8460001-PCA00001-APE-REP-001
File Name [APEM]	Ref: P00002313
Date	15/05/2018

Review / Approval

Moray East	
Catarina Rei Offshore Consents Manager	Sarah Pirie Head of Development

Table of Contents

List of Figures

List of Tables

List of Abbreviations

CV	coefficient of variation
MFRAG-O	Moray Firth Renewables Advisory Group – Ornithology subgroup

Executive Summary

Pre-construction aerial surveys of the Moray East windfarm area are scheduled to commence in May 2018. Following discussions made between stakeholders at the Moray Firth Renewables Advisory Group-Ornithology subgroup (MFRAG-O) meeting in February 2018 it was agreed that a review of the power analysis undertaken by Natural Power (2016) would be required to investigate whether the proposed survey design remains suitable for the survey scope.

The preliminary survey method, informed by the 2016 power analysis carried out using the MRSea package in R, optimises the data collection for all bird and marine mammal species using a transect survey design at 2 cm resolution. A proposed total of 18 transects spaced 2.53 km apart would be flown to achieve a minimum of 10 % coverage of the Moray East offshore windfarm and a surrounding 10 km buffer area. According to the initial power analysis this survey design delivers the large number of samples that allows 30 % or more displacement to be detected with 80 % or more power up to a CV (coefficient of variation) level of 0.6, with a probability greater than 95 %.

A revised power analysis was undertaken using MRSeaPower software. 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.

Data were simulated to replicate the calculated density from the boat based baseline surveys for each of the months of concern. These data were used to underpin the power analysis. Data were extracted to replicate different survey designs and buffer distances. The MRSeaPower package for R developed by the Centre for Research into Ecological and Environmental Modelling was used to calculate the power of the survey designs. This analysis suggests that all survey designs analysed within this report met the required level of power to identify a 50 % decline in the survey area. Only the transect design with 450 m transect widths within the windfarm, or the grid design had enough power to detect a 50 % redistribution from the windfarm to the buffer area with more than 80 % power with three surveys, one in each of May, June and July. Based on this analysis either of these designs should meet the requirements of the surveys. Although the power of grids is greater, in this case APEM recommends that transects for the Moray East site + 10 km buffer (450 m width transects passing through the windfarm) are undertaken. By matching the transect approach used at BOWL these transects would provide the additional benefit of allowing for relatively simple analysis to detect any cross-platform effects.

1 Introduction

The Moray East Offshore Windfarm is located 22.2 km from the Caithness coast at its closest point to shore on the Smith Bank in the outer Moray Firth. Pre-construction aerial surveys of the Moray East Offshore Windfarm area are scheduled to commence in May 2018. Following discussions made between stakeholders at the MFRAG-O meeting in February 2018 it was agreed that a review of the power analysis undertaken by Natural Power (2016) would be required for to investigate whether the proposed aerial survey design remains suitable for the survey scope and to detect any changes (i.e. between pre- and post-construction or within and outside the windfarm).

The aim of the initial power analysis was to determine if the statistical power to detect a change was a potential limitation to survey design and identify 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. The preliminary survey method, informed by the 2016 power analysis carried out using the MRSea package in R, optimises the data collection for all bird and marine mammal species using a transect survey design at 2 cm resolution. A total of 18 transects spaced 2.53 km apart was proposed to achieve a minimum of 10 % coverage of the Moray East Offshore Windfarm. According to the initial power analysis this survey design would deliver the large number of samples that would allow for 30 % or more displacement to be detected with 80 % or more power up to a CV level of 0.6 and with a probability greater than 95 %.

This report summarises the methodologies and results of the revised statistical power analysis undertaken by APEM Ltd using the MRSeaPower software to investigate the most appropriate final survey design to detect change. 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

The power analysis review consisted of the following three stages to determine the most appropriate survey design:

1. Review of the power analysis for direct comparison using MRSeaPower software.
2. Power analysis for a survey design of 4 km and 10 km buffer zones.
3. Power analysis for grid and transect survey designs.

2.1 Survey Design

Transects were aligned to match up with existing digital aerial transects that have been undertaken in the Beatrice Offshore Wind Limited (BOWL) windfarm, which provided the transect spacing at 2.53 km (Figure 2-1). The transects used in this power analysis included only the length within the Moray East study area (pale green shaded area in Figure 2-1). The survey area used with the power analysis consists of a 2,009 km^2 rectangle which buffers the Moray East site by at least 10 km on all sides.

Transects were assigned numbers from 1 to 18, and analysis was undertaken using a strip width of 225 m to obtain an approximately 10 % coverage, and it was assumed 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 (in line with the pre-construction monitoring survey approach agreed with MFRAG-O). Analysis was also undertaken for a scenario where the width of the strips that pass through the Moray East site was increased to 450 m.

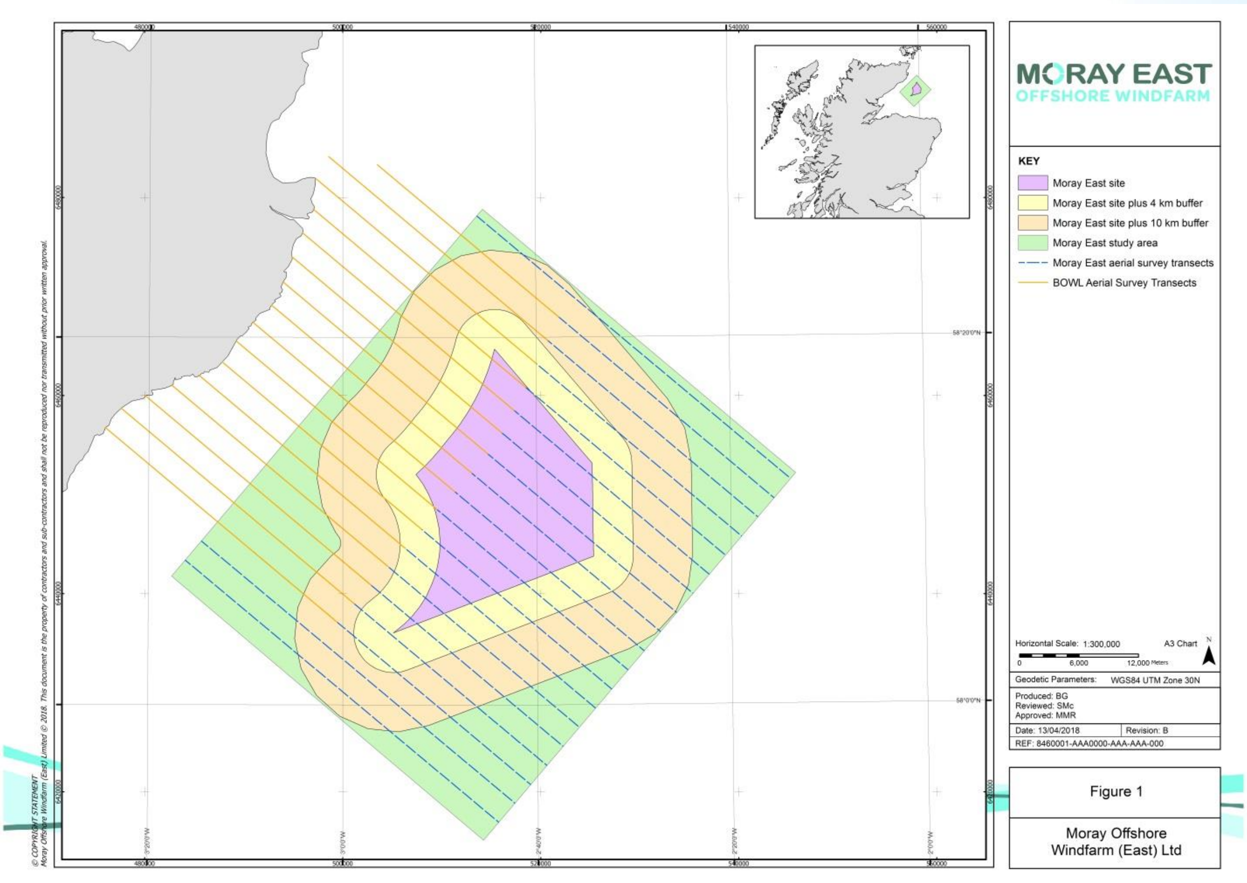

Figure 2-1: Digital aerial transects and survey areas used in power analysis of the Moray East Offshore Windfarm.

2.2 Data Simulation

For each month, data were simulated using a Poisson process to obtain the same density of puffins as calculated from the boat-based baseline surveys for each of the months under investigation. Data were simulated in R using the package spatstat for the total area designated as the Moray East study area (Figure 2-1 above). The numbers and density from the boat based surveys and simulated samples included in the modelling process are shown in Table 1 and Figures 2-2 to 2-4 below. These data were simulated for a larger area than data were collected from during the boat baseline surveys and therefore may not be representative of the total study area.

Table 1: Estimated puffing densities and numbers included in the power analysis simulations.

Month	Minimum estimate over the two years		Simulated numbers in the study area
	Number	Density per km^2	
May	2,121	3.25	6,603
June	470	0.72	1,463
July	970	1.49	3,057

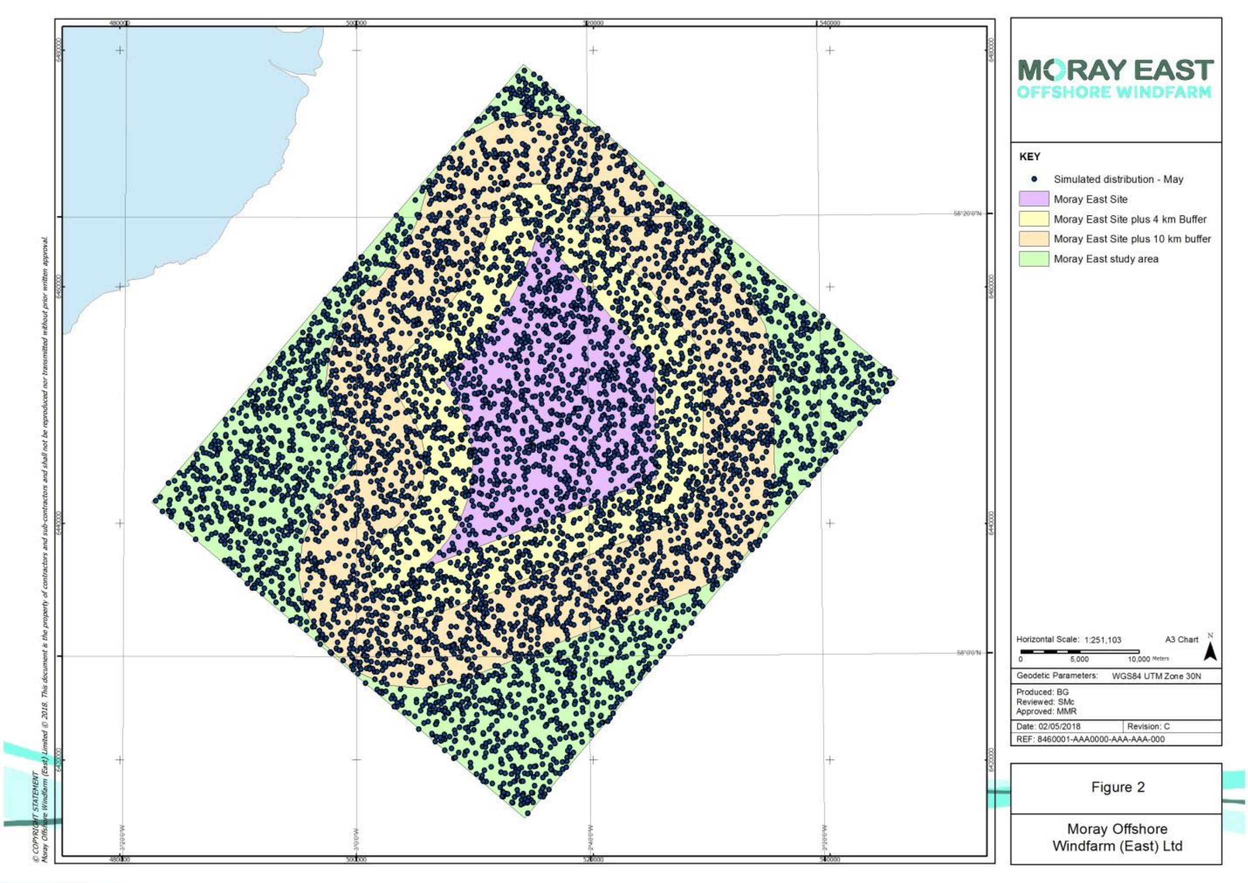

Figure 2-2: Simulated puffin densities in May.

