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Beatrice Offshore Wind Farm

AN INTERIM ESTIMATE OF THE PROBABILITY OF PORPOISE DISPLACEMENT AT DIFFERENT UNWEIGHTED SINGLE-PULSE SOUND EXPOSURE LEVELS

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Contents

1 Introduction

This report represents a Briefing Paper presenting an interim estimate of the probability of porpoise displacement at different unweighted single-pulse sound exposure levels. The authors of this report are Isla Graham (Aberdeen University), Adrian Farcas (CEFAS), Nathan Merchant (CEFAS) & Paul Thompson (Aberdeen University).

In May 2014, a Marine Mammal Monitoring Programme (MMMP) was developed by Aberdeen University for the Moray Firth. The programme aims to address both project-specific and strategic research and monitoring questions relating to the potential impacts of offshore wind farm construction and operation in the Beatrice wind farm site and the Moray Firth Round 3 Zone upon key protected marine mammal populations.

In 2017, Beatrice Offshore Wind Farm Limited (BOWL) commissioned additional studies by Aberdeen University in implementing their construction monitoring programme. As part of this, the MMMP is using earlier baseline data to underpin a series of behavioural response studies, including additional work on the responses of harbour porpoises to noise from pile driving and Acoustic Deterrent Device (ADD) use. These passive acoustic studies of harbour porpoise responses have been conducted in two phases; during the initial and later phases of pile installation at the Beatrice wind farm site. Data from Phase 2 have yet to be recovered, but it has been recognised that early results from Phase 1 may be useful for informing assessments of other developments in Scottish waters.

This briefing note is therefore being provided to BOWL to share with Marine Scotland (MS), so that these initial results can inform ongoing assessments where MS and their advisors consider this appropriate.

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2 Background

Assessments of the potential impacts of windfarm construction in Scottish waters have often used noise modelling by Subacoustech using their dB_{ht} metric, using either arbitrary response thresholds or a behavioural dose-response curve derived from data collected by Brandt et al. (2011) at Horns Rev II (eg. Thompson et al. 2013b).

Under advice of the regulators and their advisors, more recent assessments have used range-dependant acoustic models that predict unweighted single-pulse sound exposure levels (eg. Thompson et al. 2013a, Graham et al. 2017). However, this requires additional information on the likely responses of marine mammals at different received levels. Field data for harbour seals have recently been published (Russell et al. 2016), and monitoring during construction at the BOWL site has been designed to provide similar information for harbour porpoises.

The aim of this briefing paper is to provide initial estimates for a porpoise dose-response curve, thereby allowing this information to be incorporated into assessments being developed during the last quarter of 2017. These estimates are based on data from Phase 1 of the Beatrice monitoring, which were collected during the first 6 weeks of piling (2nd April-17th May 2017). Additional data from Phase 2 of the monitoring programme (August-October 2017) will be used to update this relationship and explore other factors that may affect variation in responses at different received levels.

3 Approach

The study was conducted in and around the BOWL construction site (Figure A1) between March and May 2017. The general approach was for changes in porpoise occurrence to be estimated using echolocation detectors (CPODs) moored at different distances from the piling vessel (Annex). We first examined changes in porpoise occurrence (Detections Positive Hours per day (DPH); Williamson et al. 2016) at each of 45 sites in the 24-hour period after piling relative to a baseline occurrence two days before the start of piling. To characterise baseline variation in occurrence, data from March 2017 from 12 sites outside the wind farm were used to produce a null distribution of proportional change in occurrence (DPH). Using these baseline data, porpoises were considered to have exhibited a behavioural response to piling when the proportional decrease in occurrence was greater than 0.5 (Figure A3).

We then modelled the probability that porpoise occurrence did (1) or did not (0) show a response to piling as a binomial response with a probit link function (Williams et al. 2014) using generalized linear mixed models (GLMM) in R (R Core Team 2017). We used distance to piling, on both an arithmetic and logarithmic scale, and received single-pulse sound exposure level (SEL) as explanatory variables in separate models because these variables were collinear. The analyses were based on relative changes within single CPOD deployments, allowing site-specific differences, resulting either from differences in individual CPOD sensitivity or site-specific environmental conditions, to be accounted for by including CPOD site as a random effect in the model. Model selection was carried out using Akaike Information Criterion (AIC) (Burnham and Anderson 2002).

