Seagreen and Neart na Gaoithe PAM data analysis – methodology overview

Scope of this document

Seagreen Offshore Wind Farm Limited (Seagreen) & Neart na Gaoithe Offshore Wind Farm Limited (NnG) have commissioned SMRU Consulting to analyse passive acoustic monitoring (PAM) data being collected as part of their respective Project Environmental Monitoring Plans (PEMPs).

This document presents the suggested approach to the analysis of these data in order to meet the stated objectives as outlined by each Project in their PEMP and to best inform our understanding of the potential effects of offshore wind farm construction on marine mammals.

This document is for review by the Forth and Tay Regional Advisory Group Marine Mammal Subgroup (FTRAG-MM).

Monitoring approach

The FTRAG-MM was set up to agree appropriate marine mammal monitoring for the three consented Forth and Tay offshore wind farms (NnG, Inch Cape and Seagreen). In addition to these discussions, Seagreen and NnG have held their own consultations with MS-LOT, MSS and SNH on the nature of their proposed monitoring and the development of their respective PEMPs.

The objectives for each project's acoustic monitoring as outlined in their PEMP documents is detailed below.

NnG

The focus of the monitoring for marine mammals is to "improve the understanding of marine mammal interactions with offshore wind farms and to validate assumptions made in the EIA." The primary objectives of the proposed monitoring are as follows:

1. "To determine whether there are any significant changes in the distribution or abundance of marine mammals within the windfarm area and adjacent waters pre, during and post-construction. The monitoring aim is therefore to inform whether construction activities cause significant displacement of marine mammals."
2. "Results from noise propagation modelling conducted to inform the Application and the Piling Strategy (PS) indicates that noise from impact driving could potentially cause disturbance to bottlenose dolphin occurring in nearshore waters of the Firth of Forth and St Andrews Bay. The PEMP has been developed to determine whether the effects of impact driving during construction results in notable far field disturbance effects to the resident population of bottlenose dolphin."

Seagreen

The Seagreen PEMP proposed that monitoring should focus on monitoring of underwater noise from construction activities and potential effects on cetaceans. The specific objectives of monitoring were therefore as follows:

1. Characterise baseline levels of vocalising marine mammal activity and determine whether any change is detected between baseline, construction and post construction periods;
2. Relate these changes to levels of underwater noise and other construction activity

Combined approach

Given the existence of a long-term acoustic monitoring programme on the east coast of Scotland, the Marine Scotland Science (MSS) East Coast Marine Mammal Acoustic Study (ECOMMAS), it was considered appropriate and useful to augment this programme with additional PAM stations to support the requirements of the Seagreen and NnG PEMPs. For Seagreen, five PAM stations were deployed in March 2019 in an array stretching from the east coast of Aberdeenshire into the Seagreen 1 project site (Figure 1). Four PAM stations were deployed in November 2019 in an array stretching from the east coast of Fife through the NnG Wind Farm project site (Figure 1). These deployments complement the three ECCOMAS stations of *St. Andrews 5, 10 and 15* (Figure 1). The approach taken at these sites builds on the MSS ECOMMAS array, extending acoustic monitoring of vocalising cetaceans beyond the existing coastal ECOMMAS array using cetacean click detectors (CPODS[1]) and underwater sound recorders (Loggerhead Instruments[2]). Data collection for each PAM station at both NnG and Seagreen occurs in four-month intervals throughout the year. Data collection for both Seagreen and NnG has not been affected by Covid-19 restrictions in 2020/21.

This design was chosen to provide allow monitoring of construction activities as well as providing monitoring stations further offshore than existing ECOMMAS stations. Deployment, servicing, and retrieval is managed and carried out by MSS during their ECOMMAS deployment and retrieval cruises with the wind farm projects providing the additional instrumentation. This approach was agreed by the Forth and Tay Regional Advisory Group Marine Mammal Sub-Group (FTRAG-MM) in July 2019[3] and updated and agreed at the December 2020[4] meeting. Seagreen and NnG provided additional details of the analysis approaches both are undertaking to complete the cetacean PAM detection datasets for wider analysis. This is described further below.

