The 1st International Symposium of Conservation for Underwater Archaeology

IBEAM Institut Balear d'Estudis en Arqueología Marítima Andrea Sanz, Enrique Aragón, Javier Rodríguez

#ISCUA2019 PROCEEDINGS





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One Vision, One Mission

IBEAM and the Conservation of Maritime Cultural Heritage

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In the development of underwater archaeology, responsibility has traditionally been given to archaeologists, while conservators-restorers have seldom formed a part of the team or been assigned roles in the management or co-management of projects. Although, fortunately, there are now projects in which the situation is different and a better balance of responsibilities between archaeologists and restorers is starting to appear, the general lack of communication between these two professions remains a concern. This raises a question: how could marine archaeological research progress without a clear and necessary involvement of conservation professionals as an inherent part of it?

Following the publication of the Manual for Activities directed at Underwater Cultural Heritage with the Annex of the UNESCO 2001 Convention, which revealed the importance of "in situ conservation", a term which archaeologists seemed to immediately adopt and appropriate, the expectation was that the role of restorers was about to gain relevance and presence in all stages of underwater archaeology projects. The reality, however, continues to be quite different. In spite of the imperative necessity to preserve archaeological objects and remains at the time of their excavation, and with the knowledge, moreover, that failure to apply the appropriate preventive measures poses a risk for their long-term conservation, multidisciplinary and equitable teams are still scarce. This is possibly due to work customs anchored in behaviours of the past governed by criteria of outdated professional elitism and, in most cases, with a clear gender difference.

Despite this situation, we must not forget the numerous good examples of professionals, many of whom are the authors of the articles that make up this publication. Through their vocation, passion and experience, they have not only opened a better path to go forward, but have also become a source of inspiration for the new generations of restorers and conservators of underwater archaeological heritage. Since the creation of IBEAM, the restoration and conservation of underwater cultural heritage has been and continues to be fundamental in all of their archaeological projects, as the objectives of both disciplines have combined perfectly in order to ensure a joint, sound and efficient execution and management, by means of coordinated guidelines. In other words, we have re-

formed the conventional methods, we have adapted, we have learned from our mistakes and, together, we turned a common work vision into a single mission for the future.

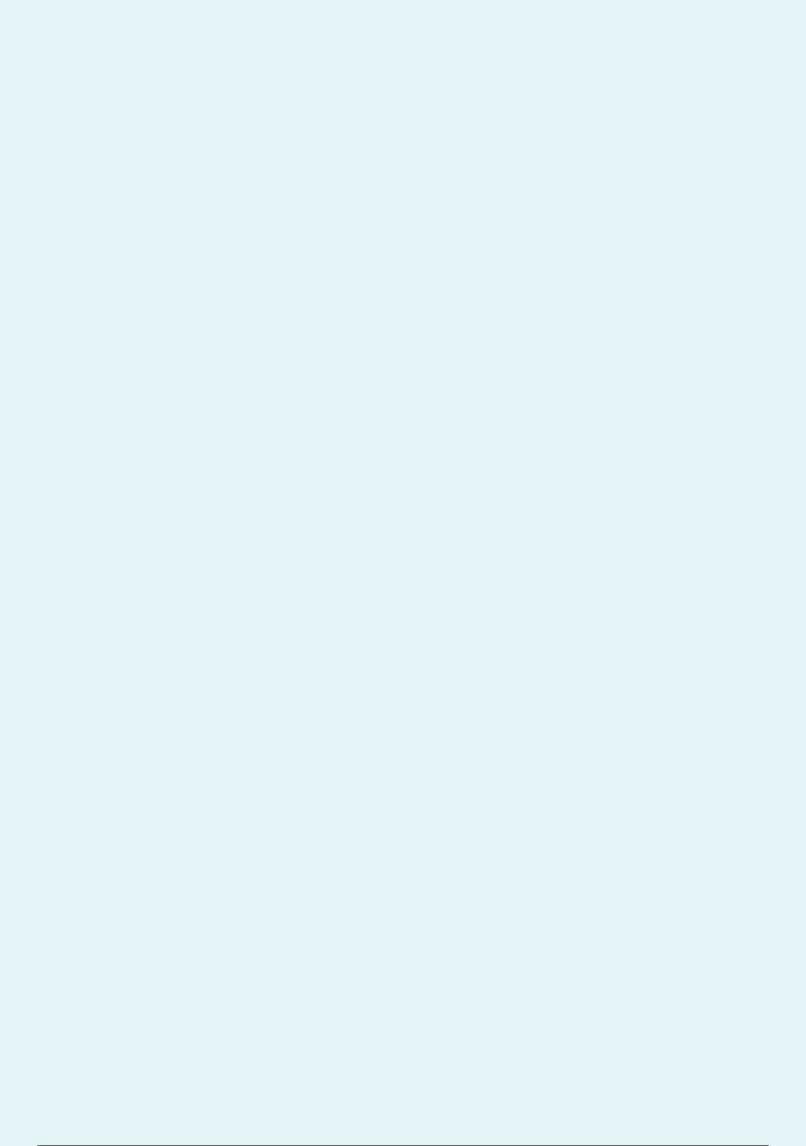
The apparent need and demand, on the part of restorers and conservators, for specialised training which would go beyond the theoretical concepts presented in the UNESCO's Manual and would delve into the real difficulties of in situ conservation, stabilisation, extraction, protection and restoration of any underwater material, prompted the IBEAM to organise a series of courses aimed at students and professionals interested in the underwater world with no or little experience in the water, through workshops on actual sites under the supervision and guidance of experts on the subject.

