SASMAP

COLLABORATIVE RESEARCH PROJECT

Development of tools and techniques to Survey, Assess, Stabilise, Monitor And Preserve underwater archaeological sites.

Progress

2012-2013

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Front page photo: Diver trialling in situ profiling equipment to characterise the geochemistry of sediments. Photo Viking Ship Museum

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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. 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 subsea 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 man made hazards such as dredging, from construction work, fishing, installation of pipe / cable lines and other subsea / coastal development. 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.

Why SASMAP?

The need for a European supported project, such as 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. The current consortium includes 11 partners from 7 European countries 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 WreckProtect (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 EU COST Actions IE0601 Wood Science for Conservation of Cultural Heritage (WoodCultHer) and TD0902 SPLASHCOS 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 led 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.

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.

Overall Strategy

The project is structured in 8 integrated Work Packages (WPs). The overall concept of the project is to use a down-scaling approach for the location and assessment of underwater archaeological sites. Having localised potential sites an up-scaling approach (bottom up) will be taken to developing technologies, tools and best practice methods for preserving them in situ or ex situ. WPs 1 and 2 focus on development of models to allow desk based assessment of the potential of finding archaeological sites, their stability and then how to localise these sites with remote sensing tools. WPs 3-6 focus on the development of tools and

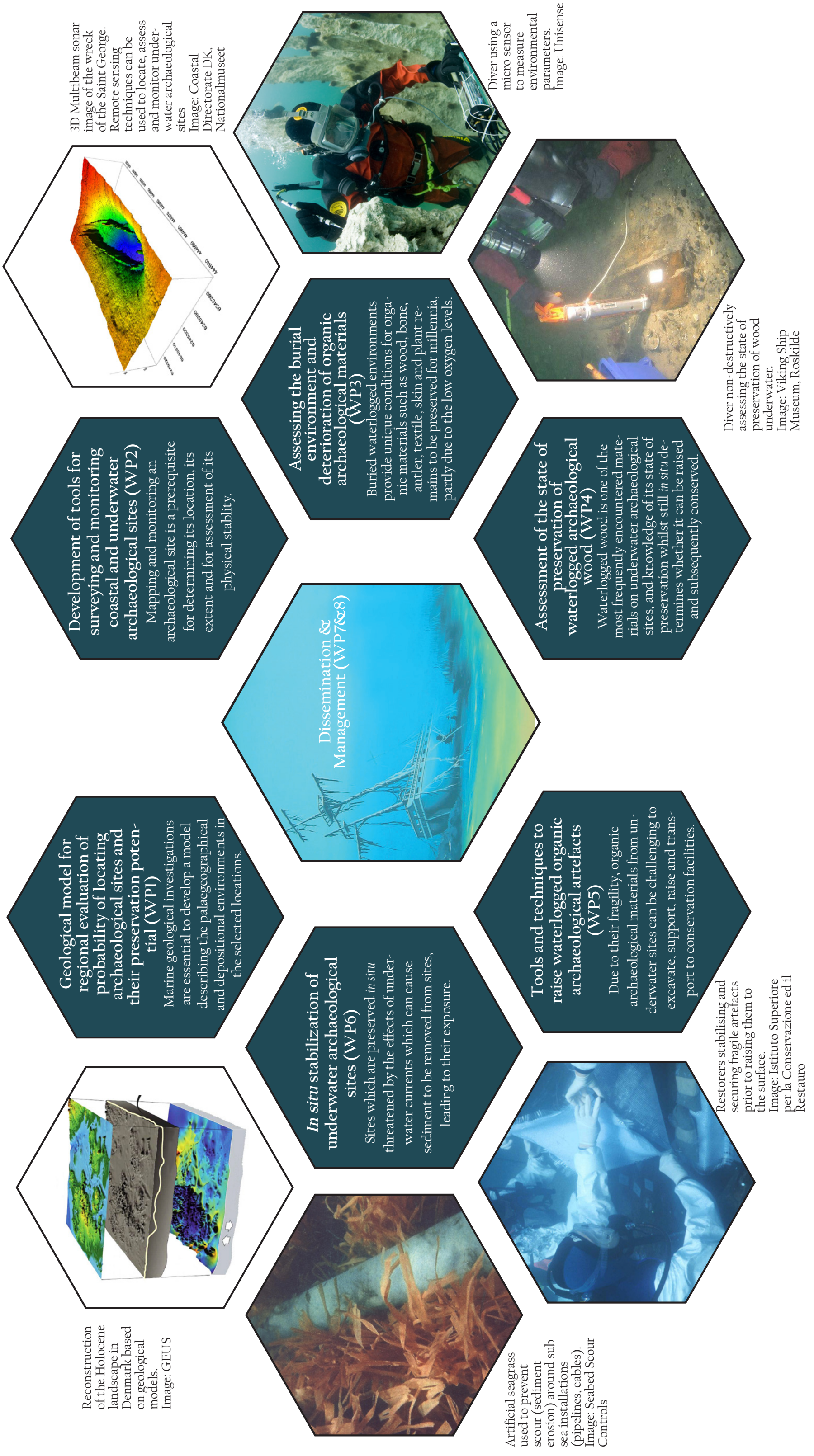

Figure 1. A down-scaling and up-scaling approach to locating, assessing and managing underwater cultural heritage.

technologies and best practice on how to deal with localised archaeological sites and how they should best be preserved in situ or excavated and raised (ex situ). WPs 7 and 8 concern the dissemination and management of the project respectively. **WP1** focuses on the development of two geological models for the two case study areas in Denmark and Greece. It involves collecting and harmonizing satellite imagery with pre-existing information including seismic, sedimentological, and biostratigraphic data in order to elucidate palaeogeography (sedimentary conditions and water level fluctuations over time) and palaeoenvironment. The models will be used to assess the potential of finding underwater archaeological sites in these environments and assessing their stability. This information will feed directly into **WP2** in which target regions for non-destructive down-scaling studies will be selected. The two case study areas will be incorporated into two GIS systems (one for each site). Based on the models from WP1 and the GIS, those areas on the case study sites most likely to contain archaeological remains will be surveyed with a suite of remote sensing geophysical tools, including a 3D sub bottom profiler which is being specifically developed within the project. The results of these surveys will be incorporated into the GIS in order to provide tools for localising, mapping and monitoring underwater archaeological sites. The final GIS will be incorporated into the existing MACHU GIS database development by the Dutch Cultural Heritage Agency who are also part of the SASMAP consortium. **WPs 3** and **4** focus on the development of tools and technologies and best practice to assess the burial environment both through in situ logged and ex situ measured parameters, indicative of the deterioration of organic archaeological materials and in situ assessment of the state of preservation of waterlogged

Figure 2. Locations of the archaological sites being examined in SASMAP.

archaeological wood. Should it not be possible to preserve a site in situ **WP5** addresses the development of tools and best practice for the raising of poorly preserved organic artefacts. **WP6** will investigate the use of methods to stabilise sites in situ, monitor their effects on sites and how typical materials used for in situ preservation interact with the marine environment. The tools developed in WPs 3-6, in conjunction with WPs 1 and 2, will enable a dual-scale (down and up scaling) approach to the location, assessment and management of hitherto unknown underwater archaeological sites. WP7 focusses on dissemination of the project results and further exploitation of the technologies developed. WP8 is devoted to the management of the project. 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. These will be published in the guidelines in the final year of the project.

The down scaling tools and methods outlined above will be trialled in the field on two shallow water submerged sites in Denmark (Tudse Hage) and Greece (Cape Sounion). The up-scaling methods will be trialled on a shipwreck site in the Netherlands (BZN 10) and a submerged shallow water site in Italy (Underwater Archaeological Park of Baiae) (Figure 2).

The SASMAP Consortium

SASMAP brings together a consortium of 7 research institutions and 4 SMEs from 7 European countries. The partners comprise an interdisciplinary group of SMEs and institutional European partners with expertise in the development and production of state of the art marine geophysical instruments, equipment for measuring bio-geochemical parameters in the marine environment, hand held diving tools and methods to prevent erosion of the seabed. 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.

In at the deep end!

Status of the project October 2013

Following contract negotiations the project started on the 1st of September 2012. The kick off meeting was held in Brussels, with representatives from all partners at the end of September. At the time of writing the project has effectively been running a year since the kick off meeting; and what a year! The project really started by jumping in at the deep end with all Work Packages effectively starting simultaneously. The satellite imagery and data for the development of WPs 1 and 2, along with the collection of the first geophysical data sets on the sites in Denmark and Greece, have all successfully been gathered. Equipment has been developed and tested in WPs 3 and 6 in the first phase of field work on the various sites in the project over the Spring and Summer of 2013. It is only through the extremely hard work of all consortium members both in the office, laboratory and in the field that the project has reached this far and is still on track. The winter of 2013 will see the further development of the models and databases in Work Packages 1 and 2. Work Package 3 will see refinement of equipment after the steep learning curve from the first field seasons trials and laboratory work to study the deterioration of organic materials will start. Work package 4 will see the further development of the hand held wood tester and Work package 5 will see evaluation of the methods trialled so far and further development of proofs of concepts for how best raise to raise fragile artefacts. The seagrass mats from WP 6, which have now been placed on site will be monitored, where possible, after winter storms to study their effects.

The overall aim of the project is to synthesise the results of the Work Packages into two guidelines which will be published in 2015. The aim of this report is to give a brief report of what has been achieved in this first year and we hope the following pages give a taster of the work the Consortium has carried out in this time.

David Gregory

Figure 3. The consortium at the kick off meeting in September 2012

WP1

Geological model for regional evaluation of probability of locating archaeological sites and their preservation potential.

Marine geological investigations are essential to develop a model describing the palaeogeographical and depositional environments of marine archaeological sites. GEUS, The Geological Survey of Denmark and Greenland, has substantial experience in investigating the postglacial geological development of the Baltic Sea region. Within the project they are reconstructing the palaeo-landscape and building a geological model of the target site. Existing information from this multi-disciplinary field will include seismic, sedimentological, biostratigraphic and AMS C-14 dating data, which has been collated. Based on these data the changing geological environments, as well as the palaeogeography, are being 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 is 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 characterised 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 the Aegean Sea, lie underwater due to postglacial transgression, local tectonics and intense coastal dynamics.

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 managed by the Dutch Cultural Heritage Agency. The final product will provide the basis for improved decision making when planning subsea development or investigating and preserving known sites in situ.

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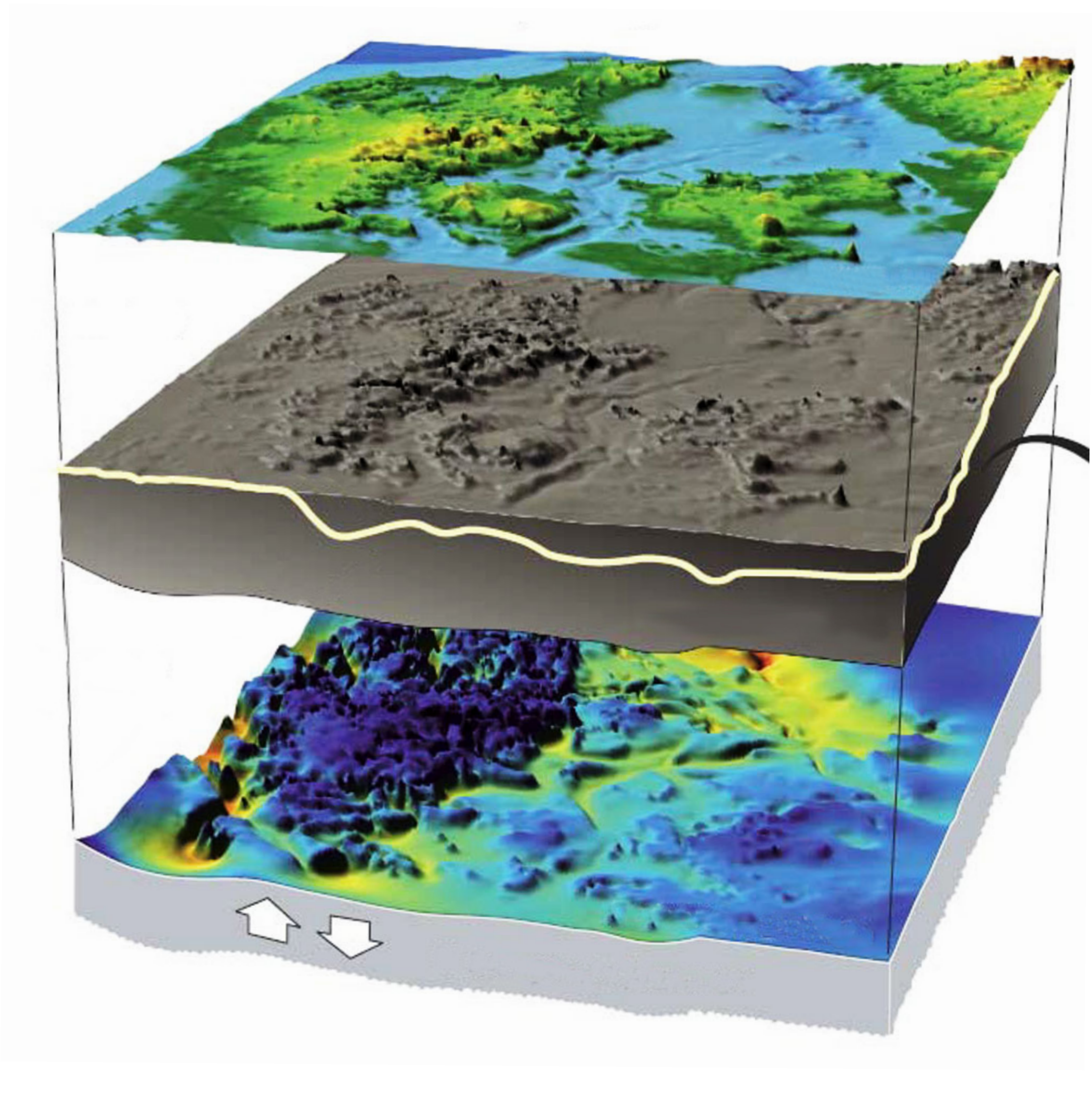

Figure 4. Reconstruction of the Holocene landscape in Denmark based on geological modes. Photo "De seneste 150.000 år, geoviden Nr.2,GEUS, 2005"

WP2

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 potentially able to monitor changes in coast line morphology and sediment transport in shallow water environments (to depths of 6-8 metres). 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 profiling is 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 is being achieved by the following:

- satellite imagery for case study areas (Denmark and Greece) has been 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 is being 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.
- The proof of concept 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 the possibility of identifying archaeological artefacts within the site. These data will also be assimilated into the GIS. Trialling the 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 environ-ments on a large scale.

Results September 2012 – 2013

The remote sensing, geophysical surveying and the production of a geological model are well under way for the test sites at Tudse Hage, Denmark, and Cape Sounion, Greece (Figure 5a). Considerable progress has been achieved during the first year of the project. In WP1 the World View 2 high resolution satellite images for the test site areas were obtained, (Figure 5b-e). These figures reveal the 8 bands satellite images as well as the calculated bathymetry deduced from the satellite images calibrated with measured points provided by the relevant partners. The bathymetry was truncated to 5-6 metres depth at Tudse Hage and 12 metres at Cape Sounion due to water clarity and seabed slope. The satellite images, the bathymetry, the sediment map, available information and expert judgment were used to optimise the planning of the areas where the geophysical survey was later conducted.

