SCIENTIFIC CULTURE
www.sci-cult.com

SCIENTIFIC CULTURE, Vol. 9, No. 1, (2023), pp. 51-88
Open Access. Online & Print

DOI: 10.5281/zenodo.7265745

DIGITAL UNDERWATER TECHNOLOGIES IN THE METHONI BAY CULTURAL HERITAGE PROJECT, GREECE: INTERDISCIPLINARY APPROACHES AND SUSTAINABILITY

Levy, T.E.[1,4,7], Papatheodorou, G.[2], Geraga, M.[2], Christodoulou, D.[2], Georgiou, N.[2], Kordella, S.[2], Gkionis, P.[2], Spondylis, I.[3], Michalis, M.[3], Dimas, X.[2], Tsoulakou, M.[5], Kylafi, M.[5], Vouvalidis, K.[6], Tamberino, A.[1,4], Clark, L.[1,4], Reece, J.[1,4], Cantu, K.[4], Walsh, R.[4], McDonald, C.[4] and Shtienberg, G.[1]

[1]Center for Cyber-Archaeology and Sustainability, Qualcomm Institute; Department of Anthropology, University of California, San Diego, La Jolla, CA, 92031, USA
[2]Laboratory of Marine Geology and Physical Oceanography, University of Patras, Greece
[3]Hellenic Institute of Marine Archaeology, 9 Saripolou Street, Athens, Greece 10682
[4]Scripps Center for Marine Archaeology, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA, 92031, USA
[5]Ephorate of Antiquities of Messenia, Archaeological Museum of Messenia, Kalamata, Greece
[6]School of Geology, Aristotle University of Thessaloniki, Greece
[7]Leon Recanati Institute for Maritime Studies, University of Haifa, Israel

Received: 28/09/2022
Accepted: 25/10/2022

Corresponding author: Levy (tlevy@ucsd.edu)

ABSTRACT

Submerged cultural heritage provides a unique opportunity to couple paleoenvironmental and culture-historical research with the contemporary cultural heritage needs of the public where field work takes place. Greece provides an ideal locale for developing what we refer to as maritime cultural heritage asset districts (MCHAD). Here we summarize two seasons (2019, 2021) of field survey work in the Methoni Bay region of Messenia off the southwestern Peloponnesus coast that provides an ideal locale for developing a MCHAD. A number of interdisciplinary survey tools were used to examine cultural and adaptive responses to environmental and cultural change in deep-time around the Methoni Bay with the aim of enhancing cultural heritage tourism in the area. Our project builds on earlier paleogeography and submerged heritage research by conducting: 1) non-invasive high definition shallow marine geophysics including Multibeam Echosounder, Side Scan Sonar, and Chirp sub-bottom profiler; 2) photogrammetry of several previously investigated shipwrecks and a unique submerged Middle Bronze Age/Middle Helladic (MH) settlement (2050/2000 – 1750/1680 BCE) using a three camera custom rig mounted on a scuba scooter for large area coverage; 3) shallow submerged sediment sampling using scuba and diver operated coring device to study the deep-time environmental history of the Methoni embayment and preliminary terrestrial coring using a Cobra percussion core drilling system; and 4) a cyber-archaeology workflow using photogrammetry and 3D laser desktop scanning tools to collaborate with a local museum to curate and disseminate research for the public. This article provides an overview of the project methods and preliminary results for melding scientific research with cultural heritage objectives.

KEYWORDS: Greece, Methoni, marine-surveys, cultural heritage, photogrammetry

1. INTRODUCTION

How can the field of cultural heritage contribute to understanding current global concerns about climate, environmental and social change? How can these academic and policy goals be communicated to the public where maritime cultural heritage research takes place? Researchers in Greece have made great strides to meld these issues together at projects such as the submerged Neolithic-Bronze Age town of Pavlopetri (about 5000–3000 BP), lying in water depths of 2.0-5.0 m (Henderson et al. 2011; N. et al. 2020); what is termed the Blue Tourism sector (Commission. 2020; Poulos et al. 2022). Other ways of developing submerged cultural attractions include the development of underwater museums such as the Museo Atlantico Lanzarote in the Canary Islands (https://underwatermuseumlanzarote.com/en/info-museo-atlantico/) - a concept being explored for the submerged site at Pavlopetri (Henderson et al. 2011; Poulos et al. 2022). By taking a deep-time perspective on human adaptation along sensitive coastal zones during the Holocene period, the *Methoni Bay Cultural Heritage Project*, off the southwest coast of the Peloponnese in Messenia, Greece, is helping to provide additional answers. The Methoni Bay hosts a submerged Middle Bronze Age settlement, shipwrecks from multiple periods, and other maritime and coastal sites to contextualize the human signature in the landscape. To answer questions of public engagement, we present a maritime cultural heritage tourism model that aims to benefit the local population of Methoni and Messenia through local and international tourism. The Methoni Bay project is a transdisciplinary effort spearheaded by the Center for Cyber-Archaeology and Sustainability (CCAS) and the Scripps Center for Marine Archaeology – University of California, San Diego, USA and the *Oceanus* Laboratory of Marine Geology and Physical Oceanography at the University of Patras, Greece. To investigate human responses to climate, environmental and social change along the world's coastal zones in deep-time perspective, two survey seasons (2019, 2021) in the Methoni Bay have focused on: 1) shallow marine geophysics; 2) sediment coring to obtain proxy data that can accurately reflect changes in the environment and climate throughout the Holocene; 3) and underwater photogrammetry surveys of a submerged Middle Bronze Age settlement and shipwrecks from multiple periods to contextualize past human activity; and 4) 3D modelling of artifacts retrieved from the full range of occupations from Methoni on permanent display at the Archaeological Museum of Messenia in Kalamata for cultural heritage outreach.

The Methoni embayment has been an important node of maritime interaction from as early as the Middle Bronze Age or Middle Helladic period, ca. 2050/2000 – 1750/1680 BCE BC (Choremis 1969; Rutter 2017; Spondilis 1996). The port has a long history spanning Late Antiquity, the Byzantine period, the Venetian and Ottoman eras, and features in the Greek War of Independence (Bees 1993; Davies and Davis 2007; Gallant 2015; Shtienberg et al. 2022) Today the most prominent feature in the vicinity is a beautifully preserved fortress and harbour dating to the Venetian occupation (ca. 1206 – 1715 CE). In the 1970s, John Kraft and Stanley Aschenbrenner (Kraft and Aschenbrenner 1977) carried out an innovative paleogeographic study of the Methoni embayment. This included an assessment of the cultural and historical features, historical maps, the physiogeography and geological setting, large-scale geomorphological observations, and the analyses of a single terrestrial borehole from the nearby alluvial plain. By contextualizing the cultural features in the landscape, the first systematic regional Holocene human-landscape geomorphological study was achieved. At the time, the earliest human occupation in this part of Messenia was attributed to the late Middle Helladic period (MH; (ca. 2050/2000 – 1750/1680 BCE) based on the terrestrial excavations by A.K. Choremis (Choremis 1969) on the tiny island of Nisakouli, ca. 1 km southeast of the Methoni harbor (Fig.1), with a possible altar feature (Hassiacou 2003). During this early phase of research in the early 1960s , while Roman wreck sites had been investigated off the nearby coast of Sapienza island (Throckmorton and Bullitt 1963), no underwater archaeological survey had been carried out in the Methoni Bay itself. It was not until the mid-1980s that Greek underwater archaeologist Ilias Spondilis discovered the presence of a large, ca. 3.5 hectare submerged MH settlement and in the early 1990s made a detailed survey of several features at the site (Spondilis 1996). Sporadic traditional mapping took place at the site, but until the project described here, very limited research was carried out at the site with the exception of a marine geophysical survey conducted in 2015 by the Laboratory of Marine Geology and Physical Oceanography (Gkionis et al. 2020; Gkionis et al. 2019). The field work reported on here is based on two field seasons (2019, 2021) of a multi-year project in the Methoni Bay region. In terms of the field work presented here, the close collaboration of marine geophysicists with researchers who conducted a range of marine cyber-archaeology methods for data capture, analyses, curation, and dissemination of data, has led to the creation of an economic model presented here to create a Maritime Cultural Heritage Asset District that can benefit the population of Methoni and the region of Messina. The use of Side

Scan sonar and Multi-beam marine geology survey data coupled with large scale photogrammetry mapping of the sea floor provided unique discovery tools for identifying a wide range of submerged cultural heritage features described below. Sub-bottom profile data from the marine survey coupled with shallow marine coring around the submerged settlement at Methoni provided a unique understanding of the size of the site – much larger than the submerged surface remains identified in the 1980s.

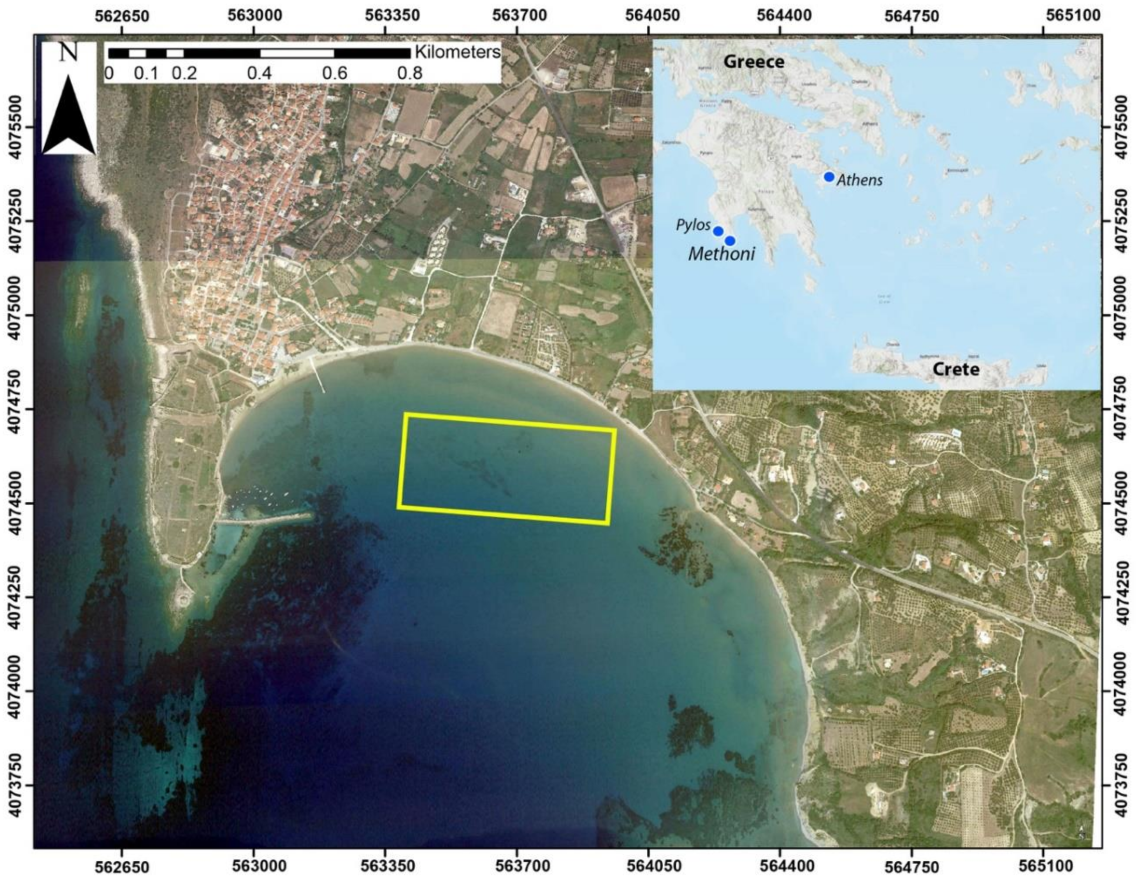

Figure 1. Methoni embayment, southwest (Messenia) Peloponnese, Greece. The main Middle Bronze Age (Middle Helladic, ca. (2050/2000 – 1750/1680 BCE) site is near the coast of the bay highlighted by the yellow rectangle. Areas of interest on the northern edge of Sapienza Island are also marked.

2. TOWARD A MARITIME CULTURAL HERITAGE ASSET DISTRICT (MCHAD)

For more than a decade, archaeologists in Greece have been interested in promoting underwater cultural heritage around Methoni with the aim of preserving submerged heritage sites and encouraging tourism for the benefit local population. In 2013, P. Georgopoulos and T. Fragkopoulou (Georgopoulos and Fragkopoulou 2013) for the creation of underwater archaeological parks (UAP) at Methoni Bay – Sapienza Island and in the Northern Sporades island chain. Similar petitions were made for the submerged prehistoric site of Pavlopetri in southwest Laconia, Peloponnese. In 2014, a team of geoscientists from the University of Patras initiated the 'Evolved G.E.N.E.S.I.S Project (A marine Geophysical investigation for marine knowledge and the anthesis of Methoni, Greece). The aim of the project was to highlight the 'underwater archaeological resources off Methoni that could locally drive sustainable socioeconomic growth, following the development of cultural and recreational maritime tourism (Gkionis et al. 2019)[158]. The Evolved G.E.N.E.S.I.S Project study is significant because it provides well-researched background data concerning the development of tourism related to Methoni to make the case for creating cultural tourism based on underwater cultural heritage (ANMES 2010; Harokopio University of Athens 2007; Iliopoulou 2015 ; Kostakis 2016). With the case having been made to create a Methoni Bay UAP, here we suggest linking the underwater and terrestrial domains in the Methoni embayment and adjacent islands to create a 'Maritime Cultural Heritage Asset District' (MCHAD) that will benefit as many of the stakeholders in area as possible (Fig. 2).

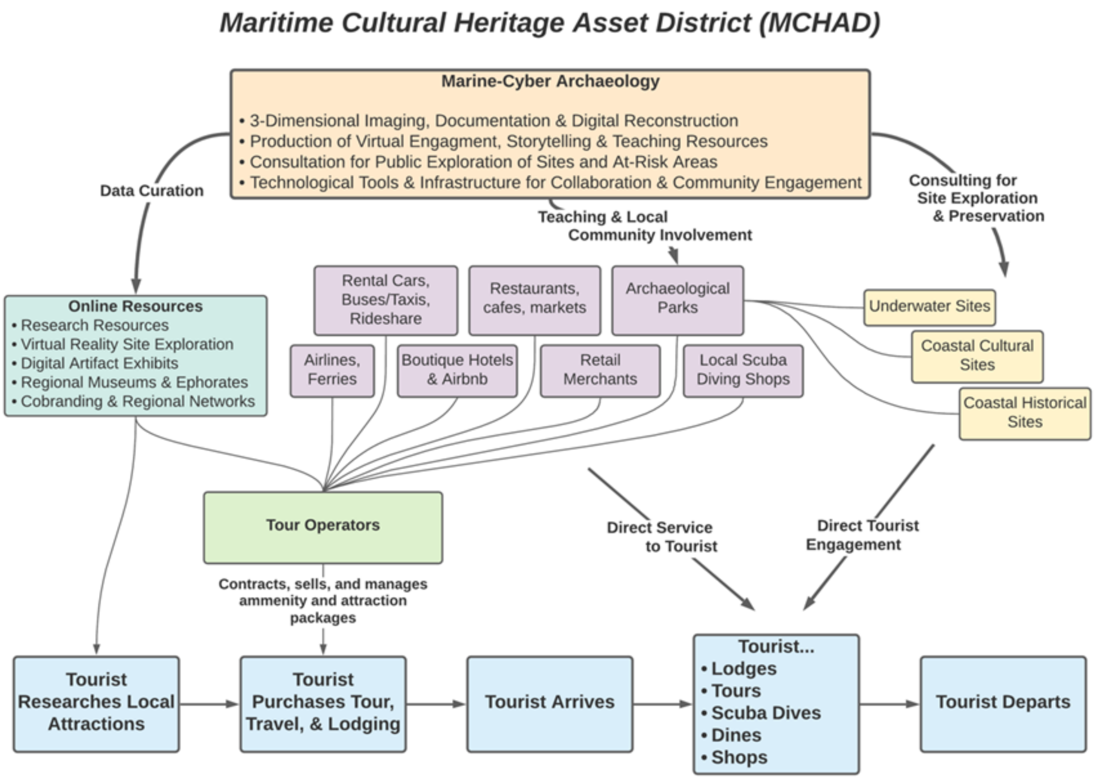

Figure 2. Maritime Cultural Heritage Asset District (MCHAD) for Methoni, Messenia, Greece.

This is the first time a Maritime Cultural Heritage Asset District has been proposed. The Cultural Heritage Asset District (CHAD) model was developed by Glenn Yago and colleagues from the Milken Institute in Santa Monica (California) and Jerusalem. The CHAD model builds sustainable public–private partnerships (PPPs) and ensures a revolving financial mechanism based on tax revenues, bond issuances, and other tools to stimulate local tourism and preserve local heritage assets (European Investment Bank Institute 2013). Using Yago et al's model, a cultural heritage asset district was proposed for the Kidron valley/Wadi Nahr in the West Bank based on a study of the Mar Saba Greek Orthodox monastery in the Judean desert (Levy et al. 2020). The model brings financially and culturally sustainable answers to meet the needs for innovation in the field of financing and management that can benefit cultural heritage conservation. In the case of Methoni, the PPPs would be the public (local municipality, Universities - Patras, San Diego; government - Ephorate of Underwater Antiquities of Greece, Ephorate of Antiquities of Messenia, Archaeological Museum of Messenia, Kalamata) and local private stakeholders (Boutique hotels, Airbnb, retail merchants, tavernas, restaurants, local scuba diving shops, tour operators, etc.).

To begin building the *Methoni Maritime Cultural Heritage Asset District* with regional public partners in Messenia, during the 2021 expedition, we worked closely with the Ephorate of Antiquities of Messenia and the Archaeological Museum of Messenia to scan the collection of Methoni Bay region artifacts on display at the museum in Kalamata. We also began discussions with the Methoni municipality, local hotel owners, taverna operators, shop keepers, a scuba shop owner, and all are very enthusiastic about participating in the Methoni-MCHAD. Below we describe the 3D work at the Ephorate of Antiquities of Messenia and the Archaeological Museum of Messenia based on photogrammetry and scanning of a Middle Helladic pottery vessel excavated at the small islet of Nisakouli adjacent the submerged MH site that is the focus of our long-term underwater archaeology field study. At this time, the artifacts retrieved by Spondylis (1996, 2006) from the submerged MH site in the Methoni Bay are stored at the Pylos Museum and have not been scanned. As only one artifact 'product' created with laser scanning, was directly related to our current MH scientific research at Methoni, most of our 3D work at the Kalamata Museum was done *pro bono* with the idea that by providing the museum with the 3D models and digital files of our work, they can use them to promote the Methoni MCHAD goals. These include: a) enhancing the visitor experience at the Kalamata Museum by displaying the 3D models on their current exhibition computer monitors; b) sharing the 3D artifact models with the scholarly community; c) creating a 3D VR exhibition that duplicates the current state-of-the-art archaeology exhibition of the Methoni Bay to host online at the museum website and other online venues including the research community in Greece (University of Patras, Hellenic Institute of Marine Archaeology (H.I.M.A), Ephorate of Antiquities of Messenia and the Archaeological Museum of Messenia, etc.) and abroad (University of California, San Diego and others), and at local venues such as the Methoni municipal community and visitor centers, and hotels. Taken together, these modest efforts are building toward the creation of a Methoni MCHAD.

2.1. Overview of the Archaeological Museum of Messenia, Artifact Metadata and 3D Documentation for Middle Helladic Methoni Bay Occupation

The Archaeological Museum of Messenia is in the heart of the city of Kalamata, ca. 45 km northeast of Methoni Bay. Artifacts on display are organized by the four geographic regions within the province of Messenia: Kalamata, Messene, Pylia, and Triphylia, and span from prehistory to the Latin periods (museum URL: http://archmusmes.culture.gr/eng/museum.htm). Those artifacts collected from around Methoni are in the Pylia wing. In total, the team collected 3D data for 46 artifacts: 6 are modelled individually, while 40 are part of 4 larger displays, modelled together. Table 1 provides information for each of the artifacts and the method with which 3D data was collected, in the order that the models appear in the final video product. By collection the data in this format, it is possible to create an online VR experience that duplicates the Methoni Bay region exhibition on permanent display at the Archaeological Museum of Messenia in Kalamata.

