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Proof of Evidence Rebuttal
Marine Mammals

Applicant: Menter Môn Morlais Limited

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1. Introduction

1.1 My name is Dr Jennifer A. Learmonth, I am the Principal Marine Mammal Consultant at Royal HaskoningDHV and the marine mammal witness for Mentor Môn in relation to the Morlais Project.

1.2 This rebuttal proof of evidence is submitted in response to the proofs of evidence submitted for exchange.

1.3 I have read the various proofs of evidence submitted to the Inquiry and I respond to issues raised in respect of marine mammals in the submitted evidence of:

- Ceri Morris on behalf of Natural Resources Wales (NRW) Proof of Evidence on Marine Mammals [CD POE021].

1.4 Insofar as I can usefully comment on it, I have. My silence on any particular point should not be taken as agreement to it.

1.5 The topic of evidence is Biodiversity - Marine Mammals.

1.6 This rebuttal proof of evidence addresses NRW's main concerns for marine mammals in relation to:

- ***Mortality resulting from collision with the proposed physical development*** This rebuttal will show that the collision risk assessments are based on a worst-case scenario and have taken a precautionary approach, based on the information currently available. The proposed approach and commitments to ensure effective monitoring and mitigation would reduce the risk of mortality resulting from collision with operational tidal turbines.

- ***Environmental Monitoring and Mitigation Plan (EMMP)*** This rebuttal will show that the revised Outline Environment Mitigation and Monitoring Plan (OEMMP) (MOR/RHDHV/DOC/0072 (04) dated November 2020) [CD MDZ/A16.8], takes into account the recent Natural Resources Wales (NRW) Advice on adaptive management of the risk of collision impacts on protected marine mammal species in Welsh waters from the Morlais Project ([CD MDZ/F15.3] dated 15/10/2020), including agreed species collision limits for the Morlais Project and recommended Collision Decision Framework, with commitments to real-time monitoring and procedures for rapid response, should a suspected collision occur.

- ***Disturbance from operational underwater noise*** This rebuttal will show that underwater noise from operational turbines has been assessed based on the information currently available and worst-case scenarios. There is a commitment in the revised OEMMP (paragraph 23) [CD MDZ/A16.8], that further underwater noise modelling will be conducted once details are known of the types of devices and arrays to be deployed as part of the development of the EMMP, to ensure there is no potential for any significant disturbance. However, it is important that the noise levels from operational turbines are sufficient for marine mammals to detect them in all conditions, so they are able to avoid collision with the tidal devices, but not high enough to result in any significant long-term disturbance.

- ***Disturbance from Acoustic Deterrent Devices (ADDs)*** This rebuttal will show the that the proposed use of ADDs as mitigation would not result in the significant disturbance of marine mammals, but is an appropriate mitigation option to reduce the potential collision risk of marine mammals with operational tidal turbines.

2. Marine Mammals

2.1 The main issue of NRW in relation to marine mammals is (NRW PoE [CD POE012] paragraph 16): "*The proposal has the potential to have an adverse impact on marine mammal species listed in Annex II and Annex IV of the Habitats Directive. The proposal would be situated within the North Anglesey Marine / Gogledd Môn Forol Special Area of Conservation (SAC) which is designated for harbour porpoise and it could also affect other species of marine mammals, including those with demonstrated connectivity to other SACs."*

2.2 As stated in the NRW PoE [CD POE021] paragraph 3.1 Appendix B Marine Mammals, the proposed Morlais Demonstration Zone (MDZ) would be situated within the North Anglesey Marine / Gogledd Môn Forol SAC which is designated for harbour porpoise.

2.3 The Environment Mitigation and Monitoring Plan (EMMP) is the commitment of Menter Môn to safeguarding all marine mammals and to ensure the proposed project will not have an adverse impact on marine mammal species.

2.4 The current version of the revised Outline Environment Mitigation and Monitoring Plan (OEMMP) [CD MDZ/A16.8], takes into account the recent Natural Resources Wales (NRW) *Advice on adaptive management of the risk of collision impacts on protected marine mammal species in Welsh waters from the Morlais Project* [CD MDZ/F15.3].

2.5 The revised OEMMP outlines the Morlais Project commitments to safeguarding all marine mammal species. This includes, but is not limited to:

- The commitment not to operate devices until it has been demonstrated and agreed in writing that marine mammal movements and collisions can be detected.
- Ensuring the risk to marine mammal species would be within the NRW maximum collision limit for each marine mammal species.
- The implementation of adaptive management measures, following any collision, to ensure that the risk of further collisions is reduced, which will be agreed and demonstrated prior to any tidal device operation. This will include demonstrating a rapid response to any detected collisions.

- Prior to any tidal device operation, the mitigation is proven to be effective and will be adapted in response to any increasing risk of causing adverse effect.

- If mitigation is not effective in preventing collisions, a failsafe will be included to ultimately prevent an adverse effect from occurring. Such a failsafe is likely to be a ceasing of operations for a tidal device.

- Commitment to further underwater noise modelling and assessments in the development of the detailed EMMP to determine the potential for any significant disturbance based on operational tidal devices and ADD noise levels in different conditions, for individual devices and the array of devices to be deployed, taking into account ambient noise, the different species hearing sensitivities and the latest Statutory Nature Conservation Bodies (SNCBs) Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs (England, Wales & Northern Ireland (JNCC *et al*. (2020). This guidance defines significant noise disturbance within a harbour porpoise SAC as "*noise disturbance within an SAC from a plan/project, individually or in combination, is considered to be significant if it excludes harbour porpoises from more than:1. 20% of the relevant area of the site in any given day, or 2. an average of 10% of the relevant area of the site over a season)*."

2.6 A key component of the revised OEMMP [CD MDZ/A16.8], is the latest NRW advice [CD MDZ/F15.3] on the maximum marine mammal collision limits for the Morlais Project (see paragraph 2.66 below). As stated in the latest NRW advice [CD MDZ/F15.3]: "*The species limits represent the maximum number of collisions between individual animals of a species or a species group, and the moving parts of the turbines, that are considered to be compatible with avoiding adverse effects on the integrity of SACs and would ensure no detriment to the conservation status of European Protected Species (EPS)."*

2.7 Therefore, with the commitments and incorporation of the latest NRW advice [CD MDZ/F15.3] in the revised OEMMP [CD MDZ/A16.8], there is unlikely to be the potential to have an adverse effect on marine mammal species listed in Annex II[1] and Annex IV[2] of the Habitats Directive. This includes harbour porpoise from the North Anglesey Marine / Gogledd Môn Forol SAC and other species of marine mammals, including those with demonstrated connectivity to other SACs.

2.8 The proposed draft Marine Licence Conditions ([CD MDZ/I4], Condition 36) will secure this and ensure NRW must be satisfied that there will be no AEOI:

"NRW must not approve any DEMMP unless it is satisfied that it provides such mitigation as is necessary to avoid adversely affecting the integrity of a European Site (as defined in The Conservation of Habitats and Species Regulations 2017 or The Conservation of Offshore

[1] Harbour porpoise (*Phocoena phocoena*), bottlenose dolphin (*Tursiops truncatus*), grey seal (*Halichoerus grypus*) and harbour seal (*Phoca vitulina*), are listed in Annex II as species for which the designation of Special Areas of Conservation (SACs) is required.

[2] All cetaceans (whales, dolphins and porpoises) are listed in Annex IV of the EC Habitats Directive as European Protected Species (EPS) affording them strict protection from deliberate disturbance, injury or killing throughout their natural range.

Marine Habitats and Species Regulations 2017) to the extent that marine mammals or diving birds are a protected feature of that European Site".

Mortality resulting from collision with the proposed physical development

2.9 **NRW PoE [CD POE021] paragraph 4.1.3 Appendix B Marine Mammals** considers that "*Due to a combination of uncertain population estimates, or in the case of bottlenose dolphin, a small, declining population; along with existing anthropogenic pressure on some populations through fisheries bycatch, it is not possible to rule out Adverse Effect on Site Integrity ("AEOSI") on the bottlenose dolphin, grey seal or harbour porpoise features of the SACs listed in paragraph 2.3 (of the NRW PoE [CD POE021] Appendix B Marine Mammals), nor is it possible to rule out significant impacts on Annex IV cetacean populations from the predicted mortality levels presented by the applicant.*"

2.10 It is important to note, that the values presented in Tables 4-1 and 4-2 of the Marine Mammals Additional Collision Risk Modelling note [CD MDZ/A31.13] quoted in paragraph 4.1.2 of the NRW PoE [CD POE021] Appendix B Marine Mammals, are worst-case scenarios. These assessments included, as outlined in Marine Mammal PoE [CD MDZ/P2] paragraph 6.5-6.6, realistic worst-case parameters for tidal devices and linear scaling of individual devices to array, assuming all devices in array could have the same collision risk. However, this linear scaling is likely to overestimate collision risk, as array avoidance rather than individual tidal turbine avoidance is expected to occur, as outlined below in paragraphs 2.34-2.37 of this rebuttal and in Marine Mammal PoE [CD MDZ/P2] paragraph 6.34-6.35. The assessments also assume, as a worst-case, that all encounters and collisions are fatal. The assessments, although based on 98% avoidance rate, do not take into account mitigation and monitoring.

2.11 Section 1.3.3 of the revised OEMMP [CD MDZ/A16.8] incorporates the current species collision limits for marine mammals as provided by NRW Advice on adaptive management of the risk of collision impacts on protected marine mammal species in Welsh waters from the Morlais Project [CD MDZ/F15.3]. It is agreed with NRW that "*these limits do not represent the point at which mitigating action should first occur; they represent the point at which any further impact must be fully mitigated to the extent that there should be no further risk to the species from the device*." As outlined in Section 1.3.3 of the OEMMP and paragraph 5.6 of the Marine Mammal PoE [CD MDZ/P2], these thresholds will be a key component in the development of the detailed EMMP, which will involve further collision risk assessments prior to deployment, based on the latest information and tidal device parameters, to demonstrate that these thresholds will not be exceeded. Monitoring will be used to determine if these limits are being approached and if further mitigation is required. For example, if a fatal collision does occur for one cetacean species then the mitigation measures will be reviewed and further mitigation implemented following the tiered approach.

2.12 Therefore, as outlined above, with the commitments in the revised OEMMP [CD MDZ/A16.8] secured in the Marine Licence Condition (as outlined in the proposed draft Marine Licence [CD MDZ/I4], Condition 36), to ensure the risk to marine mammal species would be within the NRW [CD MDZ/F15.3] maximum collision limit for each marine mammal species and that if a fatal collision does occur for one cetacean species then the mitigation measures will need to be reviewed and further mitigation implemented following the tiered approach in the detailed EMMP, there is unlikely to be an adverse effect on site integrity (AEOSI) and/or significant impacts on marine mammal populations.

2.13 Also, as noted in the Marine Mammal PoE [CD MDZ/P2] paragraph 6.2-6.3, there have been no recorded incidents at any operational tidal turbine installations around the world, including the UK.

Collision Risk Modelling

2.14 As outlined in **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.1.1**: "*Two modelling methods are used to estimate collision risk for marine mammals: Encounter Rate Modelling (ERM) and Collision Risk Modelling (CRM). Both methods use a mathematical model of the physical characteristics of the turbine rotor together with the body size and swimming activity of the animal to estimate the potential collision rate, giving a reasonable indication of the likely level of collision risk in the absence of avoidance. Although widely accepted in the renewable energy industry, neither ERM nor CRM can be regarded as an accurate calculator of encounter rate or collision risk (SNH, 2016 [CD MDZ/F19]) but are able to provide an approximate estimate to give a broad idea of risk – a limitation acknowledged by the applicant (ES [CD MDZ/A25.12 / MDZ/A31.14] para 619-620).*"

2.15 As outlined in Marine Mammal PoE [CD MDZ/P2] paragraph 6.9-6.11, for the marine mammal collision risk assessment two methods were used, Encounter Rate Modelling (ERM) and Collision Risk Modelling (CRM), both undertaken using the Scottish Natural Heritage (SNH) guidance for assessing collision risk between underwater turbines and marine wildlife (SNH, 2016 [MDZ/F19]) and accompanying spreadsheets. This approach was agreed with NRW at the 2nd Marine Mammal Technical Working Group (TWG) on 19 February 2019.

2.16 The difference in the models and the parameters used result in different results for different devices and scenarios. Therefore, as a precautionary approach, the collision risk assessments were conducted using both the ERM and CRM for all marine mammal species. It should be noted, as acknowledged by SNH (2016) [CD MDZ/F19], that the ERM and CRM methods will provide at best, an order of magnitude estimate of collision risk. As stated in SNH (2016) [CD MDZ/F19]: "*Neither the ERM nor the CRM can be regarded as an accurate calculator of encounter or collision rate. However, both are likely to provide a reasonable order-of-magnitude estimate*." In that, based on the parameters used in the models the results should provide reasonable estimations of the number of individuals that could encounter or collide with a turbine device, which is then scaled up for the potential number of devices that could be deployed. However, it is this method that has been used successfully in developments elsewhere and offers the best available scientific approach (ABPmer, 2020 [CD MDZ/F15.2]).

2.17 Results for the ERM and CRM were presented in the ES [CD MDZ/A31.14] and Information to Support HRA [CD MDZ/A31.16], assessments were based on the worst-case, i.e. the model which indicated the greatest collision risk. NRW supported this approach, as agreed at the 1st TWG meeting 27/11/18 and 2nd TWG meeting 19/02/19.

Avoidance Rates

2.18 As outlined in **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.1.4**: "*Neither the encounter rate estimated by the ERM, nor the collision rate estimated by the CRM, takes account of the likelihood of avoidance effects. It is therefore necessary to apply an avoidance factor to allow for the probability that some individual animals may avoid collision. Evidence on avoidance rates from operational turbines is limited (ABPmer, 2020 [CD*

MDZ/F15.2]), so NRW recommended to the applicant that a range of six avoidance rates (0%, 50%, 90%, 95%, 98%, and 99% as recommended by Scottish Natural Heritage (2016) [CD MDZ/F19] should be applied, to generate a range of estimates for each species (Technical Working Group meeting held on 6 January 2020, followed up with "Additional information provided by NRW Advisory following marine mammals meeting on 06/01/20 [CD MDZ/F14]")."

2.19 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.1.7** states: *"It is evident from the data presented that the choice of avoidance rate used in the modelling has a major impact on the output. There is no empirical support for the adoption of a 98% avoidance rate and this sensitivity is clear when the wider range of avoidance rates are presented (Figure.1 in NRW PoE [CD POE021] Appendix B: marine mammals), where for example a reduction in avoidance to 95% results in an increased predicted collision risk from 0.7 to 2 bottlenose dolphins and from a maximum of 25 to 63 harbour porpoise. Therefore, the adoption of the 98% avoidance rate value cannot be considered 'precautionary' or 'worst case'. Very few studies have been able to quantify this rate and the one that has (Joy et al. 2018 [CD POE039]) indicates that for harbour seals in Strangford Lough, the quantified change in local scale usage in the presence of the turbine was approximately 68%, significantly lower than the 98% adopted here. The proposal, therefore, to deploy, in the first phase of the development, the maximum number of devices achievable based on this predicted collision estimate of 0.7 bottlenose dolphins at 98% avoidance rate, places an over-reliance on the outputs of the modelling. NRW does not consider this to be appropriate and maintains that there remains a credible risk that unsustainable mortality of marine mammal Annex II and Annex IV species could occur from the first phase alone (as stated in NRW letter dated 22 May 2019, CAS-84017-M9P0)."*

2.20 As outlined in Marine Mammal PoE [CD MDZ/P2] paragraph 6.28-6.32, there is an absence of data to determine the ability of animals to avoid coming into contact with devices, either through close-range evasion, where animals take last minute evasive action, or through avoidance, which may operate at a wider scale with animals avoiding the area the devices are located in (Sparling and Smith, 2019 [CD MDZ/F13]).

2.21 Due to the lack of evidence on marine mammal avoidance from operational tidal turbines (ABPmer, 2020 [CD MDZ/F15.2]) a range of collision estimates were presented using six avoidance rates: 0%, 50%, 90%, 95%, 98%, and 99% (where 0% is no avoidance) in ES Volume III Appendix 12.2 [CD MDZ/A31.15] and Additional Collision Risk Modelling [CD MDZ/A31.13] as recommended by SNH guidance [CD MDZ/F19] and as requested by NRW at the 1st TWG meeting 27/11/18: NRW advised that the full range of avoidance rates presented as a technical note or as an appendix should be provided.

2.22 At the 2nd TWG meeting 19/02/19 the Applicant proposed to 'use the 98% avoidance rates for all species in the assessments, with the range of avoidance rates of 0%, 50%, 90%, 95%, 98% and 99% presented in an Appendix'. NRW agreed with this approach and confirmed that the ranges should be provided in the appendices.

