SAFE WAVE

STREAMLINING THE ASSESSMENT OF ENVIRONMENTAL EFFECTS OF WAVE ENERGY

DELIVERABLE 2.6
Data results and analysis towards impacts' evaluation

This Project is co-funded by the European Climate, Infrastructure and Environment Executive Agency (CINEA)

WP 2

Deliverable 2.6 Data results and analysis towards impacts' evaluation

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1. SAFE WAVE project synopsis

The European Atlantic Ocean offers a high potential for marine renewable energy (MRE), which is targeted to be at least 32% of the EU's gross final consumption by 2030 (European Commission, 2020). The European Commission is supporting the development of the ocean energy sector through an array of activities and policies: the Green Deal, the Energy Union, the Strategic Energy Technology Plan (SET-Plan) and the Sustainable Blue Economy Strategy. As part of the Green Deal, the Commission adopted the EU Offshore Renewable Energy Strategy (European Commission, 2020) which estimates to have an installed capacity of at least 60 GW of offshore wind and at least 1 GW of ocean energy by 2030, reaching 300 GW and 40 GW of installed capacity, respectively, moving the EU towards climate neutrality by 2050.

Another important policy initiative is the REPowerEU plan (European Commission, 2022) which the European Commission launched in response to Russia's invasion of Ukraine. REPowerEU plan aims to reduce the European dependence amongst Member States on Russian energy sources, substituting fossil fuels by accelerating Europe's clean energy transition to a more resilient energy system and a true Energy Union. In this context, higher renewable energy targets and additional investment, as well as introducing mechanisms to shorten and simplify the consenting processes (i.e., 'go-to' areas or suitable areas designated by a Member State for renewable energy production) will enable the EU to fully meet the REPowerEU objectives.

The nascent status of the Marine Renewable Energy (MRE) sector and Wave Energy (WE) in particular, yields many unknowns about its potential environmental pressures and impacts, some of them still far from being completely understood. Wave Energy Converters' (WECs) operation in the marine environment is still perceived by regulators and stakeholders as a risky activity, particularly for some groups of species and habitats.

The complexity of MRE licensing processes is also indicated as one of the main barriers to the sector development. The lack of clarity of procedures (arising from the lack of specific laws for this type of projects), the varied number of authorities to be consulted and the early stage of Marine Spatial Planning (MSP) implementation are examples of the issues identified to delay projects' permitting.

Finally, there is also a need to provide more information on the sector not only to regulators, developers and other stakeholders but also to the general public. Information should be provided focusing on the ocean energy sector technical aspects, effects on the marine environment, role on local and regional socio-economic aspects and effects in a global scale as a sector producing clean energy and thus having a role in contributing to decarbonise human activities. Only with an informed society would be possible to carry out fruitful public debates on MRE implementation at the local level.

These non-technological barriers that could hinder the future development of WE in EU, were addressed by the WESE project funded by European Maritime and Fisheries Fund (EMFF) in 2018. The present project builds on the results of the WESE project and aims to move forward through the following specific objectives:

1. Development of an **Environmental Research Demonstration Strategy** based on the collection, processing, modelling, analysis and sharing of environmental data collected in WE sites from different European countries where WECs are currently operating (Mutriku power plant and BIMEP in Spain, Aguçadoura in Portugal and SEMREV in France); the SafeWAVE project aims to enhance the understanding of the negative, positive and negligible effects of WE projects. The SafeWAVE project will continue previous work, carried out under the WESE project, to increase the knowledge on priority research areas, enlarging the analysis to other types of sites, technologies and countries. This will increase information robustness to better inform decision-makers and managers on real environmental risks, broad the engagement with

relevant stakeholders, related sectors and the public at large and reduce environmental uncertainties in consenting of WE deployments across Europe;

2. Development of a **Consenting and Planning Strategy** through providing guidance to ocean energy developers and to public authorities tasked with consenting and licensing of WE projects in France and Ireland; this strategy will build on country-specific licensing guidance and on the application of the MSP decision support tools (i.e. WEC-ERA[1] by Galparsoro et al., 2021[2] and VAPEM[3] tools) developed for Spain and Portugal in the framework of the WESE project; the results will complete guidance to ocean energy developers and public authorities for most of the EU countries in the Atlantic Arch.
3. Development of a **Public Education and Engagement Strategy** to work collaboratively with coastal communities in France, Ireland, Portugal and Spain, to co-develop and demonstrate a framework for education and public engagement (EPE) of MRE enhancing ocean literacy and improving the quality of public debates.

[1] https://aztidata.es/wec-era/;
[2] Galparsoro, I., M. Korta, I. Subirana, Á. Borja, I. Menchaca, O. Solaun, I. Muxika, G. Iglesias, J. Bald, 2021. A new framework and tool for ecological risk assessment of wave energy converters projects. Renewable and Sustainable Energy Reviews, 151: 111539
[3] https://aztidata.es/vapem/

2. Glossary

AIS	Automatic Identification System
ASV	Autonomous Surface Vehicle
AUV	Autonomous Underwater Vehicle
CTD	Conductivity Temperature Depth
dB	Decibel
EMF	Electromagnetic Field
MRE	Marine Renewable Energy
MSFD	Marine Strategy Framework Directive
PTS	Permanent Threshold Shift
ROV	Remotely Operated Vehicle
SPL	Sound Pressure Level
SSS	Side Scan Sonar
TTS	Temporary Threshold Shift
WEC	Wave Energy Converter

3. Executive summary

The present deliverable aims to describe and explain the data pathway, from the monitoring plan specification phase to the final report, in order to better evaluate impacts of wave energy on the environment.

To obtain high quality results, each step of the data pathway requires a specific attention. Quality results are built on scientifically robust data, spatially comparable (between sites), technically comparable (between devices), manageable in the long term (comparable over the entire lifetime of a commercial project, i.e. 20-25 years), and specifically adjusted to the threshold enabling impact evaluation.

Regardless of the scale of a project (SafeWAVE project, test site management, or a commercial farm), each step of the pathway needs to be addressed with care, and even more because various different stakeholders handle data over the course of the project.

The present deliverable capitalises on the feedbacks from the SafeWAVE project, and its predecessor WESE project, to identify the most critical steps in this pathway, in the frame of environmental monitoring for the 4 topics which were addressed (electromagnetic fields – EMF, acoustics (noise), seafloor integrity, and fish communities monitoring).

The EMF monitoring plan could only be applied at one test site at the time of writing the present report. It was applied on a power cable connecting a floating wind prototype. The plan had to be adapted considering the local sea conditions and the surveyed assets. Field raw data were directly accessible using the sensor built in software. Some artefacts were dealt with by the field operator. The primary data could directly be used as inputs for WAVEC numerical model. Results from the models are in the same order of magnitude as field data. The modelled magnetic fields (for umbilical and export cable) are compared to threshold of magnetic field where behavioural or physiological effects have been observed for sensitive species, as elasmobranch. Nevertheless, the impacts of EMF on marine species are not well known, and individual species thresholds do not exist.

Acoustic monitoring activities within SafeWAVE followed the initial plan with little adaptations being required. Due to equipment failures (some hydrophones for some of the surveys) the expected data set is incomplete, but remains sufficient in order to evaluate impacts. Raw data required significant processing efforts, and data analysis initially focused on frequency ranges identified as noise indicators for the Marine Strategy Framework Directive (MSFD). The applicability and relevance of these indicators is questioned in the present report. Considering the impact threshold of 120 dB re 1 µPa specified by de the U.S. National Marine Fisheries Service for continuous sound (NMFS, 2018), it seems that all the WECs systems could negatively impact the cetaceans in all the studied areas since the produce sound above this threshold in all wave heights regimes and sound emission frequencies.

