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Obsea: a test site to develop marine ecosystems monitoring techniques by acoustic devices

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***Abstract* – Over the past years different activities related on marine ecosystems monitoring techniques have been carried out at OBSEA observatory. The OBSEA is a cabled observatory placed at 4 km from the coast of Vilanova i la Geltrú, Barcelona (Spain), and at 20 m depth, which has been in operation for more than 10 years. The special characteristics of the OBSEA platform (e.g. unlimited power supply, high bandwidth communication, and easy access) offers an extraordinary opportunity to develop and test different acoustic monitoring techniques. In this framework, many methods have been deployed and tested on target monitoring techniques, which goes from hydrophones surveillance, to target tracking using acoustic range-only methods by the use of autonomous underwater vehicles.**

I. INTRODUCTION

Based on studies aiming to explore biodiversity and monitor ecosystem functioning, it is observed a great variability in the sampling of marine species. This variability may be produced by rhythmic population displacements at tidal, day-night, and seasonal periodicities. All this in the context of growing human impacts in the sampling areas. In this complex scenario, and under the Marine Strategy Framework Directive [1] of the European Community, the development of new monitoring technologies aims to explore the fauna, its rhythmic activity and controlling habitat cycles. The use of cabled observatories located on the bottom of the sea and equipped with video cameras will allow to study in real-time the faunal composition, the behavioural rhythms, and resulting community dynamisms with high resolution and for a long period of time [2]. Fluctuations in video-counted individuals can be used as indicator of populational rhythms and then related to surrounding habitat conditioning in terms of causeeffect principles, by measuring at the same time different oceanographic, chemical, and geologic parameters. To increase the spatial coverage and enable strategic changes in the update of data collection, mobile platforms will be employed. Therefore, the spatial representation of fixed observatories, will be complemented by the use of flexible and adaptive monitoring platforms, vehicles (autonomous underwater vehicles) and underwater robots (crawlers), which work in cooperation both spatial (various nearby areas) and temporal (coordinate with each other). That multiparameter coordinated monitoring is a challenge that must be tackled in order to implement standardized protocols in data acquisition and automation in biological indicators monitoring process that allow modelling of rhythmic activity and control of habitat cycles.

Here, we present the latest advances and tests conducted at OBSEA observatory (`www.obsea.es`) [3] in the area of acoustic target localisation. The OBSEA was installed on May, 2009 at a 20 m depth in the marine reserve *Colls Miralpeix*, 4 km offshore of Vilanova i la Geltrú (Catalan Coast, western Mediterranean). This underwater observatory is connected to a land station through a cable, which is composed of six single-mode optical fibres for data transmission, one central copper conductor tube, and one aluminium shielding sheet, enabling continuous transmission of data and power. The sea node (Fig. 1) contains a junction box with eight connectors which provides power and communications to a wide range of instruments (e.g. a broadband seismometer (Trillium 120 P) and a Current, Temperature and Pressure (CTD) sensor (SBE 37 SMP)). In addition, the underwater node is connected to a surface buoy which have their own instruments.

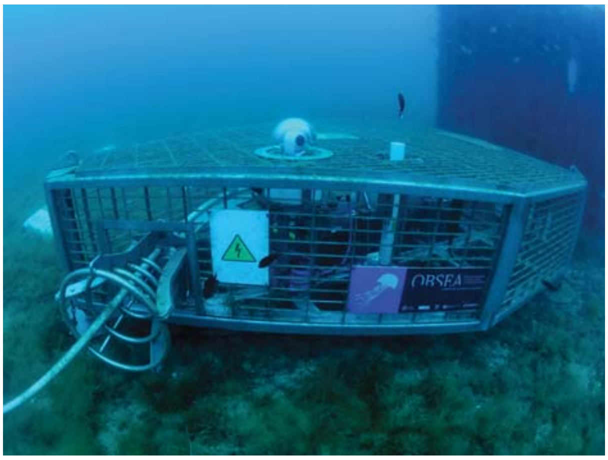


Fig. 1. OBSEA, an underwater cabled observatory located at 20 m depth and 4 km offshore of the Catalan Coast.

