WESE

WAVE ENERGY IN SOUTHERN EUROPE

DELIVERABLE 2.6

Data results and analysis towards impacts evaluation and understanding

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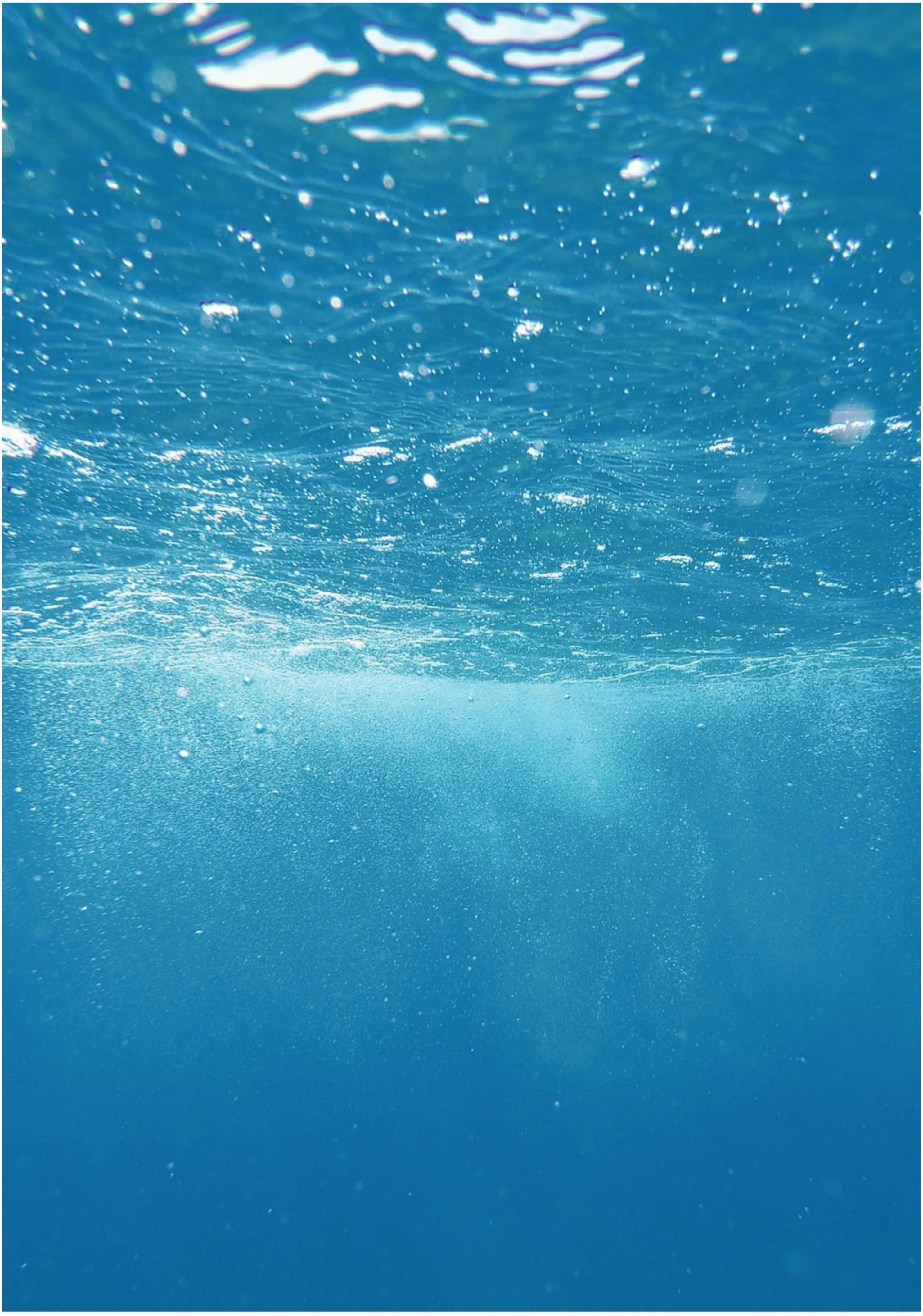

WP 2

Deliverable 2.6 Data results and analysis towards impacts evaluation and understanding

PROJECT COORDINATOR

AZTI

TASK LEADER

José Chambel (HIDROMOD)

AUTHORS

Pedro Almeida Vinagre (WavEC)

Paulo Chainho (WavEC)

Eduardo Madrid (CTN)

Iñigo Muxica (AZTI)

Juan Bald (AZTI)

