Project Title	Beatrice Offshore Wind Farm
Date:	October 2016

Addendum to the BOWL Construction MMMP – details of studies to be conducted during piling

Rev	Prepared By	Signed	Checked By	Signed	Approved By	Signed	Date of Issue
1.0							

Table of Contents

1 Introduction

The overall objectives and workplan for the Construction MMMP were outlined in the document dated 27th June 2016 (BOWL Report LF000005-REP-550) which was subsequently approved by the MFRAG. However, it was recognised that the work plan for studies to be conducted within Work Packages 3 and 4 at the BOWL Wind Farm required further development following discussion with installation teams.

This addendum to the Construction MMMP workplan has been developed following five meetings:

26/7/16 – Meeting between BOWL Consents & Engineering Teams, SHL, Aberdeen Univ & Moray First Marine to identify how engineering work may constrain mooring deployment and recovery.

30/8/16 – Internal Aberdeen Univ meeting to develop an appropriate design for the C-POD array given the information on engineering constraints.

31/8/16 – Phone meeting between Aberdeen Univ (PT) and MSS (KB) to explore MSS plans for 2017 underwater noise recording work through ECOMMAS.

5/9/16 – Meeting with Aberdeen Univ, CEFAS & SMRU to confirm C-POD array design and agree on locations and equipment for noise recordings.

22/9/16 – Meeting with Aberdeen University, BOWL, MSS & MS-LOT to discuss draft proposals for the detailed work programme under Work Packages 3 and 4.

This document now provides detail on the work to be conducted under Work Packages (WPs) 3 and 4 of the Moray Firth CMMP during the construction phase of the BOWL Wind Farm.

1.1 Key issues influencing the proposed Work Plan

Three issues emerged during these discussions that strongly influenced the proposed array design and equipment choice.

1. The 1.5km radius spread of eight anchors around the piling vessel means that any moorings deployed within active areas of the BOWL construction site will have a high risk of loss or damage.

2. The use of ADDs at German windfarms indicates that porpoises respond at distances of up to 7.5 km, indicating that C-PODs located outside the 1.5km anchor spread would still provide valuable data on response distances and return times.

3. The Wildlife Acoustics SM2M recorders used for previous noise studies in the Moray Firth are no longer available. There is therefore a need to purchase alternative noise recorders to use alongside our existing stock of SM2Ms. CEFAS

have identified the Ocean Instruments Soundtrap as an appropriate alternative device for their MSFD noise monitoring work

2 Monitoring Mitigation Measures Work Packages

2.1 Work Package 3.1: Responses of harbour seals to ADD & piling soft starts

2.1.1 Objectives

This work package will collect data that may be used to assess the fine-scale responses of harbour seals to the alternative mitigation procedures set out in the Piling Mitigation Protocol (Thompson & McGarry, 2015) that will be used during construction.

Parameters to be measured

- 3 dimensional (3D) distribution;
- Movement rates.

2.1.2 Survey Design

Following discussions at the MFRAG Marine Mammal Subgroup meeting on 15th December 2015, it was agreed that there is limited opportunity for dedicated work within the construction site due to the low numbers of individuals using these offshore foraging areas as indicated by the results from the pre-construction MMMP.

Nevertheless, broader scale tracking work under WP 1.3 (harbour seal responses to piling) may provide opportunistic evidence of responses to ADDs and soft start should harbour seal be in nearfield areas prior to start of piling activities.

2.1.3 Existing Baseline

GPS-GSM data on baseline fine-scale movements and dive patterns are available from approximately 30 individual harbour seals from the Loch Fleet study population through the pre-construction MMMP and earlier studies (Cordes et al. 2011). In addition, >30 harbour seals from the Moray Firth have been tracked during 2014 and 2015 using GPS-UHF tags as part of the MS funded SMRU studies.

2.1.4 Sampling Locations

The primary site for capturing harbour seals for tracking will be Loch Fleet (Figure 2), to maximise the chance of linking these data on at-sea distribution and behaviour to the long-term study of vital rates. Additional captures will be made at other haul-out sites in the Moray Firth if required.