Regarding seafloor integrity evaluation, two different monitoring methods were deployed: remotely operated vehicles (ROV) submarine videos, and side scan sonar (SSS) coupled to an autonomous underwater vehicle (AUV). The ROV videos enabled a focused, close ranged and direct evaluation of local impacts on the seafloor. The SSS survey covered a broader area; its raw data are processed by a sensor built-in software which directly provides images. The resulting images (from the ROV and SSS) are analysed by experts in order to evaluate impacts.

The fish monitoring plan was applied only in BiMEP test site. In the absence of a wave energy device at the BIMEP site when the survey could be carried out, it was directed at the Harshlab (a floating platform with similar dimensions compared to a wave energy prototype). However, the HarsLab does not have specific elements of the WECs that can modify or affect fish behaviour, such as noise and EMF emissions, so future studies and more trials with the ITSASDRONE device are needed to further explore the association between WECs and fish aggregations. This survey enabled the validation of ITSASDRONE autonomous surface vehicle (ASV) equipped with an echosounder for fish monitoring. In the meantime, resources could be allocated to conduct baseline fish monitoring surveys at the Aguçadoura test site.

Regardless of the type of survey, the acquisition of auxiliary data is critical to process and analyse the field data.

Data acquired within the frame of SafeWAVE project are uploaded in the MARENDATA platform, created during previous European collaborative projects, and dedicated to environmental data and information sharing for the marine renewable energy (MRE) sector. Deliverables and data are also accessible via the SafeWAVE project website and are disseminated using social networks.

In the context of emerging marine renewable energies, impacts have to be evaluated in the long term, but knowledge is missing on the technologies themselves, and the standard monitoring protocols are not yet fully relevant nor applicable. Therefore, the authors of the present report strongly emphasise the need to address each step of the data pathway with care and as early as possible in the development of monitoring strategies and plans. Based on these considerations and on the feedbacks from SafeWAVE monitoring campaigns, specific guidelines will be developed in deliverable 2.7.

4. Introduction

SafeWAVE work package 2 (WP2) aims to collect, process, analyse and share environmental data collected in sites where Wave Energy Converters are operating in real sea conditions in Portuguese, Spanish and French coastal waters. 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. And the results from the monitoring activities of each parameter were presented in subsequent Deliverables (D2.2[4], D2.3, D2.4[5] and D2.5[6]).

The present deliverable focuses on the field data analysis and processing methodologies implemented during SafeWAVE project. In fact, the monitoring plans (D2.1; Vinagre et al., 2021)[7] proposed the most standardised methods and tools possible to be implemented at the different test sites and for the different WE devices surveyed. Nevertheless, the specificities and requirements of the different sites and technologies required adapting some of the approaches locally. In addition, data might have been acquired, processed, sorted, and reported by 1, 2 or 3 entities within the consortium. Without paying attention to how data is processed, from the field to a written report, information can be lost, or results can be misinterpreted.

Eventually, environmental monitoring strategies need to be developed for the long term, around 20-30 years for a commercial farm for instance.

[4] https://www.safewave-project.eu/wp-content/uploads/2023/08/SafeWAVE-D2.2-Monitoring-of-Electromagnetic-fields.pdf

[5] https://www.safewave-project.eu/wp-content/uploads/2023/02/Deliverable-2.4-Monitoring-of-the-seabed-integrity.pdf

[6] https://www.safewave-project.eu/wp-content/uploads/2023/02/Deliverable-2.5-Monitoring-fish-communities.pdf

[7] https://www.safewave-project.eu/wp-content/uploads/2022/06/Deliverable-2.1-Development-of-Environmental-monitoring-plans.pdf

Over the course of such a long project, various contractors or surveyors can address one single activity (e.g. acoustic monitoring). In other words, the operator of surveys and data analysis of the reference levels might not be the same as for the operational or decommissioning phases of the farm. This phenomenon is even more significant for test sites, where environmental monitoring can be carried out internally, externally by a subcontractor, or by collaborative project partners. In that sense, "how" the data is processed is almost as important as the data interpretation and results.

Therefore, the objective of this deliverable is to support the standardisation of data processing and reporting among test sites to allow comparison between them and the establishment of general guidelines for the development of monitoring plans[8].

This deliverable is written in close collaboration with WP3 on modelling and WP4 on data organization, storage, and dissemination.

A first section deals with the pathway of data from acquisition to analysis and/or modelling and with the relevant steps or questions to have in mind (Chapter 5). This pathway is presented for the different topics (EMF, acoustics, seafloor integrity, and fish communities) in chapters 6, 7, 8 and 9 following the same chapter structure.

Chapter 10 presents how data can be reported and disseminated.

At the end, chapter 11 summarises the general discussion about data analysis and processing.

[8] The guidelines are developed in the deliverable 2.7.

5. Investigation on SafeWAVE data analysis and modelling

5.1 Introduction - nomenclature

The timeline below represents the data "pathway". This pathway reflects the actual trajectory of a set of data collected and analysed during the SafeWAVE project. It defines a nomenclature which is required in order to reflect on the quality of the project results.

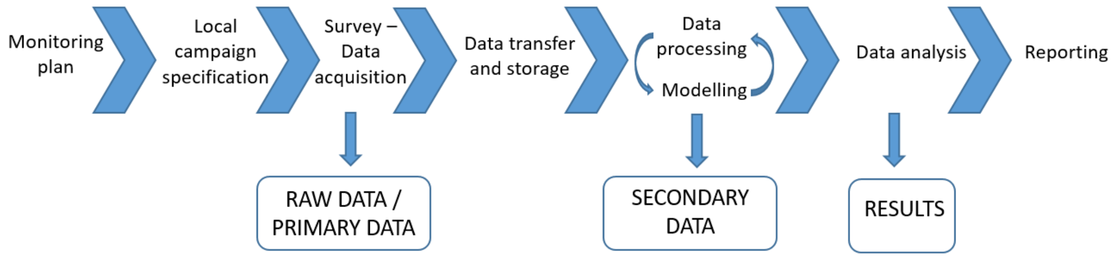


Figure 1. Data pathway.

1. **Monitoring Plan:** the monitoring plan in SafeWAVE project was developed in the deliverable D2.1 and specified the environmental monitoring surveys according to feedbacks and recommendations.

2. **Local campaign specifications:** according to specificities of the sites and/or the devices, the monitoring plan could be adapted, resulting in local campaign specifications.

3. **Survey – raw and primary data**: during the survey at sea, data are acquired in a specific format, during a temporal window and in a restricted area. It is the raw data or primary data.

4. **Data transfer and storage: generally**, including in the SafeWAVE project, the data processing is carried out by other people (part of the same entity or a third party) than the survey operator. Then, data needs to be transferred and stored.

5. **Data processing – secondary data**: during the data processing, data could be sorted, (sub- or re-) sampled, filtered, and transformed, among others, to obtain secondary data.

6. **Data analysis - results**: the secondary data are analysed and interpreted to obtain results. Data (generally secondary data) could be used by numerical **models** to assess the impacts at a larger physical scale (device to farm) or temporal scale (long-term effects). Data can also be used to calibrate or validate models.

7. **Reporting** allows to disseminate data and/or results and lessons learnt. Generally, reports are made available without data (primary or secondary). Reporting could be done on web platforms such as the MARENDATA.

The following chapters report on this data pathway for each type of survey (EMF, acoustics, seafloor integrity, fish communities) with feedbacks from the SafeWAVE project to assess the impact on the marine environment. The pathway is not necessarily as finely described as above.

5.2 From acquisition to results

As mentioned in the previous section, the data pathway is long and can be supported by different stakeholders.

