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# A low cost Unmanned Surface Vehicle for mapping shallow-water UCH sites: Ancient and historical shipwrecks in Methoni bay, Greece

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***Abstract*** **– Advancements in remote sensing technologies and marine robotics have revolutionized the surveying of underwater cultural heritage (UCH), surpassing the limitations of conventional means. In shallow water areas, Unmanned Surface Vessels (USVs) offer advantages over research vessels, such as extended autonomous operation, maneuverability, low power consumption, and reduced environmental impact. In this study, conducted at two wreck sites in Methoni Bay, Greece, an USV was employed, equipped with a side scan sonar system operating at frequencies of 455/800 kHz, which was integrated into the Lowrance Elite-7 Ti sonar device. The collected data sets were processed using ReefMaster and SeaView software to generate accurate mosaics for inspecting and mapping UCH sites. The aim of this work is to demonstrate the use of USVs as a viable method for investigating and documenting underwater cultural heritage sites situated in shallow water environments.**

## I. INTRODUCTION

Advancements in remote sensing technologies have enabled researchers to surpass the 50-meter barrier for surveying underwater cultural heritage (UCH) sites previously achievable only through scuba diving. Acoustic and optical technologies are used for producing high-quality digital 3D reconstructions for studying UCH in non-intrusive ways. Conventional marine remote sensing methods have been extensively employed over the past few decades to monitor Underwater Cultural Heritage (UCH) in numerous instances [1]–[5].

These methods include the use of side-scan sonar (SSS), which can create highly detailed maps of the shipwreck site and evaluate the texture of the surrounding seafloor based on backscatter data. Multibeam echo sounders (MBES) provide bathymetric maps valuable not only for the mapping of UCH sites but also for the palaeogeographic reconstruction of coastal areas of great archaeological importance. Subbottom profiling systems (SBP) define the seafloor stratigraphy, identify potential extensions of the wreck beneath the seafloor and/or buried archaeological items and provide valuable insights regarding the quality of the sedimentary layers where the target is located [6]. Moreover, ground truthing surveys support the remote sensing research. ROVs and underwater cameras provide valuable visual census for inspection and validation of the promising sites detected by remote sensing surveys.

Geophysical studies utilizing conventional survey vessels in shallow water areas are not optimal due to practical limitations such as hazards in navigation and limited boat accessibility in regions with extremely limited water depth. Research vessels often have specific minimum depth requirements, preventing them from operating in depths above a certain threshold. An additional factor that renders the process of mapping shallow waters with traditional techniques difficult is the fact that such environments intensify the impact of disturbances arising from propellers.

Unmanned Surface Vessels (USVs) operate autonomously over prolonged periods of time and extend the area under investigation, aided by non-conventional energy sources. USVs possess enhanced maneuverability and can easily navigate natural or artificial obstacles due to their small size. In addition, they require low power consumption, have reduced maintenance requirements, and entail fewer personnel for operation, resulting in substantial savings in human resources and fuel costs. Another advantage of USVs is that they operate with minimal acoustic and electromagnetic signatures, minimizing the potential risk to the marine environment [7], [8]

USV applications in mapping UCH areas are rather limited as the technology is still getting established as an effective and universal method. Some of these applications include research performed in submerged archaeological structures such as ancient harbors and shipwrecks. In [9] the implemented USV simultaneously used geophysical and photogrammetric sensors for mapping a submerged harbor in the Gulf of Naples. This interdisciplinary study provided a comprehensive analysis of the natural and man-made landscape and a detailed mapping of the Nisida Roman harbor's submerged remains, resulting in a vast dataset of highly accurate four-dimensional information. Similarly, [10] mapped a submerged archaeological structure at “Castel dell’Ovo islet” in Naples, Italy. [11] used a multibeam sonar mounted Autonomous Surface Vehicles (ASV) to create a bathymetric model for monitoring and assessing the current state of a shipwreck located near the coast of Premuda island in Croatia. Similarly, in [12] the same ASV was used to perform bathymetric 3D reconstructions of ancient shipwrecks in ancient shipwreck sites in the Adriatic Sea. In [13] the autonomous surface vehicle “Pladypos” employed high-resolution imaging and remote-sensing instruments to generate photomosaics and microbathymetry maps of the seafloor in the Herodian structures at Caesarea Maritima, Israel.

This work aims to provide novel insights by demonstrating the effectiveness of Unmanned Surface Vehicles (USVs) as a valuable tool for exploring and studying underwater cultural heritage sites in the challenging context of shallow-water environments.