2.1.5 Sampling Periods

Pre-construction data have been collected during the winter of 2014/15 and the summer of 2015. Deployment of an additional 32 tags are planned for February/March 2017 to cover the construction phase, and maximise the likelihood of detecting changes in behaviour in response to ADD and piling activity that is currently scheduled to start in April 2017.

2.1.6 Sampling Technique

During the pre-construction phase, twenty-five GPS-GSM tags have been deployed on harbour seals. Additional data are available through the SMRU's MS funded study that

included some tagging of seals from the Dornoch Firth SAC to assess connectivity with other Moray Firth haul-out sites.

For the construction phase studies, all study individuals will be captured using barrier nets as they flush from their haul-out sites. Capture, handling and anaesthesia will be conducted by SMRU staff under licence from the Home Office and Marine Scotland. These procedures all require suitably trained and licenced personnel and the use of specialist boats and equipment (see Sharples et al. 2012 for full details).

GPS/GSM tags will be attached to the fur at the back of the neck using Loctite® 422 Instant Adhesive and the seals released following collection of standard samples and measurements.

2.1.7 Data Analysis

GPS-GSM data on the locations and dive patterns of individual seals will be regularly transmitted via GSM to the University of St Andrews, where they will be subject to routine error checking and then archived.

Details of the timing and location of all piling activity and associated mitigation will be provided by the developers and archived for further analysis. Subsequent work within WP 1.3 will identify whether any of the tagged harbour seals were within 10km of piling activity in order to evaluate the potential for more detailed analysis of fine-scale changes in behaviour in relation to ADD use and soft start. These records will be archived to allow future comparison with control data generated using the baseline fine-scale movement data from GPS-GSM tagged seals in this area.

2.2 Work Package 3.2: Responses of harbour porpoises to ADD & piling soft starts

2.2.1 Objectives

In line with the previous work packages, monitoring related to the use of ADD and soft start aims to focus on specific questions and uncertainties that emerged during the development of the Piling Mitigation Protocol (Thompson & McGarry, 2015). Priority questions are:

a) To what extent are porpoises displaced from piling areas by ADD use prior to soft start, and during soft starts?
b) How long does it take porpoises to return to the piling area during breaks in piling?
c) How do levels of response and return times vary in relation to (i) time since the start of construction and (ii) habitat quality?

2.2.2 Parameters to be measured

- Presence of porpoise echolocation clicks in given time periods (minutes, hours and days) at different distances from piling;

- Probability of foraging buzzes occurring in those time periods that porpoises are detected.

2.2.3 Survey Design

The design of these surveys has been based upon previous studies of this species at other European wind farm sites (e.g. Brandt et al. 2013), and studies of this species' response to other noise sources within the Moray Firth (Thompson et al. 2013b). Arrays of C-PODs will be used to study changes in the occurrence and activity of porpoises in relation to distance from the ADD and piling noise. Arrays will thus be designed to provide a gradient of distances from a sample of piling locations and variation in baseline harbour porpoise density (which is assumed to reflect differences in habitat quality).

It was previously agreed that studies of responses within 100m of the ADD were not considered feasible because extremely low numbers of animals are expected to be within the 60m injury zone (see Annex 3 in the Piling Mitigation Protocol (Thompson & McGarry, 2015)). This means that sample sizes would be too small to draw robust conclusions about whether or not animals were excluded from these areas. Fine-scale studies of responses to ADDs have therefore been designed to focus on responses within 0.5-10 km, building upon recent studies in the Southern North Sea that indicate that porpoises respond to ADD at distances of up to 7.5 km. If animals can be shown to respond to an ADD at this scale, then this will provide confidence that an ADD also provides protection within the injury zone.

In addition, broader scale studies of responses to ADD and piling noise, and return times following individual piling events, will use the combined BACI and gradient analysis design previously used to detect responses of porpoises to seismic surveys in the Moray Firth (Thompson et al. 2013b).

For both aspects of this design, studies will focus on the first 4-weeks of piling, with a similar baseline period before construction starts in early April. Results from these deployments will be used to inform the final design of a second phase of monitoring later in the summer.