Table 1: Archaeological Museum of Messenia Artifact Documentation

Object Id	Model ID	Age	Caption	Data Collection Method
Depas Amphikypellon Vessel	Ritual Double-Cup Vessel	Unknown	Part of a two-handled cup, which is probably related with worship practices. Its original shape follows the type known today as “depas amphikypellon.”	Structured-light scan
Villa Mosaic	Chariot Mosaic	5^{th} c. CE	Part of a mosaic floor from a villa, with a hunting scene. It depicts a chariot drawn by panthers, a theme possibly related to the worship of Dionysus or the mysteries of Andania, with which the name ΕΥΗΝΙΩΝ (“exceptional charioteer”) is also related.	SfM photogrammetry
Templon Closure Slab: Two-Sided	Two-Sided Marble Slab	11^{th} c. CE	Fragment of a two-sided templon closure slab.	SfM photogrammetry
Methoni: Ceramic Finds	Methoni Ceramic Finds	9^{th} – late-15^{th} c. CE	Methoni. Ceramic finds from the Castle.	SfM photogrammetry
Templon Epistyle: Large Fragment	Small and Large Epistyle Sculptures	6^{th} c. CE	Fragment of a templon epistyle. The use of drill for the decoration is distinctive.	SfM photogrammetry
Templon Epistyle: Small Fragment	Small and Large Epistyle Sculptures	8^{th} c. CE	Fragment of a templon epistyle.	SfM photogrammetry
Basilica Excavation: Finds	Methoni Basilica Finds	5^{th} – 14^{th} c. CE	Methoni. Finds from an excavated Early Christian basilica.	SfM photogrammetry
Mosaic: Early Christian	Early Christian Mosaic	6^{th} c. CE	Fragment of a mosaic floor from the church.	SfM photogrammetry
Templon Closure Slab: Christogram	Marble Sculpture Wall	14^{th} c. CE	Templon closure slab displaying the Christogram and dense surrounding decoration.	SfM photogrammetry
Inscribed Plaque: Wall Repair	Marble Sculpture Wall	11^{th} – 12^{th} c. CE	Inscribed plaque. It refers to the repair of walls, probably those of the Castle of Methoni, by the Byzantines, following destructions caused by a Norman invasion.	SfM photogrammetry
Female Saint Carving	Marble Sculpture Wall	11^{th} – 12^{th} c. CE	Icon of a female saint in gesture of prayer (orans). Probably from the	SfM photogrammetry

			Monastery of Aghia Marina on the islet of the same name.	
Templon Door-frame	Marble Sculp-ture Wall	11th – 12th c. CE	Fragment of a templon doorframe ending in a half-colonnette.	SfM photogrammetry
Marble Post Block	Marble Sculp-ture Wall	11th – 12th c. CE	Impost block of a colonnette.	SfM photogrammetry
Latin Castle In-scription	Small Inscrip-tion Marble	Mid-15th c. CE	Fragment of a Latin inscription from the Castle.	SfM photogrammetry
Votive Seahorse	Votive Seahorse Figurine	5th – 1st c. BCE	Votive figurine of a seahorse, a mythical being symbolizing Posei-don.	Structured-light scan

Two methods of 3D data capture were employed at the museum in Kalamata: Structure-from-Motion (SfM) Photogrammetry and Structured-Light Scanning over a two-day period. The method of SfM photogrammetry data acquisition is widely used by archaeologists in both terrestrial and underwater environments, and the interested reader is referred to the extensive literature concerning archaeological applications (Al-kheder et al. 2009; Fernández-Hernandez et al. 2015; Georgopoulos 2014; Hatzopoulos et al. 2017; Koutsoudis et al. 2015; Levy et al. 2014; Ludvigsen et al. 2006; Prins and Adams 2013; Vavulin et al. 2019; Yamafune et al. 2017). Structured-light scanning uses the speed of light and the distortion of patterns with known frequencies and intervals projected on a surface to calculate the locations of points on that surface in 3-dimensional (3D) cartesian space (Bell et al. 1999). The light projector (e.g., an Acer LED projector) shines unique black-and-white patterns onto the object being scanned, while the scanner camera (e.g., an HP 3D HD Camera Pro) observes the distortion of the patterns to calculate the angle at which the light is reflecting off the object. Since light particles travel at a known speed and the distance between the projector and scanner camera is predetermined and constant, a computer can precisely triangulate the locations of points on the surface of the object using the geometric principles of trigonometry. Many structured-light scanners can also capture accurate color data for each point on the object. For the system used here, this is done by projecting a standard red, then green, then blue light onto the object to determine the red-green-blue (RGB) color value of each point. That color data is then applied as a texture to the 3D model in the final stages of processing.

To create a more accurate and precise 3D model, an object should be scanned many times from multiple angles, with the area of each scan overlapping the area of at least four other scans: those to the right, left, top, and bottom. This redundancy helps the computer program or technician 'stitch' scans together and reduces holes in the model caused by shadows or blocked visibility. Working in a dark space is also preferred so that ambient light does not create unwanted noise in the model. While structured-light does have the capacity to produce models with sub-millimeter accuracy, the system does have its limitations: the system should be recalibrated if it is moved, increasing the time needed to scan large artifacts; model accuracy and precision decrease with an increase in ambient or direct light; increased resolution requires an increase in time during both scanning and post-processing; and the system requires a nearby source of electricity as its many components cannot run off of battery power. Here we present the Middle Helladic *Depas Amphikypellon* vessel excavated at Nisakouli near the Methoni submerged MH site as it contributes to our understanding of the MH occupation in the Bay area and represents the first time it is published as a computer-generated line drawing based on 3D data recording (Fig. 3).

Figure 3. (upper) Structured-Light Scanning of Middle Helladic Depas Amphikypellon vessel excavated at Nisakouli, Methoni Bay by Choremis (1969). lower) digital line drawing (left) and profile (right) of the vessel from 3D model.

Photogrammetry provides more flexibility when compared to other types of 3D data collection. Except for the MH double-cup *depas amphikypellon* vessel and a 5th – 1st c. BCE bronze votive figurine depicting a *hippocampus*, a mythical seahorse sacred to the god Poseidon (Table 1), our team used SfM photogrammetry to model all of the artifacts *in situ* because they could not be removed from their displays and, therefore, could not be rotated 360° in front of the stationary structured-light setup. These objects and the *hippocampus* will be published elsewhere as part of the virtual Methoni Bay exhibition from the Archaeological Museum of Messenia in Kalamata and are playing an important role in the creation of the Methoni MCHAD.At the time of Choremis (1969) excavations in 1968 on the small islet of Nisakouli in the gulf of Methoni (Fig. 1), the presence of the large MH submerged settlement was unknown. The Nisakouli islet, ca. 70 x 80 m (5600 m^2), is ca 1 km southeast of the exposed remains of the submerged MH site visible on Google Earth (Fig. 1). Based on new marine geophysical data from the Methoni Bay Cultural Heritage Project described below, the two sites are part of the same settlement system. According to Choremis (ibid. p. 13 -14) excavations, there was an earthen altar with two small walls that formed an angle to protect the fire from south and west winds on the summit of the small islet. The altar contained numerous burned animal bones and ceramic sherds, which may point to the importance of feasting (Wright 2004) during the MH period in the Methoni bay area during this period. According to Choremis (ibid.), the 'most important find' at Nisakouli was half of a twin-bowl that was part of a cultic vessel that is now on display at the Archaeological Museum of Messenia described as a *Depas Amphikypellon* vessel. As this was the only MH object available for study from the Methoni Bay research area, we scanned it for the *Methoni Cultural Heritage Project* and present here (Fig. 3). Two walls of a building were found ca. 8.5 m to the northwest of the altar. Numerous pottery sherds found associated with the building were of the same type found with the altar, including a pithos similar to one found associated by Spondilis with the well-preserved circle structure described below at the nearby submerged site (Fig. 11). This supports the contemporaneity between Spondilis' (1996) dating of the submerged site and Choremis (1969) dating of Nisakouli to the Middle Helladic period.

3.1. 3D Visualization: Integrated Shallow Marine Geophysics and Photogrammetry System

To understand the earliest settlement, paleoenvironmental history and potential for cultural heritage tourism in Methoni Bay area, marine geophysical surveys were carried out by our team. The first season of the *Methoni Bay Cultural Heritage Project* (October 11 – 30, 2019) focused on high resolution shallow marine geophysics of the submerged MH settlement and four shipwrecks, verification of geophysical results using scuba divers at the MH settlement, and photogrammetric mapping of heritage features found on the seafloor associated with both the submerged MH settlement and two of the shipwrecks (Roman period) found off the north coast of Sapienza island (the underwater photogrammetry of these wrecks and their potential for the Methoni MCHAD are described below). The second expedition (November 4 – 30, 2021) carried out a marine magnetic survey of the submerged MH site and underwater photogrammetry work to rectify missing data from the 2019 expedition. One of the main goals of the joint expedition is to meld the University of Patras shallow marine geophysics system along with the UC San Diego cultural heritage survey, sediment core sampling, and photogrammetry system at the submerged MH site (Fig. 4). Shallow marine geophysics has been applied successfully for the investigation of submerged settlement sites and nearshore coastal paleogeographic evolution (Ferentinos et al 2015; Geraga et al 2016) in the Aegean region, including preliminary work at Methoni (Gkionis et al. 2019). By combining shallow marine geophysics and underwater photogrammetry (cf. Benjamin 2019; Seman and Saeed Salama 2019) into an effective data capture, curation, analyses and dissemination workflow, it is possible to create an underwater 'digital scaffold' on which all subsequent paleoenvironmental and heritage data can be hung.

The 2019 marine geophysical and photogrammetry field survey of the Methoni bay was organized into four phases. First, a systematic survey of the sea floor of Methoni bay was carried out using three marine geophysical systems. The second phase consisted of visual inspection based on the results of the first phase. The third phase consisted of very detailed geophysical surveys of specific architectural features thus constituting focused downscaling approach to the first phase. The fourth phase was marked by the efforts of analytical photogrammetry on specific locales visible on the seafloor. This methodological approach provides a cost-effective tool to rapidly survey areas of cultural heritage interest. During the first phase, the Methoni Bay was systematically surveyed and potential targets and regions of interest for further investigation were located. During the second phase, a towed camera and the ROV hovered over these locations of interest and were recorded on the video camera for evaluation in terms of archaeological and historical importance.

A number of marine geophysical instruments were employed simultaneously during the Methoni Bay survey to obtain high precision geophysical mapping of the sea floor and cultural heritage features: 1) To retrieve submerged data on slope, hill relief, and variation in height, a Swath Bathymetric Sonar ITER Systems (BathySwath1 interferometric MultiBeam Echosounder) was employed with two transducers attached to the mounting pole that was tied up over the side of the vessel (Fig. 5), and the digital recording and display unit. BathySwath1 uses wide swath widths that increases survey speed significantly, especially in shallow water. This is because the swaths cover an area of 150 m of slant range, with operational depth ranging from 0.2 m to 100 m and accuracy of 2 cm. Bathymetric georeferenced data for these multibeam data was acquired using a Hypack / Hysweep suite; 2) Side Scan Sonar - Edgetech 4200 SP (SSS) system that transmits and stores georeferenced sonographs at 100 kHz and 400 kHz chirp acoustic signal frequencies simultaneously. This instrument was towed behind the research vessel (Fig. 5). Triton ISIS & Triton Delphmap software were used to process and interpret the acoustic backscatter data; 3) A Kongsberg GeoPulse Plus (GeoAcoustics Universal) Chirp sub-bottom profiler and SBInterpreter software were used to acquire and interpret data respectively to determine geological data a few meters below the sea floor. The system can operate using various signal waveforms, providing high penetration - high resolution georeferenced seismic profiling data. The penetration of the system can reach up to - 40m in loose sediments and its vertical resolution is less than 10 cm. To ensure the highest level of data acquisition, additional instruments were used: 4) a Teledyne single beam echo sounder was used as duplicate checking system of the Swath Bathymetric Sonar ITER; 5) end of day readings from an RBR Tide & Wave logger were collected from the home dock in Methoni Bay to continuously record the elevation of the sea surface. These data are critical as an additional control for accurate marine geophysical measurements; 6) To account for the physical properties of the sea water an in-situ CTD (Conductivity, Temperature, Depth) logger was employed to assess the density of the seawater and thus to calibrate the multibeam echosounder data; 7) to supplement scuba observations, a *Seaviewer* tow camera for underwater video and real-time observations of the data collection along geophysical track lines (we attached a GoPro Hero 7 to collect additional video data) and for a single day test; 8) a Mini-ROV (remotely operated vehicle) Guardian rated to – 150 m with a high resolution video-camera and LED lighting; 9) GPS (Global Positioning System) – a Hemisphere VS101 GPS system with accuracy of approximately 1.5 m was used for the navigation and the positioning the vessel, was integrated with a Leica GS08 plus RTK GPS linked to Greece's nearby national geodesic base stations to geo-locate all the marine geophysical data collected at sea; and for the second expedition we added an Emlid Reach RS+ Real-time Kinnematic GPS base station and rover for better accuracy (geospatial accuracy of 1 to 2 cm) to geo-locate underwater survey, photogrammetry and aerial drone data. The model in Figure 4 illustrates the integration of the marine geophysical survey workflow with that of the photogrammetry.

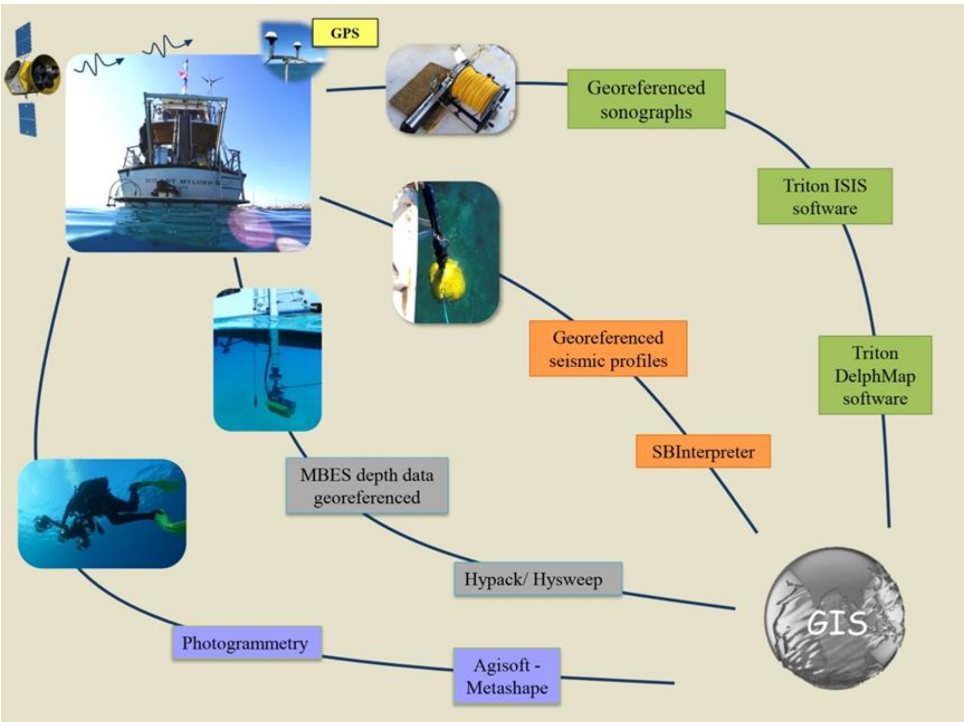

Figure 4. Flow-chart of the integrated marine geophysical and photogrammetry survey employed at Methoni, 2019.

Over the past decade, 3D recording and interpretation techniques for underwater cultural heritage research has moved from innovation to standard practice (McCarthy et al. 2019). Underwater exploration continues to be a challenge necessitating constant methodological innovation. Based on skin diving at the submerged MH site at Methoni in 2018, Google Earth imagery, and communications by Spondilis, our team knew that the submerged site was quite large (ca 3.5 hectares in size) and would require a more streamline underwater photogrammetry data collection tool than simple swimming utilizing a single high definition SLR camera. Accordingly, we partnered with the Sandin Lab at the Scripps Institution of Oceanography, UC San Diego, which uses high-resolution imagery collected by divers in situ to create detailed 3D models and 2D photomosaics of the coral reefs as part of the Scripps 100 Island Challenge (see - http://100islandchallenge.org/overview/). As the largest sampling plot size used by the Sandin Lab is 10 m x 10 m, they were interested in helping to facilitate our Methoni Bay research to see if an automated system could be developed to image significantly larger grid squares (ca. 25-meter x 25 meter). Accordingly, we worked with the Scripps Sandin lab to design an underwater motorized photogrammetry system with the help of the Jaffe Lab's *Piranha P1 Dive Scooters*. A T-shape aluminum frame was built at the Scripps Marine Facility Shop that could accommodate (Fig. 6) three Nikon D7000 SLR cameras equipped with Nikon ED 18-55mm F3.5-5.6 autofocus zoom lens set to 18mm, each housed in an Ikelite Nikon D7000 underwater camera case with an 8-inch dome. For field processing of photogrammetric models, we use an *Origin PC EON17-SLX Laptop* with 64 GB RAM, an Intel 8 Core i9-9900K 3.60GHz processor, and two *Nvidia GTX-1080* graphics cards. In the field, datasets were processed using *Agisoft Metashape* on the lowest settings to evaluate data collection parameters, and to ensure sufficient coverage over the areas of archaeological interest. A total of 45,643 images were shot for photogrammetry during seven days of diving during the 2019 season at the submerged MH site and two Roman wreck sites off the northern Sapienza island coast (see below). During the 2021 expedition, a total of 7,300 images were recorded during 2 days of diving (October 20 – 21). The aim of this smaller photogrammetry project was to 'fill in' areas missed between the survey squares at the submerged MH settlement during the 2019 project. For 2021, we developed a higher resolution photography system that required less images. Like the original system, 3 cameras were mounted for use with a *Piranha* dive scooter. Juxtaposition and disparity in image quality from 2019 helped the team select a new camera system to replicate the positive aspects of the 2019 runs over the submerged settlement and the Sapienza wrecks, and build on their success. Sony A7RIV 61mp cameras were selected due to their full frame sensor, superior low light performance, imaging performance, extended battery life, and when run with a 26mp image setting superior data processing speed. Also, a modular intervalometer system and aluminum T-bar were designed from the ground up to work with the new camera rig system.

3.1.1. Phase 1: Shallow Marine Geophysical Survey

The research vessel was loaded with expedition equipment on October 14, 2019 and sailed that evening from Patras, arriving 15 hours later in Methoni around 9 am on the 15th. In 2021, the same vessel, 'MiLady MyLord' (Fig. 5) was used leaving Patras on October 5. The Methoni municipality provided use of a small dock less than 100 meters northwest of the submerged Middle Helladic site (Fig. 7) where we could establish our permanent RTK GPS base-station and tide logger for daily measurements during the expedition. The first phase of the marine geophysical survey took place from October 15th to the 20th covering a total area of about 3 km² of the Methoni bay (Fig. 7).

Figure 5. Research vessel, 'Mi Lady My Lord' outfitted with sub-bottom profiler on right, multibeam, diving platform, and other instruments.

The most promising areas in terms of cultural heritage interest were selected for additional contact by scuba divers. The selection of the areas was based on combined interpretation of the sub-bottom profiling and side scan sonar datasets. The backscatter intensity, the shapes and geometric characteristics of the targets (acoustic anomalies) and sites of interest together with their stratigraphic position were the main criteria for their selection for diver contact. Furthermore, the geophysical survey revealed a wide range of new insights concerning the evolving Holocene geomorphology of the embayment and other issues that is reviewed below and will published in detail in the near future.

3.1.2. Phase 2: Detailed geophysical survey

During the marine geophysical and photogrammetry survey of Methoni bay, two days were dedicated to carrying out focused surveys of the most promising regions of interest based on the results of the marine geophysical survey. The focused survey was carried out primarily using a camera towed over track-lines that were designed based on the marine geophysical data. Five large-scale targets of cultural heritage importance were identified: four ancient and historic shipwrecks and a submerged settlement (Fig. 6).

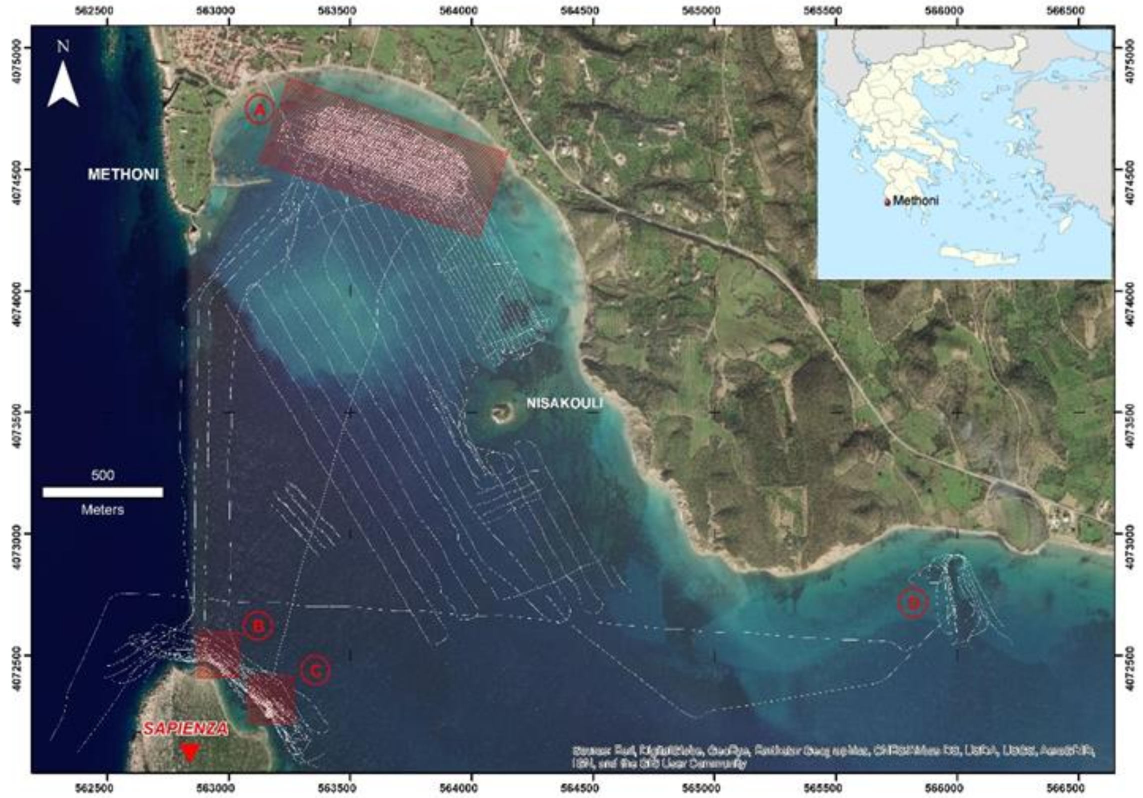

Figure 6. Methoni embayment, southwest (Messenia) Peloponnese, Greece with white track lines showing areas intensively surveyed with marine geophysics. The main Middle Bronze Age (Middle Helladic, ca. (2050/2000 – 1750/1680 BCE) site is near the coast of the bay (A). Three shipwrecks (B, C and E) were surveyed around the coast of the island of Sapienza to the southwest and one shipwreck (D) is located to the northeast.