[1] https://www.chelonia.co.uk/cpod_home_page.htm

[2] https://www.loggerhead.com/acoustic-datarecorders-2

[3] FTRAG - Marine Mammals - Meeting Minutes - 02/07/2019 | Marine Scotland Information

[4] FTRAG - Marine Mammals - Meeting Minutes - 02/07/2019 | Marine Scotland Information

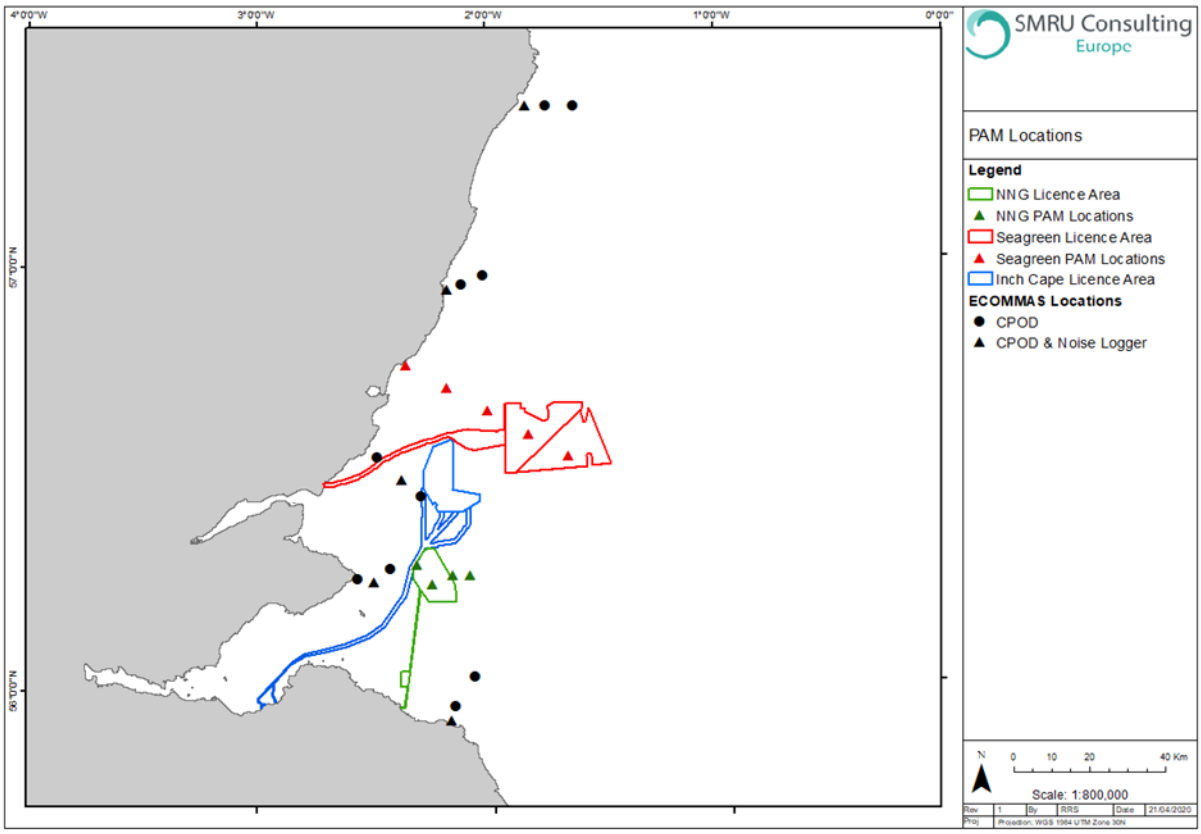

Figure 1 - Seagreen PAM locations (red triangles) stretching from the east coast of Aberdeenshire into the Seagreen project area (red surrounded area). Also shown are the PAM locations of the ECOMMAS project and the NnG PAM locations (green triangles). Each Seagreen and NnG location had a CPOD and a broadband noise recorder (Loggerhead Instrument) deployed. Note: For Seagreen, in the first deployment period, only Station 5 had a Loggerhead Instrument.