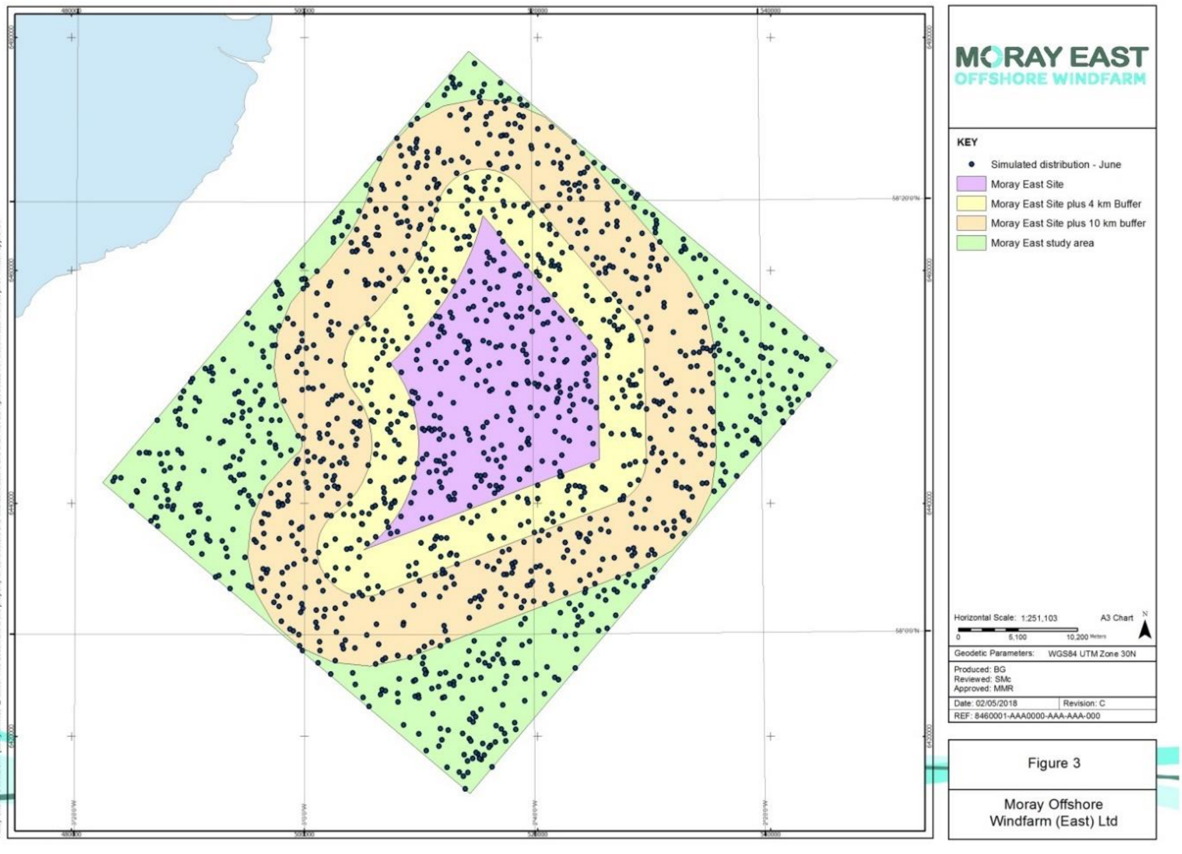

Figure 2-3: Simulated puffin densities in June.

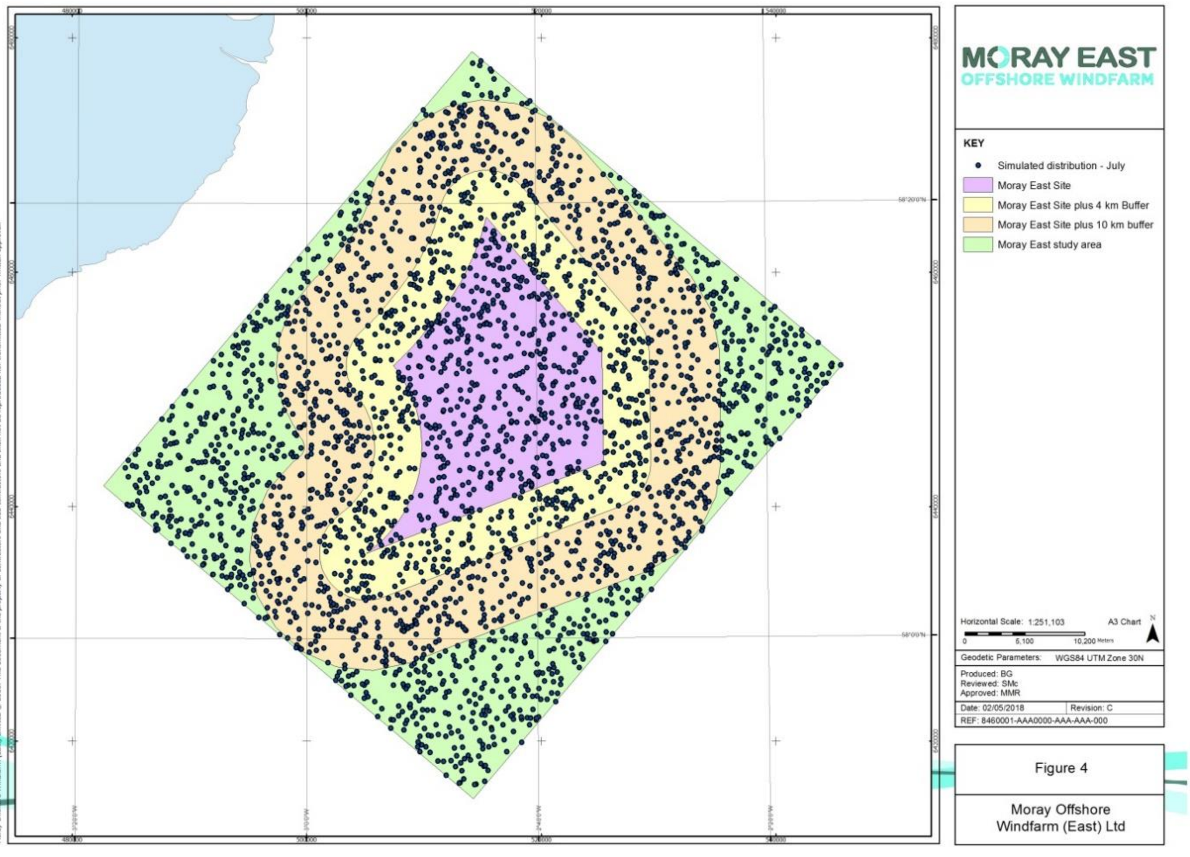

Figure 2-4: Simulated puffin densities in July.

2.3 Data Analysis

Polygons representing both the grid and transect designs were created. The transect design used the existing transect placements that have been undertaken in the BOWL windfarm, which provided the transect spacing at 2.53 km (Figure 1 above) with a 225 m strip width to provide an approximately 10 % coverage of the aerial survey area. Transects were segmented into approximately 500 m lengths. Transects that passed through the Moray East site were also increased to 450 m widths for a separate analysis achieving approximately 15 % coverage in the Moray East site.

The grid design aimed to achieve 10 % coverage and as such grid spacing equated to approximately 890 m between grid centre points evenly spaced across the survey area. Flight lines did not match up with those surveyed in BOWL.

For both the transect segments and grid points the coordinates of the mid-point of each segment were calculated and the average sea depth within the segment was calculated. The number of puffins that fell within each of the segments was summed to provide the response variable of number of simulated puffins within the survey segments. This information was used as the baseline data to be analysed using the MRSea and MRSeaPower packages in R.

The MRSea package was used to model the data. The SALSA model selection routine was used to determine which variables were necessary to remain in the model and a 2D spatial smooth between x coordinate and y coordinate was created. These models were used as the basis for the power analysis. The MRSeaPower package in R was used to assess the power of each survey design. Assessment of a reduction in overall density and redistribution from the Moray East site into the surrounding buffer was completed. For the redistribution analysis, an interaction term between impact (pre- and during construction) was incorporated. Models were selected using Bayesian Information Criterion selector suitable for Poisson distributed data.

2.4 Evaluation

Data were simulated 50 times for the power calculation and 100 times for the null distribution within the MRSeaPower package. Model specification incorporated correlation functions as appropriate to ensure autocorrelation between segments and within transect was taken into account. MRSeaPower records the number of success or otherwise of the model to identify a decline or redistribution from the windfarm footprint in puffin density.

3 Results

Power was estimated based on one survey per month in each month (May, June and July) with a 50 % reduction in numbers of birds within the survey area during the operational phase, or a 50 % reduction of birds in the Moray East site and redistribution into the buffer area. An additional analysis testing the power to detect a 30 % reduction of birds in the Moray East site and redistribution into the buffer area for the option with 450 m transect widths running through the windfarm was also completed. Results of the power analysis for different survey designs and buffer distances are shown in Table 2 below. Model outputs are provided in Appendix 1.

Table 2: Power analysis results for the grid and transect survey designs

Survey design	Survey area	50 % decline (power %)	50 % redistribution (power %)	30 % redistribution (power %)
Transect	Aerial study area (450 m width in Moray East site)*	100	96	NA
	Aerial study area	100	74	NA
	Moray East site + 10 km buffer	100	78	NA
	Moray East site + 10 km buffer (450 m width in Moray East site)*	100	100	86
	Moray East site + 4 km buffer	96	66	NA
Grid	Moray East site + 10 km buffer*	100	100	NA
	Moray East site + 4 km buffer*	100	94	NA

* Design options suitable for aerial surveys as power to detect change (decline and redistribution) > 80 %.