The structure of the paper is divided in chapters, each one focused on a particular topic about acoustic localisation methods as follows:

- Static target localisation using AUV
- Moving target tracking using AUV
- Range error correlation with sea state
- Marine animal tracking using acoustic tags

where an Autonomous Underwater Vehicle (AUV) developed at Universitat Politècnica de Catalunya, which is called Guanay II [4], Fig. 2, is also used.

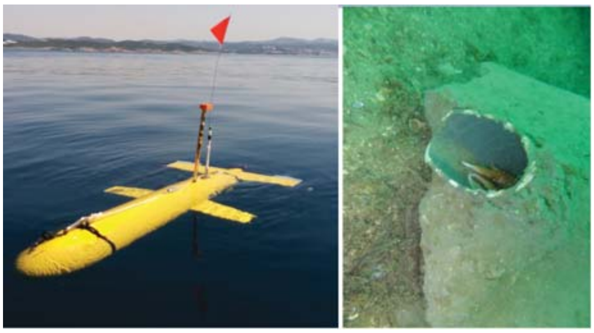


Fig. 2. Photography of the Guanay II AUV during a field test conducted in the OBSEA (left). And a Norway lobster in an artificial burrow near the OBSEA area (right).

II. STATIC TARGET LOCALISATION

The range-only and single-beacon (ROSB) methods [5] can be used to localise and track underwater targets. These methods over-perform traditional Long Base-Line (LBL) systems (e.g. deployment complexity). In general, the ROSB methods are based on an autonomous vehicle which is used as a tracker (or observer). This vehicle conducts a set of manoeuvres in order to track (or localise) some target(s). In this manoeuvre, the vehicle periodically performs new slant range measurements using the Time Of Flight (TOF) of exchanged messages between the tracker and the target. Then, applying triangulation methods the target position can be estimated.

In this test, the acoustic modems used were from linkQuest Inc., one installed on the OBSEA's buoy, and another one installed on the Guanay II AUV. The path designed for this test was two pentagon lines around the target, which had respectively 100 m and 200 m of radius. The AUV was constantly measuring the ranges between the target and himself, with a period of 30 seconds, approximately.

A. *Field test results*

The path conducted by the AUV can be observed in Fig. 3, where the big blue circles are the waypoints (WP) of the path, the small grey circles are the true path conducted, and the red triangle is the true target position. Moreover, the black start and square indicate the start point, and the end point, respectively.

We can see that the Guanay II started at 50 meters from the target and then it did a first pentagon, then it went to the centre and started the second trajectory. During all the path, the AUV acquired 83 ranges between himself and the target position.

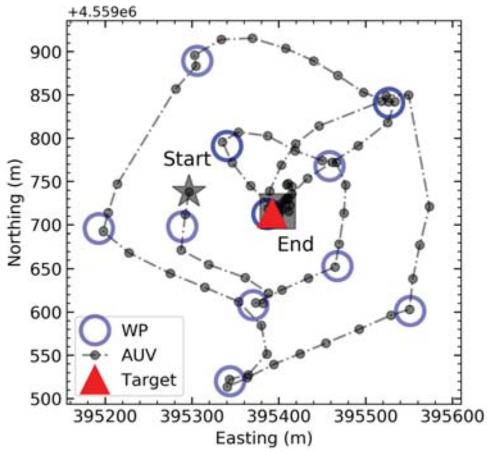


Fig. 3. Guanay II trajectory during the field test (blue dots). Moreover, we can observe the initial and final position (black start and dot respectively), the waypoints which indicated the path (big blue dots), and, finally, the true target position (red triangle).