Construction programmes

NnG

NnG pre-construction monitoring commenced in November 2019, with CPODs and loggerhead sound recorders deployed at all four NnG stations indicated on Figure 1. These were recovered and redeployed in March, July and November 2020, and March 2021. Offshore construction commenced in August 2020, and it is anticipated that PAM data will continue to be collected throughout the period of offshore windfarm construction, with pre-construction activities in the wind farm area, having been underway since 24th May 2019.

The preconstruction activities included:

- Geophysical surveys in the windfarm and offshore export cable corridor, between 24th May and 22nd September 2019, and 18th March and 18th April 2020
- Geophysical surveys of the nearshore export cable corridor between the 29th August 2019 and 17th October 2019
- Geotechnical survey in the windfarm, between 1st September 2020 and 31st January 2020;
- Geotechnical survey of the nearshore export cable corridor between 1st February 2020 and 2nd May 2020
- Boulder clearance in the in the windfarm, between 27th December 2019 and 11th September 2020

- Boulder clearance within the export cable corridor between 24th June 2020 and 11th September 2020, and will recommence in the Spring of 2021
- Gravel placement (infilling of seabed depressions) in the windfarm between 23rd May 2020 and 6th October 2020
- UXO inspection in the windfarm and offshore export cable corridor between 2nd December 2019 and 26th April 2020
- UXO inspection in the nearshore export cable corridor between 9th and 25th January 2020 and 10th and 15th July 2020; and
- UXO clearance between 3rd May 2020 and 8th July 2020. .

Offshore construction activities commenced on the 11th August 2020: activities to date have included:

- Foundation casing installation ongoing since 8th September 2020; and
- HDD works at the export cable landfall between 2nd and 19th December 2020 and 11th February and 1st March 2021

Seagreen

At Seagreen, pre-construction activities commenced during 2020 and will continue in 2021, with construction activities commencing in Q3 2021. Key stages are as follows;

- Geophysical surveys (export cable route) June/July 2020 and Nov 2020
- Geophysical surveys (wind farm site) March – July 2021
- Site clearance activities (UXO, boulders etc) July - August 2021
- Offshore substation installation planned to commence July 2021
- Wind farm offshore construction activities planned commencement September 2021

Proposed analysis approach

Because of the regional scale of the monitoring approach, the proximity of the sites to each other and the differing timelines of each project, separation of analysis into traditional pre-construction, construction and post construction periods of monitoring for each project in isolation would be extremely challenging. Analysing data from each project in isolation is not appropriate due to the potential for activities at one site to affect cetacean occurrence at the other. In addition, due to the potential for high levels of spatial and temporal variation in cetacean occurrence, increasing the volume of data by including monitoring over a larger scale, with more locations and devices will increase the statistical power of the analysis and increase our ability to explain observed variation in cetacean occurrence using environmental and project activity related covariates.

This may be especially the case given the lack of significant levels of pile driving now anticipated to be required during the installation of wind turbine foundations on both projects. Significant responses on the scale of tens of kilometres from the activities are not anticipated, therefore the traditional approach of single site 'gradient' monitoring of porpoise occurrence in relation to distance from pile driving activity may not be appropriate or possible. Analysis of data from an array covering both wind farm sites and the wider surrounding area, and linking in with the wider regional ECOMMAS array will provide an opportunity to develop a more holistic understanding of the effect of offshore wind farm

construction activity on cetacean occurrence and distribution, in the absence of significant amounts of pile driving. The following section provides more detail on the proposed approach to analysis.

Figure 2 outlines the analysis and reporting elements relating to PAM data collected.

The data analyses are effectively split into two phases:

1. PAM data analysis (blue shaded area in Figure 2) which invovles the pre-processing of all the PAM data to provide both a complete dataset of the response variable (porpoise or dolphin presence, dark blue shaded box in Figure 2) from the CPODs and Loggerheads and also background noise levels from the Loggerheads (pink shaded box in Figure 2);
2. Final statistical analysis which involves combining the outputs from Phase 1 with a range of explanatory variables, the Project final baseline and construction periods and neighbouring ECOMMAS stations to inform a final larger statistical analysis (green shaded area in Figure 2).