The present section provides a structure to analyse the data processing and analysis methodologies for each environmental topic addressed within SafeWAVE. This structure is not a roadmap or a guideline directly applicable to specify generic or tailored monitoring plans. Nevertheless, it suggests setting up an investigation process specific for SafeWAVE, which is required to conclude on the quality of the project data and results. This process is articulated around 5 main steps reflecting the data pathway main milestones. For each step, the authors provide a list of questions or matters of interest which need to be addressed:

- **Survey**: Acquisition methodology, raw data associated, and the way to report deviations from the initial monitoring plan:

  - Was the plan tailored for each site?
  - Were data acquired using different tools?
  - Were survey logs registered?
  - What is the raw data format for each campaign?
- **Data processing** (from raw data to processed data): criteria to validate/discard data, sampling, and filtering:
  - Was data partially discarded? On which criteria was it discarded? Where do the criteria originate from (e.g. analyser experience, standards, sensor proprietary tools)?
  - Was data filtered? How was the raw signal filtered? For which purpose?
  - Was the processing methodology influenced by the feedbacks from the survey campaign? (e.g. from logs)?
  - Was the need for processing different for different sites?
- **Data Analysis and Results**: brief description of the analysis methodology, relevant/key steps for the analysis, which results are relevant to assess impact, required auxiliary parameters;
  - Is the analysis carried out on raw or secondary data?
  - Was data analysis carried out by the operator who processed the data?
  - Can the bias from the data analyst be evaluated? (standardized processing? Bias? Other constraints such as time constraint or budget constraint? Use of internal tools or commercial software?)
  - Were auxiliary parameters required for the analysis? (Which parameters? Format? Spatial and temporal extension? Spatial and temporal resolution? Need for accuracy?)

- How is the assessment of the impact done? Comparison to a threshold? To a reference level? Expert judgement?
- Even if monitoring is standardized for all test sites, could data be compared between each other? Differences due to the device or the location of the site? Could other parameters affect the comparison?

- **Numerical modelling**: Steps from field results (WP2) to modelling results (WP3): what are the requirements from modelling experts towards field data operators regarding acquisition processing, and analysis?
  - Is the modelling carried out on raw or secondary data?
  - How is data used for modelling: calibration of models, verification of models, or as input data for the model?
  - Which auxiliary parameters are required for modelling? Their format? Spatial and temporal extension? Spatial and temporal resolution? Are they different from data analysis auxiliary parameters?
  - Did auxiliary parameters "gaps" appear during the progress of WP3? How could that be improved? Authors suggest setting up an interface sheet where auxiliary data required for modelling (specifying the format, the spatial and temporal extent, etc.) are explicitly specified early in the monitoring campaign specification phase
- **Data interpretation**: Scalability (from one device to a farm) and representativeness (spatial and temporal – yearly and medium to long term).

In the following chapters these 5-step investigation process is applied for each environmental topic.

6. Investigation for: Electromagnetic fields

6.1 Data acquisition: deviations, limits, success factors

According to the environmental monitoring plan (D2.1), the EMF monitoring methodology was similar for the three test sites: measuring the EMF using an AUV (Comet-300 from RTsys) equipped with a magnetic field gradiometer (Bartington Grad-13). The AUV was expected to navigate perpendicularly to the cable, a few meters above the seafloor. Additionally, EMF would be measured at the Aguçadoura onshore substation to allow measurements during high sea states and compare those with the underwater measurements. However:

- At BIMEP, the device – Penguin II – was removed before the EMF survey could be carried out.
- In Aguçadoura, the Corpower Ocean's C4 WEC – HiWave-5 – was nstalled for 3 months during the project and did not produce energy in that period. Hence, the EMF survey, together with an onshore survey, could not yet be conducted.
- At SEM-REV, the WEC – WAVEGEM – was not grid-connected. Hence, the umbilical cable (5 MVA) of an offshore floating wind turbine prototype (2 MW) was monitored instead. Overall, results indicate that the device was producing low power during the EMF survey, leading to low EMF values which, according to the literature, should not represent significant impacts on marine life.

Therefore, only one EMF survey was carried out (at the SEM-REV test site, on an umbilical cable of a floating wind turbine prototype) at present. For the offshore survey, the environmental monitoring plan recommended investigating 5 stations for a cable laid on the seafloor and one station for an umbilical cable, at several distances from the cable (5, 7 and 10 m). But SEM-REV's survey protocol **deviated from the initial plan**, because, actually, 8 navigation transects, crossing the umbilical cable, were performed. Therefore, there was **no measurement on umbilical cable in**

the water column but only on the section laid on the seafloor. In addition, the **distance between the gradiometer and the seafloor was approximately of 3 m**. Indeed:

- Due to the fact the AUV towed the gradiometer, there is a risk of entanglement with the electrical cable in the water column[9]. It explains why the survey was focused on the cable laid on the seafloor. In addition, to secure the survey, a SSS survey was performed (with the AUV only, without towing the gradiometer) just before the EMF monitoring in order to detect any object that could prevent the navigation of the AUV with the gradiometer.
- In addition, the AUV (and gradiometer) navigated at the minimum distance from the seafloor (3 m), instead of the several distances planned. Indeed, the expected magnetic value generated by the cable was low and the sensor needed to be as close as possible from the cable. Moreover, at the SEM-REV test site the monitored section of the umbilical cable is naturally buried, with no estimation of the burial depth (probably a few centimetres).

The main limitation of this survey is vessel constraint for the launch and retrieval of the AUV. This implies sea state constraints (Hs < 1m, at SEM-REV for instance). When this condition is met, WECs are not at their maximum power rate and the measured EMF are generally very low. This is why an onshore survey was planned (at Aguçadoura, Portugal), to encompass higher sea states and, hence, greater power production.

One of the main strength of the EMF survey strategy in SafeWAVE is that the field campaign was supposed to be performed by the same entity with the same material for all the sites. The survey direct outcomes are provided by the operator.

The gradiometer is provided with a proprietary software and provides data directly in nanotesla (nT). Each measurement is geotagged (latitude,

[9] There is no risk of entanglement with the AUV only.

longitude, depth, distance to the seafloor). This software automatically corrects the geomagnetic field. Data could be exported as a .txt file or a map with the variation of the relative magnetic field. The available raw data are presented in Table 1.

Table 1. Raw data exported by the software.

Raw data	Unit	Definition
LONGITUDE	UTM30	Coordinates
LATITUDE	UTM30	Coordinates
MAG	nT	Outputs from magnetometer
DELTA_MAG	nT	Outputs from gradiometer
DEPTH	meter	
BOTTOM	meter	Distance between the AUV and the seafloor

Feedbacks from field campaigns are important to 1) adapt future monitoring plans and 2) understand some of the results (for instance, gaps during acquisition). A complete survey log would be useful to collect such information. But this survey log would need to be written at the beginning of the project (during the planning phase) and tailored for each monitored topic. This survey log should remind (briefly) the monitoring plan and have a section for all the topics of interest (deviation to the plan, operator name, auxiliary parameters, among others).

6.2 Data processing: criteria to validate/discard data

For different reasons, not all data acquired during field campaign could be used for the analysis, for example:

- The sensor didn't work properly, and some data could be aberrant;
- There were problems during the survey and the operator knows that the data acquired at that moment are not relevant.

For instance, during the EMF survey at SEM-REV, a repositioning of the AUV due to a loss of acoustic connection, led the operator to discard data acquired at that moment.

In this case, the experience of the field operator was essential to validate or discard data.

The validation step was expected to be performed by the same person for all the test sites.

The processing of raw data was directly performed by the embedded software (Sonarwiz). Table 2 shows the primary and secondary data of EMF with the processing methods.

Table 2. EMF monitoring: primary and secondary data with processing methods.