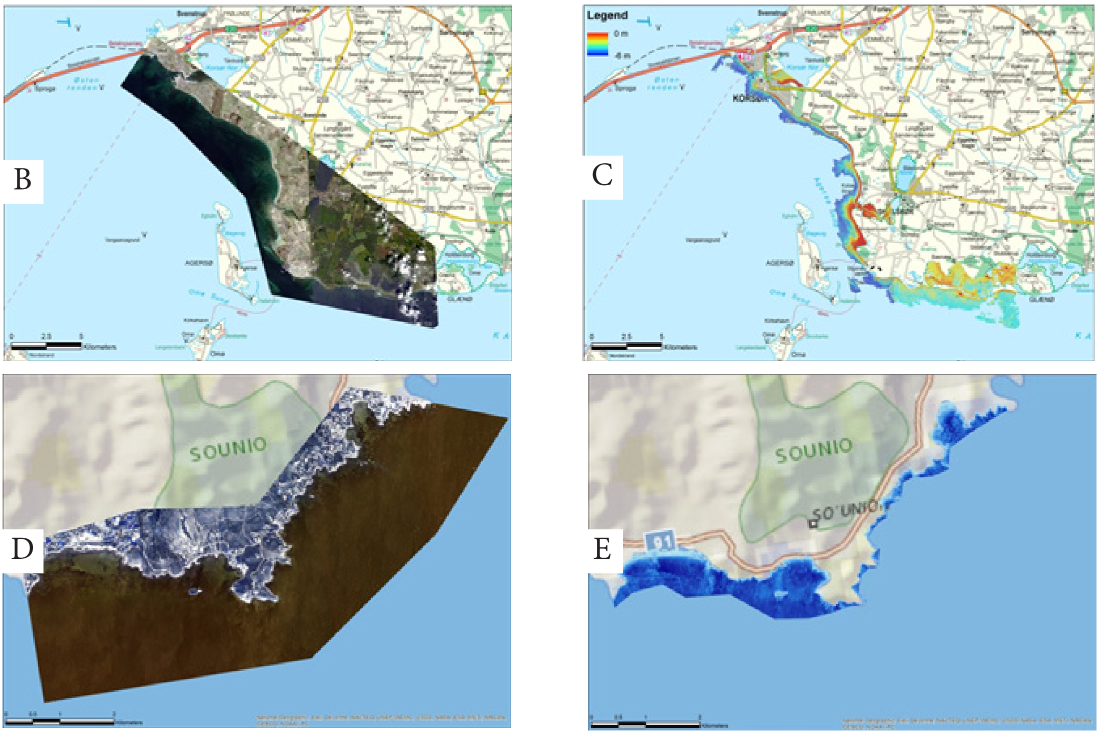

Figure 5. WP1 & WP2 study areas at Tudse Hage and Cape Sounion. Photos Viking Ship Museum and The University of Patras (A). World View 2 satellite images at (B) Tudse Hage /DK and (D) Cape Sounion /GR. Also shown bathymetry data extracted from the satellite images at (C) Tudse Hage, and (E) Cape Sounion. Photos GEUS

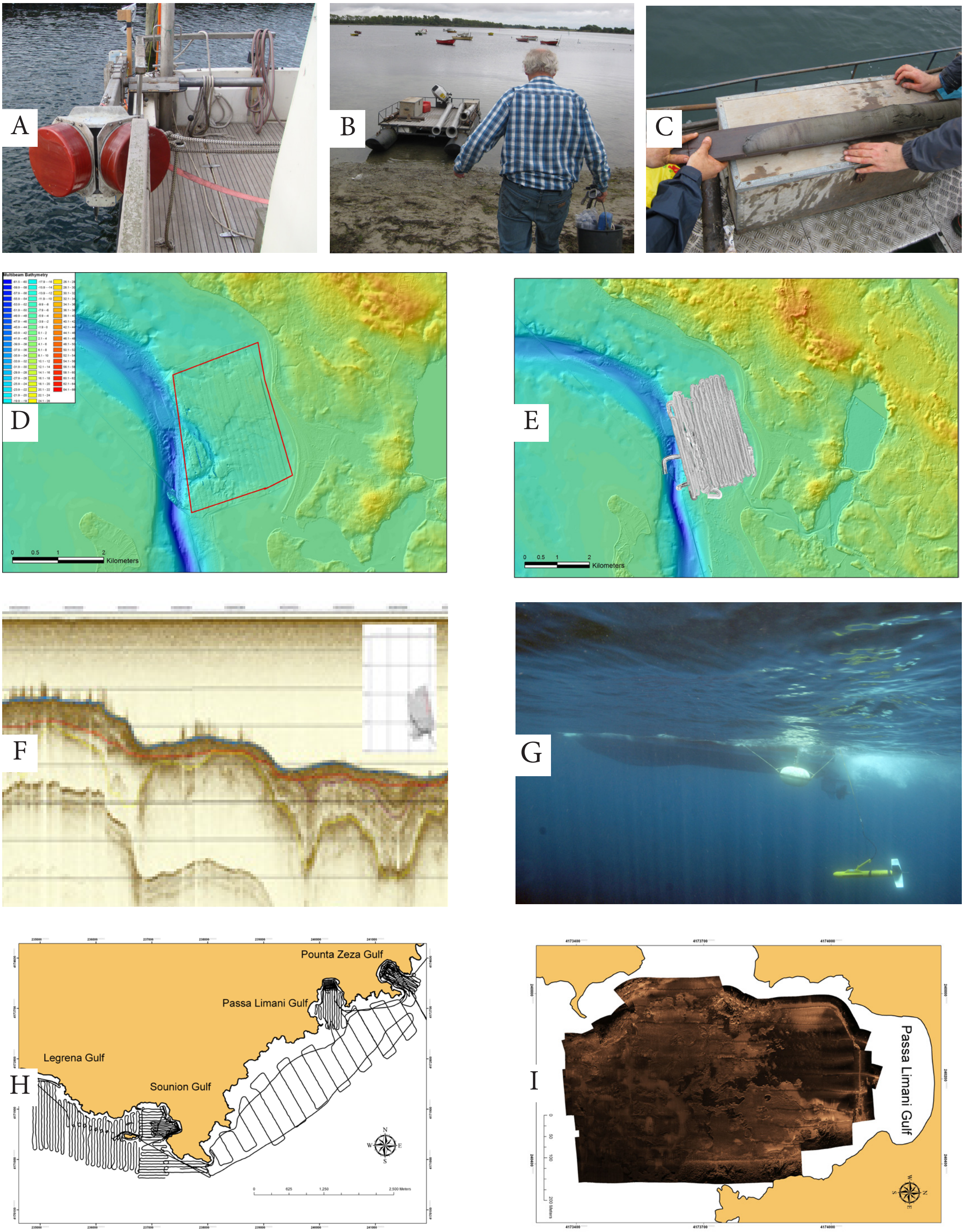

Figure 6. WP2 field work activity in 2013. A: Multibeam echosounder on board Maritina, DK. B: Coring at Tudse Hage with a coring raft and a Russian Corer, DK. C: Extracted sediment cores, DK. D: Processed multibeam bathymetry data merged with satellite bathymetry and land DTM, DK. E: Sidescan image of the survey area, DK. F: Seismic profile taken with Innomar parametric sub-bottom profiler, DK. Photos GEUS. G: Survey boat with sidescan fish in Sounion, GR. H: Survey lines for the geophysical survey, GR. I: Sidescan image of a surveyed area in Sounion, GR. Photos University of Patras

The field work was conducted in the Summer of 2013 and the data was analysed and potential locations for coring were delineated (Figure 6). Coring off-shore was conducted at Tudse Hage Denmark. The core samples will be used for dating and construction of the geological model and the paleogeographical environment of the area. To get a complete sequence of sea level rise in the area which will positively determine probable locations of potential archaeological sites in the Tudse Hage study area, an on-shore GeoRadar survey was suggested at the on-shore region east of the area where off-shore coring took place; this will be conducted in October and sediment cores will also be taken from the area for dating. In the Greek study area (Cape Sounion) field work included the gulfs of Passalimani, Pountazeza, Sounio and Legrena and was conducted using multibeam, side scan sonar (two systems), sub-bottom profilers (two systems) and magnetometer. The data collected will be compared with each other and with the data from the satellite images. Furthermore the results of the geophysical survey will be combined with the submerged archaeological findings in order to depict the geological model and the palaeogeographic evolution of the coastal zone of the area.

An innovative sub-bottom 3D imaging system is being developed and will be used in the allocated test sites for detailed studies in the Summer of 2014. A parametric transducer array has been designed and manufactured by Innomar Technologie GmbH, (Figure 7). The transducer was field tested in a local Marina and data have been collected for further analysis. Preliminary results indicate that the array is working within its design specifications.

The next step in these work packages will be the production of a GIS based database encompassing all the background data used in the production of a geological and palaeogeographic model. The model and the archaeological information of prehistoric sites will be incorporated into a GIS platform where the potential archaeological sites in the test site areas and their environmental status and stability are elucidated. The 3D sub-bottom profiler will be used in the surveyed test areas to produce a fully geo-referenced 3D image of the archaeological sites.

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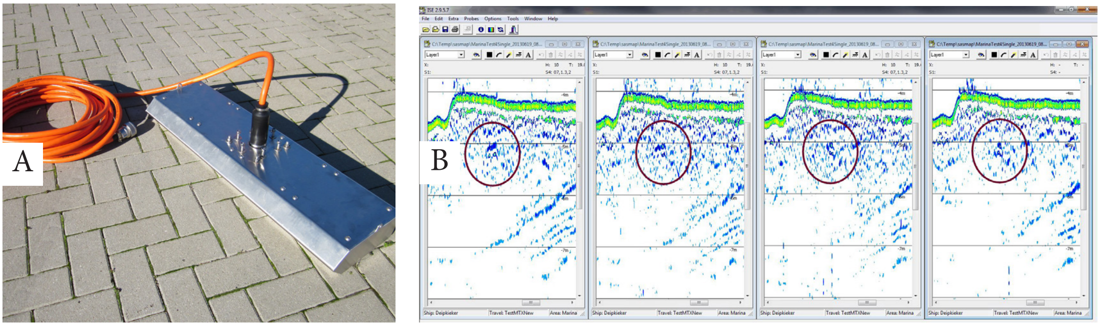


Figure 7. Parametric transducer array (A) for the sub-bottom 3D imaging system and test data collected for signal analysis. Echo plots of sub-bottom data channels with 25 cm separation show morphological differences of embedded features (B). Photos Innomar

WP3

Assessing the burial environment and deterioration of organic archaeological materials.

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 objectives of WP3 are to develop tools to enable the sampling and characterisation of marine sediments both in situ and in the laboratory to assess the potential for preservation of organic archaeological materials. To achieve this the following is being carried out:

- Develop test and provide proof of concept of in situ data logging devices which can characterise the environment of marine archaeological sites both in the open water and sediment environment
- Develop, test and provide proof of concept of diver held technology to sample sediments from archaeological sites
- Correlate the data obtained from the sub bottom profiler in WP2 with the environmental data in order to assess the potential of using this system to remotely assess the preserving capabilities of sediments.

The majority of trialling work is being carried out in Denmark but will also be made available to the partners in the project and be trialled in the Netherlands and Italy.

The overall results of the work package will be combined to prepare a Guideline for best practice to characterise the preservation potential of sediments on marine archaeological sites.

Results September 2012 to October 2013

The winter of 2012 and spring of 2013 saw an intensive development of the vibracoring device carred out by AKUT, with preliminary field testing in collaboration with the National Museum of Denmark. At the same time Unisense began work on developing the data logging systems. Shortly after the start of the project it was decided that two separate systems should be developed to best achieve the desired results of measuring and logging environmental parameters in both the open water and sediments. These were to be based on existing systems within the Unisense range of products, yet entailed considerable re-development and integration of new software and hard ware. The various equipment designed was trialled in earnest in the Summer of 2013 on the site of Tudse Hage in order to get a first impression of the applicability of the first concept devices.

Vibracoring System

The specifications for the vibracoring system were such that it should:

- be able to take samples down to a depth of 50 cm in the seabed,
- be diver held and ideally operated by one diver only,
- be easy to pass/vibrate into the bottom and easy to retrieve,
- be able to preserve the core with a suitable sediment retainer
- ensure best possible preservation of the core, in order to take gas measurements and pore water analysis through sealed holes in the coring tube.

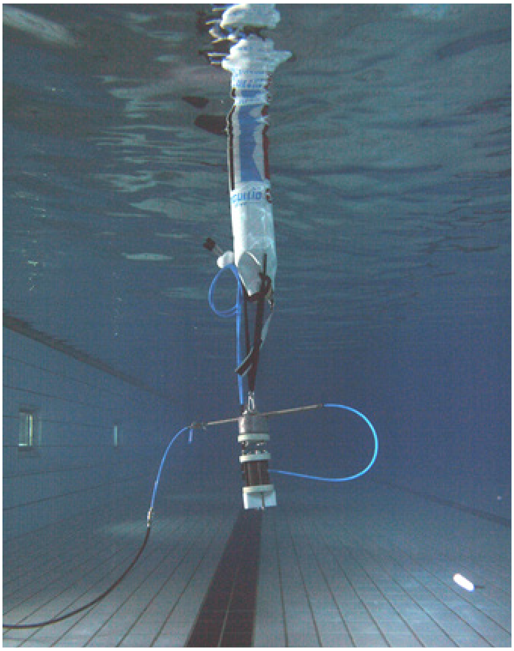


Figure 8. Mark I of Vibracoring system in trialled in swimming pool without coring tube. Photo AKUT

In general the system should improve upon currently available corer systems in terms of diver deployment, retrieval and ease of analysis of samples. The resultant system based on the above criteria consists of the following:

- 80 mm diameter polycarbonate tube for collecting the sediment samples although smaller tube sizes can be relatively easily adapted
- An interchangeable vibrator head
- A pneumatic vibrator providing longitudinal vibrations
- A spring connecting vibrator with weight
- Weight system for creating downward force on vibrator and coring tube
- A lifting bag connected to the weight for balancing the unit
- A “handle bar” with operating valve
- An exhaust system with buoyancy

The vital part of the corer is the vibrator. A pneumatic driven unit was selected, as divers are familiar with compressed air and because compressed air is available in connection with diving activities. The unit can be supplied by an umbilical cord from the surface or from tanks at the bottom depending on numbers of samples to be made, working depth, and the facilities of the supporting dive vessels. The coring tube is made of transparent polycarbonate. The tube has a simple system for attachment to the vibrator head and for allowing water to escape the coring tube during penetration. Both systems can easily be operated by divers even with gloves. The coring

Figure 9. The AKUT vibracorer on test in dry soil (A, B) and an artificial seabed (C, D). Photos AKUT

tube is mounted on the vibrator by an interchangeable head, in order to be able to use tubes of different diameters. The head also makes changing of coring tubes under water simple. The downward force on the tube is achieved by a weight with a diver held "handle bar" connected to the vibrator through a spring. The spring protects the diver from the vibrations and insures that all vibration energy is channelled to the coring tube. The weight system is connected to a lifting bag, making it possible to adjust the downward force by regulating the amount of air in the bag. The lifting bag can be filled by exhaust air from the vibrator and provides upward force to ease the retrieving of the core from the seabed.

Datalogging Systems

Open water

The open water data logging system was to be based on the lander technologies that Unisense have currently developed. The parameters to be measured were standard CTD data (conductivity (salinity), temperature and depth data) and an Acoustic Doppler Current Profiler (ADCP water current meter). Integration of these instruments and modification of hardware, software and firm ware took place over the Winter of 2012 – 2013 ready for an initial trial on the site of Tudse Hage in the Summer of 2013.

Sediment profiling system

It was desired to measure sediment profiles in situ using a diver based

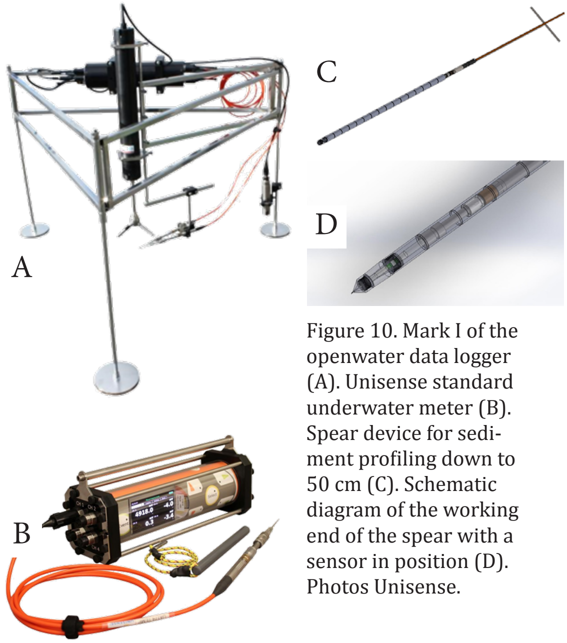


Figure 10. Mark I of the openwater data logger (A). Unisense standard underwater meter (B). Spear device for sediment profiling down to 50 cm (C). Schematic diagram of the working end of the spear with a sensor in position (D). Photos Unisense.

datalogging system down to a depth of 50 cm. An existing diver operated underwater meter manufactured by Unisense was re-developed for this purpose. The standard equipment has the capability of measuring dissolved oxygen, pH, redox and sulphide using Unisense's microsensors that are fitted with hypodermic needles to give them added robustness. However, this system was developed for measuring in the upper few centimetres of sediments; not profiling down to 50 cms depth. As with the open water data logger extensive development of the existing equipment and a "spear" system, which could be pressed into the sediment was developed. This again required re-configuration of the hardware, software and firmware of the existing underwater meter and the re-design of sensors to fit into the spear system which would be relatively easily operable by a diver underwater. The concept was to make a hollow spear which could be hammered into the sediment to the desired depth and then the sensors placed into this to take the desired measurements.