B. *Postprocess results*

Several simulations could be performed using the information acquired by the Guanay II during the test. This allows us to simulate different scenarios with different noise levels or different algorithms in order to study their performance.

For example, the target position estimations obtained during the OBSEA test using different algorithms are shown in Fig. 4, where the last 10 estimations of the following filters are represented: Particle Filter (PF), Extended Kalman Filter (EKF), Unscented Kalman Filter (UKF), Maximum A Posterior (MAP) estimation, Least Square (LS). The figure also shows the error covariance (elliptic lines). This covariance represents a 2D standard deviation of the estimations with a 95.45% of confidence interval.

We can see that the MAP estimation method was the best one, which had the best accuracy and precision.

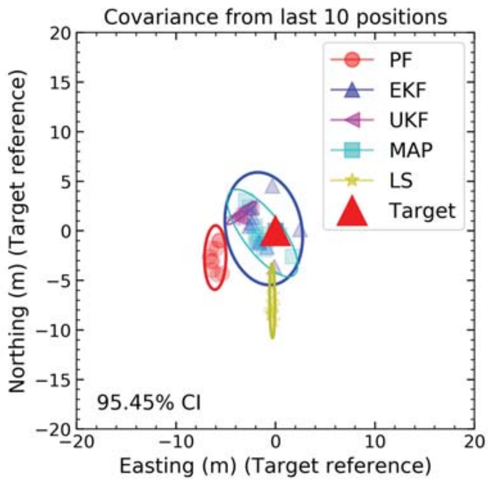


Fig. 4. Representation of the last 10 target estimations during the OBSEA test, using the PF, EKF and LS algorithms. Ellipse circumference shows the point's covariance.

III. MOVING TARGET TRACKING

The S2C-18/34 acoustic modems from EvoLogics company were used to measure ranges between the observer and target. In this case, a small boat was employed as observer and a buoy as a target, Fig. 5.

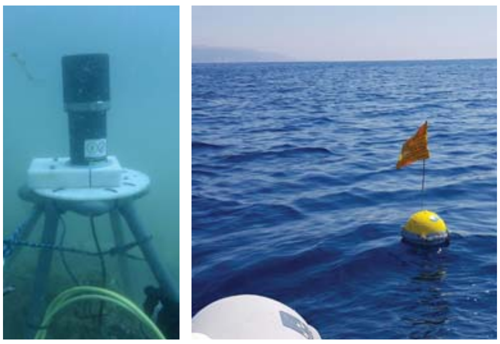
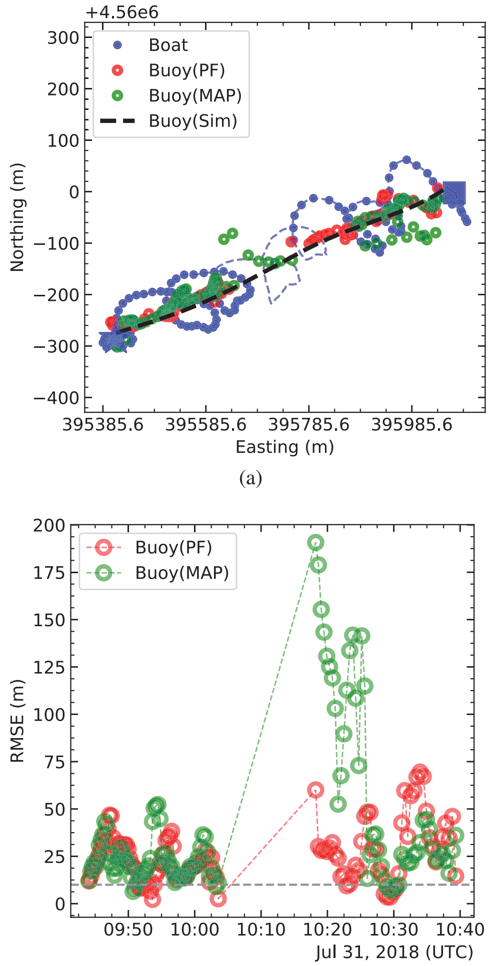


Fig. 5. Underwater photography of an acoustic underwater modem (left) used as a target to localise during the static test, and the drifter buoy (right) used as a target to track during the dynamic test conducted in the OBSEA.

