Underwater sound on wave & tidal test sites: improving knowledge of acoustic impact of Marine Energy Convertors

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***Abstract*-**
The effects of anthropogenic underwater noise on different marine species is open to study and debate, as it is a source for tension between and within sea users' (e.g. fishermen, shipping companies, energy companies, etc.), scientists and politicians. This paper aims at identifying and circumventing environmental constrains for better characterising sound emissions from various marine energy converter (MEC) types deployed on both wave and tidal sea-trial test sites. This study benefits from the collaborations of the scientific operators of marine energy sites from Spain (AZTI) and France (Energie de la Lune). Several underwater acoustic measurement campaigns were conducted on Biskay Marine Energy Platform (BIMEP) and SEENEOH tests sites and Mutriku Oscillating Water Column (OWC) wave power plant. The methodology used for data acquisition relies on both drifting and bottom moored hydrophones thus enabling to characterising both ambient operating noises and comparing two different underwater acoustic equipment. Long and time expensive data post-processing allowed for identifying and circumventing different kind of sound emissions from different origins: anthropogenic sound, site-related noises, and ambient noise. Impulsive and continuous sounds were assessed following criteria compliant with the Marine Strategy Framework Directive (MSFD). Results presented here allow for identifying difficulties in operating with different instrumentation and monitoring methodologies in these harsh environments. Analysis of acoustic samples during MEC operation allowed for identifying impulsive noise sources mainly related with mooring lines of MECs. Collection of device-generated noise during various operating states and seasons, for the purpose of evaluating potential noise impacts on marine organisms of concern is needed for a better understanding and characterization of these potential impacts.

Keywords - Ambient & operating noises, Underwater acoustic, Wave & Tidal, Impact, Harsh environments.

I. INTRODUCTION

According to Copping *et al*. (2016), animals use sound in marine environments for communication, social interaction, orientation, predation, and evasion. The extent to which marine animals detect and emit sound varies by frequency and amplitude. The addition of anthropogenic noise sources from operational wave and tidal Marine Renewable Energy (MRE) devices may induce behavioural changes in marine animals. In addition to behavioural changes, the addition of noise may, in some cases result in injury. Physical impacts may include temporary or permanent reduction in hearing ability, damage to nonauditory tissues, irregular gas bubble formation in the tissues of fish and marine mammals, and neurotrauma. Behavioural changes may also occur, such as avoidance of or attraction to the source, as well as masking—interference with communication, navigation, and detection of prey. To date, there have been no observations of operational noise from MRE devices affecting marine animals.

In addition, the Marine Strategy Framework Directive (MSFD) adopted on 17 June 2008 aims at establishing a framework for community action in the field of marine environment policy and leads each Member State to build a strategy in order to reach or maintain a Good Environmental Status (GES). Among the descriptors defined by the Directive, the Descriptor 11 refers to the introduction of energy into the marine environment (including underwater noise). It establishes that the GES will be reached when the introduction of energy, including underwater noise (both impulsive and continuous sound emissions), is at levels that do not adversely affect the marine environment. In the present study, the indicator 11.1.2 of the MSFD, trends in the ambient noise level within the 1/3 octave bands 63 and 125 Hz (center frequency) (re 1µPa RMS; average noise level in these octave), was employed as this indicator is intended to determine trends over time of ambient noise, even in the medium or long term.

Consequently, measuring the sound from an operational MRE is becoming more routine, although measuring low-frequency sounds that may be in the hearing range of large whales continues to be challenging. Underwater, noise propagation varies according to the local bathymetry, temperature and salinity. The noise propagation underwater also depends on the geomorphology of the area, the season and local weather conditions. Measuring noise in the ocean is rather tricky as it might also detect additional noise sources, such as vessels or other anthropogenic noise sources. Pre-existing long term anthropogenic noise sources, such as boat traffic, underwater instrumentation or acoustic deterrent devices, should be considered as parts of the local baseline acoustic environment. However, care should be taken to avoid any short-term noise contamination not representative of a typical baseline condition, such as atypical passing vessels or rain fall events.