Preliminary Field Testing in Tudse Hage August 2013

At the end of August all equipment was ready for the first serious field trials on the site of Tudse Hage. The team consisted of partners from the National Museum of Denmark, the Viking Ship Museum, AKUT, Unisense and the University of Gothenburg. Field work took place over two weeks with the first week dedicated to localisation and preparation of suitable areas for testing and monitoring of the artificial sea grass mats (see section on WP6 in situ preservation). The second week was trialling of the various systems developed. Following kind permission from the Danish Cultural Heritage Agency it was agreed that there could be minimal intervention on the site in order to trial the equipment and take sediment, wood samples and place modern wood into the site. The vibracoring system was to be used in order to obtain cores for further analysis in the field and laboratory. Profiles of the aforementioned parameters were to be measured in the cores in the field in order to compare these results with in situ profiles measured using the in situ spear /sediment profiler so as to compare and validate both methods. The open water data logger was trialled around one of the artificial seagrass mats to see if differences in current strength and direction around the mat could be determined. Samples of archaeological wood were also taken from the various layers of the site in order to examine their state of preservation, which could be compared with the environmental parameters measured in the cores and with the in situ profiling equipment. Similarly,

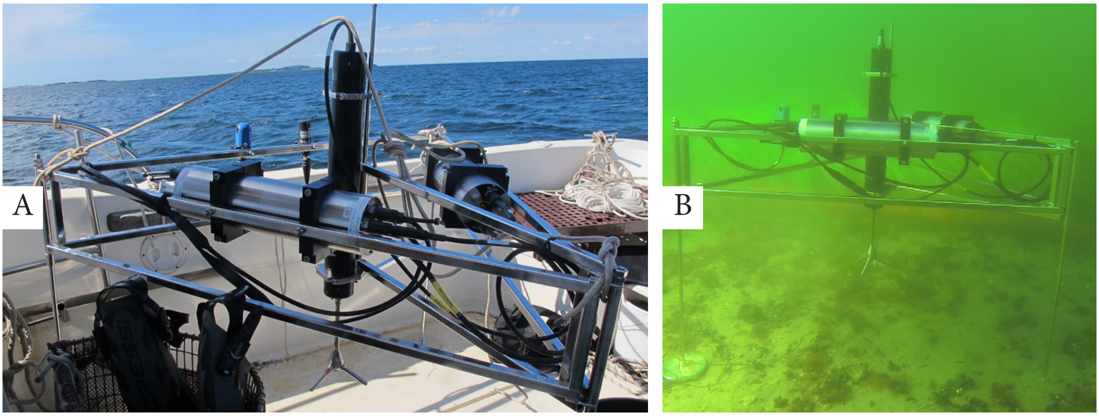


Figure 11. The Unisense openwater data logger ready for deployment (A). The logger on the on shore side of the seagrass mat (the mat can be seen in the back ground) (B). Photos National Museum of Denmark.

modern samples of wood were placed into the site so that their deterioration processes could be examined over time.

Testing of the open water datalogger

In connection with the trialling of the artificial seagrass the open water datalogger was to be placed on one of the mats near Tudse Hage. The idea was to log data over two days on the shoreward side of the mat and then move it to the off shore side. The hypothesis being that there may be more current on the off shore side due to the greater fetch from the Great Belt and in this way it may be possible to see if the seagrass was actually reducing any eventual currents and thus prevent any resultant

Figure 12. Test pit area where the vibracorer and in situ spear/profiler were trialled and where wood samples were taken for analysis. Photo National Museum of Denmark.

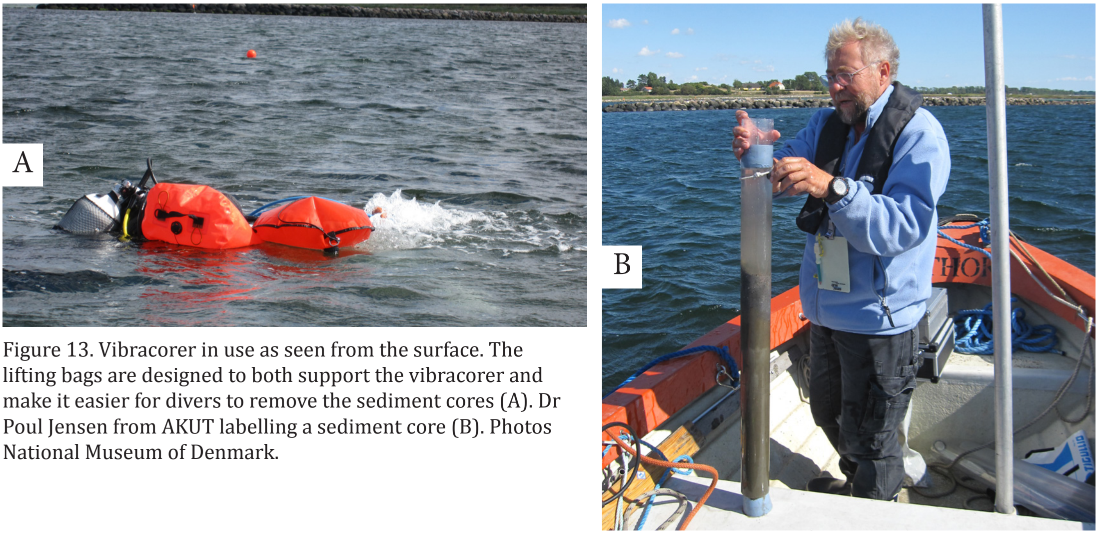


Figure 13. Vibracorer in use as seen from the surface. The lifting bags are designed to both support the vibracorer and make it easier for divers to remove the sediment cores (A). Dr Poul Jensen from AKUT labelling a sediment core (B). Photos National Museum of Denmark.

scouring of sediment. The logger was assembled in the harbour of Skælskør and transported onto site using a small vessel (6.2 metres). Although relatively large and heavy the logger was easily lowered by two people onto the seabed (Figure 11). A single diver was then able to position it in the correct orientation on the seabed and on the onshore side of the mat. Following logging for two days the logger was moved to the opposite side of the seagrass mat (off shore), using a diver on the seabed and support on the surface. CTD and current data were successfully collected and are currently undergoing post processing. The system will be trialled further in the coming year of the project.

The test area in Tudse Hage

A 1 × 1 metre test pit which had been previously excavated and re-buried as part of the Viking Ship Museum's investigations on the site between 2009 – 11 was selected as the test area (Figure 12). This pit had yielded a ca 50 cm profile of sand / gravel and organic gytjja with numerous fragments of wood (both worked and natural) overlying the natural clay and provided the perfect area to test the vibracorer and in situ spear / profiler.

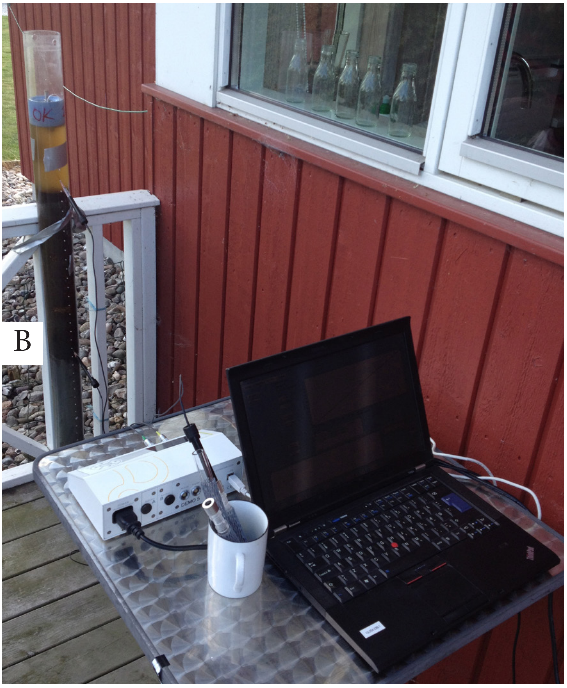
The Vibracoring system

The Vibracorer was used to take sediment cores from around the edge of the test pit. Locations ca 50 cm from the edge of the pit were selected and three cores from the southern, eastern and western edge taken. The shallow water of the site (ca. 2 metres) made working with the system slightly challenging as the weight of the device is designed to be supported by lifting bags (Figure 13a). Nevertheless, the cores were quickly taken (ca. 10 minutes per core) (Figure 13b) and the experience of working on an actual site and in shallow water gave rise to numerous improvements to the system, which will be worked on in the coming months. The cores were taken back on land and profiles of dissolved oxygen, pH, redox potential and sulphide were taken using Unisense's standard laboratory sensors (Figure 14a,b).

In situ spear / sediment profiler

Measurement of environmental parameters within cores, either using microsensors or from extracted pore water, is cur-

Figure 14. Dr Mikkel Holmen Andersen (Unisense) and Anne Marie Eriksen (National Museum of Denmark) measuring sediment profile parameters in the cores (A). Set up for measuring profiles. The plastic core tubes had silicone filled holes drilled into them every 5 cm, enabling a microsensor to be passed through and the parameters measured (B). Photos National Museum of Denmark.



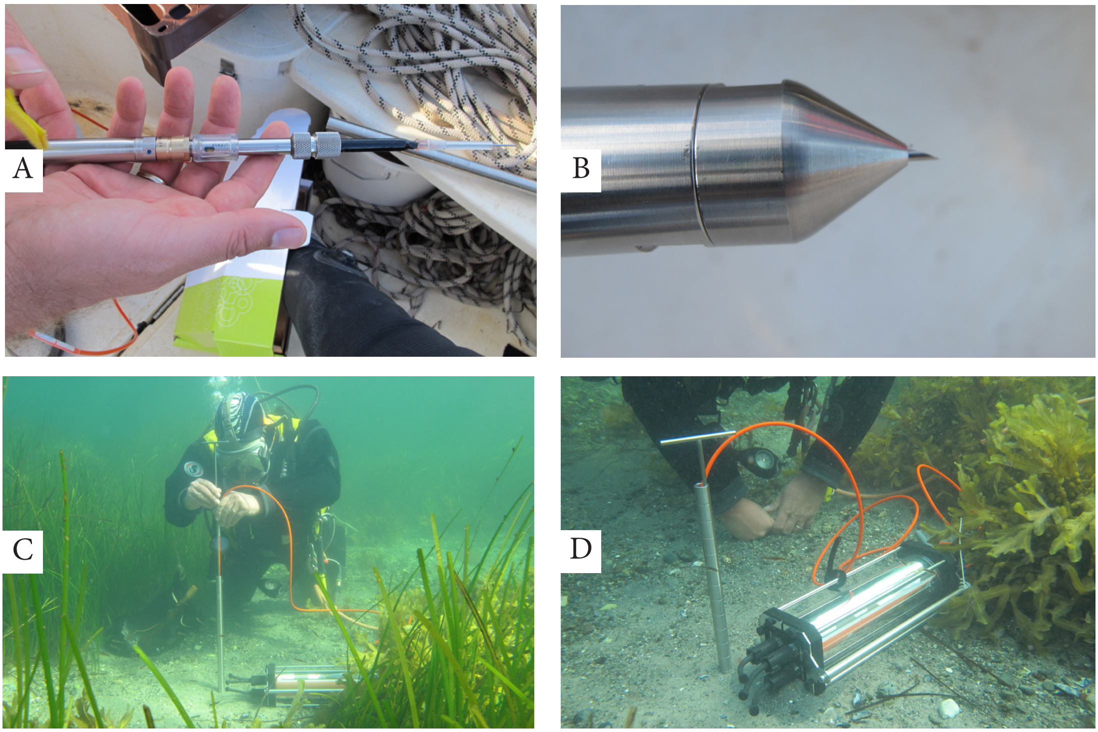
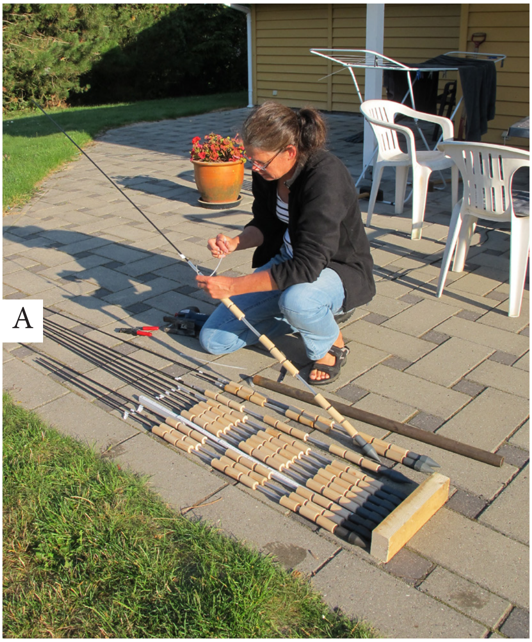


Figure 15. The microsensor with hypodermic needle which is passed into the metal spear and passes through the septum into the sediment (A). End of the spear with the hypodermic needle of the microsensor passing through (B). Inserting the microsensor into the spear (C). Waiting for the sensor to stabilise (D). Photos Viking Ship Museum.



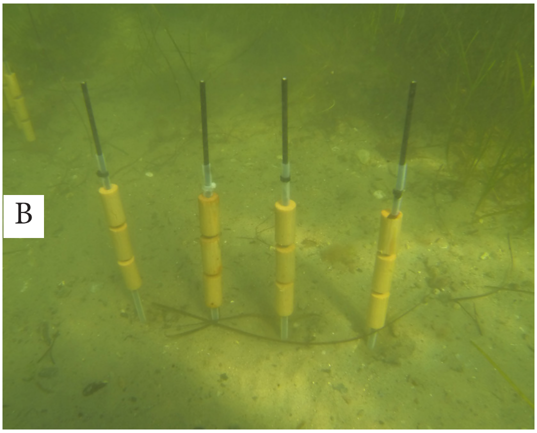


Figure 16. Dr Charlotte Björdal from the University of Gothenburg preparing modern wood samples (A). On each kebab there are two sets of samples that are buried within the sediment and one set of samples exposed to the open seawater as a negative control. (B). Photos National Museum of Denmark.

rently the most frequently used method for analysing environmental parameters within sediment. However, it is advantageous if these parameters could also be measured in situ. The in situ profiler system was trialled in two areas adjacent to where the cores had been taken in order to compare and contrast the methods and in this way validate both methods. In this instance only sulphide microsensors were used as the main aim of this trial was to test the use of the equipment. The first impressions of the system were such 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 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.

Wood Deterioration

To supplement the environmental monitoring aspects of the project wood samples were taken from the discrete layers of the test pit; wood overlying the natural clay substrate; wood within the gyttja, wood overlying the gyttja and below the mobile sand / gravel layer and also currently exposed lying on the seabed. Dr Charlotte Björdal of the University of Gothenburg is currently assessing these samples with the aid of microscopic techniques in order to look at the state of preservation of the wood and importantly ascertain what organisms have caused the deterioration. This will be correlated with the results of the environmental monitoring and future laboratory microcosm tests to look at the turnover of organic archaeological materials in waterlogged environments.