2.23 The collision risk assessments in the ES [CD MDZ/A31.14] and Information to Support HRA [CD MDZ/A31.16], were based on an avoidance rate of 98%, which was consistent with other assessments for consented projects, such as the European Marine Energy Centre (EMEC) Falls of Warness tidal test site off Orkney, Scotland. EMEC (2014) states (Section 4.5 page

83) that "*ongoing monitoring and research will be important in refining understanding of avoidance rates, but as a starting point we assume avoidance rates of 98% for harbour porpoise*" a similar approach is also being undertaken for the Morlais Project. The assessment for the Minesto tidal kite off North Wales also assumed that 98% avoidance was most realistic avoidance rate in the ES for the Deep Green Holyhead Deep Project Phase I (0.5 MW), although presented results for a range of avoidance rates (Minesto, 2016).

2.24 As outlined in paragraph 2.13 above and presented in the Marine Mammal PoE [CD MDZ/P2] paragraph 6.2-6.3, there have been no recorded incidents at any operational tidal turbine installations around the world including the UK. This includes the 23 examples with an approximated 51.3 years overall operational time in Table 2 in the Marine Mammal PoE [CD MDZ/P2]. Although acknowledged that none of the tidal turbine installations listed in Table 2 have been operational for as long as is planned for Morlais, it does however, give a good indication for different types of tidal turbines, in different locations, including locations where marine mammals are known to be present in and around the area. Most of these sites listed in Table 2 have had monitoring. Thereby indicating a high rate of avoidance.

2.25 As such an avoidance rate of 98% is considered a realistic, but precautionary approach. Precautionary as 100% avoidance behaviour is not assumed. Underwater noise from operational turbines will be detected by marine mammals (see paragraph 2.113-2.153 below), as recognised by NRW in their concerns regarding disturbance from operational underwater noise (Section 4.3 of NRW PoE [CD POE021] Appendix B Marine Mammal PoE). In addition, the tidal devices are relatively large with solid structures, which would be detectable by marine mammals, as outlined in Plates 4-1 to 4-4 and Table 4-2 in Chapter 4 of the ES [CD MDZ/A25.4].

2.26 The 68% spatial avoidance (95% C.I. = 37% to 83%) by harbour seals within 200m of the SeaGen tidal turbine at Strangford Lough, Northern Ireland (Joy *et al*., 2018 [CD POE039]) provides useful information on the potential avoidance rates for harbour seal. It is important to note this 68% spatial avoidance refers to a decline in the use of habitat within 200m of the turbine location compared to probabilities of seals being within 200m of the location before the turbine was installed (not that 32% of seals collided with the turbine). The study found the relative proportion of time spent within 200m of the turbine location declined with the installation of the turbine (i.e., the percent time spent there went from 3.5% pre-turbine to 1.2% in the operational phase). However, as noted by Joy *et al*. (2018) [CD POE039] one of the risk mitigations at the SeaGen site was the shutdown of turbine operations when a seal was seen within a fixed distance of the turbine. This may have confounded assessments of close range seal behaviour, and it is therefore possible that seals became habituated to the shutdown (Joy *et al*., 2018 [CD POE039]). There were no marine mammal collisions during the operation of the SeaGen tidal turbine at Strangford Lough.

2.27 The relative avoidance of the turbine region by harbour seals declined with increased distance from the turbine (Joy *et al*., 2018 [CD POE039]). The data (200m distance bands) suggested there was evidence that the avoidance region extends beyond 200m, and likely beyond 400m, but there was no evidence of differences in habitat utilisation beyond 600m. This is consistent with the operational SeaGen turbine which was expected to be audible at distances of at least 311m at maximum rotational speeds.

2.28 Importantly the study also showed that by incorporating information on depth distribution and behavioural avoidance around the turbine there was a 90.3% (95% C.I., 83%, 98%) reduction in computed strike risk over that associated with assumptions of uniform depth and no behavioural avoidance of the turbine (Joy *et al*., 2018 [CD POE039]). This study suggests that seals are adapting their behaviour to fine-scale temporal dynamics associated with tidal states and demonstrates that harbour seals further adapt behaviours in response to turbine presence. This plasticity in harbour seal behaviour observed at local scales is shown to be key to understanding what risks turbines pose (Joy *et al*., 2018 [CD POE039]).

2.29 The tagged seals in the study by Joy *et al*. (2018) [CD POE039] also indicated that the seals preferred to dive to the seafloor, below where the SeaGen turbine rotors were situated. These predominately U-shaped dives were observed in both 2006 and 2010. There did not appear to be turbine-related differences in the dive profiles after the turbine was installed during moderate or high current speed conditions. U-shaped dives are typical of harbour seal foraging dives in shallow coastal regions and represent an important reduction in turbine strike risk for this species (Joy *et al*. 2018 [CD POE039]).

2.30 This study therefore indicates that harbour seal are able to detect and reduce the potential collision risk and that having information on occurrence and behaviour, including time spent at different depths within the water column, in and around the site before and during operation is fundamental in addressing data gaps for marine mammals and understanding the potential collision risk.

2.31 Further collision risk modelling will be conducted during the development of the detailed EMMP prior to deployment, based on the latest information and tidal device parameters, to demonstrate that the collision risk thresholds will not be exceeded. These assessments will be based on the latest guidance and scientific information, with avoidance rates agreed with NRW.

2.32 As outlined above, a key component of the revised OEMMP [CD MDZ/A16.8], is the latest NRW advice [CD MDZ/F15.3] on the maximum marine mammal collision limits for the Morlais Project (see paragraph 2.66).

2.33 The monitoring proposed for Morlais will improve the scientific understanding of the ability of marine animals to avoid tidal stream turbines which is critical to enable the subsequent phases of deployment at Morlais and for the industry as a whole.

Linear scaling

2.34 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.1.8** states: *"There is further uncertainty about how collision rates will 'scale up' with multiple devices. The approach used by the applicant is a simple linear increase in collision risk with additional devices. There is currently no information about how animals might behave around arrays and therefore this assumption is highly uncertain."*

2.35 It is acknowledged that there is no information about how animals behave around arrays. As outlined by Sparling and Smith (2019 [MDZ/F15]), currently there is no way of realistically modelling the collision risk posed by multiple devices, other than simply multiplying the risk for a single device by the total number of devices. However, this is likely to be unrealistic as it is difficult to predict how animals might respond to an array of devices. For example, the probability of avoidance is likely to be modified as a result of a close-range encounters with preceding devices. There is the possibility that animals might learn from encountering and avoiding the first device and then subsequently avoid additional devices at a greater distance.

2.36 As a precautionary approach, a linear scaling of individual devices to an array was used, which assumes all tidal devices in the array could have the same collision risk. Although, as outlined in the Marine Mammal PoE [CD MDZ/P2] paragraph 6.33-6.35, this is likely to overestimate collision risk, as array avoidance rather than individual tidal turbine avoidance is expected to occur. It is therefore my view, that marine mammals would encounter and therefore avoid the outer array devices and would, as such, be less likely to encounter the inner devices, depending on the layout of the array and spacings. As such, the linear scaling is a precautionary and currently the only possible approach to the assessment.

2.37 Monitoring at Morlais would provide a unique opportunity to collect information on how marine mammals behave around an array of multiple devices, compared to most studies which have involved only one device. This would be very important in addressing data gaps, improving our understanding of the potential risk from multiple devices and how this can be used to remove some of the uncertainty associated with collision risk modelling. Therefore, it is important that the scale of the Morlais first phase is sufficient in order to ensure adequate data is collected to inform the next phase of deployment and other tidal projects.

Potential Biological Removal (PBR) and Species Collision Limits

2.38 Potential Biological Removal (PBR) is an approach used to calculate the number of animals that could be removed from a population each year without adversely affecting the long-term growth of the population.

2.39 In the NRW [CD POE021] PoE Appendix B: marine mammals (footnote to paragraph 4.1.5 page 35) defines PBR as "*a formula which predicts how many animals could be removed from the population without adversely reducing it. In the calculations, the population is based on the relevant Management Unit (MU). It gives a number of animals that can be sustainably removed from the population, therefore all anthropogenic take within the relevant MU must be subtracted from this value*."

2.40 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.1.5** states: "*The applicant has presented the maximum number of devices and megawatt output (MW) for each device type that could be deployed with a collision risk of 0.7 bottlenose dolphin per year assuming an avoidance rate of 98%. This figure of 0.7 was recommended by NRW ('Additional information provided by NRW Advisory following marine mammals meeting on 06/01/20' [CD MDZ/F14]) as the maximum sustainable annual mortality of bottlenose dolphin calculated through Potential Biological Removal (PBR), therefore NRW recommended that the collision risk associated with this proposal must fall below this figure to be able to rule out AEOSI*."

2.41 As outlined in Section 5 paragraphs 5.1-5.3 and Section on PBR paragraphs 6.40-6.45 in the Marine Mammal PoE [CD MDZ/P2]:

2.42 Since submission of the ES [CD MDZ/A31.14] and Information to Support HRA [CD MDZ/A31.16], additional information was provided by NRW Advisory following a marine mammals meeting on 06/01/20 [CD MDZ/F14], on the current NRW PBR calculations. Therefore, additional collision risk modelling [CD MDZ/A31.13] was undertaken to take into account the NRW PBR values, specifically the 0.7 PBR for bottlenose dolphin.

2.43 This additional collision risk modelling was used to determine the maximum number of devices and MW output that could be possible, for each of the device types, while remaining within the 0.7 limit for bottlenose dolphin collision risk. As each of the device type parameters shown are examples only, and the final design (including the MW output) is still to be determined, results are shown as an example for a number of these devices, and for the maximum MW possible for each of the device types.

2.44 Further post consent assessments for the detailed EMMP will take into account any updates and changes to the PBR values to ensure the proposed Phase 1 deployment will be less than the PBR for bottlenose dolphin, for the project alone and in-combination effects, to ensure there is no significant adverse effect on the population.

2.45 In addition, as outlined above, the maximum species collision limits have been incorporated into the OEMMP and includes a commitment that ensures the risk to marine mammal species would be within the NRW maximum collision limit for each marine mammal species.

Phase 1

2.46 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.1.9** states: *"NRW considers that reducing the scale of the first phase array such that it would fall below a predicted collision risk of 0.7 for bottlenose dolphin at 98% avoidance rate, and suitably reducing the scale of subsequent phases, would considerably reduce the risk. Due to the uncertainties in the modelled outputs, it is not possible to prescribe what this level of reduction should be, but a reduction in scale would add precaution and allow discussion to progress on a pragmatic solution to achieving an initial test phase that would minimise risk whilst accounting for uncertainty. NRW made this position clear at the Technical Working Group meeting held on 6 January 2020."*

2.47 The assessments for the possible Phase 1 were, as outlined in the Marine Mammal PoE [CD MDZ/P2] paragraphs 6.6-6.7, based on worst-case scenarios and to limit the uncertainties associated with modelling, a precautionary approach has been undertaken, using the worst-case parameters for marine mammal species and the tidal devices.

2.48 This additional collision risk modelling [CD MDZ/A31.13] was used to determine the maximum number of devices and MW output that could be possible, for each of the device types, while remaining within the 0.7 limit for bottlenose dolphin collision risk. This provides the 'Rochdale Envelope' for Phase 1 of the Morlais Project by establishing the maximum limit and therefore any deployment would be less than those assessed. As each of the device type parameters used in the assessments are indicative to cover a range of possible turbine types in each category of tidal turbine design (as outlined in Table 4-2 in Chapter 4 of the ES [CD MDZ/A25.4]) and the final design is still to be determined, results are shown as an example for a number of these devices, and for the maximum MW possible for each of the device types.

2.49 The revised OEMMP [CD MDZ/A16.8] outlines the approach that will ensure that the first phase (Phase 1) of deployment will be defined by the PBR for bottlenose dolphin and the species collision limits provided by NRW (MDZ/F15.3), to ensure no significant impact on marine mammals or adverse effect on any designated sites with marine mammals as a qualifying feature (see paragraph 2.51-2.56 below).

2.50 As outlined above, monitoring at Morlais would provide a unique opportunity to collect information on how marine mammals behave around an array of multiple devices, compared to most studies which have involved only one device. This will be very important in addressing data gaps, improving our understanding of the potential risk from multiple devices and how this can be used to remove some of the uncertainty associated with collision risk modelling. Therefore, it is important that the scale of the Morlais first phase is sufficient in order to ensure adequate data is collected to inform the next phase of deployment and other tidal projects.

Environmental Monitoring and Mitigation Plan (EMMP)

2.51 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.2.1** states: "*To reach a conclusion of no AEOSI, or to be able to rule out significant population level effects on Annex IV marine mammal species, an adaptive management process will be essential to secure conditions to remove or reduce predicted adverse effects before AEOSI occurs. However, NRW considers that there is considerable uncertainty over whether the monitoring and mitigation proposed in the Outline Environmental Monitoring and Mitigation Plan ("oEMMP") will be deliverable and effective*."

2.52 The EMMP is the commitment of Menter Môn to safeguarding all marine mammal species and to ensure the proposed project will not have an adverse impact on marine mammal species listed in Annex II and Annex IV of the Habitats Directive and there will be no AEOSI.

2.53 The current version of the revised OEMMP [CD MDZ/A16.8], as outlined below, takes into account the recent NRW Advice on adaptive management of the risk of collision impacts on protected marine mammal species in Welsh waters from the Morlais Project [CD MDZ/F15.3]. The revised OEMMP [CD MDZ/A16.8] outlines the project commitments, as outlined in paragraph 2.5-2.8 above, to ensure the monitoring and mitigation will be deliverable and effective.

2.54 With the commitments and incorporation on the latest NRW advice [CD MDZ/F15.3] in the revised OEMMP [CD MDZ/A16.8], there is unlikely to be the potential to have an adverse effect on marine mammal species listed in Annex II and Annex IV of the Habitats Directive. This includes harbour porpoise from the North Anglesey Marine / Gogledd Môn Forol Special Area of Conservation (SAC) and other species of marine mammals, including those with demonstrated connectivity to other SACs.

2.55 It is acknowledged that the NRW advice [CD MDZ/F15.3]: "*These limits are based on the best evidence available at this time, but they must be adaptable to take account of changing environmental conditions and will be subject to review on an annual basis*."

2.56 As such the development of the EMMP prior to construction will allow the scale of Phase 1 and subsequent phases, based on the potential collision risk, to be determined taking into account the latest information, scientific understanding and guidance at that time, "*avoiding adverse effects on the integrity of SACs and no detriment to the conservation status of European Protected Species (EPS)*".

2.57 Examples of similar approaches to the Morlais OEMMP for marine mammals, used in consented projects presented in the Marine Mammal PoE [CD MDZ/P2] paragraphs 6.77-6.79, include Site Integrity Plan (SIP) for the harbour porpoise Southern North Sea SAC. Where offshore wind farms (OWFs) in and around the Southern North Sea have been developing In Principle SIPs as part of the consenting process, this includes the consented East Anglia THREE and Norfolk Vanguard OWF projects (Norfolk Vanguard Limited, 2019). These In Principle SIPs set out the framework for each project to deliver mitigation measures post consent, to ensure the avoidance of AEOSI of the designated features of the Southern North Sea SAC. The final SIPs are then developed prior to construction to meet the consent condition requirements.

2.58 The In Principle SIP is the commitment of the project to ensure adequate mitigation is in place so that there is no adverse effect, without having to detail what mitigation will be required prior to consent, as this will be determined in the final SIP prior to construction based on final design of the project, the in-combination effects based on the final programme, and any updated information on management measures, advice or guidance for the Southern North Sea SAC.

2.59 This is a similar approach to the proposed outline EMMP for the Morlais project, where the project is committed to ensure adequate and effective mitigation and monitoring, but the details of what is required will be developed in the final EMMP based on the type, number size and layout of the tidal array.

2.60 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.2.2** states: *"NRW considers that real time monitoring of marine mammal movements, and rapid response to any detected collisions, will be necessary in order to avoid adverse effects. The application currently does not include enough detail on how this would be delivered or maintained. While several monitoring and mitigation options are described, evidence of their efficacy on the range of device types proposed, and across all species, is limited."*

2.61 Following the NRW *Advice on adaptive management of the risk of collision impacts on protected marine mammal species in Welsh waters from the Morlais Project* [CD MDZ/F15.3], the OEMMP has been revised [CD MDZ/A16.8] to include further information and commitment to demonstrate that the proposed monitoring and mitigation will be deliverable and effective in avoiding significant impacts and AEOSI. This includes commitment that:

1. It will be demonstrated prior to any tidal device operation (for Phase 1 and full build) that the real-time monitoring will be able to:

- Detect marine mammal movements in and around the array and collisions with the devices as they occur, in real-time, and report accordingly.
- Determine, in the event of a collision, what species or species groups have collided with the devices, in real-time.