4 Conclusion

The power analysis conducted using MRSeaPower suggests that all of the survey designs analysed in this report would be suitable to detect a 50 % decline in puffin densities within the study area. This power analysis suggests that either the transect or grid designs would be suitable to identify a 50 % decline in puffin densities based on the simulated data contained within this report.

With the redistribution analysis however, only the transect surveys with 450 m wide strips within the Moray East site or the grid design provided more than 80 % power to detect a 50 % redistribution from the Moray East site to the surrounding area. Caution should be noted due to the simulated data exceeding the area of the boat based baseline survey area which may not be indicative of this wider area.

The power analysis suggests that redistribution can be detected using two transect and two grid designs. One of the transect designs delivers 15.3 % coverage for the Moray East site + 10 km buffer collecting data from a 450 m wide strips within the Moray East site and the other 14.3 % coverage from the full aerial study area collecting data from a 450 m wide strips within the Moray East site. The grid designs obtain 10 % coverage for the Moray East site for both the 4 km and 10 km buffer options. Based on analysis by the MRSea package, these designs provide sufficient power to detect this change with three surveys, one a month in May, June and July. As such, the statistically more powerful grid design surveys per unit area covered and the two transect survey options with 450 m wide strips within the Moray East site meet the desired design requirements.

To meet the survey requirements, in this instance, APEM recommends that the Moray East site + 10 km buffer is surveyed in May, June and July by transect using 450 m wide strips for transects that pass through the Moray East site and 225 m wide strips within the 10 km buffer area to achieve 15.3% coverage. In the 10 km buffer area imagery would be captured for 450 m wide strips however from this imagery 250 m wide strips would be extracted for analysis. Although transects have been shown to be less powerful than grid-based survey designs per unit coverage due to the lower number of spatially independent ‘samples’ that they generate (McGovern and Rehfisch 2015), the recommended transect design approach, being similar to that used at BOWL, would provide the additional benefit of allowing for any cross-platform effects to be identified.

Appendix 1 Power Analysis Model Outputs

A.1 Grid with 4 km buffer design outputs

Figure A-1: Figure for the grid 4 km buffer option showing how the power to detect change varies with the error rate chosen for the Moray East Site redistribution analysis.

Note: The first grey dashed line is at 1 % and the second at 5 %; traditionally values used as p-value cutoffs. The blue dashed lines indicate the error rate required to get a power of 80 %. The value is given in the title.

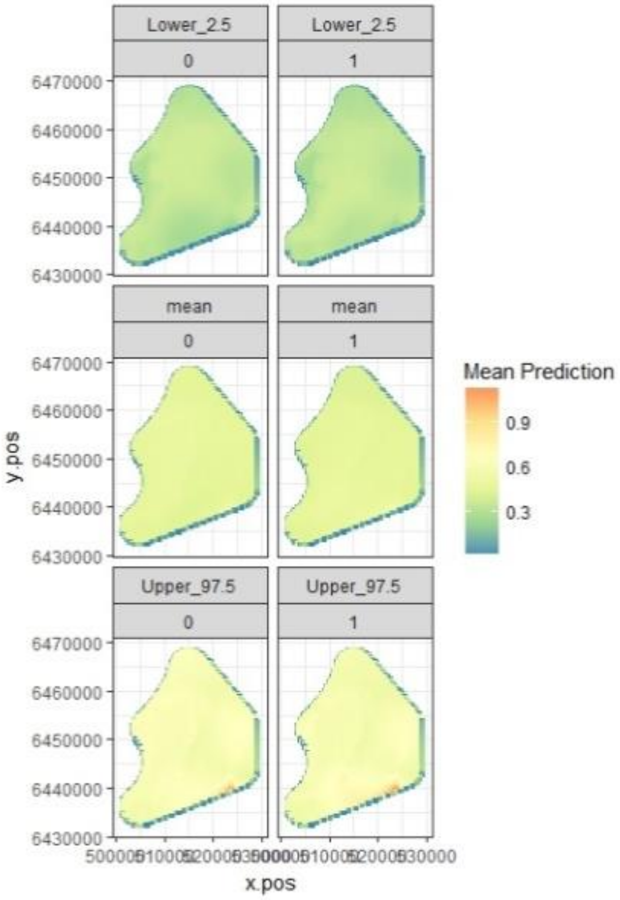

Figure A-2: Figure for the grid 4 km buffer option showing the mean (middle), lower 2.5 % (top) and upper 97.5 % (bottom) of predicted animal counts before (left) and after (right) the event.

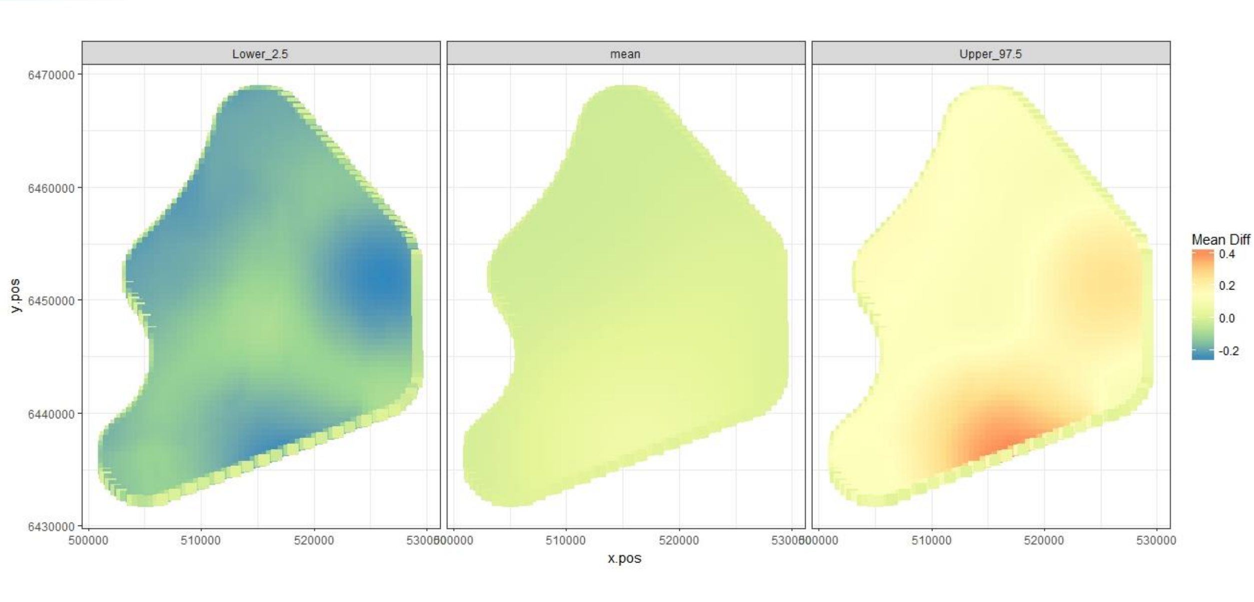

Figure A-3: Figure for the grid 4 km buffer option showing the mean (middle), lower 2.5 % (left) and upper 97.5 % (right) of estimated differences between before and after the event, (difference = post - pre).

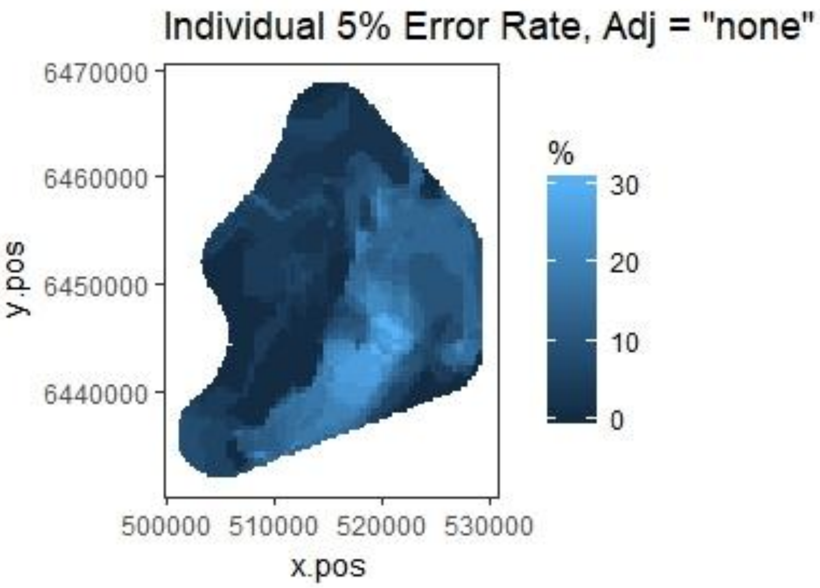

Figure A-4: Figure for the grid 4 km buffer option showing, for every grid cell, the proportion of simulations that showed a significant difference.

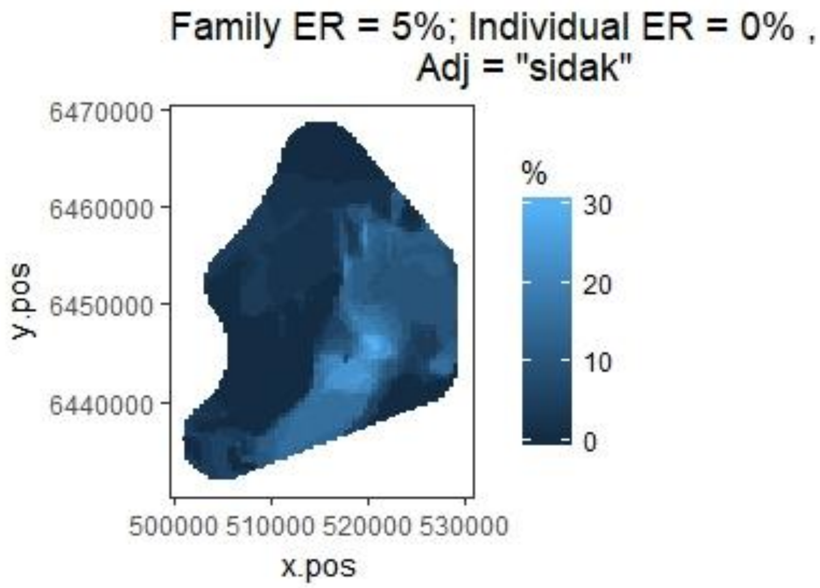

Figure A-5: Figure for the grid 4 km buffer option showing, for every grid cell, the proportion of simulations that showed a significant difference (with Sidak adjustment for family error rate of 0.05).

A.2 Grid with 10 km buffer design outputs

Figure A-6: Figure for the grid 10 km buffer option showing how the power to detect change varies with the error rate chosen for the Moray East Site redistribution analysis.

Note: The first grey dashed line is at 1 % and the second at 5 %, traditionally values used as p-value cutoffs. The blue dashed lines indicate the error rate required to get a power of 80 %. The value is given in the title.