In order to gain more information on the actual deterioration of wood a

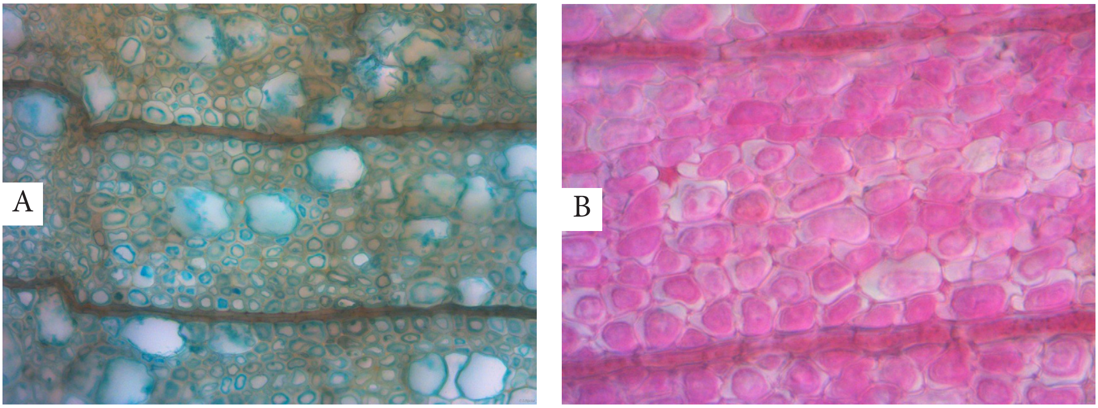


Figure 17. Micrographs showing a cross section of hazel (Corylus sp.) with total decay of the secondary cell wall. Degradation is caused by erosion bacteria known to degrade wood in low oxygen environments. The secondary cell wall is transformed to a residual material detached from the compound middle lamella visualised as a loose material in the lumen. Remaining skeleton / network that provides the wood its physical integrity is the lignin rich middle lamella. The wood sample (a tiny branch) was found in the upper layer of the sediment at Tudse Hage. Photos: University of Gothenburg.

series of modern pine samples were placed on site using a "kebab" system (Figure 16). This entailed threading small cylinders of fresh pine wood onto a carbon fibre rod at different depths down to ca 50 cm, with a spear mounted on the end and pressing them into the site using the vibracoring system. These samples will be examined over the life time of the project and it is hoped in the future to better understand the deterioration and preservation of wood in waterlogged / marine environments.

Future work

Following the successful preliminary trials of the various concept devices much has been learned. Refinements of the equipment will be made over the Winter in preparation for further trials on the sites in the project when final proofs of concept are ready. The sediment cores taken from the site will undergo further analysis and in particular be incorporated in a series of in vitro microcosm studies whereby the rates of turnover of organic material and wood deterioration in particular in different sediment types will be examined under controlled conditions in the laboratory. The results of all these developments and the implications of the results in terms of the assessment of the marine environment and sediments on the preservation of archaeological materials will be synthesised into the Guidelines to be prepared towards the end of the project in 2015.

David Gregory, Anne Marie Eriksen,
Mikkel Holmen Andersen,
Robert Fløng Pedersen,
Poul Jensen and
Charlotte Björdal

Assessment of the state of preservation of waterlogged archaeological wood.

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. Even when buried in the seabed micororganisms will still cause deterioration of archaeological materials and, in the case of wood, 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 is being developed. This will be based on research and development work which has been on going by the National Museum of Denmark and AKUT. The prototype will be based on the non-destructive determination of the density of the wood. The net effect of microbial 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.

Although other commercial instruments such as the Pilodyn (Figure 18d) are available to assess the strength / density properties and deterioration of wood these instruments tend to be sensitive to wood species, depth of measurement and the direction of penetration relative to the growth rings of the wood. Therefore they do not provide consistent and absolute data about the wood examined, furthermore they cannot all be used underwater (in situ).

The overall goal of the project is to develop a proof of concept for an underwater diver held system for measuring the state of preservation of wood quantitatively. In the first year of the project a laboratory based stand (Figure 18a,b) has been developed to check the feasibility of the proposed device. This has been able to characterise fresh and archaeological wood recording profiles down to a depth of 10 cm from the surface of the wood. The Lab stand electronically transfers corresponding data of depth and strength of the wood to a computer. These data are transformed into a density profile of the wood, by means of physical computerised models and standard curves for wood (Figure 18c).

Based on the laboratory model, AKUT will manufacture a handheld wood tester, which will be tested on archaeological wood samples provided by the National Museum of Denmark and analysed by the National Museum of Denmark and the University of Gothenburg. Following this the wood tester will be developed in order to be used underwater.

Robert Fløng Pedersen, Poul Jensen and David Gregory

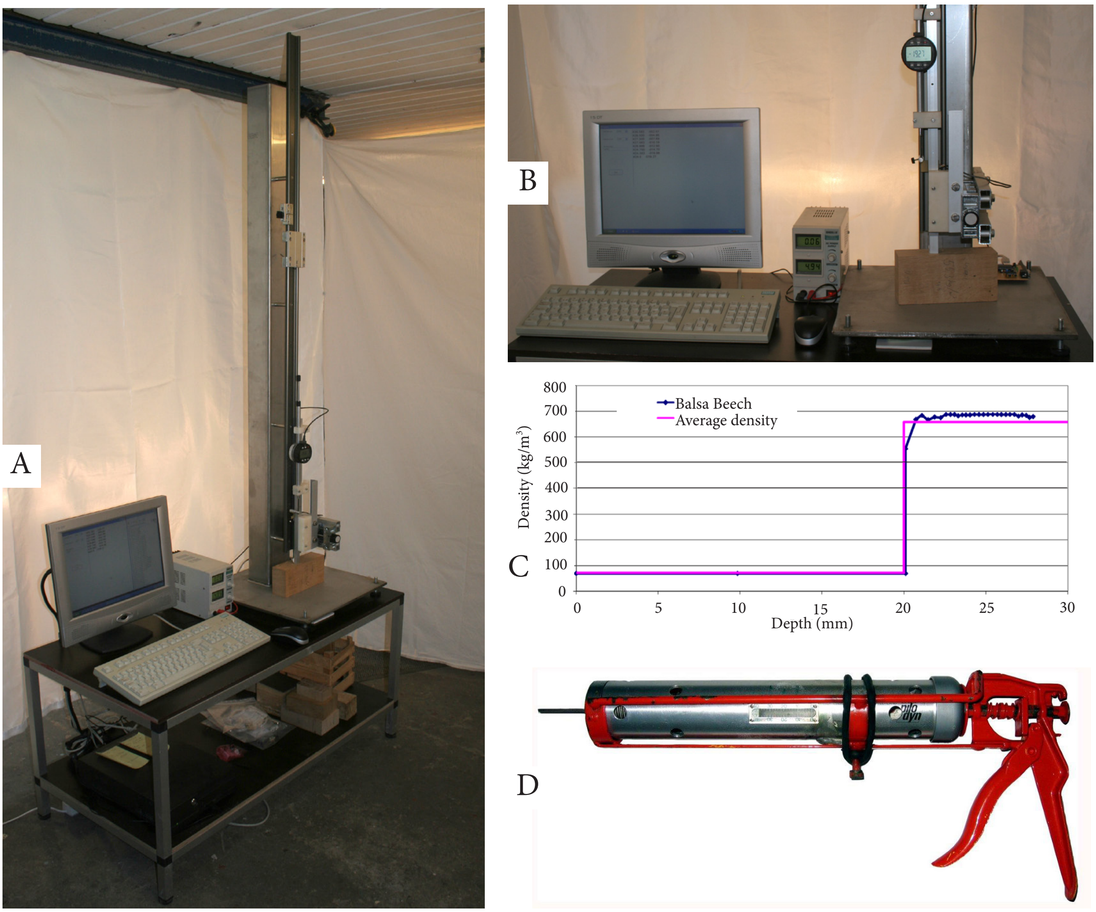


Figure 18. Lab stand with computer, sensors measuring depth of penetration and energy applied to the needle, plus hard and soft ware for collecting data (A,B). Density gradient for laminated balsa and beech wood (C). photos AKUT. Pilodyn (D) photo National Museum of Denmark.

WP5

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 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. The Work Pacakge draws upon the extensive excavation and lifting experience of the Viking Ship Museum and the pioneering research into stabilising and consolidating archaeological remains underwater of the Istituto Superiore per la Conservazione ed il Restauro (ISCR) and National Museum of Denmark in order to develop best practice methods.

Improved techniques to consolidate sediment for block lifting.
Two methods will be tested to enable the consolidation of sediments: 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.

Development of methods for block-lifting of fragile organic artefacts.
Consolidation of sediments is a prerequisite to block lifting. Following on from the experience gained above, a system to block lift consolidated sediments containing organic artefacts will be developed. Based upon previous experience from earlier attempts at raising complex and fragile organic artefacts (log boats, fish traps) a new type of lifting equipment will be developed which will consist of a complete unit which ensures that artefacts / sediment sections can be raised as a complete unit without having to be cut into smaller fragments. Furthermore it will be designed so that excavation can take place in a controlled manner and subsequently be completely secure during the raising, transport and subsequent excavation in the laboratory.

Results September 2012 – October 2013

Improved techniques to consolidate sediment for block lifting.
Istituto Superiore per la Conservazione

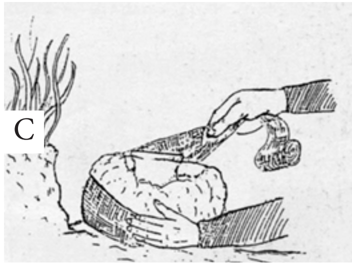


Figure 19. Diving conservators using the product to recover a wooden fragile archaeological object (A). 3M™ Scotchcast ™ Plus Casting Tape (B). The cast stabilises the sediment around the find together with archaeological object (C). Photos ISCR.

ed il Restauro (ISCR) and The National Museum have been focusing upon the use of new materials and freezing of sediments in order to assess the feasibility of using these methods to stabilise and raise fragile organic artifacts.

New materials to stabilise fragile organic artefacts and facilitate their raising and transport to conservation facilities.

Laboratory and field experiments have taken place at the ISCR Physics Laboratory, and in the lake of Bolsena, during the excavation of the village called ”Gran Carro” generally dated to the Iron Age, and in the underwater site of Baiae. The participants from the ISCR team have included Dr Barbara Davidde director of the SASMAP’s ISCR activities, Dr. Marco Ciabattoni, technician of Physics Laboratory; Dr. Giancarlo Sidoti, chemist; Dr. Giulia Galotta, biologist, Gabriele Gomez de Ayala, scientific researcher and Riccardo Mancinelli, restorer.

The first product tested was 3M™ Scotchcast ™ Plus Casting Tape (Figure 19). 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, in contact with water or simply exposed to moist air, hardens, enabling immobilisation of fragile artefacts yet being extremely lightweight and durable. In the ISCR Physics Laboratory the 3M™ Scotchcast ™ Plus Casting Tape was tested in a tank with sea water. Then its effectiveness was validated underwater in the village called ”Gran Carro”. The tests took place underwater with the diving conservators reporting the ease of use of the product to recover a wooden fragile archaeological object. The 3M™ Scotchcast ™ Plus Casting Tape is environmentally friendly and it is easily removed post lifting (if it is in direct contact with the archaeological find too). The second product tested, first in the ISCR Physics Laboratory and after in the ”Gran Carro” Village was a sheet of carbon fibre, previously treated with cured

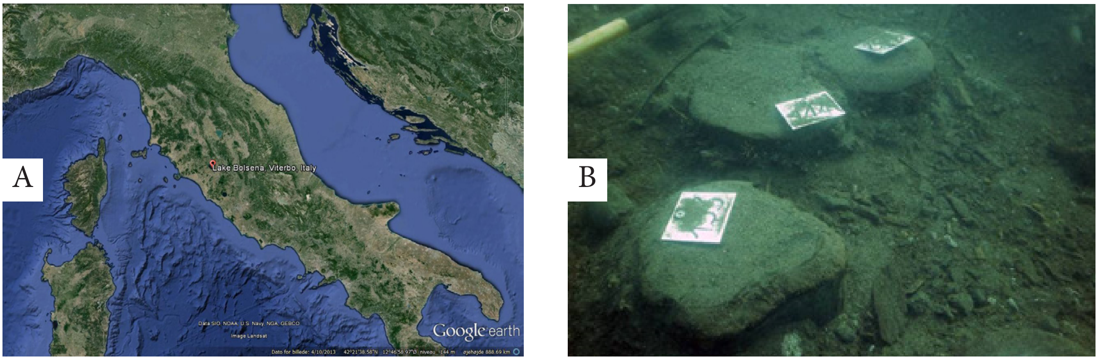


Figure 20. The lake of Bolsena in Latium region, in the centre of Italy not far from Viterbo and Tuscany region (A). Particular of the pole of the pile-dwelling (B) Photo ISCR.

epoxy-resin, in a plastic bag vacuum. The excavation of the "Gran Carro" Village (Figure 20a) is coordinated by the Soprintendenza per i Beni Archeologici dell'Etruria Meridionale, under the direction of the archaeologist Patrizia Petitti and we would like to thank them for hosting us and our experimentation. The lake of Bolsena is in Latium region, in the centre of Italy not far from Viterbo and Tuscany region.

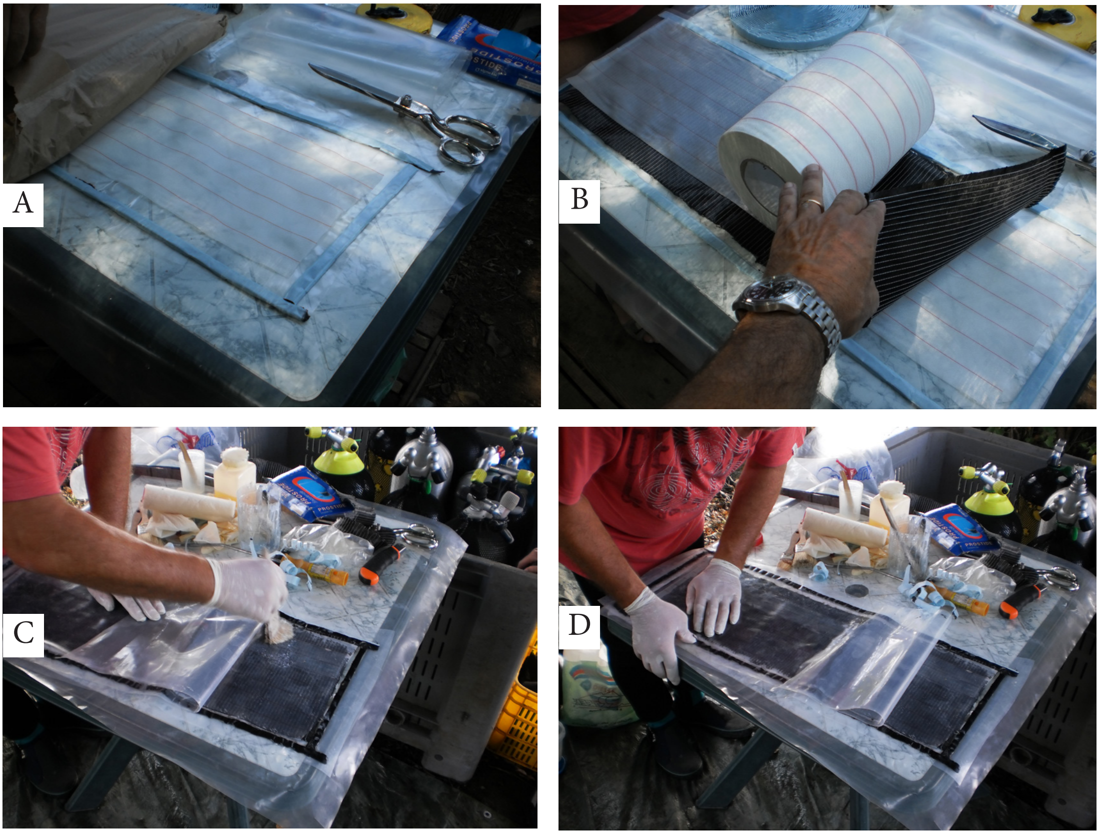
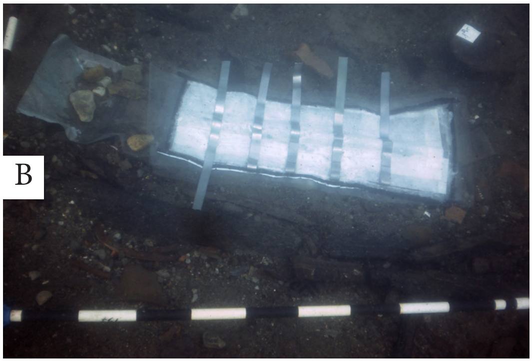


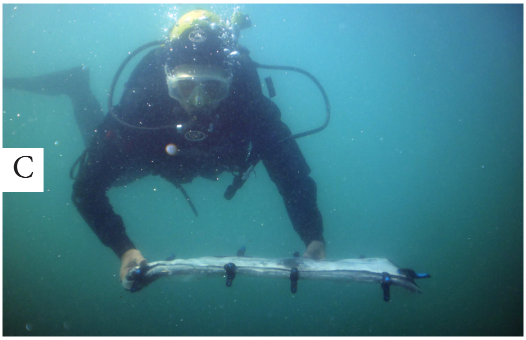
Figure 21. A polyethylene vacuum waterproof bag was first shaped in the form of the artefact to be recovered. The vacuum and waterproof are obtained by adherence of perimetral strips. Before the closure of the strips we had inserted a multilayer composed by Peel Ply tissue (A). Carbon sheet and Peel Ply tissue (B). Inside the bag an epoxy resin was applied over the multilayer (C) and then the bag was closed (D). Photos ISCR.