A. Results

The results obtained are presented in Fig. 6a, where the boat path (blue dotted line), the range measurements (blue dots), the real target position (black dotted line), the Particle Filter (PF) estimation (red dots), and the Maximum A Posteriori (MAP) estimation (green dots) are represented. On the other hand, Fig. 6b shows the Root Mean Square Error (RMSE) between the estimated target position and its real position. Whereas the communication with the drifter was lost around 10:10 h UTC, the boat was able to track the drifter as soon as the communication was available again.

As a main difference between the algorithms studied, we can see that the MAP estimation method had a recovery time greater than the PF algorithm.



(a)

(b)

Fig. 6. (a) The small blue dots represent the X-Y coordinates where a range measurement between the boat and drifter was carried out. The dotted blue line represents the boat trajectory. The red dots represent the target's estimation using the PF algorithm, whereas the green dots represent the target's estimation using the MAP algorithm. The black slashed line is the drifter trajectory. (b) represents the RMSE between the real and the estimated target's position.

IV. RANGE ERROR CORRELATION

On the other hand, due to the different instruments that are continuously monitoring the OBSEA's area, different tests to correlate the sea or weather state have been conducted using the Evologics modems.

For example, in the framework of JERICO-NEXT project, this was done between the range accuracy and the see state. Some of the results are shown in Fig. 7, where the range variability is compared with the wave height and the buoy inclination. We can observe that the range variation was greater during the worst sea conditions. Because the acoustic modem M3 was attached on a buoy, the sea state had more influence on the measured ranges. Therefore, when an autonomous surface vehicle is used to localise and track underwater targets, the sea state is a key factor which must take into consideration to ensure an accurate estimated target position.

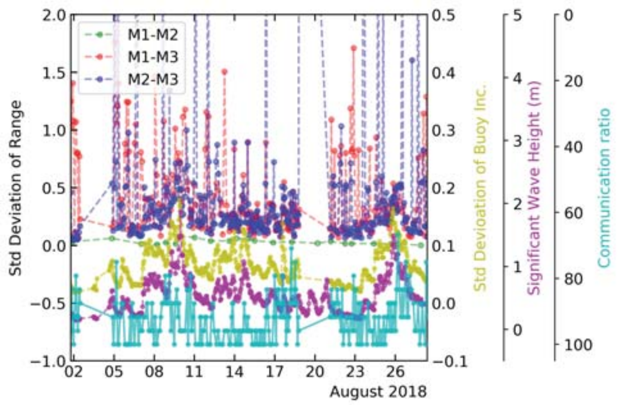


Fig. 7. Range standard deviation between three acoustic modems (M1, M2, and M3) compared with Buoy inclination and wave height. Test conducted on August 2018.

V. MARINE ANIMAL TRACKING

Beyond the potential global effect of climate change, the use of high impact fishing-gear methods has lead that many populations of marine resources are actually overexploited. For example, the Norway lobster stock assessment indexes show a reduction in the size of individuals, and a clear reduction in the density of their populations. To solve this problem, a greater efford to study and find sustainable management options is crucial.

In this framework, the project RESNEP (Marine no take areas as a tool to recover iconic Mediterranean fisheries in decline: the case of *Nephrops norvegicus*) was born. Here, the OBSEA observatory offers a great laboratory to tests different devices and methodologies, which then will be used in the real scenario.

Usually, acoustic tags are used to conduct behavioural studies of marine animals, such as movement patterns or presence/absence detection [6]. For example, in the OBSEA observatory, different tests to find the maximum range where the tag's transmissions can be received were conducted (e.g. in Fig. 8 the tag could be detected up to ~300 m).