4 Results

Harbour porpoise responses to piling were best explained by distance from piling on a logarithmic scale. Based on this relationship there was ≥ 50% chance of harbour porpoises responding to piling at distances up to 6.8 km from piling (Figure 1a). Based on the relationship with received single-pulse SEL, there was a ≥ 50% chance of porpoises responding to received single-pulse sound exposure levels of ~ 144.8 dB re 1 μPa^2 s (Figure 1b). The difference between these two models was small (ΔAIC = 2.8; Table A3).

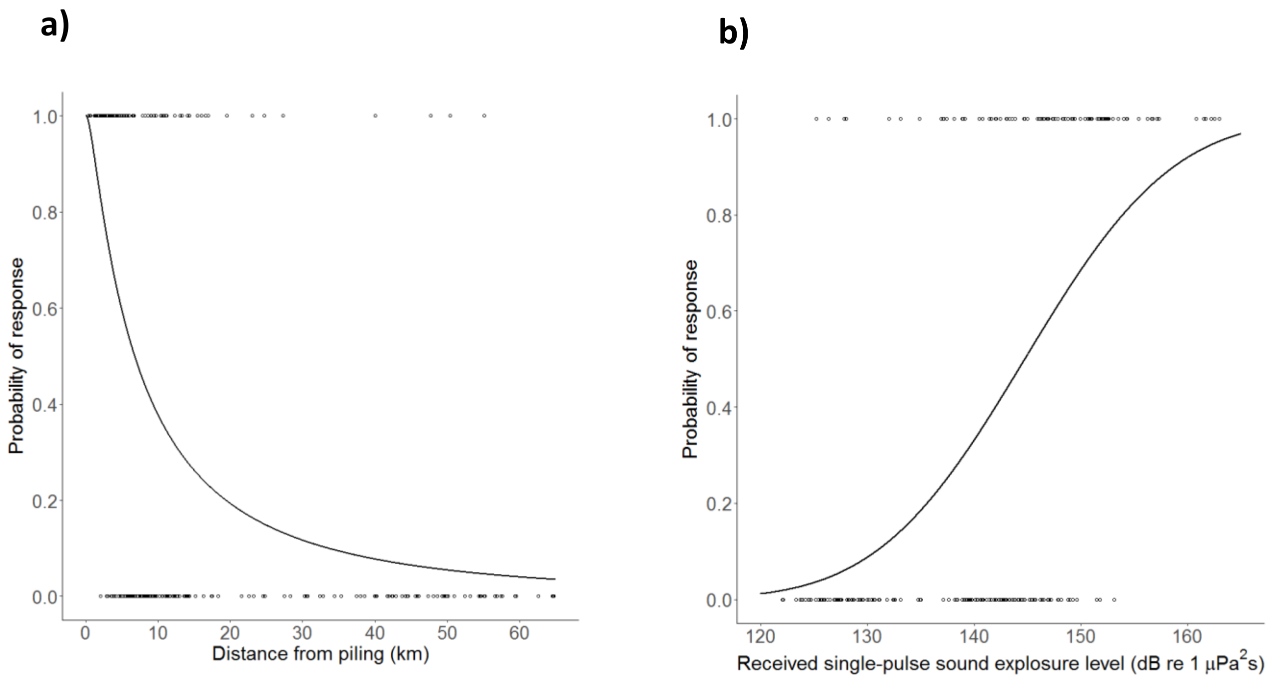

Figure 1. The probability of a harbour porpoise response in relation to a) distance from piling and b) received single-pulse SEL. Harbour porpoise occurrence was considered to have responded to piling when the proportional decrease in occurrence (DPH) exceeded a threshold of 0.5. Points show actual response data.