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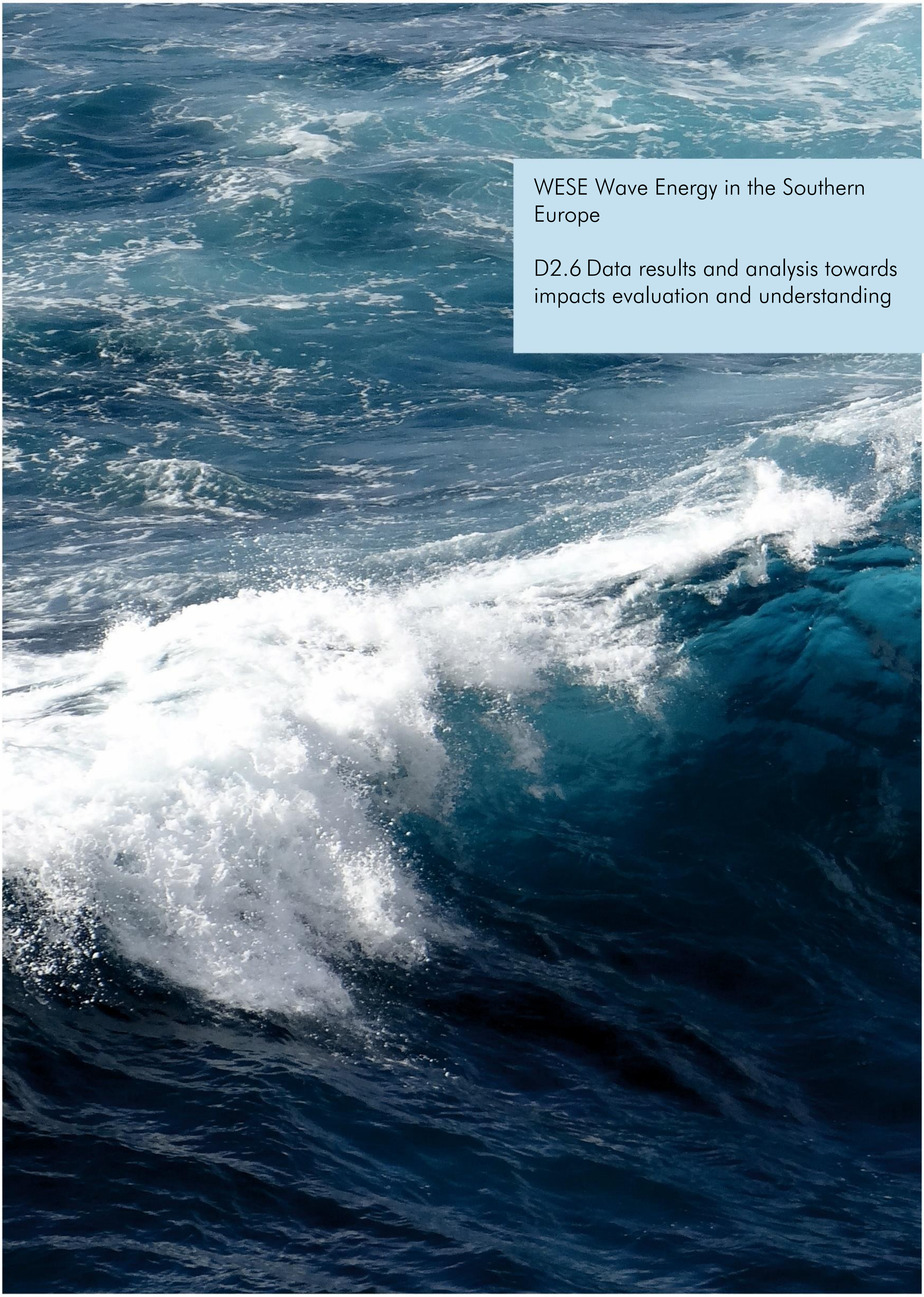

WESE Wave Energy in the Southern Europe

D2.6 Data results and analysis towards impacts evaluation and understanding

CONTENTS

1. WESE project synopsis

The Atlantic seaboard offers a vast marine renewable energy (MRE) resource which is still far from being exploited. These resources include offshore wind, wave and tidal. This industrial activity holds considerable potential for enhancing the diversity of energy sources, reducing greenhouse gas emissions and stimulating and diversifying the economies of coastal communities. Therefore, the ocean energy development is one of the main pillars of the EU Blue Growth strategy. While the technological development of devices is growing fast, their potential environmental effects are not well-known. In a new industry like MRE, and Wave Energy (WE) in particular, there may be interactions between devices and marine organisms or habitats that regulators or stakeholders perceive as risky. In many instances, this perception of risk is due to the high degree of uncertainty that results from a paucity of data collected in the ocean. However, the possibility of real risk to marine organisms or habitats cannot be ignored; the lack of data continues to confound our ability to differentiate between real and perceived risks. Due to the present and future demand for marine resources and space, human activities in the marine environment are expected to increase, which will produce higher pressures on marine ecosystems; as well as competition and conflicts among marine users. This context still continues to present challenges to permitting/consenting of commercial-scale development. Time-consuming procedures linked to uncertainty about project environmental impacts, the need to consult with numerous stakeholders and potential conflicts with other marine users appear to be the main obstacles to consenting WE projects. These are considered as non-technological barriers that could hinder the future development of WE in EU and Spain and Portugal in particular were, for instance, consenting approaches remain fragmented and sequential. Consequently, and in accordance with the Ocean Energy Strategic Roadmap published in November 2016, the main aim of the project consists of overcoming these non-technological barriers through the following specific objectives:

- Development of environmental monitoring around wave energy converters (WECs) operating at sea, to analyse, share and improve the knowledge of the positive and negative environmental pressures and impacts of these technologies and consequently a better knowledge of real risks.
- The resulting data collection will be used to apply and improve existing modelling tools and contribute to the overall understanding of potential cumulative pressures and impacts of larger scale, and future, wave energy deployments.

- Development of efficient guidance for planning and consenting procedures in Spain and Portugal for WE projects, to better inform decision-makers and managers on environmental real risks and reduce environmental consenting uncertainty of ocean WE introducing the Risk Based Approach suggested by the RiCORE, a Horizon 2020 project, which underline the difficulties for developers with an existing fragmented and sequential consenting approaches in these countries;

- Development and implementation of innovative maritime spatial planning (MSP) Decision Support Tools (DSTs) for Portugal and Spain for site selection of WE projects. The final objective of such tools will be the identification and selection of suitable areas for WE development, as well as to support decision makers and developers during the licensing process. These DSTs will consider previous findings (both environmental and legal, found in RiCORE) and the new knowledge acquired in WESE in order to support the development of the risk-based approach mentioned in iii);

- Development of a Data Sharing Platform that will serve data providers, developers and regulators. This includes the partners of the project. WESE Data Platform will be made of a number of ICT services in order to have: (i) a single web access point to relevant data (either produced within the project or by others); (ii) Generation of OGC compliant requests to access data via command line (advanced users); (iii) a dedicated cloud server to store frequently used data or data that may not fit in existing Data Portals; (iv) synchronized biological data and environmental parameters in order to feed models automatically.

2. Executive summary

The ocean energy development is one of the main pillars of the EU Blue Growth strategy. However, while the technological development of devices is growing fast, their potential environmental effects are not well-known.

