

DEVELOPMENT OF TOOLS AND TECHNIQUES TO SURVEY, ASSESS, STABILISE, MONITOR AND PRESERVE UNDERWATER ARCHAEOLOGICAL SITES: SASMAP.

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ABSTRACT:

Development of Tools and Techniques to Survey, Assess, Stabilise, Monitor and Preserve Underwater Archaeological Sites (SASMAP) is an EC funded project, with the purpose of developing new technologies and best practices in order to locate, assess and manage Europe's underwater cultural heritage in a more effective way than is possible today. SASMAP will take holistic- and process- based approaches to investigate underwater environments and the archaeological sites contained therein. SASMAP will benefit the management of underwater cultural heritage in Europe and in the rest of the world by providing valuable tools to plan the preservation of offshore archaeological sites and their contents in accordance with both the Treaty of Valletta (1992) and research driven investigations.

The need for SASMAP is based on the results from previous and current EU initiatives, the networks resulting from these projects and on-going research at the consortium's institutions. Within SASMAP a holistic approach will be taken to locating, assessing, monitoring and safeguarding underwater cultural heritage. This will involve developing and utilising tools and technologies to allow "down-scaling" from the large scale regional level, moving on to the local site level and finally to the individual components of a site. Results obtained from the down-scaling approach at the proposed study areas will show the effectiveness of such an approach for locating and detailed mapping of archaeological sites and their preservation potential. The end results of this approach will be used to develop a plan for assessing archaeological sites in European waters. From a management point of view this is an up-scaling approach to planning (bottom up). All information and experiences obtained during the course of the project will be utilised to enhance and develop existing legislation and best practice for mapping and preserving Europe's underwater and coastal heritage. The project started in September 2012 and the aim of the paper is to give a brief introduction to the project.

1. CONCEPTS AND OBJECTIVES

1.1 What is SASMAP?

SASMAP's purpose is to develop new technologies and best practices in order to locate, assess and manage Europe's underwater cultural heritage in a more effective way than is possible today. SASMAP will take holistic- and process- based approaches to investigate underwater environments and the archaeological sites contained therein. This is necessary regardless of whether or not investigations are research driven or in connection with sub-sea development. Investigations of underwater heritage which are associated with subsea developments in Europe often require pre-disturbance studies to comply with the Treaty of Valletta (1992).

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 results and products of the project fulfilled the scientific requirements of the call for proposals ENV. 2012.6.2-6. Development of advanced technologies and tools for mapping, diagnosing, excavating and securing underwater and coastal archaeological sites.

It is hoped that SASMAP will benefit the management of underwater cultural heritage in Europe and in the rest of the world by providing valuable tools to plan the preservation of offshore archaeological sites and their contents in accordance with both the Treaty of Valletta (1992) and research driven investigations.

1.2 Why SASMAP?

The need for SASMAP is based on the results from previous and current EC initiatives, the networks resulting from these projects and on-going research at the consortium's institutions. The proposed pan-European consortium includes partners who have been involved in previously funded and successfully completed projects related to underwater cultural heritage, namely The MoSS Project (<http://www.mossproject.com/>),

MACHU (<http://www.machuproject.eu/>), BACPOLES (no existing website) and Wreck Protect (<http://wreckprotect.eu/>). In addition, partners have also worked in The Baltic Gas Project (<http://balticgas.au.dk/>) and The Balance Project (<http://www.balance-eu.org/>) reflecting the interdisciplinary nature of the consortium. It also contains partners from the networking opportunities provided by the COST Actions IEO601 Wood Science for Conservation of Cultural Heritage (WoodCultHer) and TD0902 SPLASHCOST concerning submerged prehistoric landscapes. Many of these projects are directly related to the current ethos within maritime archaeology and conservation, namely to preserve underwater cultural heritage in situ, that is to say where it lies on or in the seabed. Within Europe this has been politically galvanised by the Valetta treaty (1992) and internationally by UNESCO's Convention for the Protection of the Underwater Cultural Heritage (2001). Both these treaties advocate that, as a first option, the underwater cultural heritage should be protected in situ and, where possible, non-intrusive methods to document and study these sites in situ should be used. This is understandable in terms of the underwater cultural heritage resource. UNESCO currently estimates that, "over 3 million wrecks are spread across ocean floors around the planet" (<http://www.unesco.org/en/the-underwater-cultural-heritage/underwater-cultural-heritage/wrecks/>). This figure does not include the numerous submerged landscapes (and archaeological sites therein), found around Europe as a result of postglacial sea level change.