## II. SURVEY AREA

### A. *Physiography*

The survey area is located at Methoni Bay in the southwestern extremity of Peloponnesus (Greece) (Fig. 1). The Methoni cape and coast are the prominent natural physiographic features. In the southward direction, the Methoni bay seabed deepens gradually from the bay head down to about 40m water depth. The seabed is covered by sandy sediments. *P. oceanica* meadows also cover an important part of the seabed southwest worth of Methoni cape (Fig. 1).

### B. *Archaeological background*

The archaeological importance of the study area has been highlighted by underwater archaeological [14] and geoarchaeological surveys [15] and [16]. Underwater archaeological investigations started back in 1962 [14] bringing to light two ancient shipwrecks (sarcophagi 3rd c. AD, granite columns 5th c. AD). [15] studied three shipwrecks sites using conventional geophysical methods (MBES, SSS and SBP). In the context of this work, two out of those three shipwreck sites were re-surveyed using USV. Shipwreck site 1 (SW1) is located very close to the coast (Fig. 1) and is extending at water depths between 0.5 and 2.5m. This unidentified shipwreck is possibly connected to the naval battle between the Greek and the Turko-Egyptian fleet in April 1825 [15]. The shipwreck site 2 (SW2) lies 100m southeast of the Methoni cape is also unidentified and consists of an aggregation of marble blocks and columns [15].

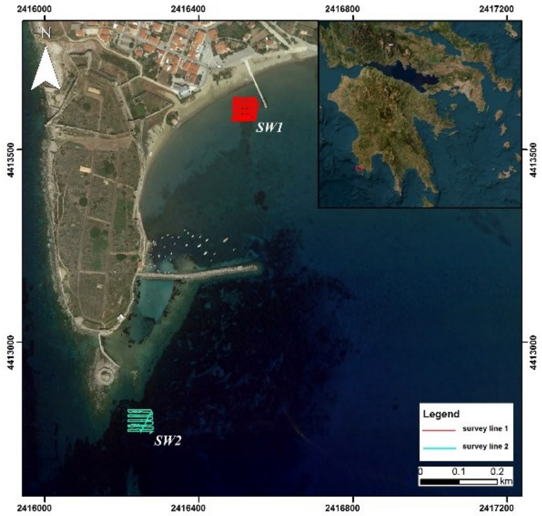


*Fig. 1. Survey area map showing the sites of the two shipwreck and the USV’s tracklines. (Google Earth-based imagery).*

## III. MATERIALS AND METHODS

### *A. Instrumentation and Survey design*

The USV survey of Methoni Bay was carried out in October of 2021. The research employed the i-USV170 model, a catamaran-shaped vehicle measuring 1.7m x 1.0m with a total weight capacity of 20 kg, developed by iMachines (https://imachines.gr) (Fig. 2). The USV featured a side scan sonar system operating at 455/800 kHz integrated within the Lowrance Elite-7 Ti sonar. The survey lines were tactically planned to ensure adequate coverage with a slant range of 22 meters (Fig. 1).


*Fig. 2. The iUSV170 used in the survey (https://imachines.gr).*

*B. Software*

Two software; SeaView developed by Moga Software and ReefMaster were used for the generation of the side-scan mosaics.

The original SSS sonographs obtained from the USV in .sl2 format underwent radiometric and geometric adjustments in both software. Radiometric corrections included compensating for beam patterns and normalizing ping energy levels, while geometric adjustments involved slant range correction and spatially registering each ping.

More specifically, in ReefMaster the Autogain, Brightness, Contrast, and Sharpening options were employed, along with the utilization of Min Curve and Range functions, to create the first mosaic. Similarly, in SeaView, the same process was followed to generate the second mosaic. Initially, optimal lines were created using ping trim and range techniques. Subsequently, the slant range correction tool was applied to effectively remove the water column. Finally, the automatic gain correction tool was carefully utilized, ensuring the application of optimal settings.

## IV. RESULTS AND DISCUSSION

*A. Shipwreck site 1*

The shipwreck site 1, from which acoustic data were collected is located a short distance away from the Methoni Bay shoreline and stretches across water depths ranging from 0.5 to 2.5 meters. Figure 3 displays the corresponding georeferenced side-scan sonar mosaic. The mosaic portrays two areas of different reflectivity. The interpretation of the mosaic, combined with ground-truthing data, showed that the low reflectivity (dark tone) represents featureless sandy seabed, bare of vegetation. The high reflectivity (light tone) covers a N-S trending zone and can be divided in two areas (Area A and B) based on the backscatter. Area A shows slightly lower reflectivity, compared to Area B, and at its northern end consists of high reflectivity patches. Ground truthing data showed that those patches correspond to an elongated mound related to wreck (Fig. 3-a) and scattered wreck-related material (Fig. 3-b, c) at the northern periphery of the area. The wreck-related elongated mound (a) shows a SW-NE orientation and a cannon resting on the top of the mound. Target (b) corresponds to an elongated gunwale-like feature and Target (c) to the steering wheel of the wreck. In the case of Target (b), the presence of multiple echoes depicting the same object in proximity suggests a metallic composition. Area B represents accumulated sediments and seagrass meadows (*Cymodocea nodosa*). The above results are completely identical to those that arose from the previous survey [15] that used conventional geophysical methods.