2.2.4 Existing Baseline

The MORL and BOWL ESs present the extensive existing baseline on the distribution of harbour porpoises in the outer Moray Firth, with robust estimates of density available within the MORL and BOWL sites and PAM data on porpoise occurrence from multiple locations (see also Brookes et al. 2013 and Williamson et al. 2016). A series of other studies both in the Moray Firth (Thompson et al. 2013b; Pirotta et al. 2014) and at other European wind farm sites (Brandt 2013; Dahne 2013b) have demonstrated how dispersed PAM arrays can be used to measure responses to anthropogenic noise. Two C-POD sampling sites within the BOWL site have provided year-round baseline data on seasonal variation in porpoise occurrence that are presented in the BOWL ES. The spatial coverage of data from other sites in the region tends to be highest during August and September (see Williamson et al. 2016).

2.2.5 Sampling Locations

To assess responses to ADD noise, three fine-scale arrays (each of 6 C-PODs) will be deployed at distances of 0.5, 2, 3.5 and 5 km from turbines at the beginning and end of the first construction string. In combination, this will provide sampling sites at distances of between 0.5 and 10 km from 6 -10 turbine locations. An indicative design is provided in Figure 1, but it should be noted that this must remain flexible to possible changes in the

construction timetable. Recognising the risk to equipment from anchor handling vessels at the closest (0.5 km) sites, each array will include 3 C-POD moorings at this distance to provide redundancy.

To assess broader scale responses to piling, 12 additional C-PODS will be moored in 25 x 25 km impact and control blocks, with additional moorings between these blocks providing a gradient of exposure to piling noise at distances up to 60 km. The proposed locations for this sampling are shown in Fig 2.

2.2.6 Sampling Periods

There will be two sampling periods during the 2017 piling operations at the BOWL wind farm, each focussing on one cluster of structures (turbines and/or offshore sub-station platforms). The intention is to deploy the first set of C-PODs 3 to 4 weeks prior to the start of piling. The first set will therefore monitor initial responses to ADD and piling noise within a relatively naive group of animals. The second set of C-PODs will be deployed later in the installation programme to assess whether responses vary in relation to time since the start of construction (for example due to habituation or increased tolerance). Each of these deployments is anticipated to last between 4 and 6 weeks. It is anticipated that the second sampling period will be during August and September, coinciding with the period containing the most detailed baseline data, and that the Phased Piling Mitigation Period will occur either just prior to, or overlapping with, this second CMMMP sampling period.

2.2.7 Sampling Technique

Sampling will be based upon arrays of C-PODs as previously used by Thompson et al. (2013b) and Pirotta et al. (2014), and described in WP 2.3. To minimise interactions with construction activities, devices within the wind farm sites will be anchored using a short mooring and mid-water float and recovered using an ROV. Devices at some sites outside the construction site may be moored using acoustic releases.

2.2.8 Data Analysis

C-POD data will be analysed as outlined in WP 2.3, using appropriate train filters for harbour porpoise. The resulting data on variation in occurrence and foraging buzzes will be analysed in relation to information on the known timing and location of ADD use and piling activity, and measured and modelled estimates of received noise levels at different distances from source.