In the WESE project scope, Work Package 2 aims to collect, process, analyse and share environmental data (Electromagnetic fields, Acoustics, and Seafloor integrity) collected in sites where Wave Energy Converters (WEC) are operating in real sea conditions in Spanish and Portuguese coastal waters, representing different types of technology, sites and, therefore, types of marine environment (onshore, nearshore and offshore) that can potentially be affected by wave energy projects: (i) MARMOK-A-5 by IDOM, installed offshore in the Biscay Marine Energy Platform (BiMEP, Spain); (ii) Wave Roller by AW-Energy, installed nearshore in Peniche (Portugal), and (iii) Mutriku Wave Power Plant, in operation in Mutriku (Spain).

The present report provides information about the electromagnetic fields, underwater noise, and seafloor integrity monitoring activities undertaken in previous Tasks, and how the data was processed, used for analysis, and reported. The aim was to provide the background for the establishment of general guidelines for the development of future monitoring plans (to be presented in Deliverable 2.7).

3. Objectives

In the WESE project scope, Work Package (WP) 2 aims to collect, process, analyse and share environmental data collected in sites where Wave Energy Converters are operating in real sea conditions in Spanish and Portuguese coastal waters, representing different types of Wave Energy technology deployed onshore, nearshore, and offshore (Table 1).

Table 1. Wave Energy devices under study.

Device	Technology	Site	Location
WaveRoller	Oscillating Wave Surge	Peniche, Portugal	Nearshore
MARMOK-A-5	Floating Oscillating Water Column	BiMEP, Spain	Offshore
Mutriku Wave Power Plant	Oscillating Water Column	Mutriku, Spain	Onshore

Earlier in the scope of Task 2.1, the environmental monitoring plans for electromagnetic fields (EMF), acoustics (noise), and seafloor integrity to be carried out around those devices were defined in Deliverable 2.1[1] (Vinagre et al., 2019), and the results from the monitoring activities of each parameter were presented in Deliverable 2.2[2] (Chainho & Bald, 2020), Deliverable 2.3[3] (Felis et al., 2020) and Deliverable 2.4[4] (Muxika et al., 2020), respectively.

Within WP2, the main objective of Task 2.5 and of the present report (Deliverable 2.6) is to provide understanding in EMF, acoustics, and seafloor integrity data collection, processing, validation, and reporting to allow comparison among sites and set the basis for the establishment of general guidelines for the development of future monitoring plans (to be presented in Deliverable 2.7).

[1] https://wese-project.weebly.com/uploads/1/2/3/5/123556957/wese_report_d2.1._monitoring_plans_for_noise_emf_and_seabed_integrity.pdf
[2] https://wese-project.weebly.com/uploads/1/2/3/5/123556957/d2.2_monitoring_of_electromagnetic_fields.pdf
[3] https://wese-project.weebly.com/uploads/1/2/3/5/123556957/d2.3_acoustic_monitoring.pdf
[4] https://wese-project.weebly.com/uploads/1/2/3/5/123556957/d2.4_monitoring_of_seafloor_integrity.pdf

4. Legislation accounting for the monitored parameters

In Europe, the three parameters addressed in the WESE project – EMF, acoustics, and seafloor integrity – are accounted directly or indirectly by several EU and broader scale legislative frameworks which address the Environment and its Conservation (Table 2).

Table 2. Legislation accounting for EMF, Acoustics and Seafloor integrity in Europe.

	EMF	Acoustics (noise)	Seafloor integrity
MSFD	Directly: Descriptor 11	Directly: Descriptor 11	Directly: Descriptor 6
WFD		Indirectly	Indirectly
Habitat Directive		Indirectly	Indirectly
EIA Directive	Indirectly	Indirectly	Indirectly
SEA Directive	Indirectly	Indirectly	Indirectly
Helsinki, Barcelona, OSPAR, CBD Conventions	Indirectly	Indirectly	Indirectly
CMS Convention		Directly	
IMO		Directly	Indirectly

The EU Marine Strategy Framework Directive[5] (MSFD; Directive 2008/56/EC) establishes a framework to assess and implement "good environmental status" of marine waters and explicitly accounts for all of the parameters, namely in its Descriptor 6 (D6; seafloor integrity) and Descriptor 11 (D11; EMF and noise). The D6 describes seafloor integrity as a state "at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected". The D11 mentions "introduction of energy (…) is at levels that do not adversely affect the marine environment", with "introduction of energy" referring to noise and electromagnetic radiation, among others.

The EU Water Framework Directive (WFD; Directive 2000/60/EC[6]) mandates Member States to achieve 'good status" of coastal waters (among other typologies) using "quality elements" including the benthic communities (i.e., benthic fauna and flora), therefore indirectly addressing seafloor integrity.

The EU Habitats Directive (HD; Directive 92/43/EEC[7]) is a cornerstone of Europe's nature conservation policy, establishing the EU Natura 2000 ecological network of protected areas aiming to "ensure the long-term survival of Europe's most valuable

[5] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32008L0056
[6] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32000L0060
[7] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31992L0043

and threatened species and habitats". Under the Directive Article 3 and Article 4, Member States designate Special Areas of Conservation (SACs) and Sites of Community Importance (SCIs) to ensure the favourable conservation status of each habitat type and species throughout their range in the EU. In this sense, benthic habitats are accounted by the Directive, therefore, it indirectly addresses seafloor integrity.

The EU Environmental Impact Assessment (EIA) Directive (Directive 2011/92/EU as amended by 2014/52/EU[8]) and the EC Strategic Environmental Assessment (SEA) Directive (Directive 2001/42/EC[9]), despite having overlaps, similarities, and differences, both set out categories of activities or projects that must be subject to mandatory assessment, and both require effects on the environment to be identified and described. A difference is that the EIA Directive requires the effects to be assessed while the SEA Directive evaluated. In the scope of both Directives, impact assessment will cover physical, biological, and socioeconomic receptors, hence, both indirectly address the three parameters monitored by WESE.