3.1.3. Phase 3: Very detailed marine geophysical surveys – a downscaling approach

High resolution marine geophysical surveys were carried out at five sites in the Methoni embayment including (Fig. 7): 1) Submerged Middle Helladic settlement, 2) Historic 15th century French shipwreck in the east, 3) Roman shipwreck west coast Sapienza island, 4) Roman columns shipwreck north coast Sapienza island, and 5) Roman sarcophagi shipwreck north coast Sapienza island [see below] (Throckmorton and Bullitt 1963). The majority of the survey focused on the MH settlement (Fig. 8). Table 2 presents the total number of track lines and their length for the three geophysical survey instruments used in the 2019 survey. In most cases, the interval between track lines was ca. 2 m to insure collection of the highest quality data for 3D mapping and modelling.

After more than 16 km of geophysical track lines over the submerged MH site, spaced in less than two-meter intervals, a side scan sonar mosaic with target areas for archaeological investigation was produced on board the research vessel (Fig. 7). Surveying in this phase focused on the acquisition of sub-bottom profiling data to investigate the possibility of a subsurface continuity of the submerged MH settlement below the surface sand on the seafloor. This way researchers can penetrate under the sand covering the seafloor. Thus, the sub-bottom profiler provides a high-resolution seismic profile of the seafloor based on the acoustic impedance of the subsurface sediment layers. In this way it is possible to determine if there are any archaeological remains below the sand of the sea floor.

Table 2. Marine geophysical equipment used in the Methoni embayment including the number of track lines and their lengths (in km).

Marine geophysical equipment	No of Track lines	Total Length (km)
Interferometric Multibeam	61	32
Side Scan Sonar	10	12
Sub-bottom Profiler	45	27

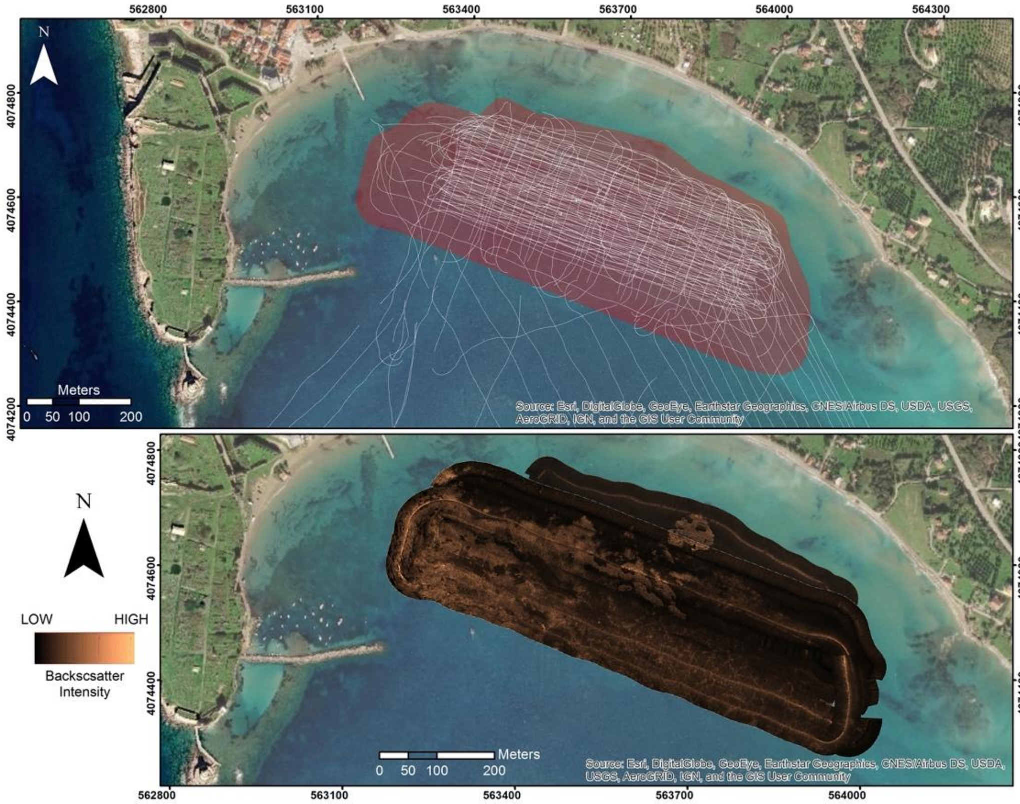

Figure 7. Closely spaced (ca 2 meters) marine geophysical track lines at the submerged Middle Helladic site in the Methoni bay and the resulting side scan sonar mosaic of the submerged settlement. Light tones represent hard substrate (submerged settlement) and vegetation and dark tones correspond to fine-grained sediments (sand).

3.1.4. Phase 4: Non-Invasive Underwater Archaeological Survey - Photogrammetry

The primary aims of the underwater survey at the submerged MH site were to assess the possible extent of the architectural remains, carryout large-scale photogrammetry in areas with clusters of built features, and observe the targets with architectural interest revealed by the previous week's marine geophysical survey. The site ranges in depth from ca. – 2 meters below sea level (bsl) to – ca. 6 meters bsl as the bathymetry gently slopes away from shore. In seven days carried out in 2019, four divers completed a total of 72 dives. In 2019, because of logistical and staffing constraints associated with performing field work in remote areas, two divers each performed 24 dives (48 total), while one diver performed 14 dives and the other diver performed 10 dives. In 2021, over the two days of underwater photogrammetry operations 26 dives were completed by the team. Due to the photogrammetry rig being operated near the surface of the water by a single diver (Fig. 8), a surface swimmer, not on scuba, accompanied the operator for safety. To provide important logistical data on carrying out the photogrammetry project, we focus on the 2019 data here. With an average bottom time of 44 mins, the total accumulated bottom time was 52.8 hours and 48 minutes. In those ca. 53 hours, we were able to scout targets identified by geophysics, establish grids, and thoroughly photograph six 25 m x 25 m squares (J12, J13, H13, F8, F9 and D8) (Figs. 8 and 9), one 30 m x 30 m square (at the Sapienza Roman columns shipwreck), and a 15-meter by 15-meter square (at Sapienza Roman sarcophagi shipwreck; see below). In all, our dive team was able to get imagery of 4,875 m². For the MH site, a grid based on magnetic north was established to facilitate underwater work (Fig. 9). On the first day of diving, an area with clusters of submerged architecture was identified and the initial grid lines for the site were established. The first 25 m x 25 m grid square was established using one 100-meter plastic tape for the primary latitude line and three 50-meter tapes were used to construct the grid square. Once the corners of the grid square were established with 25 cm long metal rebar capped with orange plastic markers, two divers used an RTK GPS rover situated on a float with a metal pole long enough to reach the grid point on the sea floor, with one diver floating on the surface operating the instrument and the other at the bottom orienting the pole.

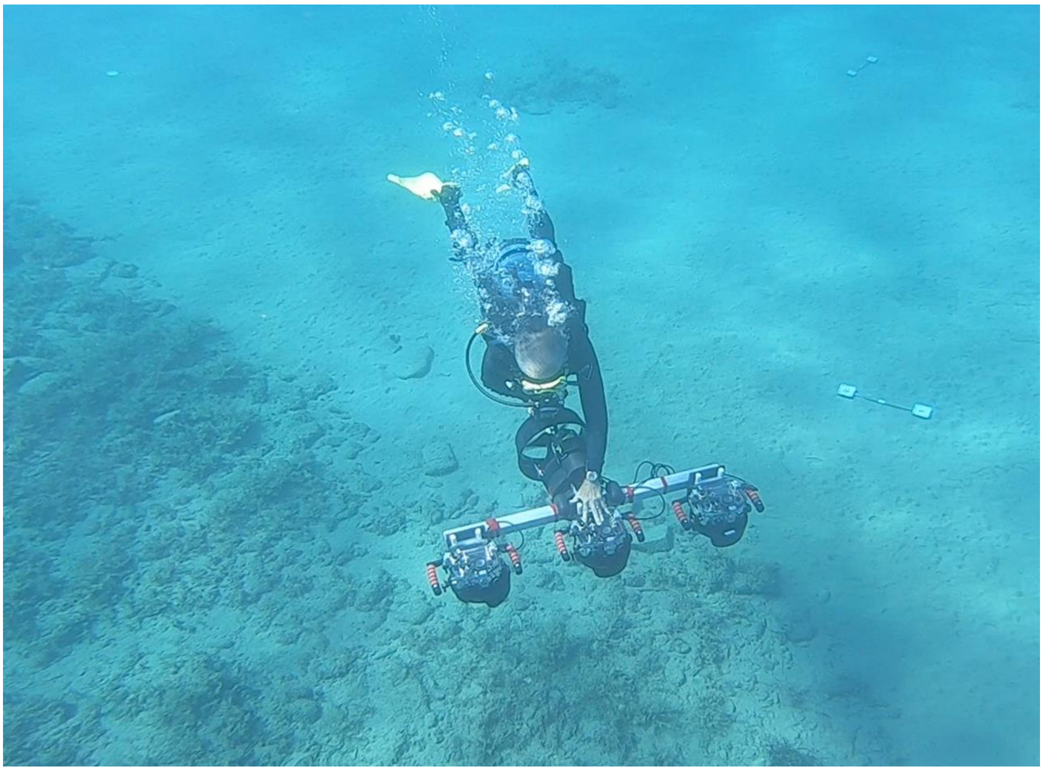

Figure 8. Three-camera photogrammetry rig developed for the Methoni project powered by a Piranha P1 Dive Scooter. The large size of the submerged Middle Helladic settlement (seen below the diver) made it necessary for divers to use a power source to facilitate large-scale exploration.

The six 25 m x 25 m squares (J12, J13, H13, F8, F9 and D8) and the ten (10) targets (T1-T10) of potential heritage interest inside the squares are represented in Figure 10 and required swimming more than 250 meters a dive. Fortunately, we had two Dive X Piranha P1 Dive Scooters for the survey. Accordingly, the science diving officer would navigate using a simple Garmin GPSMAP 78sc Handheld Marine GPS kept in a simple Tupperware container purchased in the village, trailing the GPS unit on the surface on an Omer Atoll Float Buoy with Flag. While the diving officer obtained the exact coordinates, a second diver remained below surveying. Once the coordinates were secured, the diving officer would drop down and the second diver recorded the target location (with a GoPro camera) indicated by the diving officer with hand gestures. This worked well as 5 target areas were the maximum number that could be investigated with one tank of air. Once these data were recorded the science diver could carry out an assessment of the target area. The area around Target 4 (Fig. 10) included a large stone-lined circle over 6 meters in diameter (Fig. 11), first discovered in the mid-1980s by Spondilis (1986). The wealth of architectural features in the vicinity of Target 4 led the team to establish a survey grid square in this area that was labelled Square F9.

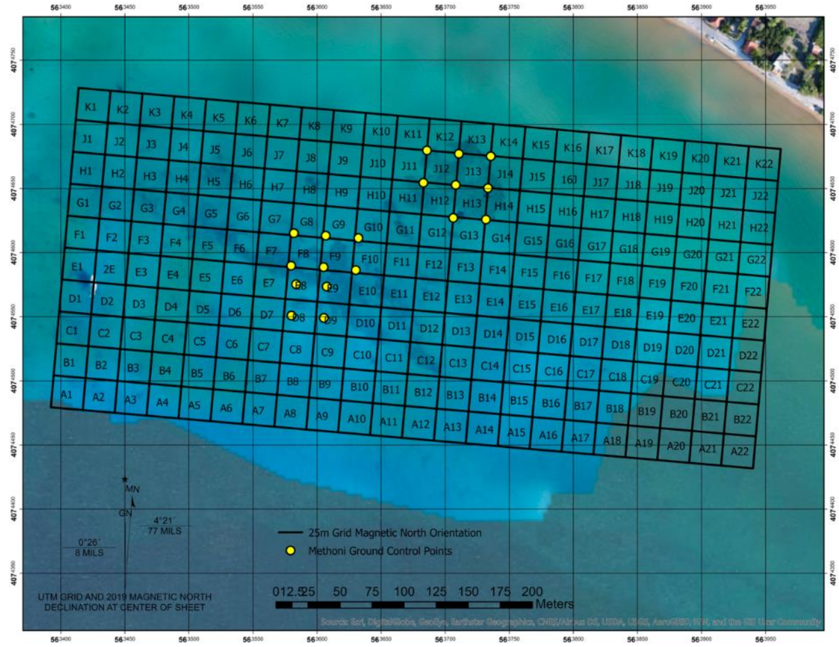

Figure 9. Map superimposed over the submerged Middle Helladic site at Methoni. Cultural heritage remains are visible from the surface and seen here as the dark patches below the grid squares. The UTM grid is established with 2019 magnetic north declination at center of map. Yellow dots indicate ground control points.

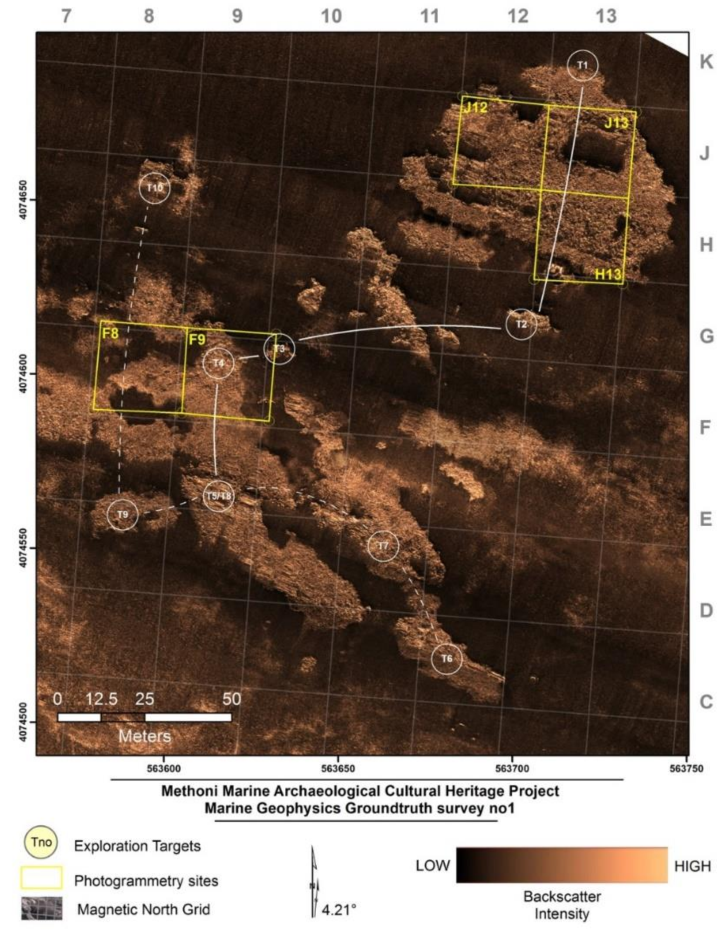

Figure 10. Target areas (25 m x 25 m squares and targets) superimposed on side scan sonar sonograph of the submerged Middle Helladic settlement at Methoni, Greece. Light tones represent hard substrate (submerged settlement) and dark tones correspond to fine-grained sediments (sand).

Figure 11. Diver surveys stone-lined circle over 6 meters in diameter at the submerged Middle Helladic site of Methoni.

Using our underwater photogrammetric system (Fig. 8), it takes three ca. 45-minute dives to complete the recording on one 25 m x 25 m grid square. The process includes: 1) lay out grid with 2 or 4 divers; 2) use motorized camera rig to image square north - south with ca 1.5 m track widths, followed by east – west imaging with same density to insure 60 % overlap between images; and 3) clean-up and removal of all tapes, stakes, and equipment to boat. As seen in Figure 12, Square F9 surveyed on 10-23-2019, the three rig cameras aligned with coverage resulting in a Digital Elevation Model (DEM; Fig.12, bottom) with 5.94 mm/pix resolution, ground sampling distance, and an orthorectified photomosaic with 0.742mm/pix. The total number of photographs collected to produce this model was 3,205 images. As noted above, with the 2021 higher resolution camera system, fewer images were needed.

During the 2021 expedition each of the new squares surveyed were processed individually in the field. After processing the newly acquired dataset of squares E8, E9, D8, and D9, the digital elevation models (DEMs) and ortho-photos were exported as Geo tiff files and imported into ArcGIS Pro. Figure 13 shows the surveyed squares from 2021 that provided more than 2,500 square meters of additional coverage. Particular attention was given to providing coverage to the north of squares E8 and E9 in order to provide sufficient overlap between the adjacent squares F8 and F9 that was excluded in 2019. Additionally, the survey of square E8 included coverage of exposed features to the south in square D8 (i.e., the majority of square D8 had no visible surface features so the remaining survey focused on other features which could be covered within the limited amount of time).

Once the 2021 dataset was imported into ArcGIS Pro, the 2019 dataset was overlaid on the 2021 dataset to verify the overlap (Fig. 14). This process to verify overlap can be done in the field to provide researchers feedback to verify if the desired coverage is achieved before returning from the field research. Additionally, Fig.15 provides a zoomed-out perspective of the same map as Figure 14 to assist in planning future surveying operations based on the widespread distribution of MH architectural remains.

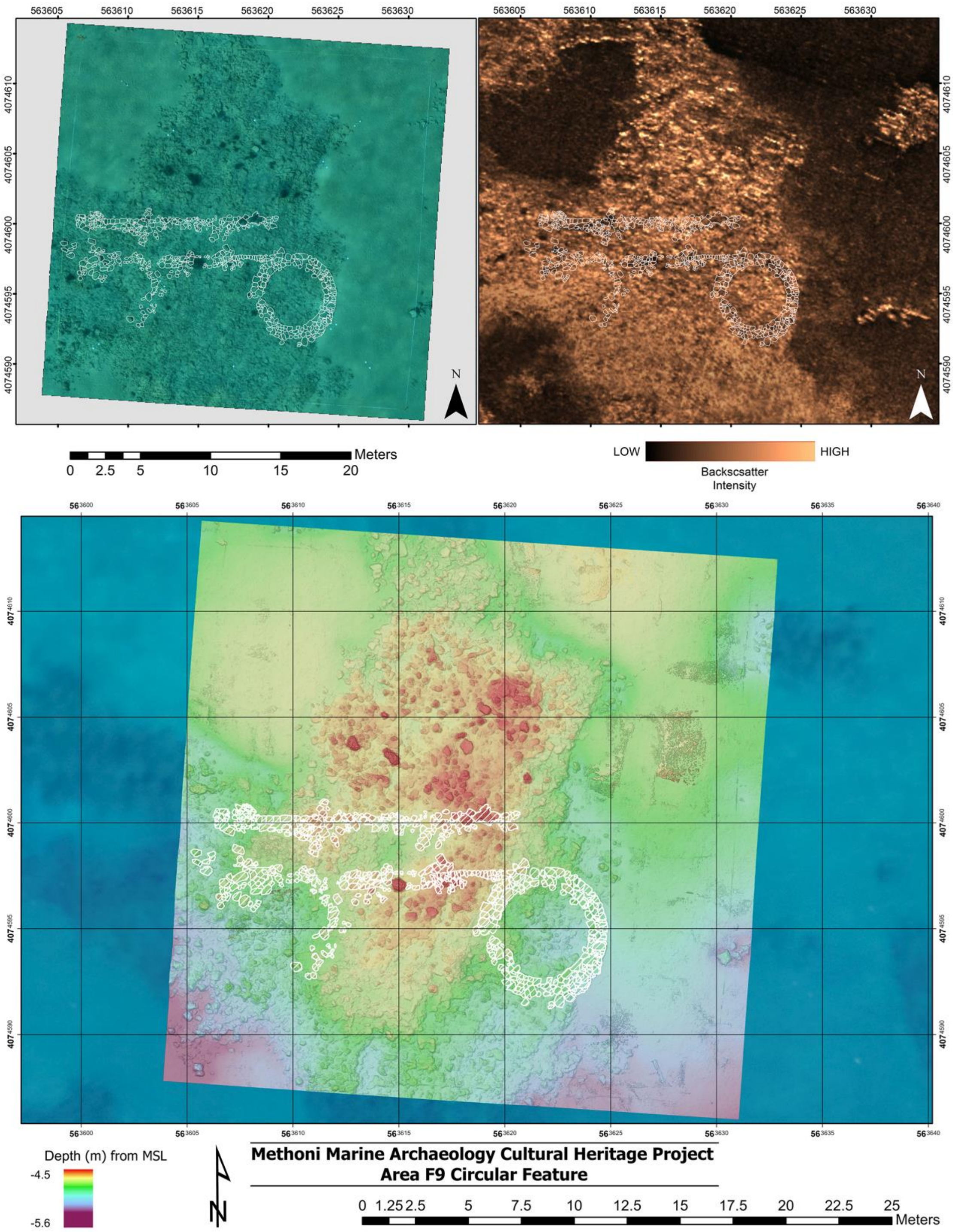

Figure 12. Orthophotomosaic (top, left) and side scan sonar mosaic (top, right) of Square F9 at the submerged Middle Helladic site of Methoni, Greece. A small part of the model has been digitized to map the large (+ 6 meter diameter) stone circle found here and another to the west. Bottom - digital elevation model with digitized features of Square F9.