The North Sea, adjacent to the Netherlands, is effectively one large submerged prehistoric landscape consisting of settlements dating back to the Pleistocene. It is financially prohibitive in either research- or development lead investigations to excavate, conserve and curate the many finds. In Danish territorial waters alone, it is estimated that there are 20,000 submerged settlement sites lying around the present day coastline and out to a water depth of 30 – 40 metres. The recently completed EU supported project WreckProtect (<http://www.wreckprotect.eu/>) carried out a cost benefit analysis for the costs of excavation, conservation and curation versus in situ preservation. A single large wooden wreck, such as the Mary Rose in the UK, has to date cost ca. 80 million Euros to raise, conserve and exhibit, whereas the physical in situ preservation of a similar sized wreck in Sweden cost around 0.07 million Euros.

Even though at first glance it appears to be several orders of magnitude more economical to preserve an archaeological site in situ, efficient and well informed management requires significant investment of resources to continually monitor and safeguard these sites. SASMAP will develop and assess tools, techniques and methods in order to develop best practice for the cost effective and successful investigation and management of underwater cultural heritage

1.3 The SASMAP Concept

Within SASMAP a holistic approach will be taken to locating, assessing, monitoring and safeguarding underwater cultural heritage. This will involve developing and utilising tools and technologies to allow "down-scaling" from the large scale regional level, moving on to the local site level and finally to the individual components of a site as shown in Figure 1.

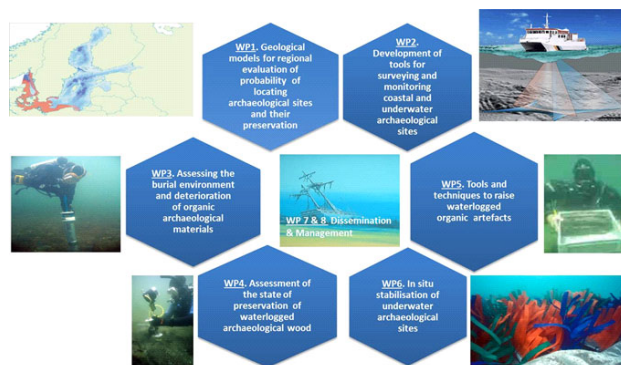


Figure 1. A down-scaling and up-scaling approach to locating, assessing and managing underwater cultural heritage.

Results obtained from the down-scaling approach at the proposed study areas will show the effectiveness of such an approach for locating and detailed mapping of archaeological sites and their preservation potential. The end results of this approach will be used to develop a plan for assessing archaeological sites in European waters. From a management point of view this is an up-scaling approach to planning (bottom up). All information and experiences obtained during the course of the project will be utilised to enhance and develop existing legislation and best practice for mapping and preserving Europe's underwater and coastal heritage.

1.4 The SASMAP Consortium

SASMAP brings together a consortium of seven research institutions and four Small Medium Enterprises (SMEs) from seven European countries. The partners comprise an interdisciplinary group with the SMEs having expertise in the development and production of state of the art marine geophysical instruments, equipment for measuring biogeochemical 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.	Participant organisation name	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 Control Systems (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

Table 2. The partners of the SASMAP consortium.

2. RESEARCH & INNOVATION WITHIN SASMAP

SASMAP has multiple scientific objectives that all have as their aim to develop a structured and optimized approach to

safeguarding underwater cultural heritage. The objectives are divided up into the following Work Packages (WPs):

2.1 A Geological model for regional evaluation of probability of locating archaeological sites and their preservation potential (WP1).

Marine geological investigations are essential to develop a model describing the palaeogeographical and depositional environments in the selected study areas. GEUS has substantial experience in investigating the postglacial geological development of the Baltic Sea region. The study will be developed in the initial phase of the project to reconstruct the palaeo-landscape and to build a geological model of the Baltic target site. Existing information from this multi-disciplinary field will include seismic, sedimentological, biostratigraphic and AMS C-14 dating data, which will be collated. Based on these data the changing geological environments, as well as the palaeogeography, will be reconstructed with respect to sedimentary conditions and water level fluctuations that occurred in the course of the various postglacial lake stages, as well as regional sea level changes.