The Helsinki (1974), Barcelona (1995) and OSPAR (1998) Conventions set the frameworks for the protection of the North-East Atlantic, Mediterranean, and Baltic marine environments, and indirectly address the three parameters monitored in WESE.

The Convention on the Conservation of Migratory Species of Wild Animals (CMS) is an environmental treaty of the United Nation providing a global platform for the conservation and sustainable use of migratory animals and their habitats. The CMS addresses in different documents (e.g., UNEP/CMS/Resolution 12.14; UNEP/CMS/COP12/Doc.21.2.3; UNEP/CMS/COP12/Doc.24.2.2) "adverse impacts of anthropogenic noise on cetaceans and other migratory species" from activities of different industries including the MRE.

The International Maritime Organization (IMO) Marine Environmental Protection Committee addresses "noise" introduced from commercial shipping operations into the marine environment and also other matters indirectly related to seafloor integrity, such as ballast waters, antifouling, and ship-source pollution (including littering), among others[10].

[8] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0052.
[9] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32001L0042.
[10] https://www.imo.org/en/MediaCentre/MeetingSummaries/Pages/MEPC-default.aspx

5. Monitoring in the WESE Scope

An overview of the EMF, acoustics (noise), and seafloor integrity monitoring results is presented in the next subsections.

5.1 EMF monitoring

A two-day campaign was carried out by MAPPEM Geophysics team around the Marmok-A-5 device at the BiMEP site in May 2019 (Chainho & Bald, 2020). Various route lines crossing the electrical cable positions, from the nearshore to the test area, were monitored. No signal identified as the cables electromagnetic signatures could be isolated. This was because of two different issues. First, the sea conditions were very calm during the survey and the WEC power output was small (estimates account for less than 6 kW). Consequently, the phase currents responsible for potential electromagnetic signals outside of the cable were very small (estimates account for less than 0.26 A). Second, the analysis of the EMF signals showed the classical 50 Hz and harmonics signals from power lines, together with a strong 53.1 Hz (harmonics) unusual signal. This 53.1 Hz signal masked the signals from the cables themselves and was identified to (most probably) come from the vessel's electric generator. The generator was probably faulty and inducing strong signals in the water, then detected by the measuring instrument (PASSEM system) which itself is powered through an UPS set to 50 Hz output. This signal may have masked any residual EMF radiated from the cable (Chainho & Bald, 2020, 2021).

5.2 Acoustic monitoring

Acoustic monitoring was carried out in the three test sites by spatial monitoring (great spatial resolution, lower temporal resolution) and by temporal monitoring (lower spatial resolution, greater temporal resolution) (Felis et al., 2020).

In May 2019, a two-day and a one-day spatial monitoring campaigns were performed around the Marmok-A-5 device (BiMEP, Spain) and the Mutriku powerplant (Mutriku, Spain) during their operation. In addition, for each device, ~1.5 months of temporal monitoring (May-June 2019) was undertaken (Felis et al., 2020).

For Marmok-A-5, evidence of some noise generation in both low and intermediate frequencies was found, due to turbine operation and mooring chains clashing, respectively. In particular, the frequencies in the band from 40 to 120 Hz are most energetically relevant, showing a maximum increase in sound pressure levels (SPLs) (with respect to non-working regime of the device) for the [0,1] m wave height range of about 14±12 dB re 1 µPa, at a radial distance of less than 100 meters from the device. In the higher frequency range, an increase of 3.2±11 dB re 1 μPa is found and attributed to the mooring chains, well below under uncertainty values.

For the Mutriku powerplant, no clear indication of an increase in the SPLs when the plant is operating was observed, with the higher difference in SPL values between the device working and non-working regime of 5±12 dB re 1 μPa for the 80 Hz third-octave band and the [2,5] m wave height range. In fact, there is even a decrease in the intermediate wave height bin, particularly around 100 Hz; for the other wave height bins, the difference is positive in these frequencies. Considering the uncertainties under which these quantities are subject, we reckon there is not a significative noise generated by the functioning of the plant at 1 km.

In Peniche (Portugal), a one-day hybrid monitoring survey was carried close to the WaveRoller device during its removal for maintenance (October 2020). Three hydrophones were deployed at increasing distances from the device (maximum 440 m) for a period of 8 h. Auxiliary CTD casts were carried out every hour. The noise from the device could be detected before the decommissioning took place. During the decommissioning, noise was registered mainly from the vessels, with minor contribution from mooring chains and sediments movement.

5.3 Seafloor integrity monitoring

The seafloor integrity was monitored at the BiMEP site in May 2019 and at Peniche site in October 2020 to assess potential impacts from the Marmok-A-5 and WaveRoller devices, respectively. All the results, difficulties, and deviations to the planned (see Deliverable 2.1) were presented in Deliverable 2.4.

At BiMEP, two days of ROV and one day of side-scan SONAR surveys were undertaken, covering the mooring lines and anchors of the MARMOK-A-5 device including the area where the chains landed on the bottom and the area where the anchors settled. The operation was repeated for the electric cable and the connector that provides service to the device.

No evidence of relevant physical disturbance to the seafloor caused by the anchors was found. On the other hand, the oscillation of the moorings and the electrical cable caused a removal of the ripple-marks in their close vicinity. It was estimated that the total area affected by the sections that were moving over the sediment could add up to roughly 250-300 m^2, approximately 0.1% relative to the total occupied area; thus, impacts were considered negligible. With regards to the side-scan SONAR survey, the images acquired were not sufficiently clear to have a clean vision of possible impacts (Muxika et al., 2020).

At Peniche (Portugal), a one-day ROV survey was undertaken at the WaveRoller test site covering the routes of moorings and the electrical cable and the device foundation. No outstanding impact was observed around the WaveRoller device, with only a small "sand dune" being observed at the device foundation, probably related to its lifting from the seafloor and which would be cleared in a few days after it (Muxika et al., 2020).