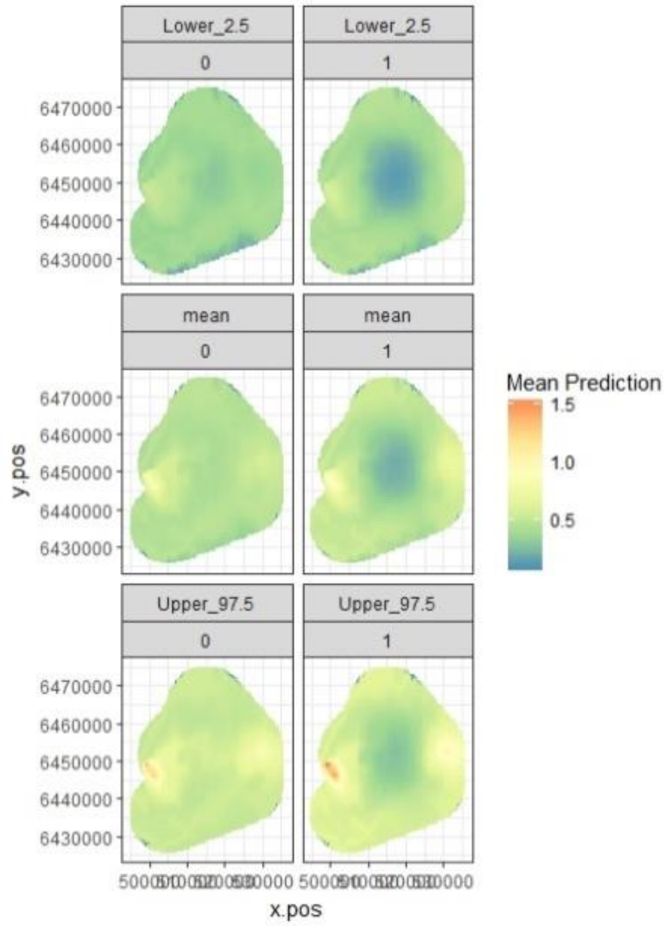

Figure A-7: Figure for the grid 10 km buffer option showing the mean (middle), lower 2.5 % (top) and upper 97.5 % (bottom) of predicted animal counts before (left) and after (right) the event.

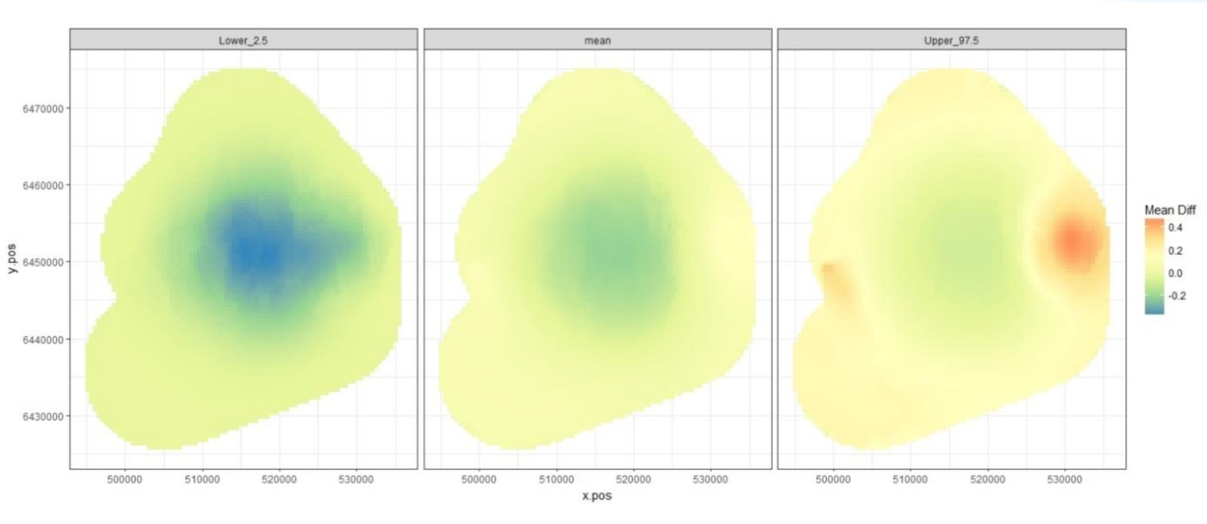

Figure A-8: Figure for the grid 10 km buffer option showing the mean (middle), lower 2.5 % (left) and upper 97.5 % (right) of estimated differences between before and after the event, (difference = post - pre).

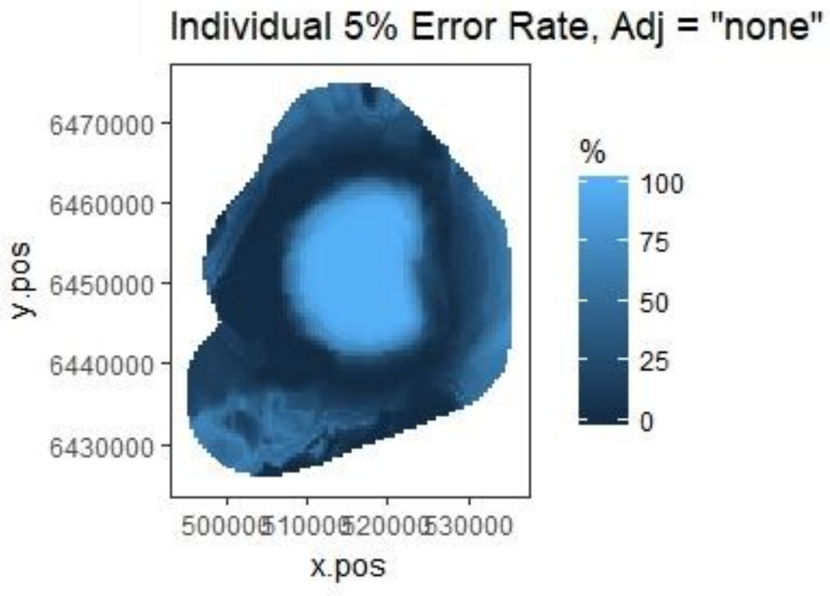

Figure A-9: Figure for the grid 10 km buffer option showing, for every grid cell, the proportion of simulations that showed a significant difference.

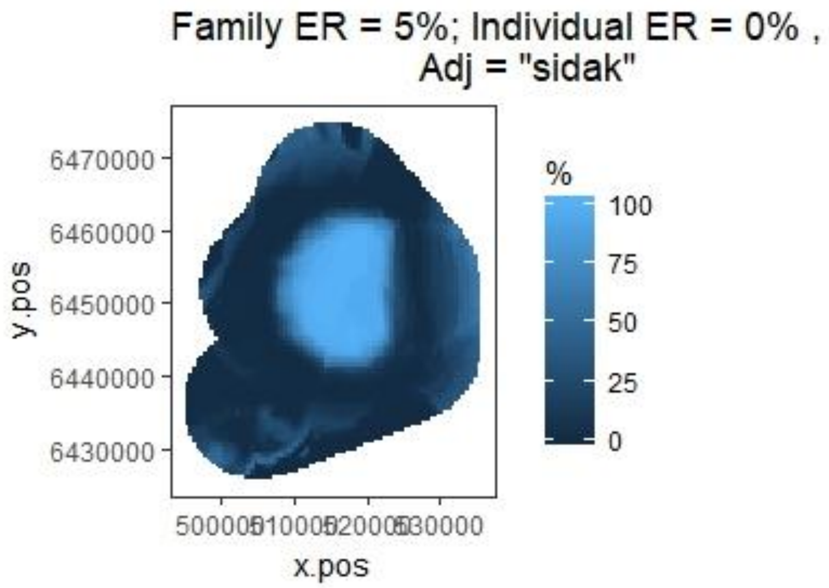

Figure A-10: Figure for the grid 10 km buffer option showing, for every grid cell, the proportion of simulations that showed a significant difference (with Sidak adjustment for family error rate of 0.05).

A.3 Transect with 4 km buffer design outputs

Figure A-11: Figure for the transect 4 km buffer option showing how the power to detect change varies with the error rate chosen for the Moray East Site redistribution analysis.

Note: The first grey dashed line is at 1 % and the second at 5 %, traditionally values used as p-value cutoffs. The blue dashed lines indicate the error rate required to get a power of 80 %. The value is given in the title.

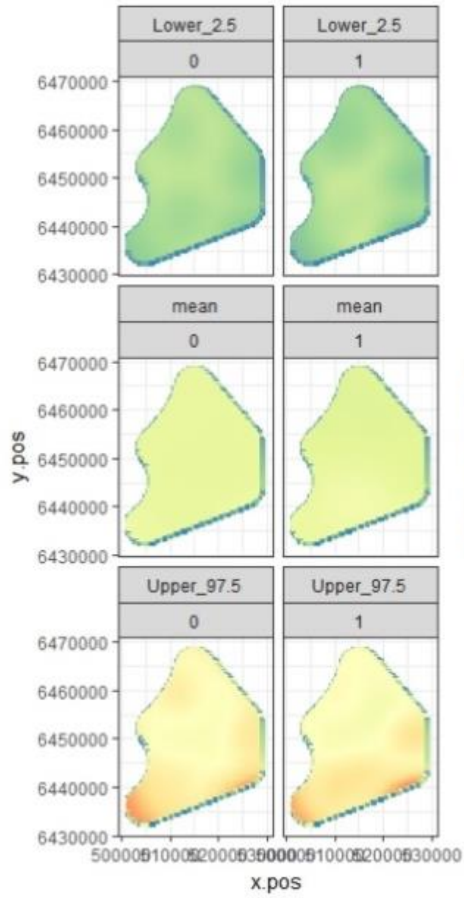

Figure A-12: Figure for the transect 4 km buffer option showing the mean (middle), lower 2.5 % (top) and upper 97.5 % (bottom) of predicted animal counts before (left) and after (right) the event.