We soon realised that restoration and conservation professionals in underwater archaeology were in need of a single platform where they would be able to exchange ideas and experiences in relation to the preservation of the underwater cultural heritage. This is how the 1er Simposio Internacional de Conservación en Arqueología Subacuática (ISCUA) (1st International Symposium on Conservation in Underwater Archaeology), which took place in September 2019 on the idyllic island of Formentera, came to be. This symposium brought together more than 40 world-class professionals, experts in conservation and restoration of the UCH. Throughout the different sessions, it became clear that the two disciplines (archaeology and conservation) are very much interconnected despite their current separation. This connection let us fantasise about applying the latest technological advances to safeguard the underwater archaeological heritage. It is important to highlight all the technological innovations in research projects which are presented in this publication and which will be an inspiration for current and future generations of restoration-conservation professionals, as well as for other, direct or indirect, roles involved in archaeology.

The creation of this communication platform for researchers and institutions involved in the preservation of the UCH was one of the main objectives in the organisation of the ISCUA. The symposium was the ideal context for specialised, up-to-date and quality training, and made it possible to transform the real, tangible, physical distance between all the researchers into a more intimate and collaborative environment, creating solid personal and professional relations stimulated by a common preoccupation, i.e. the conservation of the underwater cultural heritage. This and many more aspects will appear in this publication, which is the first step towards the materialisation of an idea that was shaped by the vision of teamwork, a more realistic, evolved, complete archaeology, an archaeology of the future.

The in-situ preservation:

Conservation, Management and Protection Strategies of Underwater Archaeological Sites



The SASMAP project

A process based approach to managing underwater cultural heritage

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Abstract Keywords

The SASMAP Project (Development of Tools and Techniques to Survey, Assess, Stabilise, Monitor and Preserve Underwater Archaeological Sites was an EU funded project which ran from 2012-2016. The project took holistic and processed based approaches to develop new technologies and best practices in order to locate, assess and manage underwater cultural heritage in a more effective way.

underwater cultural heritage
in-situ preservation
down and upscaling
assessment
monitoring