According to Copping et al. (2016), coordinated monitoring approaches, standardized methodologies, and new technologies for measuring noise in high-energy environments will contribute to the continued understanding of the interactions of MRE device-generated noise with marine organisms. This has been the aim of the Euskadi - Aquitania project named Acoustic Around Ocean Energy (AAOE) undertaken between AZTI and Energie de la Lune profiting the opportunity that Mutriku OWC wave power plant and Biscay Marine Energy Platform (BIMEP) and SEENEOH test sites brings to the consortium in order to undertake underwater sound measurements in real conditions around MRE wave and tidal devices working in these facilities.

Through a collaborative effort between AZTI and Energie de la Lune in the framework of the AAOE project, these works have focused in the implementation of methods and techniques to characterize ambient noise in these sites sharing data, knowledge, equipment's and personnel among project partners. This task is underlined by Copping et al. (2016) as one of the four research priorities around the study of the risk to marine animals form underwater sound generated by MRE devices. In this paper, we will present feedback from operating hydrophones in these harsh environments based on data obtained in three case studies: Mutriku wave power plant and BIMEP test site for offshore wave and SEENEOH test sites for tidal.

Figure 1: Mutriku OWC plant

The Mutriku OWC Plant is an onshore infrastructure for wave energy harnessing promoted by the Basque Entity of Energy (Ente Vasco de la Energía - EVE). The plant is based on the Oscillating Water Column principle. Voith Hydro Wavegen handed over the Mutriku OWC plant to EVE in November 2011. The facility is housed within a breakwater at the port of Mutriku (Basque Country, Northern Spain) and opened in July 2011. The plant consists of 16 turbines and 16 OWCs giving a total installed capacity of 296 kW.

BIMEP is an offshore infrastructure for the demonstration and testing of wave energy harnessing devices promoted by the Basque Entity of Energy (Ente Vasco de la Energía - EVE). Bimep is located close to Arminza town (Basque Country, Northern Spain) and it consists on a 5.3 km^2 sea area between 50 and 90 m depths where four static submarine cables will be placed, operating at 13kV and 5MW. It is operational since 2015.

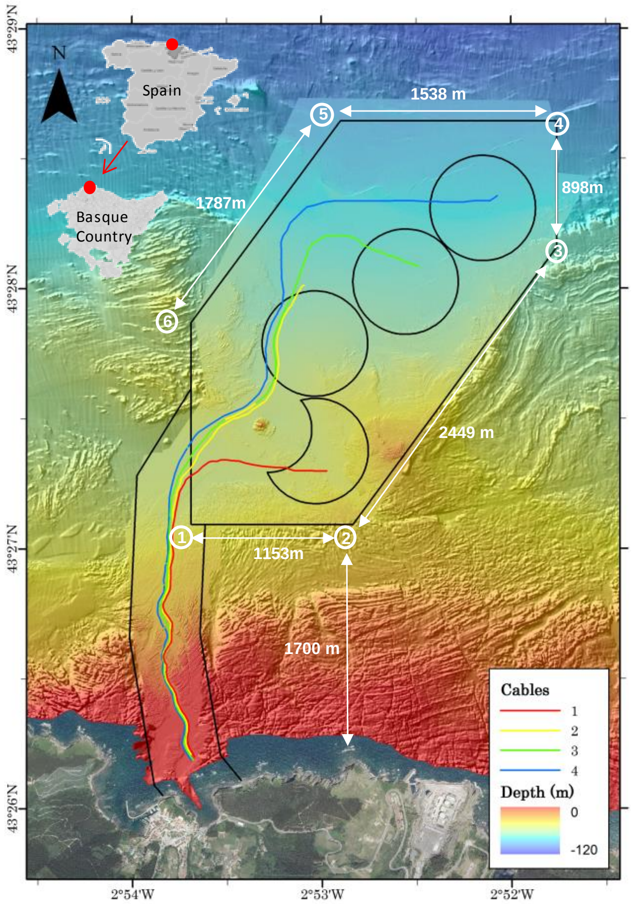

Figure 2: BIMEP test site

SEENEOH is located upstream the largest estuary in Europe, the Gironde Estuary in the city of Bordeaux (France) and is influenced by tidal currents. Infrastructures are composed of three available berths that are connected to the onshore substation by individual export cable. The test site is located right in the city center of Bordeaux. The berths are designed to accommodate tidal devices with either mounted or floating fixation type. The grid connection has a total capacity of 250kW. Depth at the test area is greater than 5m. These characteristics allow the testing of full and/or intermediate scale machines relevant for addressing an extensive tidal market in rivers, estuaries and oceans.