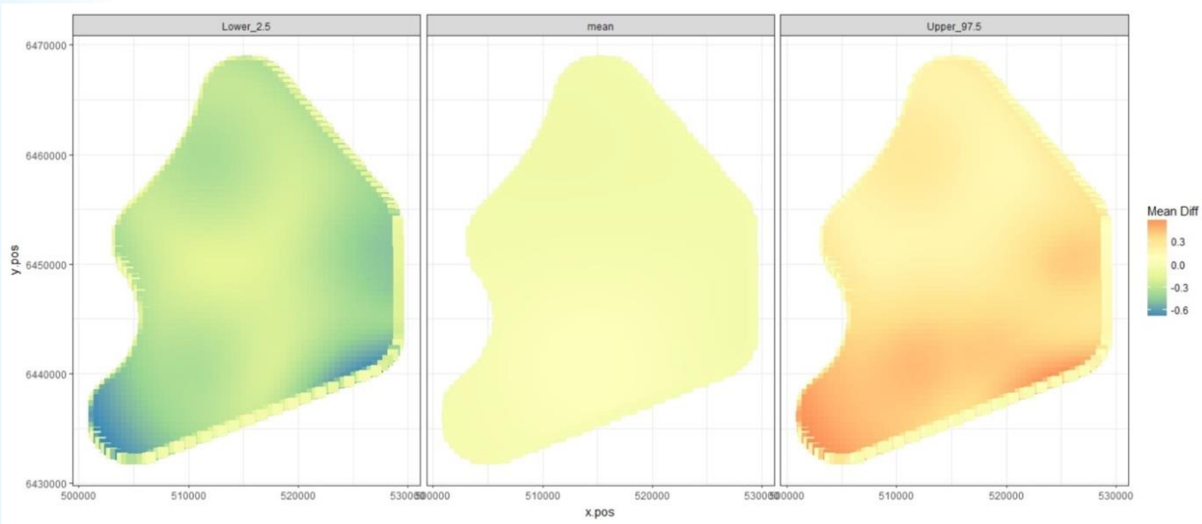

Figure A-13: Figure for the transect 4km buffer option showing the mean (middle), lower 2.5 % (left) and upper 97.5 % (right) of estimated differences between before and after the event, (difference = post - pre).

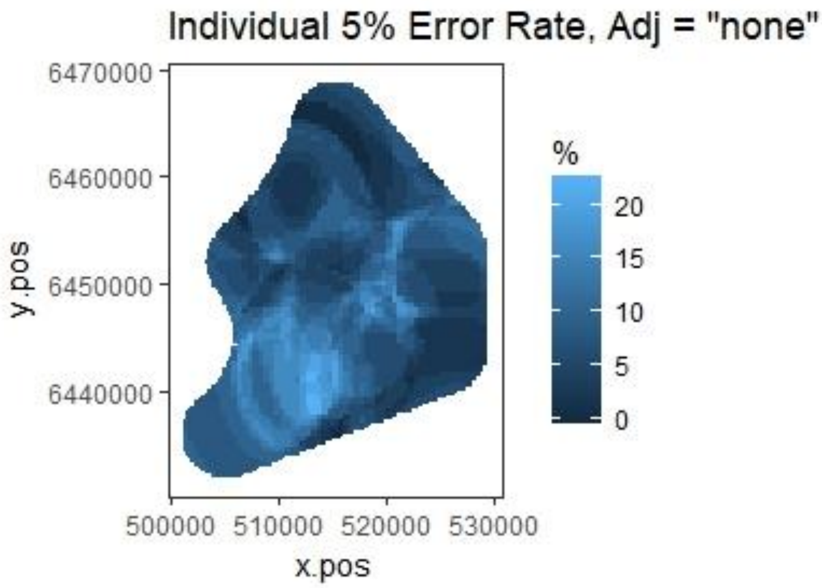

Figure A-14: Figure for the transect 4 km buffer option showing, for every grid cell, the proportion of simulations that showed a significant difference.

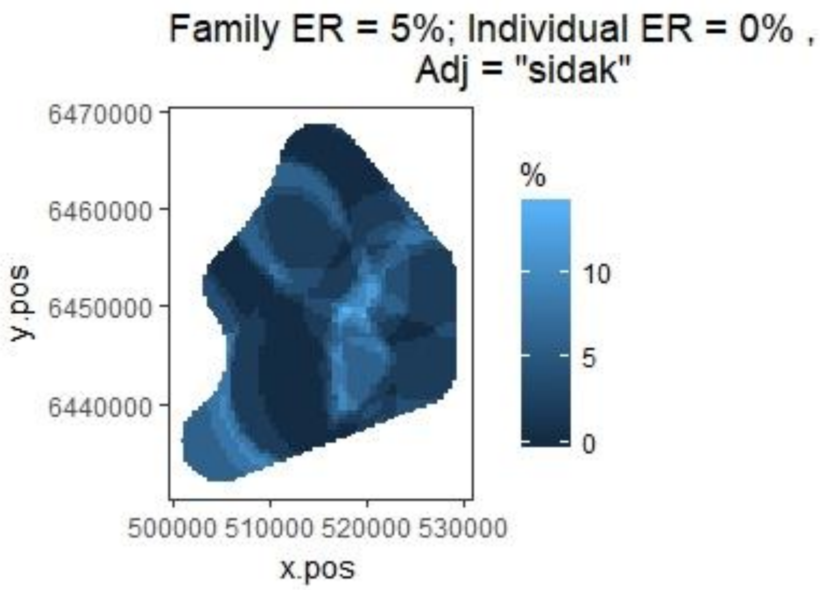

Figure A-15: Figure for the transect 4 km buffer option showing, for every grid cell, the proportion of simulations that showed a significant difference (with Sidak adjustment for family error rate of 0.05).

A.4 Transect with 10 km buffer design outputs

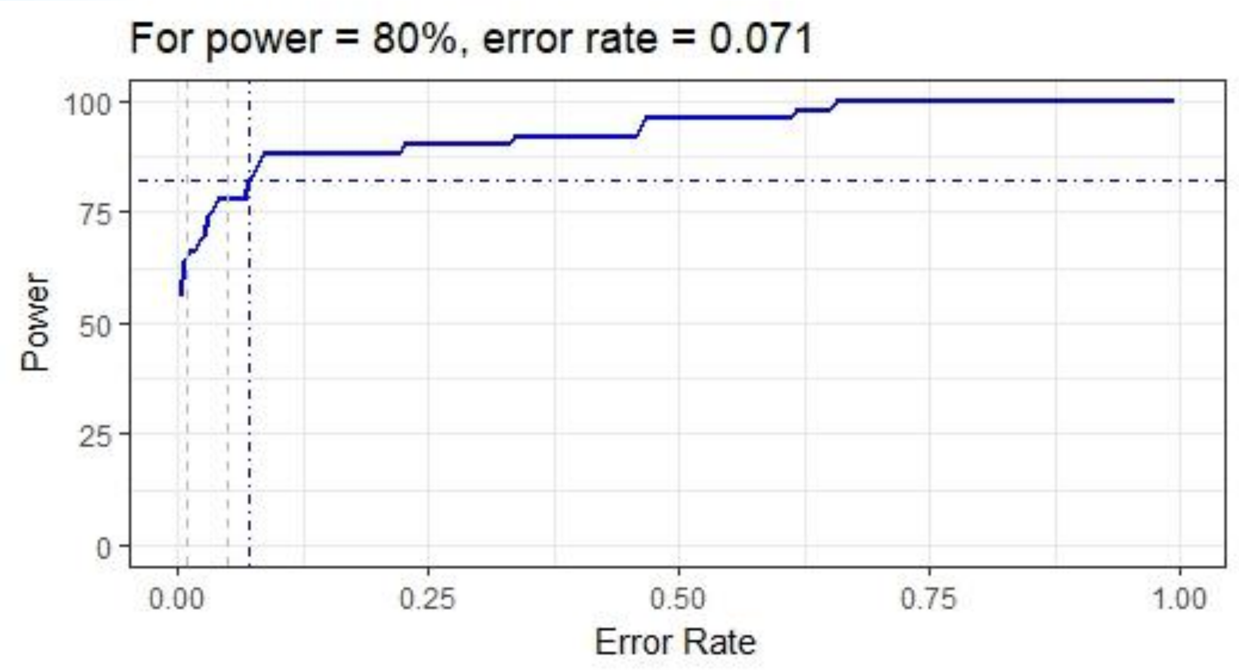

Figure A-16: Figure for the transect 10 km buffer option showing how the power to detect change varies with the error rate chosen for the Moray East Site redistribution analysis.

Note: The first grey dashed line is at 1 % and the second at 5 %, traditionally values used as p-value cutoffs. The blue dashed lines indicate the error rate required to get a power of 80 %. The value is given in the title.

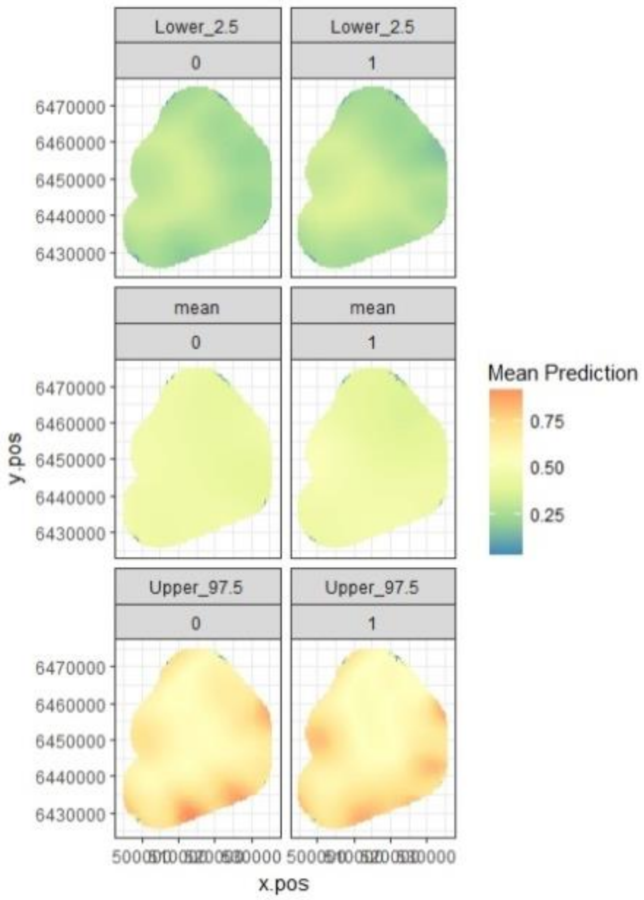

Figure A-17: Figure for the transect 10 km buffer option showing the mean (middle), lower 2.5 % (top) and upper 97.5 % (bottom) of predicted animal counts before (left) and after (right) the event.

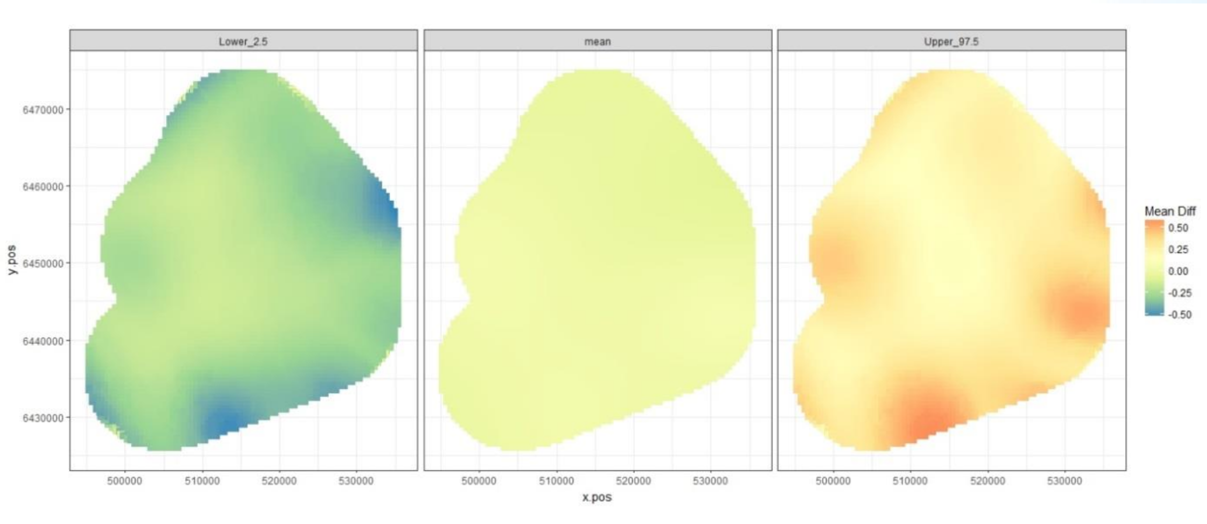

Figure A-18:Figure for the transect 10 km buffer option showing the mean (middle), lower 2.5 % (left) and upper 97.5 % (right) of estimated differences between before and after the event, (difference = post - pre).