The use of the carbon fibre is described visually on the previous page:

1. A polyethylene vacuum waterproof bag was first shaped in the form of the artefact to be recovered. The vacuum and waterproof are obtained by adherence of perimetral strips. Before the closure of the strips we had inserted a multilayer composed by Peel Ply tissue (Figure 21a), carbon sheet and Peel Ply tissue (Figure 21b).
2. Inside the bag an epoxy resin was applied over the multilayer (Figure 21c) and then the bag was closed (Figure 21d).

This is basically a technique of manual lamination (wet layup) which allows us to obtain products in full laminate (single skin), already widely used in ship-building. The two mats in carbon fabric thus obtained 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 slings in lead that have also been used to weight the mat so as to ensure it remained on the lake bottom and adhered to the artefact (Figure 22a,b). After waiting for the resin to harden (about 12 hours) the upper mat and the lower mat were placed with plastic





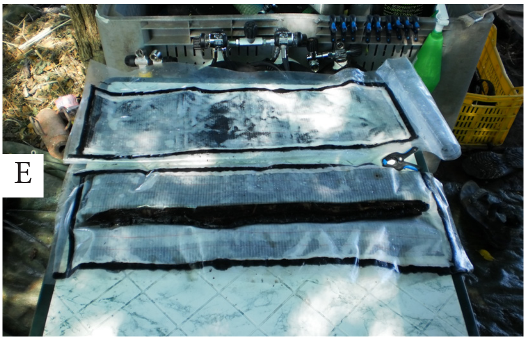


Figure 22. The upper mat was made to adhere to the pole with the aid of slings in lead that have also been used to weight the mat so as to ensure it remained on the lake bottom and adhered to the artefact (A,B). After waiting for the resin to harden the upper mat and the lower mat were placed with plastic clamps and brought to the surface (C,D,E). Photos ISCR

clamps and brought to the surface (Figure 22c,d,e). The carbon fibre fabric, impregnated with epoxy resin, is a real shell of protection 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 include:

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). They are polysaccharides of high molecular weight (including Xanthan, Guar, Agar) and can absorb and retain extremely large amounts of liquid. The results of these tests will be presented in the future.

Effects of freezing sediments on organic artefacts and the feasibility of block lifting sediments

To look at the effects of block lifting through freezing of sediment, an experiment was carried out at the laboratory of the School of Conservation in Copenhagen. The aim was firstly to see if fragile wooden artefacts would be damaged by the shock of freezing. Second, if there was no damage to freeze them in different sediment types (sand and gyttja) to see what effect this had on the process and if there were any significant weight changes.

Effects of Freezing

To assess the state of preservation of the wooden artefact before and after freezing, a small ca. 2000 year old, heavily degraded spear shaft (Figure 23a) was cut into six pieces, where one was used to examine the density (81 kg/m^3) of the wood and used as a control sample for scanning electron microscopy. The five other pieces were treated as shown in figure 23b and table 1.

After the pieces were weighed liquid nitrogen was poured over the five different setups (Figure 24). As soon as the "smoke" had cleared they were weighed again. As seen in table 1 only

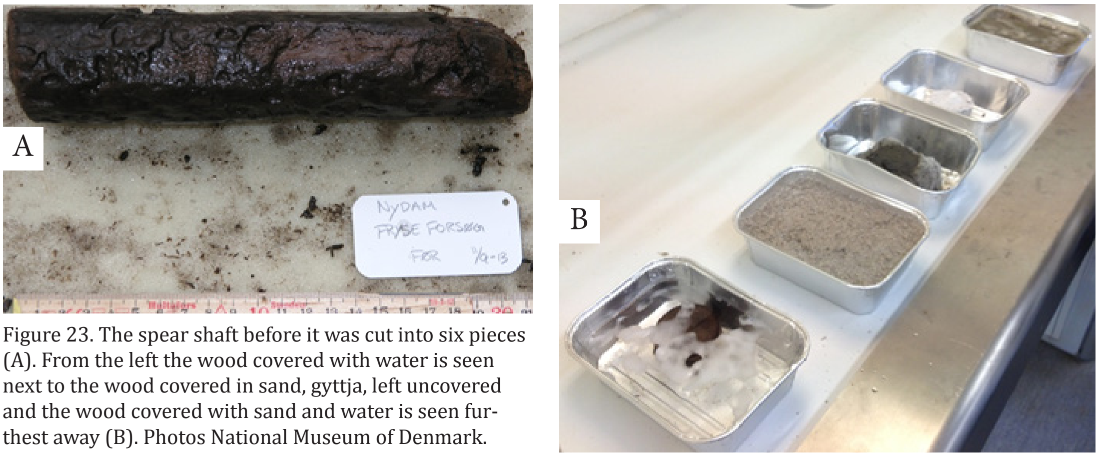


Figure 23. The spear shaft before it was cut into six pieces (A). From the left the wood covered with water is seen next to the wood covered in sand, gyttja, left uncovered and the wood covered with sand and water is seen furthest away (B). Photos National Museum of Denmark.

Figure 24. Liquid nitrogen is poured onto the different setups. Photo National Museum of Denmark

Table 1. The pieces were treated in the five ways seen here and was weighed before and after liquid nitrogen was poured onto them

	Weight before (g)	Weight after (g)
Without water	48.75	48.38
With water	337.72	334.26
With gyttja	184.12	183.27
With sand	414.31	412.61
With sand and water	621.70	620.10

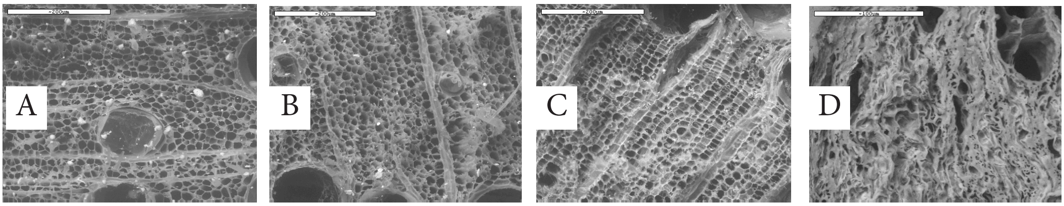


Figure 25. SEM of the non-frozen wood (A). SEM of the wood covered with gyttja (B). SEM of the wood covered with sand and water (C). SEM of ovendried wood (D). Photos National Museum of Denmark.

minor differences in weight were noticed from before and after the freezing treatment. To evaluate the possible damaging effect from the freezing on the artefacts, SEM microscopy was carried out on the six pieces. No damage, collapse of cells, was seen after the freezing treatment (Figure 25). In figure 25d it is possible to see how a piece of waterlogged wood in this state of preservation looks in the SEM after uncontrolled drying. These results show that the weight of the frozen sediment is almost the same as in an unfrozen condition and that the wooden artefacts are not notably damaged from the freezing. The future potential of this method will be evaluated when all methods within the Work Package are assessed.

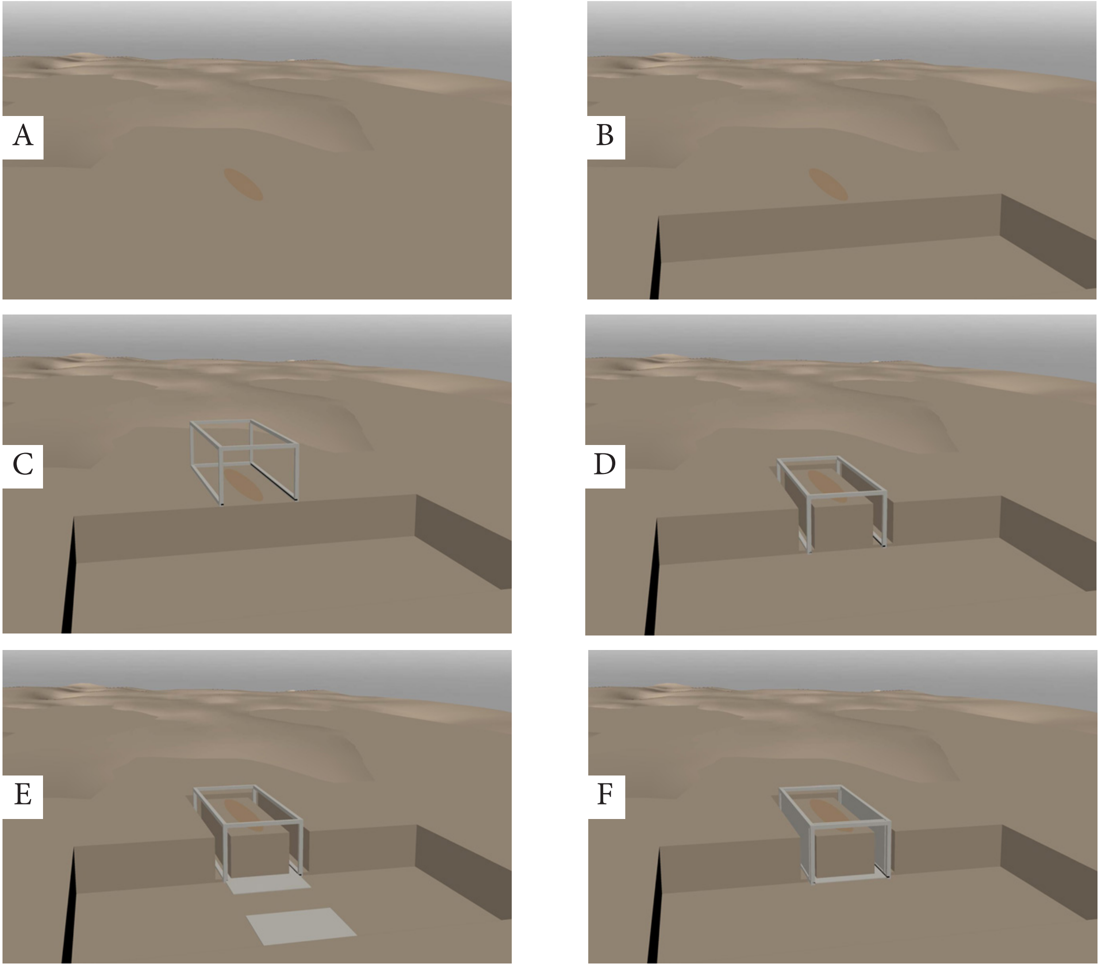
Development of methods for block-lifting of fragile organic artefacts.

A system to block lift consolidated sediments containing organic artefacts will be developed. Based upon previous experience from earlier attempts at raising complex and fragile organic artefacts (log boats, fish traps) a new type of lifting equipment will be developed which will consist of a complete unit which ensures that artefacts / sediment sections can be raised as a complete unit without having to be cut into smaller fragments. Furthermore it will be designed so that excavation can take place in a controlled manner and subsequently be completely secure during the raising, transport and following excavation in the laboratory. The equipment will be:

- Modular so that it can be expanded / reduced to take account of different sized artefacts which can range from log boats (which can be 10 × 0.60 metres) to typical excavation sized areas (1.5 × 1.5 metres).

Currently the Viking Ship Museum are developing a model of a lifting system that will be trialled in the near future, the concept is illustrated below.

Barbara Davidde, Anne Marie Eriksen and Jørgen Dencker



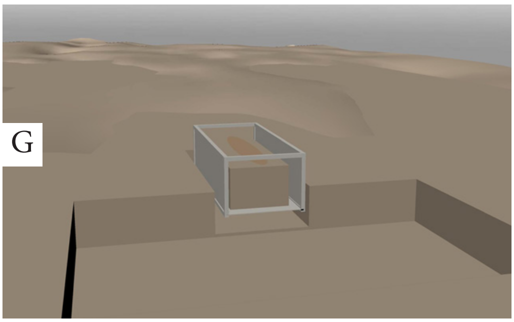


Figure 26. Hypothetical Log boat found on the seabed (A). Excavation of the area surrounding the log boat (B). When the baulk of the excavation area is reached a lifting frame is placed over the log boat (C). The frame is excavated down through the sediment so it surrounds the log boat (D). Metal plates are then pressed into the metal frame in order to support the sediment containing the log boat (E). Vertical metal plates are then placed into the sides of the frames to completely encapsulate the sediment (F). Finally the frame containing the sediment and log boat is raised to the surface as a complete unit where upon the log boat can be excavated under controlled conditions at the surface (G). Drawings by Morten Johansen.

Introduction

The aims for Work Package 6 are:

- To develop assess and monitor the applicability of artificial seagrass to the in- situ protection of underwater archaeological sites with wooden and stone remains.
- To evaluate the durability of manmade materials used for the protection of underwater archaeological sites

General Introduction to the use of Artificial Seagrass Mats

Over the past 30 years, Seabed Scour Control Systems (SSCS), one of the small companies (SMEs) involved in the SASMAP project, have become world leaders in the design and manufacture of specialised scour protection systems for the protection and stabilisation of subsea installations. In 1984 the company developed an artificial seagrass frond mat to harness the natural effects that create scour (erosion of the seabed) in order to produce a permanent, maintenance- free scour protection system. The mats were mainly used to protect pipelines against scour.

Figure 27. Diver inspecting an Artificial Seagrass Frond Mat. Photo Viking Ship Museum.

The original / standard frond mat is lowered to the seabed in a roll. After fixing one side with anchors, driven into the seabed, divers roll out the mat in the area to be protected and fix it in position with additional anchors. The plastic fronds, which float in the water column, effectively slow any currents running through them, thus reducing turbulence and hence erosion or scour, of the sediment. 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.

In terms of the SASMAP project, the company has been involved in marine archaeological projects over the past 10 years, with frond mats being trialled on sites in Denmark and the United Kingdom. It was through the collaboration on a wreck in Denmark (Haarbølle) that it was discussed about the possibility of developing a system more suitable for archaeological sites should the finances for a collaborative project arise. This is because the anchors used on the mats, although extremely effective at holding the mats on the seabed, may penetrate any underlying cultural heritage. To this end and in preparation for the SASMAP project, it was discussed whether a mutually beneficial development of the frond mats would both fit in with the research and development plans

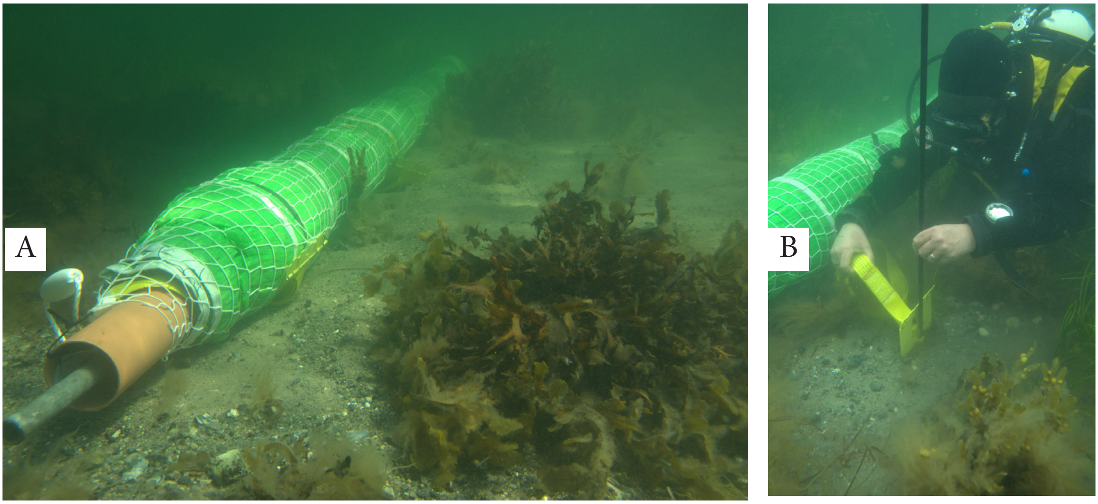


Figure 28. Rolled frond mat on the seabed (A). Positioning of anchor with spigot, ready for driving into the seabed (B). Photo Viking Ship Museum.

of SSCS and their archaeological use. SSCS were interested in developing a so called "Edge Weighted Frond Mat". This was a standard frond mat but instead of using anchors to fix it to the seabed it was held in place by a weighted apron. Deployment of these mats would also be different, with the use of a frame which could lower the mat to the seabed from the surface and both release the mat and the plastic seagrass fronds. Although these mats revolutionise their use and deployment for offshore industrial purposes, the large lifting capabilities required may be outside of the typical budgets available to marine archaeologists and conservators. It was thus decided to develop a third system within the SASMAP project which would entail the use of sand bags to weight and hold the edges of the mats down. Furthermore different frond lengths and various colours were also trialled to see what effect these had on protection from scour in shallow waters. Regardless of the combinations of frond size, colour, and anchoring or weighting methods, mats were 2.5 metres wide and 5 metres in length. The first year of the project has seen the development of the different mats and deployment on the three case study sites in the Netherlands, Italy and Denmark. What follows is a short summary of the installation of the different types of mats on these sites and preliminary monitoring of their effectiveness after 3-6 months deployment.