On the basis of the geological model it will be possible to optimise the process of selecting the target region ideal for non-destructive down-scaling studies, spanning from regional satellite scanning of theoretical optimal target coastal areas, detailed multibeam echosounder and shallow seismic surveying of selected target areas to 3D-seismic investigations of identified archaeological target sites.

All data will be applicable to GIS presentation, interpretation and modelling of the physical appearance of the archaeological sites. The GIS will be custom made for input of hydrodynamic and sediment regime data for evaluation of site stability and preservation status.

Similarly, the University of Patras (UPAT) has for decades in cooperation with the Finnish Institute at Athens, University of Peloponnesus, Hellenic Institute of Marine Archaeology (IENAE) and Ephorate of Underwater Archaeology of Greece (Hellenic Ministry Of Culture and Tourism) carried out marine-geological investigations in Greek waters focusing on palaeo coastal morphology in archaeological sites of Greece (Cape Sounio, Poros and Dokos Islands, Killini, Neapoli). UPAT has experience in investigating ancient submerged archaeological sites and reconstructing the coastal palaeogeography in the eastern Mediterranean Sea. Aegean shorelines usually are characterized by rocky and narrow (and steep) coasts with low sediment accumulation rates. Today most of the prehistoric and historic coastal settlements (harbour and cities) in Aegean Sea, lie underwater due to postglacial transgression, local tectonics and intense coastal dynamics.

These models will be supplemented with input from partners 8 (RCE) The Cultural Heritage Agency of the Netherlands. RCE has a long standing tradition in researching the seabed with the help of other (governmental) institutes such as Rijkswaterstaat. Their previous works have resulted in large scale and small scale models published within the EU- Culture 2000 project MACHU. Within SASMAP the models will be combined to produce maps of individual archaeological value and potential, which will be incorporated into the existing MACHU GIS. The final product will provide the basis for improved decision making when planning subsea development or investigating and preserving known sites in situ.

2.2 Development of Tools for Surveying and Monitoring Coastal and Underwater Archaeological Sites (WP2)

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). SASMAP will be one of the first projects to use such remote sensing techniques to monitor coastal changes. On underwater sites, sidescan 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 surveying a cutting edge method and together with other new technologies developed within the project, will give detailed 3D imagery of archaeological sites and environs. Following a down-scaling approach, i.e. working from the large regional scale to the detailed site scale, will yield seamless maps that can be used for assessing coastal and submerged archaeological sites. This will be achieved by the following:

- satellite imagery for case study areas (Denmark and Greece) will be purchased from a satellite image providing company and assimilated into a Geographical Information System (GIS), in order to map the coastline and sediment transport in 3D. The development and use of the GIS will contribute to developing a best practice for large scale assessment of the coastal and foreshore zone.
- the stability of the case study areas will be investigated through observing the 3D terrain models of the sea bed surface area obtained from multibeam echosounder (MBES) surveys over the case study areas during the project time span. These data will also be assimilated into the GIS and by comparing data sets from the satellite imagery with MBES data, hot spot areas of the sites which are being eroded, due to sediment transport or conversely covered with sediment, will be identified. These areas will be verified (ground truthed) in connection with research undertaken in WPs 3, 4 and 6.
- A prototype 3D parametric sub bottom profiling system (SBP) will be applied to the area at a local scale in order to obtain a 3D map of the sediment structures and to identify archaeological artefacts within the site. This system has not previously been used in shallow water and will be trialled alongside a proprietary 'CHIRP' SBP system, currently considered the best commercially available tool for imaging buried archaeological artefacts. The potential application of this new system to archaeological prospection will thus be assessed. These data will also be assimilated into the GIS. Trialling the prototype system on the site in Greece where the carbonate bedrock is very different to the postglacial and glacial sediments typical of north-west Europe, will evaluate its range of applicability to marine archaeology. A GIS will be developed using state of the art remote sensing techniques and data in order to holistically localise, map and monitor archaeological remains in submerged environments on a large scale.

2.3. Assessing the burial environment and deterioration of organic materials (WP3)

Buried waterlogged environments provide unique conditions for organic materials such as wood, bone, antler, textile, skin and plant remains to be preserved for millennia, partly due to the low oxygen levels. Conditions in open seawater can, in the absence of wood boring organisms (see <http://wreckprotect.eu>) also preserve these materials for many hundreds of years. However, deterioration of organic material can occur in oxygen free (anoxic) environments due to the activity of anaerobic

bacteria. Research into the reburial of archaeological materials in the marine environment has shown that the rates of organic turnover (deterioration) are dependent on sediment type and their pore water composition (<http://www9.vgregion.se/vastarvet/svk/reburial/index.htm>).