*B. Shipwreck site 2*

The mosaic of SW2 is shown in Figure 4. The SW2 site is characterized by disparities/variations in the intensity of the backscatter exhibiting a rough texture on the sonographs due to seagrass vegetation. In spite of that fact, within the central portion of the mosaic, there are discernible targets that serve as the prominent points of interest in this area. The clear geometric shapes and specific arrangement of these targets distinguish them from the surrounding environment, significantly facilitating their detection. Ground truthing data showed that the geometric targets represent the cargo of an ancient shipwreck and more specifically, marble fragments and columns. Similarly, to the SW1, the USV survey results are identical to those of the previous conventional geophysical survey [15].

## V. CONCLUSION

This study highlights the effectiveness of Unmanned Surface Vessels (USVs) in investigating and studying underwater cultural heritage (UCH) sites in challenging shallow water environments. By utilizing a USV equipped with a side scan sonar system and the ReefMaster and SeaView software, accurate mosaics of two wreck sites in Methoni Bay, Greece, were generated and analyzed, enabling precise spatial positioning and examination of points of interest. The results showcased the capability of USVs to successfully identify targets of archaeological interest and provide valuable insights into the study area, contributing to the growing evidence of USVs as a valuable tool for exploring and preserving UCH sites. With additional benefits such as extended autonomous operation, maneuverability and low environmental impact, as well as further refinements in technology, USVs have the potential to become a cost-effective, reliable and widely adopted option for UCH surveying and marine data acquisition, advancing our understanding of our underwater cultural heritage.

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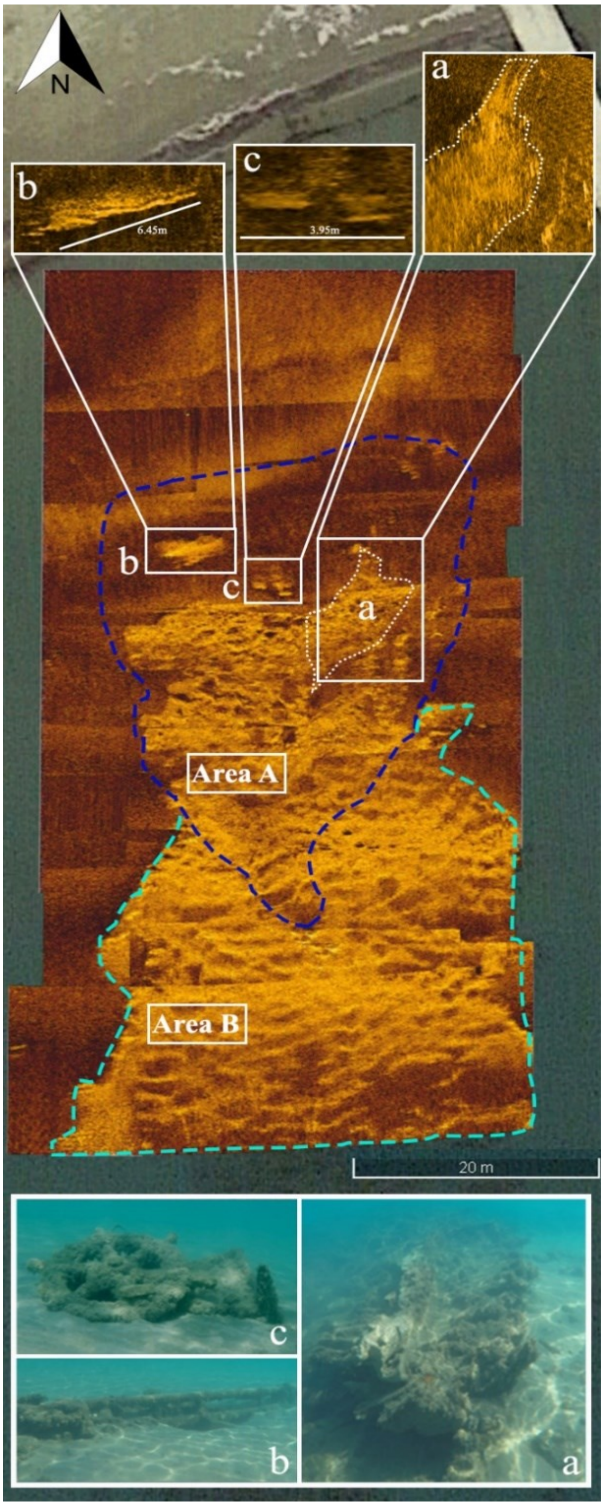