As it could be seen in the videos recorded in the ROV campaigns, both the MARMOK-A-5 and WaveRoller devices and their support structures (device, foundation, moorings, and anchors) seemed to be facilitating refuge and food resources to marine organisms such as crustaceans and fishes, and enhancing local biodiversity owed to the artificial reef effect promoted by the artificial substrates (Muxika et al., 2020).

6. Data validation and reporting process

Marine data are collected by different entities (institutes, governmental organizations, or private companies) using heterogeneous instruments and sensors installed in various observing platforms. Depending on the data type, the acquisition systems, the delivery time frame or operations of the archiving centre, there is not a unique data model and structure used, and the original measurement format may not be the same as the format that the archiving centre can accept.

Some guidelines for marine data quality control are available, for example:

- European Commission Regulation No 1205/2008 of 3 December 2008 implementing Directive 2007/2/EC of the European Parliament and of the Council as regards metadata[11]
- Pan-European infrastructure for ocean & marine data management (SeaDataNet)[12]
- ICES Working Group on Data and Information Management[13]
- European Marine Observation and Data Network (EMODnet)[14]
- Infrastructure for Spatial Information in Europe (INSPIRE)[15]

In the WESE project, the data acquisition methodology (e.g., spatial and temporal frames, methods and equipment used) was planned to be as standardized and homogeneous as possible among test sites and devices. The methodology was developed considering recommendations from researchers (see details in Deliverable 2.1, Deliverable 2.2, Deliverable 2.3, and Deliverable 2.4) and according to the specificities of the devices and their location.

In the monitoring of each parameter (i.e., of EMF, acoustics, and seafloor integrity), a survey log sheet (as defined in Deliverable 2.1) was filled with the specific information (e.g., survey date, equipment surveyed, coordinates, depth) including any difficulties encountered or necessary deviations to the planned.

[11] https://eur-lex.europa.eu/legal-content/EN/LSU/?uri=celex:32007L0002

[12] https://www.seadatanet.org/content/download/596/3118/file/SeaDataNet_QC_procedures_V2_(May_2010).pdf?version=1

[13] https://www.ices.dk/data/guidelines-and-policy/Pages/ICES-data-type-guidelines.aspx

[14] https://www.emodnet-ingestion.eu/guidelines/how-to-handle-different-marine-data-types

[15] https://inspire.ec.europa.eu

6.1 Processing and validation

To the purpose that data can be comparable, and transferable between data platforms, for example the EMODnet, the SeaDataNet[16], and the MARENDATA[17] developed in WESE (presented in section 6.2), data is classified as primary data (raw data, or metadata) and secondary data (post-processed primary data, results, and reports). Table 3 presents the methods used to acquire the primary data for each parameter.

Table 3. Monitoring activities carried out within the WESE project, and their respective primary data acquired.

Monitoring Activity	Study Site	Date	Type	Data acquired
EMF	Marmok-A-5 – BiMEP	May 2019	Magnetic fields Electric fields	Magnetic fields Electric fields
	WaveRoller – Peniche	Not undertaken	Magnetic fields	Magnetic fields
Acoustics (noise)	WaveRoller – Peniche	October 2020	Acoustic Auxiliary	Audio files Sound velocity
	Marmok-A-5 – BiMEP	May-June 2019	Acoustic Auxiliary	Audio files Sound velocity
	Mutriku power plant	May-June 2019	Acoustic	Audio files
Seafloor Integrity	Marmok-A-5 – BiMEP	May 2019	ROV Side-scan SONAR	Video files Image files
	WaveRoller – Peniche	October 2020	ROV	Video files

In WESE, data validation was conducted to accept or reject data considering all limitations and acceptance limits described for the methods used (or equivalent methods) that may invalidate data. In this sense it should be underlined that the limitations and acceptance limits were internally established from the beginning of the process, i.e., already for the data acquisition in the surveys carried out.

6.1.1 EMF monitoring and modelling

The data acquired during the EMF monitoring campaign were post-processed by the subcontracted MAPPEM Geophysics team. Table 4 presents for BiMEP the methods used in EMF primary data acquisition and processing and the secondary data that they generate.

[16] https://www.seadatanet.org
[17] https://marendata.eu

Table 4. EMF monitoring: primary and secondary data with processing methods.

Method/Equipment	Primary data	Processing	Secondary data
• Fluxgate Magnetometer *(Bartington Mag-03 low noise)*	• 3-axis (B_x , B_y , B_z) magnetic field |B| amplitude in [nT] *(2kHz sample rate)* • GPS position, Water depth, altitude to seafloor	• Vector magnitude [nT] • Spectral analysis	Along each transect: • Graph with the water depth and altitude to seabed (image file) • Graph with magnetic field amplitude (image file) • Spectrogram showing magnetic field strength at various frequencies (image file)
• 4 x Measurement dipoles (with length of 19m, 17m and 2x4m) (AgCl non-polarisable electrodes + low noise preamplifier)	• 4 Dipole (e_1 e_2 e_3 e_4) potential [V] (2kHz sample rate) • GPS position, Water depth, altitude to seafloor	• Electric field |E| computed using the four dipoles normalized by each dipole length (V/m) • Spectral analysis	Along each transect: • Graph with the water depth and altitude to seabed (image file) • Graph with electric field amplitude (image file) • Spectrogram showing electric field strength at various frequencies (image file)

The acquisition and processing methods most relevant for this methodology were:

- Because the PASSEM instrument was towed, the distance to the seabed needed to be continuously monitored and recorded simultaneously to the other signals, to guarantee the distance to the cable was properly estimated.

- According to Nyquist's criteria, the sample rate must be higher than at least two times the natural frequency of the grid – 2 x 50 Hz – to allow for a proper capture of the signal of interest. Ideally, the sample rate should be higher to identify the harmonics, which could retain significant energy. For WESE EMF campaign, the sample rate used was 2 kHz.