If it is not possible to determine species, then a worst-case scenario will be assumed that it was a bottlenose dolphin.

- If it is not possible to determine the severity of the collision, then a worst-case scenario will be assumed that it was a fatal collision.

2. There will be the implementation of adaptive management measures, following any collision, to ensure that the risk of further collisions is reduced, which will be agreed and demonstrated prior to any tidal device operation.

3. The maximum collision limit for any marine mammal species is not exceeded, for example, if a fatal collision does occur for one cetacean species then the mitigation measures will need to be reviewed and further mitigation implemented following the tiered approach.

4. Prior to any tidal device operation the mitigation is proven to be effective and will be adapted in response to any increasing risk of causing adverse effect.

2.62 In addition, following the recommendations by NRW [CD MDZ/F15.3] with respect to marine mammals, a Collision Decision Framework has been included in the revised OEMMP [CD MDZ/A16.8] to ensure a rapid response and demonstrate the decisions that will be made in real-time should a suspected collision occur.

2.63 Further details will be developed in the detailed EMMP and agreed with the Advisory Group on (i) the tiered approach to mitigation (ranging from no mitigation; active deterrence; device modification; cease operation); (ii) the pre-agreed species triggers in relation to the tiers of mitigation; and (iii) the failsafe. Such a failsafe is likely to be a ceasing of operations for tidal device.

2.64 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.2.3** states: "*The oEMMP details phased deployment of arrays of tidal devices (Section 1.3.1) giving indicative examples of potential phases of deployment e.g. paragraph 30: "Phase 1: Will be installed at a capacity (MW) at which no significant impact is predicted on marine mammals or diving birds using the MDZ. This commitment ensures an initial level of mitigation in place at the start of the EMMP through the limitation of the scale of the development". However, the collision risk modelling for the proposed Phase 1 does show the potential for significant impact on marine mammals (see section 4.1 above), so we do not consider that the scale of Phase 1 represents sufficient mitigation to rule out AEOSI. As described in paragraph 4.1.9* ***NRW do not consider it possible to define a scale at which no significant impact is predicted, since even a single collision with a bottlenose dolphin would be significant****, however NRW consider that a reduction in scale would add precaution."*

2.65 As outlined in paragraph 2.48 above, the additional collision risk modelling [CD MDZ/A31.13] was used to determine the maximum number of devices and MW output that could be possible, for each of the device types, while remaining within the 0.7 limit for bottlenose dolphin collision risk. This provides the 'Rochdale Envelope' for Phase 1 of the Morlais Project by establishing the maximum limit and therefore any deployment would be less than those assessed. As each of the device type parameters used in the assessments are indicative to cover a range of possible turbine types in each category of tidal turbine design (as outlined in Table 4-2 in Chapter 4 of the ES [CD MDZ/A25.4]) and the final design is still to be determined, results are shown as an example for a number of these devices, and for the maximum MW possible for each of the device types.

2.66 The latest NRW advice on adaptive management of the risk of collision impacts on protected marine mammal species in Welsh waters from the Morlais Project [CD MDZ/F15.3] provides the maximum marine mammal collision limits for the Morlais Project:

- Harbour porpoise = 3 per year
- Grey seal = 5 per year
- Bottlenose dolphin = 2 over 3 years
- Common dolphin = 5 per year
- Risso's dolphin = 1 per year
- Minke whale = 1 per year
- All other cetacean species = 1 per year

2.67 As stated in the latest NRW advice [CD MDZ/F15.3]: "*The species limits represent the maximum number of collisions between individual animals of a species or a species group, and the moving parts of the turbines, that are considered to be compatible with avoiding adverse effects on the integrity of SACs and would ensure no detriment to the conservation status of European Protected Species (EPS)*."

2.68 Therefore, based on these limits, which are now a key component of the revised OEMMP [CD MDZ/A16.8], it is possible to "*define a scale at which no significant impact is predicted*".

2.69 Also based on the NRW advice [CD MDZ/F15.3] of the maximum of two bottlenose dolphin over three years (which equates to 0.67 dolphin per year), a single collision with a bottlenose dolphin would not be significant.

2.70 It is agreed that '*these limits do not represent the point at which mitigating action should first occur; they represent the point at which any further impact must be fully mitigated to the extent that there should be no further risk to the species from the device'*.

2.71 Therefore, there is a commitment in the revised OEMMP [CD MDZ/A16.8], that the development of detailed EMMP will involve updated collision risk assessments prior to deployment, based on the latest information and tidal device parameters, to demonstrate that these thresholds will not be exceeded. Monitoring will be used to determine if these limits are being approached and if further mitigation is required. For example, if a fatal collision does occur for one cetacean species then the mitigation measures will need to be reviewed and further mitigation implemented.

2.72 Consequently, taking into account the NRW species collision limits and the commitments in the revised OEMMP, the scale for the first phase (Phase 1) can be defined through the development of the EMMP to ensure no significant impacts or AEOSI.

2.73 In the updated collision risk modelling note [CD MDZ/A31.13] Tables 3.5 and 3.6, based on the scenarios for the maximum number (and MW) of each type of tidal device with a collision risk of 0.7 or less bottlenose dolphin, the number of individuals that could be at risk varied widely for the different tidal device categories:

- Bottlenose dolphin = 0.7 per year
- Harbour porpoise = 2.39-24.89 per year
- Risso's dolphin = 0.99-1.08 per year
- Common dolphin = 5.19-7.30 per year
- Minke whale = 0.72-2.34 per year
- Grey seal = 2.48-3.94 per year
- Harbour seal = 0.01 per year

2.74 It is important to note, as outlined in paragraph 2.65 above, these values are based on realistic worst-case parameters, as each of the device type parameters used in the assessments are indicative to cover a range of possible turbine types in each category of tidal turbine design (as outlined in Table 4-2 in Chapter 4 of the ES [CD MDZ/A25.4]) and the final design is still to be determined, therefore the results are shown as an example for the number of these types of devices, and for the maximum MW possible for each of the device types categories.

2.75 Development of the detailed EMMP will involve updated collision risk assessments prior to deployment, based on the latest information and tidal device parameters. This is likely to refine the modelling results as the tidal device parameters will be actual parameters for each tidal device to be deployed, rather than the parameters currently used to cover a range of possible turbine types in each category as a worst-case.

2.76 It is therefore acknowledged that further assessments and modelling will be required in order to ensure Phase 1 is within the NRW species collision thresholds. However, as agreed with NRW the actual in the field real-time monitoring and mitigation to ensure these thresholds are not exceeded will be more important than the modelled predictions.

2.77 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.2.4** states: "*Paragraph 39 (now paragraph 59 of the revised OEMMP [CD MDZ/A16.8]) states that a tiered hierarchy of mitigation will be developed. NRW support the consideration of tiers of mitigation, including the stopping or removal of devices as a failsafe option.*"

2.78 The detailed EMMP will include a series of potential mitigation measures that will be agreed pre deployment and will form a tiered hierarchy of mitigation. The revised OEMMP [CD MDZ/A16.8] outlines the proposed tiered hierarchy of mitigation.

2.79 The revised OEMMP [CD MDZ/A16.8] also includes the Collision Decision Framework, as recommended by NRW [CD MDZ/F15.3] with regard to marine mammals. This will be an agreed framework to demonstrate the real-time and rapid decisions that will be made should a suspected collision occur. This framework will be developed as part of the ongoing development of the EMMP. The collision decision framework will include details on how real-time monitoring and mitigation measures will be effective in reducing the risk of subsequent collisions to avoid adverse effect.

2.80 The process would use pre-agreed trigger level as stages in the collision decision framework. These would relate to any suspected or confirmed collisions that would lead to increasing mitigation, up to the point that collisions reach the species mortality limits, beyond which there will likely be a requirement to cease operation of the tidal device.

2.81 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.2.5** on 'trigger points' has been addressed in the rebuttal proof of Frank Fortune dealing with EMMP matters (Document MMC558 MOR-AEC-DOC-001).

2.82 **NRW PoE [CD POE021] Appendix B: marine mammals paragraph 4.2.6 states**: "*Paragraph 55 (now paragraph 69 of the revised OEMMP [CD MDZ/A16.8]) states: "Updated modelling is expected to show that avoidance of operational tidal devices is much higher than assessed within the ES and that the level of deployment (MW) for which no significant effect is predicted can be revised upwards, allowing further phases of tidal device deployment". There is no evidence presented to support this expectation of higher avoidance of operational tidal devices."*

2.83 As outlined in paragraph 2.48 and 2.65 above, the collision risk modelling was used to determine the maximum number of devices and MW output to provide the 'Rochdale Envelope' for Phase 1 of the Morlais Project by establishing the maximum limit and therefore any deployment would be less than those assessed. As each of the device type parameters used in the assessments are indicative to cover a range of possible turbine types in each category of tidal turbine design (as outlined in Table 4-2 in Chapter 4 of the ES [CD MDZ/A25.4]) and the final design is still to be determined, results are shown as an example for a number of these devices, and for the maximum MW possible for each of the device types.

2.84 These assessments included, as outlined in Marine Mammal PoE [CD MDZ/P2] paragraph 6.5-6.6, are based on realistic worst-case parameters for tidal devices and linear scaling of individual devices to array, assuming all devices in array could have the same collision risk. The assessments also assume, as a worst-case, that all encounters and collisions are fatal. The assessments, although based on 98% avoidance rate, do not take into account mitigation and monitoring.

2.85 Development of detailed EMMP will involve updated collision risk assessments prior to deployment, based on the latest information and tidal device parameters. This is likely to refine the modelling results as the tidal device parameters will be actual parameters for the tidal devices to be deployed rather than worst-case parameters for the device type categories that have been currently modelled as a worst-case.

2.86 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.2.7** on 'gateway reviews' has been addressed in the rebuttal proof of Frank Fortune dealing with EMMP matters. However, the commitments in the revised OEMMP [CD MDZ/A16.8] and incorporation of NRW recommended Collision Decision Framework, as outlined above, which will include real-time monitoring and detection to allow rapid response address this.

2.87 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.2.8** is in relation to Table 4-1 of the OEMMP titled 'Review of Potential Monitoring Methods', in which NRW provides comments on each of the suggested marine mammal monitoring methods, which includes Passive Acoustic Monitoring (PAM), active sonar, underwater cameras and Acoustic Deterrent Devices (ADDs).

2.88 The title of Table 4-1 in revised OEMMP [CD MDZ/A16.8] has been amended to 'Review of Potential Monitoring and Mitigation Methods' and this will be further development as the project and EMMP is developed. Detailed design of the monitoring and mitigation within the EMMP is most appropriately done when the technologies for deployment are known, post-consent.

2.89 A range of possible monitoring and mitigation options were provided in the note on Marine Mammals Monitoring and Mitigation Options [CD MDZ/A28.13]. Some of these have been include as possible examples in the OEMMP [CD MDZ/A16.8]. However, all possible monitoring and mitigation options will be reviewed and assessed for consideration in developing the detailed EMMP, including new and emerging technologies, as the detailed EMMP is developed and more information is available on effectiveness and any limitations of the potential monitoring and mitigation options, as well as details of the tidal devices, array layout and the mitigation and monitoring requirements.

2.90 It is proposed that a range of different monitoring options will be deployed rather than relying on one method, to take into account the potential limitations of some methods, such as PAM being unable to detect non-vocalising animals such as seals and possible limitations for detecting and tracking minke whale or other baleen whales. However recent studies, such as Kowarski *et al*. (2020) indicate PAM can be an effective and reliable technique for near real-time monitoring of baleen whales, although this study uses gliders, fixed buoys with hydrophones at depth connected to surface with real-time detections relayed to land could be an option .

2.91 A range of different monitoring options, rather than one method, will also allow for different tidal devices to be adequately monitored at different ranges (for example, active sonar is most effective at detecting marine mammals in close proximately, whereas PAM can be used to cover a wider area).

2.92 Although the use of surface infra-red / visual spectrum cameras and underwater cameras and / or videos is not currently considered further in the OEMMP, this will be reviewed as part of the ongoing development of the EMMP, when further information is available, including any further data on the underwater visibility of at the site. Therefore, following NRW suggestion, the potential use of underwater video will be investigated further.

2.93 There is currently ongoing research and development of monitoring and mitigation of marine mammals for tidal energy devices at a number of locations around the world, including Bay of Funday and MeyGen, as well as other sectors including oil and gas seismic surveys and offshore wind farm developments. The information and scientific understanding from these studies will be continuously reviewed during the development of the EMMP.

2.94 The use of ADDs are currently proposed as a mitigation measure to emit a sound designed to deter or alert marine mammals from coming into danger of collision with the devices. ADDs have been proven to be effective as mitigation during unexploded ordnance (UXO) and piling for offshore wind farms and to deter seals from fish farms. Although, as indicated by NRW, their use for tidal energy devices is as yet unproven, it is possible. However, it is acknowledged that careful consideration will be required to determine the most appropriate and effective type(s) of ADDs to ensure adequate mitigation.

2.95 The type of ADDs, number and locations will be determined prior to deployment and will be based on the latest information, technology, guidance and consultation (further response to NRW comments on ADDs is provided in paragraphs 2.154-2.179 below).

2.96 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.2.9**: *"We note that the Marine Mammals Monitoring and Mitigation Options document provides more detail on additional monitoring and mitigation methods. However, it is unclear how this document relates to the oEMMP; the document contains detail that was previously in a draft of the oEMMP, but is now set out separately. It is not clear how these documents are intended to relate to each other."*

2.97 As outlined above in response to NRW paragraph 4.2.8, a range of possible monitoring and mitigation options were provided in the note on Marine Mammals Monitoring and Mitigation Options [CD MDZ/A28.13]. Some of these have been include as possible examples in the OEMMP [CD MDZ/A16.8]. However, all possible monitoring and mitigation options, will be reviewed and assessed for consideration in the EMMP, including new and emerging technologies, as the EMMP is developed and more information is available on effectiveness and any limitations of the potential monitoring and mitigation options.

2.98 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.2.10**: "*Section 1.4 lists options for monitoring and mitigation. Here, a number of options appear which are not considered in the oEMMP" this included device modification or removal, seal tagging studies, light mitigation methods, thermal imaging technology and underwater cameras*.

2.99 As outlined above in response to NRW paragraph 4.2.8, a range of possible monitoring and mitigation options were provided in the note on Marine Mammals Monitoring and Mitigation Options [CD MDZ/A28.13]. Some of these have been include as possible examples in the OEMMP. However, all possible monitoring and mitigation options, will be reviewed and assessed for consideration in the EMMP, including new and emerging technologies, as the EMMP is developed and more information is available on effectiveness and any limitations of the potential monitoring and mitigation options.

2.100 **NRW PoE [CD POE021] Appendix B: marine mammals paragraph 4.2.11**: "*NRW considers that adaptive management will be essential in removing or reducing predicted adverse effects, and that mitigation and monitoring must be secured through a comprehensive adaptive management plan, to be agreed in writing, pre-consent, which will be fundamental to providing confidence in the conclusions of the HRA. Supplementary advice on adaptive management has been provided to the applicant. NRW considers that, prior to device operation, it must be demonstrated that it will be possible to:*

• Detect marine mammal movements in and around the array and collisions with the devices as they occur, and report accordingly;

• Determine, in the event of a collision, what species or species groups have collided with the devices;

• Implement adaptive management measures, following any collision, to ensure that the risk of further collisions is reduced;

• Ensure that a maximum collision limit for any marine mammal species is not exceeded."

2.101 Paragraphs 2.61-2.63 above, outlines the commitments of the EMMP to address these points.

2.102 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.2.12**: "*NRW advise that comprehensive real-time monitoring must be deployed to detect animal movements around the devices and detect or infer any collisions should they occur. Monitoring must be sufficient to differentiate between inanimate objects and marine mammals, but also to discriminate between dolphin species, porpoise and seals. If it is not possible to determine what has collided with the device, the 'worst case scenario' must be assumed, i.e. that the collision was with the species with the lowest collision limit. NRW advise that unless the Applicant clearly demonstrates a robust and reliable means of distinguishing severity of injury, the precautionary principle must be applied and the 'worst case scenario' must be assumed, i.e. that all collisions are assumed to result in the death of the individual involved.*

2.103 Paragraphs 2.61-2.63 above, outlines the commitments of the EMMP to address this.

2.104 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.2.13**: *"Given the uncertainty over what monitoring system will be used, and whether it will be effective for the different device types – NRW advise that any monitoring system must be demonstrated to be effective in detecting real-time animal movements around the devices prior to device operation."*

2.105 Paragraphs 2.61-2.63 above, outlines the commitments of the EMMP to address this. It is my opinion, based on what has been undertaken at other projects and for other activities, along with the current research and development of monitoring and mitigation for marine mammals, that what is proposed in the EMMP is deliverable and will be effective.