The project will develop tools and methods to:

- improve sampling techniques for sediments, not only for the purposes of this project, but archaeology in general (dating, pollen and other environmental analyses). Currently available diver operated coring devices can be notoriously difficult to use in terms of deployment, retrieval and obtaining deep and undisturbed sediment cores. A diver deployable vibrocore-type coring system, will be constructed and tested by AKUT and NM, which can sample sediments down to a maximum sediment depth of 50 cm and without disturbing the surface layers of sediment which are very difficult to sample due to their often mobile nature. The corer will be constructed in such a way that discrete layers within sediments (taken both vertically and horizontally) can be easily sub sampled in order to characterize both sediment type and porewater composition in the laboratory. The device will be used for ground truthing other elements of this and other work packages
- develop a data logging system which can be deployed for periods of up to six months to assess pore water composition of sediments in situ to a maximum sediment depth of 50 cm. Proposed parameters to be measured are dissolved oxygen, sulphide content, pH, redox potential and methane, which in combination provide information on the biogeochemical process on going in the sediment and their effect on organic material turnover. This data logger will be developed by partner 3 (UNI), who are world leaders in development of microsensor technology for use in underwater and marine environments

The developed tools will be used to obtain sediment samples and monitor conditions on the test sites in order to better understand why artefacts are so well preserved, archaeologically speaking, and determine which sediment types offer the optimal conditions for preservation should sites be preserved either in situ or through re-burial. The results of this environmental monitoring will also be compared and contrasted with microscopic analysis of representative samples of archaeological wood, carried out by partner 9 (UGOT) from the sites in order to contribute to our understanding of the effects of the environment and deterioration process of waterlogged archaeological wood. Similarly the results will be compared and contrasted with the data obtained by the 3D sub bottom profiler. The EU financed project Baltic Gas (<http://balticgas.au.dk/balticgasau.dk/>) has shown the possibility of monitoring methane development with similar equipment. In this manner it may be possible to use this tool not only to localise artefacts but also characterise the biogeochemical processes on-going in the sediment to assess the preservation capabilities of sediments.

2.4. Assessment of the state of preservation of waterlogged archaeological wood (WP4)

Waterlogged wood is one of the most frequently encountered materials on underwater archaeological sites, and knowledge of its state of preservation whilst still in situ determines whether it can be raised and subsequently conserved, or whether it is sufficiently strong to withstand being preserved in situ. As noted previously, anaerobic bacteria cause deterioration of archaeological materials in marine sediments and, in the case of wood, they utilise the sugars and complex carbohydrates present in the wood cell wall as a source of nutrition. As deterioration proceeds material is removed and subsequently replaced with water – it is this water which fills the “voids” and allows the

material to retain its form. Thus although freshly excavated wood may appear well preserved from an archaeological perspective, i.e. surface details and form are retained, it can be poorly preserved from a conservation perspective and if allowed to dry in an uncontrolled manner it will suffer irreversible shrinkage and collapse.

Within SASMAP a prototype hand held tool for assessing the state of preservation of waterlogged archaeological wood both in situ on the seabed and in the laboratory will be developed. This prototype will be based on research and development work which has been on going by partners 1 (NM) and 4 (AKUT). The prototype will be 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. Density is a good physical parameter to provide information about the condition of wood and the implications this has for subsequent conservation or suitability for preservation in situ. Currently there is no device commercially available that can provide this information for marine archaeologists and conservators. Furthermore such a device could have broader implications for the non-destructive testing of non- archaeological timbers used in the marine environment (pilings, harbour installations) or on land (forestry, construction industry).

2.5. Tools and techniques to raise waterlogged organic archaeological artefacts (WP5)

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 the crucial stage of lifting artefacts from the seabed to the surface where mechanical damage can easily occur. Submerged prehistoric sites in particular contain a wealth of the aforementioned organic materials and complex structures such as fish traps. 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 on land in the laboratory. Methods of encapsulating and block lifting have been used in the past to address this, yet can be very time consuming underwater, with artefacts being left exposed to physical damage at crucial stages while consolidating materials are allowed to “set” underwater.

