ITSASDRONE, an autonomous marine surface drone for fish monitoring around wave energy devices

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Abstract— **One of the primary foundations of the EU Blue Growth policy is the development of ocean energy. While the technological development of devices is advancing quickly, little is known about their possible environmental implications. The SafeWAVE initiative aims to increase understanding of potential environmental effects from wave energy projects in the coastal waters of Portugal, Spain, and France. The aim of this work was to monitor the interaction between the WEC and the fish community in the Spanish study area (BiMEP). However, the device to be monitored had to be replaced by a floating laboratory (HarshLab) in the same area, since the WEC suffered a series of unforeseen events that made its use impossible. The monitoring was carried out using an autonomous vehicle (ITSASDRONE) equipped with a scientific echosounder, which recorded acoustic data that provided information on the abundance of fish in the area. Schools of unidentified small pelagic fish were observed distributed throughout the water column, predominantly near the bottom in the area of the device. The acoustic sensors showed a relatively high abundance in the BiMEP area, generally equal to or higher than in the access route from Armintza harbor. However, these results are preliminary and should be considered as baseline information. Future studies are needed to further investigate the relationship between WECs and fish aggregation.**

Keywords— **autonomous echosounder, fish abundance monitoring, floating laboratory, wave energy converter**

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I. Introduction

ARTIFICIAL structures deployed in the sea (e.g. sea cages, oil rigs, offshore platforms) and coastal infrastructures are now considered pollutants due to their association with the discharge of toxins and nutrients, the increase of noise and light pollution, the establishment and spread of non-native species, and also because they often destroy and fragment natural habitats [1]. A very significant increase in the installation of marine energy devices is foreseen, therefore public administrations, regulators, marine energy industrial developers, scientists and citizens in general are concerned about the possible impacts generated by these devices on marine fauna, flora and habitats. Some authors have developed a conceptual framework, considering technical, environmental and conflict for space aspects that play a role on the development of these projects [2]. In general, any artifact in the sea can have an attracting effect on fish communities, especially if it is floating. Similar effects have been observed by [3] in relation to floating structures for aquaculture (fish cages, mussel nets, etc.). Such attraction may favour changes in species composition in the area of study and alter predator-prey relationships [4]. In the case of marine renewable energy devices, the placement of any artifact in the sea during the operational phase can generally have an attracting effect on fish communities, especially if it is floating [5]–[7]. However, noise and vibration from the operation of the devices could offset this attraction effect [8].

In the offshore wind sector, it has been observed that the increase of epibiont fauna on wind turbine piles favors the creation of habitats and the presence of species that can be food sources for ichthyofauna [9]. A study by [10] in the Baltic Sea found a higher abundance of fish near the turbines, but similar richness and diversity to the control areas. Some studies found an increase in biodiversity richness and abundance of reef species in the vicinity of offshore renewable energy foundations located in cold temperate regions compared to the surrounding sandbed areas [11]. However, there is currently no

Fig. 1. ITSASDRONE, an autonomous marine surface drone (Source: AZTI).

evidence that large energy farms affect fish aggregation below the facilities.

In general, the association between marine energy devices and fish aggregations can be studied using a wide range of methods and techniques [12], [13]. Traditional monitoring methods (underwater visual census by divers, line or encircling fishing techniques, etc.) are complemented by new technological developments (autonomous underwater video cameras, ROVs, hydroacoustic devices). Over the past decades, the technological development of autonomous vehicles has increased the capability of sampling previously unreachable environments such as the sea surface, deep-sea or underwater ice with the potential of operating remotely avoiding the limitations of weather of man-related operability [14], [15]. At the same time, engineering solutions related to sensor manufacturing are remarkable, designing and producing more sensitive and accurate sensors.

Data collection procedure and further data processing and interpretation analysis can also be done according to various techniques and methodologies. The use of active acoustics has been widely used for monitorization of fish communities [16] from either stationary [17], [18], drifting [19], [20] or moving platforms [21]–[23]. Also, approaches including new machine learning tools for processing and interpreting data are being developed in recent years to improve the interpretation of the registered acoustic data [24], [25].