2.106 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.2.14**: *"NRW recommends that a framework is agreed to demonstrate the process that would be followed, and the decisions made, should a suspected collision occur. Figure 2 gives an example provided by NRW. The collision decision framework should include detail on how monitoring and mitigation measures will be effective in reducing the risk of subsequent collisions to avoid adverse effect."*

2.107 As outlined in paragraph 2.79 above, the revised OEMMP [CD MDZ/A16.8] includes the Collision Decision Framework, as recommended by NRW [CD MDZ/F15.3] with regard to marine mammals. This will be an agreed framework to demonstrate the real-time and rapid decisions that will be made should a suspected collision occur. This framework will be developed as part of the ongoing development of the EMMP. The collision decision framework will include details on how real-time monitoring and mitigation measures will be effective in reducing the risk of subsequent collisions to avoid adverse effect.

2.108 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.2.15**: "*The process should use pre-agreed trigger levels as stages in the collision decision framework. These should relate to numbers of suspected or confirmed collisions that should lead to increasing mitigation, up to the point that collisions reach the species mortality limits described in paragraph 4.2.14 below, beyond which there will likely be a requirement to cease operation."*

2.109 As outlined in paragraph 2.80 above, the Collision Decision Framework process, included in the revise OEMMP [CD MDZ/A16.8] would use pre-agreed trigger level as stages in the collision decision framework. These would relate any suspected or confirmed collisions that would lead to increasing mitigation, up to the point that collisions reach the species mortality limits (see paragraph 2.66 above), beyond which there will likely be a requirement to cease operation of the tidal device.

2.110 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.2.16**: *"NRW have defined a set of maximum collision limits which will ensure that, through adaptive management, the project will avoid causing an adverse effect. In the case of Annex II marine mammal species - bottlenose dolphins, grey seals and harbour porpoise - these limits are considered to be below the level considered to constitute an adverse effect on the integrity of the Welsh SACs. For all other cetaceans (as Annex IV European Protected Species) these limits are considered to represent values that, if exceeded, may be detrimental to maintaining the populations of EPS concerned at a favourable conservation status in their natural range. Full rationale for these limits is given in the NRW Advice note [CD MDZ/F15.3]."*

2.111 As outlined above, Section 1.3.3 of the revised OEMMP [CD MDZ/A16.8] incorporates the current species collision limits for marine mammals as provided by *NRW Advice on adaptive management of the risk of collision impacts on protected marine mammal species in Welsh waters from the Morlais Project* [CD MDZ/F15.3]. It is agreed with NRW that "*these limits do not represent the point at which mitigating action should first occur; they represent the point at which any further impact must be fully mitigated to the extent that there should be no further risk to the species from the device*." As outlined in Section 1.3.3 of the revised OEMMP [CD MDZ/A16.8] and paragraph 5.6 of the Marine Mammal [CD MDZ/P2] PoE, these thresholds will be a key component of the EMMP and development of detailed EMMP will involve updated collision risk assessments prior to deployment, based on the latest information and tidal device parameters, to demonstrate that these thresholds will not be exceeded. Monitoring will be used to determine if these limits are being approached and if further mitigation is required. For example, if a fatal collision does occur for one cetacean species then the mitigation measures will need to be reviewed and further mitigation implemented following the tiered approach.

2.112 As previously indicated, the commitments in the revised OEMMP [CD MDZ/A16.8] ensure the risk to marine mammal species would be within the NRW maximum collision limit for each marine mammal species and that if a fatal collision does occur for one cetacean species then the mitigation measures will be reviewed and further mitigation implemented following the tiered approach in the EMMP.

Disturbance from operational underwater noise

2.113 **NRW PoE [CD POE021] paragraph 20** outlines NRW concern that "*The assessment of whether the operational tidal devices would generate underwater noise causing disturbance to marine mammals is deficient. In particular, aspects of the underwater noise modelling are not adequately explained, and do not appear to consider the full complexity of the project design envelope (PDE). In particular:*

- *The source of the operational noise characteristics for the noise modelling is not identified or adequately explained.*
- *The assumption that the sound level of a large rotor device can be obtained by scaling up from a small rotor device is not supported by evidence.*
- *It has not been explained how the sound emanating from a single rotor is extrapolated to an array of 120 or 620 devices for the large and small rotor turbines respectively.*
- *It has not been explained how the use of two noise levels from a small and large rotor source adequately considers the multiple different device types within the PDE.*
- *No estimate is given of what the maximum noise disturbance range would be for an array of either small or large turbines. However, the noise model plots appear to show that it could range to approximately 17km from the centre of the array. Continuous noise disturbance at this range could potentially cause AEOSI on North Anglesey Marine SAC for the duration of the project operation."*

2.114 As outlined in the Marine Mammal PoE [CD MDZ/P2] paragraph 6.47-6.56, underwater noise from operational turbines has been assessed based on the information currently available and worst-case scenarios. There is a commitment in the revised OEMMP (paragraph 23) [CD MDZ/A16.8] that further underwater noise modelling will be conducted once details are known of the types of devices and noise source levels to be deployed as part of the development of the EMMP.

2.115 The potential for any significant disturbance will be assessed in the EMMP, based on operational tidal device noise levels in different conditions, for individual devices and the array of devices to be deployed, taking into account ambient noise, the different species hearing sensitivities and the latest SNCB Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs (JNCC *et al*., 2020). If there is the potential for any significant disturbance, then possible options and mitigation measures would be investigated.

2.116 However, the assessments indicate no potential for any significant disturbance or AEOSI (see paragraph 2.143 below).

2.117 It should also be noted, that it is important that the noise levels from operational turbines are sufficient for marine mammals to detect them in all conditions, so they are able to avoid collision with the tidal devices, but not high enough to result in any significant long-term disturbance.

2.118 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.3.1**: "*The applicant's Underwater Noise Modelling Report (MDZ/A28.10) reports that operational turbine noise was modelled using estimated source levels for two models of tidal turbine: a small turbine with a rotor diameter of 16.13m and a larger turbine consisting of two rotors, each 24.6m in diameter. The source level was scaled based on the rotor diameter of the proposed tidal turbine resulting in:*

• 16.13m diameter rotor tidal turbine (small): 155.7dB re 1µPa @ 1m (SPL_{RMS}[3]).

• Dual 24.6m diameter rotor tidal turbine (large): 161.2dB re 1µPa @ 1m (SPL_{RMS})."

2.119 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.3.2**: *"NRW queries where these operational noise levels were sourced from, and whether deriving the source level of the large rotor device by scaling up from the small rotor device is realistic. It is not clear whether these two source levels adequately consider the multiple different device types with potentially different noise characteristics. Given the uncertainties, NRW believe it is not currently possible to assess whether the information presented is a realistic worst case."*

2.120 The outline source of the operational noise characteristics for the noise modelling are given in section 3.1.4 of the Underwater Noise Modelling Report (MDZ/A28.10). References for these inputs were not given as the measurements are not formally published or publicly available. Subacoustech conducted the underwater noise modelling for the Morlais Project. Subacoustech have over 20 years experience in conducting underwater noise modelling for the marine industry to monitor and mitigate the effects of noise in the marine environment. The data used in the modelling of the operational turbines was taken from Subacoustech's database which includes (i) an assessment of tidal current turbine noise (11m rotor, 350kW) at Lynmouth site and predicted impact of underwater noise at Strangford Lough; and (ii) measurement and assessment of underwater noise from the Openhydro tidal turbine device (250kW) at the EMEC facility, Orkney. However, it is important to note that the underwater noise modelling was indicative and was conducted post-submission in response to NRW request. There is now a commitment in the revised OEMMP [CD MDZ/A16.8] that further underwater noise modelling will be conducted for operational turbines once details are known of the types, noise source levels and number of devices to be deployed as part of the development of the detailed EMMP post consent.

2.121 The assumption that the sound level of a large rotor device can be obtained by scaling up from a small rotor device is a worst case assumption based on Subacoustech data, with a simple line drawn between source levels of Subacoustech measurements of tidal turbines from Lynmouth and Orkney in order to extrapolate expected noise levels for Morlais. Subacoustech had insufficient data to produce a more refined model, but this would produce precautionary noise levels. Subacoustech have recently become aware of Risch *et al*. (2020) (provided in Appendix 1) which presents measured noise levels for a 1.5 MW, 18m rotor

[3] The Sound Pressure Level (SPL) is normally used to characterise noise and vibration of a continuous nature. The variation in sound pressure can be measured over a specific time period to determine the root mean square (RMS) level of the time varying acoustic pressure, therefore SPL (i.e. SPL_{RMS}) can be considered as a measure of the average unweighted level of the sound over the measurement period.

diameter turbine. This is slightly smaller than the large turbine design at Morlais (24m dual rotor, output TBC) but more comparable than the earlier data from smaller designs. Risch *et al*. (2020, provided in Appendix 1) measured 138 dB SPL at ~60m. For the slightly larger turbines, Subacoustech modelled 140-145 dB at 60 m. Thus, the projection appears reasonable.

2.122 In relation to how the sound emanating from a single rotor is extrapolated to an array of 120 or 620 devices for the large and small rotor turbines, respectively, the calculation of the noise levels from multi-device arrays uses a dedicated feature of the dBSea model (full documentation is at the dBSea website, dbsea.co.uk). Using this, the interaction of the complex sound field between multiple locations is calculated automatically. The dBSea model developed by Marshall Day Acoustics and Irwin Carr Consulting in widely used as a tool for the prediction of underwater noise in a variety of environments by acoustic professionals, such as Subacoustech who undertook the underwater noise modelling for the Morlais site. The three solvers used by dBSea are based on codes widely used and tested within the underwater acoustics industry. They have been extensively tested against measured data and analytical solutions, validating the model.

2.123 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.3.3**: "*Section 3.2.3 of the report states that a 142dB threshold taken from Hastie et al. (2018) [CD POE035] is the most specific and relevant disturbance threshold available for this type of assessment, as the low-end threshold of 120dB (SPL_{RMS}) for continuous noise disturbance for marine mammals drawn from Southall et al. (2007)[CD POE053] is approaching the level of background noise reported from other areas. However, rather than comparing against background noise published from elsewhere, NRW advises that the predicted noise level should be compared against that measured at the proposed development site by SEACAMS as reported in Table 1.1 of the Marine Mammals Underwater Noise Modelling Note [CD MDZ/A28.11]: the maximum background noise level was 106.6dB SPL_{RMS}, while the average was 98dB SPL_{RMS}. The lower disturbance threshold of 120dB is therefore higher than the maximum background noise measured at the site so could feasibly be audible to marine mammals.*"

2.124 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.3.4**: *"The 142dB threshold is taken from Hastie et al. (2018) [CD POE035], where playback experiments were conducted in the vicinity of harbour seals. The paper's author has confirmed that 142dB was not intended to represent a threshold for avoidance, simply that these were the estimated levels within an area where seals showed a significant reduction in abundance, and that caution should be applied if using this as a threshold for other species."*

2.125 A range of thresholds and criteria were presented and assessed in the ES [CD MDZ/A25.12 / MDZ/A31.14], Information to Support HRA [CD MDZ/A27.11 / MDZ/A31.16] and the Underwater Noise Modelling Report [CD MDZ/A28.10]. As there are currently no agreed thresholds and criteria for disturbance of marine mammals from underwater noise, the best currently available information was used. Providing a range of potential thresholds and criteria was a precautionary approach to ensure a range of potential impact ranges were included in the assessments.

2.126 The underwater noise modelling [CD MDZ/A28.10] included two possible thresholds for the potential disturbance of marine mammals: 120dB re 1 μPa (SPL_{RMS}) and 142 dB re: 1 μPa

(SPL_{RMS}). For a marine mammal to be significantly disturbed over a wide area, for a long period of time, the underwater noise needs to be greater than background / ambient noise levels.

2.127 It is important to note that the 120dB re 1 µPa (SPL_{RMS}) criteria based on Southall *et al*. (2007) [CD POE053], was not included in the subsequent Southall *et al*. (2019) Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects [CD POE049]. However, the noise threshold level of 120dB re 1 µPa (SPL_{RMS}) was included in the underwater noise modelling [CD MDZ/A28.10] to indicate the lower noise level that could result in a behavioural response in marine mammal species.

2.128 As presented in Southall *et al*. (2007) [CD POE053], the historical perspective is that 'early observations of bowhead and gray whales exposed to continuous industrial sounds, such as those associated with drilling operations, suggested 120 dB re: 1 µPa as the approximate threshold for behavioural disturbance of these baleen whales'. However, there was significant individual variability. As such the authors question as to whether 'behavioural responses are most appropriately described by the exposure received level (RL) of the stimulus at the animal, the signal-to-ambient noise differential, the rate of change of the signal, or simply to the presence of the human activity as indicated by acoustic cues and/or visual stimuli.'

2.129 Similarly, as presented in Southall *et al*. (2007) [CD POE053], there is also considerable variability in the observations for other species, including mid-frequency species (which include dolphin species) to non-pulse sounds (as operational turbines are classified), with some individuals in the field showing behavioural responses to exposures from 90 to 120 dB re: 1 µPa, while others failed to exhibit such responses for exposure RLs from 120 to 150 dB re: 1 µPa.

2.130 Southall *et al*. (2007) [CD POE053], also noted that harbour porpoises are quite sensitive to a wide range of human sounds at very low exposure RLs (~90 to 120 dB re: 1 µPa), at least for initial exposures. However, Southall *et al*. (2007) [CD POE053], acknowledge that it is unknown if this behavioural sensitivity to anthropogenic acoustic sources extends to non-pulse sources other than ADDs and that strong initial reactions of harbour porpoise at relatively low levels may in some conditions wane with repeated exposure and subject experience.

2.131 This therefore indicates that, the 120dB re 1 µPa (SPL_{RMS}) criteria is a very precautionary approach for a possible behavioural reaction in marine mammals, particularly harbour porpoise, however, this could be an initial reaction to the introduction of a new noise and not all individuals would react the same. Therefore, marine mammals, including harbour porpoise, would not be significantly disturbed for a continuous period of time from the maximum area predicted by the 120dB re 1 µPa (SPL_{RMS}) criteria (for example, up to the maximum predicted range of up to 1.3km for large tidal turbine (2 rotors) at a single location [CD MDZ/A28.10]).

2.132 As presented in Underwater Noise Modelling Note [CD MDZ/A28.11], a series of underwater noise monitoring stations were installed by SEACAMS (University of Bangor) to sample the background noise levels in and around the MDZ, the data indicated a range of noise levels of 89 dB to 107 dB SPL_{RMS} re 1 µPa. These background noise levels were lower than baseline level of noise in the vicinity of Cemlyn Bay, Cemaes Bay and the Wylfa Newydd Development Area, which were between 111.4dB re 1µPa (SPL_{RMS}) and 120.9dB re 1µPa (SPL_{RMS}) (Section 12.6.3.3.1 of Chapter 12 of the ES [CD MDZ/A25.12]). The Wylfa Newydd Development Area is located on the Wylfa peninsula, extending into the Irish Sea between the bays of Cemlyn and Cemaes, on the northern tip of the Isle of Anglesey, approximately 16.6km from the MDZ. The lower background noise levels at the MDZ reflect the site being further offshore compared to the other locations, with less noise from breaking waves. However, it does illustrate that background noise levels can exceed 120dB re 1 µPa (SPL_{RMS}).

2.133 As outlined in NRW PoE [CD POE021] Appendix B: marine mammals paragraph 4.3.3, the predicted sounds levels for the operational turbines are above the maximum ambient noise measured at the site by SEACAMS, therefore would be audible to marine mammals so they will be able to detect and avoid any collision risk. However, the underwater noise modelling indicates that there is no risk of any permanent or temporary auditory effects and that marine mammals will not be significantly disturbed over a wide area, based on the 142 dB re 1 µPa (SPL_{RMS}) criteria.

2.134 It is acknowledged that "*142dB was not intended to represent a threshold for avoidance, simply that these were the estimated levels within an area where seals showed a significant reduction in abundance, and that caution should be applied if using this as a threshold for other species*". However, this is consistent with the observations in Southall *et al*. (2007) (POE053), that exposures exceeding 140 dB re: 1 µPa induced an avoidance behaviour response in wild harbour porpoise.