1. Introduction

In-situ preservation is increasingly being seen as a means to manage marine archaeological sites which, for economic reasons and current international trends favouring in-situ preservation, are not excavated, raised and conserved. This is both the case within Europe (Valetta Treaty, 1992) and UNESCO Convention for the Protection of underwater cultural heritage. However, in-situ preservation should not be a case of leaving a site where it is and hoping that it will be there when archaeologists and conservators have the capacity, research questions and desire to investigate these finds in the future. Cost effective methods to locate and assess the dimensions of archaeological sites both on and beneath the seabed are essential. The presence and extent of potential threats to archaeology must also be determined. Threats may arise from the natural physical environment including strong currents, from manmade hazards such as dredging, from construction work, fishing, installation of pipe/cable lines and development of recreation centres. The stability of the site and the state of preservation of the artefacts present must also be assessed. The various assessments provide information on how best to approach or manage a site. If the physical and bio-/geochemical environments are unstable or pose a threat to the site, the opportunities for stabilising it in situ must be determined. The options for monitoring the continued integrity of the site must be identified. If none exist, it needs to be determined whether areas can be identified that need to be excavated, or sampled non-destructively, before information is lost. The current author (Gregory 2009) has previously discussed that there are five fundamental steps to ensuring the successful and responsible in-situ preservation and management of archaeological sites in general. These are:

- 1. the extent of the site to be preserved;
- 2. the most significant physical, chemical and biological threats to the site;
- 3. the types of materials present on the site and their state of preservation;
- 4. strategies to mitigate deterioration and stabilise the site from natural impacts; and
- 5. subsequent monitoring of a site and implemented mitigation strategies.

2. Scope of SASMAP

The SASMAP project addressed many of the above points and was divided into six scientific themes:

- 1. Developing Geological models for regional evaluation of probability of locating archaeological sites and their preservation potential.
- 2. Development of Tools for Surveying and Monitoring Coastal and Underwater Archaeological Sites
- 3. Assessing the burial environment and deterioration of organic materials
- 4. Assessment of the state of preservation of waterlogged archaeological wood
- 5. Tools and techniques to raise waterlogged organic archaeological artefacts.
- 6. In situ stabilization of underwater archaeological sites

To achieve all these objectives, the project was of necessity inter and cross disciplinary and involved a consortium of seven research institutions and four Small Medium Enterprises (SMEs) from seven European countries (Table 1). The SMEs had expertise in the development and production of state of the art marine geophysical instruments, equipment for measuring bio-geochemical parameters in the marine environment, protection of sub-sea installations (pipelines, cables) and hand held diving tools. Institutional partners encompass synergistic group researchers in marine archaeology and conservation, in situ preservation, wood degradation, marine geochemistry and marine geophysics working in museums, universities and governmental institutions with relevant know-how, facilities and resources to realise SASMAP.

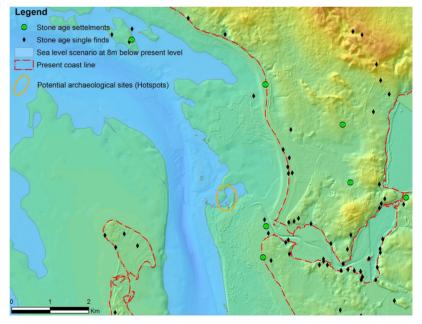
Participant No.	Partner	Country
1. (Coordinator)	The National Museum of Denmark (NM)	Denmark
2	Innomar (IMAR)	Germany
3	Unisense (UNI)	Denmark
4	AKUT (AKUT)	Denmark
5	Seabed Scour Controls (SSCS)	United Kingdom
6	Geological Survey of Denmark and Greenland (GEUS)	Denmark
7	The Viking Ship Museum (VM)	Denmark
8	Cultural Heritage Agency of the Netherlands (RCE)	The Netherlands
9	University of Gothenburg (UGOT)	Sweden
10	Superior Institute for Conservation and Restoration (ISCR)	Italy
11	University of Patras (UPAT)	Greece