The main objective of the present work was to design and perform the monitorization of fish communities around the Penguin Wave Energy Converter WEC-2 in the BiMEP test site (Lemoiz, Northern Spain) with the ITSASDRONE surface drone (Fig. 1) equipped with an acoustic echosounder.

Fig. 2. HarshLab 2.0 (Source: https://harshlab.eu/en/).

To achieve this, the following operational objectives were set:

1. To condition and tune the ITSASDRONE. This is the first time this autonomous vehicle has been used, so it was necessary to adapt the technical specifications of the vehicle, both structurally and operationally, to this type of sampling. For this, the reliability during the deployment and recovery manoeuvres, mission control and overall performance were assessed.
2. To develop a sampling design and conduct monitoring trials in BiMEP using acoustic methods to estimate biological abundance. The sampling design was pre-programmed by a specific software and it was also evaluated whether the software was sufficiently intuitive and easy to use without the need for specific training.
3. To analyze the impact of the WECs on fish communities by studying variations in acoustic abundance in areas of WEC influence.

II. MATERIAL AND METHODS

A. *Survey design*

The Penguin WEC-2 was deployed off the coast of Armintza, Basque Country, Spain in August 2021. On December 19, 2021, the WEC was towed to port for inspection, maintenance and repair after a leak alarm was detected on November 28.

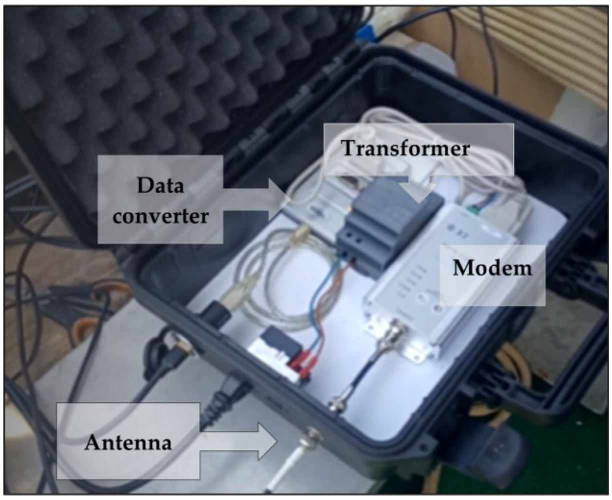

Fig. 3. Communication Ground Control Station system (Source: AZTI).

Although the plan was to repair Penguin WEC-2 and return it to its location in the BiMEP area, after more than 10 months, the Penguin is still in the port of Bilbao. Therefore, we decided to carry out the monitoring work around the HarshLab floating laboratory device of Tecnalia. Although the floating lab is not a WEC, it is very similar and can be used as a good model for the potential reef effect associated to floating objects. The dimensions are close to those of a WEC with mooring lines that are similar to those used for the installation of some WECs. As it has been previously published, the placement of any artifact in the sea can have an attracting effect on fish communities, especially if it is floating *[5]–[7]*. Therefore, this option was considered as a mitigation strategy to the fact that Penguin WEC-2 was no longer operational in BiMEP.

HarshLab is an advanced floating laboratory developed and operated by Tecnalia Research for the validation and testing of materials, components and equipment in a real offshore environment (Fig. 6).

The installation of the first HarshLab version (HarshLab 1.0) in the BIMEP area took place in September 2018. It was moored at a depth of 65 m and at a distance of 1.8 nautical miles. The second version (HarshLab 2.0) was moored three years later, in June 2021, at the same location (Fig. 2). According to Tecnalia, this location ensures 100% offshore testing conditions, perfect for evaluating new materials and solutions against corrosion, aging and fouling.

The laboratory has a diameter of 8.5 m and a height of 7 m. It has an outdoor area of 60 m^2 and an indoor area of 57 m^2. It is ready to perform tests in the atmospheric zone, splash zone, immersion zone, seabed zone and is also prepared to test antifouling solutions in dynamic conditions. In 2023, it will be connected to the BiMEP submarine network, which will provide power and fiber optic communications. Until then, it will be powered by a renewable energy generation system that will allow data from the installed equipment to be collected and transmitted in real time from sea to shore.