5 Application

Using R, these relationships can now be used to predict the probability of observing a behavioural response to piling at a specific distance or SEL using the command "*pnorm*" to obtain the cumulative distribution function of the standard normal distribution for a particular value:

$$P(response) = pnorm((-0.8030 * \log(distance)) + 1.5390)$$

$$P(response) = pnorm((0.09181 * SEL) - 13.28992)$$

ANNEX

Methods

From 02/04/2017 – 17/05/2017, 12 sets of piles were installed (Table A1), with an average time from the start to the end of piling of 7.8 h per set of four piles (range: 6.0 – 11.5 h). For this analysis, we used data collected following piling at six locations: the first location piled and five locations where the interval between piling at the previous location and the current location exceeded 96 hours (Table A1).

Table A1*. Summary of piling activity from 01/04/2017 – 17/05/2017 at the BOWL construction site. Emboldened OTM/turbine locations were used in the analysis.*

OTM/Turbine	Start time	End time	Maximum hammer energy	Days since last piling
G7	02/04/2017 06:51	02/04/2017 18:20	662	-
F8	07/04/2017 17:52	08/04/2017 01:35	951	5.0
E1	09/04/2017 16:21	09/04/2017 22:47	1035	1.6
E2	14/04/2017 02:38	14/04/2017 11:49	861	4.2
F3	16/04/2017 14:26	16/04/2017 21:19	655	2.1
E3	18/04/2017 20:49	19/04/2017 02:48	1048	2.0
H6	20/04/2017 07:43	20/04/2017 14:47	766	1.2
J5	04/05/2017 06:36	04/05/2017 15:45	737	13.7
G6	05/05/2017 17:01	06/05/2017 01:04	1007	1.1
G5	10/05/2017 07:34	10/05/2017 15:39	958	4.3
F6	11/05/2017 13:10	11/05/2017 20:38	887	0.9
F5	17/05/2017 01:22	17/05/2017 07:34	884	5.2

Underwater noise levels were recorded at five locations (see Figure A1) using autonomous noise recorders (Wildlife Acoustics SM2M Ultrasonic and Ocean Instruments SoundTraps). Recorders were independently calibrated as described in Merchant et al. (2014). Measurements were made at a sampling rate of 96 kHz, recording continuously with the SM2Ms and for 10 minutes per half-hour with the SoundTraps. Data from the noise recorders were analysed in PAMGuide (Merchant et al. 2015) to determine received noise levels. These received levels were used to model piling source levels, taking account of local bathymetry, tide levels and sediment types (RAM; Collins 1993, Farcas et al. 2016). These source levels were then used to predict the received single-pulse sound exposure levels (SEL) at all PAM sites for a hammer strike with the maximum hammer energy recorded at each OTM/turbine location (for example Figure A2).

47 CPODs were deployed between 17/02/2017 – 17/03/2017, and recovered between 14/05/2017 – 23/05/2017 (one CPOD was recovered later on 31/07/2017) (Table A2). 45 of these successfully recorded data between 17/03/2017 – 07/05/2017 covering a two-week period before the start of piling and the first five weeks of piling. Data were downloaded and processed using v. 2.044 of the manufacturer’s custom software to identify porpoise echolocation clicks. Click trains categorized as high or moderate quality were used for analyses.