During the analyses of the already collected PAM data there were indications that the CPODs were missing true detections of dolphins (i.e. they are not reflected in the CPOD record). Therefore the PAM analyses were expanded to the logger data to extract true dolphin detections (primarily in the form of dolphin whistles, shown in red shading in Figure 2). This provides a complete PAM dataset for use in the larger statistical analysis, using combined CPOD (porpoises and dolphins) and logger data (dolphins only) (blue box in Figure 2) ensures we maximise the cetacean detections dataset.

Summary data for each four monthly data collection period is being processed, provided and reported on an individual project level (via Interim Summary PAM reports; Figure 2) but when it comes to the final analysis SMRU Consulting propose to analyse data from all monitoring stations together in a single framework, including those from the neighbouring ECOMMAS stations as indicated in Figure 1. This approach will maximise statistical power and allow analysis on a regional scale, which is appropriate for a better understanding of patterns in cetacean occurrence.

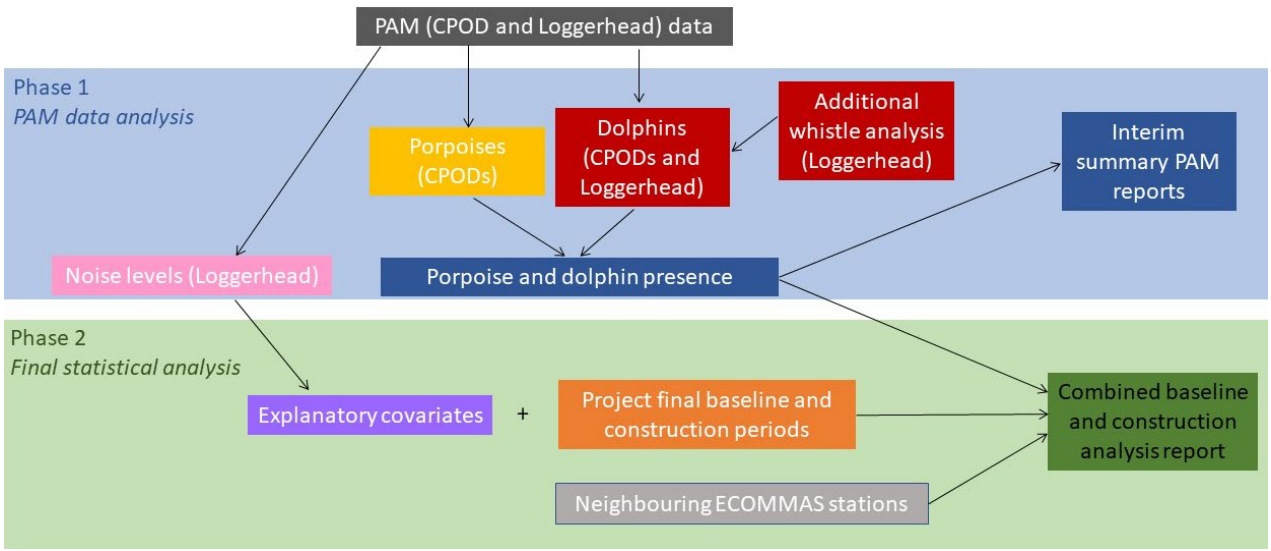

Figure 2 –Phases and element relating to PAM data analysis and reporting.

Pre-processing of PAM data

Data quality

For both Seagreen and NnG, all CPOD data retrieved to date have been assessed and are considered to be of good quality. Data were processed and analysed according to the procedure used in

ECOMMAS, utilising 'High' and 'Moderate' click train detections to identify time periods with detections. This will be continued for all current and future deployments.