Method/Equipment	Primary data	Processing	Secondary data
• Digital three-axis gradiometer *(Bartington Grad-13)*	• Total magnetic field |B| amplitude, in nT • Relative* magnetic field |B| amplitude, in nT • GPS position, water depth, altitude to seafloor	• Vector magnitude, in nT • Spectral analysis	• Graph showing relative magnetic field along each transect (image file) • Map with relative magnetic field amplitude (image file) • Spectrogram showing magnetic field strength at various frequencies (image file)

*: the software directly corrects the geomagnetic field.

6.3 Data analysis and results

The analysis of the processed data was expected to be performed by the same person for all the test sites. Due to the previously mentioned deviations, EMF for different devices and tests sites could not yet be compared.

The effect of EMF on marine species has been studied, mainly in laboratory. An example can be found in Chapman et al. (2023) and Rebecchi et al. (2023). The studies are species-specific. Those studies allow to define thresholds for marine species, sometimes depending on their life cycles. Those thresholds are in Tesla (T), generally, species are sensitive at a scale of microTesla (μT), and can be directly compared to data obtained by the survey.

According to the Deliverable 2.2, EMF values generated by SEMREV's cable during the SafeWAVE campaign are 10^4 times less than the geomagnetic field and, as far as the authors of this report know, the species do not appear sensitive to the project measured levels of EMF.

6.4 Modelling

Besides the monitoring campaign, the EMF modelling tool presented in deliverable 3.1 (Imperadore et al. 2024) is able to provide accurate results at any current level. For the modelling, the geometry of the cable is fundamental and, once the phase current and the frequency (0 in case of a DC cable) are known, it is possible to simulate any condition outputting both magnetic and electric field.

In order to model the EMF generated by a WEC, auxiliary information is required, such as:

- cable characteristics;
- cable burial depth;
- power production profile.

As mentioned earlier, the EMF survey was carried out during a calm sea state (for operational constraints), when the device was operating below its rated power. As a consequence, the EMF measured were not at high levels. This justifies the need to model the EMF: (i) to assess the EMF at the maximum power rate; (ii) to assess the EMF for a farm (several devices/cumulated effects), and (iii) to assess the spatial extent of the EMF.

The modelling tool was developed internally by WavEC for WESE and improved for SafeWAVE within WP3. The same data operator analysed the data from the field campaign and performed the modelling task.

The modelling tool shall be validated based on the monitoring data, using the instant value of current to compare the output in terms of magnetic flux density. In the case of SEM-REV, only an average value of current was available, so deliverable 3.1 presents a tool that could not be fully validated. Once again, the modelling accuracy can decrease in the case of the power cable subjected to natural burial that cannot be quantified and therefore modelled. Additional validation is expected using the data acquired at Aguçadoura.

Regarding the deliverable 3.1, the data collected during the campaign and the data obtained by modelling show that the flux density is in the same order of magnitude but with slightly different values. In particular, the observed magnitude of the magnetic field is higher than the one outputted by the model.

The modelled electro and magnetic fields (for umbilical and export cables) are compared to thresholds where behavioural or physiological effects have been observed for sensitive species, such as elasmobranch fish. Nevertheless, the impacts of EMF on marine species are not well known, and individual species thresholds do not exist.

7. Investigation for: Acoustics

7.1 Data acquisition: deviations, limits, success factors

According to the environmental plan (D2.1), the underwater acoustics (i.e. noise) around the WECs would be recorded by 3 hydrophones (model SoundTrap ST300 HF) during 1 month. Several campaigns were planned in order to measure noise emissions for different stages of the WECs life cycle (installation, operation, decommissioning). For all the test sites, the hydrophones recorded for 10 minutes every hour, with a sampling rate of 96 Hz.

- In **Aguçadoura** (Portugal), an acoustic survey was carried out during two pre-installation campaigns of the Corpower Ocean's HiWave WEC. A five-day monitoring and a four-day monitoring was performed, respectively in January 2022 and May 2022, before the installation of the WEC. These campaigns allowed obtaining baseline information about the background noise within the test site. The deployment was done in shallow waters, approximately 30 m depth. The median sound pressure levels (SPL) were recorded between the 75 dB re 1 µPa and 105 dB re 1 µPa (for the lowest end of the spectrum and the band centred around 200 Hz, respectively).
- At **BIMEP** (Spain – Basque Country), two campaigns were carried out: one during the pre-installation/installation phase and another one during the operational phase of the Penguin II WEC. The BIMEP test site is in approximately 70 m depth. The pre-installation and installation campaign was performed in June to August 2021 (1.5 months) with only 1 hydrophone. The operational campaign took place during November 2021 to January 2022, with the recommended 3 hydrophones. Moreover, an airborne acoustic monitoring was performed during the recording of underwater noise, to further help in the assessment of the source level of the WEC. The operator observed a difference of more than 15 dB re 1 µPa between the pre-installation and the operational phase, especially for the high wave heights, and

up to 20 dB re 1 µPa during the installation phase. The larger differences of SPL are observed in the low frequencies. In addition, mooring lines are detectable above the background soundscape at 3-4 kHz, for rough sea state.

- One-month campaign (March-April 2022) was carried out at the onshore test site of **Mutriku** (Spain – Basque Country). Only one operational campaign was performed. Unfortunately, one of the 3 hydrophones did not work properly. No contribution to the background soundscape from the WEC was observed.
- At the **SEM-REV** test site (France), one underwater acoustic survey and one airborne acoustic monitoring campaign were carried out, respectively from July to August 2021 and from August to September 2021. Unfortunately, one the 3 hydrophones did not perform properly and recorded only 10 days instead of the 42 days planned. In addition, it was not possible to retrieve information about the WEC operational state (or power level) during the most part of the underwater acoustic monitoring. No significant contribution of the WEC to the ambient noise was observed in the operational phase. The highest values of SPL measured were centred in a narrow band (30 Hz), but data were too scarce to state on the WEC's specific contribution compared to other devices present on site. As in BIMEP, mooring lines are detectable (peak centred in 4 kHz, increasing with wave height).

  At the **SEM-REV** test site, RTsys tested a mobile underwater acoustic survey with a hydrophone inside an AUV (Nemosens).

Together with modifications in the scheduling, small deviations were required compared to the initial plan:

- In Aguçadoura, baseline surveys lasted 4-5 days;
- At BIMEP, only one hydrophone was used during the installation of the WEC.

In acoustic studies, based on SafeWAVE feedbacks, two major problems related to the acquisition phase could be identified:

- The hydrophones record during a long period (1 month approximately) and the operator cannot verify if the sensor is performing as expected until the end of the campaigns. Generally, data is downloaded only when the hydrophones are retrieved.
- Due to the large quantity of data, problems can occur during the retrieval and the transfer of data. Hydrophones record sounds and the obtained raw data are audio files (.wav). Those files are generally heavy. This type of survey generates a lot of raw data.

At each test site, the data acquisition was carried out by different operators (staff of the test site) but with the same material and similar settings (10 minutes of registration every hour at 288 or 576 kHz). This simplifies the post-processing because raw data are in the same format.

Due to the long period of acquisition (1 month), the 'survey log' should be very complete (material, serial number, location, depth, launch/removal time and date, settings + auxiliary parameters). The auxiliary parameters are sea state, conductivity, temperature, depth (the latter three obtained using a CTD), sound velocity, wind speed, rain, tide, and the operational regime of the device. Ideally, those parameters should be recorded hourly in order to accurately analyse noise pressure; recording daily is often not enough for most of them. SafeWAVE often did not implement a standard and complete survey log, only a log sheet with minimal information (date and time of launching and removal, location of hydrophones, among others). Acoustic data analysts should create a survey log with all data they need and notify the format and sampling of those data.