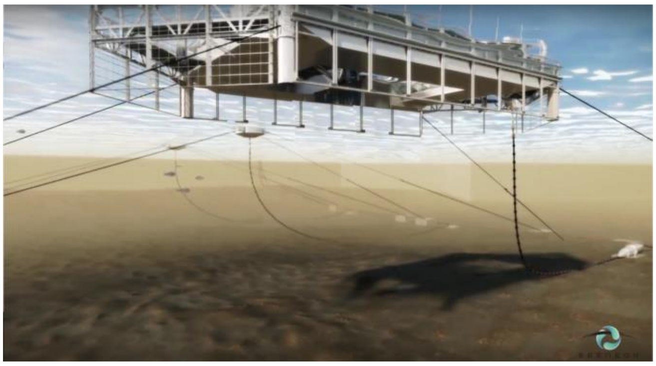

Figure 3: SEENEOH tidal test site

II. METHODOLOGY

Several sampling campaigns were undertaken in each of the above MRE sites in order to characterising ambient and operating MEC noises.

In the case of BIMEP, a sampling grid of 12 sampling stations was established around the Oceantec MARMOK Wave Energy Device installed at BIMEP. In each sampling station 10 minutes of sound recording at 10 m depth with both AZTI and Energie de la Lune sound recorders was planned. AZTI equipment was composed of an icListen HF 200 kHz hydrophone of Ocean Sonics. Equipment deployed by Energie de la Lune is composed of an acoustic recorder RTSYS EA-SDA 14 with two hydrophones HTI-96-MIN & Colmar. The sampling campaign was done in the 30th of October 2017, but due to hard climatic conditions, the field works were aborted during and only data on 3 sampling stations was acquired. The data coming from this 3 sampling stations was then compared with data acquired by AZTI in July 2013 in the framework of the monitoring works of BIMEP infrastructure during installation of submarine cables (Bald *et al.*, 2015). At the same time, data coming from a sound recorder developed by Bioacoustics Laboratory of the Polytechnic University of Barcelona (http://www.lab.upc.edu/) installed in BIMEP during pre-operational monitoring field works developed by Bald *et al.* (2014) has been incorporated to the present work. The sound recorder was installed on the 6th of June 2012 and recovered on the 29th October 2012, thus, 5 months of continuous recording

In the case of Mutriku, the same equipment and strategy undertaken at BIMEP was implemented, but in this case over a grid of 13 sampling stations that can be seen in Figure 4. Sampling campaign was done on the 31th October 2017. In this case, the data taken by Energie de la Lune were compared with those taken by Bald *et al.* (2017) following the same sampling strategy.

In the case of SEENEOH, acoustic measurements using drifting methods allowed for assessing noise at different locations in the near field and the far field. Simultaneous GPS measurements allowed for positioning each acoustic sample. Moreover AIS tracking was used for identifying boat traffic in marine environment and non-acoustical observations were made while measuring in Bordeaux in order to qualify timing and distance of both boat traffic (no AIS system on the Garonne river) and tramway activity on the Bridge. Current velocity was assessed using platform mounted ADCPs. The duration of acoustic drifting samples was adapted to the environment and therefore it was set to 1 minute on SEENEOH. The sampling campaign was done on the 10 th of November 2017.