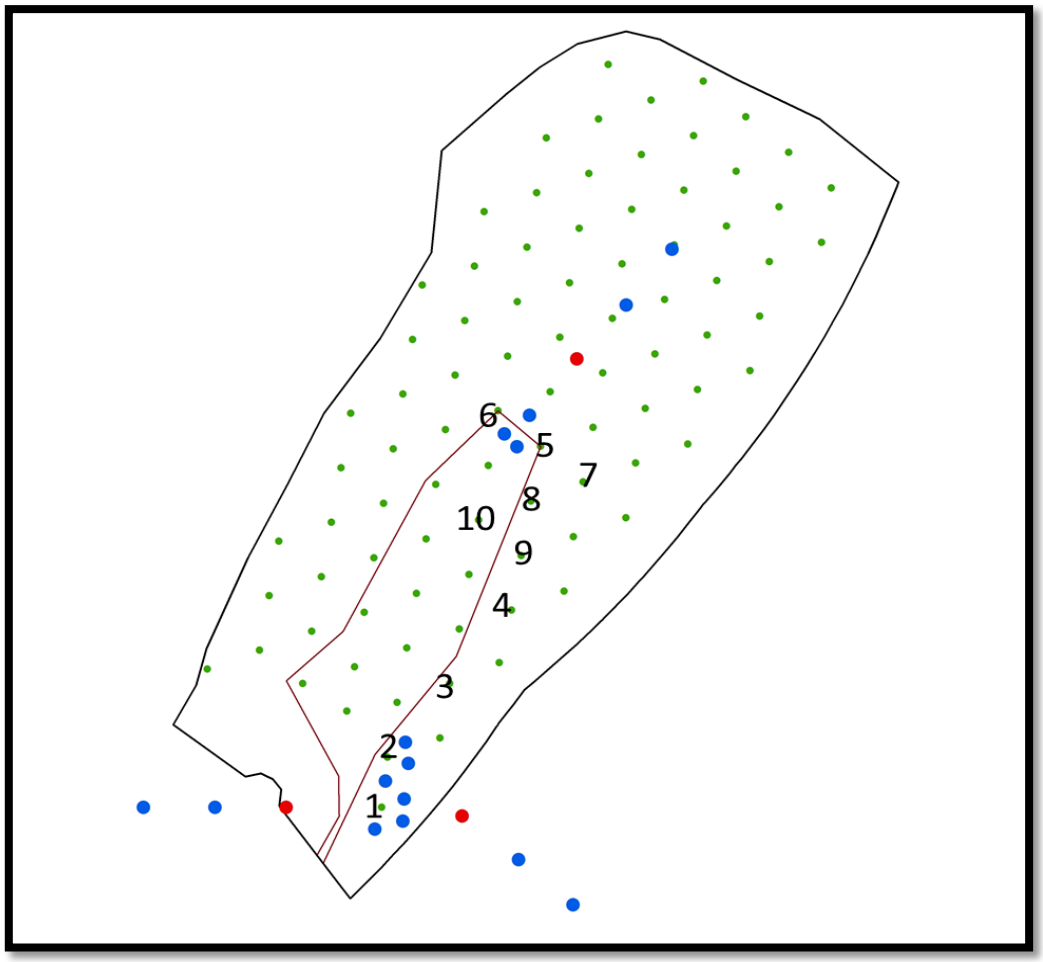

Figure 1: Indicative design for the fine-scale array of C-PODS and noise recorders during the first survey phase. Turbines are numbered in anticipated order of installation. C-PODS moorings are shown as blue circles, C-PODS + SM2M moorings are shown as red circles