2.135 As outlined above, it is important to note that the underwater noise modelling is based on the based available information currently available and further underwater noise modelling will be conducted once details are known of the types and noise levels of devices to be deployed as part of the development of the EMMP, this will include the scenarios required for each phase, including, the maximum potential impact areas for the arrays. The maximum areas of potential disturbance will be assessed to determine the potential for any significant disturbance based on operational tidal device noise levels in different conditions, for individual devices and the array of devices to be deployed, taking into account ambient noise, the different species hearing sensitivities and the latest criteria and thresholds to use in the assessments, which will be agreed with NRW.

2.136 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.3.5**: *"The disturbance ranges estimated by using a 142dB threshold are considerably smaller than the impact ranges estimated from the Southall et al. (2019) weighted* SEL_{cum} *injury criteria. When using these criteria, the maximum predicted Temporary Threshold Shift (TTS) ranges for the group of cetaceans with very high frequency hearing (which includes harbour porpoise) exceed the maximum predicted disturbance ranges for operational turbine noise and ADD noise. This suggests that animals would experience temporary hearing damage without being disturbed (Table 1-21 of the Marine Mammals Underwater Noise Modelling Note). For example, the modelling for ADD noise shows a disturbance range of 840m but a temporary threshold shift (TTS) range of 5.3km."*

2.137 It is important to note that the 5.3km range is for ADDs and not operational turbines. As outlined in the Underwater Noise Modelling Report (MDZ/A28.10), the maximum modelled range for Temporary Threshold Shift (TTS) / temporary reduction in hearing sensitivity, using the Southall *et al*. (2019) [CD POE049] criteria for harbour porpoise (classed as 'very high-frequency cetaceans due to their sensitivity to high frequency sounds) was out to a maximum of 5.3km due to the high-frequency nature of the ADD noise modelled. As a worst-case, the underwater noise modelling was based on one of the loudest (but not the loudest) ADDs currently used, the Lofitech Sea Scarer [CD MDZ/A28.10]. This ADD has been used as mitigation prior to underwater activities with high noise levels, such as underwater explosions and offshore wind farm piling, to ensure marine mammals are beyond a range that could result in any physical or permanent auditory injury. Therefore, it is important for these activities that the ADD is loud and audible over a large area to deter marine mammals from the area they could be at risk. However, as outlined in the Marine Mammals Monitoring and Mitigation Options note [CD MDZ/A28.13], prior to deployment a detailed review will be conducted to determine the most suitable and effective ADDs for the Morlais site. This will take into account the hearing range of marine mammal species likely to be present, ambient noise levels at different tidal states, the underwater noise modelling and proven effectiveness of different types of devices and systems. The latest technology, devices and systems will be considered, including, if required, adapting systems, so they are suitable for the intermittent activation as animals approach the tidal devices to reduce the risk of any collision, but would not result in any potential TTS or significant disturbance.

2.138 The Southall *et al*. (2019) [CD POE049] 'weighted' criteria takes into account the species hearing sensitivity. Consequently, the maximum predicted Temporary Threshold Shift (TTS) ranges for the group of cetaceans with very high frequency hearing (which includes harbour porpoise) exceeds the maximum predicted disturbance ranges for operational turbine noise and ADD noise, as the disturbance criteria is not weighted and therefore does not take into account the species hearing sensitivity. As outlined in footnote 41 of NRW PoE [CD POE021] Appendix B: marine mammals paragraph 4.3.5, 'sound outside the hearing range of an animal would be unlikely to affect its hearing, while the sound energy within the hearing range could be harmful'. Weighting is used in the criteria to take into account the hearing sensitivity of the different species. For example, harbour porpoise are sensitive to high frequency noise sources, therefore the weighted criteria takes this into account.

2.139 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.3.6**: "*The noise propagation from a sample array of small turbines was modelled at 620 locations, and large turbines at 120 locations (Underwater Noise Modelling Report [CD MDZ/A28.10]. The results are shown as noise plots (Fig. 4-10 & 4-11) but the associated data are not presented. No estimate is given of what the maximum noise disturbance range would be for an array of either small or large turbines. An estimate of the disturbance range is necessary to calculate the area of the likely noise disturbance 'footprint' (or zone of influence) within North Anglesey Marine / Gogledd Môn Forol SAC in order to assess the significance of this impact. While no data on disturbance range is given, the noise plots appear to show noise up to a 120dB threshold may propagate approximately 17km from the centre of the array (Figure 3). Continuous noise disturbance at this range could potentially cause AEOSI on North Anglesey Marine SAC for the duration of the project operation.*"

2.140 The noise modelling presented as noise plots is an indicative worst-case. As outlined in section 4.2.3 Underwater Noise Modelling Report [CD MDZ/A28.10], ranges for cumulative impact have not been calculated as there are multiple source locations, and no possible 'start' location for any receptor for exposure calculation. In respect of prediction of the maximum distance, the modelling would have to decide on what reference point to use – for example, a point in an array, either an end of an array or the centre of array. Therefore, as the underwater noise modelling is indicative and not based on actual noise levels from potential array scenarios, this has not yet been modelled in detail. However, as outlined above in paragraphs 2.127-2.133, the 120dB re 1 µPa (SPL_{RMS}) criteria is the worst case for a possible initial behavioural reaction in marine mammals, particularly harbour porpoise. However, marine mammals, including harbour porpoise, would not be significantly disturbed from the maximum area predicted by the 120dB re 1 µPa (SPL_{RMS}) criteria. For example, background noise levels of 120dB re 1 µPa (SPL_{RMS}) have been recorded in the vicinity of Cemlyn Bay, Cemaes Bay and the Wylfa Newydd Development Area off north Anglesey.

2.141 As such, "*the noise plots that appear to show noise up to a 120dB threshold may propagate approximately 17km from the centre of the array (Figure 3)"* would not result in continuous disturbance at this range and would not cause AEOSI on North Anglesey Marine SAC for the duration of the project operation.

2.142 Therefore, as a precautionary approach and as outlined above, noise levels exceeding the 142 dB re 1 µPa (SPL_{RMS}) criteria could have the potential to result in some disturbance, particularly harbour porpoise. For a large tidal turbine (2 rotors) at a single location the maximum range is up to 70m for 142dB re 1 µPa (SPL_{RMS}).

2.143 The underwater noise modelling note [CD MDZ/A28.11] presented an assessment for the full deployment was based on arrays rather than individual tidal devices, as individual marine mammals would be more likely to be disturbed by the closest turbine they approach rather than all individual turbines within the array. As an indicative precautionary worst-case, the assessment has been based on up to 10 arrays, however the maximum number of arrays at the Morlais is likely to be eight. The assessment assumes no overlap in disturbance areas between arrays / groups of turbines. The potential impact area of 0.015km^2 for an individual large tidal turbine (based on up to 70m maximum impact range) could result in a disturbance area of 0.15km^2 for 10 tidal devices representing 10 areas. This represents up to 0.005% of the North Anglesey Marine SAC, which has an area of 3,249km^2. Even if based on a similar approach for the maximum impact area of 5.31km^2 (based on 1.3km maximum impact range) the maximum area for 10 devices representing 10 areas could result in area of up to 53.1km^2, 1.6% of the North Anglesey Marine SAC. The assessment in the Information to Support HRA [CD MDZ/A27.11] was based on a maximum area of potential disturbance of harbour porpoise from operational turbines of 11.7km^2, 0.36% of the North Anglesey Marine SAC. Therefore, under these circumstances, based on the current SNCB guidance (JNCC *et al*., 2020), the area of potential disturbance would not exceed 20% of the area of the SAC at any given time. As such there would be no significant disturbance of harbour porpoise and no AEOSI for the North Anglesey Marine SAC.

2.144 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.3.7**: "*The plot for the large turbine array (Figure 4-11) (Underwater Noise Modelling Report [CD; MDZ/A28.10] does not appear to show any locations where noise exceeds 135-140dB. This does not appear accurate, given that the plot is modelled on an array of 120 turbines with an estimated source level of 161.2dB re 1µPa @ 1m (SPL_{RMS}). The plot of the single large turbine (Figure 4-7) and the small turbine array (Figure 4-10) appear to show higher source levels than the large* *turbine array. Furthermore, the noise plot in Fig 4-11 does not appear to match the array configuration in Plot C of Figure 3-1. Clarification is therefore required as to whether this is accurate."*

2.145 As explained in the Underwater Noise Modelling Report [CD MDZ/A28.10], 'the results show that overall noise levels are louder overall for the small turbines at 620 locations than they are for large turbines at 120 locations. Although the large turbines are louder individually, the fact that there are 400 fewer locations, and the locations are more spaced out, results in a lower overall level.' As outlined above, the noise modelling presented as noise plots is an indicative worst-case.

2.146 The underwater noise modelling is based on the best available information currently available and further underwater noise modelling will be conducted once details are known of the types and noise levels of devices to be deployed as part of the development of the EMMP, this will include the scenarios required for each phase, including, the maximum potential impact areas for the arrays. The maximum areas of potential disturbance will be assessed to determine the potential for any significant disturbance based on operational tidal device noise levels in different conditions, for individual devices and the array of devices to be deployed, taking into account ambient noise, the different species hearing sensitivities and the latest criteria and thresholds to use in the assessments, which will be agreed with NRW.

2.147 However, as outlined in paragraph 2.143 above, the assessments indicate no potential significant disturbance and no AEOSI for the North Anglesey Marine SAC.

2.148 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.3.8**: "*NRW seeks clarification as to how the modelled arrays (of 620 'small turbines' and 120 'large turbines') relate to the proposed full project deployment. While 620 is stated for the worst-case scenario of the full deployment in ES Volume I, Chapter 4: Project Description it is not clear where 120 large turbines are derived from."*

2.149 The 120 large turbines is based on 120 x 2MW devices for a maximum of 240MW at the site.

2.150 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.3.9**: *"Given the lack of information on the range of potential disturbance impact, and the uncertainty over the accuracy of the information presented, NRW believes it is not currently possible to assess the likely impact footprint of disturbance from operational turbine noise, which will occur for the duration of the project. NRW therefore cannot agree with the conclusion of the report regarding operational noise and further information is required."*

2.151 The assessments and underwater noise modelling for operational turbines have been based on the information currently available and worst-case scenarios. A range of thresholds and criteria were presented and assessed in the ES [CD MDZ/A25.12], Information to Support HRA [CD MDZ/A27.11] and the Underwater Noise Modelling Report [CD MDZ/A28.10]. As there are currently no agreed thresholds and criteria for disturbance of marine mammals from underwater noise, the best currently available information was used. Providing a range of potential thresholds and criteria was a precautionary approach to ensure a range of potential impact ranges were included in the assessments.

2.152 Assessments, as outlined in paragraph 2.143, indicate no significant disturbance and no AEOSI for the North Anglesey Marine SAC due to underwater noise from operational turbines.

2.153 There is a commitment in the revised OEMMP (paragraph 23 [CD MDZ/A16.8]) that further underwater noise modelling will be conducted once details are known of the types of devices and noise source levels to be deployed as part of the development of the EMMP.

Disturbance from Acoustic Deterrent Devices (ADDs)

2.154 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.4.1**: *"The 'Underwater Noise Modelling Report' [CD MDZ/A28.10] cites evidence from field trials and a review of the evidence base for the use of ADDs as marine mammal mitigation in which the disturbance range for the Lofitech ADD was estimated as 7.5km for harbour porpoise. This is cited as a worst-case in the ES for the potential displacement of harbour porpoise during ADD activation. NRW agrees that this is the best available evidence for the effectiveness of this ADD. However, it is not appropriate to use assumed disturbance ranges based on 142dB for the reasons explained above, nor to use these assumed ranges contrary to peer-reviewed evidence supporting considerably longer disturbance ranges."*

2.155 The information on ADDs in Chapter 12 of the ES [CD MDZ/A25.12], the Marine Mammals Monitoring and Mitigation note [CD MDZ/A28.13] and the Underwater Noise Modelling Report (MDZ/28.10) has been provided to show the effectiveness of ADDs as mitigation and that they will be audible to marine mammals above ambient noise levels.

2.156 The use of ADDs are currently proposed as a mitigation measure to emit a sound designed to deter or alert marine mammals from coming into danger of collision with the devices. ADDs have been proven to be effective as mitigation during unexploded ordnance (UXO) and piling for offshore wind farms and to deter seals from fish farms, where there is a requirement to ensure marine mammals are deterred from a wide area.

2.157 The examples provided indicated that in some studies on the Lofitech ADD there has been a decline in harbour porpoise PAM detections up to 7.5km from the source [CD MDZ/A28.13]. The underwater noise modelling [CD MDZ/28.10] was conducted for the noise source levels of the Lofitech ADD and predicted that based on the weighted criteria the maximum predicted range for temporary reduction in hearing sensitivity (TTS) could be up to 5.3km for harbour porpoise, taking into account species hearing sensitivity (see paragraph 2.138 above). It is acknowledged, see paragraph 2.138 above, that the 142dB re 1 µPa (SPL_{RMS}) criteria used in the underwater noise modelling [CD MDZ/28.10] to predict disturbance is not weighted and therefore does not take into account the species hearing sensitivity. Howe]er, this noise level is consistent with the observations in Southall *et al*. (2007) [CD POE053), that exposures exceeding 140 dB re: 1 µPa induced an avoidance behaviour response in wild harbour porpoise (paragraph 2.134 above).

2.158 As outlined in the Marine Mammal PoE [CD MDZ/P2] paragraph 6.57-6.60, the use of ADDs will be considered as the final EMMP is developed post consent, in consultation with NRW. It is important to note that, ADDs would only be activated if marine mammals were in close proximity and there is a potential risk of collision. The type(s) and number of ADDs to be deployed would be based on the latest technology and information to ensure adequate and effective mitigation. Activation of the ADDs and disturbance range of the ADDs would be determined to the lowest source level possible that would ensure the marine mammal is beyond the range of potential collision risk, but without causing any significant disturbance or increased collision risk with other devices. ADDs would only be activated for very short periods and intermittently. There would be no long term ADD activation over a wide area.

2.159 Developing the detailed EMMP pre-construction will allow the latest technology and information to be taken into account, including lessons learned from other projects and how to develop the most effective deployment of ADDs for the Morlais site, including the types of ADDs, number and configuration of ADDs based on and the type of tidal devices and layout within an array for each phase of deployment. Careful consideration will be given to determine the most appropriate and effective type(s) of ADDs to ensure adequate and effective mitigation, this could include the modification or adaptation of existing ADDs and systems, to ensure they are suitable for all marine mammal species in and around the Morlais site, taking into account the different species hearing sensitivity, and that noise levels are high enough, in all environmental conditions to be audible over background noise levels at a distance to alert marine mammals and avoid collision with the tidal turbines, without causing any significant disturbance. This could include the use of different types of ADDs on the tidal arrays. As outlined in NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.2.8, NRW "*advocates using an ADD with the lowest source level possible, enough to elicit a short-range avoidance of immediate danger of collision, whilst minimising wider disturbance impacts*".

2.160 There is a commitment in the revised OEMMP (paragraph 24 [CD MDZ/A16.8]), that the underwater noise from ADDs will be reviewed as part of the ongoing development of the EMMP when details on the types and numbers of ADDs to be deployed are available post consent. The assessments during the development of the detailed EMMP, once information on noise source levels for the types of ADDs to be used is available, will determine the potential for any significant disturbance based on individual and multiple ADDs that could be activated across the Morlais site, taking into account ambient noise, agreed thresholds and criteria, the different species hearing sensitivities and the latest SNCB Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs (JNCC *et al*., 2020).

2.161 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.4.2**: *"There is no information available on the effectiveness of the preferred Lofitech ADD on dolphin species, and very limited information for other devices. The assumption in the Underwater Noise Modelling Report (MOR/RHDHV/DOC/0116, F1.0, 25/03/20) that a deterrence range for bottlenose dolphin from an ADD could be 'more than 4km' does not appear to be supported by evidence. The literature cited to support this assumption (McGarry et al., 2017 [CD POE041] is from a field trial on the effectiveness of ADDs on minke whales but there is no evidence to support the conclusion that the same is true in relation to bottlenose dolphin or any other species."*

2.162 To clarify in the Marine Mammal Monitoring and Options note [CD MDZ/A28.13] (not the Underwater Noise Modelling Report [CD MDZ/28.10]) provided a summary review on the effectiveness of ADDs in Appendix 1 of the note [CD MDZ/A28.13], based on the information provided in primarily in 2-3 reviews and supporting data sources and publications, where relevant, to give an indication of the current information available on the effectiveness of ADDs for different marine mammal species. For dolphin species, including bottlenose dolphin, this review (Appendix 1 of [CD MDZ/A28.13]) acknowledged that there is limited information compared to other species, but there is evidence that different ADDs have been effective mitigation to prevent the accidental by-catch of dolphins by fishing vessels (Appendix 1 of MDZ/A28.13). The statement in the review (Appendix 1 of [CD MDZ/A28.13]: "There is no information available on the effectiveness of the Lofitech device on dolphin species. However, studies on the effectiveness of ADDs in captive dolphins has shown startle responses in bottlenose dolphins at ADD source levels of 135 dB re 1µPa RMS. It could therefore be assumed that the deterrence range of bottlenose dolphins from an ADD emitting a sound source level of 190 dB re 1 µPa with a high frequency could be more than 4km (McGarry *et al*., 2017). However, it should be noted that this is untested." The reference should have been to the McGarry *et al*. (2018) Guide for the selection and deployment of acoustic deterrent devices (JNCC Report No. 615) as listed in the references for Appendix 1 of [CD MDZ/A28.13], not the McGarry *et al*. (2017) report on the effectiveness of ADDs on minke whales.