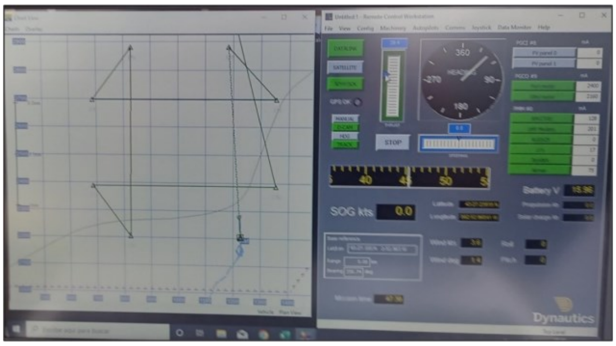

Fig. 4. Main panel of Dynautic's Navigation System of ITSASDRONE. Left side, programmed track; right side, main panel of navigation indicators (Source: AZTI).

B. *ITSASDRONE tuning and conditioning.*

The ITSASDRONE is an autonomous marine surface drone for long-term missions (3 months or more), capable of performing different tasks autonomously (Fig. 1) by means of an automated remote control with radio or satellite communication (Fig. 3). This catamaran (designed and built by BRANKA Solutions Inc.[1]) has been used to conduct fish monitoring surveys in the BiMEP test site.

It operates on 100% renewable energy in the marine environment and has a zero-emission propulsion system. The system has a length of 145 cm, beam of 207 cm, draft of 50 cm and weight of 50 kg. With 2 electric thrusters and two solar panels, it can reach 3-4 knots. The applications of the drone can range from oceanographic, meteorological or biological research to surveillance by marine authorities, including target monitoring.

The ITSASDRONE navigation system has been developed by Dynautics Ltd[2]. The software developed allows an operator to monitor and control a vehicle from a remote location or even from the vehicle itself. Thus, it is possible to connect through analogue signals to various engines and also to on-board sensors such as GPS, MEMS motion sensors, compasses, speed logs. Thus, the track or trajectory can be programmed by designing a sequence of "waypoints" (Fig. 4).

[1] https://www.brankasolutions.com/en

[2] https://www.dynautics.com/

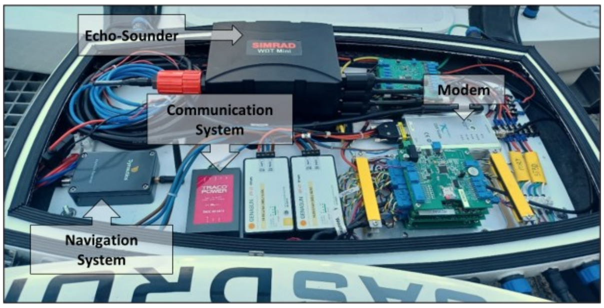

Fig 5. Marine station system (Source: AZTI)

The main panel of the software provides real-time displays of required and achieved machine settings, water and ground speeds in two axes, yaw rate, heading, wind and tide. The recorded data is logged into a file for later analysis.

C. *Data collection*

A Wideband Autonomous Transceiver Mini (WBAT mini) echosounder developed by SIMRAD was integrated into the ITSASDRONE (Fig. 5) to collect acoustic data. The WBT mini is a Simrad EK80 programmable, stand-alone, split-beam acoustic echosounder. In this scenario, 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 (Fig. 6) to identify significant schools of fish to assess the potential aggregation effect of the device.

It must be taken into account that acoustic recordings are not selective, so it is necessary to perform a post-processing of the data to ensure that the acoustic energy used for the analysis is exclusively associated with biological elements.

The first step is to scrutinize the echogram and manually eliminate the echoes of the seafloor as well as possible traces associated with noise. A minimum detection threshold of -60 dB [16] was also applied to discard echoes that are not of interest to the study (e.g. plankton) and retain only echoes associated to fish. Then, acoustic energy is echo-integrated by depth and time in cells of 500 pings x 10 m depth. The acoustic density of the fish was estimated by calculating the Nautical Area Scattering Coefficient (NASC, s_A, $m^2\ nm^{-2}$ [26]), and used as a proxy of biomass of the fish. Finally, by mapping the acoustic energy around each structure and plotting the relative abundance as a function of the distance of each cell from the center of each installation, it was possible to assess the impact of the presence of structures on the fauna in the area.