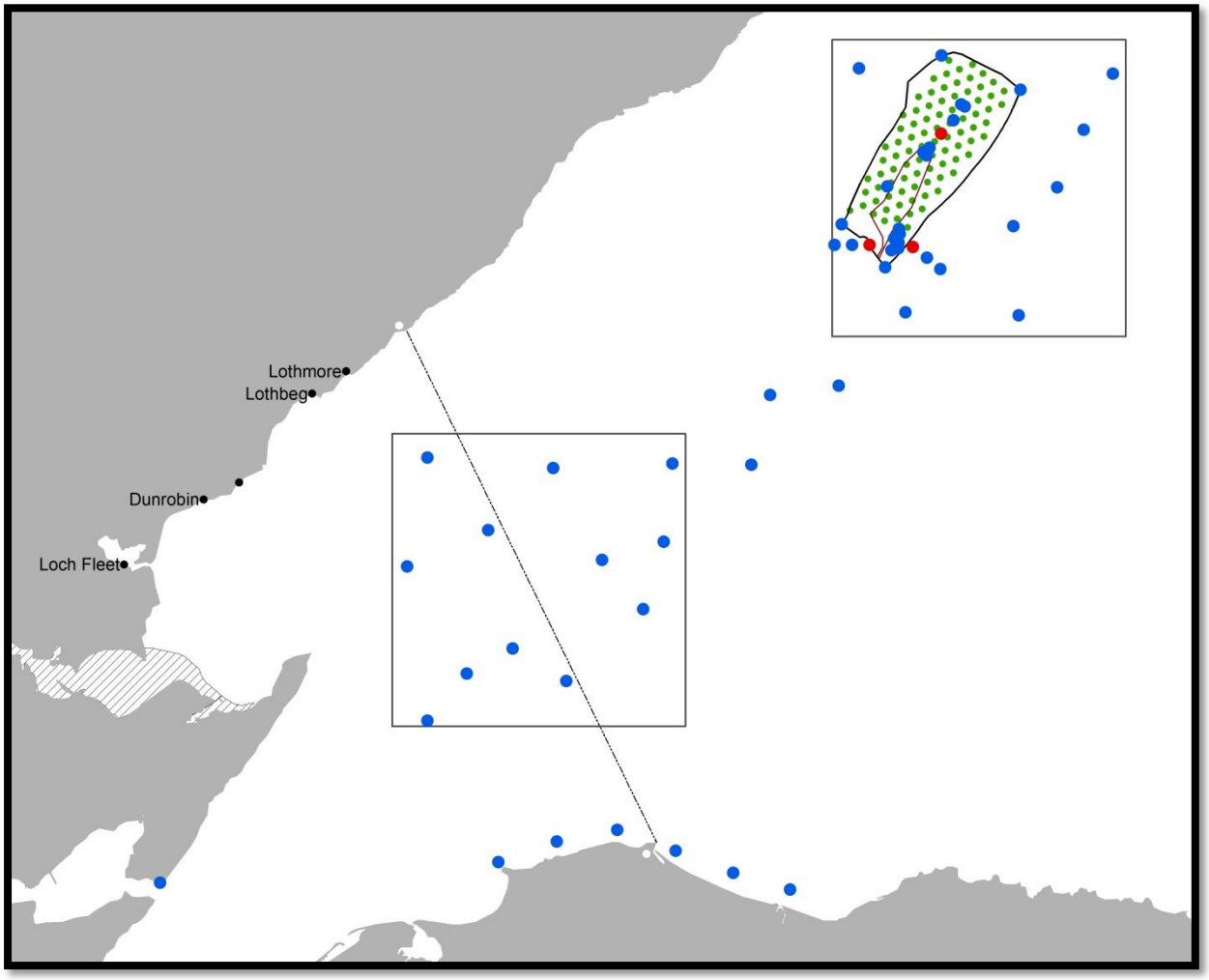

Figure 2: Design for the broad scale array of C-PODS in the 25x25 km impact and control survey blocks. Additional locations between the blocks are planned to provide a gradient of exposure from the pile driving locations. Also shown are the coastal long term sites and south coast sites where data will be collected under WP 2.3.

3 Noise Measurement and Modelling Work Packages

3.1 Work Package 4.1: Temporal variation in source levels of piling noise in relation to differences in hammer energy and ground conditions.

3.1.1 Objectives

This work package will address key uncertainties identified during the development of the Piling Mitigation Protocol (Thompson & McGarry, 2015). Specifically, noise monitoring during construction aims to understand how predicted source levels and near-field noise levels (i.e. at ~ 2km) vary in relation to changes in hammer energy and ground conditions. This package also aims to collect data on received levels of ADD and soft-start piling noise that can be related to behavioural response data from WP 3.

3.1.2 Parameters to be measured

- Frequency spectra
- Pk to pk Sound Pressure Levels (SPL) and single pulse Sound Exposure Levels (SEL)

3.1.3 Survey Design

Seabed mounted, calibrated noise recorders will be deployed at a sample of sites in parallel with the short term C-POD deployments being made within WP 3.2 (Figure 1).

Lower resolution longer term deployments will also be made to assess variation in piling and other anthropogenic noise sources through the construction period (to also inform WP 1.3), complementing other data that will be available from MSS through their East Coast PAM Array.