All Loggerhead Instrument recordings were processed with the software PAMGuard 2.01.03 Beta. The peak-to-peak, zero-to-peak and root-mean-square (RMS) sound pressure levels and spectrum levels in 1/3rd octave frequency bands were measured to characterise the prevailing background noise. These data were both visually and aurally inspected for their quality at random positions with and without detections. All recordings include false detections, especially at times where low frequency noise was recorded (i.e. < 5 kHz) and at times with high frequency noise (> 20 kHz). The false detections at low frequencies were, amongst others, caused by self-noise from movement of the anchoring system (e.g., strumming noise, rubbing of robes against buoys). The high frequency false detections were caused by an anthropogenic sound source. Background noise levels were increased where vessel and other anthropogenic activity was audible, giving rise to some of the false detections. In addition to the obvious increase in noise levels caused by anthropogenic activities, a cyclical variation in the noise levels was clear, likely caused by the tidal cycle. Visual and aural inspection of the detections was conducted to find criteria in order to discriminate true dolphin detections from false detections.

Based on the data inspection, to identify dolphin whistles, the PAMGuard 'whistle and moan detector' was used and set to only include the frequency range of 5 kHz to 10 kHz (to exclude the frequent false alarms outside that frequency range). To expedite data review, a visual screening tool has been developed that allows an around 5 times faster review of the detections compared to the screening procedure without the tool. An additional data logging tool has also been developed and implemented which has reduced the amount of time needed to review a dataset in PAMGuard. However, noisy datasets are still expected to be challenging (e.g. if echosounders are present or faulty moorings). For future PAM data processing, each 10-minute recording bin has been categorised as either "dolphin positive" (i.e. at least one confirmed dolphin detection) or "dolphin negative" (no dolphins whistles detected). This will be continued for all current and future deployments.

We intend for all Loggerhead Instrument data to continue to be visually screened for dolphin detections, using a 5 kHz to 20 kHz bandpass filter to exclude the high amount of false detections outside this frequency range. Based on the dataset retrieved it will be investigated if further parameters can be defined that help towards a more automatic approach to separate true detections from false ones. This will not eliminate the need for visual screening of future datasets but will hopefully help to reduce the effort. For the noise analysis of the recordings, summary statistics of the noise parameters will be presented to help assess any changes in background noise over time.

All porpoise and dolphin detection data and effort will be prepared into text files along with covariate data for the larger final statistical analyses.

Noise analysis methodology

In addition to utilising Loggerhead Instruments to detect dolphin presence, the recordings from these noise loggers will be used to conduct a noise analysis, determining the background noise levels present at each PAM station for both Seagreen and NnG. The metrics that will be used to analyse and visually present noise levels include:

- Broadband RMS sound pressure level (SPL) and
- 1/3 octave band spectrum levels.

1/3 octave bands with centre frequencies ranging from 25 Hz to 40.5 kHz will be used to show the energy distribution across the full frequency spectrum for set periods of time (i.e., one month), whereas four specific bands will be analysed in more detail. Two of these 1/3 octave bands are centred around 63 Hz and 125 Hz, respectively, and are chosen according to the recommendations given by

the Marine Strategy Framework Directive (MSFD) for monitoring underwater noise in order to maintain a Good Environmental Status of the sea. Two more bands centred around 1 kHz and 2 kHz were chosen because these lie within the hearing range of toothed whales, while the bands chosen by the MSFD may hardly be heard by these animals.

The SPL and 1/3 octave band noise levels will be extracted from the PAMGuard databases, in the form of measurements averaged over a period of 10 seconds. The data will be loaded into the statistical software R, where percentiles (L1, L5, L25, L50, L75, L95, L99) will be calculated for SPLs and spectrum levels in all the 1/3 octave bands mentioned above. As the noise loggers recorded for 10 minutes per half hour (10 mins ON, 20 mins OFF), the percentiles will be calculated for each 10-minute recording period (bin). These estimates will be used to investigate the fine-scale changes in noise levels as a result of, for example, tidal changes or detect other diel patterns in noise levels. Moreover, percentiles will be calculated per day to explore long-term noise measurements. Changes in background levels due to construction noise can also be investigated by choosing defined time periods and calculating, e.g., the percentiles of the sound levels before, during, and after a known construction activity has happened near a logger-station.