2.163 Since the review in Appendix 1 of [CD MDZ/A28.13], McGarry *et al*. (2018) Guide for the selection and deployment of acoustic deterrent devices (JNCC Report No. 615) was reviewed, this report has since been updated and is now McGarry *et al*. (2020) [CD POE 042] Evidence base for application of Acoustic Deterrent Devices (ADDs) as marine mammal mitigation (JNCC Report No. 615, Version 2.0). This updated report indicates that some ADD devices (e.g. DDD and DID STM Products; Aquamark 848) have a range of deterrence of 1.2-3km for dolphins [CD POE 042].

2.164 As presented in the McGarry *et al*. (2017) [CD POE041] report the Lofitech ADD has a nominal Sound Pressure Level (SPL) output of 191 dB re 1 µPa and a frequency of 20-20kHz. Dolphin species, including bottlenose dolphin, are classed as high-frequency cetaceans and have a generalised hearing range of 150Hz to 160kHz (Southall *et al*. (2019) [CD POE049]; Underwater Noise Modelling Report [CD MDZ/28.10]). Therefore, the Lofitech ADD and other ADDs (as outlined in the example in paragraph 2.163 above) would be audible to dolphin species, including bottlenose dolphin. However, it is acknowledged that the potential distance of more than 4km, is unproven. However, a distance of 4km would not be required for the Morlais site, as the ADDs would be used to ensure the marine mammal is beyond the range of potential collision risk, but without causing any significant disturbance or increased collision risk with other devices.

2.165 As previous indicated, the types of ADDs to be deployed would be based on the latest technology and information to ensure adequate and effective mitigation for all marine mammal species that could be present in and around the Morlais site. This would be reviewed as part of the development of the EMMP to take into account the hearing range of marine mammal species likely to be present, ambient noise levels at different tidal states, the underwater noise modelling and proven effectiveness of different types of devices and systems. The latest technology, devices and systems will also be considered, including, if required, adapting systems, so they are suitable to ensure adequate mitigation for a range of species.

2.166 **NRW PoE [CD POE021] paragraph 21 included the point**: *"The noise modelling is based on a single ADD, but the applicant has suggested deployment of an array of up to 40 ADDs.*

There is no assessment of how disturbance from a single device might be extrapolated across the array."

2.167 When deployed the noise levels and potential disturbance range of the type(s) and number of ADDs would be determined and set to ensure the marine mammal is beyond the range of potential collision risk, but without causing any significant disturbance.

2.168 Up to 40 ADDs was provided as an indicative example, however, the detailed EMMP will determine the number and location of ADDs to ensure adequate coverage of the site and effective mitigation based on the type of ADD(s) and the noise levels and potential disturbance range of the ADDs.

2.169 A worst-case assessment of up to 40 ADDs was provided in the ES [CD MDZ/A25.12], based on 1km disturbance range for each ADD with no overlap, although it is unlikely that 40 ADDs (up to 125.6km^2) would be activated at the same time.

2.170 In the Information to Support HRA [CD MDZ/A27.11] up to 10 ADDs were assessed as a worst-case for the maximum number of ADDs that could be activated at the same time. The assessment for 10 ADDs (31.4km^2) indicates potential disturbance of up to 1% of the Gogledd Môn Forol/North Anglesey Marine SAC (3,249km^2), with a seasonal average of up to 1% (based on 183 days in summer season). If multiplied up for 40 ADDs (up to 125.6km^2) this could be up to 3.8% of the North Anglesey Marine SAC area, with a seasonal average of up to 4% based on the unlikely event that all the ADDs were activated every day. Therefore, the potential disturbance of harbour porpoise in the North Anglesey Marine SAC would not exceed the current SNCB guidance for significance of noise disturbance against Conservation Objectives of harbour porpoise SACs (JNCC *et al*., 2020), of: 20% of the relevant area of the site in any given day, or an average of 10% of the relevant area of the site over a season.

2.171 There is a commitment in the revised OEMMP (paragraph 24 [CD MDZ/A16.8]), that the underwater noise from ADDs will be reviewed as part of the ongoing development of the EMMP when details on the types and numbers of ADDs to be deployed are available post consent. The assessments during the development of the detailed EMMP, once information on noise source levels for the types of ADDs to be used is available, will determine the potential for any significant disturbance based on individual and multiple ADDs that could be activated across the Morlais site, taking into account ambient noise, agreed thresholds and criteria, the different species hearing sensitivities and the latest SNCB Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs (JNCC *et al*., 2020).

2.172 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.4.3**: *"There is no information on how the ADD array will be configured, which ADDs would be used, how this might affect noise propagation, how ADDs might be triggered in response to marine mammals, or how disturbance from up to 40 ADDs would extrapolate across the array. NRW also request clarification on if/how the ADDs will interact with each other e.g. how the sound from one set of ADDs might interact with another set."*

2.173 How the ADD array will be configured, which ADDs will be used and how many ADDs will be required is dependent on the type, number and array layout of the tidal turbines to ensure adequate and effective mitigation.

2.174 As outlined above, the use of ADDs as mitigation will be determined in the development of the EMMP. Developing the detailed EMMP pre-construction will allow the latest technology and information to be taken into account, including lessons learned from other projects and how to develop the most effective deployment of ADDs for the Morlais site. Careful consideration will be given to determine the most appropriate and effective type(s) of ADDs to ensure adequate and effective mitigation, this could include the modification or adaptation of existing ADDs and systems, to ensure they are suitable for all marine mammal species in and around the Morlais site, taking into account the different species hearing sensitivity, and that noise levels are high enough, in all environmental conditions to be audible over background noise levels at a distance to alert marine mammals and avoid collision with the tidal turbines, without causing any significant disturbance. This could include the use of different types of ADDs on the tidal arrays. The options for triggering the ADDs will be researched and developed, based on automation of triggers from the monitoring techniques, such as active sonar, cameras and PAM, when a possible marine mammal is approaching close proximity and could be at risk of collision. This would be real-time triggers with back-up mechanism based on a precautionary approach, e.g. if it could be a marine mammal or it is unidentified then the mitigation would be triggered. As outlined in NRW PoE [CD POE021] paragraph 4.2.8 NRW "*support the aspiration to use an automated 'detect and deploy' system using active sonar to trigger ADDs, thereby ensuring their deployment is limited to only when it is necessary*".

2.175 Underwater noise from ADDs will be reviewed as part of the ongoing development of the EMMP when details on the types and numbers of ADDs to be deployed are available prior to deployment. The assessments will determine the deterrence ranges based on individual and multiple ADDs, including the potential for any 'interaction' if multiple devices are activated at different locations at the same time, to ensure the marine mammal is beyond the range of potential collision risk, but without causing any significant disturbance or increased collision risk with other devices.

2.176 **NRW PoE [CD POE021] Appendix B marine mammals paragraph 4.4.4**: *"Given the uncertainty over the accuracy of the information presented and the lack of information on the likely deployment and configuration of the ADD array, it is not possible currently to fully assess the likely impacts from ADDs."*

2.177 The information, assessments and underwater noise modelling for ADDs have been based on the information currently available and worst-case scenarios and presented in the ES [CD MDZ/A25.12], Information to Support HRA [CD MDZ/A27.11], Underwater Noise Modelling Report [CD MDZ/A28.10] and the Marine Mammals Monitoring and Mitigation note [CD MDZ/A28.13]. This indicates that ADDs are effective mitigation and that they will be audible to marine mammals above ambient noise levels.

2.178 Assessments, as outlined in paragraph 2.170, indicate no significant disturbance and no AEOSI for the North Anglesey Marine SAC due to underwater noise from ADDs.

2.179 There is a commitment in the revised OEMMP [CD MDZ/A16.8] that further underwater noise modelling will be conducted once details are known of the types of ADDs to be used as part of the development of the EMMP.

3. Summary

3.1 **NRW PoE [CD POE021] Paragraph 22*:*** "*NRW requires significant progress from the applicant on these matters ahead of the public inquiry. At present, the information provided by the applicant does not enable NRW to have sufficient confidence that issues relating to marine mammals are capable of being dealt with adequately in the terms of the order sought*."

3.2 As outlined above, the EMMP is the commitment of Menter Môn to safeguarding all marine mammal species and to ensure the proposed project will not have an adverse impact on marine mammal species listed in Annex II and Annex IV of the Habitats Directive, including harbour porpoise from the North Anglesey Marine / Gogledd Môn Forol Special Area of Conservation (SAC) and other marine mammal species with demonstrated connectivity to other SACs.

3.3 The current version of the revised OEMMP (MOR/RHDHV/DOC/0072 (04) dated November 2020), as outlined below, takes into account the recent NRW advice on adaptive management of the risk of collision impacts on protected marine mammal species in Welsh waters from the Morlais Project (MDZ/F15.3).

3.4 In addition, the EMMP outlines the commitment that:

- Device deployments will only be allowed at scales at which Regulators agree that the best available scientific understanding does not predict adverse impacts upon marine mammals.
- No device operation will be allowed until Regulators are satisfied that effective monitoring is in place that can directly inform the implementation of the EMMP, and inform the agreed aims, objectives and management questions set by the EMMP for the Project.
- Deployment of tidal devices by the Project will subject to approval of the Regulators, following the process outlined and agreed in the EMMP.
- NRW will be part of the Advisory Group for the EMMP.

3.5 A key component of the revised OEMMP [CD MDZ/A16.8], is the latest NRW advice (MDZ/F15.3) on the maximum marine mammal collision limits for the Morlais Project (see paragraph 2.70). As stated in the latest NRW advice (MDZ/F15.3): "*The species limits represent the maximum number of collisions between individual animals of a species or a species group, and the moving parts of the turbines, that are considered to be compatible with avoiding adverse effects on the integrity of SACs and would ensure no detriment to the conservation status of European Protected Species (EPS)*."

3.6 The proposed draft Marine Licence Conditions ([CD MDZ/I4], Condition 36) will secure this and ensure NRW must be satisfied that there will be no AEOI:

3.7 "*NRW must not approve any DEMMP unless it is satisfied that it provides such mitigation as is necessary to avoid adversely affecting the integrity of a European Site (as defined in The Conservation of Habitats and Species Regulations 2017 or The Conservation of Offshore Marine Habitats and Species Regulations 2017) to the extent that marine mammals or diving birds are a protected feature of that European Site*".

3.8 Assessments, as outlined in paragraph 2.143 and paragraph 2.170, indicate no significant disturbance and no AEOSI for the North Anglesey Marine SAC due to underwater noise from operational turbines or ADDs.

3.9 The current version of the revised OEMMP and commitments based on the latest advice from NRW, provides further information to reduce uncertainty and to enable NRW to have sufficient confidence that issues relating to marine mammals are capable of being dealt with adequately in the terms of the order sought.

3.10 The Project has engaged with NRW throughout the assessment process for marine mammals and development of the OEMMP, prior to and after submission. This has included taking into account any advice and suggestions, addressing any concerns, providing further assessments, information and clarification.

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3.16 Risch, D., van Geel, N., Gillespie, D. and Wilson, B. (2020). Characterisation of underwater operational sound of a tidal stream turbine. J. Acoust. Soc. Am. 147 (4), 2547 (2020); doi: 10.1121/10.0001124 https://asa.scitation.org/doi/10.1121/10.0001124 Provided in **Appendix 1**

Appendix 1 - Risch, D., van Geel, N., Gillespie, D. and Wilson, B. (2020). Characterisation of underwater operational sound of a tidal stream turbine. J. Acoust. Soc. Am. 147 (4), 2547 (2020); doi: 10.1121/10.0001124

Characterisation of underwater operational sound of a tidal stream turbine

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JASA ARTICLE

Characterisation of underwater operational sound of a tidal stream turbine[a]

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ABSTRACT:
The underwater sound emitted during the operation of the Atlantis AR1500 turbine, a 1.5 MW three bladed horizontal axis tidal-stream turbine, was measured in the Pentland Firth, Scotland. Most sound was concentrated in the lower frequencies, ranging from 50 to 1000 Hz. Within 20 m of the turbine, third-octave band sound pressure levels were elevated by up to 40 dB relative to ambient conditions. In comparison, ambient noise at these frequencies fluctuated by about 5–10 dB between different tidal states. At the maximum recording distance of 2300 m from the turbine, median sound pressure levels when the turbine was operational were still over 5 dB higher than ambient noise levels alone. A higher frequency, tonal signal was observed at 20 000 Hz. This signal component appears at a constant level whenever the turbine is operational and did not change with turbine rotation rate. It is most likely produced by the turbine's generator. This study highlights the importance of empirical measurements of turbine underwater sound. It illustrates the utility and challenges of using drifting hydrophone systems to spatially map operational turbine signal levels with reduced flow noise artefacts when recording in high flow environments.
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I. INTRODUCTION

Climate change and loss of biodiversity are the most pressing challenges for modern, global societies (Steffen *et al.*, 2018). The world's oceans, in particular, are vulnerable to the effects of global warming and loss of species richness and diversity (Kaschner *et al.*, 2011; Tittensor *et al.*, 2019). The global mean surface temperature is projected to arrive at 1.5 °C above pre-industrial levels during 2030–2052, and the recent IPCC Special Report clearly stated that limiting warming to 1.5 °C is required to maintain substantial amounts of global ecosystems and significantly reduce the risks of climate change to human health and global economies (Hoegh-Guldberg *et al.*, 2019). Due to this urgent need to stabilise global climate change, there is an increasing demand for clean energy, and, correspondingly, the marine renewable energy sector has grown rapidly in recent years (Gattuso *et al.*, 2018). This development has also raised questions about the potential impacts of these new technologies on marine species, including concerns around auditory injury due to underwater noise during their construction and operation (Simmonds and Brown, 2010).

In the case of tidal-stream energy, environmental concerns have primarily focused on the potential risk of injury to animals related to collision with moving parts of underwater turbines (Band *et al.*, 2016; Waggitt and Scott, 2014; Wilson *et al.*, 2007). However, underwater sound, both the sound pressure and particle motion components, as generated by tidal turbines may also affect marine life, including invertebrates, fish, and marine mammals (e.g., Kunc and Schmidt, 2019; Southall *et al.*, 2019). While risk of auditory injury from turbine underwater sound is predicted to be low for marine mammals and fish (Lossent *et al.*, 2018), other potential impacts include behavioural disturbance, as well as acoustic masking (Pine *et al.*, 2019) and barrier effects, which may result in habitat exclusion (Polagye *et al.*, 2011). With respect to the latter, sounds from tidal turbines might be a mixed blessing, as it may act as a useful cue for animals to avoid collisions with these devices. For example, it has been shown that harbour seals (*Phoca vitulina*) demonstrate avoidance behaviour to sounds from operating tidal turbines (Hastie *et al.*, 2018; Joy *et al.*, 2018), and harbour porpoise (*Phocoena phocoena*) click activity within a few hundred metres of an operational turbine was significantly reduced compared to baseline levels (Tollit *et al.*, 2019). Whether these small-scale effects lead to long-term habitat exclusion or barrier effects is currently unknown, but it is a potential concern for future deployment of large-scale arrays of tidal turbines. However, evidence from a demonstration project suggests that the deployment of a single turbine [SeaGen (MCT), Strangford Lough, Northern Ireland, UK] did not result in large-scale area avoidance by harbour seals (Savidge *et al.*, 2014; Sparling *et al.*, 2018).

To better understand and predict these potential environmental effects of tidal turbines, it is important to

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characterise the spatial and temporal variation in their emitted sound along with site-specific ambient noise and sound propagation characteristics of these otherwise rarely studied acoustic environments. Since impact ranges will be highly dependent on ambient noise (e.g., Pine *et al.*, 2019), these measurements should ideally be carried out in different seasons and capture a variety of weather and tidal state conditions.

