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Combining acoustic and optical cameras onboard an ROV as a detection and expertise tool for underwater preventive archaeology: a case study off Marseilles (France)

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Abstract: The development of preventive archaeology at sea and particularly offshore has led to the establishment of a protocol for geophysical detection and in situ identification of potential maritime cultural assets. Nevertheless, difficulties and issues remain in precisely characterising, and therefore selecting for in situ expertise, acoustic anomalies corresponding to isolated or scattered objects, which are potential indicators of homogeneous buried sites or sites at the surface but deteriorated or very old. A new protocol for a combined detection and visual expertise was tested, using an acoustic camera mounted on an ROV, during a deep archaeological survey in the Mediterranean. The results of this work demonstrate the relevance of this method, and point to a number of possible applications.

Keywords : underwater preventive archaeology, acoustic camera survey, ROV, deep archaeological detection

I. INTRODUCTION

The development of preventive archaeology in French waters, particularly over the last decade, has driven archaeologists to experiment with new tools and protocols for detecting archaeological sites that might be adversely affected by construction projects or exploitation of the seafloor and riverbeds. Although the main protocol implemented 10 years ago to identify large areas affected by offshore development projects [1], such as wind farms or submarine cable routes, enables detection of obvious archaeological sites emerging from the seabed, large areas of invisibility still remain [2]. To fully achieve the objectives of underwater preventive archaeology, it is therefore necessary to fully test and develop new hydrographic applications.

In the context of a deep-sea archaeological survey carried out in 2022 on the future route of an underwater cable off Marseilles, Inrap (Institut National de Recherches Archéologiques Préventives), in collaboration with Copetch-SM and in consultation with the Drassm (Département des Recherches Archéologiques Subaquatiques et Sous-marines), tested a systematic survey protocol using an acoustic camera and an optical camera on board an ROV. The results were conclusive, filling one of the gaps in the protocol used until now for remote sensing of submerged cultural heritage.

II. HYDROGRAPHY AND PREVENTIVE ARCHAEOLOGY IN FRANCE: A BRIEF OVERVIEW

For the past 10 years, the main stakeholders in preventive archaeology at sea in France[1] - the Drassm[2] and Inrap[3] - have been applying, for the assessment of vast zones with severe constraints, a detection and expert

[1] In France, preventive archaeology, which is carried out upstream of development projects to assess the risk of destroying archaeological remains and, where necessary, preserve them through study, has been carried out since 2001, on land and underwater, within a very precise regulatory framework. State services (Ministry of Culture, Drassm and SRA) prescribe archaeological diagnostic when deemed necessary, and Inrap (for underwater cases) or other public operators (for land cases) carry out the diagnostics.

[2] The Drassm (French Ministry of Culture) is the department that issues prescriptions for preventive archaeology at sea. The Drassm also carries out part of the archaeological assessments, in particular the survey and analysis of hydrographic data for archaeological purposes.

[3] Inrap, a public institute under the aegis of the French Ministry of Culture and Research, is the historic French operator and the only one in charge of diagnostics in the maritime domain. Inrap has an underwater division which carries out preventive operations at sea and in rivers [3].

appraisal protocol introduced in 2014 on the first underwater archaeological evaluations of wind farm projects in French waters (Fontaine et al. 2019).

This protocol comprises two main stages:

- a first stage consisting of a systematic survey and analysis of hydrographic data, previously acquired by the planners or acquired by the archaeological team on his own, aiming to establish a selection of anomalies with archaeological potential.
- a second stage consisting of an expert appraisal, by human or robotised diving, of these targets in order to characterise them, define their nature and, where relevant, their function, chronology and state of conservation.

The hydrographic survey, whether conducted by the planners or by the archaeologists themselves, is carried out according to minimal specifications that allow it to be read for archaeological purposes. It combines several sensors (Multibeam, Side-Scan Sonar, Magnetometer and, less often, Sub-bottom profiler), the results of which are systematically correlated in order to select the targets to be assessed in situ.