7.2 Data processing: Criteria to validate/discard data

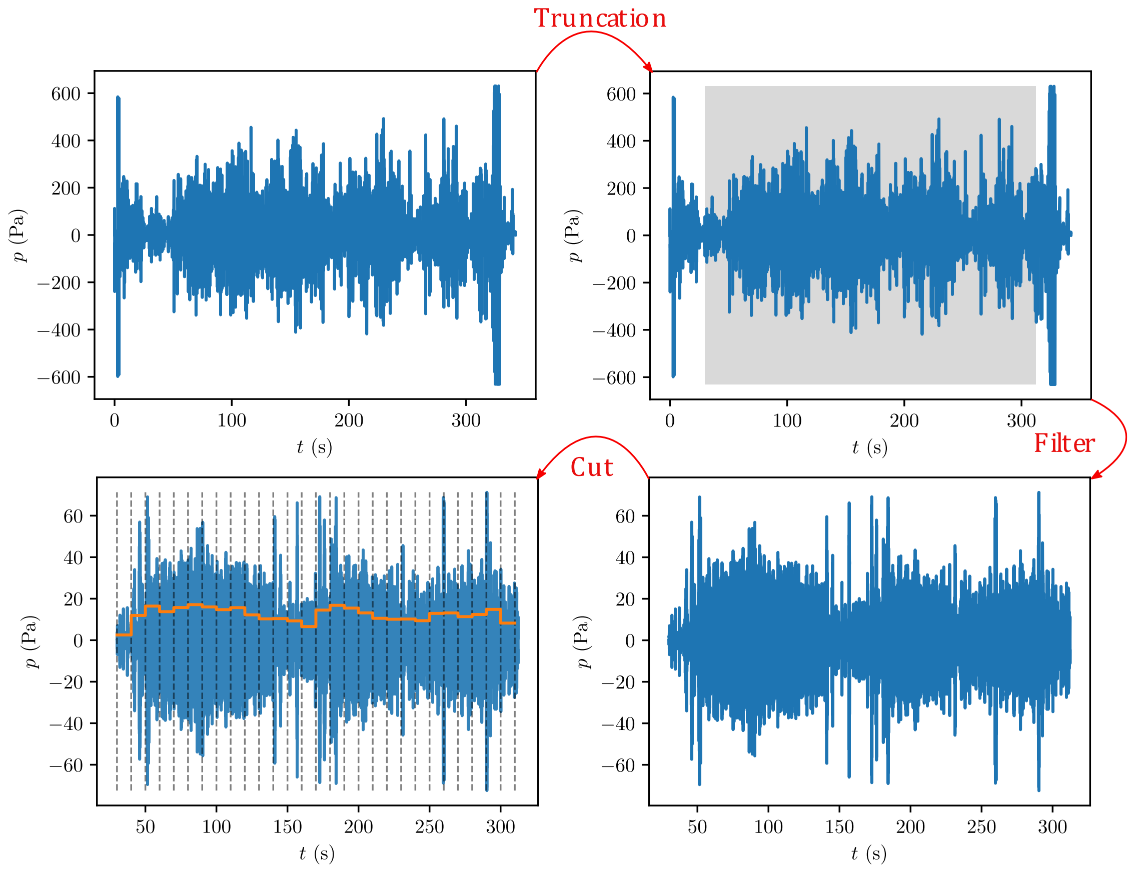
The operator listens to a sample of the audios, to check saturated signals and signals with extreme artefacts, and checks with the dates of installation and extraction, among others.

To avoid artefacts, the beginning and end of the recording are discarded.

It is assumed that auxiliary parameters have no artefact, i.e. any data to discard – files are 'clean'.

Various metrics are used to represent underwater noise. The one chosen for the SafeWAVE project is SPL (Sound Pressure Level). The SPL is the function of the root mean square of the pressure in some chosen interval of time.

Given a pressure signal in the appropriate units, the processing scheme consists in the following steps :



At the end, the SPL of the individual sub-signals is calculated for each frequency and a multidimensional matrix is obtained.

The SPL of three frequencies (1/3 octave band centred to 62.5 Hz, 125 Hz and 1 kHz) are displayed. The two first is the required frequencies in the framework of MSFD, the third one is chosen by CTN in order to record noise at higher frequencies and detect other components (such as mooring systems) (Table 3).

Table 3. Acoustic monitoring: primary and secondary data with processing methods.

Method/Equipment	Primary data	Processing	Secondary data
• Spatial and temporal deployment of hydrophones	• WAV files of underwater noise recordings	• SPL 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 (image file) • Graph of hourly median SPL time series for 62.5, 125 and 1000 Hz • Graph of percentile distribution of the SPL for each point, for each regime and sea state
• Airborne sampling with microphones	• WAV files of airborne noise recordings	• SPL in the frequency range between 20 Hz to 20 kHz	• SPL time series for each frequency band (image file)

7.3 Data analysis and results

Besides acoustic recordings, essential **auxiliary** (time, CTD, sound velocity, sea-state, rain, wind speed, water depth, GPS location, operational regime of the device) and optional **complementary** (bathymetry, seafloor properties, sound speed profile, shipping) parameters are necessary to model sound propagation.

Table 4. Auxiliary parameters.

Auxiliary parameters	Sampling / Acquisition frequency	Note / Important to check
• Time	• 96 Hz	• Check clock synchronization with all materials
• CTD cast (conductivity and temperature change relative to depth)	• Punctual (for instance, during launching and removal of the hydrophones)	• CTD data are converted into speed sound profile

• Sea-state (Hs in meter)	• Hourly, at least	• Chose the same time step than sound file
• Rain (in mm)	• Daily, at least – ideally hourly	•
• Water depth (in m, variation with tide)	• Hourly	• Chose the same time step than sound file
• GPS location	• Once	• Check the location at the launching
• Operational regime of the device (on/off)	• Daily at least, ideally hourly	• Chose the same time step than sound file

Regarding the results acquired at SEM-REV, shipping and other maritime activities are important to analyse sound profiles and they could be added to the auxiliary parameters. The ships automatic identification systems (AIS) data provide information about shipping.

Auxiliary and complementary parameters influence the level of the underwater noise. They should be recorded, ideally, hourly.

The analysis of the processed data was performed by the same analyst for all the test sites. This allowed to homogenize the results and their interpretation. Thus, it was possible to compare the results between devices. The comparison between test sites could be more complicated because site-specific environment (e.g. bathymetry, seafloor properties) affects sound propagation.

Marine fauna, especially marine mammals, are sensitive to the underwater noise. They use sound to socialize, mate, and hunt, among other activities. Studies provide thresholds for various species according to the band of frequencies in which they are sensitive. The impact on those species can be partly assessed, at least at the location where the hydrophone was deployed. Nonetheless, it is possible to compare with known frequency curves of Temporary Threshold Shift (TTS) and Permanent Threshold Shift (PTS) of marine mammals.

The radiated underwater noise from the WEC must be modelled in order to compare with marine fauna sensitivity thresholds and to know the extension of the area where species could be affected.

For acoustics, in order to assess relevant metrics on broader areas, modelling is essential to assess the impact on the environment.

7.4 Modelling

In the SafeWAVE project, the acoustic modelling was performed by the same person who analysed the field data.

In order to model the underwater sound propagation, complementary data are required, such as bathymetry, seafloor properties and sound velocity profile.

Modelling allows to obtain spatial sound propagation and comparison with the background noise. At the time of writing the present report, the spatial sound propagation (footprint) is displayed at the frequencies suggested by the MSFD, i.e. 62.5 Hz, 125 Hz and 1kHz.

Nevertheless, in order to characterise the noise produced by the WEC and its mooring lines the analysis must focus on the relevant frequencies, i.e. those where the device under study is expected to produce most of the noise. In the same way, in order to assess the impact on fauna, especially on marine mammals, the noise produced by the WEC must be compared to sensitivity thresholds of the fauna at the relevant frequencies, and not necessarily the frequencies suggested by the MSFD.