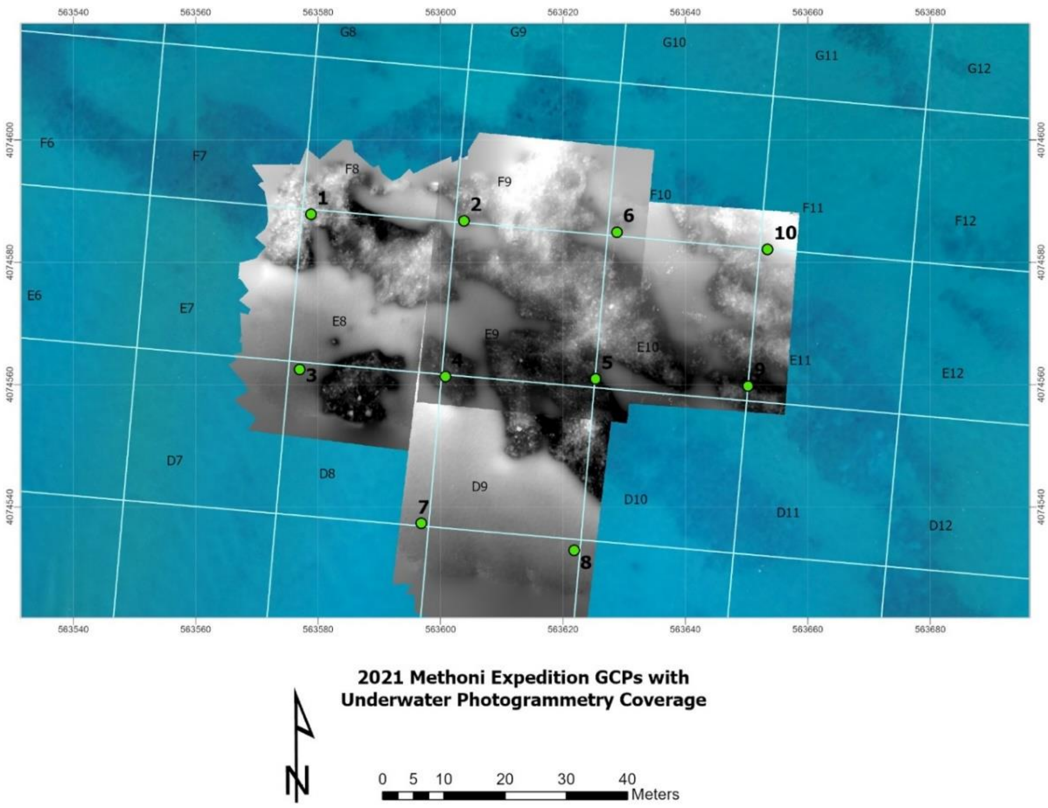

Figure 13. Individual squares digital elevation models (DEM) of the 2021 Methoni Expedition data set, overlaid with 2021 GCPs.

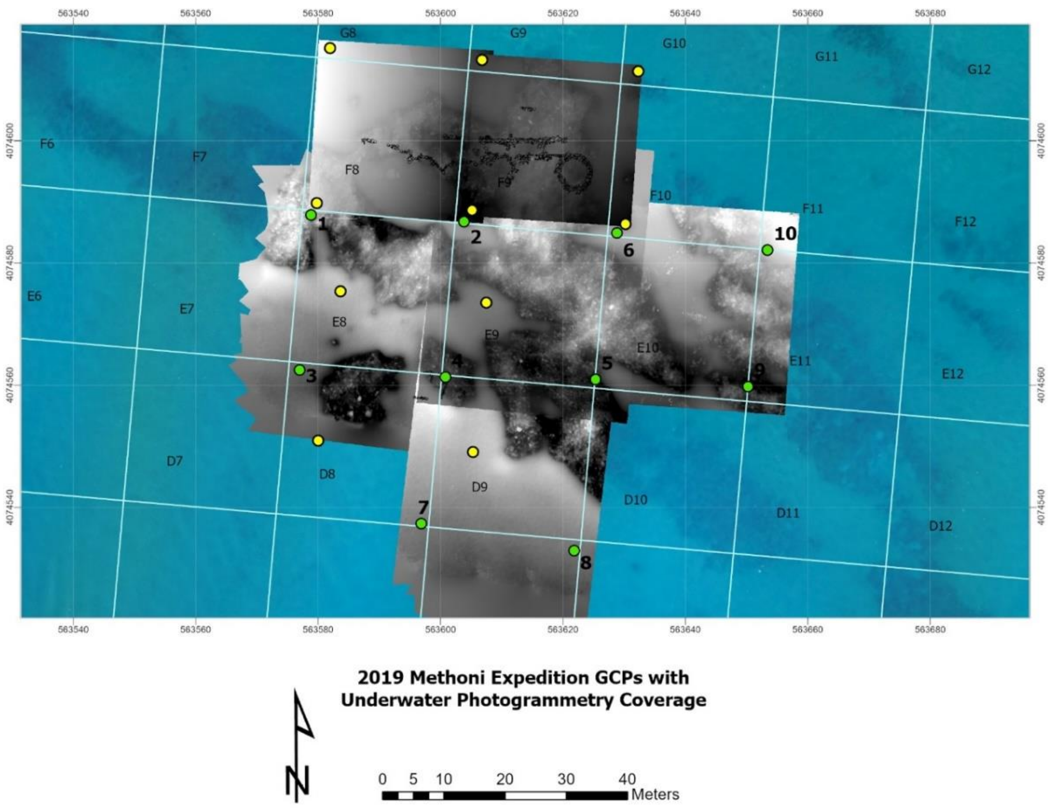

Figure 14. The 2019 Methoni dataset overlaid on the 2021 Methoni dataset.

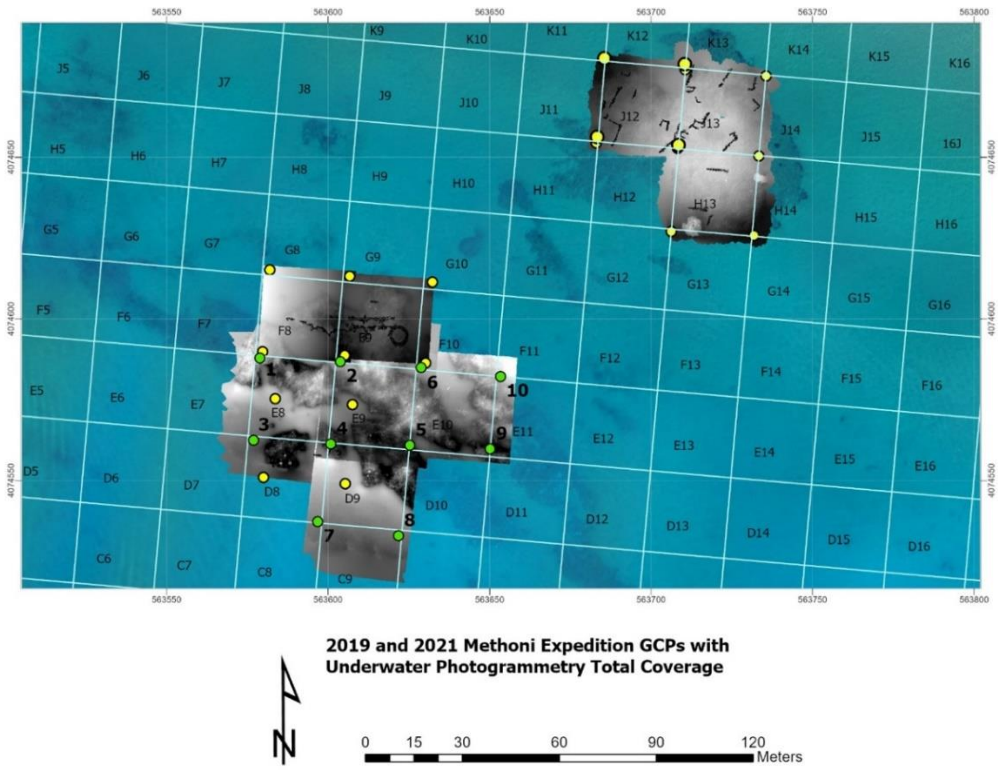

Figure 15. A map of all photogrammetric surveying of architectural data to assist in planning future surveys in the area.

The underwater mapping of the exposed surface architecture at the MH site at Methoni demonstrates the great potential of this site for understanding the spatial layout of this Middle Bronze Age site in relation to contemporary settlements in Messenia. While stone collapse from the MH building structures covers the sea floor of the ca. 3.5-hectare site, it is only now with the photogrammetry described above that large, separated areas of the site clustered separated by over 100 m in Squares F8/F9 and J12/J13/H13 (Fig. 15) can be shown to share a general east – west orientation and large-scale building activity (Fig. 12) indicating settlement planning. There preliminary results highlight the importance of this submerged site for the history of Messenia. Previous surveys in Messenia have shown that compared to the Early Helladic period, Middle Helladic site numbers declined in most parts of Greece (Bintliff 1977; Dietz 1988; McDonald and Rapp 1972; Renfrew 1972; Worsham 2015; Worsham et al. 2018). One of the MH type-sites in Messenia is Malthi, studied in the 1930s by N. Valmin (Valmin 1938), that may have had an elite residence (chief's house) surrounded by domestic houses encircled by a rudimentary fortification wall. According to Rutter (2017:25), the major differences that distinguish MH culture from the preceding EH III period include the gradual increase in scale of settlement architecture (Wiersma 2014) [194–196, 205, 221], increase in number of burials in visible aboveground tumuli [cf. (Müller 1989) (Merkouri and Kouli 2011; Papakonstantinou 2011; Petrakis 2021; Petrakis 2010; Voutsaki 2011), and the establishment of what (Tartaron 2014) conceptualizes as Mycenaean maritime networks and interregional and coastal trade systems. The large circular structure documented by Spondilis and in this project may reflect the foundation of tumuli, storage facility, or other large-scale feature. The architectural elements spread over the site and recorded with photogrammetry highlight the importance of the submerged site of Methoni for MH settlement pattern studies in Messenia and beyond.

To enhance our understanding of the multi-scalar aspects of the settlement pattern of the submerged MH site (Bevan and Conolly 2006), including intrasite spatial analysis and the overall extent of the site (Hietala 1984), the sub-bottom profiler survey was especially useful. Figure 16 presents a typical seismic profile recorded from the area of the MH settlement. There the exposed remains of the MH settlement (yellow color) have been recorded as a very prolonged reflector of about 350 meters in length. Although the amplitude of this reflector attenuates aside the site, can be detected for over 100 m to the west and over 400 meters to the east buried beneath the seafloor. It should be noted that the seismic reflector representing the subsurface continuation of the visible part of the settlement may be interpreted in many ways. It could be a change in the density of the sediment due to different sedimentary processes, erosion, paleosurface or cultural debris.

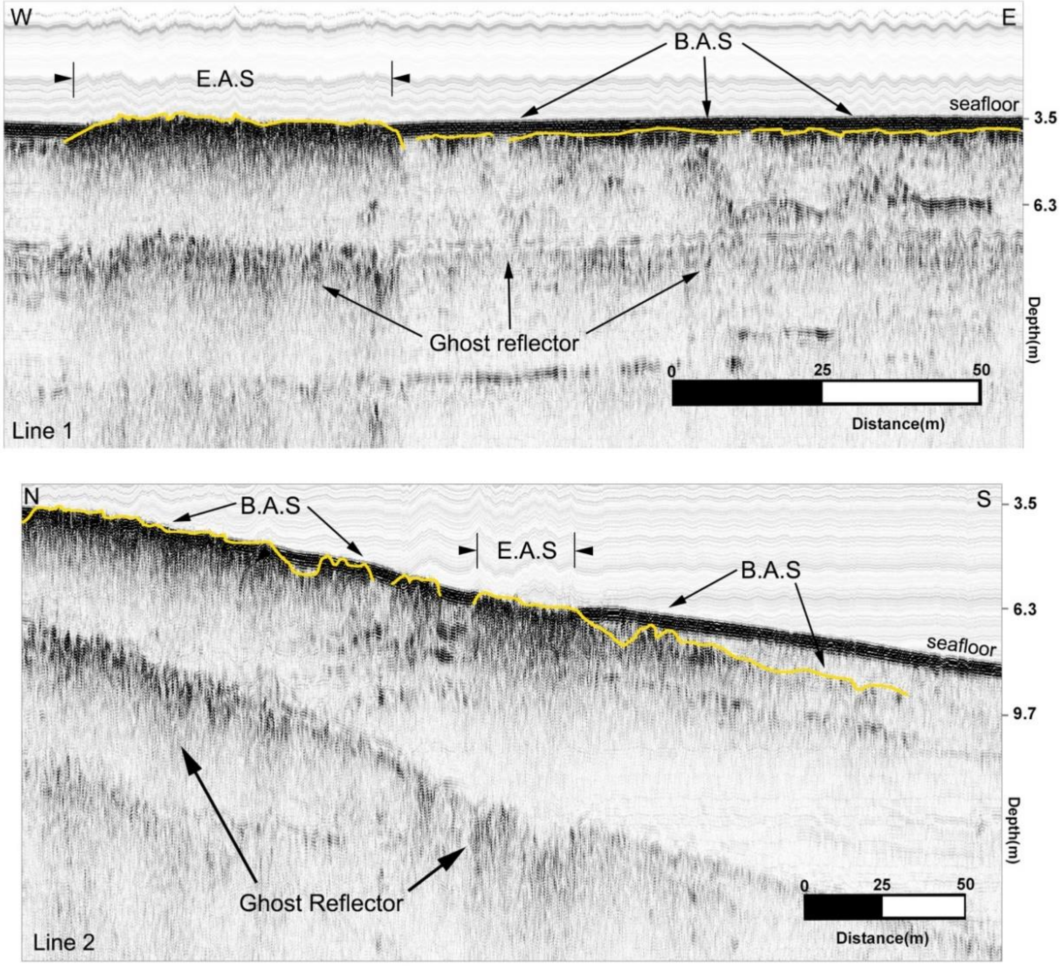

Figure 16. Typical high-resolution seismic profiles acquired at the submerged Middle Helladic site of Methoni using a Chirp sub-bottom profiler. The exposed archaeological site (E.A.S.) is characterized by a strong and prolonged seismic reflection. The continuation of that reflector below the seafloor indicates that an extended part of the archaeological site is now buried under loose sediments (B.A.S. = buried settlement site). An east/west (Line 1) and north/south (Line 2) seismic profile are shown here. The yellow lines indicate the top of the cultural deposits.

Figure 17 was produced as a preliminary GIS map that combines the side scan sonar, multi-beam and sub-bottom profile collected and processed on board during the 2019 Methoni expedition. The red polygon shows the exposed part of the cultural heritage site (such as the walls and circular architecture) and the yellow polygon shows the possible subsurface extension of the submerged archaeological site. While diving over those sandy areas void of archaeological surface debris (walls, collapse, features, etc.), the divers observed widespread evidence of settlement refuse supporting the large site hypothesis indicated by the sub-bottom profile data. Accordingly, prior to the 2019 expedition, we estimated the submerged MH site at Methoni to be ca. 3.5 hectares in size and now show it to be + 10 hectares in area (Fig. 17) by tracking the paleo-land surface that the site architecture was built on. The presence of MH remains on the small island of Nisakouli (Choremis 1969) ca. 1 km to the southeast in the Methoni embayment described above is now determined to be less than 350 m from the eastern edge of the submerged site. This may indicate that the submerged Middle Helladic sites may be even larger than the ca. 10-hectare paleo-surface identified here and extend even closer to the Nisakouli islet– an hypothesis suggested by Spondilis (1996) that will be tested in the future as it has ramifications concerning the size of the submerged site that will inform socio-economic models of Middle Helladic society in this part of Greece. To begin testing this hypothesis, a sediment sampling investigation took place in 2021 and is described below.

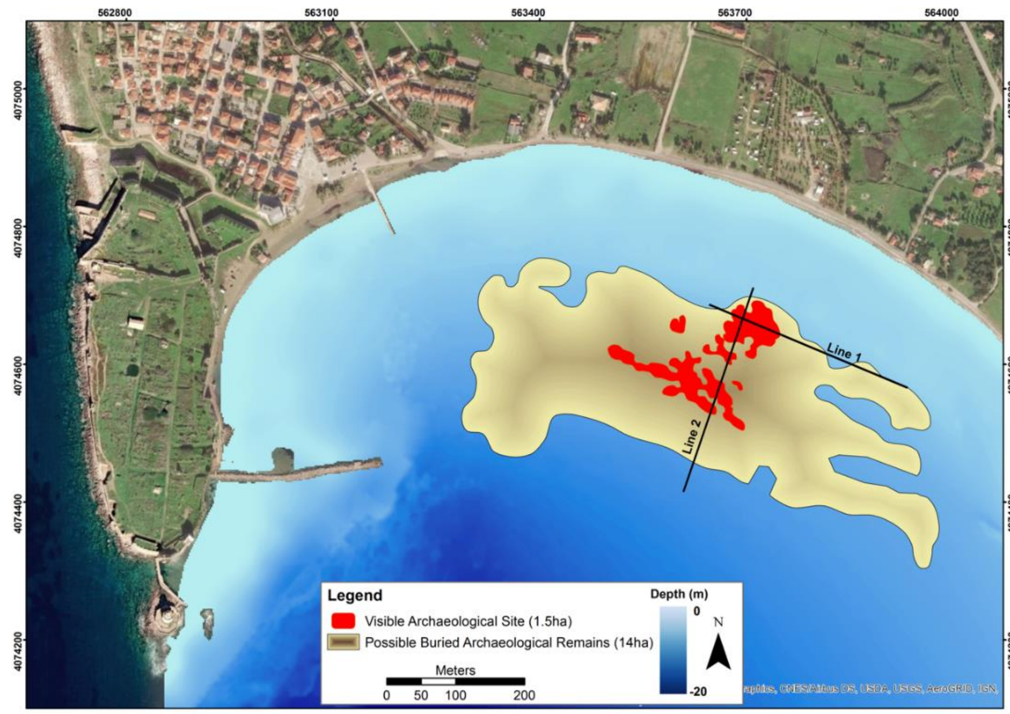

Figure 17. Composite map based on sub-bottom profiler, side-scan sonar, multi-beamdata and ground-truthing showing the exposed part of the submerged Middle Helladic site of Methoni in red (area = 1.5 ha). The larger yellowish polygon indicates the subsurface extent of a much larger settlement (area = 14 ha). east/west (Line 1) and north/south (Line 2) detailed in the Figure 17 seismic profiles are shown here.

4. UNDERWATER SEDIMENT CORING

One of the primary goals of the 2021 season was the collection of underwater cores around the submerged settlement. These cores will be important in determining the stratigraphy of the sediment on and around the site, hopefully providing paleoenvironmental and site formation data. Using the 2019 and 2021 sub-bottom profiler data as a guide, between October 8-19, a total of 17 underwater coring locations were identified. 15 successful cores were recovered in varying lengths while two were not recovered due to issues with core penetration into the shallow sand and cobbles (Figure 22; Table 3). The coring system used was developed by UC San Diego Scripps Institution of Oceanography Prof. Richard Norris and fine-tuned during the 2016 Antikyra Bay Gulf of Corinth expedition led by Profs. Levy and Papatheodorou (Cantu 2022; Levy et al. 2018).

4.1. Aim

The sub-bottom profile seismic data collected in 2019 and 2021 showed layered sediments of varying thicknesses and densities over and around the extant architectural elements. These reflections suggest that there were changes in the depositional processes through time, specifically since the inundation/burial of the Bronze Age site. Similar to other investigation conducted in the Peloponnese (Geraga et al. 2017) the aim of the underwater coring portion of this project was to extract a sample of cores from different areas of the site (and areas adjacent to the site) in order to confirm the layers seen in the geophysical data and further understand the depositional processes in and around the site, and in the Bay of Methoni overall. The data set will build on Kraft et al. (1977) palaeoceanographic reconstruction identifying that valley of Methoni and its embayment have changed from a narrow, fertile valley with occupancy around the peripheries to a marine embayment progressively intruding and drowning the valley system to its present level giving precise spatial and temporal constrain of these natural forcing and influences on human habitations.

4.2. Core locations

Core locations were selected based on the geophysical data (sub bottom profiles and multibeam sonar), diver assessment of surface sediment, and proximity to visible sections of the submerged cultural heritage site. In most cases, the sub-bottom profile data provided by the University of Patras team determined the thickness of the proposed coring locations and was the determining factor for choosing a sediment coring locale. Coring locations were marked and labelled on PVC pipes by divers for revisit. While every attempt was made to select locations that would offer the potential for the deepest recovery, the core recovery only averaged approximately 70 cm.