In broad terms, detection is effective for evident archaeological sites, whether wrecks or built structures, and for isolated objects larger than fifteen centimetres, so long as they emerge, at least partially, from the seabed.

Nevertheless, among the still problematic areas of invisibility, we would highlight the following:

- the difficulty of detecting fully buried archaeological remains
- the severe limitations of detection in coastal areas, in very shallow water[4]
- the difficulty in precisely characterising, and therefore selecting for in situ expertise, acoustic anomalies corresponding to isolated or scattered objects, which are potential indicators of homogeneous buried sites or sites that are at the surface but deteriorated or very old.

It is this third pitfall that the option of a systematic ROV survey using an acoustic camera combined with a high-definition optical camera makes it possible to overcome, at least in certain configurations. In fact, when the anomalies that are difficult to characterise are numerous, as it is impossible to be exhaustive, choosing a reasoned selection of sites to be appraised in situ sometimes comes down to almost random sampling.

Until now, in France at least, the use of an acoustic camera on board an ROV had only been used as an auxiliary tool to locate, easier and faster, a previously selected target based on hydrographic data. Here, it was used as a means of continuous acoustic imaging to conduct a systematic survey in real time over the entire archaeological diagnostic area. In this way, the detection of anomalies and the expert appraisal of the total number of anomalies detected were carried out at the same time, without any prior discrimination and without data processing

III. A CASE STUDY: ARCHAEOLOGICAL DIAGNOSIS PRIOR TO AN UNDERWATER CABLE PROJECT NEAR MARSEILLES

Prior to a project of burying two sections of an underwater fibre-optic telecommunications cable off the coast of Marseilles, the French Ministry of Culture (Drassm) prescribed an archaeological diagnosis, to be carried out by Inrap during 2022. Concerns about the operation lay in the cumulative length of the right-of-way (50 km), the surface area (1,501,800 m^2), i.e. a corridor 30 m wide on either side of the future cable route, as well as the depth and relief of the seabed, which, situated on the edge of the Mediterranean continental shelf, crossed a canyon zone that in some sectors exceeded 500 m in depth.

According to the above-mentioned protocol, the operation comprised several successive phases:

- Step 1- Analysis of the data acquired by the planner, namely a hydrographic dataset (MBES and SSS) and 77 hours of video footage taken using an ROV along the route of the future cable.
- Step 2 - An additional hydrographic survey if the planner's data appeared insufficient to establish the archaeological diagnosis.
- Step 3 - An ROV expert appraisal of targets selected from anomalies identified as potentially anthropogenic and archaeological.

The first stage identified 12 anomalies based on SSS data and a further 113 based on video recordings. It should be noted that three of these anomalies, of an archaeological nature, had already been declared as such by the planner prior to the archaeological diagnosis: two isolated amphorae and a cluster of ceramics.

However, analysis of the data also revealed that the specifications of the acoustic survey were not sufficient for an archaeological reading, that gaps in the coverage left areas of invisibility and finally that the ROV's field of view did not give an overall view of the right-of-way on either side of the cable route (Fig. 1).

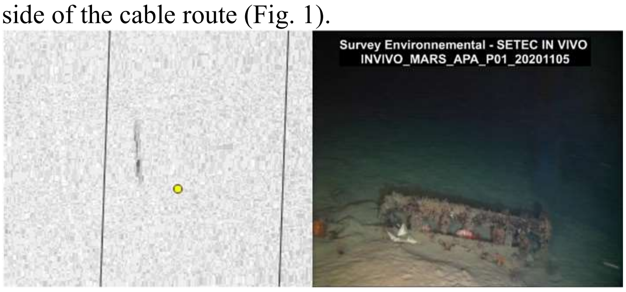


Fig.1: Anomaly identified on the low acoustic data of the initial survey and its visual correspondence during the Rov survey of Setec In Vivo.