Considering the impact threshold of 120 dB re 1 µPa specified by de the U.S. National Marine Fisheries Service for continuous sound (NMFS, 2018), according to the results coming from Deliverable 3.2 (Garcia et al., 2024), it seems that all the WECs systems could negatively impact the cetaceans in all the studied areas since the produce sound above this threshold in all wave heights regimes and sound emission frequencies. Regarding the affected area, it highly varies between sites, being smaller areas when analysing one device, but increasing when considering an array with a target production of 1200 kW, reaching in some cases up to 10 km of disturbance distance.

8. Investigation for: Seafloor integrity

8.1 Data acquisition

According to the Deliverable 2.1, the seafloor integrity was monitored by video techniques (camera installed on a ROV) and Side Scan Sonar (SSS) installed on an AUV COMET 300 owned by RTsys.

The **ROVs** used varied among the test sites but the **SSS** was the same for all the test sites: the one embedded on the AUV, COMET-300 of RTsys. The monitoring strategies differed slightly among the test sites, depending on the status, design, and mooring system of the WEC, and oceanographic conditions, among others, as described in Deliverable 2.1. The survey configuration was different among the three test sites.

At **Aguçadoura**, the WEC HiWave-5 (CorPower Ocean) was not installed at the time of writing this report. ROVs were deployed for baseline surveys in October 2021 and January 2022. These two surveys provided the same information: the seafloor is made of sandy sediment with ripple marks. The ROV technology allowed to observe flora (algae) and fauna (squids, razor clams, crabs). Other ROV and AUV-SSS surveys are planned after the installation of the WEC.

At **BIMEP**, due to the premature decommissioning of the Penguin II WEC (WELLO), the ROV and AUV-SSS surveys occurred after the removal of the device but anchors and mooring lines were still laid on the seafloor. One ROV campaign was carried out in July 2022 and two SSS surveys (low and high frequency) were carried out in August 2022. The acquired images allowed the observation of the anchors and mooring chains, some of which were partially buried. Regarding the seafloor morphology, there was no alteration beyond the presence of the mooring components. Mooring components offered colonisable surfaces to fauna and flora in a soft bottom environment and attracted fishes (pouting, conger, red gurnard, and other) and crustaceans.

At **SEM-REV**, the monitoring of the seafloor occurred during the operational phase and after a partial decommissioning of the WAVEGEM device (similarly to the survey at BIMEP, the mooring components were kept laid on the seafloor). Due to poor visibility, the ROV surveys (in July 2021 and in May 2022) focused only on one or two anchors (out of four). Those were partially buried, colonised by biofouling, and attracted some fishes and crustaceans (e.g. pouting, lobster). Videos acquired by ROV allowed to observe vertical movement of mooring lines and no contact with the seafloor by the inspected mooring lines was detected. The SSS surveys during the operational phase (June 2022) revealed the footprint of the floating section of the mooring lines. Other sections (close to seafloor) were totally or partially buried or just above the seafloor. After partial decommissioning (anchors and bottom chains remained), the SSS survey (May 2022) found no alteration to the seafloor morphology beyond the presence of remaining parts of the moorings. The footprints observed previously had disappeared.

Deviations from the initial plan were caused by changes in the scheduling of the WECs testing:

- CorPower Ocean's WEC is not yet installed in Aguçadoura. Therefore, only baseline ROV surveys have been performed;
- Because of premature decommissioning of the Penguin II WEC at BIMEP, only post-decommissioning surveys with ROV and SSS were possible, but operational surveys were not.
- At SEM-REV, the WAVEGEM device has not been totally decommissioned and anchors and bottom chains are still laid on the seafloor. Moreover, the underwater visibility is very poor which made the videos by ROV only partially usable.

With a ROV, the visibility and luminosity (despite lights on the ROV) are critical success factors for seafloor integrity assessments. The turbidity directly impacts the outcomes of this type of survey. For instance, at SEM-REV, the turbidity is often high, especially close to the seafloor. ROVs can't be successfully operated all the time which can have a significant impact on survey protocols.

The ROV surveys were performed by different team members and with different ROVs. Nevertheless, the performance of each ROV was equivalent.

The SSS surveys were carried out by the same operators (RTsys team) and using the same equipment (COMET-300).

ROVs are equipped with at least one camera. Therefore, the raw data are the videos recorded during the survey (video files). The ROVs must be operated in low speed to allow to identifying species and interactions.

The **SSS** used has an embedded software (Sonarwiz). The software directly processes the sound reflection waves into graphic images of the seafloor characteristics. The raw data obtained are geotagged images of the seafloor characteristics (image files). RTsys also provided a brief report on the campaigns.

A complete survey log with initial plan, reminder of the status of the device, and other information about the test site or activities surrounding the site that can influence the results, weather conditions, deviations/issues, number of videos/files, among other information, is required.

8.2 Data processing: Criteria to validate/discard data

The **ROV** videos are visualized on a screen by the operator at the same time of the recording. The operator can pilot the ROV in order to adapt the acquisition parameters (e.g. location, depth) to optimise the video quality and improve results. The criteria to discard data depends on the visibility. The problem of visibility can be caused by low light conditions, turbidity, or a high speed or parasite movement of the ROV. Data discarding/validation also depends on the sensitivity of the person analysing the data. Moreover, if there are a lot of videos, a pre-sampling could be done to select only useful videos (where the assets are visible on the video for instance). The processing of video recordings consisted of the removal of clips that did not contain any relevant information (e.g. landing of the ROV, navigation to the moorings and/or mooring lines). That could be done by a technician using any of the multiple video processing software available (e.g. Avidemux).

During the **SSS** surveys, some artefacts can be recorded due to issues during the surveys (e.g. rough sea state forcing to higher distance between the sonar and the seafloor). This is managed by field operators.

The SSS surveys carried out during SafeWAVE project did not record artefacts.

8.3 Data analysis and results

After the discarding/validation process, videos by **ROV** are directly usable for the analysis. The expert watches the video and analyses the type of interaction with the seafloor, the footprint caused by the device and components, and biological aspects (e.g. colonization, mobile species around, etc.).

The sound reflection waves acquired by the **SSS** are automatically and internally processed by the embedded software (Sonarwiz) to provide images of the seafloor.

The processing of the imagery (videos and SSS images) is done by experts (human analysis). This analysis provides information about modifications/alteration to the seafloor (e.g. sweeping by mooring lines, sediment deposition), the extension of the footprint, biofouling, and attracted species.

Once the video recordings are reduced in length, frames can be extracted as samples of the impacts on seafloor integrity, for which a media player can be used (e.g. VLC media player). This task should be carried out by personnel trained to identify the impacts by the analysed structures on the seafloor. For this type of sampling, at least the following should be considered:

- alteration to the seafloor morphology;
- impacts on outcrops (reef habitats);
- changes in animal behaviour (e.g., in sedimentary bottoms attraction of organisms that typically occur in rocky habitats).

The availability of clips and frames with a sufficient level of quality to assess the impacts mentioned above will depend mainly on (1) the quality of the camera with which the ROV is equipped (which should be taken into consideration prior to the survey), (2) the metocean conditions that could affect the navigation of the ROV that could affect the smoothness of the recordings and (2) the underwater visibility (limited by the turbidity or the presence of suspended particles) that could affect the sharpness of the images. In this sense, as an example, different cameras were used at the three sites monitored in the framework of the SafeWAVE project, and the site conditions were also different in terms of water transparency, which led to the images being obtained with different quality levels among sites (Figure 2).