*Fig. 3. SSS mosaic of SW1 site showing three aggregations of wreck-related materials and corresponding visual census data obtained from* [15]

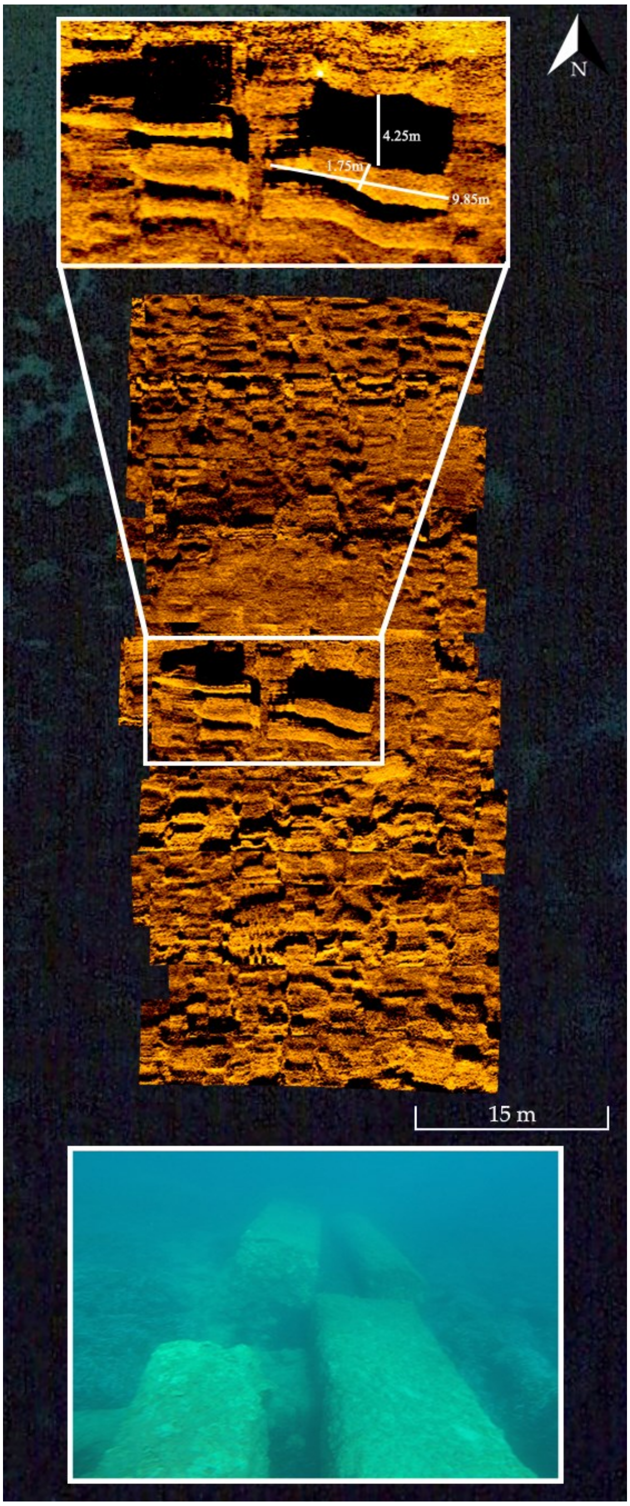


*Fig.4. SSS mosaic of SW2 site showing wreck-related materials and corresponding visual census data obtained from* [15]

VII. REFERENCES


[1] G. Bucci, “Remote Sensing and Geo-Archaeological Data: Inland Water Studies for the Conservation of Underwater Cultural Heritage in the Ferrara District, Italy,” *Remote Sens (Basel)*, vol. 10, no. 3, p. 380, Mar. 2018, doi: 10.3390/rs10030380.

[2] M. Geraga *et al.*, “Atlas of shipwrecks in inner ionian sea (Greece): A remote sensing approach,” *Heritage*, vol. 3, no. 4, pp. 1210–1236, Jun. 2020, doi: 10.3390/heritage3040067.