The fish monitoring survey took place on August 30, 2022 between 12:00 - 15:00 GMT in the BiMEP area (Fig. 7). The ITSASDRONE was towed by a 6.0 m long and 3.0 m wide support vessel (OLATU) from the port of Armintza (Basque Country, Spain) to the initial survey point and, after data collection, it was towed back to the harbor (Fig. 8 top). Prior to departure, the remote control was tested inside the limits of the harbor using a specifically designed docking station (Fig. 8 bottom) for deployment and retrieval (Fig. 9). The ITSASDRONE navigated following the predefined transects (Table I) using an automated remote control (Fig. 10).

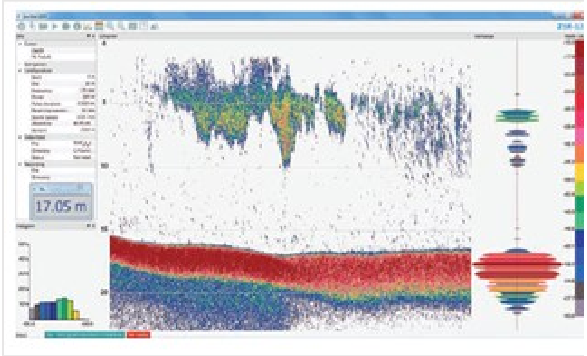

Fig. 6. Backscattering data of WBT echo sounder integrated in the ITSASDRONE (source: AZTI).

TABLE I
SELECTED WAYPOINTS (WP) COORDINATES (WGS 84; DECIMAL DEGREES) AND CONSECUTIVE DISTANCE BETWEEN WAYPOINTS IN METERS (SOURCE: AZTI).

WP	Transect	Lat	Lon	Distance (m)	Cum. Distance (m)
P1	VE	43.4541	-2.8863	0	0
P2	VE	43.4586	-2.8863	500.04	500.04
P3	HS	43.4554	-2.8881	380.51	880.55
P4	HS	43.4554	-2.8819	500.11	1380.66
P5	VW	43.4541	-2.8838	211.60	1592.26
P6	VW	43.4586	-2.8838	500.04	2092.30
P7	HN	43.4572	-2.8881	381.59	2473.89
P8	HN	43.4572	-2.8819	500.10	2973.99
A1	A1A2	43.4682	-2.87486	1479.33	4453.32
A2	A1A2	43.4381	-2.88584	1226.48	5679.8
A3	A3A4	43.4721	-2.88029	745.41	6425.21
A4	A3A4	43.4646	-2.88030	839.10	7264.31

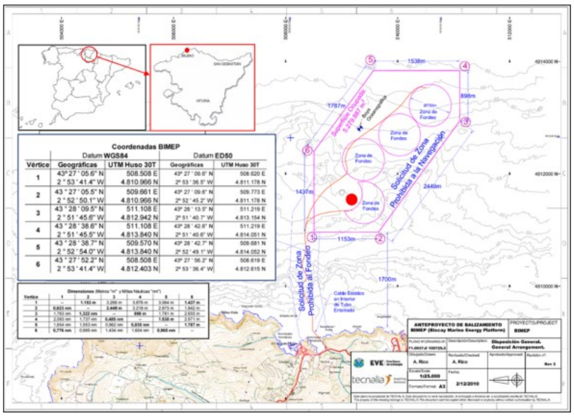

Fig. 7. HarsLab 2.0 position (red dot) in BIMEP area.