3.1.4 Existing Baseline

Data on variations in pk-pk SPL were collected during the installation of the Beatrice Demonstrator Turbine (Bailey et al. 2010b), but only for a more limited range of the hammer energies and ground conditions. Measurements of other impact noise sources have also provided baseline on propagation losses across the Moray Firth (Thompson et al. 2013b).

3.1.5 Sampling Locations

Short term deployments of approximately 8 weeks will be made at each of the three arrays being used to assess responses to ADD in WP 3.2 (see Figure 1.) To minimise the risk from construction vessel anchors, these noise recorders will be deployed at the three sites which are a minimum of 2 km from piling locations, providing recording at approximately 2-10km from source.

Lower resolution longer term deployments will be made at two sites on the periphery of the BOWL construction site, where sites will be selected to minimise risk from construction traffic, fishing vessels and interference from navigation buoys.

3.1.6 Sampling Periods

Short-term deployments will be made in March-April and August-September 2017 as for WP 3.2

Longer term, lower resolution recordings will be made throughout the entire piling period, through two sequential deployments and recoveries at these sites.

3.1.7 Sampling Technique

Measurements will be made using two different models of calibrated seabed mounted noise recorders. One (Wildlife Acoustics SM2M) has previously been used by Merchant et al. (2014) to monitor ship noise and by MSS in their East Coast Passive Acoustic Monitoring (PAM) array. The second (Ocean Instruments Soundtrap) is being adopted by CEFAS as the primary tool for noise monitoring work under the Marine Strategy Framework Directive.

Devices will be programmed to provide a balance between a duty cycle that permits recordings to capture important events throughout the deployment period and a sampling rate that allows the characterization of ADD and/or piling noise.

Mooring design during longer term deployments will be as used for the C-POD array in WP 3.2. Short term deployments (< 6 hrs) whilst the survey vessel is on site will be marked with a surface buoy.

3.1.8 Data Analysis

Recordings will be analysed by CEFAS using PAMGuide (Merchant et al. 2015) to determine single-pulse sound exposure levels (SEL) and peak-to-peak sound pressure levels (SPL) for impact piling strikes received at each location. These received levels will be used to predict the source level of impact piling (defined as the sound level at a notional distance of 1 m from the pile), based on acoustic propagation modelling using a parabolic equation approach that takes account of local bathymetry and sediment types (RAM; Collins 1993, Farcas et al. 2015). Previous data modelling undertaken post consent will also be used to support these predictions.

These data will be related to detailed piling records and baseline geotechnical data to explore how source levels vary in relation to hammer energy and ground conditions.

3.2 Work Package 4.2: Spatial variation in received levels of piling noise and ADD noise

3.2.1 Objectives

This work package aims to use noise measurements collected in WP 4.1 to validate models for predicting the behavioural and population consequences of noise disturbance to marine mammals. Assessment frameworks within the BOWL and MORL ESs used noise propagation modelling that was based upon Subacoustech's proprietary modelling programme and the $dB_{(ht)}$ noise metric (see Thompson et al. 2013a). Subsequent attempts to validate predicted levels of seismic noise using the $dB_{(ht)}$ metric proved unsuccessful, particularly for far field measurements (see Thompson et al. 2013c). More recent studies by Hastie et al. (2015) have recently used alternative noise propagation models to estimate cumulative noise exposure.

Thus, this work package focuses on using new noise measurements collected through WP 4.1 to validate alternative noise propagation models to test the Seal Assessment Framework. This, in turn, will better inform future environmental assessments that use developing best practice for underwater noise modelling (see Farcas et al. 2016).

In particular, this work package aims to address the following questions:

- How do received levels of piling noise and ADD noise vary in time and space?
- What are the predicted cumulative sound exposure levels from piling noise for different species or individuals using different parts of the Moray Firth (to inform Work Packages 1, 2 & 3)?

3.2.2 Parameters to be measured

- Frequency Spectra
- Pk to pk Sound Pressure Levels (SPL) & single pulse Sound Exposure Levels (SEL)
- RMS levels

3.2.3 Survey Design

Measurements of pile driving noise collected within WP 4.1 will be used to optimise a parabolic equation model for the Moray Firth that is based upon RAM (developed by Collins (1993) and Collins (1999)), and utilises local data on bathymetry, sediment structure, and sound speed.