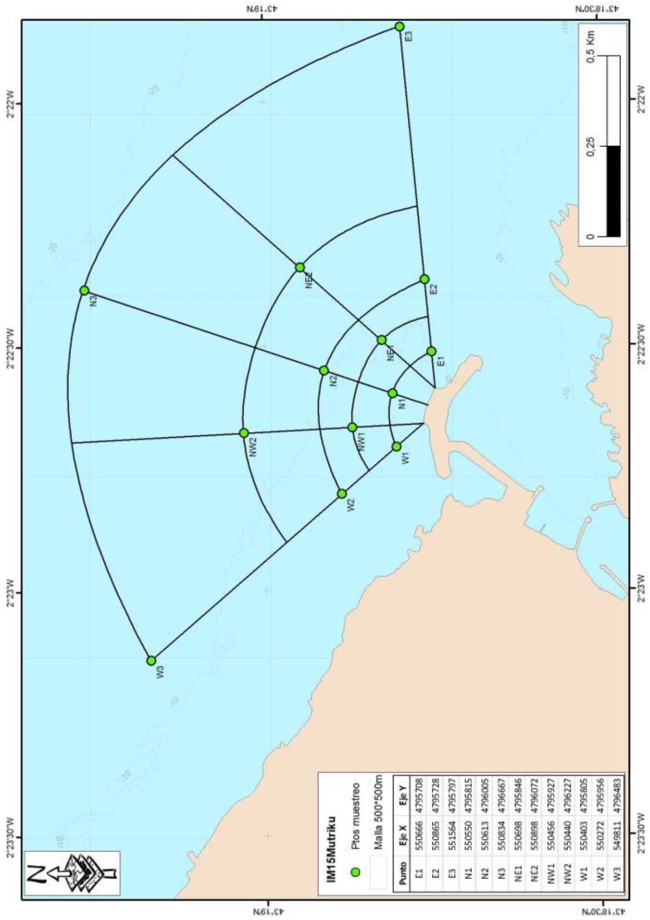

Figure 4: Location of acoustic samplings off Mutriku

III. RESULTS

A. BIMEP

Data obtained by Bald *et al.* (2015) shows a background ambient noise around 70-80 dB re 1µPa (Figure 5). As it can be seen in the Figure 6, the results for the third octave of the 63 and 125 kHz frequencies obtained by Bald et al. (2014) shows a mean value of approximately 90 dB and 85 dB respectively. The data coming from the sampling campaign undertaken in the framework of the AAOE project taken with the RTSYS equipment of Energie de la Lune showed a SPL average of 131 dB re 1µPa. However, sea state was characterised by very windy conditions (4-5 Bft) with average wave height of 1.5m. These sea state conditions contributed to pollution in the quality of noise recorded. Data post-processing and cleaning allowed for circumventing source of noise pollution. This approach showed SPL value of 121 dB re 1µPa and third octave 63 Hz and 125 Hz of 101 and 104 dB re 1µPa. Assessment of operating noise identified impulsive noise source coming from mooring lines of the Oceantec WEC installed in BIMEP.

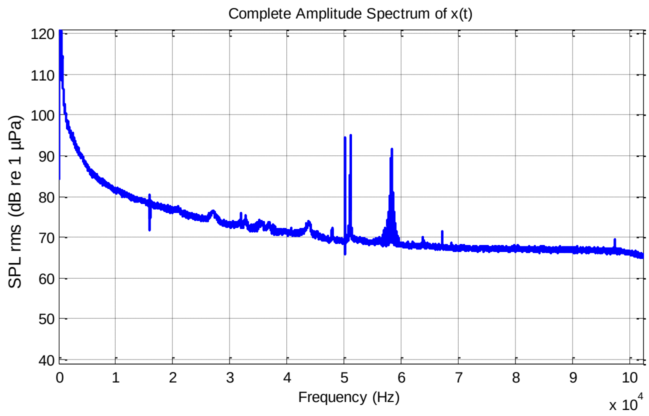

Figure 5: Ambient noise in BIMEP taken by Bald et al. (2015).