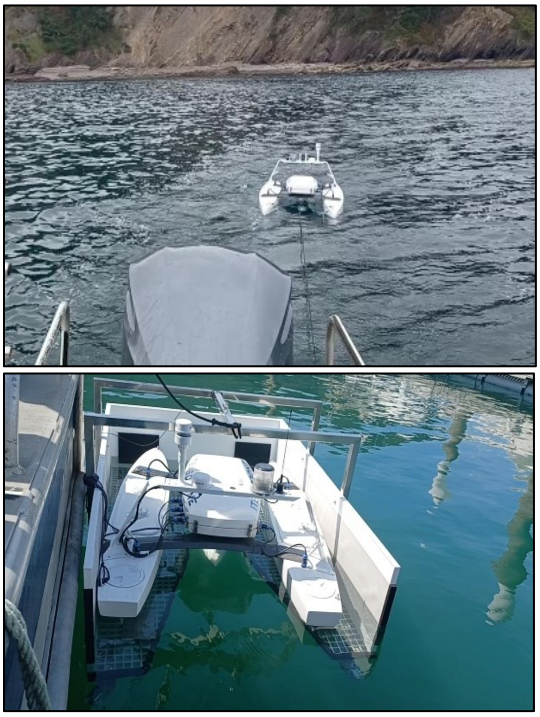

Fig. 8. ITSASDRONE towed by OLATU yacht (top), ITSASDRONE inside the docking station (bottom) (source: AZTI).

III. RESULTS

A. Conditioning and tuning of the ITSASDRONE

The drone, designed and constructed by BRANKA Solutions Inc. in collaboration with AZTI, underwent conditioning and tuning activities in 2021 to enhance its performance. This involved physical modifications like replacing broken propellers and designing a docking station, as well as improving the communication and navigation system. During the summer of 2021, the ITSASDRONE underwent its first trials in the Urdaibai estuary. After ensuring proper communication between the drone and the Ground Control Station, the navigation

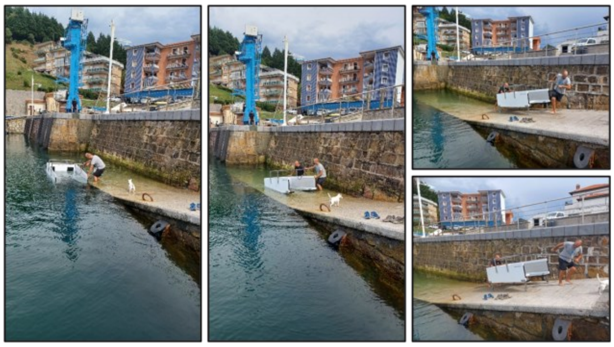

Fig 9. Retrieval of docking station in Armintza's harbor (source: AZTI).

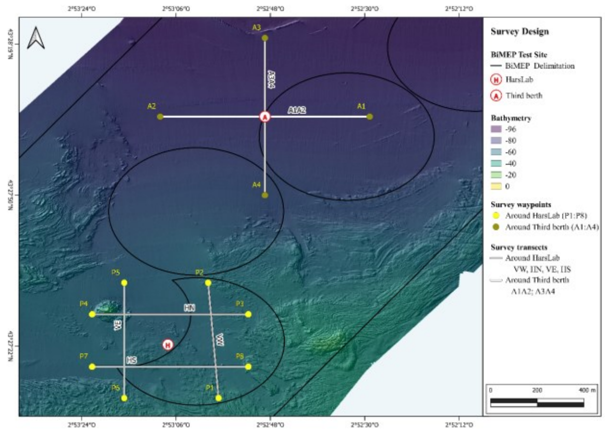

Fig. 10. Survey designed around HarsLab and Third berth area (source: AZTI).

system was checked, updated, and customized. This can be seen in the Youtube channel of AZTI[1].

B. Operational procedure

The operational procedure of the ITSASDRONE proved to be successful. The docking station, with its lightweight composite structure, allowed for easy deployment and retrieval, requiring only two people (Fig. 9). The drone was towed between the harbor and BIMEP area using the Olatu yacht, which also proved adequate for this task.

C. Navigation

The interface of the Dynautics navigation system is neither smart nor intuitive. Its appearance is sometimes confusing and requires from the user a good knowledge of the abundant options provided by the software configuration menus.