SASMAP will draw upon the extensive excavation experience of partner 7 (VM) and the pioneering research into stabilising and consolidating archaeological remains underwater of partner 10 (ISCR) in order to develop best practice methods. This will involve the development of the use of polymer based consolidants which can both encapsulate and consolidate sediments, as well as freezing of sediments in order to enable the safe lifting and transport of waterlogged organic archaeological objects.

2.6. In situ stabilization of underwater archaeological sites (WP6)

Sites which are preserved in situ are threatened by the effects of underwater currents which can cause sediment to be removed from sites, leading to their exposure. Upon exposure, sites are susceptible to mechanical abrasion and erosion, which can lead to their total loss. Furthermore, wooden artefacts can, under the right environmental circumstances, be attacked by wood boring organisms such as shipworm, which can also lead total loss of archaeological materials within relatively short periods of time – years or decades rather than centuries or millennia. The EU

supported project Wreck Protect (<http://www.wreckprotect.eu>) assessed ways to protect historical wooden shipwrecks in situ from the threat of wood boring organisms. All potential methods identified relied upon limiting the access of oxygen to the wood 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. Innovative methods identified actually took advantage of currents and sediment transport within the water column to either entrap sediment and create a burial mound or disperse currents so that seabed erosion was reduced. Partner 5, (SSCS) is a world leader in scour control systems to prevent seabed scouring and erosion for the offshore industry (gas and oil pipelines, offshore windturbine footings). To achieve this they use mats of artificial seagrass, which float upright in the water column and entrap passing sediment particles, effectively creating an artificial seabed. These mats will be developed further to test their applicability to protecting shallow water submerged archaeological sites, which are under threat from near shore and coastal erosion. Furthermore, 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, will be tested.

3. IMPACTS OF SASMAP

SASMAP with its holistic and process based approach to underwater cultural heritage will provide an improved understanding of the environment of underwater archaeological sites, and contribute to best practice for management decisions. Although in situ preservation should be seen as a first option for the preservation of underwater cultural heritage this is not always viable due to either the nature of the site environment or the fact that, due to subsea development, sites have to be excavated. SASMAP addresses both these scenarios. The innovative tools and new technologies that will be developed to improve both location and mapping of sites; the excavation and raising of fragile organic materials if it is not viable to preserve them in situ. If in situ preservation is an option, SASMAP will also see the development of new technologies to stabilise sites and monitor their effectiveness and also the effects these stabilisation materials have on the environment.

The SASMAP consortium includes four SME partners. The SMEs are already leaders in their respective fields and the project is mutually beneficial as it provides the SMEs the opportunity to fulfil many of their own business development plans and develop new tools and technologies. The impact of these new technologies has wider implications than just the SASMAP project and will enable the SMEs to increase their business profiles after the completion of the project.

SASMAP is adopting a European rather than a national approach because the implications of the Treaty of Valletta affect all European nations with territorial waters and thus responsibility for dealing with underwater archaeology. The development of the SASMAP technologies requires strong collaboration between complementary research disciplines that are only found at a European level. Moreover, the involvement of four SMEs in the project is only possible due to the European approach taken. The active involvement of these SMEs will ensure awareness and effective dissemination of the technologies to heritage agencies, cultural resource managers and end users in the offshore sub sea industry. These activities are of vital importance for successful exploitation and marketing of the technologies beyond SASMAP. By taking a European approach, SASMAP will improve the assessment of

underwater archaeology in connection with sub sea development by providing heritage agencies with new tools and best practices

The project will produce two main products; Prototype technologies, and other tools and methods which will contribute to best practice when investigating underwater archaeological sites. The prototype tools developed by the SMEs will be disseminated through both the project's own home page and the home pages of the SMEs involved along with media (TV, radio, press) coverage. Intellectual property of the prototypes will be the rights of the SMEs but directions for their practical use will form an integral part of the guidelines produced in the project. The new technologies developed by the SMEs will be promoted through the field school that will take place at the end of the three year project. Furthermore, the tools and techniques developed to locate, assess and manage underwater cultural heritage will be synthesised into two guidelines. These will be made available to stake holders, end users and policy makers at the field school and on the project home page as downloadable pdf files in order to make them freely available.

Further to the prototypes and the guidelines, the project results will be disseminated through publication in peer reviewed scientific journals, popular press, presentations at national and international conferences for marine archaeology, conservation and subsea development. It is also hoped that the project can contribute to European policy for the improved management of Europe's underwater cultural heritage.

4. SELECTED REFERENCES

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