3. Research and innovation within SASMAP

3.1. Geological model for regional evaluation of probability of locating archaeological sites

Within SASMAP the focus was on submerged prehistoric sites as opposed to shipwrecks or other inundated sites and marine geological investigations are particularly essential to develop models describing the palaeogeographical and depositional environments of underwater archaeological sites, Using a downscaling approach the palaeo-landscape of the mesolithic site of Tudse Hage was used to build a geological model. This entailed desk based assessment of online databases of existing information included satellite imagery and Lidar data, which were incorporated into a GIS. These were supplemented with multibeam, sidescan sonar and seismic surveys over the area. In this way it was possible to generate maps of the study area and identify areas where sediment samples could be taken in order to obtain sedimentological, biostratigraphic and AMS C-14 dating data. Based on all these data the changing geological environments, sealevel change as well as the palaeogeography, were reconstructed with respect to sedimentary conditions and water level fluctuations that occurred in the course of the various post glacial lake stages in the area. In this way "hot spots" of where archaeological finds could potentially be found for different archaeological time periods were identified (Fig 1) (Al-Hamdani et al, 2014).

Figure 1. Geo-archaeological paleogeographical scenario 8 m below present sea level (~8,000 calendar years BP). Palaeocoastlines can be digitally recreated for archaeological periods of interest based on the modelling method developed.



3.2. Development of Tools for Surveying and Monitoring Coastal and Underwater Archaeological Sites

Mapping and monitoring of an archaeological site is a prerequisite for determining its location, its extent and for assessment of its physical stability. Remote sensing techniques are one of the most cost effective tools for regional scanning of the seabed surface, sediments and their morphology as well as assessing the physical stability of archaeological sites. State of the art satellite imagery techniques are now able to monitor changes in coast line morphology and sediment transport in shallow water environments (to depths of 6-8 metres). On underwater sites, side scan sonar, sub-bottom profilers, magnetometers, and single and multibeam echosounders have been used to locate

and map archaeological sites both on and within the seabed. Although the use of these tools is not new to marine archaeology, development of existing technologies is one of the significant impacts of the SASMAP project. By contrast, 3D shallow seismic is a cutting edge method and within the project, a proof of concept 3D sub bottom profiler was developed by the SME Innomar (https://www.innomar.com/index.php). This has subsequently gone on to be used in several archaeological projects following the completion of the project (Missiaen et al., 2017)

Following the down-scaling approach, i.e. working from the large regional scale to the detailed site scale, yielded seamless maps that were used in the upscaling ie. Site specific studies in the project.

3.3. Assessment of the burial environment and deterioration of organic archaeological remains

The project developed tools and methods to characterise the burial environment and use this information to assess its effects on the deterioration of organic materials. The main tools developed were a diver-held coring device designed to make the taking of sediments easier and two data-logging systems which could: a) monitor the open-water environment; and b) assess pore water composition of sediments in situ to a maximum sediment depth of 50 cm.

3.3.1. Diverheld Vibracorer

The vibracoring system in its current state (Fig 2) consists of a pneumatically driven vibrating unit that is supplied by compressed air from scuba-diving tanks. The coring tube is made of transparent polycarbonate up to 80mm in diameter.



Figure 2 Diver held vibracore attached to diving cylinder.

The tube has a simple system for attachment to the vibrator head and allows water to escape the coring tube during penetration. The head also makes changing of coring tubes under water simple. The downward force on the tube is achieved by a weight connected to the vibrator ensures that all vibration energy is transferred to the coring tube. Trials of the corer have been made on a shallow, submerged prehistoric site in Denmark and were successful in obtaining and retaining sediment cores (of gytjja) down to ca. 70 cm, although other trials in sandy sediments have obtained cores 2 m in length. Nevertheless, the cores were quickly taken (ca. 10 minutes per core) and the experience of

working on an actual site and in shallow water gave rise to numerous improvements to the system, which are currently being worked on. The cores from the prehistoric site were taken back on land and profiles of dissolved oxygen, pH, redox potential and sulphide were taken using Unisense's standard laboratory sensors. The sediment obtained can be used to assess the turnover of organic material, in general we found that coarser grained sediments have a higher porosity, lower organic material content, and thus lower turnover rates meaning better preservation for organic materials.