[1] https://youtu.be/12XZhNtiFmA

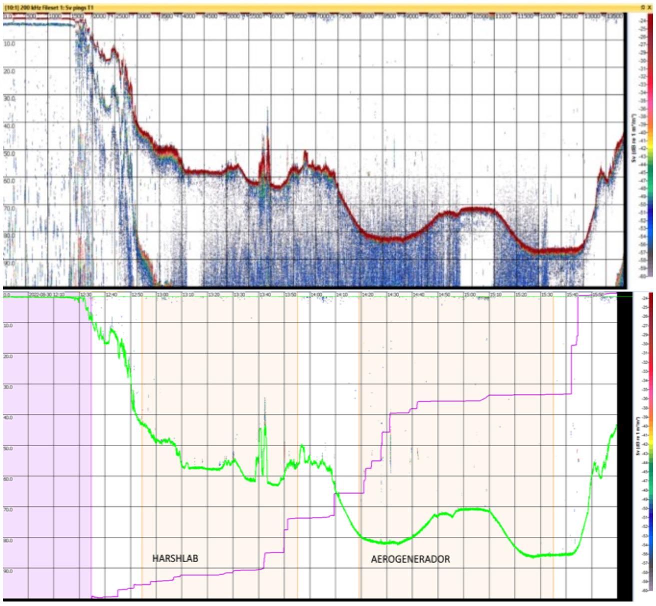

Fig. 11. Echograms showing an acoustic energy distribution along the entire acoustic survey. (Top) echogram showing the distribution of raw acoustic energy during the entire BiMEP acoustic survey run, from the departure of the Itsasdrone from Armintza harbor to its return to port. The grid shows the 500 ping x 10 meter cells set up for echo integration. (Botom) The same echogram is shown after preprocessing that removes interference and noise before echo integration. The green line indicates the bottom detection, and the violet line shows the cumulative relative acoustic abundance. The orange regions illustrate the two surveyed areas of analysis: HarshLab (H, left area) and third berth (A, right area). The color scale represents the acoustic energy and ranges from –60 dB to –24 dB.

The Dynautics navigation system of the ITSASDRONE was successfully configured according to predefined waypoints and transects around HarshLab, BiMEP's third mooring position and surrounding areas far enough away from the HarshLab device (denoted as "Control Site"). The ITSASDRONE should have navigated over these predefined transects, but the ITSASDRONE skipped two of the predefined waypoints of the transects (Fig. 9). The exact cause of this error is unknown, but it is likely due to a technical aspect of the Dynautics navigation software related to the configuration parameters of the diameter of the confusion zones defined around the waypoints.

An automatic remote control communication system works correctly both on the open sea and in tacking and lowering operations with the docking station.

The sea state, with a wave height of 0.5 m and a wind speed of about 8 knots, was sufficient for the correct navigation of the ITSASDRONE. The navigation speed of the autonomous vehicle varied between 2 and 4 knots.

In short, in order to provide a useful navigation system for the ITSASDRONE, the Dynautics navigation system should make changes and improvements related to the technical specifications, design and appearance of the software.

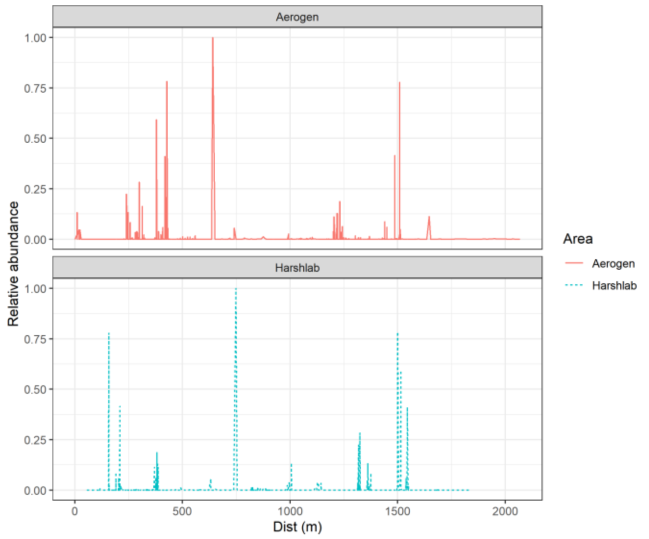

Fig. 12. Biomass relative abundance as a function of the distance from third berth and HarsLab in the surveyed area

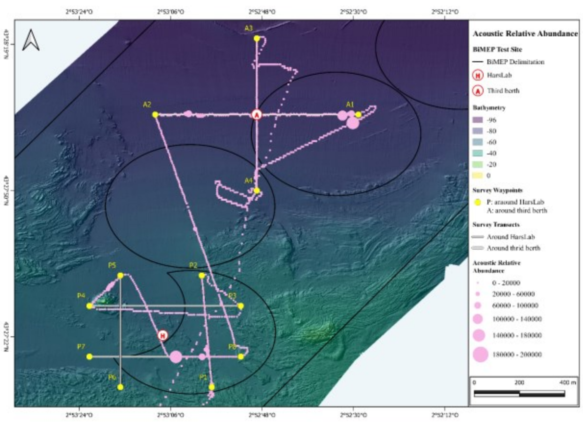

Fig. 13. Chart of the acoustic sampling carried out by the ITSASDRONE at BIMEP area. The diameter of the circles represents the acoustic abundance (NASC, mn2m-2) along the path navigated by the ITSASDRONE.