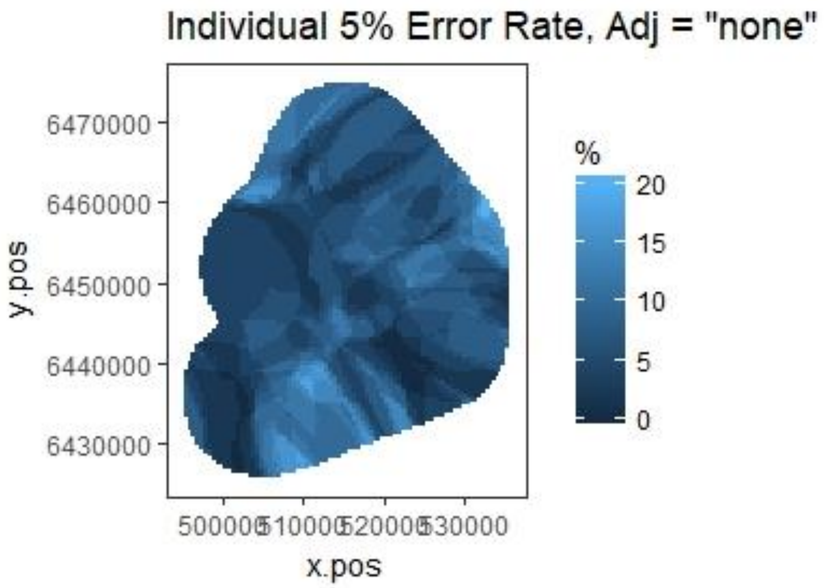

Figure A-19: Figure for the transect 10 km buffer option showing, for every grid cell, the proportion of simulations that showed a significant difference.

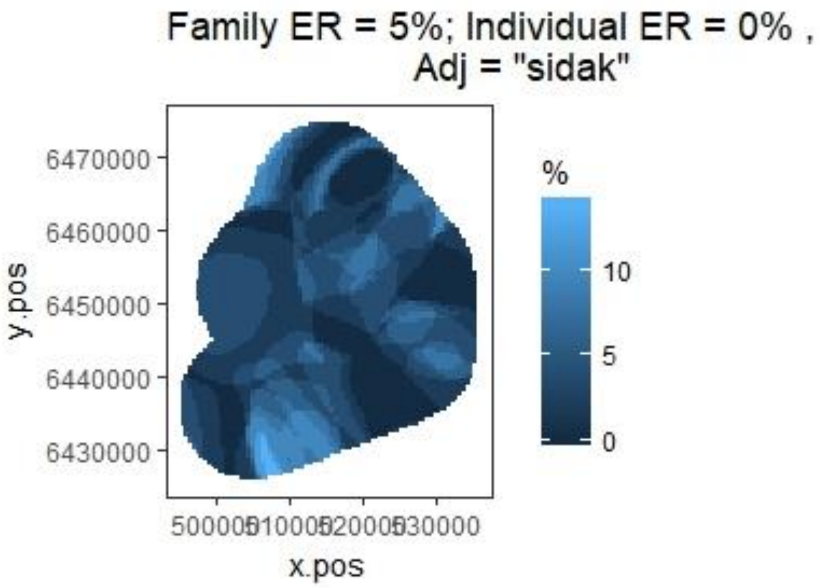

Figure A-20: Figure for the transect 10 km buffer option showing, for every grid cell, the proportion of simulations that showed a significant difference (with Sidak adjustment for family error rate of 0.05).

A.5 Transect design within aerial study area outputs

Figure A-21: Figure for the transect aerial study area option showing how the power to detect change varies with the error rate chosen for the Moray East Site redistribution analysis.

Note: The first grey dashed line is at 1 % and the second at 5 %, traditionally values used as p-value cutoffs. The blue dashed lines indicate the error rate required to get a power of 80 %. The value is given in the title.

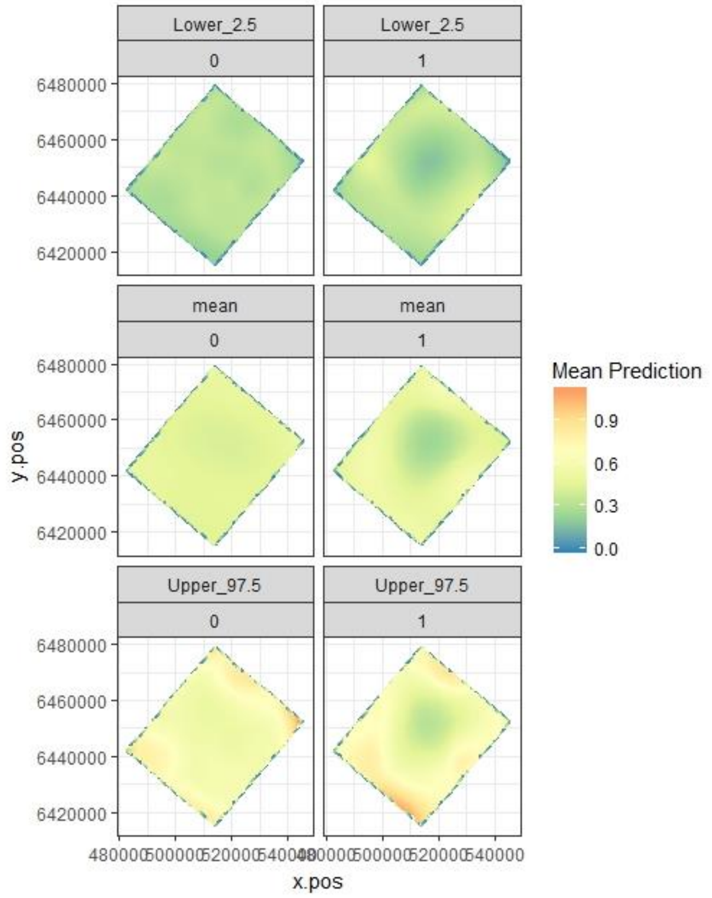

Figure A-22: Figure for the transect aerial study area option showing the mean (middle), lower 2.5 % (top) and upper 97.5 % (bottom) of predicted animal counts before (left) and after (right) the event.

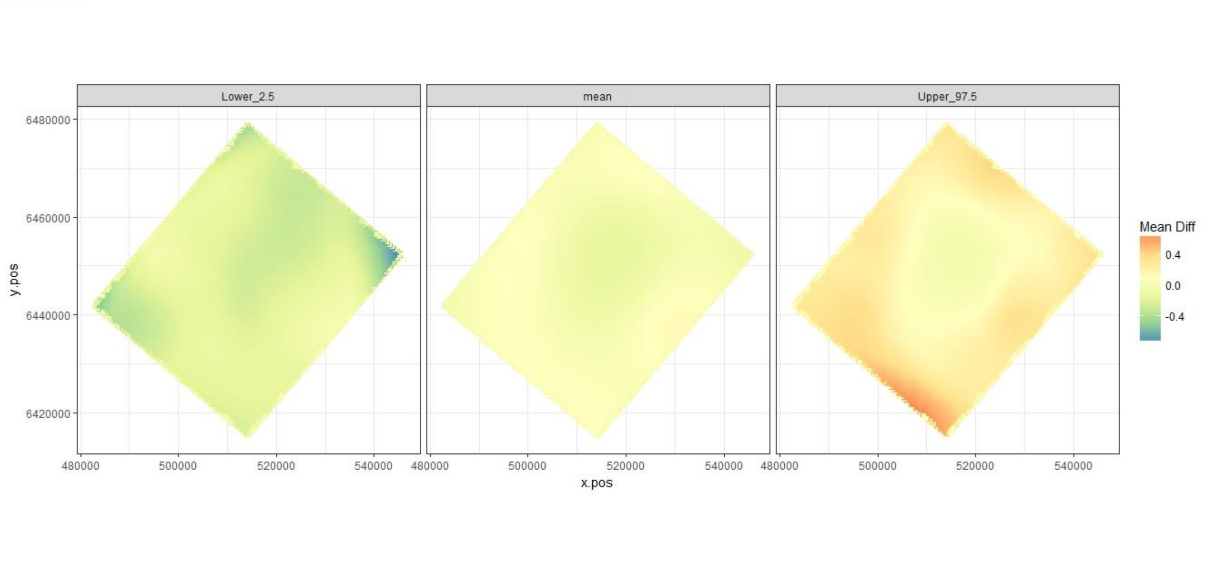

Figure A-23:Figure for the transect aerial study area option showing the mean (middle), lower 2.5 % (left) and upper 97.5 % (right) of estimated differences between before and after the event, (difference = post - pre).

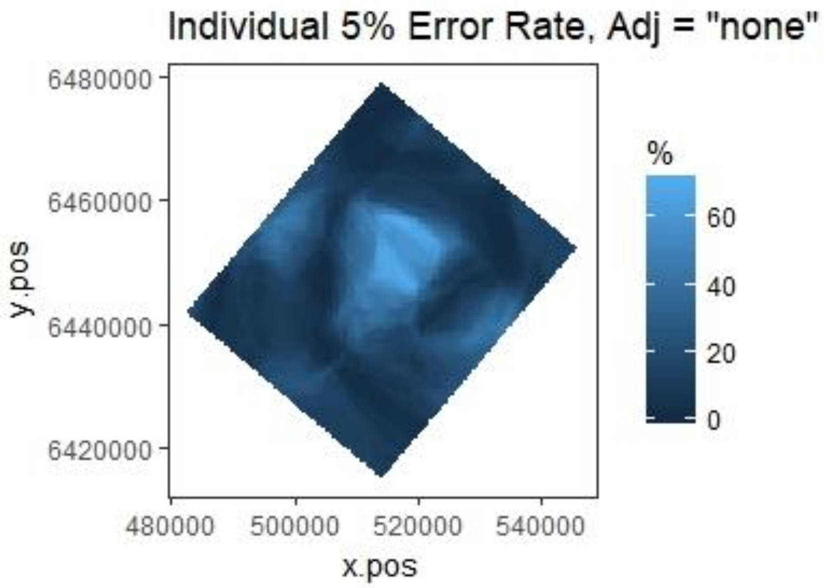

Figure A-24: Figure for the transect aerial study area option showing, for every grid cell, the proportion of simulations that showed a significant difference.