Acoustic measurements in environments with strong tidal currents present several difficulties. Next to the logistical difficulties in fixing acoustic moorings to the seabed, stationary hydrophones exposed to moving water experience spurious "flow noise" particularly in the lower frequencies of interest to characterise tidal turbine signals (up to 500–1000 Hz) (Bassett *et al.*, 2014). Flow noise is an artefact arising from the interaction of turbulent flowing water over the hydrophone element (shear stress) and can mask sounds of interest (Wilson *et al.*, 2014). Measurements using drifting hydrophones reduce these effects, but have the disadvantage of intertwining temporal and spatial patterns (Robinson *et al.*, 2014; Wilson *et al.*, 2014). The latter can be somewhat relieved by collecting enough data through multiple drifts across areas of the same spatial extent at different times of day and within the tidal cycle to account for some of the observed variability, as was done in this study.

In relation to the characterisation of tidal turbines, drifting hydrophones have the advantage of allowing measurements of the turbine sound field as a function of range. These measurements can then be used to estimate local propagation loss (PL) (ISO, 2017).[1] Propagation loss is a measure of the reduction of sound intensity between two points; it is influenced by the environment through which a sound is propagating. Accurate measurements of turbine sound at distance from the source and estimates of PL are necessary for back-calculating the source level (SL) of the measured devices (Lossent *et al.*, 2018).

Since only a few operational tidal stream turbines have so far been deployed worldwide, there is currently little publicly available information on the actual underwater sound emitted by these devices. The only system that has been described in detail in the peer-reviewed literature is the 2.2 MW "Arcouest" tidal current turbine (OpenHydro; Lossent *et al.*, 2018). Information on other systems, such as the SeaGen (MCT), OpenHydro, SCHOTTEL SIT, or the Hammerfest (Andritz Hydro) turbines, resides in the grey literature such as project reports, conference proceedings, environmental impact assessments, and other non-peer reviewed documents (Robinson and Lepper, 2013; Schmitt *et al.*, 2015; Thomsen *et al.*, 2015).

The aim of this study was to characterise the operational sound of a single Atlantis[2] AR1500 tidal-stream turbine across different tidal states and flow conditions. The secondary aim was to compare and contrast results with measurements of local ambient noise obtained at the same site prior to turbine installation.

II. METHODS

A. Site description

The study was carried out at the MeyGen tidal array in the Pentland Firth, a strait linking the Northeast Atlantic with the North Sea, between mainland Scotland and the Orkney Isles. The strait has a maximum water depth of 80 m in the deep channel. Tidal currents in this area are among the strongest in the world and frequently exceed 5 $\mathrm{ms^{-1}}$, yielding estimates of tidal energy potential of at least 1.9 GW in this area (Adcock *et al.*, 2013; Neill *et al.*, 2017). The MeyGen project is sited between the Island of Stroma and the Scottish mainland in a narrow channel called the Inner Sound. The MeyGen array was installed in 2016 and is currently the largest tidal-stream turbine array (6 MW) in the world, comprised of four 1.5 MW turbines. The MeyGen project aims to initially build out Phase 1 up to 80 MW, with the view of supporting up to 400 MW in later stages of the project (Last viewed: 16 April 2020). Retrieved from http://simecatlantis.com/projects/meygen/.

The Atlantis AR1500 tidal current turbine (T4; 58° 39.5′ N, 3° 8.2′ W), was deployed as part of an approximately rectangular array along with three Andritz Hydro Hammerfest AHH 1500 turbines and individual turbines were spaced 200 m apart (Fig. 1). The turbine is installed at a water depth of 37.2 m, with the rotor centre at a depth of 17 m [mean low water springs (MLWS)], and rotor diameter

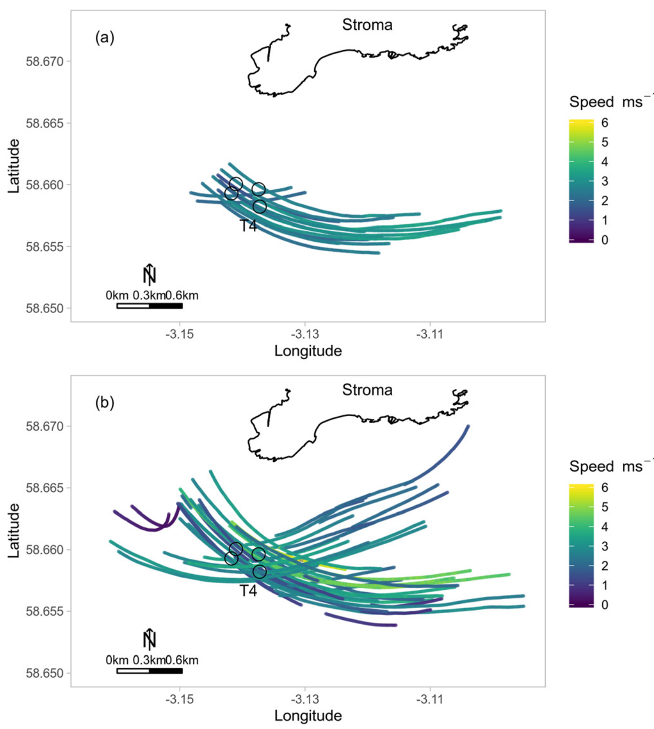

FIG. 1. (Color online) Map of the study area in the Pentland Firth, Scotland. (a) Drifter trajectories while demonstration Atlantis AR1500 turbine (T4) was operational (2018-08-06). (b) Drifter trajectories during ambient noise recordings (2015-10-01, 2016-05-24, 2016-06-23, 2016-06-24). Locations of three Andritz Hydro Hammerfest AHH1500 turbines, which were deployed but inactive during turbine measurements, are also marked on map as hollow circles.

is 18 m. At the time of the study, water depth above the rotor centre varied between 22.5 and 24 m.

The AHH1500 turbines were deployed but not operational at the time that the acoustic recordings of the Atlantis AR1500 turbine were made.

B. Acoustic measurements

In an effort to reduce flow noise, turbine sound and ambient noise were measured using multiple freely moving Lagrangian drifters each with an autonomous acoustic recorder and hydrophone setup, designed to keep the hydrophone fixed to the moving body of water (Fig. 2; Wilson *et al.*, 2014). Recorders (RTSYS EA-SDA14) and hydrophones (Reson TC4032 and TC4014; sensitivities TC4032: −162.6 and −169.5 dB re 1 V/1 μPa; and TC4014: −179.9 dB re 1 V/1 μPa) were placed inside underwater drogues, connected to surface floats via shock cords, which in turn were attached to tag-along surface floats with GPS (Garmin Etrex 10) and Iridium satellite units for real-time tracking and recording accurate track information at 1–2 s resolution (see Wilson *et al.*, 2014 for details). The hydrophone was suspended approximately 6 m below the surface. Sound files were recorded as .wav files and stored on SD cards. Sound measurements were amplified (gain: 14.7 dB) and digitised using the RTSYS EA-SDA14 recorders at a sampling rate of 312 500 Hz with a resolution of 32 bit. The sound acquisition chain (Reson hydrophones plus RTSYS recorders) was calibrated using information provided by the recorder and hydrophone manufacturers. At the start of each recording day, acoustic recorders were GPS synchronised and set to UTC time to ensure accurate time sampling.

Acoustic baseline surveys before turbine installation were carried out on 2015–10-01, 2016–05-24, 2016–26-23, and 2016–26-24 covering an area of approximately 12 km^2 around the turbine (T4) deployment site [Fig. 1(b)]. The acoustic survey of the Atlantis AR1500 turbine was carried out on 2018–08-06. The drifts covered an area of approximately 10 km^2 around the turbine and overlapped in space with the earlier ambient noise surveys [Fig. 1(a)]. At the time of the survey, only the Atlantis AR1500 turbine was

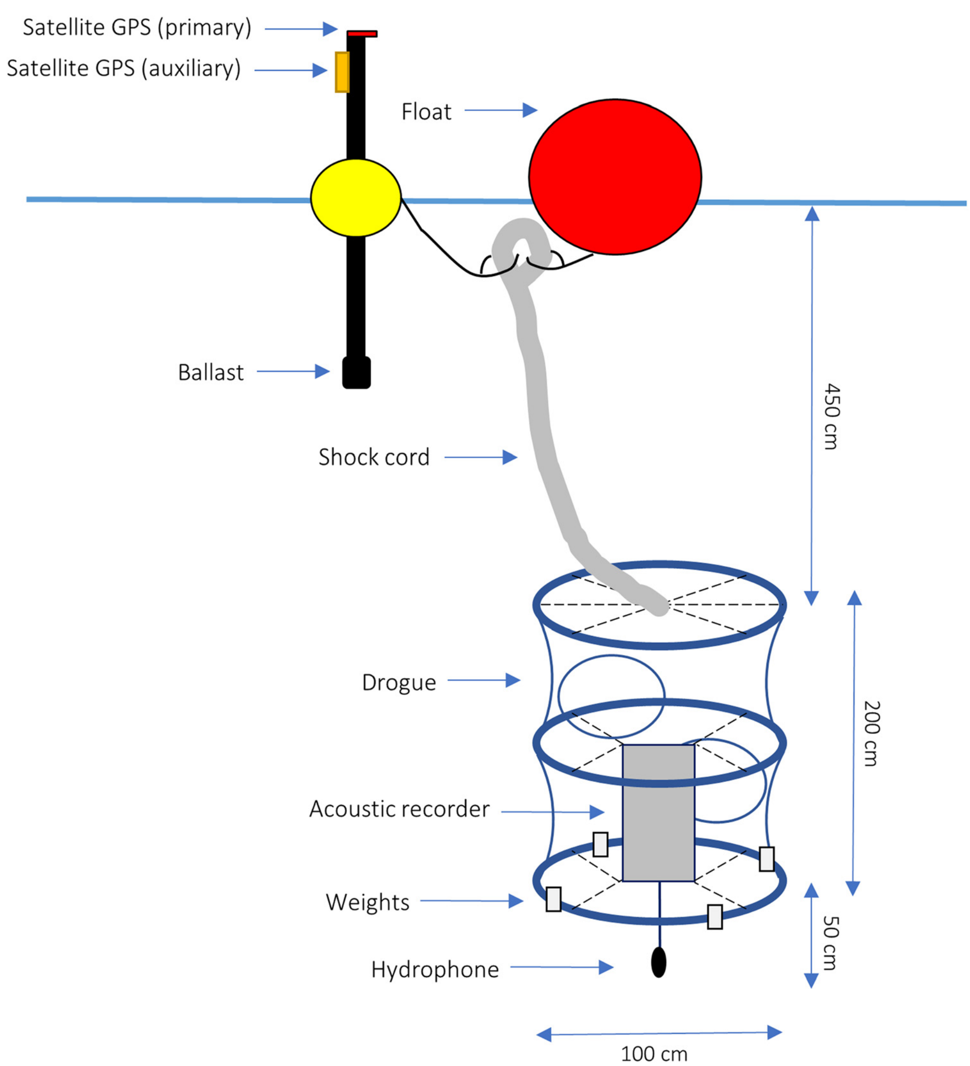

FIG. 2. (Color online) Schema of the Lagrangian drifter equipped with satellite GPS systems for accurate positioning, and carrying the hydrophone and acoustic recording system used to record ambient noise and turbine signals in this study. Figure adapted from Wilson *et al.* (2014).

active. Turbine operational data [e.g., turbine rotation per minute (RPM)] were provided by Simec Atlantis Energy and ranged from 3 to 10 min^{-1} throughout the recording period (Table I).

C. Acoustic data quality

All acoustic measurements used in this study were recorded at sea states representative of 3 or below on the Beaufort wind force scale. The Beaufort wind force scale was used to describe sea state throughout this manuscript, as is common practice in marine ecological surveys (e.g., Virgili *et al.*, 2019). After deployment of the drifters (one to three at a time), the deployment vessel, a rigid hull inflatable boat (RHIB), was manoeuvred away from the drifters before the engine and echosounder were switched off. The separation distance between the boat and the drifters was such that the drifters were in line of sight to ensure safe recovery, but kept beyond 100 m to minimise noise contamination from the vessel. The Pentland Firth is traversed by several ferry lines connecting mainland Scotland with the Orkney Isles. In addition to ferries, fishing vessels and other small boats were sometimes in the vicinity of the drifting hydrophones. For this reason, all acoustic spectra were manually screened using Raven Pro v. 1.5 (Center for Conservation Bioacoustics, 2014) and sections with contaminating vessel noise or drifter self-noise (immediately following deployment or before recovery) were excluded from further analysis.

D. Acoustic analyses and data manipulation

Spectrograms (10–1000 Hz; 10–5000 Hz; 10–40 000 Hz) over each entire drift were generated and viewed using PAMGuide (Merchant *et al.*, 2015), with a 1-s Hann window and 0% overlap, yielding a frequency resolution of 1 Hz. After initial inspection of the acoustic raw data, sound pressure levels (SPLs) were quantified in third-octave bands with centre frequencies from 25 to 125 000 Hz over a 1-s time window, using the third-octave level (TOL) function in PAMGuide.

Acoustic analysis results were georeferenced by comparing time stamps of the recordings to time stamps of the Iridium satellite or GPS units, and each transect was divided into 10-m non-overlapping segments. The median SPL (dB re 1 μPa) was then calculated for each third-octave band and each 10-m segment. These data were subsequently aggregated by tidal and turbine rotational state to evaluate noise level variations with and without operational turbine signals present.

Spatial variations in low frequency sound levels were evaluated by calculating a broadband (100–1000 Hz) SPL using PAMGuide, and plotted against distance from turbine location. This frequency range was chosen as it contained the most energy and was high enough to avoid potential flow noise issues. The higher signal levels measured within the third-octave band centred around 20 000 Hz, where a distinctive tonal signal was observed, were also plotted against distance to turbine.

Except for sound level analyses and spectrogram generation, all data aggregation, manipulation, and figure production was performed in R (R Core Team, 2019) using the *tidyverse* (Wickham *et al.*, 2019), *adehabitatLT* (Calenge, 2006), *amt* (Signer *et al.*, 2019), and *move* (Kranstauber *et al.*, 2019) packages.

III. RESULTS

A. Acoustic data and signal characterisation

During ambient noise baseline surveys in October 2015 and May and June 2016, 54 drifts were performed covering both flood and ebb tides in similar weather conditions (3 Beaufort and below) [Fig. 1(b), Table I]. Current speeds, as measured by the drifters, ranged from 0.2 to 6.1 ms^{-1}. The acoustic survey to measure the Atlantis AR1500 turbine on 2018-08-06, yielded 15 drifts in Beaufort 2 and below [Fig. 1(a), Table I], with current speeds ranging from 1.2 to 3.8 ms^{-1}.

The example spectrogram in Fig. 3, shows drift 'D13' (covering 1.5 km in 9.4 min) with the closest point of approach [CPA (horizontal distance) = 7.6 m] to the active Atlantis AR1500 turbine (see Mm. 1 for a sound example from this drift). This drift was recorded during neap flood tide and with a median of Beaufort 2. The turbine sound was clearly discernible and peaked at the CPA (i.e., over the turbine). Highest broadband sound levels were observed in the range 50–1000 Hz (Fig. 3). The turbine signal was tonal with an oscillating (bandwidth: 25–75 Hz) fundamental frequency at about 100 Hz, and several harmonics clearly visible up to 2000 Hz. In close range to the turbine (<200 m), an additional tonal signal was observed at approximately 20 000 Hz (Fig. 3).

Mm. 1. Example of sound emitted from the Atlantis AR1500 turbine, recorded during drift D13, recorded on 2018-08-06 (see also Fig. 3). This is a file of type "WAV" (5033 KB).

TABLE I. Summary of drifts. Beaufort wind force, turbine RPM (min^{-1}), and current speed (ms^{-1}) measurements are median values with 25th and 75th percentiles in parentheses.