- In post processing, a spectral analysis was essential to identify the amplitude of the signals of interest, plus its harmonics, around the fundamental frequency of the grid (50 Hz).

As concluded in Deliverable 2.2 (Chainho and Bald, 2020), no electromagnetic signature of the cable could be found. Several reasons (mentioned earlier) could justify this which, along with the instrumentation distance to the seabed (around 5 m), would return negligible EMF signal. It is worth mentioning that, according to the EMF model developed in Deliverable 3.1[18] (Chainho & Bald, 2021) (see in Table 5 the primary data acquisition, its processing, and the secondary data generated), this specific cable current and cable distance conditions would return a cable magnetic field in the sub-

[18] https://wese-project.weebly.com/uploads/1/2/3/5/123556957/d3.1_emf_modelling.pdf

nano order of magnitude, which is hardly distinguishable from the ambient noise. Even when considering cables carrying their maximum current capacity, the EMF estimated at the surface of the cables used by MarMOK-A-5 ($|B| = 127\ \mu T$ and $|E| = 4200\ \mu V.m^{-1}$) and WaveRoller ($|B| = 7\ \mu T$ and $|E| = 215\ \mu V.m^{-1}$) should not have behavioural or physiological effects on marine animals occurring near to the cables (e.g., Scott et al., 2021; Taormina et al., 2021).

Table 5. EMF modelling: primary and secondary data with processing methods.

Primary data	Processing	Secondary data
• Equivalent charge and current of the source, or magnetic and electric field surrounding it • Cable properties • Cable burial depth • Soil properties • Power production profile (voltage, current and frequency at the time of measurement)	• All of them are introduced in the underwater electromagnetic propagation model by WavEC	• 2D colour-graph of the propagated electric field at different distances from the cable (image file) • 2D colour-graph of the propagated magnetic field at different distances from the cable (image file) • Report of EMF propagation for each site (.pdf)

6.1.2 Acoustics monitoring and modelling

As mentioned earlier, two main types of acoustic monitoring campaigns were carried out: spatial and temporal monitoring. In the case of MARMOK-A-5, the sea conditions during the spatial campaign were less than ideal, which compromised the obtained recordings. On the other hand, there were no problems associated with the temporal monitoring. Table 6 presents the methods used in acoustic monitoring primary data acquisition and processing and the secondary data that they generated.

The data from the temporal acoustic monitoring were visually, aurally, and programmatically analysed to assess its validity. In this regard, some recordings were discarded as they corresponded to times when no proper acoustic signal was recorded (e.g., when immersing or collecting the hydrophone). Furthermore, some samples were rejected for being outliers. When processing these data, standard deviation and percentile measures were considered to characterize the uncertainty in the final results, which consisted in mean values. This allowed to detect a high variability in the results around the mean, which was a consequence of the myriad of acoustic sources that occur in the BiMEP site (and which are expected in similar environments).

For the acoustic modelling, several primary data types and sources were used, as specified in Deliverable 3.2[19] and shown in Table 7. These consist in environmental data (bathymetry, temperature and salinity in water column, sea bottom acoustic properties) obtained from available databases (EMODnet, CMEMS[20]), and Source Level (SL) data obtained from the processing as presented in Table 6 (fully escribed in Deliverable 2.3). The environmental data are presented as rasterized data, allowing easy georeferenced analysis and processing. The SL data consists in SPL at 1 m from the source, classified by significant wave height and frequency values. For the data that show temporal dependence (i.e., temperature and salinity), the data eventually used corresponded to the month of the temporal monitoring.

Table 6. Acoustic monitoring: primary and secondary data with processing methods.

Method/Equipment	Primary data	Processing	Secondary data
• CTD cast	• Conductivity and temperature change relative to depth	• Convert .csv data to graph • Convert CTD data speed of sound following Mewin expression (if 0<T<35°C and S<45ppt): $c = 1449.2 + 4.6T - 0.055T^2 + 0.00029T^3 + (1.34 - 0.01T)(S - 35) + 0.016z$ Where c is the speed of sound in m/s, T is temperature in °C, z is depth in m, and S is salinity in ppt	• Graph of CTD for each sampling station (image file) • Sound speed profile for BiMEP
• Spatial and temporal deployment of hydrophones	• WAV files of underwater noise recordings • WEC operation parameters time series • Sea surface state	• SPL (as well as mean and deviation) in the 1/3 octave frequency bands between 10 Hz to 10 kHz • WAV files processed to get sound spectrum levels in 1/3 octave bands and the power spectrum	• SPL time series for each frequency band. • Average (all monitoring interval) of SPL classifying in significant wave height and frequency. • Report of underwater noise (.pdf)
• Airborne sampling with microphones	• WAV files of airborne noise recordings	• SPL (mean and deviation) in the frequency range between 20 Hz to 20 kHz	• Graph of SPL vs frequency for each measured point with deviation (image file) • Report of airborne noise sheet for BIMEP (.pdf)

[19] https://wese-project.weebly.com/uploads/1/2/3/5/123556957/d3.2_acoustic_modelling.pdf.
[20] https://marine.copernicus.eu.

Table 7. Acoustics modelling: primary and secondary data with processing methods.

Primary data	Processing	Secondary data
• Source Level (SL) of the device (obtained from the results of the acoustic analysis and a transmission loss model) • Temperature and salinity with depth[21] (raster) • Bathymetry[22] (raster) • Sea surface state (.csv) • Sea bottom properties (.shp)	• SSP was calculated used the Mackenzie model • SSP, bathymetry and seabed elastic properties were all interpolated to the same regular grid of cell size of 100 m to be fed to the acoustic transmission model • Transmission losses model applied in transects from the source (WEC) • SPL distributions obtained from TL distributions and SL	• 4-dimensional arrays of underwater TL with shape (latitude, longitude, depth, frequency) for all devices (.npy file). • 5-dimensional arrays of underwater SPL with shape (latitude, longitude, depth, frequency, wave height) for MARMOK-A-5 and Mutriku power plant (.npy file). • Radial distances of acoustic disturbance around the WEC. • Area of acoustic disturbance around the WEC • Report of underwater propagation sound for each site

Primary data was processed to properly feed the acoustic propagation model. To do so, from the temperature and salinity fields the sound speed profile (SSP) was analytically obtained by means of the Mackenzie model (Mackenzie, 1981). Along with bathymetry and seafloor properties, the SSP was visually and programmatically validated in search of erroneous data and further interpolated to a common spatial regular grid of 100 m cell size covering the whole areas of interest. There were spatial regions in which seafloor properties were absent for some scenarios; in those cases, the most frequent seafloor types were correspondingly chosen.