Burgzand Noord, The Netherlands

For years the Dutch Cultural Heritage Agency (RCE) has been working on the research and management of underwater cultural heritage. One of the focus areas of the RCE is the protection of archaeological sites for future generations. This principle is called in-situ preservation, and is also one the main points of the 2001 UNESCO Convention on the Protection of the Underwater Cultural Heritage.

For SASMAP, Work Package 6 partners joined to test the new in-situ preservation method, namely artificial seagrass, developed by SSCS. The RCE tested this method on the wrecksite

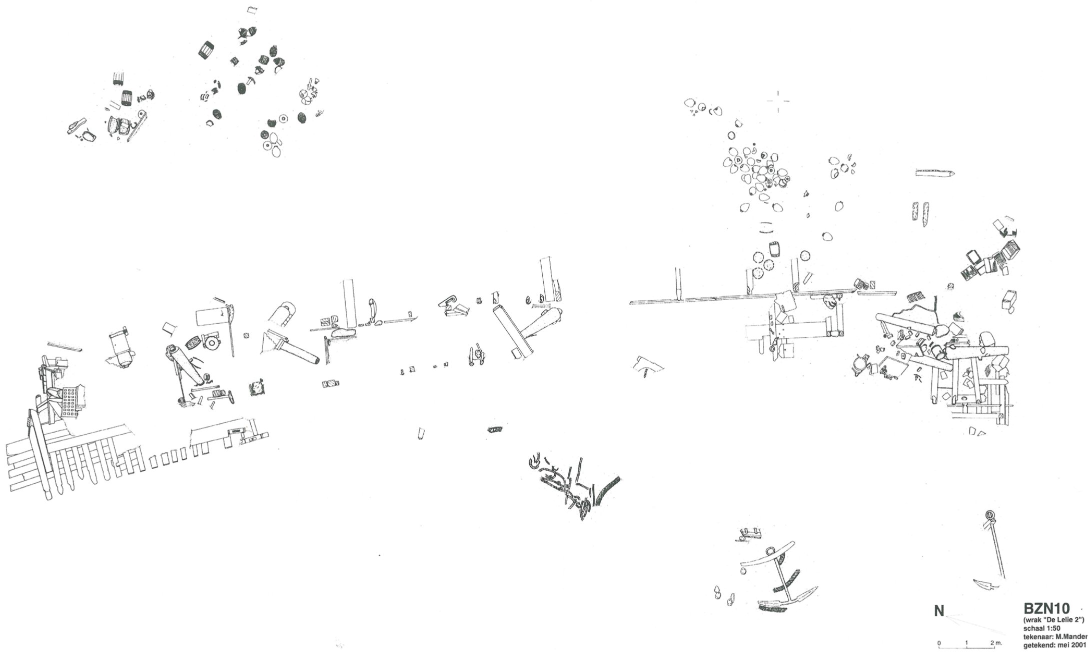


Figure 29. Siteplan of the BZN 10 wrecksite. Drawing by M.Manders/RCE

BZN10, a 17th century shipwreck which sank on the Texel Roads, east of the island Texel (Figure 29).

Wrecksite Burgzand Noord (BZN)

On this location, threatened by natural erosion, ships anchored between 1500-1800 ready for transport of goods at the Amsterdam harbour. Despite the shelter the island provided from Northwest winds, hundreds of ships sank. One of these was the merchant ship BZN10, which carried Iberian jars, slate, barrels of grapes and anchovy, and several small objects. Although the wreck has been physically protected for over 10 years, additional methods may be necessary to preserve if for future generations.

Protective measures

The current protection comprises a cover with scaffolding mesh, which

Figure 30. Preparation of the artificial seagrass on the ship. Photo RCE Maritime Programme (A). The artificial seagrass is deployed on the wreck. Photo RCE Maritime Programme/ Paul Voorthuis (B).

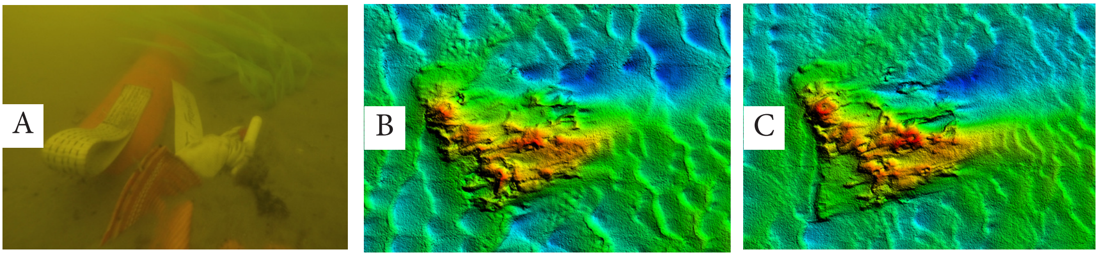


Figure 31. After only 6 days the mats have caught some sediment. Photo RCE Maritime Programme (A). Monitoring from 2012, without the seagrass (B). Monitoring from July 2013 shows that the effects of the mats are already clearly visible (left bottom corner) (C). Image by Periplus Archeomare B.V.

catches sand. From the annual (2001-2013) monitoring of Texel Roads using multibeam sonar to reveal erosion or sedimentation, it was clear that a scour gully was threatening the archaeological site. Therefore new measures were necessary, making this a good location to test the artificial seagrass in these highly dynamic circumstances (strong currents, lots of sediment in the sea).

After a few days of preparation, on June 12th, four 2.5 × 5 metre mats were deployed on the BZN10 wreck. Frond lengths of 62.5 cm and 125 cm were used in order to find the most effective protection. The mats were placed on the south east corner of the wreck site in the order of a short frond mat, then two long frond ones, and finally a short one. By using the deployment frame developed by SSCS, the mats were placed in less than two hours in rough conditions and poor visibility.

First results

Six days later a first monitoring was carried out, by diving the site again. This revealed that the fronds had already caught a lot of sand. The short fronds seemed to work better, as they remained longer upright thus catching sediment. The longer fronds had a tendency to quickly lie flat because of the strong current, thereby losing their sediment catching-effect.

A second effect was that, because the fronds slow down the current, sediment had been caught up to two metres behind the mats. Because the layer of sediment caught by the fronds is dynamic (where sand is eroded, the fronds rise again, and start catching sediment), it could be a good method to protect the scaffolding mesh itself, which can easily be damaged. Monitoring over the next year will reveal if this effect persists.

First multibeam sonar results

After a month the location was monitored again using multibeam sonar. This confirmed our first impressions that not only had the mats themselves trapped sediment, but behind the mats there was also sedimentation (Figure 31).

Tudse Hage, Denmark

Four frond mats were placed near the

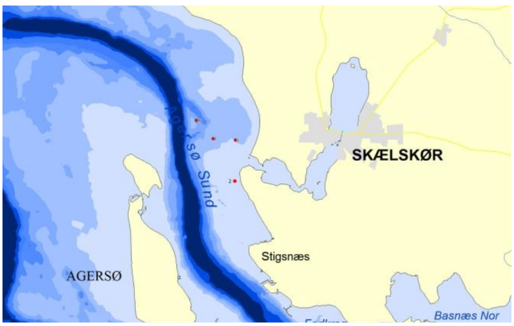


Figure 32. Locations of the four frond mats deployed on the site of Tudse Hage. Drawing Viking Ship Museum.

Danish site of Tudse Hage, a submerged Mesolithic site in approximately 2 metres of water, off the west coast of Sjaelland (Figure 32). The mats were not to be placed directly on the site, in order to be certain that the experiment did not negatively affect any archaeology in the area. Originally it was planned to use three standard mats with anchors for fixing and one edge weighted frond mat. All mats were green as opposed to the standard orange coloured. The mats were to be placed in four different areas. Just outside the area where archaeological remains are found (in ca. 2 metres water depth), to see if it could prevent and protect the areas closer to shore where cultural heritage was known to lie. As the standard frond size is 1.2 metres it was deemed that these may come too near to the water's surface (the area is frequently visited by canoeists, fishermen etc.) and as with the Italian site green fronds of 0.8 metres were used. The three remaining mats were to be placed at 5, 7.5 and 10 metres water depth. The mats at 5 and 7.5 metres depths were standard mats with 8 anchors and 1.2 metre green fronds. The mat to be placed at 10 metres was to be an edge weighted frond mat, again with 1.2 metre green fronds. Mats were generally oriented with the long edge (i.e 5 metres) in a north-easterly / south-westerly orientation in order to maximise the chance of catching sediment and dissipating currents running in from the Great Belt. Initial trials were started in May 2013 (25 - 29th May) with the shallow water 2.5 metres mat. Normally, a hydraulic jackhammer is used to hammer the anchors into the seabed. Due to the requirements of large road compressors to do this, it was decided to trial the vibracoring system being developed in Work Package 3, together with a special spigot mounted to see if the anchors could be vibrated into the seabed – a synergy between the work packages which potentially may have made deployment of mats much easier.

The work was unfortunately hampered in the first instance by the initial placement of the mat in an area with a relatively thin layer of sediment overlying the compact clay rich natural subsurface. Because the anchors need to be 80 – 100 cm beneath the seabed in order to firmly anchor the mats, it was decided to move the mat. Furthermore the vibracorer, which has not been designed as a jack hammer, did not transfer enough energy to vibrate the large anchors into the seabed. It was therefore decided to move the mat to an area where the sediment overlying the natural substrate was ca 1 metre thick, yet still well away from the former coastline and outside the area of previous excavations. The original planned position was a clear area, but the only suitable location found was among scattered beds of natural seagrass, which had grown on the site in 2013. Finally an open area was located and a large 8 kg sledge hammer was used to hammer the anchors into the seabed – good experience had been gained with this method on the Haarbølle wreck. Because the Haarbølle wreck lies in a sandy

Figure 33. Diver hammering a seagrass anchor into the seabed. Photo Viking Ship Museum.

seabed and the sediment of Tudse Hage is predominantly a thick organic gyttja, it took two divers, three hours to hammer the eight anchors into the seabed.

Based on this experience and the length of time taken on the most shallow site together with the number of diving cylinders required and with the risk of bad weather hampering the operation, it was decided to re-think deployment of the mats. After discussion with SSCS it was decided to use edge weighted anchor mats for the 5 and 7.5 metres areas – the original plan was to use such a mat on the 10 metres area.

The mats were rapidly prepared and shipped to the warehouse facilities of JD-Contractor A/S in Kalundborg, Denmark (http://www.jydskdyk.dk/) who had very kindly and generously offered to support the project with a jackup vessel, *Marcos*, that had a crane and crew helping deploy the Edge Weighted mats in the desired positions and was on its way from Nyborg to another job via Tudse Hage.

The logistics came together with the mats being loaded onto the ship and the frame being transported to Nyborg to meet it. On Sunday the 7th July, divers and a photographer from the Viking Ship Museum, along with Alan Hall from SSCS met in Skælskør harbour and sailed out to meet the *Marcos*. In the meantime the crew of *Marcos* had assembled the frame with the first mat ready for deployment and following instructions from Alan the mat was lowered into the water to a depth of 3.7 metres. Divers from the Viking Ship museum followed and filmed the process under the water. The mat was moved into position by divers, positioned on the seabed and the safety net covering the plastic fronds released. The system, just as in The Netherlands, worked perfectly. Following this successful deployment *Marcos* moved to the next area (7.5 metres) and the process was repeated. On lowering this mat it was noticed that the webbing strops which the fronds are attached to were bowing. This was attributed to the edge weighted system not being fully taut. However, this was remedied by a diver stretching out the weighted bags at the edge of the mat – a relatively easy process for a single diver. Again the safety net and fronds were released without due concern. *Marcos* relocated again and the final mat was deployed in 10 metres

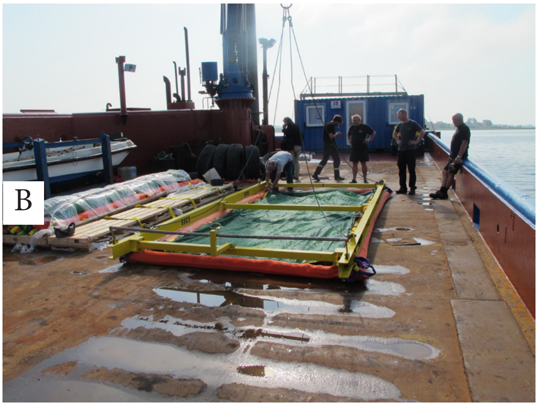


Figure 34. *Marcos*, used to deploy the Edge Weighted Frond Mats in Tudse Hage (A). Alan from SSCS makes final checks to the mat before deployment (B). Photo Viking Ship Museum.

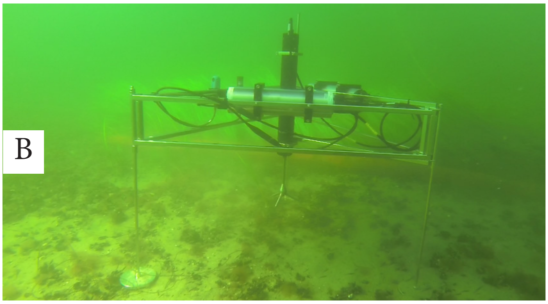


Figure 35. School of fish fry in and around the frond mat placed in 5 metres of water (A). Open water data logger developed by Unisense being trialled on the 5 metre deep frond mat (B). Photos National Museum of Denmark.

of water – again with no problems.

The final mat took 6 minutes to deploy from leaving the surface to the fronds being released. The total time spent deploying the three mats was approximately 3.5 hours and the general feeling, certainly from those who had sledge hammered the anchors of the first mat into the seabed was that the new design of mats and method of deployment was a lot easier than the conventional anchoring system. Following deployment the mats were surveyed using single beam echo sounder (SBES) at a close line spacing as a way of monitoring any changes in the seabed topography and to see if there is any deposition of sediment on the mats and development of any scour pits around the mats.

Monitoring

Following the deployment of the mats and in connection with the work carried out in Work Package 3, the mats were re-visited in August (20-24th) and survey carried out using the SBES again. The mats were accessed by divers from the Viking Ship and National Museums with video and still images being taken. The post- processing of the SBES data is pending and the use of the method will be validated prior to the next phase of monitoring in the winter of 2013-2014. Although there was no sign of sediment accretion on any of the mats (there had not been any particularly heavy weather in the time since deployment) what was particularly interesting to note on all mats and particularly those at 10 and 7.5 metres, where there was no surrounding seagrass or vegetation in the area, was that they were a haven for various fish and fish fry and it certainly appeared that the mats were acting either as a nursery or an area of protection for these fish. Species of fish present were slightly different at the various depths and it is being considered whether more work should be done on classifying the types of fish present.

Further to the monitoring and in connection with WP3, the open water datalogger being developed was placed on the 5 metres mat (Figure 35b). This was situated on the onshore and offshore sides of the long edge of the mat and logged for two days in each location. The logger records CTD data (conductivity, temperature and depth) and current strength and direction. In this way it was intended both to trial the logger but also gain information about the environment around the 5 metres mat.

Baiae Deployment, Naples (Italy)

The artificial seagrass mats were placed in the Underwater Archaeological Park of Baiae, Naples from June 26th 2013 to July 6th 2013.

The project's aims are:

1. to reduce or stop the erosion process that is currently threatening the perimeter wall of the *viridarium* of the Villa dei Pisoni. This phenomenon has caused the exposure of the wood planks of the foundations of the wall, that now are at risk of loss because of biological attack (*Terredo navalis*);
2. to evaluate the effects of the artificial seagrass on the biology in the Villa con ingresso a protiro.

In order to install the artificial seagrass the Istituto Superiore per la Conservazione ed il Restauro (ISCR) Team (Dr Barbara Davidde director of the SASMAP's ISCR activities, the architect Filomena Lucci and the scientific researcher Gabriele Gomez de Ayala) was joined by SASMAP partners Dr David Gregory from The National Museum of Denmark, Mr Jørgen Dencker from The Viking Ship Museum and Mr. Brian Smith and Mr Alan Hall from Seabed Scour Control Systems. Dr Paolo Caputo, director of the MPA of Baiae (Soprintendenza Speciale per i Beni

Figure 36. The archaeological site of Baiae (Naples).