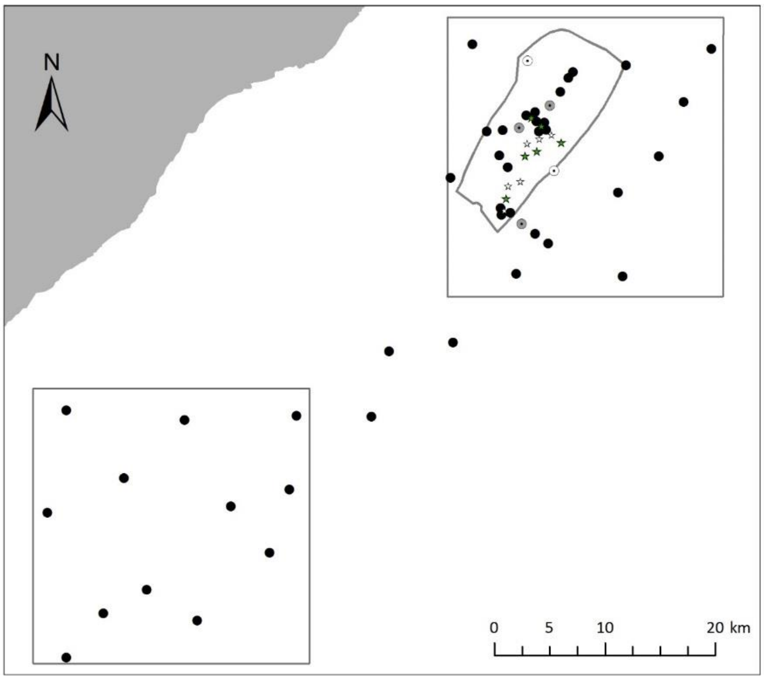

Figure A1. Map of the study area showing the location of the BOWL construction site, the OTM and wind turbine locations piled from 02/04/2017 – 17/05/2017 (stars). Filled stars indicate piling locations used in the analysis. PAM sampling sites are indicated by circles: CPOD only sites (black circles); SM2M and CPOD sites (grey circles); SoundTrap and CPOD sites (open circles). The two 25x25km squares represent areas designated as an impact block (over the wind farm site) and a control block to the SW for parallel BACI studies.

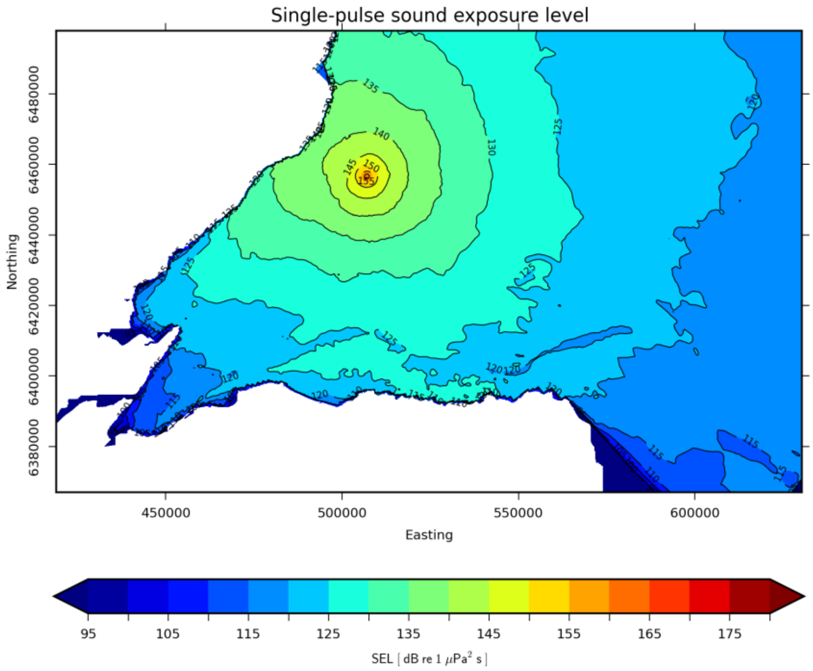

Figure A2. Modelled predictions of received levels of noise from impact piling at OTM location G7 in the BOWL construction site. Predictions are depth averaged received single-pulse sound exposure levels (SEL) for a hammer strike of 662kJ.

Baseline distribution of proportion change in harbour porpoise occurrence.

Data were available for 12 sites in the control block, from 07/03/2017 – 16/03/2017. We randomly sampled 100 times from 09/03/2017 – 15/03/2017 for each site and determined the proportion change in the number of DPH in the 24-hour period following each randomly selected time relative to the number of DPH in the 24-hour period two days prior to it.

Using the quantile function in R the 5% and 1% quantiles of this distribution were calculated. 95% of the values of proportion change in porpoise occurrence during this baseline period were greater than -0.35 and 99% of values were greater than -0.5 (Figure A3).