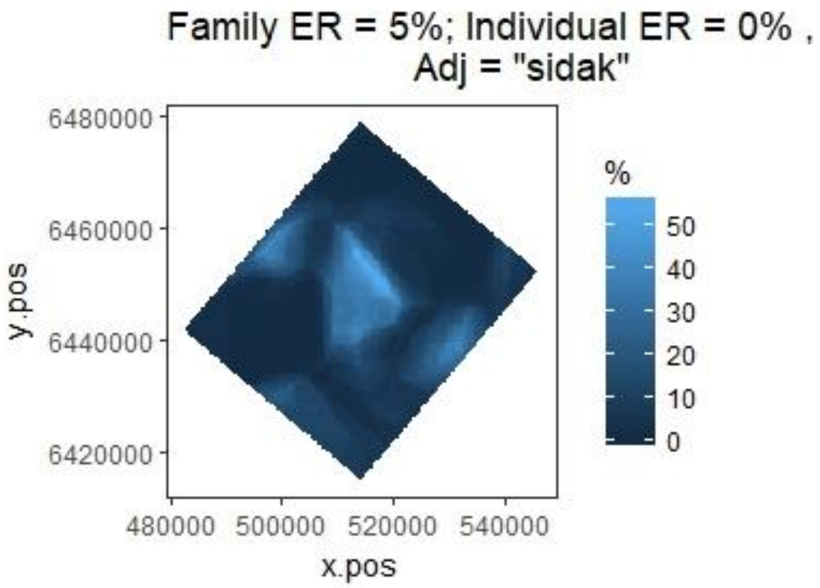

Figure A-25: Figure for the transect aerial study area option showing, for every grid cell, the proportion of simulations that showed a significant difference (with Sidak adjustment for family error rate of 0.05).

A.6 450 m transect width with 10 km buffer design and 50 % decline outputs

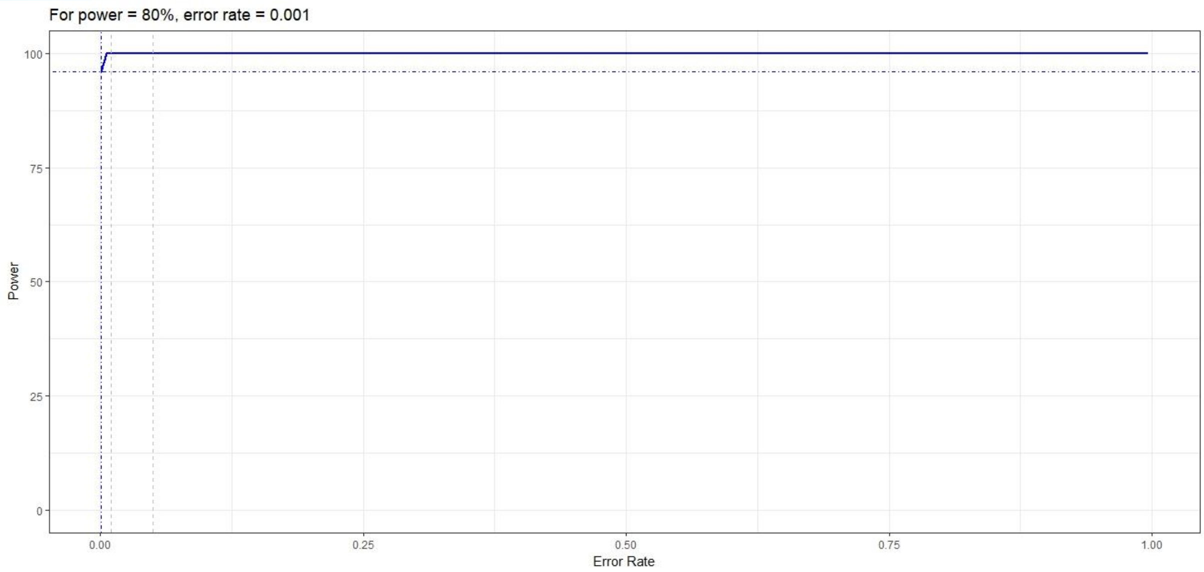

Figure A-26: Figure for the 450 m transect width 10 km buffer option with a 50 % decline in the windfarm showing how the power to detect change varies with the error rate chosen for the Moray East Site redistribution analysis.

Note: The first grey dashed line is at 1 % and the second at 5 %, traditionally values used as p-value cutoffs. The blue dashed lines indicate the error rate required to get a power of 80 %. The value is given in the title.

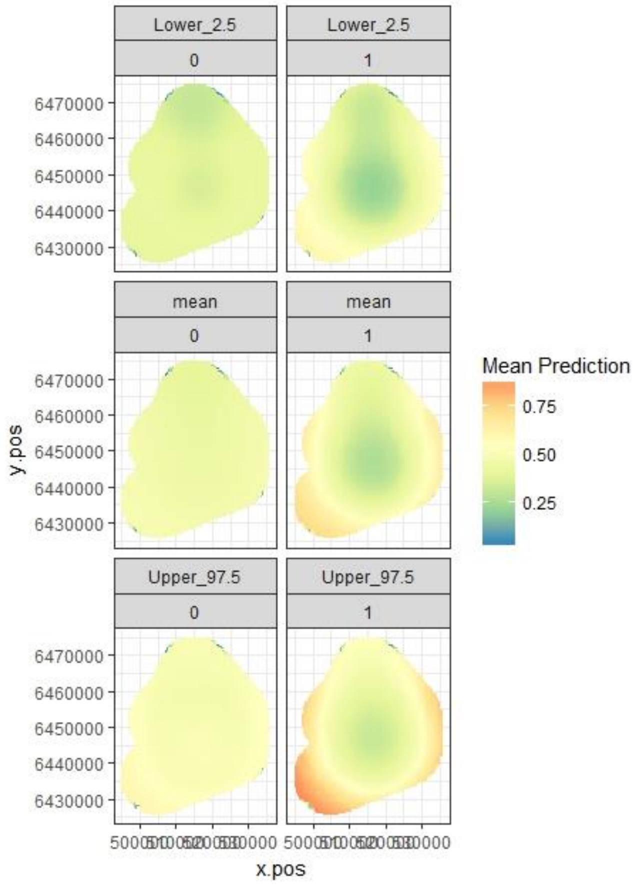

Figure A-27: Figure for the 450 m transect width 10 km buffer option with a 50 % decline in the windfarm showing the mean (middle), lower 2.5 % (top) and upper 97.5 % (bottom) of predicted animal counts before (left) and after (right) the event.

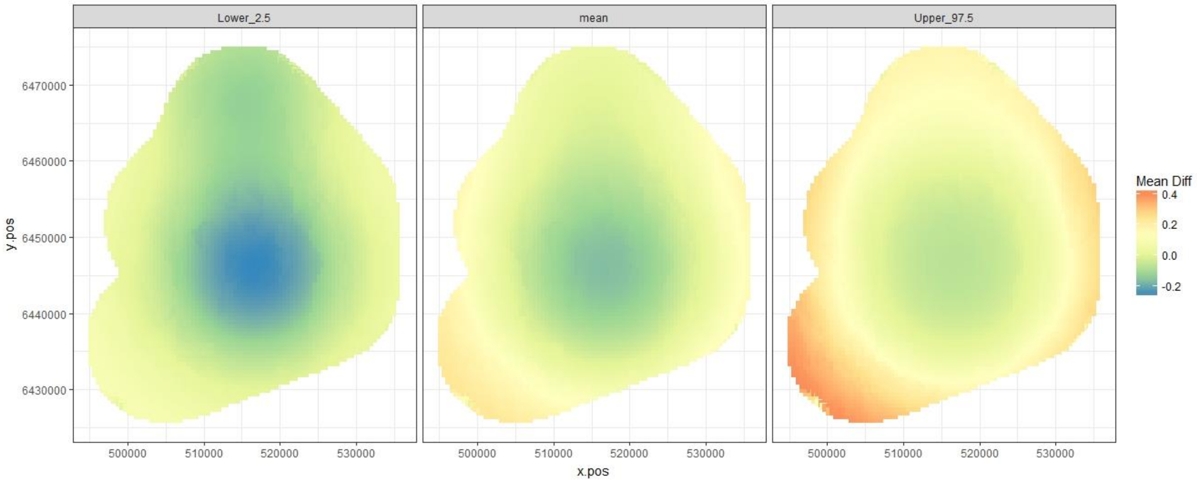

Figure A-28: Figure for the 450 m transect width 10 km buffer option with a 50 % decline in the windfarm showing the mean (middle), lower 2.5 % (left) and upper 97.5 % (right) of estimated differences between before and after the event, (difference = post - pre).

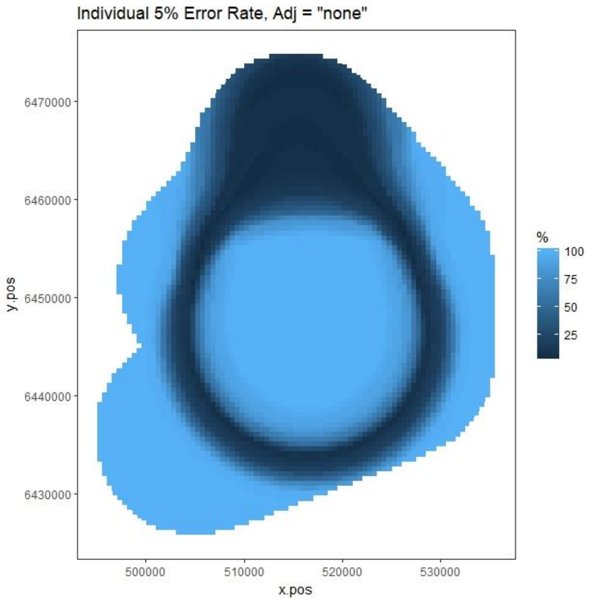

Figure A-29: Figure for the double transect width 10km buffer option with a 50% decline in the windfarm showing, for every grid cell, the proportion of simulations that showed a significant difference.

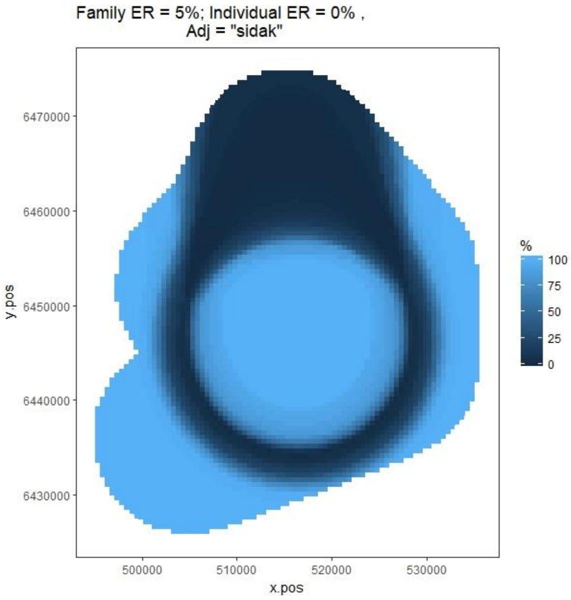

Figure A-30: Figure for the 450 m transect width 10 km buffer option with a 50 % decline in the windfarm showing, for every grid cell, the proportion of simulations that showed a significant difference (with Sidak adjustment for family error rate of 0.05).