Archeologici di Napoli e Pompei) and the underwater restorer Salvatore Carandente (SSBANP) also participated and we want to thank them for their cooperation.

The archaeological site of Baiae (Naples)

Baiae was a famous seaside town much prized in antiquity for its temperate climate, beautiful setting and the properties of its mineral waters that have been exploited since the second century B.C. It was the most popular resort among the Roman aristocracy and the Imperial family up until the end of the fourth century A.D., when a bradyseism i.e., gradual changes in level of the coast in relation to the sea level that have been positive and negative, caused the submersion of the city. Environmental problems in this area are related to a particular volcanic and deformational history. This coastal region has been characterised by periodic volcanic and hydrothermal activity and it has been subject to bradyseism. With the passing of millennia the original archaeological complex has been submerged and the archaeological remains are still underwater.

Today the remains of the luxurious maritime villas and imperial buildings, more modest houses, private thermae, tabernae, roads and warehouses and all the architectonic structures that characterise the cities of the Roman Age, lie underwater at a distance of up to 400 to 500 metres from the coast at a depth of 5-7 metres.

The interaction between natural processes and human activity has produced a marine environment characterised by a huge variety of natural habitats. For this reason in 2002 an Underwater Park, Marine Protected Area (MPA) was created covering around 176.6

hectares. The submerged area includes part of the territory of the ancient city of Baiae and *Portus Iulius*, comprising the Roman harbour and numerous constructions used as warehouses. Today, visitors to Baiae MPA can choose between a number of guided tours including the Villa con ingresso a protiro, the Villa of Pisoni (with mosaics, thermae and mansory), the Ninpheum of Punta Epitaffio (including copies of statues of the imperial families), the *Portus Iulius* and of "Secca Fumosa" (a series of 12 massive pillars recently recognised as the remains of the Thermae built in the sea by *Marcus Licinius Crassus Frugi* mentioned by Pliny and Pausanias). These tours are open to the diving public and to non-diving visitors that can visit on a boat fitted with a transparent keel.

Brief history of archaeological researches and restoration work

Topographic surveys of sunken Baiae started in 1959 thanks to an initiative by the archaeologists Nino Lamboglia and Amedeo Maturi. Works were interrupted in 1960 because of lack of funds and restarted in 1981 on the occasion of the Nimphaeum of Punta Epitaffio excavation, directed underwater by Piero Alfredo Gianfrotta. In the following years, Gianfrotta directed also a group of local researchers, including Gennaro Di Fraia, Nicolai Lombardo and Eduardo Scognamiglio, that started the ambitious topographical project of the area in the eighties and in the nineties. From 2003 this topographical project was restarted by ISCR in range of the project "Restoring underwater" with the GIS "Baia Sommersa". Some sectors of the archaeological sites (Villa Pisoni, Villa con ingresso a protiro, *Portus Iulius*, a room paved with *opus sectile* not far from Punta Epitaffio), have been restored by ISCR between 2003 and the date of writing.

The Villa dei Pisoni

The Villa dei Pisoni – property of the family *Calpurnii Pisones* – was built by *L. Calpurnius Piso Augur* between the end of the 1st century BC and the first century AD. Later it belonged to his son *Gaius Calpurnius Piso* who was one of the protagonists of the failed conspiracy against Nero. The villa was expropriated in 65 AD and became a property of the emperor; it underwent important restorations throughout the years. What remains and has been documented lies underwater at a depth of 6 metres and is the result of some restorations conducted in Hadrian Age (the perimeter wall of the *viridarium,* object of this SASMAP experimentation); restorations did not involve a fishpond and a small ditch built in the south-east of the courtyard where the pipe was located. The area is 181 × 230 metres and maximum depth about 6 metres and includes a wide rectangular courtyard in the *viridarium* (about 100 × 60 metres) with arcades on each side that are richly decorated with curvilinear niches framed in brickworked semi-columns.

Thermal plants are also located in this area, together with the villa's marine quarter – situated in the south of the courtyard

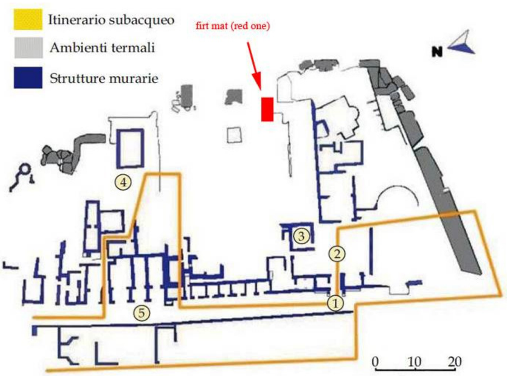


Figure 37. Map of Villa con ingresso a Protiro.

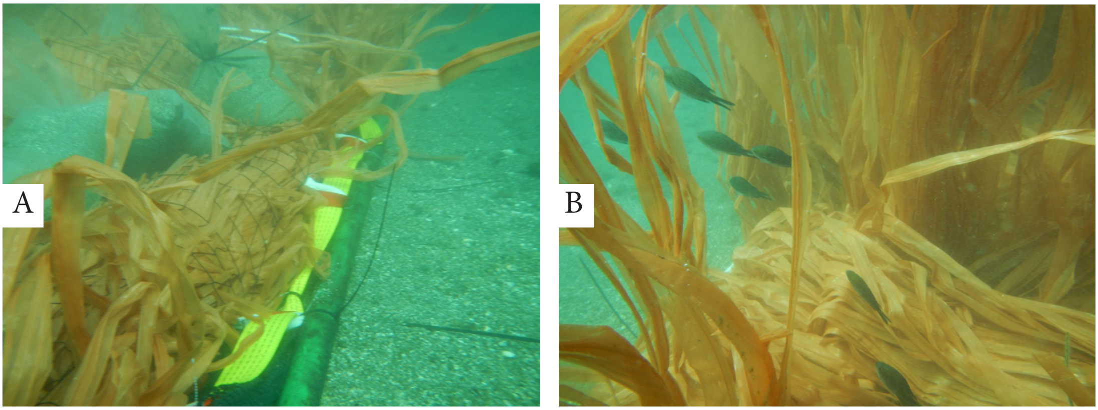


Figure 38. Fish populating the mats after installation (A, B). Photos ISCR.

– that included two landings with a quay, tanks to collect water and fishponds. The sea quarter was defended by twenty-five pilae inserted on the sea bottom. The residential part of the villa has not been found yet. The architectural decorations still existing are made of marble, stuccos and polychromatic paintings.

The restoration works and maintenance by ISCR started in 2004 to 2009 and included the wall of the *viridarium* and the room paved with a mosaic.

The Villa con ingresso a protiro

The complex of the Villa con ingresso a protiro (Figure 37) is located at a depth of 5 metres. The rooms which comprised the Villa extend for 40 metres on the road flanked by thermae, tabernae and other villas. Its original size must have been larger. The threshold – framed in stucco pilasters – is delimited by two red-plastered masonry benches. The name 'prothyrum' comes from the presence of two stuccoed column shafts – no longer in existence – that were placed on two short dividing walls built in front of the threshold. The villa's floors and walls are largely decorated with marble; almost all the surveyed rooms have marble-covered walls, and mosaic floors mostly made of white tesserae (e.g.: room restored by ISCR in 2003). A white and black mosaic patterned with hexagons, rosette diamonds and plants dating from 2nd century AD, decorated a room on the north-east of the entry hall (restored by ISCR in 2012); this entry hall had a sheet wainscot in red marble from Tenario with 'Lunense' marble mouldings.

The villa underwent a second construction phase represented by the building of a wide apsidal room south of the hall. The room had two floor levels, built from large white marble sheets which were used as covers for the walls as well. The villa is also composed of other service rooms including an area identified as a kitchen in the north-western section and a rectangular courtyard. A garden was located behind these areas, it contained the aforementioned Aphrodite "of the Gardens" statue by Alkamenes, now exposed in the garden of the Archaeological Museum of Campi Flegrei at Baiae.

Deployment of the mats
Villa con ingresso a Protiro

In this location the effects of the artifi-

Figure 39. Arrival of the mats (A,B). Placing of the sandbags (C,D,E) Installation of the mats (F,G,H,I). Photos ISCR and The National Museum of Denmark.

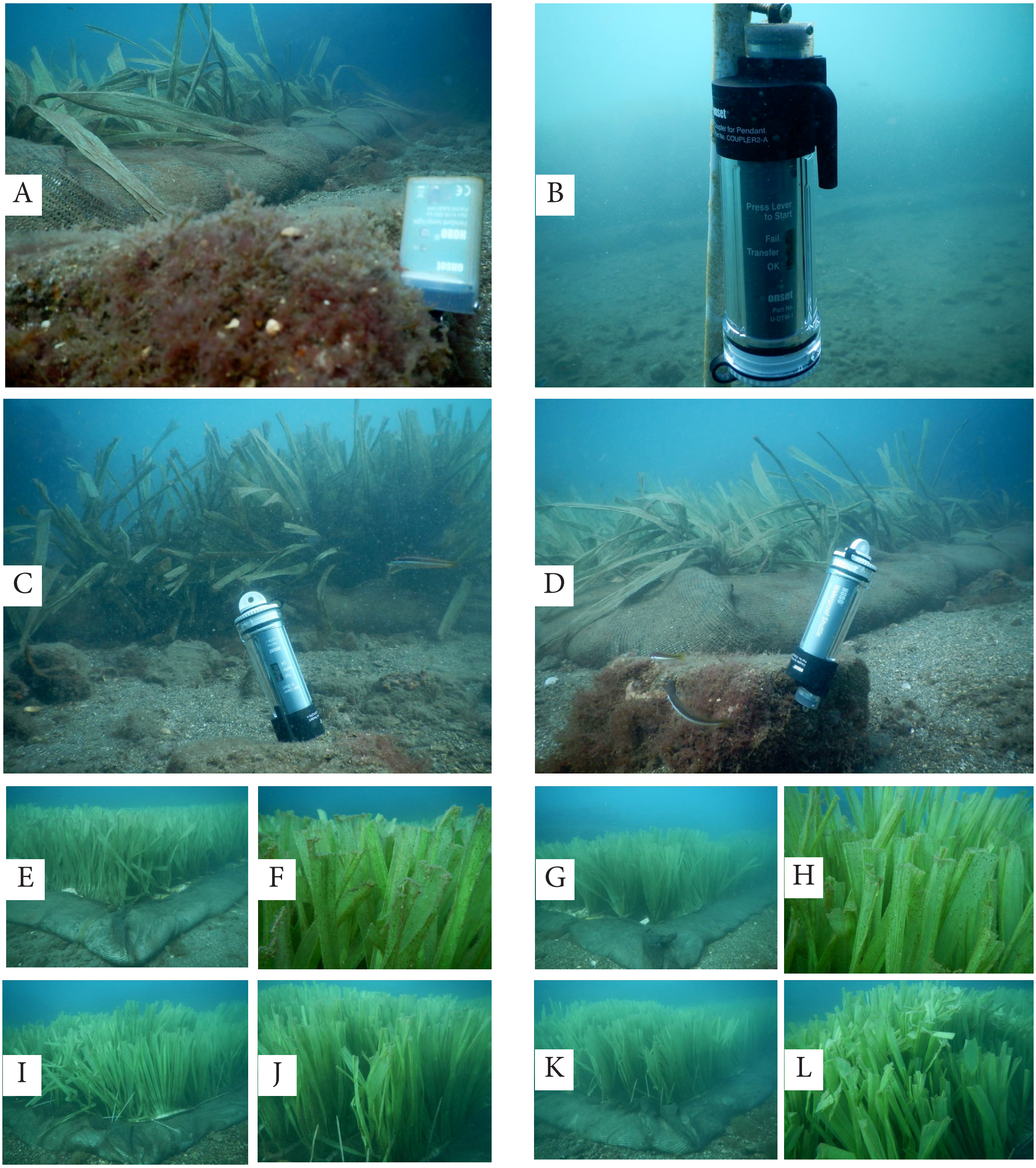
cial sea grass on the environment will be tested. The dimensions of the mat are 2.5 × 5 metres, with 1.25 metres long orange fronds. The location was monitored prior to the placement on 6th July 2013 and after the placement on 6th September 2013.

Initial results

As the mat is populated by different species of fish (Figure 38), it appears to be well integrated into the marine environment. ISCR biologist Sandra Ricci will continue the study on the biological colonisation of the fronds of these mats and of the others positioned in the Villa dei Pisoni.

Villa dei Pisoni

After long deliberation it was decided to change the planned position of the mats. The part of the wall of the *viridarium* of the Villa dei Pisoni originally chosen proved to be unsuitable, as a lot of archaeological structures collapsed near the wall, which could have a negative influence on the results. Mats of dimensions 5 × 1 metre (1), 7 × 1 metre (1), 5 × 2.5 metres (1) and 5 × 2 metres (3) were installed (Figure 38). All the six mats had short green fronds (0.625 metre). But as it was impossible in Baiae to use a large ship with crane, necessary to place the edge-weighted mats, a new method for anchoring the mats had to be found. SSCS developed a special skirt around the edges of the mat, on which sandbags could be placed to weigh them down. Although this system requires the filling of a lot



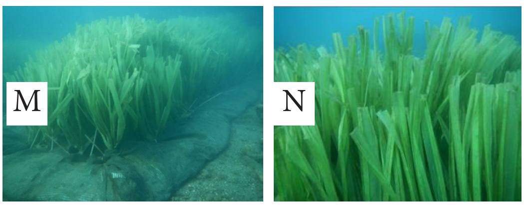
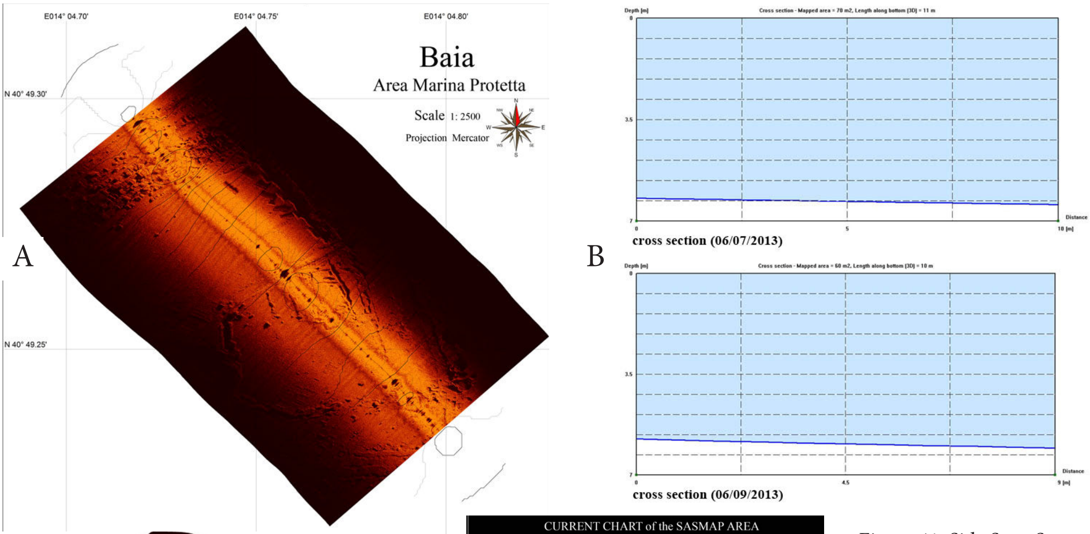


Figure 40. The SensCos (current direction and intensity, light and temperature sensors). The sensor works 24 hours, 7 days a week (A-D). Mat 1 on 6th July 2013 (E,F). Mat 2 on 6th September 2013 (G,H). Mat 3 on 6th September 2013 (I,J). Mat 4 on 6th September 2013 (K,L). Mat 5 on 6th September 2013 (M,N). Photos ISCR.

of sand bags (in Baiae 150 bags filled with around 4500 kg's of sand were used), it proved to be easy in use with smaller boats and kept the mats in place.