4.3. *Methods*

Due to previous work done by the University of Patras – UC San Diego at Antikyra (Levy et al. 2018), the majority of the large elements of the coring system was already in place in Patras. In fact, the University of Patras manufactured (cloned) a core hammer and clamp identical to the UC San Diego prototype making it unnecessary to transport this heavy equipment from California. The Antikyra project also provided a basic blueprint on coring operations from the research vessel. The coring system consisted of 6 m long aluminum core barrels, a 60lb slide hammer, and an adjustable stop clamp with handles. Steel core cutters and their associated sediment catchers were manufactured at the SIO machine shop in San Diego and transported by the SCMA team to Greece. The core cutters and catchers were riveted into the aluminum barrel and changed out after each collection. The initial plan for the cores allowed for recovery of a column of sediment over 4 m in length so the full 6 m core barrel was utilized. After several days of coring, it became apparent that recovery was much shallower than expected and there was no need for the long core barrels. The unwieldy nature of the full 6 m of core barrel in the water column led the team to cut down the remaining aluminum pipes to a max of 4m for ease of operation and conservation of materials. The core barrels were prepped on shore or on the boat deck (Fig. 18) with measurements taken and marks placed every half meter so the divers could gauge penetration during operation.

After prepping the core barrels, the handles were clamped on approximately 1m above the core cutter at the distal end of the pipe, the slide hammer was placed over the barrel and secured into place by carabiners and shackles. Two lift bags were connected to the hammer handles for the divers to inflate for transport to the location. Divers were supplied with wrenches to adjust the clamped handles as needed as well as given tape and labeled plastic caps to secure the sample before extraction. When the dive team was in the water and ready to start operations, the empty barrel/hammer setup was lowered over the side of the vessel with the boat winch and the help of the captain and surface crew. Once the barrel was in the water, the rigging diver filled the lift bags to aid in transport to the marker buoy. Upon arrival to the sea floor coring site, air was slowly let out so that the core barrel could be guided to the correct location. The lift bags were removed and secured to the buoy weights until needed for extraction and the hammer was disconnected from the handle. Divers worked together to lift the barrel and hammer so that the core would be taken at a 90-degree angle to the sediment surface. Initial strikes using the hammer set the core into the sediment. Once the core was stable, two divers worked together with the hammer to pound the barrel further into the sediment (Fig. 19). Operations were stopped when the team could feel no progress was being made and the top of the core barrel was capped and taped. The lift bags were reattached and choked to the core barrel with enough line to place the bags 1-2m below the water surface. This allowed for the extraction to be controlled by the divers and for the bottom end of the core to be capped quickly when the barrel released from the sediment. Once all divers were clear and the core was extracted from the sediment, the lift bags were reattached to the hammer handles for transport back to the boat. The core was then hoisted back on the boat with the winch attached by the rigging diver. Once on board, the top end was elevated, and the core barrel was secured on the foredeck. Depending on sea state and proximity of core locations, anywhere between 2 and 5 cores were taken each day.

Figure 18. UC San Diego researcher Loren Clark measures and marks a prepped core barrel.

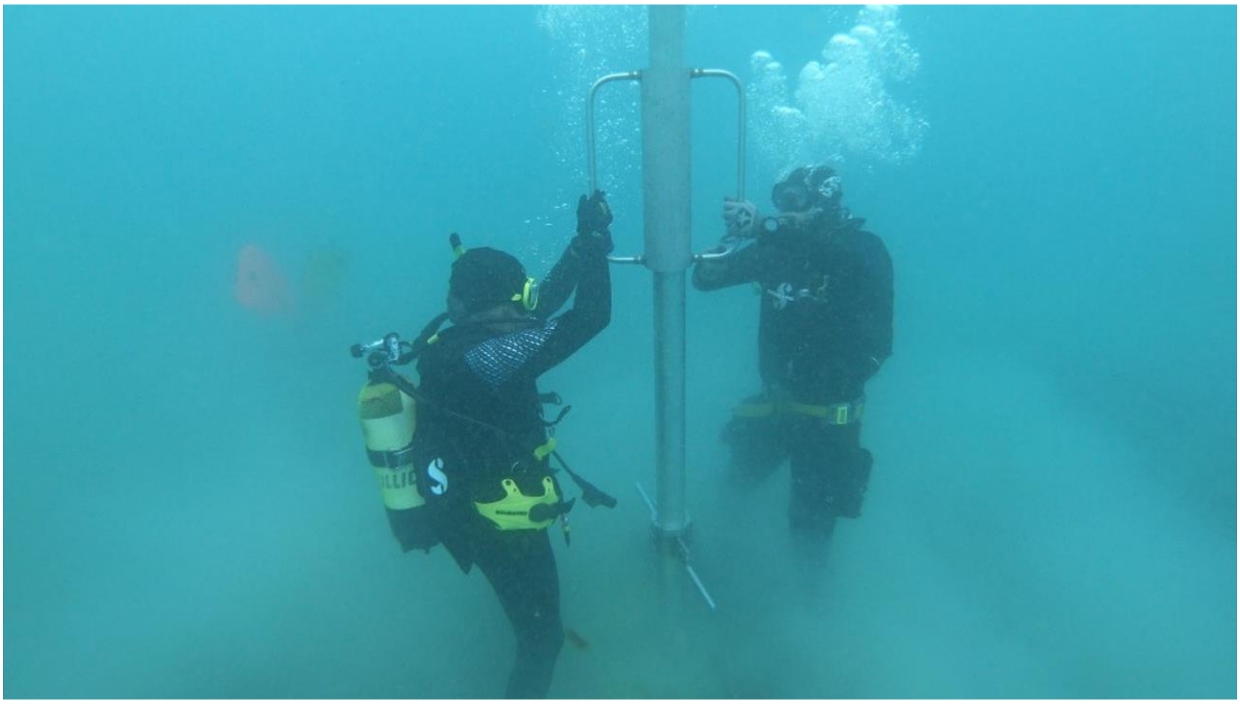

Figure 19. Prof. Thomas Levy and SIO Dive Safety Officer Christian McDonald operate the slide hammer during the collection of a sediment core.

4.4. Georeferencing

One of the other major goals of this expedition was to test some of the georeferencing techniques to pinpoint the locations of cores, features, and datum points more accurately in all sections of the project. As detailed in previous sections, the RTK unit was deployed on a floating ring with a smartphone that was linked to the receiver wirelessly that allowed a swimmer to position themselves above the core barrel to collect a GPS point (Fig. 20). The generally excellent visibility on the site allowed for this type of positioning system to be used.

Figure 20. Anthony Tamberino and Thomas Levy position the RTK over the coring team

4.5. Rigging

Under the direction of the Scripps Institute of Oceanography dive safety officers Christian McDonald and Rich Walsh, a rigging plan was set up for collection of the sediment cores (Fig. 21). During operation, the hammer and handle sections of the core system were separated, but during deployment/extraction from the boat and before extraction from the sediment underwater, these two sections were joined using shackles and carabiners. For all rigging, the lift bags were attached to the hammer arms, either with a small strap (surface extraction) or with a longer line secured around the core barrel (u/w extraction). For surface extraction, a guideline was attached by the rigging diver and the winch cable was dropped down and attached to the hammer arm. At this point the surface team lifted the core and detached the rigging elements once the core was safely secured on board.

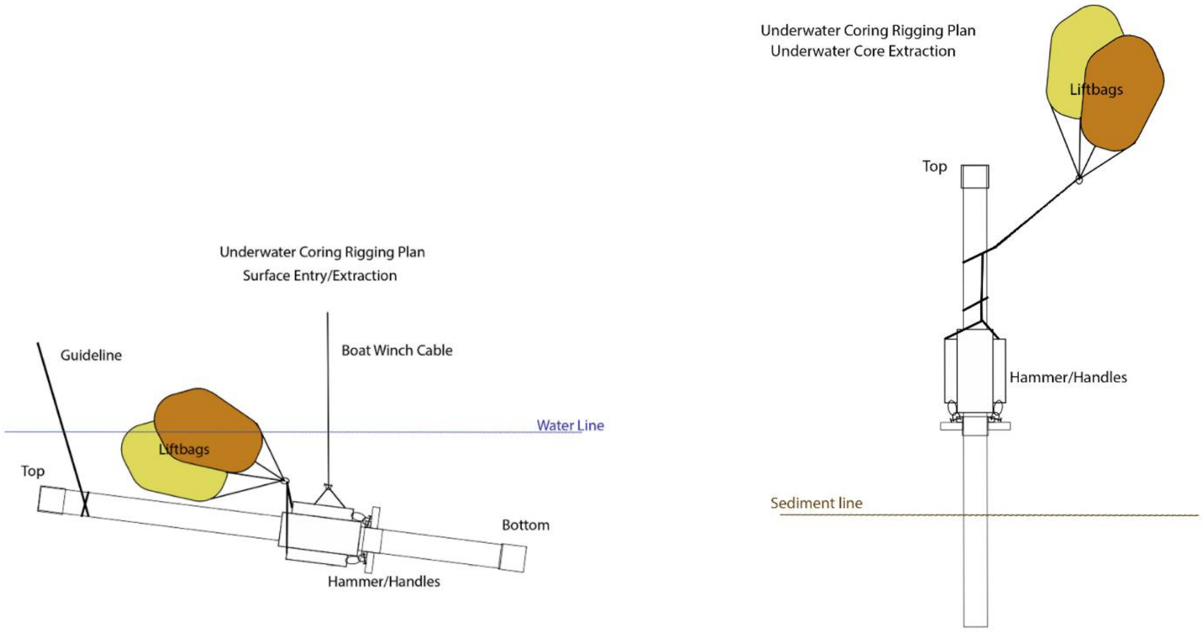

Figure 21: Underwater Coring rigging setup for boat entry/extraction (left) and underwater extraction (right).

4.6. Safety Measures

In utilizing a coring system where the primary operation is done by divers, various safety measures were put in place to ensure the safety of crew and samples alike. For the initial cores, it was unclear as to how difficult it would be to core into and extract from the submerged sediments around the archaeological sites. Due to this uncertainty, initial coring dives were conducted with a team of 4 divers to ensure that no individual was taxed too heavily in stabilizing, hammering, or extracting the core barrel. Once the core barrel was secured in the sediment (~20-30cm) two divers would work together to lift the slide hammer rotating out with the remaining divers to conserve energy and air. After the initial system was modified (see above) and all divers were comfortable with the process of coring, teams of 2 or 3 dove together to alternate sinking then extracting the cores. Surface operations were also considered carefully in regard to safety of the divers and boat crew. While lift bags were used to transport the empty core barrels and subsequently the extracted core in the water, a winch and guidelines were used on the surface to safely lift and guide the core system into the water and back on to the boat. One diver switched the rigging to the winch system then cleared the area before the surface team started hoisting the system out of the water. Once on board, the extracted cores were secured to the foredeck.

4.7. Cores and locations

The resulting core locations are plotted in Figure 22 and overlaid on the multibeam bathymetric map, demonstrating the spatial distribution of the sediment core samples. Table 3 provides the core name (MU1, MU2, etc.) basic geospatial data on the location of each core, the approximate depth of sediment retrieved, provisional sediment description and date of extraction.

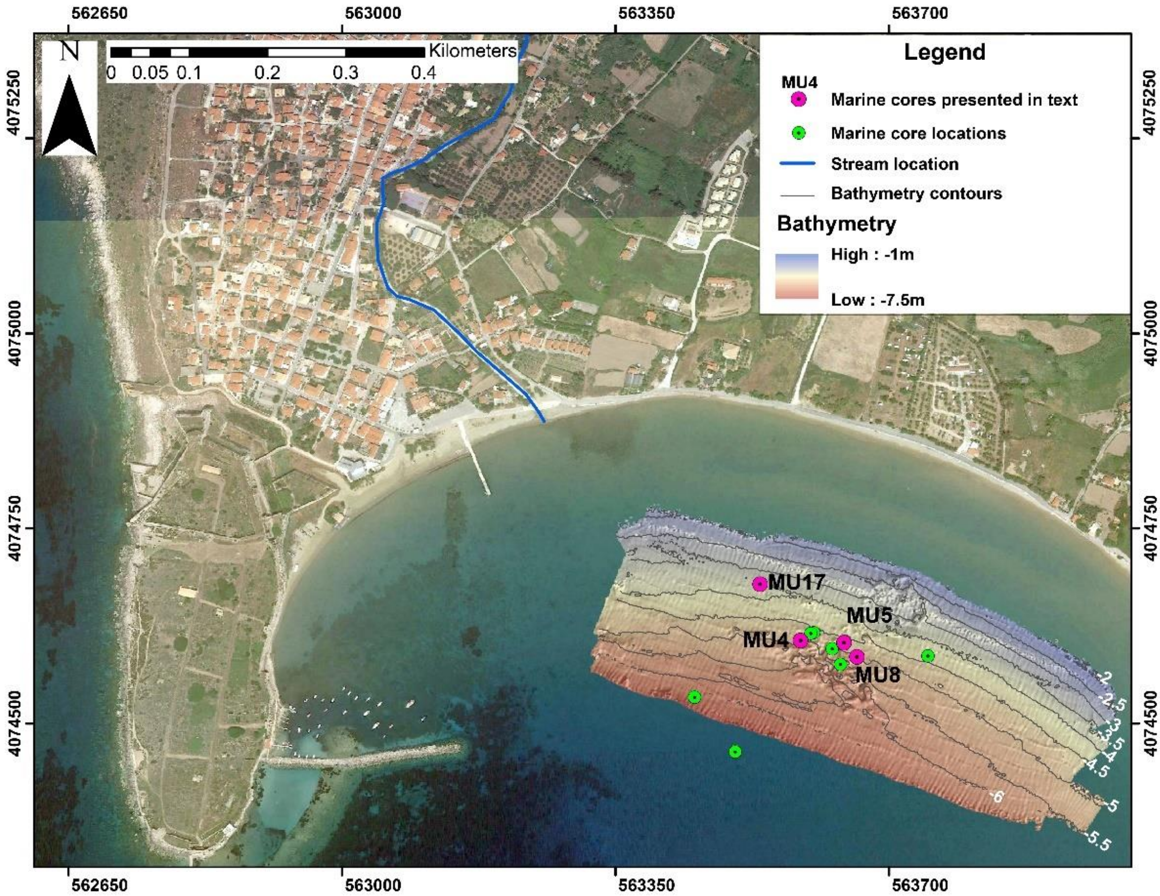

Figure 22. Map of sediment core locations overlaid on multibeam bathymetry, Methoni Bay, Greece.

Table 3. List of underwater sediment cores, depth of cores and associated data

CORE ID	Latitude	Longitude	Approximate length of core (m)	Collection date
MU1	36.81453045	21.711395	1	**8/10/2021**
MU2	36.81389797	21.71197605	0.8	**9/10/2021**
MU3	36.81526659	21.71311665	0.9	**9/10/2021**
MU4	36.81517712	21.71292301	1.75	**11/10/2021**
MU5	36.81514715	21.71354568	0.75	**13/10/2021**
MU6	36.81508017	21.71337894	0.9	**17/10/2021**
MU7	36.81502543	21.71336063	FAIL	**17/10/2021**
MU8	36.81498505	21.71372957	1.5	**12/10/2021**
MU9	36.81489821	21.71349442	0.4	**17/10/2021**
MU10	36.81484949	21.71306829	FAIL	**18/10/2021**
MU11	36.81498809	21.71475151	0.8	**18/10/2021**
MU12	36.81526	21.71307	0.6	**18/10/2021**
MU13	36.81454538	21.71416775	0.5	**19/10/2021**
MU14	36.81533457	21.71409772	1	**19/10/2021**
MU15	36.81573323	21.71285917	0.5	**19/10/2021**
MU16	36.81527748	21.71459723	0.6	**18/10/2021**
MU17	36.81583184	21.71234883	0.75	**19/10/2021**

4.8. Preliminary core observations

To enhance the cultural heritage significance of the Methoni Bay research for studying environmental change, observations on four sediment cores (MU17, MU5, MU4 and MU8) are presented here. Once extracted, the cores were sent to UC San Diego, split lengthwise, and their units (Fn) were defined based on sedimentological characteristics and the assessed Munsell-color types (Shtienberg et al., 2021, 2022). An Avaatech X-ray fluorescence (XRF) system was used for non-destructive characterization of elemental variations (photon counts per second, CPS) at 1 cm spacing along the cores. We used an excitation voltage of10 kV and 35 kV, and a 2-cm-diameter beam enabling relative difference assessment for each unit (Löwemark et al. 2011; Rothwell and Croudace 2015).

Elemental analysis was conducted for Sulfur (S) and Barium (Br) indicating oxygen concentration variations and biological activity respectively. Elemental ratios of Sr/Ca (Strontium/Calcium), Ti/Al (Titanium/Aluminum) and Zr/Rb (Zirconium/Rubidium) were assessed to evaluate changes in shell abundance, grain fraction variations and runoff contribution respectively (Croudace and Rothwell 2015). The amalgamation between the observations and geochemical analysis enabled us to establish a preliminary stratigraphic understanding of the submerged site as well as an initial interpretation of the depositional environmental changes that occurred in the area during the late Holocene. The lithostratigraphic units are presented here from young to old:

The lowermost unit, F1, was identified in core MU4 at surface elevations of -5.5 m relative to the approximated mean sea level (msl) and is 0.5 m thick (Fig. 23). This unit consists brown (5Y5/2) coarse sand with rounded silt stone, sandstone and limestone pebbles, and abraded marine shells. Elemental assessment of F1 consist of Sulfur Photon counts per second (cps) that are lower than 500 and Barium values that are lower than 1000 cps indicating oxidized conditions and low marine productivity. The elemental ratios of Sr/Ca, Ti/Al and Zr/Rb fluctuate in magnitudes of 0 – 0.2, 2 – 10 and 2 – 8 respectively representing high abundance of shells, coarse grain fraction and run-off influence. Based on these indications we suggest that Unit F1 is an alluvium deposit.

The recent sand layer covering much of the submerged site is absent in cores MU4 (Fig. 23) and MU5; Unit F2 overlies unit F1 and was identified in cores MU4 and MU5 at surface elevations ranging from -5.45 to -5.0 m relative to the approximated msl with thicknesses of 0.5 – 0.8 m (Fig. 23). The unit consists of a grey (5Y4/1) silty clay deposit abundant with *Posidonia* seagrasses and sometimes containing fragments of wood and possibly charcoal. Elemental assessment of F2 consist of S and Br values that are substantially higher than F1 indicating of periods with anoxic conditions and higher marine productivity. The elemental ratios of Sr/Ca, Ti/Al and Zr/Rb are substantially higher than F1 representing lower abundance of shells, finer grain fraction and no run-off influence. We propose that Unit F2 deposited in a shallow low energy marine environment.

Unit F3 overlies unit F2 and was identified in cores MU8, MU17 and MU5 at surface elevations ranging from -5.0 to -4.0 m relative to the approximated msl with thicknesses of 0.4 – 0.8 m (Figs. 23, 24). The unit consists of an olive (5Y4/2) silty clay deposit with abundant root remains and wood fragments. Elemental assessment of F3 consist of S and Br values that are lower than F2 indicating of mostly oxidized conditions and poor marine productivity. The elemental ratios of Sr/Ca, Ti/Al and Zr/Rb are lower than F2 representing lower abundance of shells, finer grain fractions and are devoid of run-off influence. We propose that Unit F3 deposited in a shallow low energy marine environment.

The uppermost unit, F4, overlies unit F3 and was identified in cores MU17 and MU5 at depth ranging from -4.75 to – 3.75 m relative msl with thicknesses of 0.1 – 0.25 m (Fig. 24). The unit consists of brown - Olive (2.5Y4/2 - 5Y4/2) sand to silty clay deposits abundant with wood fragments and charcoal. Elemental assessment of F4 consist of Sulfur and Barium values that resemble F3 indicating of mostly oxidized conditions and poor marine productivity. The elemental ratios of Sr/Ca resemble those of F3 while Ti/Al and Zr/Rb are substantially higher possibly indicating that the unit consists of coarser grain fractions and run-off influence. These indications suggest that Unit F4 is a mixture of marine deposits and alluvium, related to post-occupation site formation processes.