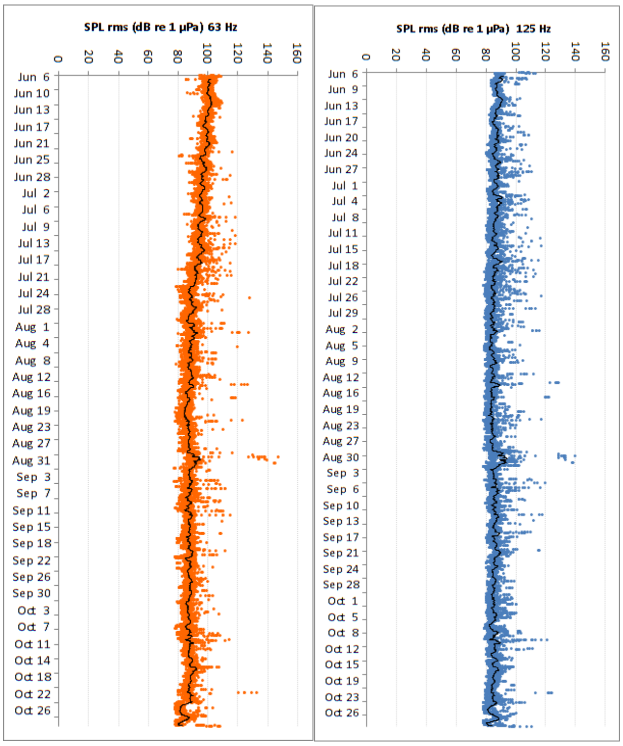

Figure 6: Third octave 63 & 125 kHz of non-polluted sounds in BIMEP between June and October 2012 (adapted from Bald et al, 2014).

B. Mutriku

Table 1 shows the results obtained by Bald *et al.* (2015) in the Mutriku OWC Power Plant with the plant off and on in two different seasons of the year (summer and winter). Data correspond to the mean value of the 13 sampling station of the 90th and 10th percentile for the third octave of 63 and 125 KHz which can be considered as the noise level close to the minimum and maximum respectively. According to the data obtained by Bald et al (2015) (Table 1), no evidences of significant acoustic impact coming from the Mutriku OWC Plant were obtained.

Table 1. dB SPL rms (dB re 1 µPa) of the 90th and 10th percentile for the third octave of 63 and 125 kHz with Mutriku OWC plant off and on during summer and winter. Adapted from Bald et al. (2015).

	Season	L90 (Off)	L90 (On)	L10 (Off)	L10 (On)
63 Hz	Summer	104,50	102,09	114,69	111,97
	Winter	100,36	98,33	113,28	110,39
125 Hz	Winter	98,26	96,04	110,56	107,64
	Summer	101,31	98,68	111,82	109,12

Results obtained with the RTSYS equipment of Energie de la Lune in the same sampling stations showed a SPL average of 133 dB re 1µPa. Sea state conditions were very calm with average wave height of 1.5m. However, boat traffic in the near field and far field was present, thus polluting most of the acoustic samples. The mean noise level for the third octave of 63 kHz and 125 kHz is around 113 and 117 dB re 1µPa respectively, and maximum values reach about 130 and 132 dB re 1µPa respectively. In line with Bald et al. (2015), post-processing and analysis of acoustic samples did not identify any operating noise from OWC power plant. However, boat traffic from the far field as well as fishing activities were identified.

C. SEENEOH

Due to risks associated with drifting with tidal currents, the length of individual acoustic sample was set to 1 min. Repeating sampling for duration of 5 to 6h allowed for assessment of noise for different current conditions: flood and ebb. Samples were taken 20-50 m across from Bilbao platform (centre of river) were depth is greater.

Results obtained with the RTSYS equipment showed different values from both hydrophones. For the HTI-96-MIN the third octave 63 kHz and 125 kHz are 89 and 87 dB re 1µPa respectively, while for the Colmar hydrophone respective values are 83 and 81 dB re 1 µPa (cf. figure. This values concerned non polluted acoustic samples from impulsive origins. Post-processing and analysis of all acoustic samples identified several sources of noise pollution from different origins: natural, anthropic, and equipment deployed in harsh environment. Natural noise concerns rain and eddy behind the bridge. Anthropic noise emissions were linked to well-known influence of boat traffic and maritime works, but in-depth analysis could identify underwater noise emitted from inland sources. Actually, the tramway passing through the bridge was identified as a regular source of noise in the study area within the frequency of 200-400 Hz. Moreover, infrastructures from the tidal test site were identified to generate some impulsive sounds that are environmental dependant. Mooring lines were identified to vibrate when current was strong, and some flexible parts of the floating platform were identified to generate impulsive noise in some wavy conditions. Other noises linked to the instrumentation of the platform (ADCP) were identified.