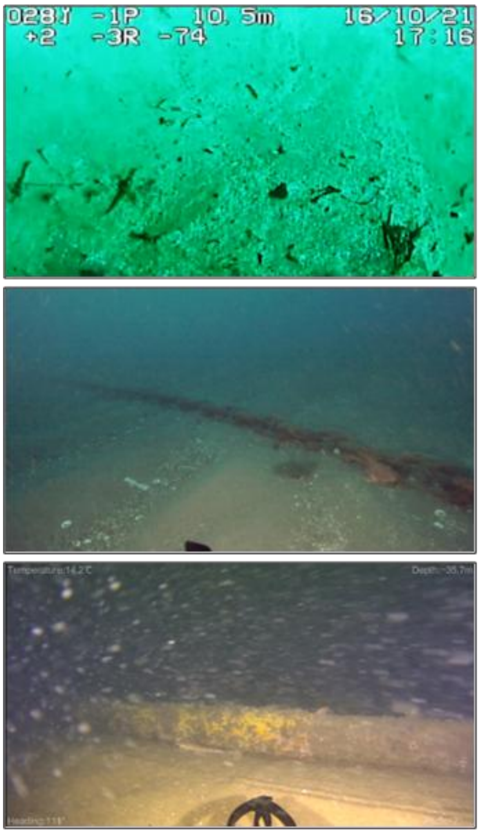


Figure 2. Frames obtained from the videos recorded by three different ROVs used in Aguçadoura (Seaeye Falcon), BiMEP (Sibiu Pro) and SEM-REV (REVOLUTION), from top to bottom respectivaly.

In order to assess the impact, the expert needs at least a comparison with an unaffected area in the vicinity or, ideally, with baseline surveys. This type of result can also support studies on the artificial reef effect. The assessment of the impact is to date carried out by the human-eye, although Artificial Intelligence methods are being improved to support this task with automatic detections. There is no threshold, the impact(s) assessment is performed according to the experts.

In the SafeWAVE project, the analysis of videos and SSS images was performed by different analysts (one by test site). The advantage is that the person knows well the test site and all the details (not especially written in a survey log) which could influence the results. Conversely, the analysis is not homogenous because each person has his/her own sensitivity.

It should be highlighted the complementarity of the information obtained by the SSS. The SSS is able to provide high-quality and high-resolution georeferenced information, where the areas physically disturbed by the structures can be measured with precision. Moreover, an AUV equipped with the SSS is able to cover large extensions of the seafloor in a short time (comparted to other techniques), which is useful to get a full/broader picture of the area occupied by the devices and components to which the impacted area can be related (in order to estimate relative measures of impacted areas).

No modelling activities were planed regarding this topic.

9. Investigation for: Fish communities

9.1 Data acquisition: deviations, limits, success factors

According to the D2.1, the fish communities monitoring would be developed around the WELLO Penguin II device; however, it was decommissioned before the monitoring period and, as described in D2.5 (Uriarte et al., 2024) , the BiMEP HarshLab floating station was used instead as a proxy to monitor the effect of a floating platform on fish communities. The monitoring of the fish communities was carried out by recording acoustic data with two autonomous devices: ITSASDRONE- and WBAT. The first one is a dynamic surface vehicle programmed to follow a route according to a sampling design and, the second, a stationary autonomous probe.

The monitoring by autonomous marine surface drone covered a previously delimited area with a star-shaped design (as detailed in D2.5) and a time window that depended on the availability of the vehicle handlers as well as weather conditions. The initial acoustic equipment of the ITSASDRONE was meant to be developed by ZUNIBAL based on the following specifications: a single beam ZSR 120 kHz scientific echo sounder with an Airmar transducer with a frequency range of 85-135 kHz capable of collecting and storing accurate acoustic backscatter data that can be post-processed and replayed. However, this equipment was not available for the study so a Simrad EK80 WBT-mini echosounder was installed that recorded data at 200 kHz.

The stationary WBAT echosounder was equipped with a Simrad EK80 echosounder that recorded data at 120 kHz in a stationary manner, anchored to the HarshLab structure and for a two-month window, regardless of operator availability or weather conditions.

Schools of unidentified small pelagic fish were observed distributed throughout the water column, predominantly near the bottom in the device area. In general, the observations made using different instruments indicate that there is no significant alteration in the distribution of fish abundances under different levels or radii of influence of the HarshLab floating platform. The combined use of these various instruments has been particularly important, allowing us to focus the study on different factors, including diurnal and seasonal variations at the same sampling point, as well as spatial variations at different distances from the HarshLab. Considering that the measurements were taken on a rather small time frame, it is highly likely that the observed variations are due to other factors. Changes in meteorological conditions prior to the measurements, the presence of fishing activity more or less close to the area, or even an increase in small pelagic predators in the area could have had a relevant effect on the results of this study. Consequently, these results are considered as baseline information being therefore necessary to increase the study effort by extending the time frame in order to obtain more conclusive results of the potential WEC effect on local fish communities.

Only one test site and one WEC were planned for the fish monitoring task: the BiMEP area and around a single nearshore device. But, as mentioned earlier, baseline fish monitoring surveys were undertaken in the Aguçadoura test site and surroundings. Two campaigns were conducted, one in July 2024 and one in November 2024, each covering an "impact area" close to CPO's HiWave-5 device location and a "control area" situated a few nautical miles to the south. Traditional fish monitoring methods (trawling, pots) were used. One limitation of these surveys was related to the "similarity" between the impact and control areas. Ideally, these should be as similar as possible in terms of oceanography, including wave height, bathymetry, and seafloor type. While the prior two were achieved, differences in the seafloor type were found. These were inevitable since the Aguçadoura test site presents mostly sandy bottom, ideal for installing offshore renewable energy devices, while the surrounding areas present much more varied seafloor types. As it was found, the seafloor type probably had a great influence on the communities between areas considering the fish and invertebrate species composition and abundance found in each area. In addition, many fishing gears were found in the control area during the surveys, which required constant adjusting of the transects performed in that area.

9.2 Data processing: Criteria to validate/discard data

In all cases, the acoustic recordings from BiMEP surveys were downloaded to a computer for analysis using specialized acoustic data software: Echoview[10]. This software operates under license and requires specific knowledge prior to use. AZTI experts were responsible for analysing and interpreting the data to assess the impact of the device on fish populations.

First, pre-processing of data was done by visualizing it in raw echograms and discarding non-useful data such as the seafloor or interference from bubbles or other non-biological elements. Invalid data were discarded using filters and thresholds.

Regarding the fish baseline surveys undertaken in Aguçadoura, fish and additional biological elements (invertebrates, macroalgae) were identified, counted, weighed, and measured on board the survey vessel. When that was not possible, specimens were frozen and taken to the laboratory for processing.

9.3 Data analysis and results

In BiMEP, the echosounder used was a Simrad EK80. It is a programmable, stand-alone split-beam acoustic echo sounder.

For this study, it was operated at a narrowband frequency of 200 kHz, at which precise acoustic backscatter data were collected, stored, and then post-processed and replayed to identify significant fish schools to assess the possible aggregation effect by the device.

[10] https://echoview.com/about-us/

The acoustic data processing followed a pre-established sequence of steps:

- Firstly, the acoustic signal should be pre-processed by: i) detecting and excluding the seafloor echo; ii) applying spike filters for interference removal; and (iii) applying a minimum threshold of -60 dB.
- Secondly, the acoustic signal is processed by means an acoustic echo-integration. In this case, an integrated acoustic energy value is obtained from 500 pings x 10 m depth cells.

The values used to compare the abundance distributions are defined as Nautical Area Scattering Coefficient (NASC), expressed in m^2 nm^{-2}.