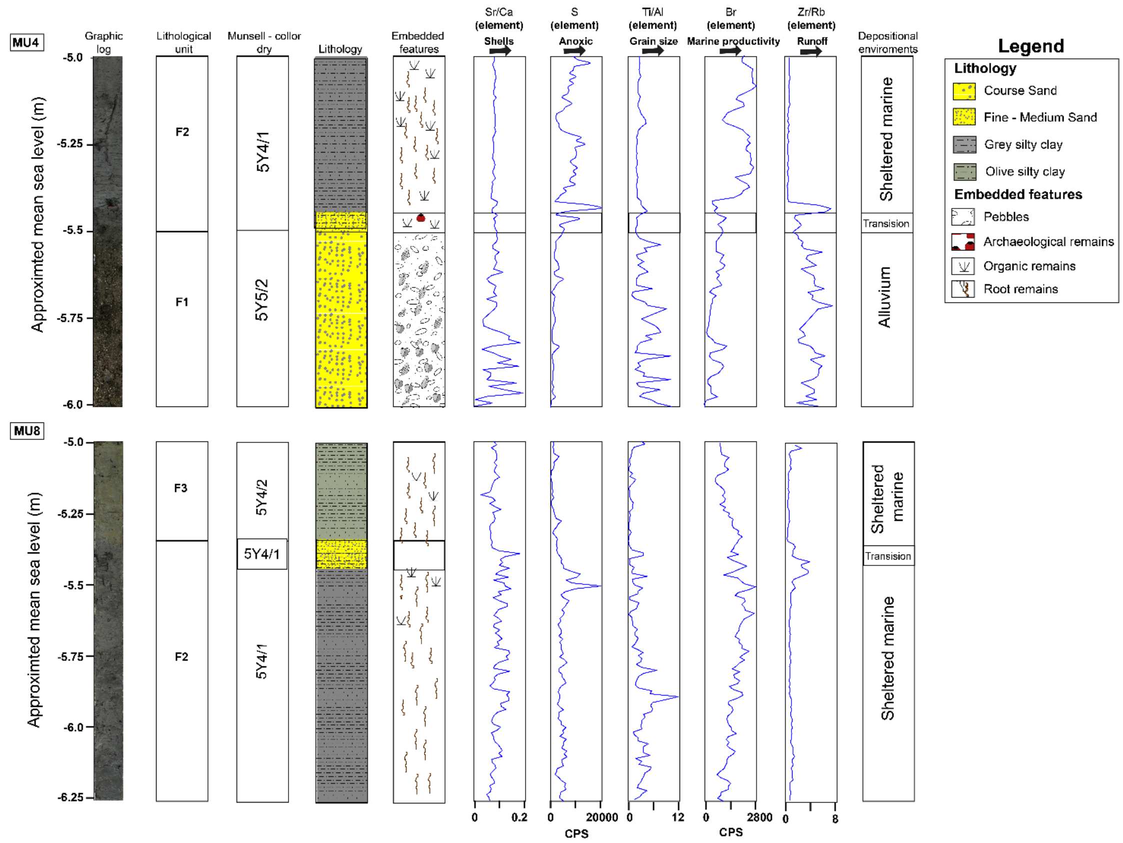

Figure 23. Marine cores MU4, MU8 with graphic log, lithological unit (see text for detailed lithological unit descriptions), accompanying features, distinguishing Munsell color, elemental variations and interpreted depositional environments. See figure 22 for locations of cores.

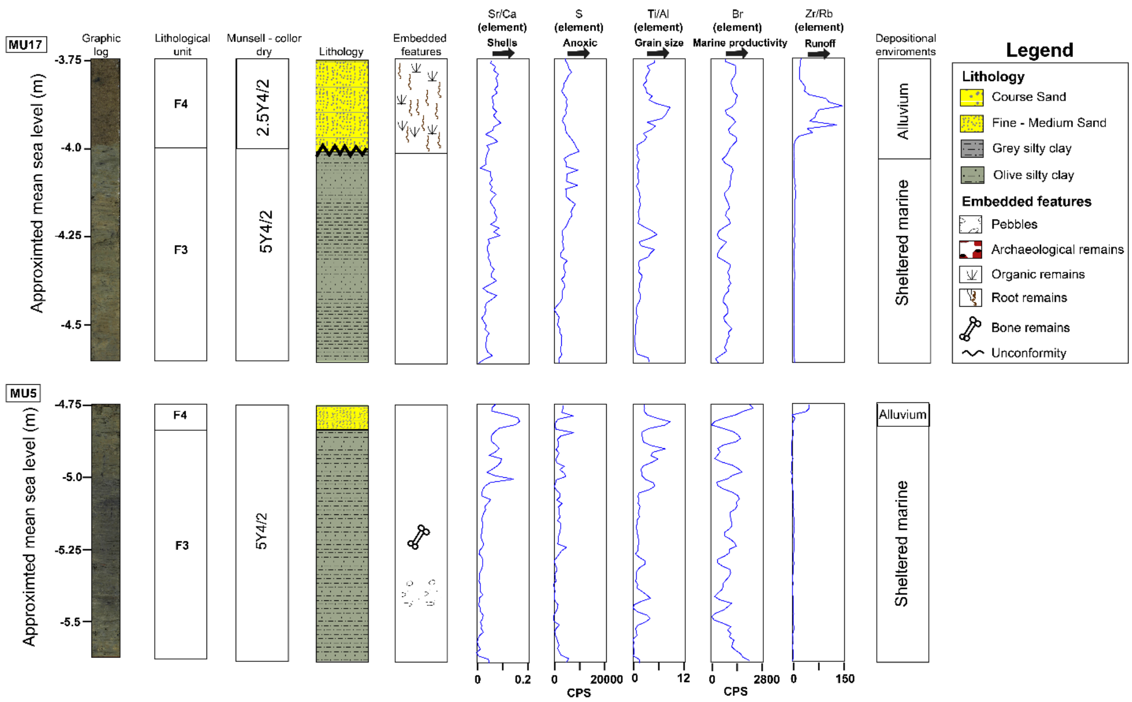

Figure 24. Marine cores MU17, MU8 with graphic log, lithological unit (see text for detailed lithological unit descriptions), accompanying features, distinguishing Munsell color, elemental variations and interpreted depositional environments. See figure 22 for locations of cores.

The stratigraphical sequence identified here potentially indicates of altering depositional environments fluctuating between fluvial - terrestrial and shallow marine geomorphic processes and possibly of tectonic subsidence. This suggestion seems probable because the southwestern Peloponnese is considered as one of the most tectonically and seismically active areas in Greece due to its proximity to the Hellenic trench subduction zone (Athanassas and Fountoulis 2013). As a result, the area was subjected from both global sea level that rose between 5 to 3 kyr (kilo-years) ago from -4 to -2 meters relative present mean sea level (Rohling et al. 2014.) and from localized subsiding land movement of ~ 0.2 mm/yr (Perissoratis and Conispoliatis 2003). Similar to the site of Pavlopetri located in southeast Peloponnese (Poulos et al., 2022) such forcings have affected the shoreline transgression that in return influences changes in the depositional environments (Malaperdas and Panagopoulos 2021).

Further assessment of these environmental changes will be substituted through additional investigation of the terrestrial cores (Fig. 25) acquired adjacent to the submerged coring site as well as radiometric dating of the lithological units identified here which will contribute a temporal constrains of the palaeogeographical changes of Methoni bay.

5. TERRESTRIAL CORING

In accord with our long-term goal to integrate studies of coastal geomorphology and archaeology, with both terrestrial and underwater components, we decided to carry out terrestrial sediment coring adjacent to the Methoni Bay. Profs. Maria Geraga, Tom Levy, Dr. Dimitris Christodoulou and Katrina Cantu identified coring locales. Three coring sites on land were sampled to complement marine core material collected near the submerged MH settlement site in the Methoni Bay. Additionally, these cores should help test some of tectonic questions arising from Spondilis (1996) research on the mechanisms that caused the submergence of the Middle Helladic settlement in Methoni Bay. Spondilis argues that this settlement subsided rapidly during an earthquake(s), given the geologic nature of Methoni as a subduction zone (Flemming 1969; Howell et al. 2016), and the fact that the submerged stone structures represent buildings and other features appear to be largely in place (Figs. 11, 12). Such an event would undoubtedly leave a sedimentological signature in the nearby wetland and in the deep sediments of the submerged MH site that our team was unable to penetrate (see above). Accordingly, there may be a layer of coarse material, perhaps with marine fossils, resulting from the displacement of seawater as the land subsided resulting in the settlement sliding further into the Methoni Bay. Finding such a layer would not only allow us to definitively determine the way the settlement was submerged but make it possible to temporally constrain the event. This hypothesis will be initially tested with the terrestrial cores described here.

5.1. *Locations of terrestrial cores*

The terrestrial coring sites were selected based on modern topography as well as the Kraft and Aschenbrenner (1977) (Fig. 25), which described the shoreward portion of the area as a salt marsh, and the land immediately behind this marsh as a "possible Hellenistic marshy embayment." Today, the marsh has been bulldozed and filled with debris in order to make it suitable for development and though it is dry, areas with lower elevation are dominated by Salsola soda or saltwort, a plant with particularly high tolerance for salty soil (Marbán and Zalba 2019), suggesting that the salt marsh sediments are not far beneath the surface. These sites are of interest because wetlands are excellent paleoenvironmental archives, as they are low lying, low energy environments that capture material from the surrounding area. This will allow us to test Kraft and Aschenbrenner's hypothesis, based in part on a single core extracted near this area, that the area behind the contemporaneous salt marsh was a marshy embayment during the Hellenistic period. It will also make it possible to construct a chronology for the demise of this possible embayment, and potentially its formation as well. This would give valuable information about the geography of the bay during an archaeologically significant period as well as allowing for past sea level reconstruction.

Table 4. Presentation of the 2021 Terrestrial Coring Locations

GCP Name	Longitude	Latitude	Elevation (m. msl)
ML-02	21.91350670	36.81820025	**22.488**
ML-03	21.71237693	36.81947754	**22.656**

5.2. *Methods*

Coring was done with a Cobra percussion core drilling system (Bailey and Thomas 1987) under the supervision of Prof. Konstantinos Vouvalidis. The process involves driving the core barrel into the sediment with a percussion driven hammer. The barrel was sunk at 1m or 0.5m intervals (depending on the depth and consistency of the sediment) and then extracted in 1m or 0.5m segments, respectively. Extraction was done with the aid of a hydraulic jack and, in the case of a jam, by hand with a simple lever extractor (Fig. 26). Each segment was collected in an opaque grey PVC barrel that was capped and marked upon extraction.

5.3. Collection

Core ML-01 reached a depth of 4 meters, and observation of the core ends shows several different stratigraphic changes. At 2 meters depth the sediment is gray with some orange mottling and is consistent with marshy deposits. There is coarse sand with what appear to the naked eye to be marine fossils at 2.5 meters depth. At 3 meters the sediment looks marshy, much like at 2 meters, and at 3.5 meters the appearance is very similar except for an apparent decrease in grain size. The bottom of the core at 4 meters shows orange-brown sand with gravel sized cobbles, and very much resembles terrestrial flood deposits and may represent a depositional period prior to the marsh formation. The core location is close to the edge of the Hellenistic "possible marshy embayment" delineated by Kraft and Aschenbrenner. Core ML-02 was not successful, as the modern, anthropogenic fill contains many large boulders. Three attempts were made to collect a core, but at ~0.3 meters the core cutter was blocked by limestone. Core ML-03 was collected ~70 meters east-northeast of ML-01. Inspection of the core bottom at 1 meter shows terrestrial soil much like the surface, and at 2 meters it is reddish brown, coarse terrestrial material. At 2.8 meters the core bottom sediment looks marshy with gray silt and orange mottling.

5.4. Initial results

While the entire stratigraphy of ML-01 and ML-03 won't be known until the opaque core liners are split and the full sedimentary sequence is exposed, these cores, particularly ML-01, are very promising in terms of displaying signatures of environmental changes. Establishing a chronology of the cores is paramount, and stratigraphic, geochemical, and grain size analysis will be performed to understand the evolution of the marsh, local sea level changes, and high-magnitude coastal flooding events such as tsunamis. Further coring in a transect perpendicular to the shore will be performed in future expeditions to better delineate the ancient marsh and see how far inland coarse sediment layers extend, which will give an idea of how impactful any coastal flood events were to the area.

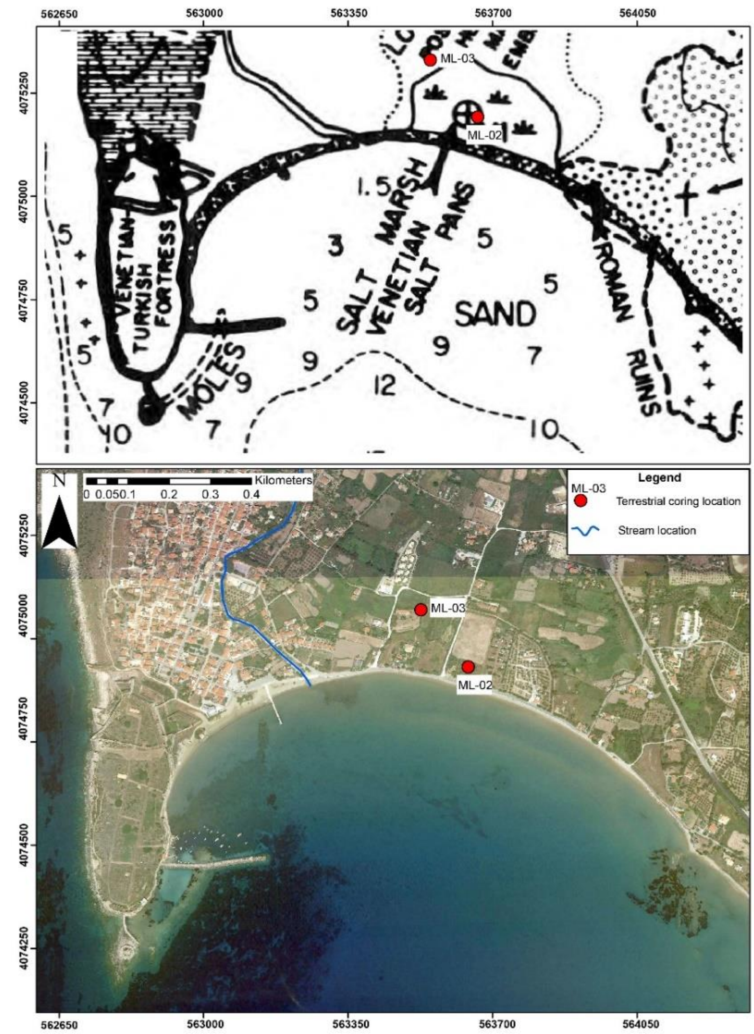

Figure 25: (top) Core locations on Kraft & Aschenbrenner (1977); (bottom) core locations on modern Google Earth imagery.

Figure 26: Coring in progress, Ilias Spondilis observing.

6. MARITIME CULTURAL HERITAGE: PHOTOGRAMMETRY AT SAPIENZA ISLAND WRECKS

In the 2013 call to establish an Underwater Archaeological Park (UAP) in the Methoni area (Georgopoulos and Fragkopoulou 2013) a case was made to include the waters around the Sapienza Island in the proposed protected area. Methoni and the northern coast of Sapienza Island were already recognized as part of the European Commission's Natura 2000 nature and biodiversity protected zone that includes over 18% of the EU's land area and more than 8% of its marine territory. From a cultural heritage perspective, the most important shipwrecks around Sapienza are the 'Shipwreck of the Sarcophagi' and the 'Shipwreck of the Columns.' These stunning wrecks are some of the most accessible and well-preserved cargoes for divers to access. The wrecks were first made famous by pioneer underwater archaeologist Peter Throckmorton in 1962 whose team surveyed these sites (Throckmorton 1970; Throckmorton and Bullitt 1963) following the 1961 – 1962 reports of a group of ancient columns lying on the seabed off Cape Spitha, the northernmost point of Sapienza Island, several kilometers south of the port of Methoni. The Column wreck probably dates to a cargo looted by the Venetians, after the occupation of Jerusalem in 1099 and were part of the 'Great Peristyle of Caesarea (Georgopoulos and Fragkopoulou 2013:192). According to Throckmorton and Bullitt (ibid., p. 18) this wreck contained 28 columns and large column fragments made from granite and the unbroken column (no. 9) measured 8 meters in length, weighing over 15 metric tons.

The 'Shipwreck of the Sarcophagi' is located 356 meters southeast of the Column wreck and contains four large granite garland-designed sarcophagi ca. 40 meters offshore. A broken glass unguent jar dated to the 2nd or 3rd century CE provides the date of the Sarcophagi wreck (ibid. p. 23). At a time when underwater archaeology was just becoming a recognized scientific field, it is remarkable how Throckmorton's team used traditional trained draftsmen and mapping tools (plastic tape measures, carpenter's level, lead diving weights; no drafting frame). They established six control points on surrounding rocks so that measurements could be triangulated at the end of each column to measure length and diameter. During our 2019 expedition to Methoni Bay – Sapienza Island, we wanted to compare the use of our 'modern' underwater photogrammetry system compared to the methods employed more than 50 years ago by the Throckmorton team. Our goals for both the Column and Sarcophagi wrecks were to: a) test the accuracy of the Throckmorton maps compared to underwater photogrammetry including identification of total number of visible stone fragments on the sea floor and weight estimates; and b) create 3D models of the wrecks that could contribute to the goals of helping to build a cultural heritage asset district for Methoni where non-diving visitors and researchers could access these wrecks in 3D environments at the local museums or online.

6.1. The "Shipwreck of the Columns"

The "Shipwreck of the Columns" was surveyed and mapped on October 26th, 2019. To begin the survey, three divers were deployed to define the boundaries of the site, and to document the process with photography and video. Two Piranha underwater scooters were used to expedite the survey and to transport both equipment and divers to the site. Throckmorton and Bullitt (1963:19) reported that there were 19 fragments at the "main site" with an additional six fragments located "sixty meters to the south" of the "main site". Our team was unable to locate these "six fragments" to the south because this location was approximately 25 meters inland and above the water surface, it is possible that Throckmorton and Bullitt were mistaken in their reporting of the directionality of this deposit. Once the "main site" was delineated, two 100-meter tapes were tied to a rock in the southwest corner and run at a 90-degree angle perpendicular to each other on a magnetic north and east heading to a length of approximately 35 meters. Each tape was then wrapped around a stake or nearby rock if a stake could not be placed. The tapes were then each run at 90-degree angles to meet in the northeast corner to complete a square. This 35-meter x 35-meter square completely included all archaeological remains found during the survey at the "Shipwreck of the Columns." Once the tapes were in place a set of 8 0.5-meter scale bars were placed around the site to help scale the 3D model. Additionally, RTK GPS positions and depths were taken of the four corners of the survey square to orient and geo-reference 3D model and the geospatial data. On the second dive, one diver navigated our three-camera photogrammetry rig propelled by a Piranha scooter to begin photographing the site. The three cameras attached to the rig were oriented nadir (i.e. facing strait down) to the seafloor, and the shutters were operated automatically by an intervalometer set to trigger the shutter at 1-second intervals. Two additional divers were deployed nearby and served as safety divers, one diver was equipped with a Piranha scooter to shadow the photogrammetry rig, and the other diver remained at the surface to monitor surface boat traffic, the activities underwater, and report to the expedition vessel anchored nearby. The photogrammetry rig began the west-east grid survey on the northwest corner. The survey pattern reversed direction and proceeded south by increments of approximately 3 meters. The initial plan for the survey included a north-south orientation pattern in addition to the west-east, however, an intervalometer failure with the rig prevented the north-south run. To guarantee sufficient overlap for photogrammetry, a third dive was conducted and each of the three divers operated a camera and photographed the square manually to complete the survey. After the survey was completed, the tapes and scale bars were recovered.

6.2. The "Shipwreck of the Sarcophagi"

The "Shipwreck of the Sarcophagi" survey (October 27th, 2019) was a much smaller site, ca. 20 meters x 20 meters when compared to the "Shipwreck of the Columns." The first dive provided the setup for the survey square around the Sarcophagi wreck. The setup was like the "Shipwreck of the Columns." However, the orientation of the square was changed from one based on a magnetic heading, to one that best fit the site because heavy seagrass (*Posidonia oceanica*) prevented the placement of stakes making it impossible to anchor good ground control point for georeferencing. Following the square setup, the corners of the square were georeferenced. The photogrammetry rig was repaired from the previous day of survey, with the same team deployed as the previous day. The photogrammetry rig survey was undertaken with a double grid pattern without issue. The survey was also monitored and documented by a Mini-ROV Guardian (see above) deployed from the nearby expedition vessel. Following the successful survey, an experiment was conducted to test the viability of directly georeferencing individual photographs using a single camera and an ultra-short baseline acoustic beacon (USBL) used for the ROV's localization when controlled by our research the vessel. The USBL transponder was attached to the top threaded screw above the hot shoe connector on the underwater camera enclosure. The experiment proved that the positioning of camera could be successfully tracked in 3D space underwater and that any future deployment of such a system would be dependent on the accuracy of the USBL, accurate timestamps of individual photos, and an accurate orientation measurement of each photo.

6.3. Results

The "Shipwreck of the Columns" and "Shipwreck of the Sarcophagi" datasets consisted of 9911 and 7054 individual images respectively. *Agisoft Metashape* software was used for photogrammetric reconstruction for both datasets. Each complete data set was processed on "high" settings for alignment, dense point cloud, 3D mesh generation, digital elevation model (DEM), and ortho-rectified photomosaic generation. Initial processing of both datasets produced significant erroneous points, artifacts of "blue-water" or the refraction of suspended sediments. These erroneous points were first filtered out by first removing the obliquely oriented photos with excessive "blue-water" or suspended sediments from the dataset. Secondly, the dense cloud was processed with the "calculate point confidence" option selected. This provided the metadata connected to each point in the dense point cloud to filter out the potentially erroneous points and provided a precise point cloud reconstruction of the area of interest. The scale bars set on the seafloor provided the points to create eight digital scale bars in *Agisoft Metashape* to precisely scale each model. Additionally, the four RTK GPS ground control points provided the latitude, longitude, and elevation in WGS84 coordinate system to accurately orient and georeferenced each dataset. The "Shipwreck of the Columns" 3D model produced photo realistic results. Figure 27 provides a side-by-side comparison of an underwater photo of the shipwreck aligned to the 3D dataset. The underwater photo in Figure 27A on the left was aligned with the photogrammetry dataset in *Agisoft Metashape*, the "look through" feature of the software then allows the textured 3D mesh to be overlaid above the underwater photo with the same orientation and perspective distortion (see Figure 27B). The DEM of the site provided a ground sampling resolution (GSD) of 1.6 mm per pixel (see Figure 27C) and an ortho-rectified photomosaic GSD of .801 mm per pixel (see Fig. 27D).