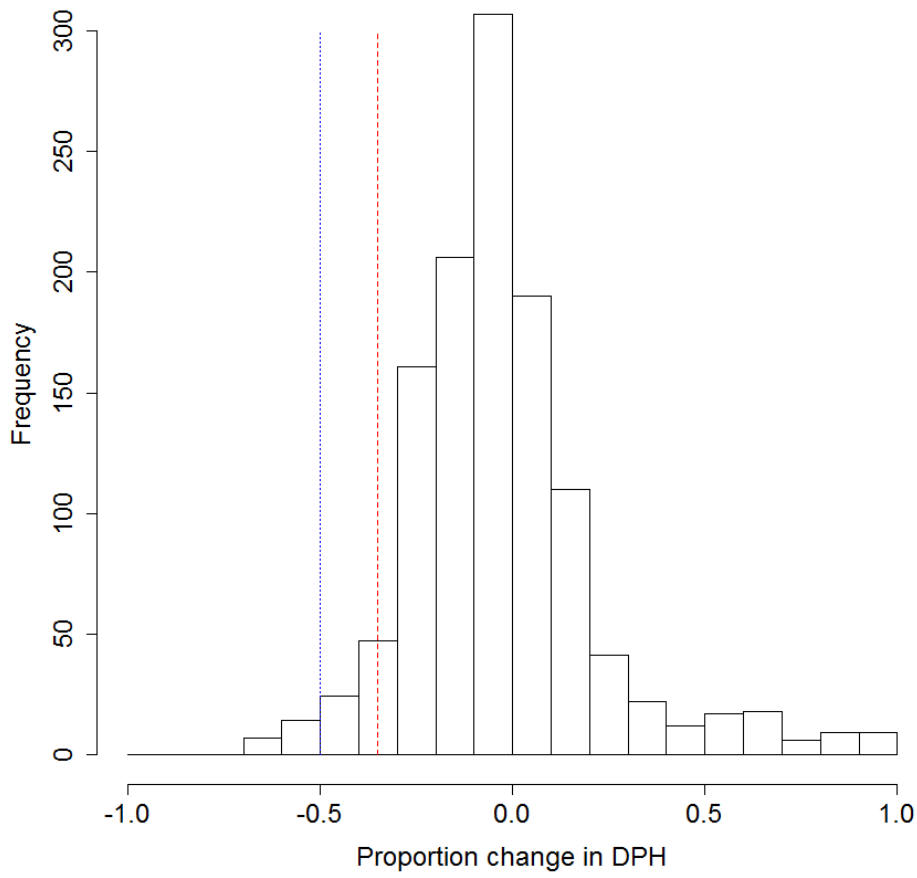

Figure A3. Frequency distribution of the proportion change in harbour porpoise occurrence (DPH) from 100 randomly sampled times at 12 sites from 07/03/2017 – 16/03/2017. The red dashed and blue dotted lines indicate the 95th and 99th percentile respectively of the distribution.

Table A2. Locations and timings of CPOD deployments during Phase 1 of the PAM programme.