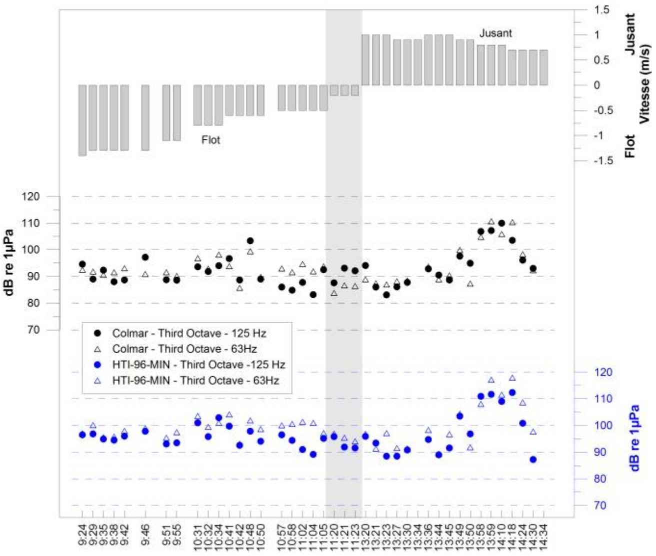

Figure 7: Third octave 63 & 125 kHz of non-polluted sounds

IV. DISCUSSION

MRE devices might produce a wide range of sound associated either with commissioning or operation of the devices. The loudest and most disruptive noise levels are associated with construction phase (Thomsen *et al.*, 2006). During the operational phase, devices with subsurface moving parts could generate noise and vibration. Sound generated by wave and tidal devices is likely to range from 116 to 170 dB re 1µPa sound pressure level at 1 m from the source, with most energy being below 1 kHz (Polagye *et al.*, 2010; Bassett *et al.*, 2012; Beharie and Side, 2012; Lepper *et al.*, 2012; Haikonen *et al.*, 2013; Cruz *et al.*, 2015). Despite the seemingly extensive number of existing studies reviewed by Robinson and Lepper (2013), these authors conclude that actually few datasets of the quality necessary to characterize noise radiation from MRE devices exist, which presents serious challenges for making impact assessments.

Wave Energy Converters (WECs) might emit mechanical-related noise as well as local breaking waves. The later challenges to distinguishing WEC sound from ambient noise. WEC sound emission differs from a Beaufort Sea State of "0" to a maximum operating state. Moreover, the wide range of WECs design (point absorbers, oscillating water columns, overtopping devices…) might create a variety of noise that is inherent to the design of the technology. For current energy converters, electric-related noise emitted in operation might be different according to the placement of the generator (above/below surface). The flow noise around the blades will depend on their shape. Noise intensity will depend on the strength of local currents.

The sound produced by MRE devices may change over time scales on the order of a second (e.g., CEC response to turbulent inflow, WEC response to wind waves). However, shorter bursts of sound are not sustained, and longer-term averages are needed to achieve statistical confidence in the resulting acoustic spectra.

Data presented in this study are based on different equipment and different methodologies of instrumentation deployment. Discrepancies observed between published (Bald et al., 2014, 2015 and 2017) and new RTSYS data might be linked to distinct hydrophone sensitivities. For instance, RTSYS data presented here use two hydrophones on the same acoustic recorder but show about 5-10 dB differences in the reported values. This difference might be explained by distinct hydrophone sensitivities to frequencies of interest. This system as well as the post-processing software used (RTQuickReport) allowed for extracting relevant acoustic parameters that comply with the Marine Strategy Framework Directive (MSFD) such as SPL, third octave band 63 and 125 Hz, etc.

The main limitation of the data and methodologies implemented in the present work are the small temporal resolution of the acquired data, together with the difficulties associated to the climate conditions in order to undertake the field works. These limitations favour methodologies based on long-term recordings through stable sensors placed in the area subject of study (both moored on the seafloor or in sea surface in buoys) able to have a better temporal resolution of the ambient noise in different sea states. These limitations could explain the results obtained in the Mutriku OWC Plant. The monitoring field works were undertaken in very good sea conditions due to security reasons, thus, with a very low activity in the plant. Consequently, no evidence of sound coming from the plant was obtained. Longer periods of sound measurement with fixed hydrophones could obtain different results of the plant operating in different sea states. However, fixed hydrophones in strong current areas are subject to flow-induced noise (Gobat 1997), therefore, drifting solution might provide better quality data in high flow conditions with greater special coverage during repeated deployments

This conclusion is in line with the recommendations of Sather and Copping (2016): collection of device-generated noise during various operating states and seasons, for the purpose of evaluating potential noise impacts on marine organisms of concern is needed for a better understanding and characterization of these potential impacts.

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