A.7 450 m transect width with 10 km buffer design and 30 % decline outputs

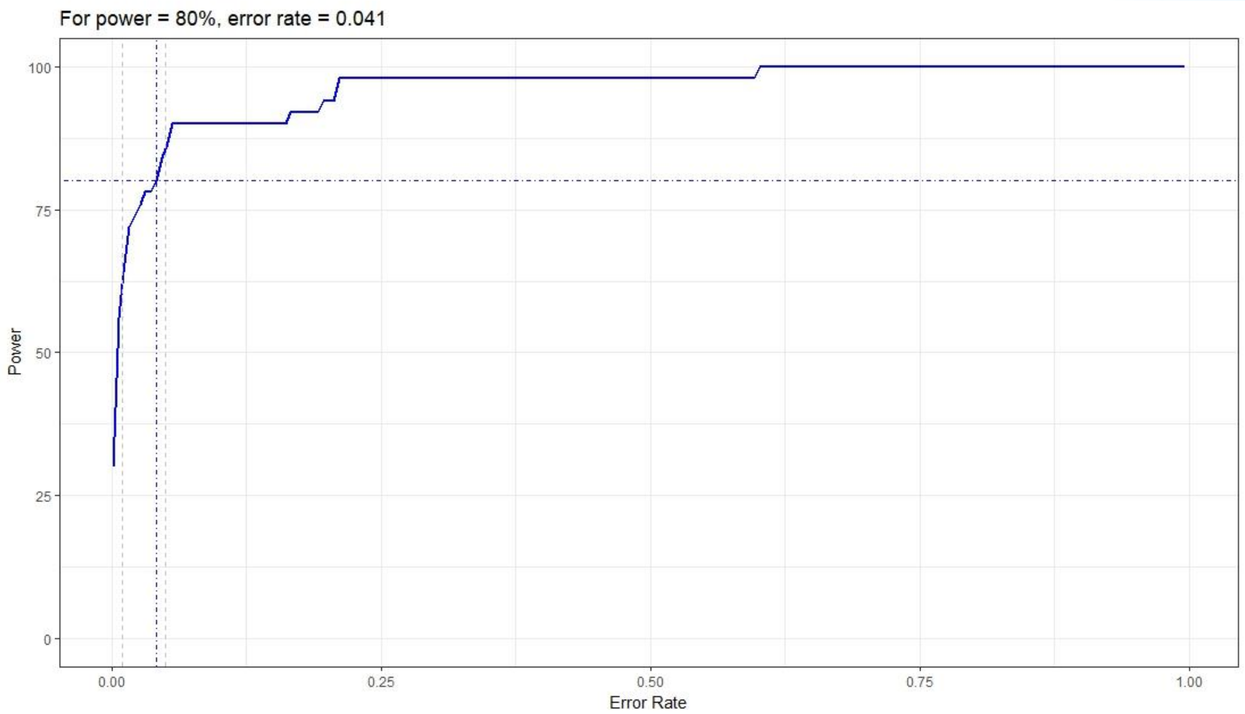

Figure A-31: Figure for the 450 m transect width 10 km buffer option with a 30 % decline in the windfarm showing how the power to detect change varies with the error rate chosen for the Moray East Site redistribution analysis.

Note: The first grey dashed line is at 1 % and the second at 5 %, traditionally values used as p-value cutoffs. The blue dashed lines indicate the error rate required to get a power of 80 %. The value is given in the title.

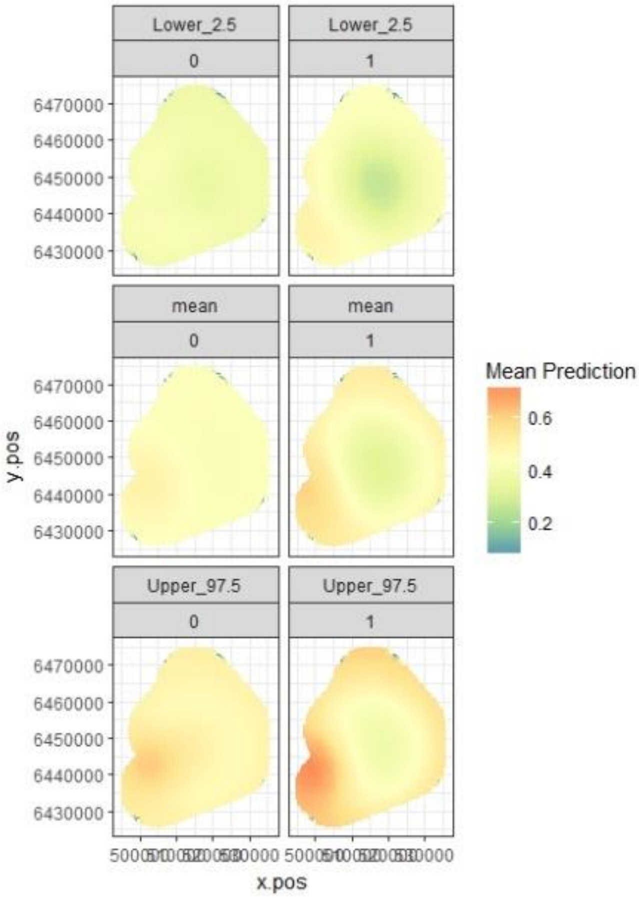

Figure A-32: Figure for the 450 m transect width 10 km buffer option with a 30 % decline in the windfarm showing the mean (middle), lower 2.5 % (top) and upper 97.5 % (bottom) of predicted animal counts before (left) and after (right) the event.

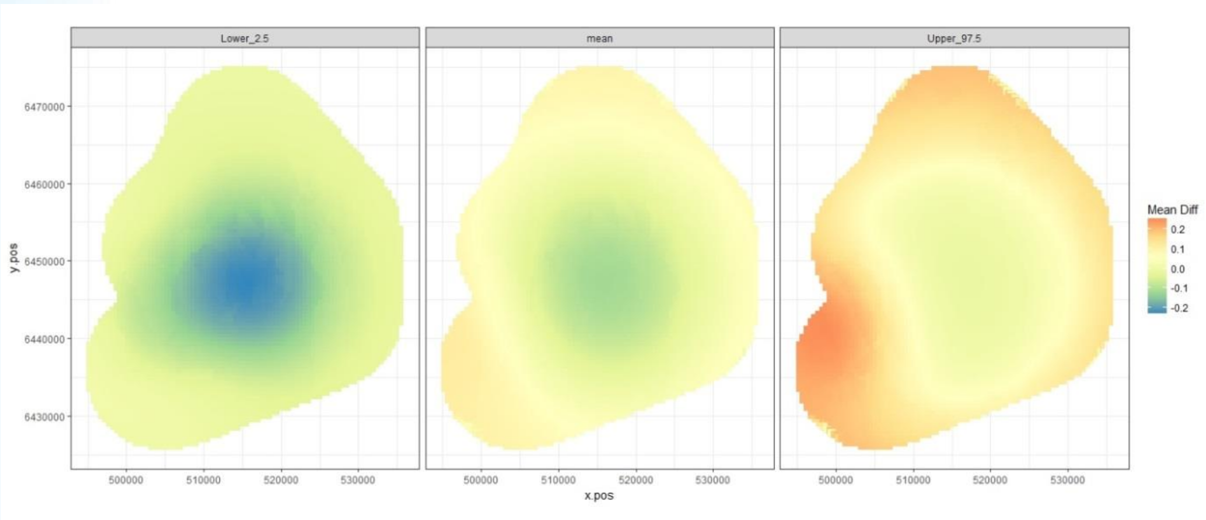

Figure A-33: Figure for the 450 m transect width 10 km buffer option with a 30 % decline in the windfarm showing the mean (middle), lower 2.5 % (left) and upper 97.5 % (right) of estimated differences between before and after the event, (difference = post - pre).

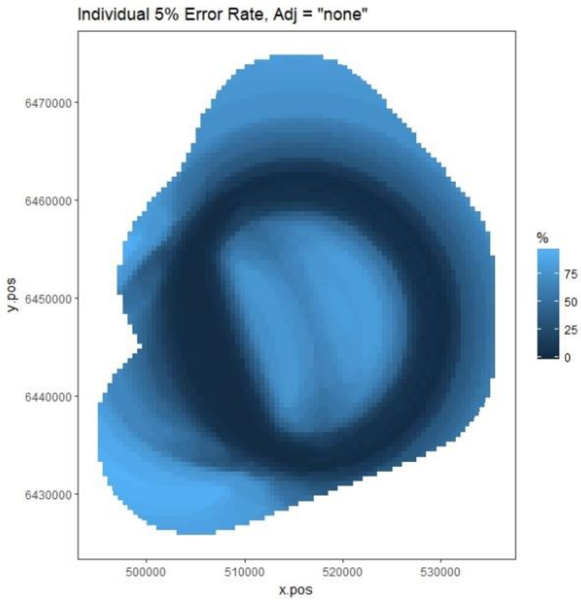

Figure A-34: Figure for the 450 m transect width 10 km buffer option with a 30 % decline in the windfarm showing, for every grid cell, the proportion of simulations that showed a significant difference.

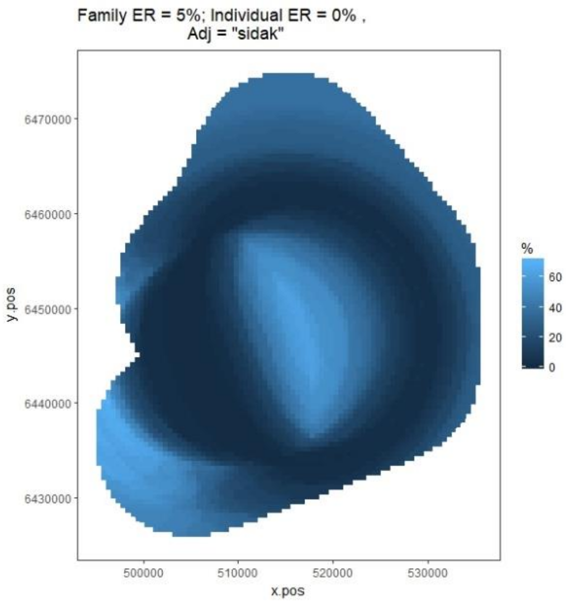

Figure A-35: Figure for the 450 m transect width 10 km buffer option with a 30 % decline in the windfarm showing, for every grid cell, the proportion of simulations that showed a significant difference (with Sidak adjustment for family error rate of 0.05).

MORAY EAST
OFFSHORE WINDFARM

Contact

Moray Offshore Windfarm (East) Limited
4th Floor, 40 Princes Street
Edinburgh EH2 2BY
Tel: +44 (0)131 556 7602