3.3.2. Sediment profiling and data logging system

With this system (Fig 3), it was desired to measure the same parameters as measured in the cores, but in situ and down to a depth of 50 cm.

Figure 3 Diver pressing a microelectrode into the seabed. Sensors can measure dissolved oxygen, sulphide, pH and redox potential.



An existing diver-operated underwater meter, manufactured by the project partner Unisense, was redeveloped for this purpose. A hollow 'spear' that could accommodate a microsensor with an attached hypodermic needle was developed, the idea being that the spear could be pressed into the sediment and an influx of water or sediment prevented by a silicon septum in the end. At the required depth, the hypodermic needle of the microsensor is pressed through the septum and a measurement taken.

The process is then repeated at the desired depths within the sediment. The in-situ profiler system was trialled in an area adjacent to where the sediment cores had been taken in order to compare and contrast the methods and, in this way, validate both. In this instance, only sulphide microsensors were used as the main aim of the trial was to test the use of the equipment. The first impressions of the system were that the meter in itself was extremely simple to use, with commands and data being logged using magnetic keys controlled by a 'wand' from outside the underwater housing. The spear itself was easy in this instance to simply press/hammer into the sediment, although it has also been pressed into more compacted sediments in another trial using the vibracoring device. It was important to ensure that sand did not get into the open end of the spear, as this collected above the rubber septum and could damage the microsensor as it was passed into the spear. In this way, measurements

were taken every 5 cm down to a depth of ca. 50 cm; the results showed that dissolved oxygen is utilized very quickly in the upper sediments and becomes anoxic, which is confirmed by the increase in the production of sulphide from sulphate reducing bacteria.

3.3.3. Open-water data-logging system

The open water data logger (Fig. 4) was used to monitor the site and check whether the artificial seagrass mats were adequate for the site's protection.

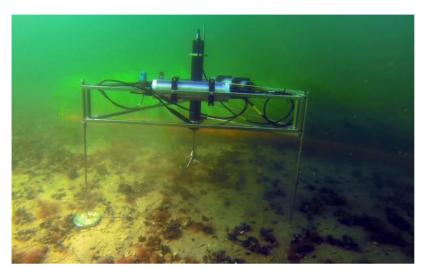


Figure 4 Open water data logger which can measure / log water current strength and direction and CTD (conductivity, temperature and depth data

Although this technique can be implemented initially during the significance assessment of a site (significance of change), repetitive research over a longer period of time can be a useful strategy for monitoring the environmental conditions (if there are indications that these may change), as well as the long-term effectiveness of the physical protection measures selected, such as the artificial sea grass. The open water data logger was relatively easy to install -a single diver was able position it correctly on the seabed and on the artificial seagrass mat that was monitored. In two days, the data logger was moved from an onshore position to an off-shore position for comparison, using a diver on the seabed and support on the surface. CTD (conductivity (salinity), temperature) and current data were successfully collected and the salinity and oxygen concentrations appeared to be very stable throughout the deployment. The data logger clearly showed how the seagrass mat reduced the speed of the water, which would eventually result in increased sedimentation of suspended solids from the water column. In using this method to monitor a site's environmental data, changes may be detected that can be mitigated in an early stage, e.g. by adjusting the protection strategy. As stated before, baseline data - collected before implementation of in situ protection measures - are required for monitoring with an open water data logger.

3.4. Assessment of the state of preservation of waterlogged archaeological wood

A handheld tool for assessing the state of preservation of waterlogged archaeological wood both in situ on the seabed and in the laboratory was developed based on the non-destructive determination of the density of the wood. The net effect of bacterial deterioration is that as cell-wall material is removed and replaced with water, the density of the wood decreases – the more degraded the wood, the lower the density.