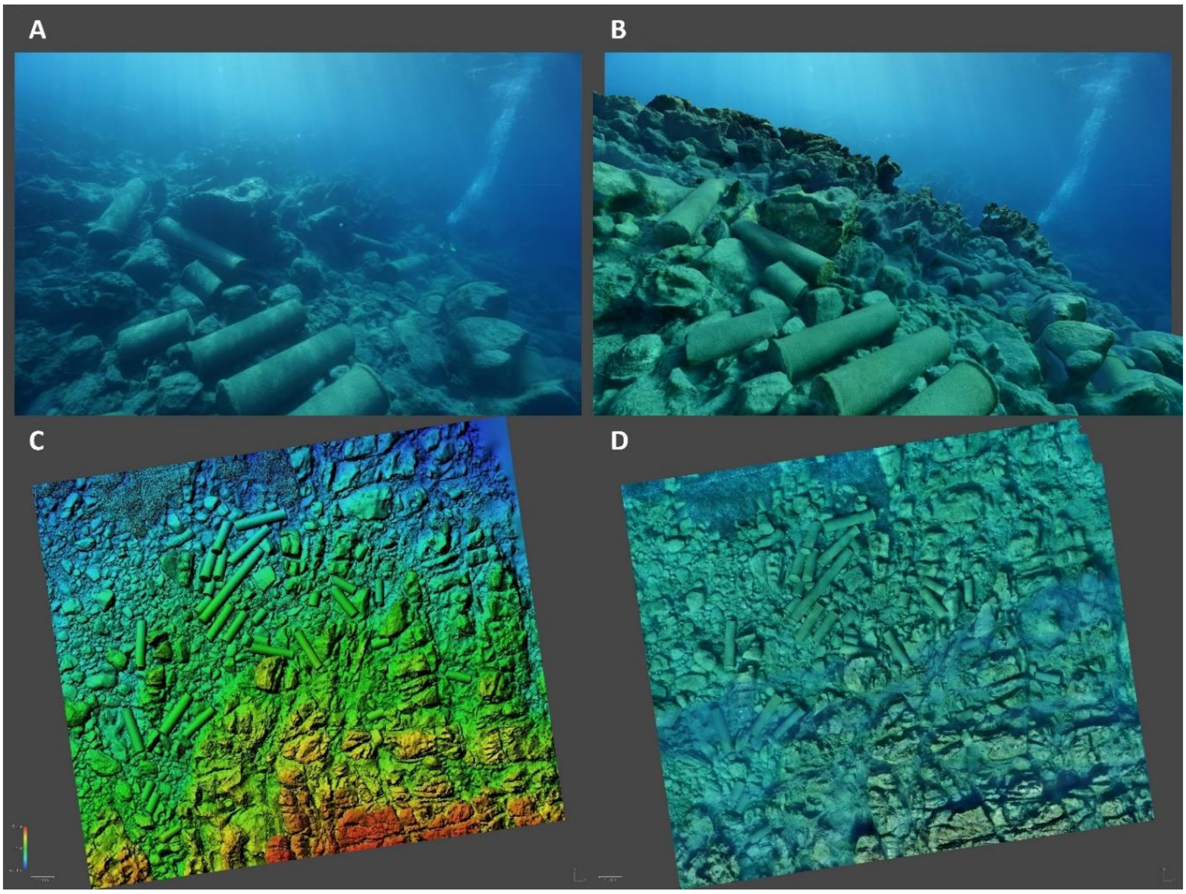

Figure 27. (A) 2019 Methoni Expedition Underwater photograph of the "Shipwreck of the Columns," (B) 2019 Methoni Expedition 3D textured mesh overlaid on an underwater photograph of the "Shipwreck of the Columns," (C) 2019 Methoni Expedition DEM of the "Shipwreck of the Columns," and (D) 2019 Methoni Expedition ortho-rectified photomosaic of the "Shipwreck of the Columns."

The "Shipwreck of the Sarcophagi" provided similar results with Figure 28 providing an underwater photo and the 3D textured mesh. The DEM of the "Shipwreck of the Sarcophagi" also provides a GSD of 2.44 mm per pixel and an ortho-rectified photomosaic of 0.61 mm per pixel GSD.

The 1962 expedition researchers to the "Shipwreck of the Columns" and the "Shipwreck of the Sarcophagi" discussed the impossibility of taking a single photograph to encompass the entire area of each wreck (Throckmorton and Bullitt 1963:19). Our methodology using modern photogrammetric techniques, digital cameras, software, and computers allowed us to achieve this "impossible" task. Comparison of the "new' 2019 dataset with the "old" hand drawn plans from 1962 provides new insight into the "Shipwreck of the Columns" and the "Shipwreck of the Sarcophagi" sites. Figure 29 provides a side-by-side comparison of each site beginning with "Shipwreck of the Columns" (Figs. 30A, B) and the "Shipwreck of the Sarcophagi" (Figure 28C&D).

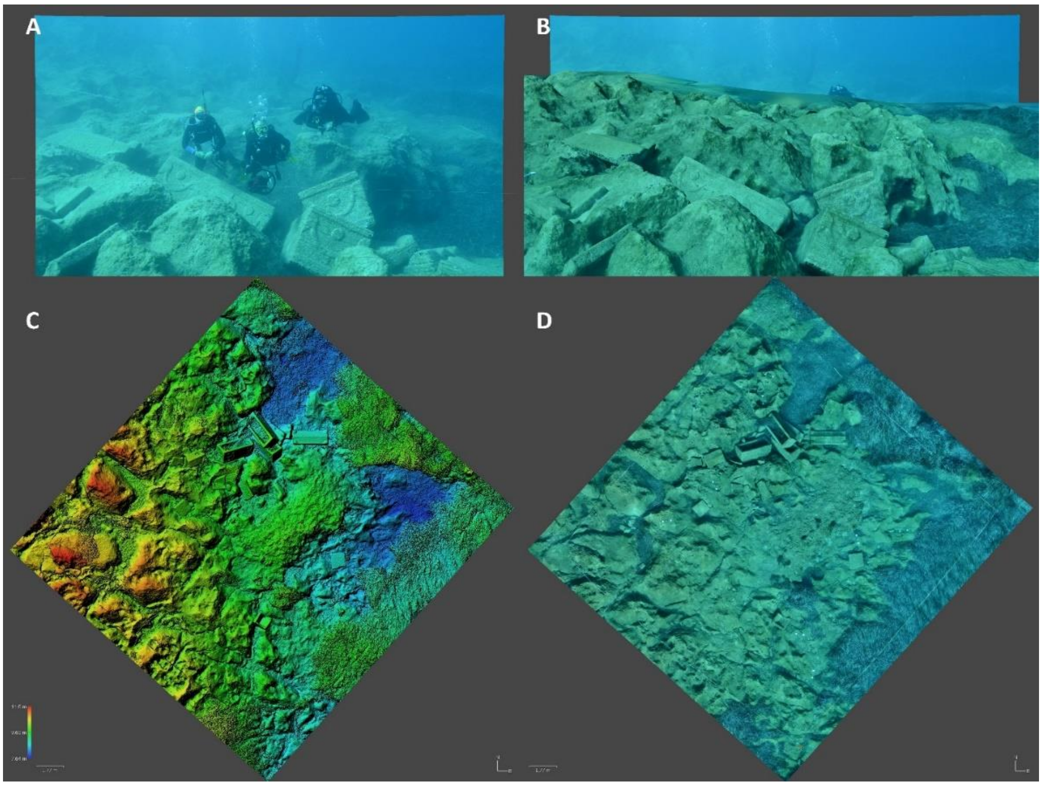

Figure 28. (A) 2019 Methoni Expedition Underwater photograph of the "Shipwreck of the Sarcophagi" with the three-diver team, (B) 2019 Methoni Expedition 3D textured mesh overlaid on an underwater photograph of the "Shipwreck of the Sarcophagi," (C) 2019 Methoni Expedition DEM of the "Shipwreck of the Sarcophagi," and (D) 2019 Methoni Expedition ortho-rectified photomosaic of the "Shipwreck of the Sarcophagi."

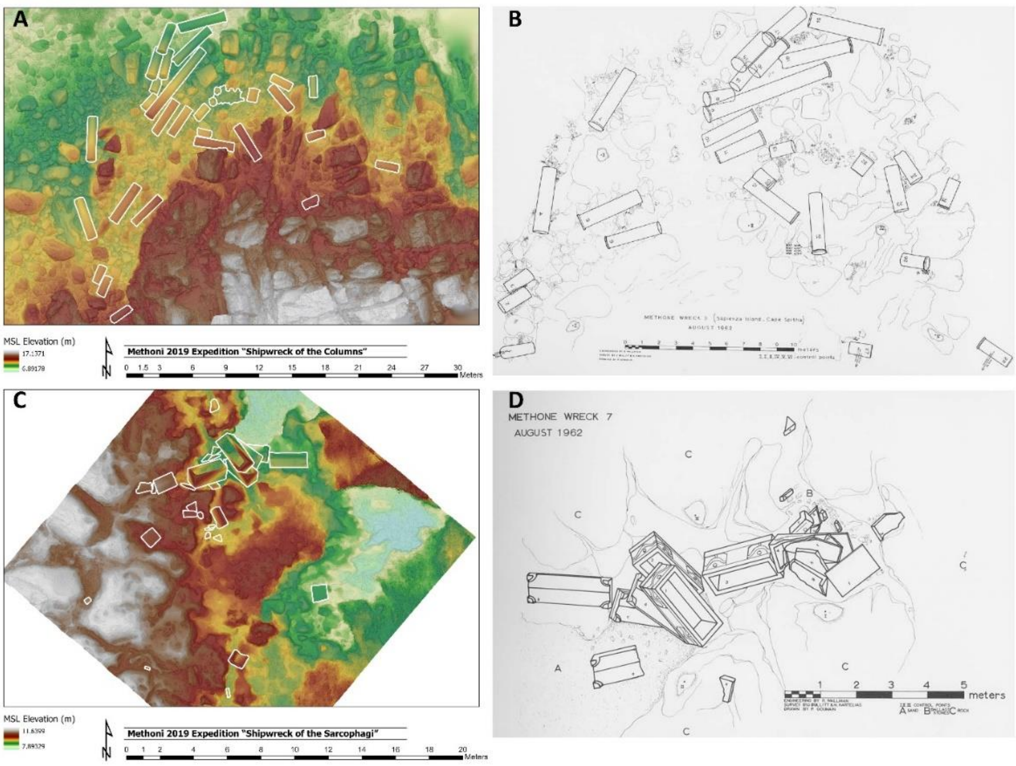

Figure 29. (A) 2019 Methoni Expedition DEM and digitized top plan of the "Shipwreck of the Columns," (B) 1962 top plan of the "Shipwreck of the Columns" (source: Throckmorton and Bullitt 1963), (C) 2019 Methoni Expedition DEM and digitized top plan of the "Shipwreck of the Sarcophagi," and (D) 1962 top plan of "Shipwreck of the Sarcophagi" (source: Throckmorton and Bullitt 1963).

In respect to the "Shipwreck of the Columns," Throckmorton and Bullitt reported the length of "column 9" to be 8 meters, this measurement of the only complete column at the site is consistent with our measurements. Throckmorton and Bullitt also reported that some of the columns were rounded, these columns are in relatively shallower water near the surf zone, and we interpret their rounded appearance as the result of erosion due to their positions in these surf zones. It is also possible that they were deposited when sea levels were lower, further exposing them to aggressive surf erosion. Our team would also like to test Throckmorton and Buillett's hypothesis that the columns did not fit together as original cargo on the ship. The nature of our data will allow us to digitally refit each column in various combinations to determine if the column assemblage indeed do or do not consist of a set of columns that were broken in the aftermath of the wreck. It was the assessment of Throckmorton and Bullitt that they were loaded on the ship in an already broken condition. The nature of these new data will also allow us to estimate the entire weight of the column cargo more accurately by digitally measuring the total 3D volume of the column cargo. Throckmorton and Bullitt also only reported "a few pot sherds," however, our observations identified a large concretion of pot sherds directly next to two very poorly preserved Corinthian style column capitals that were not reported by the 1962 expedition. These finds require further investigation and analysis. Comparison of our data for the "Shipwreck of the Sarcophagi" provides evidence of some disturbances to at the site beyond those described by Throckmorton and Bullitt (1963:21-23). The top plan from Throckmorton and Bullitt in 1962 (Fig. 29D) has an unusually flipped orientation where north is at the bottom of the plan. Keeping this in mind when comparing to Figure 29C, the fourth broken sarcophagus seems to have been disturbed and scattered to the south and southeast of its previous location in 1962. Additionally, our team was unable to map a lid fragment to the east of the three intact sarcophagi due to heavy seagrass cover, and it was unclear if this missing fragment was removed from the site by Throckmorton and Bullitt or others. Our 3D reconstruction of the decorative elements of the unfinished garland sarcophagi could allow us to better understand the origin or destination of the sarcophagi through further typological analysis.

In summary, sixty years after Throckmorton and Bullitt produced their underwater map, when compared with our photogrammetric survey of both wreck sites, we marvel at the accuracy of their map work made with simple builders' levels and tape measures. Photogrammetry, in addition to matching the accuracy of the early work, adds important new insights that earlier mapping could not achieve. This includes a better understanding of the context of both wrecks. As shown in Figure 30, using the *Agisoft Metashape* ortho-rectified photomosaics superimposed on satellite imagery, both wreck sites can now be seen in their near-shore precarious contexts. Figure 30A is a plan view of Sapienza Island that shows both wreck sites within 30 to 60 meters offshore. Regarding the Sarcophagus wreck (Fig. F30B), if not for the isolated submerged rock outcrop nearby, sailing in this area would have been fine and no accident would have occurred. Figure 30C and 30D are oblique views of the wrecks and the nearshore landscape, providing a contextual view of the artifacts (columns, sarcophagi fragments) in relation to the actual wreck sites. Future integration of these photogrammetric data with multibeam sonar bathymetry will provide an even deeper understanding and a more quantitative contextual view of the submerged landscape. Finally, the 3D models created by underwater photogrammetry can be viewed in several virtual reality (VR) platforms. The 3D models achieved in *SketchFab.com* can be viewed in personal VR devices such as Google Cardboard and Oculus Rift, or large scale immersive VR platforms (Knabb et al. 2014; Levy et al. 2020). These 3D datasets will enhance the visitor experience at local museums in Greece and for online communities that are unable to scuba dive themselves.

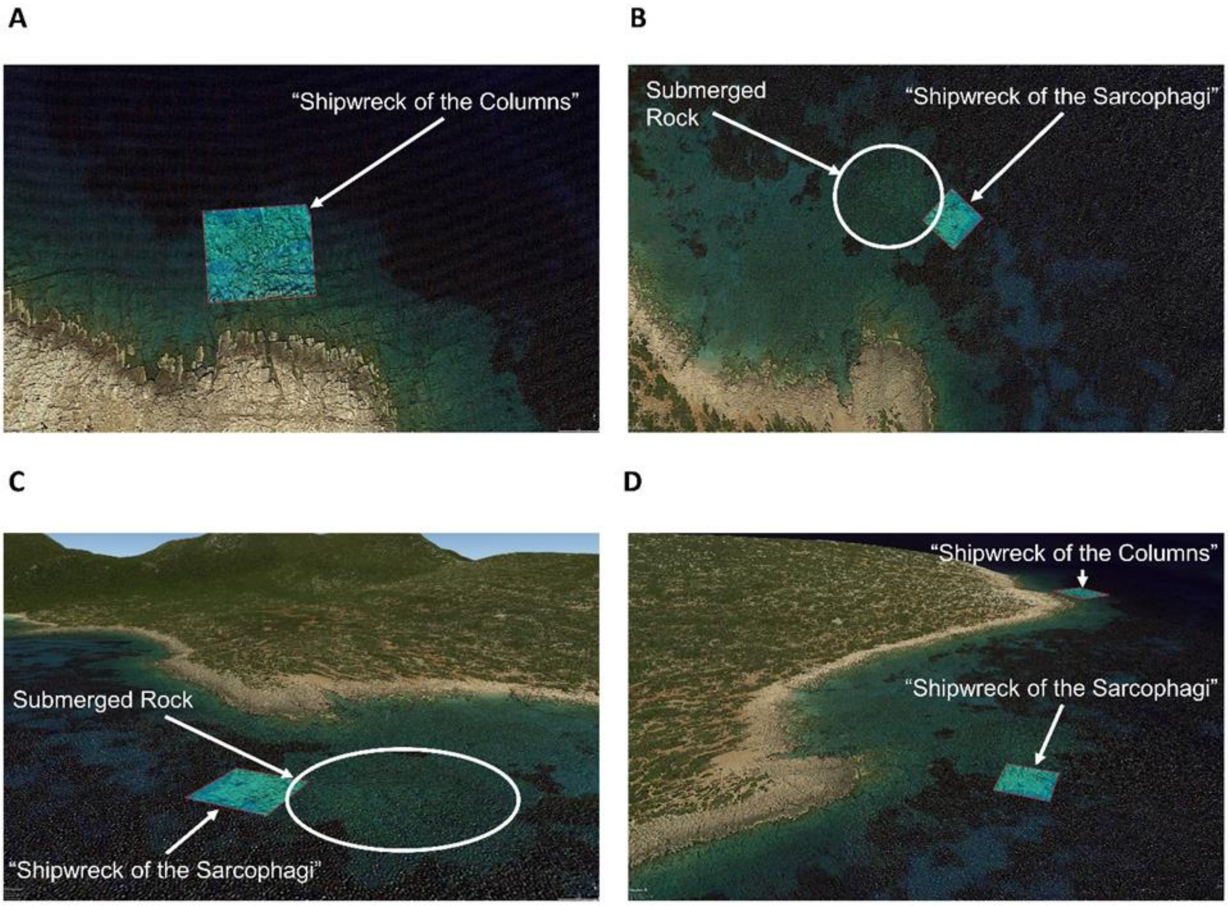

Figure 30. (A) plan view of the 2019 Methoni Expedition ortho-rectified photomosaic of the "Shipwreck of the Columns" overlain on Google Earth satellite imagery and DEM, (B) plan view of the 2019 Methoni Expedition ortho-rectified photomosaic of the "Shipwreck of the Sarcophagi" overlain on Google Earth satellite imagery and DEM, (C) 3D oblique view of the 2019 Methoni Expedition ortho-rectified photomosaic of the "Shipwreck of the Sarcophagi" overlain on Google Earth satellite imagery and DEM, and (D) 3D oblique view of both the 2019 Methoni Expedition ortho-rectified photomosaic of the "Shipwreck of the Sarcophagi" and the "Shipwreck of the Columns" overlain on Google Earth satellite imagery and DEM.

7. CONCLUSION

The Methoni Bay Cultural Heritage Project, Greece is a collaborative effort of the University of Patras and the University of California, San Diego. Here we summarize the first two seasons of field work in the Methoni embayment based on marine geophysical, sediment, photogrammetry surveys and how they contribute to cultural heritage in the Aegean region. The preliminary results point to a wealth of issues for cultural heritage and research: 1) the foundation for creating a Maritime Cultural Heritage Asset District to contribute to the economy of this part of Messenia has been outlined and proposed; 2) the marine and preliminary geophysical surveys will provide quantitative observations on the physical properties of the near shore, seafloor and sub-seafloor geology of the Holocene to understand deep-time human settlement in the embayment; 3) near shore and shallow marine sediment coring provide proxy data for reconstructing paleo-ecology and geomorphological history of this part of the southern Peloponnesus building on earlier research (cf. Kraft and Aschenbrenner 1977) and other related regions (Levy et al. 2018); 4) underwater photogrammetry of the submerged Middle Helladic site point to the potential of the site for archaeological excavations to understand the growth of Middle Helladic Aegean maritime networks (Tartaron 2014) and its relationship to the Bronze Age chronology (Rutter 2017), the Middle Helladic economy (Voutsaki et al. 2013), settlement history of the Aegean, the sediment record based on underwater coring and its relation to climate (Barnes et al. 2013), environmental and social change during the mid-Holocene. Finally, we have laid the groundwork for the MCHAD though discussions with the Methoni municipality and village community to address their contemporary cultural and economic goals (Gkionis et al. 2019) using the tools of cyber-archaeology (Levy 2013) and underwater cultural heritage in Greece and the eastern Mediterranean.

AUTHOR CONTRIBUTIONS

The conceptualization of the Methoni Cultural Heritage project and this article – T.E.L, G.P. and M.G.; methodology - T.E.L, G.P., M.G., G.S., ; software - D.C, N.G., S.K.; validation - T.E.L, G.P., M.G., R.W., N.G., M.M., A.T., L.C., J.R., and E.S.; formal analysis – T.E.L, G.P., M.G., E.S., D.C., S.K., X.D., A.T., L.C., K.C., G.S. ; investigation – T.E.L., G.P., M.G, D.C., N.G., S.K., E.S., M.M., X.D., K.V., A.T., L.C., K.C., R.W., C.M, and G.S.; resources – T.E.L., G.P., M.T., M.K., P.G.; data curation – T.E.L., G.P. and M.G.; writing—original draft preparation – T.E.L., G.P., M.G., D.C., N.G., S.K., E.S., M.M., A.T., L.C. J.R., K.C., and G.S.; writing—review and editing - T.E.L, G.P., M.G., G.S.; visualization – D.C., N.G., S.K., T.E.L., A.T., L.C., K.C., R.W., G.S.; supervision - T.E.L., G.P., and M.G.; project administration – T.E.L., G.P., M.G., J.R.; funding acquisition – T.E.L., G.P.; All authors have read and agreed to the published version of the manuscript.