As a useful metric for the report of impact evaluation, the radial distance (area) of acoustic disturbance, defined as the distance (area) around the WEC in which the

[21] The CMEMS GLOBAL_ANALYSIS_FORECAST_PHY_001_024 dataset was used (https://marine.copernicus.eu)
[22] The EMODnet Bathymetry portal was used (https://portal.emodnet-bathymetry.eu)

noise levels during operation are higher than when at rest (background levels), was considered as most appropriate given its low dimensionality. More information can be found in the Deliverable 3.2.

The most important secondary data obtained from the modelling were the spatial Transmission Loss (TL) distributions which encode all the information obtained from the application of the transmission losses model. In this case, it consists of an array (a data structure with arbitrary dimensions, i.e. a tensor) of values of TL for each depth (5, 10, 20, 30, …, 100) and frequency (62.5, 125, and 1000 Hz) considered. From this, to obtain the actual SPL distributions (that could be measured from recordings with a hydrophone) the process was simply to subtract the TL from the SL. As SL also depends on significant wave height, this operation involved adding a new dimension to the array, thus, obtaining a 5-dimensional array of SPL values distribution around the WECs.

Considering the MARMOK-A-5 predicted SPL distribution, the noise levels are inferior to the 140 dB re 1 μPa (this is the SL for the 62.5 Hz band and significant wave height between 0 and 1 meters) and are below the injury threshold (~220 dB re μPa) or the perturbance threshold (~160 dB re 1 μPa) for cetaceans and marine mammals in general (Southall et al., 2008). Although this scientific field (noise sensibility of marine organisms) still needs more research, it would seem safe to say that a single device is hardly harmful for these organisms. When considering a farm of arrays of such devices (e.g., 80 devices), the initial estimation presented in Deliverable 3.2 suggested higher noise levels considering incoherence of sources (around 154 dB re μPa); hence, some disturbance may be produced very close the WECs, although not high enough to reach injury levels.

6.1.3 Seafloor integrity monitoring

As regards to the seafloor integrity monitoring (Table 8), the ROV video images acquired around the MARMOK-A-5 (BiMEP) and WaveRoller (Peniche) devices were processed to exclude unnecessary/unsuitable videos or video sections. Besides the characterization of the seafloor (for example, type of substratum, benthic communities) around both devices, the area (in m^2) potentially affected by the devices and support structures (moorings, cables) was estimated.

Table 8. Seafloor integrity monitoring: primary and secondary data with processing methods.

Method/Equipment	Primary data	Processing	Secondary data
• Side-scan sonar	• Side-scan sonar of GeoAcoustics de 100/500 kHz sound reflection waves at 114 to 410 kHz	• Processing of sound reflection waves into graphic images of seafloor characteristics around moorings and mooring lines or WECs	• Images of seafloor characteristics (image files) • Report of seafloor integrity (.pdf)
• ROV	• Videos of seafloor characteristics around WECs taken with ROVs	• Exclude unnecessary/unsuitable videos • Identify extension of seafloor alteration around moorings and mooring lines of WECs	• Video recordings (video files) • Photo-frames (image files) • Extension (m^2) of seafloor alteration around mooring and mooring lines of WECs. • Report of seafloor integrity (.pdf)

As it was noticed in Deliverable 2.4, the survey with the side-scan SONAR in BiMEP was conducted under less-than-ideal oceanographic conditions (1.5-2 m wave heights, and great turbulence), which limited the usefulness of the data acquired due to low resolution (as the SONAR was towed at a higher altitude in respect to the bottom) and to the artefacts caused by the tugs due to the swell.

During the ROV surveys, several issues limited the usefulness of the data acquired. For instance, the positioning systems failed in the ROV surveys (both in BiMEP and Peniche). Although the video frames captured could not be geotagged, information could still be obtained from the recordings. In BiMEP, the distance and area affected by the movement of the chains could be estimated from the size of their links; in Peniche, the impacts on the seafloor were analysed visually (in this case they were practically non-existent); and in both BiMEP and Peniche the reef effect of the artificial structures could be observed.

Once at the laboratory, other issues often need to be addressed. For example, if one of the objectives of the survey is to assess the effect of the structures on biological communities, expertise is needed on the identification of animal and algal species. This could be straightforward when medium to large size common species are recorded but becomes problematic when very small or infrequent species are found. Moreover, the diversity of biological groups that could be filmed may require the participation of multiple experts in the assessment.

6.2 Data storage and reporting

Data storage and access are two important aspects of environmental monitoring. The MARENDATA platform developed in the WESE project lodges all data produced in the project, not only from monitoring (WP2) or modelling (WP3) activities but also from each WP of the project. This includes datasets, graphs, videos, and reports generated from the activities. Deliverable 6.2 (Primary data structure) and Deliverable 6.3 (Secondary data structure; updated version D6.3.3) describe how the data measured by project partners must be structured to ensure transferability among existing data platforms.

To make data findable by different groups of interest (e.g., stakeholders, regulators, researchers) additional information (metadata) is needed not only for quality control and archiving, but also for exchanging data or its integration into regional or global data sets. For all types of data, information is required about[23]:

- Where the data were collected: location (preferably as latitude and longitude) and depth.
- When the data were collected (date and time in UTC or clearly specified local time zone).
- How the data were collected (e.g., sampling methods, equipment used, analytical techniques performed).
- How to refer to the data (e.g., sampling station ids., samples ids.).
- Who collected the data, including name and institution of the data originator(s).
- What processing has been done to the data (e.g., details of processing and calibrations applied, algorithms used to compute derived parameters).
- Watch points for other users of the data (e.g., problems encountered and comments on data quality).