Although there are numerous devices available to assess wood, they are not specifically designed for waterlogged archaeological wood. Nor do they provide quantitative data about the state of wood preservation. Currently, there are no devices commercially available that can provide absolute data on wood objects in situ under water. The underwater wood profiler (christened WP4UW Fig. 5) can measure density profiles quantitatively in increments of 1 mm in both recent and waterlogged archaeological wood to a depth of 10 cm.

The data is stored in the equipment, and then transferred to a PC for processing in specially developed software. The WP4UW performs equally well above as under water, without any need for compensation factors regarding the surroundings (i.e. above or below water). Moreover, it is not hindered by any problems from intruding particles (e.g. sand) from the sea, which is often the case when measuring the density of wood with traditional instruments, such as a pilodyne. The WP4UW is also able to make profiles with a higher resolution than is possible with traditional methods. The profiles obtained are consistent with density measured as wet volume per weight and with the results found by light microscopy. In addition, the results shows that it is necessary to take several profiles on a given piece of archaeological wood in order to accurately assess its state of preservation, as there can be enormous differences between density profiles only a few centimetres apart. One of the advantages of the present WP4UW is its capacity to obtain many profiles in a short time. Depending on the size of the scuba tank, depth and divers' skills, the profiler can sample one profile every 5 minutes with an estimated total of 10 profiles on a 4-litre scuba tank at a depth of 10 metres. The profiles still need subsequent interpretation by the developed software and a trained archaeologist/ conservator. Following the end of the project the profiler has been used to assess the timbers of the Figurehead from the wreck of the Gribshund in Sweden (Jensen et al, 2017).

Figure 5 Proof of concept of wood profiler for measuring the state of preservation of exposed wood underwater. A thin needle is hammered into the wood with the help of compressed air from a diving cylinder. The data is logged and on the surface data is converted to give density profiles from the surface to the inner parts of the wood.



3.5. Tools and techniques to raise waterlogged organic archaeological artefacts

Due to their fragility, organic archaeological materials from underwater sites can be challenging to excavate, support, raise and transport to conservation facilities. This is due to the inherent difficulties of working underwater (limited time and potentially harsh conditions) and, in particular, to the crucial stage of lifting artefacts from the seabed to the surface, where mechanical damage can easily occur. To surmount this, artefacts are often raised on supporting materials, or in sediment blocks (block lifting) whereby the artefact is excavated with surrounding sediment and subsequently excavated under controlled conditions in the laboratory. The project is developing the use of polymer-based consolidants which can both encapsulate and consolidate sediments, as well as the freezing of sediments and the development of lifting systems in order to enable the safe lifting and transport of waterlogged organic archaeological objects.

The first product tested was 3M Scotchcast Plus casting tape. This is a lightweight, strong and durable casting tape that combines the benefits of a fiberglass casting tape with the handling ease of plaster. The tape (bandage) contains a synthetic polyurethane resin which hardens in contact with water or when simply exposed to moist air, enabling immobilisation of fragile artefacts while being extremely lightweight and durable. The tests were undertaken in the lab and then underwater, with the diving conservators reporting on the ease of use of the product to recover a fragile wooden archaeological object. The 3M Scotchcast Plus casting tape is environmentally friendly and it is easily removed post lifting (also if in direct contact with the archaeological find). The second product tested was a sheet of carbon fibre, previously treated with cured epoxy-time in a plastic bag vacuum. The use of the carbon fibre was as follows: a polyethylene vacuum waterproof bag was first shaped in the form of the artefact to be recovered. The vacuum and waterproofing are achieved through the use of metal strips. Before the closure of the strips, a multilayer of Peel Ply tissue, carbon sheet and Peel Ply tissue was placed in the bag. Inside the bag, an epoxy resin was applied over the multilayer and then the bag was closed. The two mats in carbon fabric were handled easily and taken to the artefact (a wooden pole) to be recovered. The upper mat was made to adhere to the pole with the aid of lead slings that had also been used to weight the mat so as to ensure it remained on the lake bottom and adhered to the artefact. After waiting for the resin to harden (about 12 hours), the upper mat and the lower mat were placed with plastic clamps and brought to the surface. The carbon-fibre fabric, impregnated with epoxy resin, is a protective shell that adheres to surfaces, protecting the artefact by rapid drying and preventing possible trauma due to the poor state of preservation of the material. Furthermore, the procedure and method may also act as an effective container for temporary storage of waterlogged organic objects. Future work to be conducted at the ISCR laboratories includes: 1) testing organic and inorganic products for consolidating sediments; 2) testing a system to 'inject' polymers into sediment in situ. Laboratory work is currently ongoing to examine the use of polymers such as neutralised polyacrylic acid, sodium polyacrylate and other superabsorbent polymers (SAP, also called slush powder). These polymers can absorb and retain extremely large amounts of liquid and polysaccharides of high molecular weight, including xanthan, guar and agar. A more through description of the various methods can be found in Davidde et al., 2014.