D. *Fish monitoring*

The spatial distribution of the echo-integrated energy along the entire acoustic track from the Armintza harbor and across the water column is illustrated in the echograms (Fig. 11). The upper figure (Fig. 11 top) displayed the raw acoustic data, prior to any post-processing, with pings along the horizontal axis and depth on the vertical axis. The red line represents the seabed, while the color scale indicates the acoustic energy in terms of volume backscattering strength (S_v, dB re 1 m^{-1}), which represents the mean echo levels that range from -60 dB (low) to -24 dB (high).

The processed echogram (Fig. 11 bottom) was obtained after applying various data processing techniques such as bottom detection, removal of bottom echo and noise interferences using filters and threshold values. The orange regions were defined to identify the two main surveyed areas: HarshLab (H, left area) and the third berth (A, right area). The violet line across the echogram represents the cumulative relative acoustic abundance of fish along the acoustic track, with each vertical step indicating an increase in the detected energy (and thus fish density).

The spatial distribution of NASC values along the acoustic tracks described schools of unidentified small pelagic fish distributed throughout the water column, predominantly near the bottom in the HarshLab area, where bottom depths were shallower (Fig. 11). In the third berth area (A point), unidentified small fish schools were also observed in the water column. However, no discernible patterns or spatial trends were observed in the horizontal distribution of energy. Values of NASC per cell estimated at the different distances from the center of the device revealed non-significant ($p<0.1$) differences with those cells belonging the areas along the access route from the port of Armintza, out of the area of influence of the HarshLab (Fig. 12, Fig. 13).

IV. CONCLUSION

The removal of the Wello Penguin WEC-2 from the BiMEP area was initially a setback for the team. As a mitigation strategy, the project team decided to conduct monitoring around Tecnalia's HarshLab floating laboratory device. Although the floating lab is not a WEC, it is very similar and can be used as a good model for the potential reef effect due to the presence of structures on the water surface. In general, the placement of any artifact in the sea can have an attracting effect on fish communities, especially if it is floating. The aim of the project was to monitor this possible effect thanks to the deployment of the ITSASDRONE device equipped with a Simrad EK80 programmable stand-alone split-beam acoustic echosounder.

The first conclusion of the project focuses on the use of ITSASDRONE for fish monitoring. According to the project results, the ITSASDRONE is a good type of autonomous marine surface drone for fish monitoring. It can be used successfully with small vessels. The main failure of the ITSASDRONE is related to the navigation system. The Dynautics navigation system needs to be technically updated and improved to avoid overshooting. A more "user-friendly" and simplified navigation system is also needed. The interface of the Dynautics navigation system is neither smart nor intuitive.

Regarding the possible reef or fish aggregating effect, schools of unidentified small pelagic fish were observed distributed throughout the water column, predominantly near the bottom in the HarshLab area and more detached from the bottom in the deeper third berth position. The acoustic sensors showed a relatively high abundance in the BiMEP area, generally as high as in the Armintza harbor access route. Although the HarshLab could be considered as a good model for the possible reef or fish attraction effect due to its similar dimensions to the WECs, it is true that it doesn't have specific elements of the WECs that could intervene or affect this potential effect. These are the underwater noise generated by the moving parts of the harnessing machine inside the WEC and the electromagnetic fields of the exporting electric cables, which could generate an avoidance effect and compensate the attraction of the floating structures of the devices.

These results can be considered as the basis of a more comprehensive study to explore the association between Wave Energy Converters (WECs) and fish aggregations, however, the present results may already have direct implications for decision making regarding the use of marine structures for green energy harvesting.

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