[4] Inrap is also carrying out tests to detect buried remains using a sub-bottom profiler at very shallow depths [4].

In consultation with the Drassm, it was therefore agreed to carry out the prescribed additional survey following the usual protocol. To optimise the intervention time and avoid redoing the SSS survey over the entire route and then redoing the selection of targets to be appraise, we decided to carry out steps 2 and 3 at the same time by carrying out a systematic survey over the entire corridor, using an ROV equipped with an acoustic and an optical camera.

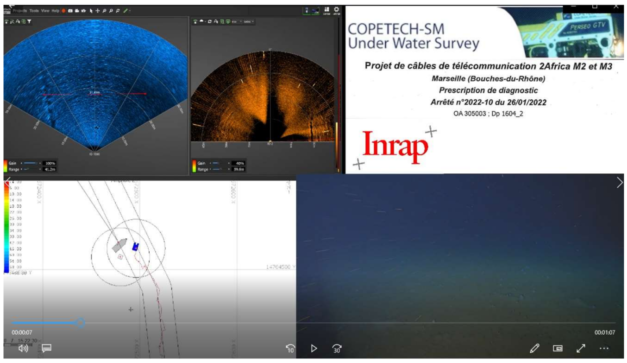
A. Process

Fig. 2: deployment of the ROV on board (S. Fontaine, Inrap)

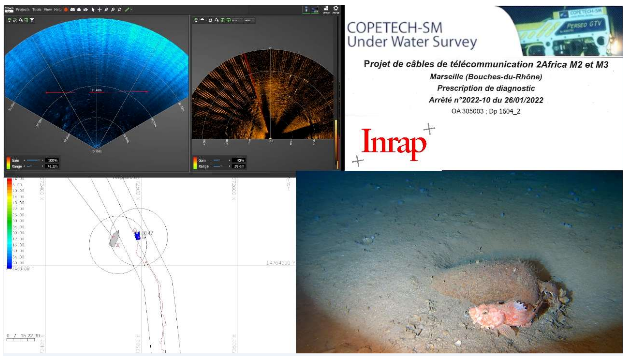
Fig. 3: Gemini 720is acoustic camera, positioned at the front of the ROV (S. Fontaine, Inrap)

This mission, carried out over 11 days[5] in July 2022, covered the 50 km route, over a corridor 30 m wide (circa 1 502 000 m2) and between 100 and 500 m deep. The ROV used was a Perseo-GTV (Copetech-SM), equipped with an acoustic camera (model: Gemini 720is), an HD optical camera, and a fixed-position side-scan sonar (Fig. 2-3).

The ROV dived each day at an entry point along the route of the future cable. The range of the acoustic camera was configured to provide constant visibility over a 40 m wide corridor. The frequency and gain of the acoustic camera have been adjusted to easily discriminate between hard materials such as ceramics and metal. Every acoustic anomaly appearing in the field was assessed and documented using the HD optical camera (HD video and pictures) (Fig. 4), and if needed some samples were taken.



A.



B.

Fig. 4a and b: Example of simultaneous feedback of optical, acoustic, sonar videos, and ROV positioning (J. Sialelli, Copetch-SM).
A- An acoustic anomaly appears in the frame of the acoustic camera screen (top left), 7 meters right in front of the Rov.
B- The acoustic anomaly is still visible just below the Rov on the acoustic camera screen (top left) and is documented by the optical camera (bottom right).