ACKNOWLEDGEMENTS

Financial support for the 2019 Methoni Bay expedition was generously provided by Charlie and Ellen Steinmetz (Manhattan Beach, CA), Dr. Ellen Lehman and Prof. Charlie Kennel (La Jolla, CA), the late Norma Kershaw (Orange County, CA), the Center for Hellenic Studies University of California San Diego, Prof. T.E. Levy's Norma Kershaw Endowed Chair in the Archaeology of Ancient Israel and Neighboring Lands, and University of California San Diego Academic Senate Research Grant Committee (to T.E. Levy). Sincere thanks to Dr. Brian Zgliczynski, Prof. Stuart Sandin, Chris Sullivan, and Nicole Pedersen, of the Sandin Coral Ecology Lab for designing the first underwater camera system used on this project and for their generous loan of their equipment, and to Dr. Jules Jaffe and the Jaffe Photogrammetry Lab for the loan of the underwater scooters used in Methoni, all from the Scripps Institution of Oceanography, UC San Diego. The 2021 expedition was funded by the Kershaw Endowment for Cyber-Archaeology at UC San Diego's Qualcomm Institute and training funds from the Koret Foundation (Grant ID 19- 0295) Thanks to Marios and Elias Markopoulos for their excellent seamanship and use of their boat 'Milady, My Lord' for this project and Nikos Piliotis and the Pilos Dive Center for supplying scuba tanks and other equipment for this project; We are grateful to the Greek Ministry of Culture and Dr. P. Kalamara, Director of EUA for issuing our permits to conduct the survey. Special thanks to E. Kouvelas for his contribution in the fieldwork, to John Hildebrand and Alina Levy for their support and the people of Methoni who made us feel at home.

REFERENCES

Al-kheder, Sharaf, Yahya Al-shawabkeh, and Norbert Haala (2009) Developing a documentation system for desert palaces in Jordan using 3D laser scanning and digital photogrammetry. *Journal of Archaeological Science* 36(2): pp. 537-546.

ANMES (2010) Strategic Environmental Impact Assessment for Municipality of Methoni, 2010 (in Greek). In *Available in http://www.pylos-nestor.gr/ portal/images/keimeno smpe methonis.pdf.*

Athanassas, C., and I. Fountoulis (2013) Quaternary neotectonic configuration of the southwestern Peloponnese, Greece, based on luminescence ages of marine terraces. *Journal Earth Science* 24: pp. 410–427.

Bailey, Geoff, and Gwyn Thomas (1987) The use of percussion drilling to obtain core samples from rock-shelter deposits. *Antiquity* 61(233): pp. 433-439.

Barnes, J., M. Dove, M. Lahsen, A. Mathews, P. McElwee, R. McIntosh, F. Moore, J. O'Reilly, B. Orlove, R. Puri, H. Weiss, and K. Yager (2013) Contribution of Anthropology to the Study of Climate Change. *Nature Climate Change* PUBLISHED ONLINE: 29 MAY 2013 | DOI: 10.1038/NCLIMATE1775: pp. 541-544.

Bees, N.A. (1993) Modon. In *The Encyclopaedia of Islam - New Edition, Volume VII*, edited by C. E. Bosworth, E. van Donzel, W. P. Heinrichs, and C. Pellat. E. J. Brill, Leiden.

Bell, Tyler, Beiwen Li, and Song Zhang (1999) Structured Light Techniques and Applications. In *Wiley Encyclopedia of Electrical and Electronics Engineering*, edited by J. G. Webster, pp. 1-24.

Bevan, Andrew, and James Conolly (2006) Multiscalar Approaches to Settlement Pattern Analysis, pp. 217-234. Springer US, Boston, MA.

Bintliff, J.L. (1977) *Natural Environment and Human Settlement in Prehistoric Greece*. BAR Supplementary Series 28, Oxford.

Cantu, K., Norris, R., Papatheodorou, G. Liritzis, I., Langgut, D., Geraga, M., and Levy, T.E. (2022) Anthropogenic Erosion from Hellenistic to Recent Times in the Northern Gulf of Corinth, Greece. In *Mediterranean Resilience Collapse and Adaptation in Antique Maritime Societies*, edited by A. Yasur-Landau, G. Gambash, and T.E. Levy. Equinox, Sheffield.

Choremis, A.K. (1969) M.H. Altar on Nisakouli at Methoni (in Greek). *Athens Annals of Archaeology*:10-14.

Commission., European (2020) The EU Blue Economy Report. *available online: https://op.eu-ropa.eu/es/publication-detail/-/publication/83843365-c18d-11ea-b3a4-01aa75ed71a1).*

Croudace, I.W. and R.G. Rothwell (2015) Twenty years of XRF Core Scanning Marine Sediments: What do Geochemical Proxies tell us? In *Micro-XRF Studies of Sediment Cores: Applications of a non-destructive tool for the environmental sciences.*, edited by I.W. Croudace, and R.G. Rothwell, pp. 25 - 102. Springer, Dordrecht.

Davies, Siriol, and Jack L. Davis (2007) Greeks, Venice, and the Ottoman Empire. *Hesperia Supplements* 40: pp. 25-31.

Dietz, Søren (1988) Nordquist (G.C.) A Middle Helladic village: Asine in the Argolid. (Boreas, 16.) Uppsala: University (distributed by Almqvist and Wiksell International, Stockholm), 1987. pp. 195, 106 illus. (incl. plates, text figs). Sw. kr. 135. *The Journal of Hellenic Studies* 108: pp. 256-256.

Fernández-Hernandez, J., D. González-Aguilera, P. Rodríguez-Gonzálvez, and J. Mancera-Taboada (2015) Image-Based Modelling from Unmanned Aerial Vehicle (UAV) Photogrammetry: An Effective, Low-Cost Tool for Archaeological Applications. *Archaeometry* 57(1): pp. 128-145.

Flemming, N. C. (1969) *Archaeological Evidence for Eustatic Change of Sea Level and Earth Movements in the Western Mediterranean during the Last 2000 Years*. The Geological Society of America. Special paper, 109. Geological Society of America, Boulder, Colo.

Georgopoulos, A. (2014) 3D Virtual Reconstruction of Archaeological Monuments *Mediterranean Archaeology & Archaeometry* 14 (4): pp. 155-164.

Georgopoulos, Panagiotis, and Tatiana Fragkopoulou (2013) Underwater Archaeological Parks in Greece: The Cases of Methoni Bay – Sapienza Island and Northern Sporades, from a Culture of Prohibition to a Culture of Engagement. In *2013 Underwater Archaeology Proceedings*. Advisory Council on Underwater Archaeology.

Geraga, M., G. Papatheodorou, C. Agouridis, H. Kaberi, M. Iatrou, D. Christodoulou, E. Fakiris, M. Prevenios, S. Kordella, and G. Ferentinos (2017) Palaeoenvironmental implications of a marine geoarchaeological survey conducted in the SW Argosaronic gulf, Greece. *Journal of Archaeological Science: Reports 12* 12: pp. 805-818.

Gkionis, Panagiotis, George Papatheodorou, Maria Geraga, Elias Fakiris, Dimitris Christodoulou, and Konstantinia Tranaka (2020) A marine geoarchaeological investigation for the cultural anthesis and the sustainable growth of Methoni, Greece. *Journal of Cultural Heritage* 42: pp. 158-170.

Gkionis, P., G. Papatheodorou, M. Geraga, E. Fakiris, D Christodoulou, and K. Tranaka (2019) A marine geoarchaeological investigation for the cultural anthesis and the sustainable growth of Methoni, Greece. *Journal of Cultural Heritage* https://doi.org/10.1016/j.culher.2019.08.009 1-13.

Harokopio University of Athens (2007) Regional Socio-Economic growth in Koroni, Methoni and Pylos City (in Greek). In *Available in http://estia.hua.gr/file/lib/default/data/2960/theFile*.

Hassiacou, A. (2003) Middle Helladic Pottery from Messenia, Department of History and Archaeology, University of Athens.

Hatzopoulos, J.N., D. Stefanakis, A. Georgopoulos, S. Tapinaki, V. Pantelis, and I. Liritzis (2017) Use of Varioius Surveying Technologies to 3D Digital Mapping and Modelling of Cultural Heritage Structures for Maintenance and Restoration Purposes: The Tholos in Delphi, Greece. *Mediterranean Archaeology & Archaeometry* 17(3): pp. 311-336.

Henderson, J. C., C. Gallou, N. C. Flemming, and E. Spondylis (2011) The Pavlopetri Underwater Archaeology Project: investigating an ancient, submerged town. In *Underwater Archaeology and the Submerged Prehistory of Europe*, edited by J. Benjamin, C. Bonsall, C. Pickard, and A. Fischer, pp. 207-218. Oxbow Books, Oxford.

Hietala, H. (editor) 1984 *Intrasite Spatial Analysis in Archaeology*. Cambridge University Press, London.

Howell, Andy, Kirill Palamartchouk, Xanthos Papanikolaou, Demitris Paradissis, Costas Raptakis, Alex Copley, Philip England, and James Jackson (2016) The 2008 Methoni earthquake sequence: the relationship between the earthquake cycle on the subduction interface and coastal uplift in SW Greece. *Geophysical Journal International* 208(3): pp. 1592-1610.

Iliopoulou, D. (2015) Alternative Tourism and Sustainable Tourism Develop- ment in Messinia, 2015 (in Greek). In *(Available in http://nemertes.lis.upatras.gr/jspui/bitstream/10889/9314/3/Iliopoulou(bio).pdf.)*.

Knabb, K.A., J.P. Schulze, F. Kuester, T.A. DeFanti, and T.E. Levy (2014) Scientific Visualization, 3D Immersive Virtual Reality Environments, and Archaeology in Jordan and the Near East. *Near Eastern Archaeology* 77(3): pp. 228 - 232.

Kostakis, I. (2016) Special Interest Tourism. Methoni Case Study, 2016 (in Greek). In *in http://dione.lib.unipi.gr/xmlui/bitstream/handle/unipi/9479/Kostakis Ioannis.pdf?sequence=1&isAllowed=y*.

Koutsoudis, Anestis, George Ioannakis, Blaž Vidmar, Fotis Arnaoutoglou, and Christodoulos Chamzas (2015) Using noise function-based patterns to enhance photogrammetric 3D reconstruction performance of featureless surfaces. *Journal of Cultural Heritage* 16(5): pp. 664-670.

Kraft, John C. and Stanley E. Aschenbrenner (1977) Paleogeographic Reconstructions in the Methoni Embayment in Greece. *Journal of Field Archaeology* 4(1): pp. 19-44.

Levy, T.E. (2013) Cyber-Archaeology and World Cultural Heritage: Insights from the Holy Land. *Bulletin of the American Academy of Arts & Sciences* LXVI: pp. 26-33.

Levy, T.E., A. Sideris, M. Howland, B. Liss, G. Tsokas, A. Stambolidis, E. Fikos, G. Vargemezis, P. Tsourlos, A. Georgopoulos, George Papatheodorou, M. Garaga, R. Christodoulou, R.D. Norris, I. Rivera-Collazo, and I. Liritzis (2018) At-Risk World Heritage, Cyber, and Marine Archaeology: The Kastrouli – Antikyra Bay Land and Sea Project, Phokis, Greece. In *Cyber-Archaeology and Grand Narratives - Digitial Technology and Deep-Time Perspectives on Culture Change in the Middle East,* edited by T.E. Levy and I.W.N. Jones, pp. 143 - 230. Springer, New York.

Levy, T.E., C. Smith, K. Agcaoili, A. Kannan, A. Goren, J. Shulze and G. Yago (2020) At-Risk World Heritage and Virtual Reality Visualization for Cyber-Archaeology – The Mar Saba Test Case. In *Digital Cities*, edited by H. Murteira, and M. Forte, pp. 151-171. Oxford University Press, Oxford.

Levy, T.E., M.L. Vincent, M. Howland, F. Kuester, and N.G. Smith (2014) The Art of Implementing SfM for Reconstruction of Archaeological Sites in Greece: Preliminary Applications of Cyber-Archaeological Recording at Corinth. *Mediterranean Archaeology and Archaeometry* 14(4): pp. 125-133.

Löwemark, L., H.F. Chen, T.N. Yang, M. Kylander, E.F. Yu, Y.W. Hsu, T.Q. Lee, S.R. Song, and S. Jarvis (2011) Normalizing XRF-scanner data: A cautionary note on the interpretation of high-resolution records from organic-rich lakes. *Journal of Asian Earth Sciences* 40: pp. 1250-1256.

Ludvigsen, M., R. Eustice, and H. Singh (2006) Photogrammetric models for marine archaeology: pp. 1-6.

Malaperdas, G., and N. Panagopoulos (2021) Mapping shoreline changes over the years: The case study of Navarino bay, Pylos, Messenia, Greece. *World Journal of Geomatics and Geosciences* 1(1): pp. 28-35.

Marbán, Leandro, and Sergio Zalba (2019) When the seeds go floating in: A salt marsh invasion. *Estuarine Coastal and Shelf Science* 231:106442.

McCarthy, John K., J. Benjamin, T. Winton, and W. van Duivenvoorde (editors) (2019) *3D recording and interpretation for maritime archaeology*. Springer, Cham, Switzerland.

McDonald, William A., and George Robert Rapp (1972) *The Minnesota Messenia expedition reconstructing a bronze age regional environment*. University of Minnesota Press, Minneapolis.

Merkouri, C., and M Kouli (2011) The Spatial Distribution and Location of Bronze Age Tumuli in Greece. In *Ancestral Landscapes: Burial Mounds in the Copper and Bronze Ages*, edited by M. Borgna, and S. Müller Celka, pp. 203–218. Travaux de la Maison de l'Orient., Lyon.

Müller, S. (1989) Les tumuli helladiques: où? quand? comment? *Bulletin de Correspondance Hellénique* 113: pp. 1–42.

N., Galanidou, Dellaporta K., and Sakellariou D. G. (2020) Greece: Unstable Landscapes and Underwater Archaeology. In *The Archaeology of Europe's Drowned Landscapes*, Vol 35, edited by G. Bailey, N. Galanidou, H. Peeters, H. Jöns, and M. Mennenga, pp. 371-392. Springer - Coastal Research Library, New York.

Papakonstantinou, M.-Ph. (2011) Bronze Age Tumuli and Grave Circles in Central Greece: the Current State of Research. In *Ancestral Landscapes: Burial Mounds in the Copper and Bronze Ages*, edited by edited by and E. Borgna and S. Müller Celka, pp. 391–400. Travaux de la Maison de l'Orient, Lyon.

Perissoratis, C., and N. Conispoliatis (2003) The impacts of sea-level changes during latest Pleistocene and Holocene times on the morphology of the Ionian and Aegean seas (SE Alpine Europe). *Marine Geology* 196(3-4): pp. 145-156.

Petrakis, V. (2021) Transforming Expressions and Perceptions of Prestige in the Middle Helladic and Early Mycenaean, Southwestern Peloponnese. In *(Social) place and space in early Mycenaean Greece international discussions in Mycenaean archaeology, October 5-8, 2016 in Athens*, edited by Birgitta Eder, and Michaela Zavadil pp. 295 - 319. Austrian Academy of Sciences Press, Vienna.

Petrakis, V. P. Athens, De Boccard (2010) Diversity in Form and Practice in Middle Helladic and Early Mycenaean Elaborate Tombs: An Approach to Changing Prestige Expression in Changing Times. In *Mesohelladika. The Greek Mainland in the Middle Bronze Age, Bulletin de Correspondance Hellénique Supplement 52*, edited by A. Philippa-Touchais, G. Touchais, S. Voutsaki, and J. Wright, pp. 403–416.

Poulos, S.E., A.P. Panagopoulou, and V.A. Kotinas (2022) An Oceanographic Insight in the Submergence and Resilience of the Pavlopetri Archaeological Site. *Scientific Culture* 8(1): pp. 161-173.

Prins, A., and M.J. Adams (2013) Practical Uses for Photogrammetry on Archaeological Excavations. *Biblical Archaeology Society - Archaeological Technology Page. http://www.biblicalarchaeology.org/daily/archaeology-today/biblical-archaeology-topics/practical-uses-for-photogrammetry-on-archaeological-excavations/.*

Renfrew, Colin (1972) *The Emergence of Civilization: The Cyclades and the Aegean in the Third Millennium B.C.* Methuen, London.

Rohling, E.J., G.L. Foster, K.M. Grant, G. Marino, A.P. Roberts, M.E. Tamisiea, and F. Williams (2014). Sea-level and deep-sea-temperature variability over the past 5.3 million years. *Nature* 508: pp. 477-482.

Rothwell, R.G., and I.W. Croudace (2015) Twenty Years of XRF Core Scanning Marine Sediments: What Do Geochemical Proxies Tell Us? In *Micro-XRF Studies of Sediment Cores: Applications of a non-destructive tool for the environmental sciences.*, edited by I.W. Croudace, and R.G. Rothwell, pp. 25-102. Springer Netherlands, Dordrecht.

Rutter, J.B. (2017) The temporal slicing and dicing of Minyan Culture: a proposal for a tripartite division of a lengthier Greek Middle Bronze Age and the issue of nomadism at its beginning. In *Social Change in Aegean Prehistory*, edited by Corien Wiersma, and Sofia Voutsaki, pp. 16-31. Oxbow Books, Oxford.

Shtienberg, Gilad, Katrina Cantu, Steffen Mischke, Dorit Sivan, Richard D. Norris, Tammy M. Rittenour, Yael Edelman-Furstenberg, Assaf Yasur-Landau, Guy Sisma-Ventura, and Thomas E. Levy (2022) Holocene sea-level rise and coastal aquifer interactions: Triggering mechanisms for environmental change and impacts on human settlement patterns at Dor, Israel. *Quaternary Science Reviews* 294:107740.

Spondilis, I. (1996) Contribution to a Study of the Configuration of the Coast of Pylia, Based on the Location of New Archaeological Sites. In *Archaeoseismology*, edited by S. Stiros, and R.E. Jones, pp. 119-128. British School at Athens Fitch Laboratory Occasional Paper 7, Athens.

Spondylis, Ilias (1996) Contribution to a Study of the COnfiguration at the Coast of Pylia, based on the Location of New Archaeological Sites. *Archaeoseismology* (IGME-The British School at Athens-Fitch Laboratory Occasional Paper): pp. 119-128.

Tartaron, Thomas F. (2014) *Maritime networks in the Mycenaean world*. Cambridge University Press, Cambridge; New York.

Throckmorton, P. (1970) *Shipwrecks and Archaeology - The Unharvested Sea*. Little, Brown and Company, Ποιοι είναι;

Throckmorton, P., and J.M. Bullitt (1963) Underwater Surveys in Greece: 1962. *Expedition* 5(2): pp. 16-23.

Valmin, Mattias Natan (1938) *The Swedish Messenia expedition*. C.W.K. Gleerup; H. Milford, Lund; London.

Vavulin, M., I. Nevskaya, and L. Tybykova (2019) Digital Macro-Photogrammetry in Documentation of Old Turkic Runiform Inscriptions in the Altai Mountains. *Mediterranean Archaeology and Archaeometry* 19(2): pp. 81-104.

Voutsaki, S., A. Ingvarsson-Sundström, and S. Dietz (2011) Tumuli and Social Status: A Re- examination of the Asine Tumulus. In *Ancestral Landscapes: Burial Mounds in the Copper and Bronze Ages*, edited by E. Borgna and, and S. Müller Celka, pp. 445–462. Travaux de la Maison de l'Orient, Lyon.

Voutsaki, Sofia, Eleni Milka, Sevi Triantaphyllou, and C. Zerner (2013) Middle Helladic Lerna - Diet, Economy, Society. In *Diet, Economy and Society in the Ancient Greek World: Towards a Better Integration of Archaeology and Science*, edited by Sofia Voutsaki, and Soultana Maria Valamoti, pp. 133-147. Peeters, Leuven.

Wiersma, Corien (2014) *Building the Bronze Age: Architectural and Social Change on the Greek Mainland during Early Helladic III, Middle Helladic and Late Helladic I*. Archaeopress Publishing Ltd, Oxford.

Worsham, Rebecca (2015) Discontinuous Settlement Structures and Social Organization in Late Early Helladic and Middle Helladic Greece Dissertation, University of North Carolina at Chapel Hill Graduate School. Carolina Digital Repository.

Worsham, Rebecca, Michael Lindblom, and Claire Zikidi (2018) Preliminary report of the Malthi Archaeological Project, 2015-2016. *Opuscula: Annual of the Swedish Institutes at Athens and Rome* 11: pp. 7-27.

Wright, James C. (editor) (2004) *The Mycenaean feast*. American School of Classical Studies at Athens, Princeton [N.J.].

Yamafune, K., R. Torres, and F. Castro (2017) Multi-Image Photogrammetry to Record and Reconstruct Underwater Shipwreck Sites. journal article. *Journal of Archaeological Method and Theory* 24(3): pp. 703-725.

Greek References

Σπονδύλης, Η. 1996: "Συμβολή στη μελέτη διαμόρφωσης των ακτών της Πυλίας με βάση τον εντοπισμό νέων αρχαιολογικών θέσεων", *Ενάλια*, IV: 3/4 (1992), pp. 30-37.

Σπονδύλης, Η. 2006: "Νομός Μεσσηνίας: Μεθώνη", *ΑΔ* 54 (1999) Β΄2, Χρονικά, pp. 1025-1028.