3.6. In-situ stabilisation of underwater archaeological sites

One of the major threats to archaeological remains preserved in situ is seabed scour, that is to say, the removal of sediment through currents in the water, which leave artefacts exposed and can ultimately lead to their complete dete-

rioration. The majority of methods used to protect sites depend upon limiting the access of oxygen, and this can most simply be achieved by covering with sediment. However, simply covering with sediment may not be sufficient as it may itself be washed away. An innovative method using artificial seagrass mats was trialled on different case-study sites within the project. The company Seabed Scour Control Systems (SSCS) is a producer of artificial seagrass mats that seek to reduce the effects of scour. Commercially, these have been used to protect pipelines and cables on the seabed. The plastic fronds, which float in the water column, effectively slow any currents running through them, thus reducing turbulence and hence erosion or scour. In many cases, the fronds actually trap sediment from the water column, creating a sediment layer between the fronds and on top of the site that needs to be protected. Within the project, different designs of mats are being trialled. As their standard mat, which uses anchors to hold the mat in place, penetrates the seabed and could potentially damage any underlying archaeological material, two new systems are being developed: a so-called edge-weighted mat, which has a gravel-filled apron around the mat that sits on the seabed surface, and a system that includes a mesh apron which can be held in place by sand bags deployed by divers (Fig. 6).

Figure 6 Diver laid seagrass mat. The plastic fronds work in two ways: 1) dissipate currents running through them 2) if there are suspended sediments in the water column, when the currents pass through the fronds they are trapped and create an underwater burial mound.



The different mats were effective in both reducing the current that washed over sites but in the case of a wreck protected the Netherlands it generated an underwater burial mound within a matter of days due to the high sediment transport in the water column. The durability of materials that have typically been used to stabilise submerged archaeological sites in the marine environment, including sandbags, plastic sheeting, geotextiles and debris netting, is being tested – an increasing challenge for stabilizing archaeological sites as the use of plastics in the marine environment is increasingly frowned upon.

4. Discussion

This article is a very brief summary of the overall project approach to managing underwater cultural heritage. The interested reader is also referred to the homepage www.sasmap.eu for the downloadable guidelines produced in the project

and further information The SASMAP project as a whole aimed to develop new tools and techniques to better locate, assess and manage underwater cultural heritage, both at a European level and hopefully globally. The project was focused on supporting SMEs (Small- Medium Enterprises) within Europe. To this end the project had four SMEs developing and trialling equipment and they receive over 30% of the overall project budget. This combination of small hi-tech companies and more traditional research institutions (universities, museums, governmental and heritage agencies) has certainly had an enormous synergistic effect. Furthermore, it reflects the need to understand the many facets of the underwater environment and only through such inter and cross disciplinary projects like this can we hope to better understand and protect our underwater cultural heritage.

Acknowledgements

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