Monitoring

The following equipment is being used by Gabriele Gomez de Ayala, a ISCR collaborator, to monitor the site:



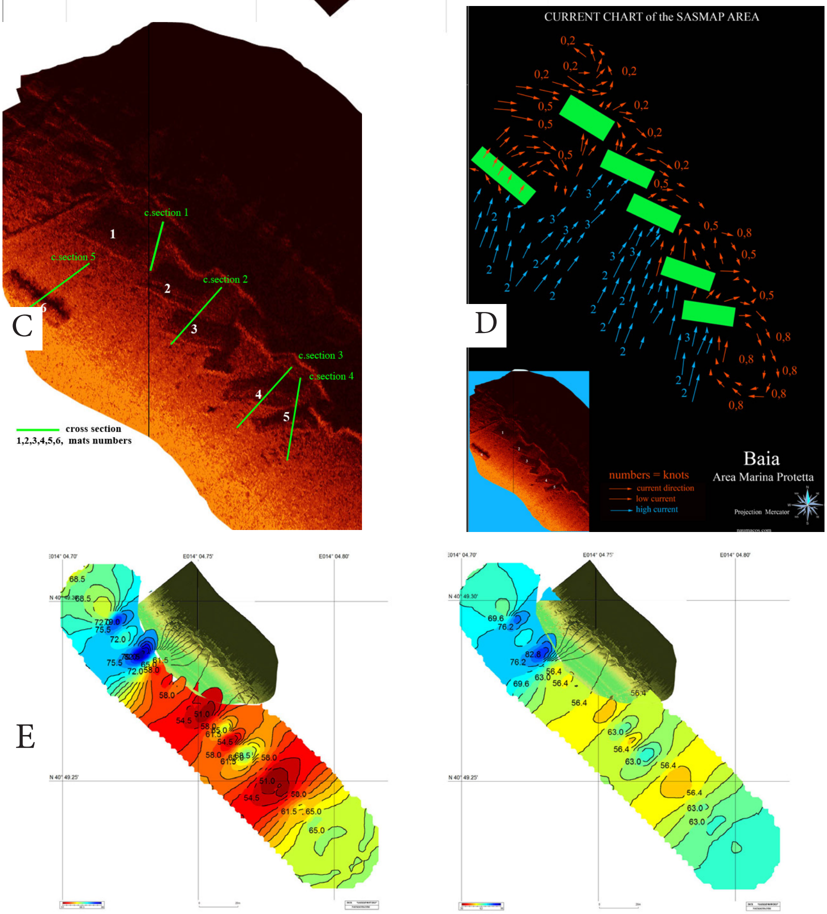
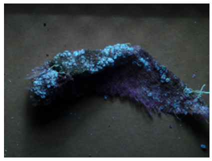
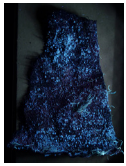
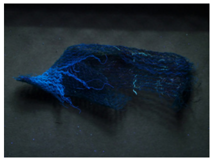
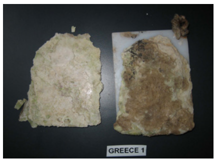
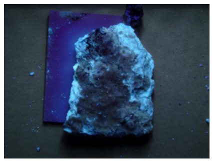


Figure 41. Side Scan Sonar of the research area on 6th September 2013. The scan shows the position of the 6 mats placed to protect the ancient remains of Villa dei Pisoni (A). The selected cross section shows the homogeneous distribution of soft sand (about 25 cm on the edge of the ancient wall) over the seabed between mat 1 and mat 2. The build-up of sediment is clearly visible after the second monitoring (B). Position of the 6 mats, the green line represents the cross sections (C). Chart of the current distribution in the area examined (D). Left: seabed hardness 6th July 2013. Right: seabed hardness 6th September 2013 (E).

- SSS Ecocos (high variable frequency side scan sonar)
- HD Dynamic (dynamic positioning system)
- SensCos (current direction and intensity, light and temperature sensors) (Figure 40a-d)
- Naumacos L3 3D scanlaser

The site was monitored on 6th July

Table 2. Results of visible and ultraviolet examination of SASMAP plastics. Photos National Museum of Denmark.

Sample	Description	Macro image	Ultraviolet image
RCE5	Cream sand bag from BZN3 installed 1988, taken up 2013. Loose fibres. Barnacles visible on front- and undersides.		
RCE6	Green, loose woven scaffolding net from BZN3 installed 1988, taken up 2013. Barnacles visible on front- and undersides except in folded areas.		
RCE8	Blue, loose woven scaffolding net from south side BZN10 installed 2001/2 taken up 2013. Folded but good condition.		
RCE10	Green, loose woven scaffolding net from south east side BZN10 installed 2001/2 taken up 2013. Folded and brown growth visible.		
Greece 1	Hard white plate, probably polyethylene, with sponge growing on front- and near surfaces. Had been partially above waterline.		

2013 prior to the fieldwork, and again on 6th September after the placement of the mats (Figure 40e-n). As sedimentation of soft sand continues, the seabed becomes softer. Therefore seabed hardness is an indication of sedimentation. The lower the seabed hardness value, the softer the seabed. The research area was monitored before, and 2 months after the placement of the mats. As fiugre 41B shows, the seabed became softer, showing that sedimentation took place. Assessing the durability of materials used in the in situ preservation of underwater archaeological sites

Background

Plastics such as sandbags, geotextiles and debris netting have often been used for mitigating the deterioration of underwater archaeological sites. The chemical types, manifestations of degradation and breakdown pathways in fresh and saltwater have not been established. Because it is important to understand how long plastic materials can protect underwater cultural sites and to ensure that degradation of these plastics will not have environmental consequences, samples of the materials after use have been collected from sites managed by SASMAP members and their properties are being investigated at the National Museum of Denmark. Data will be used to assess their suitability for use with cultural heritage and ultimately to develop guidelines for selecting materials for use by cultural heritage managers.

Collection and preparation of samples

Samples of plastics were removed from archaeological sites underwater up to one year before they were evaluated. In order to slow their deterioration after collection and to avoid contamination, they were stored below ambient temperature and without direct contact to other plastics. Researchers at San Diego University who collected samples of plastics from San Diego Bay developed a protocol for storing samples that was adapted for SASMAP and is summarised below (Rochman, C.M et al., Long-term field measurement of sorption of organic contaminants to five types of plastic pellets:implications for plastic marine debris, Environmental Science & Technology, 2013, 47, pp1646-1654):

- dry removed plastics as much as possible with kitchen roll
- wrap samples in aluminium foil or aluminium trays
- enclose wrapped samples in resealable, polyethylene bags
- place bags with clear labels in a domestic freezer at -20°C
- 24 hours before evaluation, allow samples to warm to ambient without removal from their polyethylene bags

Examination of samples

Visible light and ultraviolet examination

In addition to examination in visible light, plastics are examined in ultraviolet (UV) light at wavelengths between 320 and 380 nm produced by a UVA-Spot 400/T supplied by Deffner and Johann. Many biological materials, especially active ones, fluoresce when

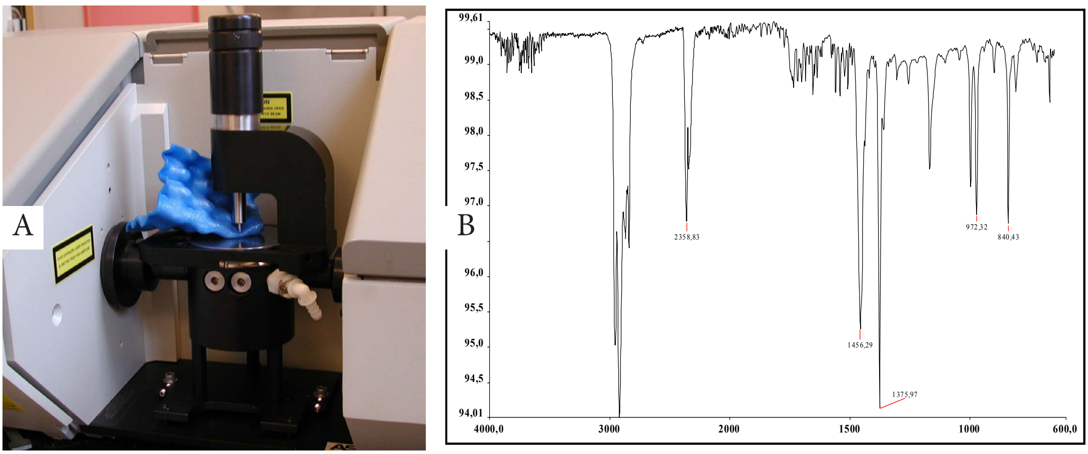


Figure 42. Analysis using Attenuated Total Reflection – Fourier Transform Infrared spectroscopy requires no sample preparation or destruction (A). The FTIR spectrum shows that the chemical groups producing the peaks are identical to those in polypropylene (B). Photos National Museum of Denmark.

exposed to ultraviolet light. They absorb ultraviolet light and re-emit it almost instantaneously. Because energy is lost during the absorption process, the emitted light has a longer wavelength than the incident which causes the material to glow or fluoresce. Plastics that have been moulded or cast contain UV absorbers from manufacture and therefore appear black in UV light.

Findings from examination by ultraviolet radiation

Exposure to UV radiation was effective at distinguishing biological materials from their plastic substrates despite both being similar colours in some cases and the technique will, therefore, be applied to all plastics examined in SASMAP. Of the plastics examined, only RCE8, a blue, loose woven scaffolding net from south side BZN10 installed in 2001/2 and Greece 1, a hard white plate with numbering in marker pen and rust showed no evidence of active biological attack.

Examination by infrared spectroscopy

Polymer types in plastics and, where possible, any changes in chemical structure induced by being under water for at least 5 years were identified using non-destructive Attenuated Total Reflectance-Fourier Transform Infrared (ATR-FTIR) spectroscopy (Figure 41). ATR-FTIR is a standard technique to detect the loss or development of chemical groups present in polymers and additives in plastics eg plasticizers, anti-ageing additives. It can be used non-destructively. The technique is poorly sensitive to changes at the initiation of degradation but more sensitive to degradation at propagation stages (degradation in progress). The surfaces of all samples were examined using a Pike MIRacle accessory fitted with a zinc selenide crystal in a Perkin Elmer Spectrum 100 spectrometer. Spectra were collected over 30 scans at a resolution of 4 cm-1 between 4000 and 600 cm-1. Spectra were compared with reference spectra run on the same instrument at the National Museum of Denmark.

Findings from examination by FTIR spectroscopy

Initial results

It is evident that the chemical composition of plastics cannot be determined from appearance alone. Scaffolding nets were made either of polyethylene, polypropylene or nylon despite appearing similar. All plastics show signs of chemical changes after use under water with the exception of polymethyl methacrylate. This finding was interesting and unexpected because these plastic types have different degradation pathways and therefore would not all be expected to degrade under aquatic conditions. Polypropylene seemed more resistant to degradation than nylon 6.6 and polyethylene, which was physically degraded and readily stained with rust and biological materials. Polymethyl methacrylate was the most stable and polyethylene the least stable plastic for underwater use from this investigation. It would be useful to know the oxygen content, temperatures and ultraviolet levels in the microclimates around the various plastics in order to further interpret the findings.

Preliminary conclusions

To test the artificial seagrass mats, three sites were selected in three different countries. Because of these different locations, the mats are tested in the most diverse circumstances. From the calm shallow waters of the bay of Naples, to the low current sea in Denmark and the rough Waddensea with its strong tidal movement, each of the sites has its own specifics. First of all the placement of the mats will be discussed. In both Denmark and The Netherlands the system of edge-weigthed mats was used. In both sites a big ship with heavy crane was used to place the mats. As it took only a couple of hours on each site to place all the mats, this can be regarded as a great success. Although there were some minor adjustments in The Netherlands (more suspension for the centre of the mat was needed), the weighted edges worked very well. Even in the rough tidal conditions the mats remained in their place.

In Baiae , Italy it proved to be impossible to use the big machinery to place the seagrass. The solution was to extend the edges on which sandbags were placed. Although filling and placing the sandbags took quite some time, it proved to be an adequate solution.

As expected, the strong tidal action and high sediment transport in the water caused the mats in The Netherlands to trap a lot of sediment. A surprising effect was that, because of the slowing of the current by the fronds, also 2 -3 metres on both sides of the mats sedimentation took place. After the first diving monitoring the shorter (0.625 metre) fronds appeared to work better, because the longer ones became trapped earlier under sand. In Denmark there was no visible sedimentation. Processing the data in the near future should reveal whether sedimentation has actually occured. Also comparing the data from the datalogger could be useful, as this will reveal the strength of the current and the amount of sediment suspended in the water. Although there is very little current in the bay of Naples, some sedimen-tation did take place. Between mats 1 and 2 almost 25 cm of sediment was deposited. As expected the mats also caught soft sediment, as is visible in the cross section and hardness maps. It is expected that this sediment will cover the wooden structures. Examining the plastic remains also revealed some interesting new information. After the initial investigations the plastic polymethyl methacrylate appears to have undergone no degradation, which would make it very suitable for protective materials. But as most of the research will take place in 2014, it is too early for definite conclusions.

Further research

In the next year monitoring of the mats will take place again using different methods: visual inspection, different sonar systems and 3D measuring systems. This monitoring should reveal what the mid-term effects of the artificial seagrass mats are. Is the sediment trapped on the mats themselves stable, or moving? And how does it effect the immediate surroundings?

Secondly the plastic-samples from the previous in-situ measurements will be further investigated by Yvonne Shashoua from the National Museum of Denmark. Hopefully this will reveal which materials are best to be used when trying to preserve an archaeological site in situ. Finally the sites will be examined using the 3D-subbottom profiler being developed in WP2 in order to find out how the sediment is built up.

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Dissemination is an integral part of the project, both in terms of publication of the achieved scientific results and promotion of the SMEs involved in the project. In the first year dissemination has focused on creating an awareness of the project primarily within the partner's respective fields of academia and cultural heritage in general. To this end partners have presented overviews and specific elements of the project at numerous conferences many of which will be published in the relevant conference proceedings (*).

As has been noted previously the outcomes of the project will be published in two guidelines in 2015. A seminar / workshop is also planned for the final year of the project so interested parties can hear more about the results and see the tools developed within the project. The project home page, www.sasmap.eu is a key portal to the developments in the project and will be updated as significant results are achieved; photos, videos and other documentation from this year's field work are currently being edited and will be uploaded onto the home page in the near future.

David Gregory

Figure 43. As part of the presentation of the project at Euromed 2012 in Cyprus, a poster was prepared and out of the over 70 posters the judging committee awarded this the best poster of the conference. Marinos Ioannides, the conference organiser, presented David with a certificate and plaque to commemorate this.

Confererences partners have presented at:

Euromed 2012; International Conference on Cultural Heritage.
Cyprus, October 2012 (* published 2012)

Splashcos, EU COST action meeting: Offshore Industry and Archaeology: A Creative Relationship, Denmark, March 2013 (* in press)
European Science Foundation Workshop: Marine Woodborers: New Frontiers For European Waters.
Italy, April 2013

International Council of Museums 12th Conference on Waterlogged Organic Archaeological Materials.
Turkey, May 2013 (* in press)

5th Baltic Sea Region Cultural Heritage Forum: The changing coastal and maritime heritage.
Estonia, September 2013 (* forthcoming)

Splashcos, EU COST action final conference: Under the sea: Archaeology and Palaeolandscapes.
Poland, September 2013

Conference of the Australasian Institute for Maritime Archaeology: Towards Ratification, Australia's Underwater Cultural Heritage.
Australia, October 2013 (* forthcoming)

The Nordic Conference on Maritime Archaeology.
Denmark, October 2013

EUPLOIA: Implementing Underwater Cultural Heritage 'Best Practices' in a Mediterranean Context.
Italy, October 2013

Danish Research Agency Conference on Horizons 2020: Present day challenges future solutions.
Denmark, October 2013

The successful completion of a complex project such as this requires extensive co-ordination and communication between the partners of the consortium. Needless to say, the numerous milestones, Gantt diagrams and report "Deliverables", prepared as part of the project provide a good "Road Map" of where and how the project is going. The consortium have currently had two meetings – the kick off meeting in Brussels in October 2012 and the 1st consortium meeting in May 2013 in Copenhagen (Figure 44). A third meeting of the consortium meeting will take place in the early spring of 2013, coinciding with the mid-term assessment of the project. On top of this numerous meetings have been held within the various Work Packages and at the various partner's institutions over the first year in order to fine tune scientific goals and plan elements of equipment development and field work. This has also entailed many e-mails, phone calls and Skype meetings.

Suffice to say, it is through this good communication between partners, patience and hard work that the consortium is currently on track for the second year of work within SASMAP.

David Gregory

Figure 44. The 1st consortium meeting at the National Museum of Denmark, Copenhagen. Photo National Museum of Denmark.

SASMAP

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