Plots will be generated using the ggplot2 package in R. These plots will be created to visually represent changes in noise levels over time or the energy content in the chosen frequency bands for a set period of time. Details for each type of plot are outlined below:

- SPL over time: line plots containing median SPL (L50) along with L1, L5, L25, L75, L95, and L99 percentiles calculated for each 10-minute bin and day, respectively.
- 1/3 octave band levels for each 10-minute bin, and day, respectively:
- Four line-plots containing median (L50) spectrum levels and all percentiles for each of the following 1/3 octave bands: 63 Hz, 125 Hz, 1 kHz, and 2 kHz.
- An overview plot containing the median (L50) spectrum levels for the four chosen 1/3 octave bands
- Full-range frequency spectrum for a specific time period (e.g., month, year, before-during-after construction): line plot containing the spectrum levels and percentiles of the centre frequencies of all frequency bands.

Final statistical analyses

Previously it was proposed to carry out this analysis in two distinct phases (as described in an earlier iteration of this note[5]); a 'baseline' period vs a 'construction' period. However due to the challenges of determining a clear 'baseline' with the phased start of different construction activities (e.g. vessels, geophysical surveys, UXO clearance, drilling, pile driving), instead this document details a new proposed approach to analyse all data together with a suite of temporal, environmental and anthropogenic covariates. This approach was presented to and agreed by the FTRAG at the December 2020[6] meeting.

The analysis will include data from the wider ECOMMAS array, as indicated in Figure 1 with consideration given to the inclusion of ECOMMAS data collected prior to the deployment of the Seagreen and NNG monitoring for a more comprehensive baseline understanding. All data would need to be processed in the same manner for this to occur (including dolphin whistle analyses). We have

[5] https://smrumarine.box.com/s/c92vqirmx9csshzsq0gq452bqxwtcjp2

[6] FTRAG - Marine Mammals - Meeting Minutes - 02/07/2019 | Marine Scotland Information

discussed with Marine Scotland Science, how the whistle analysis could be replicated for ECOMMAS datasets.

Two main work strands will be pursued, one for porpoises and one for dolphin species. Porpoise occurrence will likely be modelled as a function of various covariates using a Generalised additive model framework (GAM) using generalised estimating equations (GEE). This approach is commonly used for modelling predictive relationships between cetacean occurrence and various explanatory variables where autocorrelation is present (e.g. Forney et al. (2012), Malinka et al. (2018), Risch et al. (2019)).

The response variable will be a measure of porpoise/dolphin activity at a defined temporal scale – for example detection positive minutes per day, DPM (the number of minutes each day in which porpoise click trains were detected), or detection positive hours, DPH (the number of hours each day in which porpoise click trains were detected). The exact variable selected will depend on a few factors, including the proportion of zeros in each dataset and the temporal resolution of the available covariate data.

The explanatory covariates will be a combination of the following:

Locational/Positional covariates – to help understand how variation in porpoise/dolphin activity may be influenced by the geographical location of each monitoring station. This might include consideration of the following: Distance from shore, location id, latitude, longitude.

Temporal covariates - to help understand how variation in porpoise activity may be influenced by seasonal or diurnal influences. These are likely to include time of day, day/week of the year, time in relation to sunset/sunrise.

Environmental covariates – to help understand how environmental variables may influence porpoise occurrence and activity. These are likely to include (but not limited to) variables such as water depth, sediment type, SST, and any available information relating to prey abundance and distribution (e.g. prey maps generated by recent JNCC funded project, any available contemporary fish prey survey data).

Anthropogenic covariates – vessel activity, received sound levels, pre-construction and construction activity (vessel numbers and movements, location and nature of geophysical surveys, UXO detonation, cable laying activities, foundation installation). Exactly how these variables are incorporated into the analysis will depend on the spatial and temporal resolution of the available data but ideally will reflect the magnitude and proximity of these activities to each of the monitoring stations. For example, recent analyses of porpoise presence in relation to vessel activity in the Moray Firth during offshore wind farm construction have used AIS tracking data to generate a variable 'cumulative boat duration per hour' within a 5 km radius around each porpoise detector (Benhemma-Le Gall et al., 2020)[7].