Regarding data access and delivery, the MARENDATA is designed to work with distinct sets of operation depending on the data location, data access (authentications) and data size:

1. **Data stored in the project's dedicated server**

[23] Excerpt from https://www.emodnet-ingestion.eu/guidelines

Depending on the size of the data and computational processing demand two forms of data delivery are possible:

a. On the fly: via immediate access to the information with direct download and/or processing, such as time series and scatterplots of integral wave parameters, sound speed profile graphs, and .pdf reports.

b. Via request: for large amounts of data, for example large datasets (time and space) of significant wave height, wave peak period and wave direction, a request is sent to a queue and data is made available to the user when ready.

2. Data stored in third-party servers

Data delivery and/or processing in the platform will work similar to the data stored in the dedicated server except when further authentications are needed, therefore the two following procedures are possible:

a. request and download the information from the platform as if it were stored in the project's dedicated server.

b. the platform will redirect the user to the specific location where the information is stored.

To allow data exchange and re-use between researchers, institutions, and organisations, WESE is adopting standards for formats and metadata as much as possible, especially the standards in relation to vocabularies, metadata, and data formats. In practice, the gridded data sets addressing either dynamic data sets (similar to the CMEMS) or static data sets (similar to the EMODnet) follow procedures similar to the ones adopted by these two services. Regarding time series data, SeaDataNet procedures represent the main guidelines and Network Common Data Form (NetCDF) is the standard format. ISO standards for metadata (ISO 19115 and ISO 19139) are followed. The GeoNetwork[24] opensource tool installed on MARENDATA server guarantees that metadata follows the standards.

The design of the MARENDATA enables the generation of secondary data (post-processed primary data, results, and reports), serving the needs of the specific end-users without needing sophisticated skills to access and interpret primary data. For example, ROV (processed) video files from monitoring around WaveRoller (Peniche, Portugal) and MARMOK-A-5 (BiMEP, Spain) were lodged respectively in WavEC and

[24] GeoNetwork is a catalogue application to manage spatially referenced resources. It provides powerful metadata editing and search functions as well as an interactive web map viewer. It is currently used in numerous Spatial Data Infrastructure initiatives across the world (https://geonetwork-opensource.org).

AZTI YouTube channels[25,26] with bookmarks, allowing the user to jump to specific sections of the videos. Each video (5 recorded with the onboard camera plus 5 recorded with a HD GoPro camera at Peniche, and 9 with onboard camera at BiMEP) was linked to MARENDATA, by cataloguing the data according to the requirements defined in Deliverable 6.2. Therefore, when users select the WaveRoller or BiMEP test sites in MARENDATA they are presented (among other options) with the different videos recorded at the site and with all the information (e.g., summary of activities, coordinates, depth sampled) associated with the videos.

Table 9 presents the WESE data available for download at MARENDATA.

Table 9. WESE data available in MARENDATA.

Parameter	Primary data	Secondary data
• EMF		
• Acoustics	• MARMOK-A-5 and Mutriku power plant: - 9 WAV recordings from the fixed hydrophone monitoring campaigns (.wav). These samples are very representative, as they correspond to different sea conditions (3 WAV recordings for each of the following subsets of significant wave height values: [0,1], [1,2], and [2,5] meters.	• MARMOK-A-5 and Mutriku power plant: - SPL time series (for all monitoring time interval) for all third-octave frequency bands between 10 Hz and 10 kHz (NetCDF file). - Array of the processed average (during the monitoring time interval) SPL, characterized by frequency, significant wave height, and operation status of the WECs (NetCDF file). • MARMOK-A-5, Mutriku power plant and WaveRoller: - Array of TL (dB re 1 m) (from the WECs) spatial distributions for 62.5, 125 and 1000 Hz frequencies and 11 depths (NetCDF file).
• Seafloor integrity	-	• MARMOK-A-5: 9 videos from onboard ROV camera, covering the seafloor and biological components, electrical cable and connector, and moorings (.mkv). • WaveRoller: 10 videos (5 from HD GoPro, 5 from onboard camera) covering the seafloor and biological components, electrical cable, and moorings (.wav). In the onboard videos, momentaneous depth and water temperature are identified

25 https://www.youtube.com/channel/UCb0cJnSEq1kWpBCYKdEHDuw
26 https://www.youtube.com/c/aztitecnalia

7. Final remarks

This report provided information on approaches used in WESE to acquire and process EMF, acoustics, and seafloor data, and how the results of those parameters were reported. The monitoring (and modelling) plans were established early in the Project (Deliverable 2.1, Vinagre et al., 2019) and aimed to be conducted in the most standardised way as possible by the different monitoring teams, at the different test sites, and for the different WE devices surveyed.

However, while having standardized monitoring protocols is extremely relevant for data collection, processing and reporting, the specificities and requirements of the different sites and technologies required adapting some of the approaches locally, to fulfil the objectives of EMF, acoustics, and seafloor integrity monitoring.

The overall commonalities in the procedures implemented allowed the successful acquisition of precious environmental data and to estimate the significance of particular WE stressors on environmental components, contributing to increase understanding on environmental impacts caused by WE installations. Furthermore, work developed allowed for important environmental, methodological, and technological lessons learnt that will be useful for future monitoring. Nonetheless, we stress out the need for longer-term monitoring, the lack of which not only makes the determination of significant long-term environmental changes difficult but also hampers the validation of models which many times serve as basis for the evaluation of impacts.

The present report sets the basis for discussion to be developed in Deliverable 2.7 which will translate into guidelines the experience and lessons learnt during the development and implementation of the monitoring activities.

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