Received levels and frequency spectra of ADD noise will be measured at different distances from source, and used within the parabolic equation model to predict received levels at other distances.

3.2.4 Existing Baseline

Recent work within the inner Moray Firth has demonstrated how the use of measurements and modelling can be used to provide more robust predictions of received noise levels at a more coastal location (Farcas et al. 2016). A preliminary parabolic equation model has been developed by CEFAS for the outer Moray Firth using available noise recordings.

A similar approach has also been used in the Wash to explore variation in cumulative noise exposure (Hastie et al. 2015) and behavioural responses (Russell et al. 2016) of tagged harbour seals.

3.2.5 Sampling Locations

Noise measurements will be made at locations that are 2 - 10 km from the piling vessel, as outlined in WP 4.1. Additional short term recordings will be made within areas known to be frequented by foraging seals to optimise the propagation model within those areas in which seals are most likely to be exposed.

Because of the risk of damage from the piling vessel, recordings from these deployments will not provide information on near-field (< 2km) characteristics of ADD noise. To address this, additional ADD playbacks will be made from a separate survey vessel during March, before the piling vessel is on site. To balance exposure of animals to ADD noise during this baseline period, playbacks will be made over turbine locations within the impact block and matched sites within the control blocks (see Figure 2 for the location of impact and control blocks). These 15 minute playbacks will also provide an additional opportunity to assess porpoise responses to four independent ADD playbacks in the absence of piling noise.

3.2.6 Sampling Periods

ADD noise will be recorded on 2 days during the March pre-construction period, with at least

5 days recovery time between each exposure. In addition, ADD noise recordings will be made through the April and Aug-Sept survey periods within the construction period. Additional short term recordings of received levels of piling noise within seal foraging areas will be made throughout the construction period. The Moray Firth model will be optimised using all these noise measurements, and will then be integrated with detailed piling records to predict cumulative noise exposure levels throughout the construction period.

3.2.7 Sampling Technique

Measurements will be made using calibrated Wildlife Acoustics SM2M and Ocean Instruments Soundtrap noise recorders as outlined in WP 4.1.

Additional calibration of these recorders will be undertaken by collecting comparative data using these two different devices during the 2 days of ADD playbacks planned for March 2017. Soundtraps will be deployed for several hours alongside the SM2M devices, and additional Soundtraps will be moored at distances of 100m – 2 km from source to provide near field recordings of ADD noise.

Mooring design during longer term deployments will be as used for the C-POD array in WP 3.2. Short term deployments (< 6 hrs) made whilst the survey vessel is on site will be anchored with a surface marker.

3.2.8 Data Analysis

Recordings will be analysed by CEFAS using PAMGuide (Merchant et al. 2015) as outlined in WP 4.1.

The preliminary parabolic equation model developed by CEFAS for the outer Moray Firth will be further optimised using new measurements of noise propagation, and data on variation in source levels in relation to hammer energy and ground conditions.

The model will then use the detailed records on pile-driving timings and hammer energies to model cumulative sound exposure levels for marine mammals with different known or simulated movement patterns (see WP 1.3).

4 Reporting

The agreed reporting timescale in the Construction MMMP (LF00005-REP-550) will be followed, with an interim reports provided during Q3 of 2017 and 2018 and annual reports during Q2 2018 and 2019.

5 References

Bailey, H., Senior, B., Simmons, D., Rusin, J., Picken, G. & Thompson, P.M. (2010b) Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. Marine Pollution Bulletin, 60, 888-897.

Brandt, M.J., Höschle, C., Diederichs, A., Betke, K., Matuschek, R. & Nehls, G. (2013). Seal scarers as a tool to deter harbour porpoises from offshore construction sites. Marine Ecology Progress Series, 475: 291–302.