[3] A. Grządziel, “Using Remote Sensing Techniques to Document and Identify the Largest Underwater Object of the Baltic Sea: Case Study of the Only German Aircraft Carrier, Graf Zeppelin,” *Remote Sens (Basel)*, vol. 12, no. 24, p. 4076, Dec. 2020, doi: 10.3390/rs12244076.

[4] G. Papatheodorou, M. Geraga, and G. Ferentinos, “The Navarino Naval Battle site, Greece - An integrated remote-sensing survey and a rational management approach,” *International Journal of Nautical Archaeology*, vol. 34, no. 1. pp. 95–109, Jun. 2005. doi: 10.1111/j.1095-9270.2005.00047.x.

[5] G. Papatheodorou *et al.*, “The battle of lepanto search and survey mission (1971–1972) by throckmorton, edgerton and yalouris: Following their traces half a century later using marine geophysics,” *Remote Sens (Basel)*, vol. 13, no. 16, Jun. 2021, doi: 10.3390/rs13163292.

[6] M. Geraga, G. Papatheodorou, G. Ferentinos, and E. Fakiris, “The study of an ancient shipwreck using marine remote sensing techniques, in Kefalonia Island (Ionian Sea), Greece Advanced Technologies for Maritime and Underwater Archaeology View project AN ATLAS OF GEO-HAZARDS IN THE HELLENIC SEAS View project.” 2015. [Online]. Available: https://www.researchgate.net/publication/285471219

[7] Z. Liu, Y. Zhang, X. Yu, and C. Yuan, “Unmanned surface vehicles: An overview of developments and challenges,” *Annual Reviews in Control*, vol. 41. Elsevier Ltd, pp. 71–93, 2016. doi: 10.1016/j.arcontrol.2016.04.018.

[8] V. Dobref, I. Popa, P. Popov, and I. C. Scurtu, “Unmanned Surface Vessel for Marine Data Acquisition,” in *IOP Conference Series: Earth and Environmental Science*, Institute of Physics Publishing, Jul. 2018. doi: 10.1088/1755-1315/172/1/012034.

[9] G. Mattei, S. Troisi, P. P. C. Aucelli, G. Pappone, F. Peluso, and M. Stefanile, “Sensing the submerged landscape of Nisida Roman harbour in the gulf of Naples from integrated measurements on a USV,” *Water (Switzerland)*, vol. 10, no. 11, Nov. 2018, doi: 10.3390/w10111686.

[10] G. Pappone, P. P. C. Aucelli, G. Mattei, F. Peluso, M. Stefanile, and A. Carola, “A detailed reconstruction of the roman landscape and the submerged archaeological structure at ‘castel dell’ovo islet’ (Naples, Southern Italy),” *Geosciences (Switzerland)*, vol. 9, no. 4, Apr. 2019, doi: 10.3390/geosciences9040170.

[11] N. Kapetanović, A. Vasilijević, and K. Zubčić, “Assessing the Current State of a Shipwreck Using an Autonomous Marine Robot: Szent Istvan Case Study,” 2021, pp. 126–135. doi: 10.1007/978-3-030-53829-3_12.

[12] N. Kapetanović, A. Vasilijević, Đ. Nađ, K. Zubčić, and N. Mišković, “Marine robots mapping the present and the past: Unraveling the secrets of the deep,” *Remote Sens (Basel)*, vol. 12, no. 23, pp. 1–39, Dec. 2020, doi: 10.3390/rs12233902.

[13] A. Vasilijevic *et al.*, “An ASV for coastal underwater archaeology: The Pladypos survey of Caesarea Maritima, Israel,” in *OCEANS 2015 - Genova*, IEEE, May 2015, pp. 1–7. doi: 10.1109/OCEANS-Genova.2015.7271495.

[14] Peter Throckmorton and John M. Bullitt, “UNDERWATER SURVEYS IN GREECE,” *Expedition Magazine*, vol. 5, no. 2, 1962, [Online]. Available: http://www.penn.museum/sites/expedition/?p=520

[15] P. Gkionis, G. Papatheodorou, and M. Geraga, “The Benefits of 3D and 4D Synthesis of Marine Geophysical Datasets for Analysis and Visualisation of Shipwrecks, and for Interpretation of Physical Processes over Shipwreck Sites: A Case Study off Methoni, Greece,” *J Mar Sci Eng*, vol. 9, no. 11, p. 1255, Nov. 2021, doi: 10.3390/jmse9111255.

[16] T. Levy et al., “Digital Underwater Technologies in the Methoni Bay Cultural Heritage Project, Greece: Interdisciplinary Approaches and Sustainability” Scientific Culture, vol. 9, no. 1, pp. 51-88, 2023, DOI: 10.5281/zenodo.7265745