On the other hand, thank to the OBSEA's instruments, we also could correlate a tag detection conducted by Vemco receivers and by standard hydrophones (Bjørge

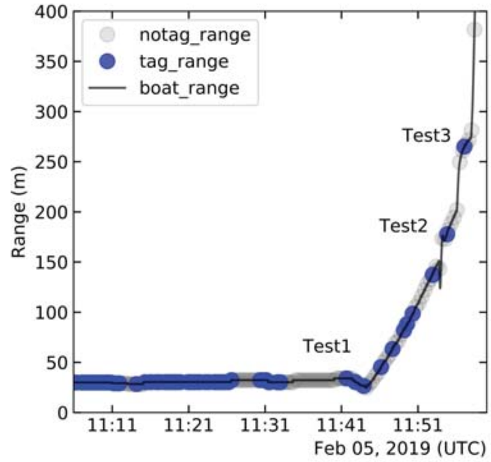


Fig. 8. Distance between the tag and the receiver (grey line) in meters, and when a tag's transmission was detected (blue dots) and when not (grey dots).

ASA, Norway, Naxys Ethernet 02345). For example, in Fig. 9 the time between pings for each tag's transmission is presented, which are compared with the detections conducted by the Vemco VR2AR receiver (blue stars).

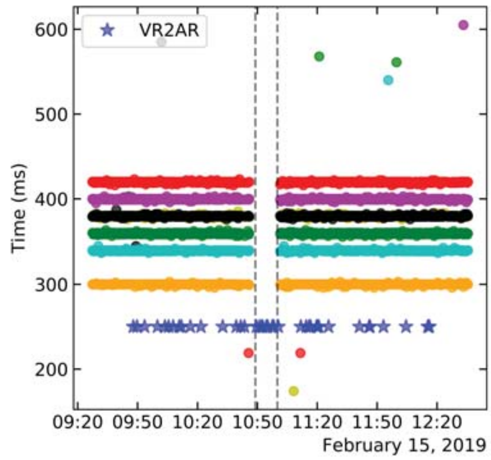


Fig. 9. Colour dots represent the time between pings for each tag's transmission. The blue stars represent the receptions conducted by the Vemco VR2AR receiver.

VI. DISCUSSION

As a main contribution, this paper presents a brief description of different solutions to track underwater targets by acoustic devices, focused on ROSB techniques. All these methods have been implemented and tested in the OBSEA observatory, a sea test site which have a great flexibility to conduct underwater experiments.

Moreover, we have demonstrated the great performance of ROSB methods to track underwater targets using AUV, for both static and moving objectives. In this paper, we have compered different algorithms (e.g. LS, EKF, MAP and PF), whereas the MAP technique had the best performance to localise a static target, the PF setting time was better to track moving targets (i.e. the PF convergence time was faster). Nonetheless, more tests with different scenarios (e.g. sea state and range measurement errors) should be conducted in order to find the best method overall. For example, a long study carried out at OBSEA shows a correlation between the sea state and the range error/variability, see Section iv.. This behaviour is especially appreciated when the acoustic modem is placed on the sea surface, which is the typical scenario in ROSB target tracking (where the tracker is usually an ASV).

Finally, we present the first sea trials to measure the maximum range which an acoustic tags can be detected. These kind of measurements are a key factor on methods such as the Area-only Target Tracking (AOTT). This novel technique, uses the presence/absence of tag ping receptions to compute a PF algorithm and estimate the position of the target. The AOTT is conducted by an AUV, such as in ROSB methods, and was firstly presented by [7].

VII. CONCLUSIONS

In this paper, different acoustic monitoring techniques conducted in the OBSEA observatory have been presented, where the use of autonomous underwater vehicles had an important role to extend the observable area beyond the cabled observatory. Some of this methods can be used to extend the marine animal monitoring techniques and increase the knowledge about their behaviour.

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