Additionally it is planned that the construction periods will provide additional covariates relating to construction activity. If received levels of sound are a significant predictor of cetacean occurrence, weighted levels will also be included in models to determine whether the use of weighted levels (taking into account hearing sensitivity of cetaceans) improves predictive power. There will be an initial exploration of the data required to define the appropriate format for covariates and the appropriate temporal and spatial scale for analyses.

[7] video presentation at the online conference "Environmental Interactions of Marine Renewables", April 2020. Benhemma-Le Gall, A., Thompson, P., Graham, I. and Merchant, N. Lessons learned: harbour porpoises respond to vessel activities during offshore windfarm construction https://stream.uhi.ac.uk/Player/8cf515F7

Depending on levels of overall variation in cetacean occurrence and the strength of observed responses, it may be necessary to refine the approach to this analysis. For example, if baseline levels of variability in cetacean presence is high, the effect of specific construction activities may need to be explored by identifying specific periods of activity which are preceded by clear periods of no activity to provide a contrast to allow the presence of a response to be determined. This is the approach that was taken by Graham et al. (2019) when analysing porpoise responses to pile driving activity from the Beatrice Offshore Wind Farm due to high levels of variation in porpoise activity over the scale of weeks and months. The analysis team will liaise closely with researchers at the University of Aberdeen's Lighthouse field station to learn from their experience in analysis of similar data.

Reporting

NnG and Seagreen PAM data reporting will take place via two mechanisms (as displayed in Figure 2), interim summary PAM reports and a final report summarising the full statistical analysis combining baseline and construction analysis report.

1. Interim summary PAM reports are being produced and updated with each deployment. These reports summarise porpoise (CPODs only) and dolphin (CPODs + noise loggers) occurrence across each of the deployment sites over time. As agreed at the FTRAG-MM meeting held on the 8th Dec 2020, these reports will be delivered to NnG and Seagreen but the FTRAG-MM did not need to see these interim reports. FTRAG-MM will be provided with updates via the regular FTRAG-MM meetings to ensure that the group is up to date with data collection successes or any issues arising.
2. A combined baseline and construction analysis report will report on the outcomes of the larger statistical analysis between porpoise and dolphin occurrence and the covariate data. This report will detail the detection data collected, the covariates considered in the analysis (and how they were derived), the methodologies applied in the statistical analyses and the final results of the statistical analyses.

Comparison to aerial survey data findings

Digital aerial surveys have beeen undertaken by Hi-Def across the combined Forth and Tay region (NnG, Seagreen and Inch Cape windfarm areas plus buffers). The combined Forth and Tay region was surveyed monthly from April 2019 to September 2020.

Prior to this NnG undertook monthly digital aerial surveys of the NnG site plus 12km buffer June 2018 and following the cessation of the combined Forth and Tay region in October 2020 NnG will continue to undertake digital aerial surveys of the NnG site plus 12km buffer throughout the year through construction and for a period post construction (2 years at a minimum); but this is subject to review and agreement with the FTRAG. Seagreen started aerial surveys in March 2019 and continued to the end of the 2020 seabird breeding season, in September 2020. Aerial surveys are expected to resume in breeding season 2023.

These surveys overlap spatially with the area covered by the acoustic monitoring stations and are based on transects spaced 2 km apart. There are several reasons why we do not anticipate a close correlation between the two datasets. The aerial survey data represent a single snapshot of marine mammal occurrence at single point in time each month, whereas the PAM data will provide data on cetacean occurrence at a very high temporal resolution, including overnight when visual surveys cannot take place. In addition, cetacean vocalisations can be highly directional, harbour porpoises in particular, therefore a sighting of a porpoise close to a PAM station may not necessarily result in an

associated acoustic detection. However, the broad patterns in sightings rates and detection rates will be compared and any notable visual sightings close to PAM station locations will trigger a closer inspection of the acoustic records at the same time to identify any matches.

References

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