This solution, which is perfectly effective on an evenly sloping seabed, provided an exhaustive view of the seafloor over the area of the prescription. A fairly large number of anomalies, both geological and man-made,

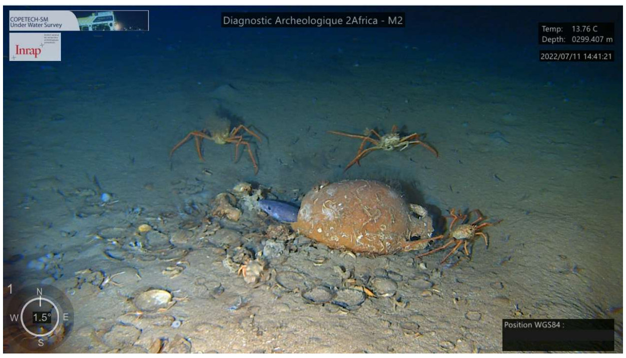
[5] Out of 12 hours of daily work, an average of 6-7 hours of acquisition was carried out.

which had not been identified either from the prior acoustic data or from the video recordings of the planner's first ROV survey, were identified.

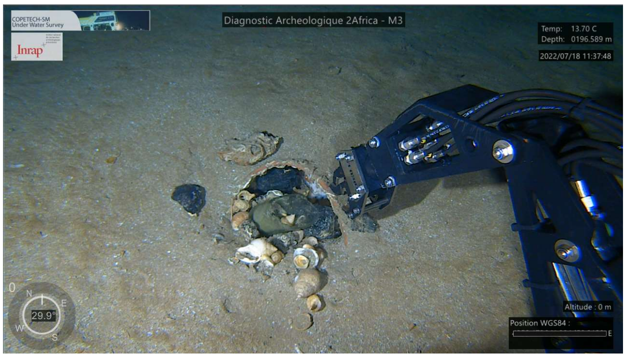
B. Results

In addition to the two amphorae already identified during the first “classical” survey (In Vivo-Setec), three other isolated amphorae (Fig. 5) and a wrought-iron cannon probably dating from the 16th century, which had not been previously identified, were detected and documented. Over and above these results, the method used, covering an area of this size ensured that all the project area was exhaustively examined (over 95% coverage) and that all anomalies of the seabed relief, even very small ones, even geological, have been assessed visually (Fig.5). Even if the acoustic data acquired by the SSS prior to the archaeological diagnosis had been of better quality, the amphorae and cannon would not necessarily have been visible, or sufficiently characterisable to have been selected for an in situ assessment dive.

This first experiment clearly demonstrated its relevance for systematic surface detection, preferably on a regularly sloping seabed. The configuration of a narrow linear right-of-way lends itself perfectly to this type of investigation, but the method could also be transposed to wider right-of-ways by carrying out a survey using successive transects. Concerning the duration of the fieldwork, the ratio is satisfactory in comparison with the cumulative time required for the SSS acoustic survey, processing and analysis of the data, followed by a survey by diving in situ. Certain improvements or additions to the installation and settings of the acoustic and optical cameras could make it even easier to adapt this protocol to other contexts. In the very near future, we plan to extend the application of this protocol, which combines a systematic acoustic survey with an expert assessment, to freshwater, in lakes or rivers, or other contexts with severe constraints other than depth (turbidity, pollution, pyrotechnic risk, etc.).

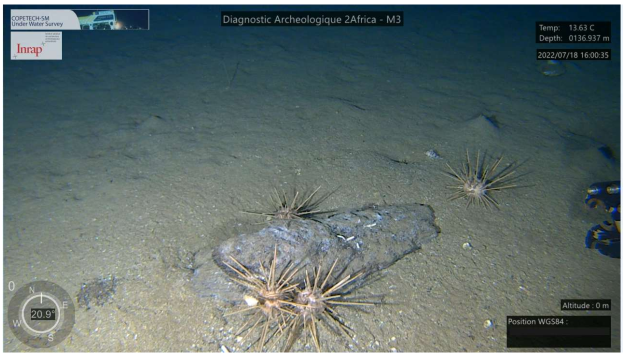


A. Amphora Almagro 51c laying on the seafloor



B. Half amphora buried in the sand

C. Recent coffee cup buried



D. Small piece of wood

E. Cable loop partially buried

Fig. 5 (A-E): Examples of small artifact, archeological or not, detected by the acoustic camera and visually appraised by the Rov (Copetech-SM)

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