Brookes, K.L., Bailey, H. & Thompson, P.M. (2013) Predictions from harbor porpoise habitat

association models are confirmed by long-term passive acoustic monitoring. Journal of the Acoustical Society of America, 134, 2523-2533

Collins, M.D. (1993) A split-step pade solution for the parabolic equation method. Journal of the Acoustical Society of America 93, 1736-1742.

Collins, M.D. (1999) The stabilized self-starter. Journal of the Acoustical Society of America 106, 1724–1726

Cordes, L.S., Duck, C.D., Mackey, B.L., Hall, A.J., & Thompson, P.M. Long-term patterns in harbour seal site-use and the consequences for managing protected areas (2011). Animal Conservation 14, 430-438.

Dähne, M., Gilles, A., Lucke, K., Peschko, V., Adler, S., Krügel, K., Sundermeyer, J. & Siebert, U. (2013b). Effects of pile-driving on harbour porpoises (Phocoena phocoena) at the first offshore wind farm in Germany. Environmental Research Letters, 8: 25002.

Farcas, A., Thompson, P.M. & Merchant, N.D. (2016) Underwater noise modelling for environmental impact assessment. Environmental Impact Assessment Review, 57, 114-122.

Hastie, G.D., Russell, D.J.F., McConnell, B., Moss, S., Thompson, D. & Janik, V.M. (2015) Sound exposure in harbour seals during the installation of an offshore wind farm: predictions of auditory damage. Journal of Applied Ecology.

Merchant, N.D., Pirotta, E., Barton, T.R. & Thompson, P.M. (2014) Monitoring ship noise to assess the impact of coastal developments on marine mammals. Marine Pollution Bulletin, 78, 85-95.

Merchant, N.D., Fristrup, K.M., Johnson, M.P., Tyack, P.L., Witt, M.J., Blondel, P. & Parks, S.E. (2015) Measuring acoustic habitats. Methods in Ecology and Evolution, 6, 257-265.

Pirotta, E., Brookes, K., Graham, I. M. & Thompson, P. M. 2014 Variation in harbour porpoise activity in response to seismic survey noise. Biology Letters 10: 20131090

Russell, D., Hastie, G., Janik, V.M., Hammond, P.S., Scott-Hayward, L., Matthiopoulos, J., Jones, E. & McConnell, B.J. (2016) Harbour seals avoid windfarms during pile driving operations. Journal of Applied Ecology. doi:10.1111/1365-2664.12678

Sharples, R. J., S. E. Moss, T. A. Patterson, and P. S. Hammond. 2012. Spatial variation in foraging behaviour of a marine top predator (Phoca vitulina) determined by a large-scale satellite tagging program. Plos One 7:e37216.

Thompson, P.M., Hastie, G.D., Nedwell, J., Barham, R., Brookes, K.L., Cordes, L.S., Bailey, & McLean, N. (2013a). Framework for assessing impacts of pile-driving noise from offshore wind farm construction on a harbour seal population. Environmental Impact Assessment Review, 43: 73-85

Thompson, P.M., Brookes, K.L., Graham, I.M., Barton, T.R., Needham, K., Bradbury, G. & Merchant, N.D. (2013b) Short-term disturbance by a commercial two-dimensional seismic survey does not lead to long-term displacement of harbour porpoises. Proceedings of the Royal Society, B. 280: 20132001. DOI:10.1098/rspb.2013.2001

Thompson, P., Brookes, K., Cordes, L., Barton, T., Cheney, B. & Graham, I. (2013c) Assessing the potential impact of oil and gas exploration operations on cetaceans in the Moray Firth. Final Report to DECC, Scottish Government, COWRIE and Oil & Gas UK

Thompson, P.M., McGarry, T. (2015) “Protocol for mitigating the risk of instantaneous death

or injury to marine mammals during piling at the BOWL and MORL Wind Farms". Paper presented to MFRAG.

Williamson, L.D., Brookes, K.L., Scott, B.E., Graham, I.M., Bradbury, G., Hammond, P.S. & Thompson, P.M. (2016) Echolocation detections and digital video surveys provide reliable estimates of the relative density of harbour porpoises. Methods in Ecology and Evolution, 7: 762-969.