Location	Latitude	Longitude	Deployment Date	Data End Date	Data
17	57.96265	-3.52097	28/02/2017	14/05/2017	✓
40	57.81640	-3.60637	28/02/2017	14/05/2017	✓
41	57.85257	-3.55080	28/02/2017	14/05/2017	✓
42	57.87230	-3.48443	28/02/2017	14/05/2017	✓
44	57.94027	-3.35695	28/02/2017	14/05/2017	✓
45	57.95435	-3.26772	18/02/2017	14/05/2017	✓
46	58.01430	-3.25660	18/02/2017	14/05/2017	✓
47	58.01360	-3.14232	18/02/2017	23/05/2017	✓
48	58.06677	-3.11523	18/02/2017	23/05/2017	✓
49	58.07415	-3.01663	18/02/2017	No data	×
53	58.19568	-2.76270	18/02/2017	23/05/2017	✓
54	58.22528	-2.69948	17/02/2017	23/05/2017	✓
55	58.26930	-2.66073	17/02/2017	21/05/2017	✓
56	58.31208	-2.61772	17/02/2017	21/05/2017	✓
76	58.28895	-2.83853	17/02/2017	07/05/2017	✓
78	58.22608	-2.94583	17/02/2017	18/05/2017	✓
82	58.01035	-3.42820	28/02/2017	14/05/2017	✓
89	57.93418	-3.63750	28/02/2017	14/05/2017	✓
90	58.01768	-3.60973	28/02/2017	14/05/2017	✓
98	57.90275	-3.29757	18/02/2017	14/05/2017	✓
99	57.84760	-3.40742	28/02/2017	14/05/2017	✓
108	58.31663	-2.98685	18/02/2017	18/07/2017	✓
110	58.12778	-2.75613	18/02/2017	23/05/2017	✓
143	58.24550	-2.88427	17/02/2017	18/05/2017	✓
144	58.24697	-2.87357	17/02/2017	18/05/2017	✓
145	58.25290	-2.87592	17/02/2017	18/05/2017	✓
146	58.25385	-2.88868	17/02/2017	19/05/2017	✓
147	58.25872	-2.90427	17/02/2017	19/05/2017	✓
148	58.26148	-2.89023	17/02/2017	18/05/2017	✓
149	58.26670	-2.86728	17/02/2017	18/05/2017	✓
150	58.27767	-2.85127	17/02/2017	09/05/2017	✓
151	58.24888	-2.91505	17/02/2017	19/05/2017	✓
152	58.24680	-2.94018	17/02/2017	19/05/2017	✓
153	58.24577	-2.96520	17/02/2017	19/05/2017	✓
154	58.17950	-2.92908	17/02/2017	19/05/2017	✓
155	58.17797	-2.94272	17/02/2017	19/05/2017	✓
156	58.18322	-2.94373	17/02/2017	05/03/2017	✓
157	58.17068	-2.91105	17/02/2017	19/05/2017	✓
158	58.16245	-2.89073	17/02/2017	21/05/2017	✓
159	58.15437	-2.87047	17/02/2017	21/05/2017	✓
160	58.29393	-2.83185	17/02/2017	21/05/2017	✓
161	58.21663	-2.93237	17/02/2017	18/05/2017	✓
162	58.30325	-2.90188	17/03/2017	21/05/2017	✓
163	58.29933	-2.74980	18/02/2017	21/05/2017	✓
164	58.21385	-2.86152	17/03/2017	21/05/2017	✓
165	58.20785	-3.02100	03/03/2017	23/05/2017	✓
166	58.12998	-2.92008	18/02/2017	23/05/2017	✓

Model results

***Table A3**. a) Modelled relationships of harbour porpoise behavioural response to piling. Response was defined as a proportional decrease in harbour porpoise occurrence > 0.5 in the 24 hours after cessation of piling. Relationships were modelled using generalised linear mixed models with a binomial error distribution and the probit link function. Distance from piling and received single-pulse sound exposure levels (SEL) were used as explanatory variables and PAM sampling site as a random effect (Variance = 0; Std. Dev. = 0). b) Without a random effect of PAM sampling site.*

a)

Model		Estimate	Std. error	*z* Value	*P*	AIC
Response ~ log(distance) + (1 | site)						247.9
	(Intercept)	1.5390	0.2429	6.336	< 0.001	
	log(distance)	-0.8030	0.1019	-7.877	< 0.001	
Response ~ distance + (1 | site)						272.8
	(Intercept)	0.4124	0.1263	3.266	0.001	
	distance	-0.0446	0.0071	-6.291	< 0.001	
Response ~ SEL + (1 | site)						250.7
	(Intercept)	-13.2899	1.6811	-7.905	< 0.001	
	SEL	0.0918	0.0118	7.801	< 0.001	

b)

Model		Estimate	Std. error	*z* Value	*P*	AIC
Response ~ log(distance)						245.9
	(Intercept)	1.5390	0.2385	6.453	< 0.001	
	log(distance)	-0.8030	0.1012	-7.934	< 0.001	
Response ~ SEL						248.7
	(Intercept)	-13.2899	1.6865	-7.880	< 0.001	
	SEL	0.0918	0.0118	7.795	< 0.001	

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