Data from the ITSASDRONE surface vehicle were used to study the variability of biomass at different distances from the surveyed platform, considering the most distant areas as control zones or unaffected by the platform. The stationary echosounder (WBAT) data were evaluated on the time scale, analysing the variation of biomass over the two months of data collection. Even though the instruments were equipped with different frequencies, this did not affect the comparability of the measurements, since the determined relative biomass variations in space and time are not affected by the frequency of measurements.

Finally, the mapping of the acoustic energy around each structure and the plotting of the relative abundance as a function of the distance of each cell to the centre of each of the installations, allows to assess the effect generated by the presence of structures on the fauna in the area.

The required auxiliary parameters were wave, rain, and wind data.

This survey is at the frontier of the R&D and study because there is an important work of tuning and conditioning the ASV. Therefore, the initial plan had to be deviated. Thus, this survey was considered as a baseline survey.

The impacts could not be assessed because there was no WEC on site, (the HarshLab does not have specific elements of the WECs that can modify or affect fish behaviour). In addition, the design of the surveys needs to be improved, considering different times, seasons and sea states

The impacts will be assessed by comparing future data with the baseline data. For this topic, a long-term study is recommended to account for seasonal variations. No modelling is suggested for this topic.

10. Reporting and dissemination

In this section, we focus on data sharing to try to answer, "how can we be more efficient to share marine data?". Various marine data platforms exist[11] but none of them allows to share all the data collected in SafeWAVE project. Some are dedicated to specific topics or countries. Few of them allow to share data; often the platforms share reports.

MARENDATA was created in the framework of the SOWFIA project, improved in the framework of WESE and SeaWAVE projects and with further improvement in the SafeWAVE project. This platform allows to share various data formats (e.g. images, sounds, videos) and reports about MRE.

In general and in the context of MRE, data sharing addresses several issues:

- Confidentiality: MRE is a competitive industry but researchers and other stakeholders need design or production data to understand and assess the environmental impacts. Despite the involvement of WEC developers in the SafeWAVE project, it has been proven to be complicated to share power production figures, for instance. A way to overcome this barrier would be to use non dimensional figures for instance.
- Long-term storage constraints: Storing large amount of data and for a long period of time has impacts in terms of costs, security, and environmental impacts (GHG). Avoiding duplicates (on different platforms for instance) and choosing specific hardware (locally operated for instance) are two possible impact-reduction pathways.
- Long-term environmental assessment: In a context where thresholds and impact assessment methods evolve, how can data reporting and sharing contribute to long-term environmental impacts assessments? Storing raw data seems more adequate because it will be processed again with new software, new techniques and, at the end, compared

[11] http://www.coastalwiki.org/wiki/Marine_data_portals_and_tools

to new thresholds. In that sense, metadata are very important. According to EMODnet[12], required metadata are:

- Where the data were collected: location (preferably as latitude and longitude) and depth/height
- 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, instrument types, analytical techniques)
- How you refer to the data (e.g. station numbers, cast numbers)
- Who collected the data, including name and institution of the data originator(s) and the principal investigator
- What has been done to the data (e.g. details of processing and calibrations applied, algorithms used to compute derived parameters)
- Watch points for other data users (e.g. problems encountered and comments on data quality)

Table 5 presents data available in MARENDATA (14/04/23).

Processed video files from BiMEP were uploaded to AZTI's YouTube channel (https://www.youtube.com/watch?v=ndE7FACIWks). At the same time, the metadata for each of the videos, together with the corresponding link, was uploaded to MARENDATA. The metadata included a brief description of the test site and the device installed and an indication of the elements monitored in each of the video recordings, as well as some general information (including the date of the survey, the coordinates of the area monitored, the owner of the data, and contact information to request additional information). As YouTube is widely used to store videos, while providing tools for third party development, in the

[12] https://www.emodnet-ingestion.eu/guidelines

development of MARENDATA it was assumed that videos would be stored in YouTube, while also being indexed in MARENDATA.

Table 5. SafeWAVE data available in MARENDATA. (consultation 14/04/2023)

Parameter	Primary data	Secondary data
• **EMF**	-	-
• **Acoustics**	• Penguin II (BIMEP): - 6 WAV recordings from the fixed hydrophone monitoring campaigns (.wav). • WAVEGEM (SEM-REV): - 4 WAV recordings from the fixed hydrophone monitoring campaigns (.wav).	-
• **Seafloor integrity**	• Penguin II (BIMEP): - 6 SSS images (.tif) - 7 videos acquired with ROV	-
• **Fish monitoring**	-	-

Despite MARENDATA can store reports, public reports from SafeWAVE are also available on the dedicated Project website.

Reports are disseminated via social network (Twitter, LinkedIn, Facebook) at the moment of their publication.

11. Overall discussion

One of the main takeaways from the authors of the present deliverable is the importance of standards in the specification of a monitoring plan and the need to adapt it to local constraints and conditions (site and/or WEC). In addition, standards are not always applicable, relevant, or even existing for MRE applications. Indeed:

- Some standards originate from other sectors, providing indicators which are not entirely relevant for MRE applications. For instance, the acoustic acquisition frequencies are aligned with maritime transport activities, which are not relevant for permanently moored floating structures. A broader bandwidth is required to evaluate the impact of both continuous sounds from devices machineries, and punctual noises resulting from mooring motions.
- The applicability of standard protocols (in the field or during the processing and analysis phases) is not always straightforward for MRE. Using the acoustic monitoring as an example again, the recommended noise characteristics would need to be adapted to sensitive frequencies of marine mammals, fish, turtles, and other organisms.
- Regarding EMF for instance, monitoring standards do not exist.

More precisely regarding the results obtained within the project, SafeWAVE partners concluded on negligible impacts in the marine environment (by EMF, noise, or on the seafloor) for an individual WEC. Some effects were observed very close to the assets (device, the mooring lines and anchors, or the electrical cable) with potential limited impacts on the fauna and flora.

Additional conclusions can be drawn thanks to modelling with regards to the change of scale towards commercial deployments:

- Wave energy farms impacts in marine environments are expected to have a greater spatial and temporal extents and/or reach greater levels.
- For EMF, even if the maximum expected magnetic/electric fields intensities calculated for a farm remain under thresholds leading to detrimental effects on marine fauna, some studies show that some species could be affected physiologically or behaviourally. Therefore, for EMF, there is a lack of knowledge about thresholds and impacts on marine fauna, especially for the electric field.
- For underwater acoustic, considering the impact threshold of 120 dB re 1 µPa specified by de the U.S. National Marine Fisheries Service for continuous sound (NMFS, 2018), it seems that all the WECs systems could negatively impact the cetaceans in all the studied areas since the produce sound above this threshold in all wave heights regimes and sound emission frequencies. Regarding the affected area, it highly varies between sites, being smaller areas when analysing one device, but increasing when considering an array with a target production of 1200 kW, reaching in some cases up to 10 km of disturbance distance.
- Regarding seafloor integrity and fish communities monitoring, the SafeWAVE project did not run models to evaluate the changes with increased project scale. The project results focused on observations at the scale of a few devices. Unlike EMF or acoustics with numerical thresholds, for the topics of seafloor integrity and fish communities monitoring, broader impacts have been assessed by experts.

During the data acquisition phase, the environmental conditions can influence the representativeness of the recorded data. For instance, for EMF surveys calm sea states are require, often far from rated power production conditions, which is not representative to evaluate the impact by EMF. Similarly, seafloor integrity surveys, the season of the survey could influence the observations. In addition, auxiliary information from the surrounding environment also used to calibrate and validate numerical models. This justifies the need for a detailed evaluation of the auxiliary surveys required at early stages of the monitoring planning.

The present deliverable clearly highlights that each step of the pathway of the data can influence the results and so the assessed impacts. Therefore, the authors reinforce the need to provide guidelines covering each step adequately, to have a relevant monitoring plan and to be able to compare data between different sites and WECs and in the long term.

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