Date	Drifts (analysed/total)	Beaufort wind force	Tidal cycle	Drifts (ebb/flood)	Turbine RPM (min^{-1})	Current speed (ms^{-1})
2015-10-01	25/25	2 (2-2)	spring	6/19	—	3.1 (2.0–4.2)
2016-05-24	11/11	2 (2-2)	spring	6/5	—	2.7 (2.0–3.2)
2016-06-23	12/18	1 (1-1)	spring	6/6	—	2.8 (2.2–3.1)
2016-06-24	6/15	1 (1-1)	spring	5/1	—	2.3 (2.1–2.7)
2018-08-06	15/16	1 (1-2)	neap	2/13	7 (6-9)	2.6 (2.2–3.1)

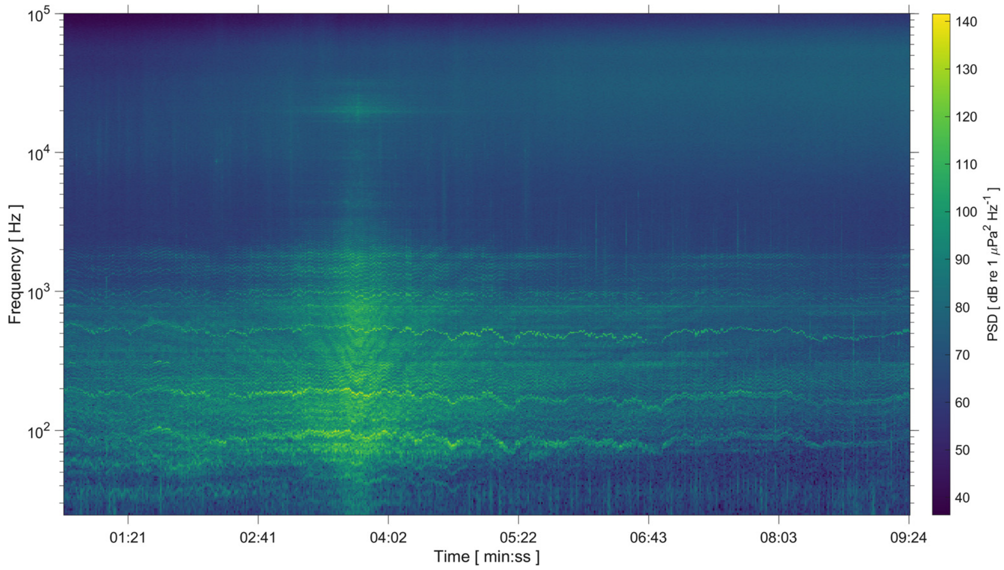

FIG. 3. (Color online) Power spectral densities (PSD in dB re 1 μPa^{2}Hz^{-1}) over the range of 25 Hz–100 kHz using a 1-s Hann window and 0% overlap, for drift 'D13'. The drift shown in this spectrogram was recorded on 2018-08-06 during neap flood tide, with a median wind force of 2 Beaufort, while the Atlantis AR1500 turbine was operational. The drift started about 500 m upstream and ended about 900 m downstream of the operating turbine with a closest point of approach (CPA) between acoustic recorder and turbine of approximately 7.6 m after about 4 min.

B. Variation of turbine sound with rotational and current speed, and distance to turbine

To evaluate turbine signal levels in relation to current speed and turbine rotations per minute (RPM; min^{-1}), the spectra of turbine sound, measured during flood tide and a Beaufort 2 or below, within 0–20 m and those measured at a distance of 100–120 m are shown in Fig. 4(a) and Fig. 4(b), respectively. It is evident that sound levels across the full spectrum were about 10–20 dB higher when measured within 20 m from the active turbine compared to those measured 100–120 m from it.

Generally, turbine sound levels were reduced when the RPM was lower, while the shape of the frequency spectrum was similar. At current speeds of 2–3 ms^{-1}, there was a 5–15 dB difference in signal levels at peak frequencies [100–200 Hz; Fig. 4(b)]. Turbine rotational speed was positively linked to current speed and rotational speeds of 7–9 min^{-1} were only observed at current speeds of at least 2–3 ms^{-1} [Fig. 4(b)]. At current speeds of 3–4 ms^{-1}, rotational speed was always 7–9 min^{-1} (Fig. 4), while it was equal or below 5–7 min^{-1} at current speeds of 1–2 ms^{-1} [Fig. 4(b)].

C. Turbine sound in relation to ambient noise and tidal state

Median broadband sound levels (100–1000 Hz) close to the turbine ($\leq$60 m) were raised by about 35–40 dB above ambient levels while the turbine was running (Fig. 5). The median broadband SPL (100–1000 Hz) during flood at this distance was 138 dB re 1 μPa, compared to 100 dB re 1 μPa during ambient conditions. In contrast, the difference in median sound levels, when comparing ebb to flood under the same conditions, was 10 dB or less, independent of whether the turbine was operational or not (Fig. 5).

D. Spatial footprint of turbine sound

As expected, turbine signal levels were highest close to the turbine and decreased with distance (Fig. 6). Broadband SPLs in the 100–1000 Hz frequency range, and measured during flood tide with current speeds from 1 to 4 ms^{-1} and 2 Beaufort or below, were about 136 dB re 1 μPa within 100 m from the turbine and about 109 dB re 1 μPa at a distance of 2200–2300 m. At this distance, median turbine signal levels were still over 5 dB above median ambient noise levels (100–105 dB re 1 μPa), measured for this frequency band under similar conditions, and across the same spatial range [Fig. 6(a)]. The median SPLs for the third-octave band centred at 20 000 Hz were about 126 dB re 1 μPa within 25 m from the turbine and about 112 dB re 1 μPa at 200 m from the turbine [Fig. 6(b)], after which signal levels were similar to median ambient noise levels measured under comparable conditions. Ambient noise levels in this frequency band showed great variability, likely caused by local turbulence caused by tidal features such as eddies and standing waves.

IV. DISCUSSION

Acoustic measurements using drifting hydrophones in a dynamic tidal channel showed that, in low wind conditions ($\leq$2 Beaufort) and under medium flow conditions (1–4 ms^{-1}), low-frequency underwater sound (100–1000 Hz) from the active Atlantis AR1500 turbine was clearly detectable above ambient noise out to distances of at least 2300 m. Due to greater low frequency ambient noise in higher sea states (Wenz, 1962), these detection distances are likely to be less in higher wind conditions (i.e., 5 Beaufort and above).

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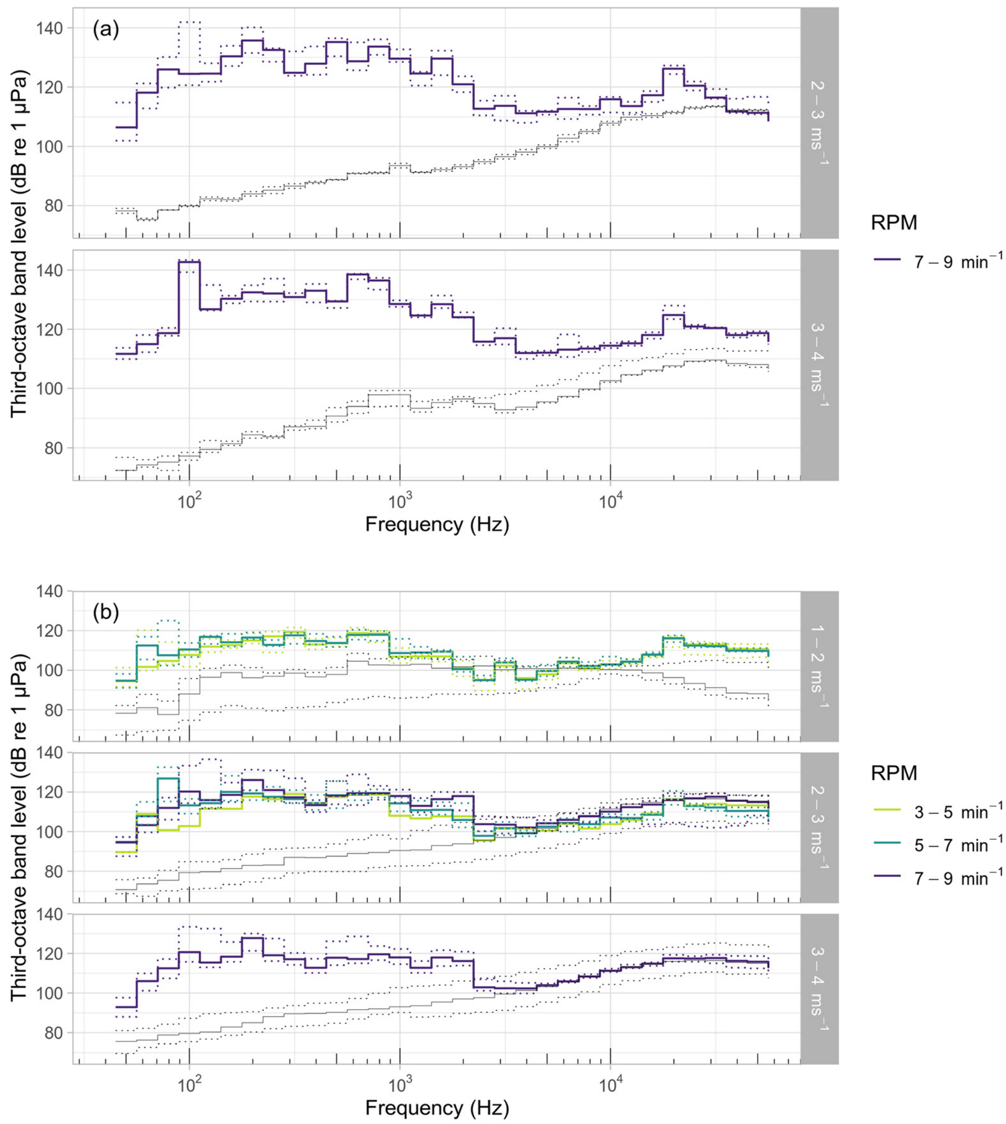

FIG. 4. (Color online) Median third-octave sound pressure levels (50 Hz–63 kHz; TOL in dB re 1 μPa) (thick lines), and 5th and 95th percentiles (dotted lines), calculated over a 1-s integration window. Plots are faceted by current speed in ms^{-1} (as measured by drifters) and coloured by turbine rotational speed in min^{-1} (RPM). All data collected during flood tides and 2 Beaufort or below. (a) Data recorded between 0 and 20 m, and (b) between 100 and 120 m from the operational Atlantis AR1500 turbine. Grey solid lines are median ambient third-octave band levels collected under similar conditions and across the same spatial range. Grey dotted lines indicate 5th and 95th percentiles of ambient noise levels.

The turbine signal was tonal (fundamental frequency around 100 Hz) with several harmonics up to 2000 Hz. There was also another tonal signal observed at 20 000 Hz close (within 200 metres) to the turbine. The frequency and amplitude modulated, lower frequency tonal signals recorded in this study from the Atlantis AR1500 turbine resembled those described for other operational horizontal axis tidal-stream turbines (Lossent *et al.*, 2018; Schmitt *et al.*, 2015). For example, it has been shown that the signal of the SCHOTTEL SIT turbine also shows frequency modulation. Sound emissions of the SCHOTTEL turbine also varied in relation to its operational mode (e.g., constant spinning, free-wheeling, braking) (Schmitt *et al.*, 2015).

In the current study, only turbine rotations per minute but not the operational state of the Atlantis AR1500 turbine was known. It would therefore be useful in future studies to assess the signal type and levels for different operational states of the active turbine using a robust experimental design. Describing typical turbine sounds might then also be a useful diagnostic tool to monitor and assess the health status of these turbines (Bashir *et al.*, 2017; Schmitt *et al.*, 2015; Walsh *et al.*, 2017).

There was a clear relationship between current speed and RPM, with an increase of 10–20 dB at higher RPM and flow speeds. This might be beneficial, as it makes the signal more detectable above ambient noise during high flow conditions. Turbine sound and local ambient noise levels, measured in this study at low wind conditions and sea states, suggest detectability of the turbine signal by seals as well as porpoises at distances of at least several hundred metres from the turbine, independent of tidal state. A recent study showed that harbour seals avoid simulated tidal turbine sound at distances of over 500 m, but also highlighted the

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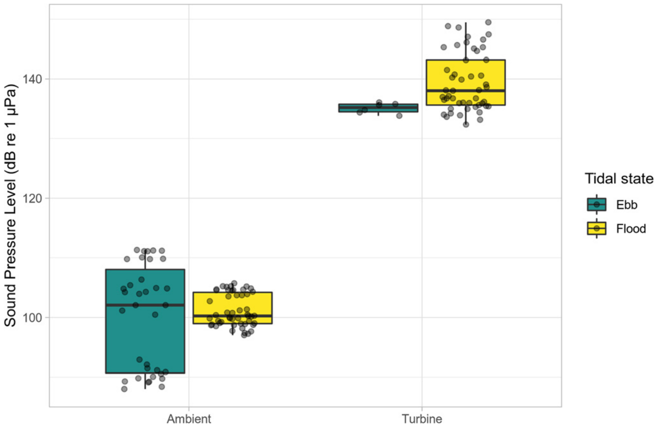

FIG. 5. (Color online) Grouped boxplot of broadband sound pressure levels (SPL in dB re 1 μPa) measured for the frequency range of 100–1000 Hz (1-s integration window), within 60 m of the Atlantis AR1500 turbine location, at 2 Beaufort or below and current speeds of 1–4 ms^{-1}. Lower and upper bounds of boxes represent lower and upper quartiles, respectively. Solid lines represent medians, and whiskers indicate furthest data points within 1.5 × interquartile range. Jittered data points plotted on top of boxplot. Data aggregated by tidal and turbine operational state.

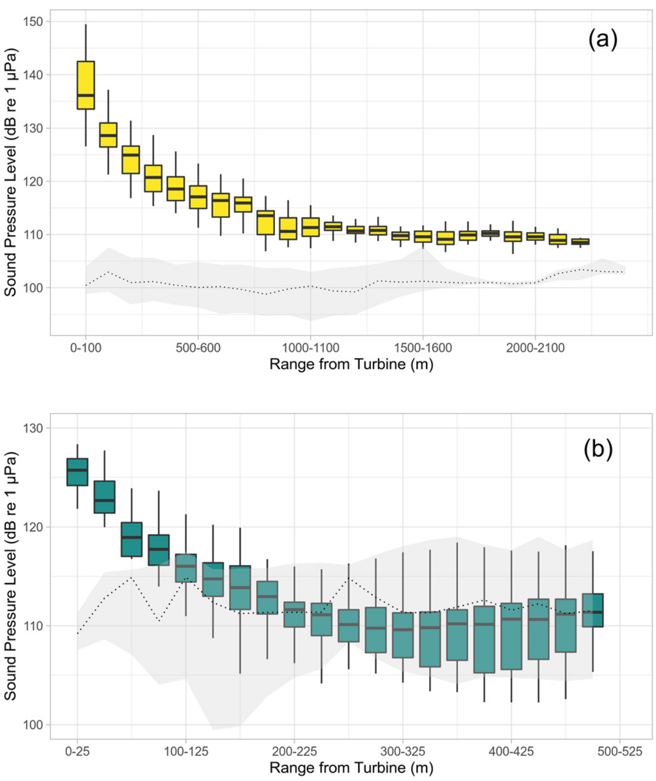

FIG. 6. (Color online) Boxplot of (a) broadband sound pressure levels (SPL in dB re 1 μPa) measured for the frequency range of 100–1000 Hz, and (b) sound pressure levels (SPL in dB re 1 μPa) for the third-octave band centred at 20 kHz against range from the operational Atlantis AR1500 turbine. Data collected during flood tide (2 Beaufort or below; current speeds: 1–4 ms^{-1}) and SPL calculated using a 1-s integration window. Lower and upper bounds of boxes represent lower and upper quartiles, respectively. Solid lines represent medians, and whiskers indicate furthest data points within 1.5 × interquartile range. The dotted lines and grey ribbons represent the median, and 5th and 95th percentiles of the ambient noise SPLs collected prior to turbine installation across the same frequency ranges and spatial scales and in similar recording conditions.

potential costs of chronically elevated noise levels and area avoidance, such as reduced foraging opportunities or barrier effects (Hastie *et al.*, 2018).

Finally, it is important to consider increasing array size and the use of acoustic measurements of single turbines, such as performed in the current study, to predict underwater sound related to larger scale tidal turbine arrays. Such data could inform future array design to mitigate potential habitat exclusion for marine wildlife.

V. CONCLUSION

This study contributes to the small number of *in situ* measurements of radiated sound emitted by tidal-stream turbines. The active Atlantis AR1500 turbine produces a frequency modulated tonal signal with harmonics as well as peak sound levels between 100 and 1000 Hz. The turbine emissions elevate noise levels by about 30–40 dB above ambient in low sea states, making the signal measurable at ranges of over 2000 m from the turbine. Sound levels are linked to and increase with turbine RPM and current speeds. An additional and unexpected tonal signal was observed at about 20 000 Hz, within an approximate radius of 200 m from the turbine. Further work is needed to describe the emitted signal during different turbine operating modes, identify exact sound generation processes, and estimate signal levels of incrementally larger turbine arrays. Evaluating the validity of sound propagation models to estimate turbine source levels will also be essential for such extrapolations and realistic ecological impact assessments of operational tidal-stream turbine arrays.

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[1]All further acoustic terminology used within this paper follows the international standards and definitions described by the ISO in (ISO, 2017).
[2]https://simecatlantis.com (Last viewed: 16th April 2020).

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