



United Nations
Educational, Scientific and
Cultural Organization



The Protection of the
Underwater Cultural Heritage

UNIT 9

Author Martijn R. Manders

In Situ Preservation



Published by UNESCO Bangkok
Asia and Pacific Regional Bureau for Education
Mom Luang Pin Malakul Centenary Building
920 Sukhumvit Road, Prakanong, Klongtoey
Bangkok 10110, Thailand

© UNESCO 2012
All rights reserved

ISBN: 978-92-9223-413-3 (Print version)
ISBN: 978-92-9223-414-0 (Electronic version)

The designations employed and the presentation of material throughout this publication do not imply the expression of any opinion whatsoever on the part of UNESCO concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

The authors are responsible for the choice and the presentation of the facts contained in this book and for the opinions expressed therein, which are not necessarily those of UNESCO and do not commit the organization.

UNESCO Bangkok is committed to widely disseminating information and to this end welcomes enquiries for reprints, adaptations, republishing or translating this or other publications. Please contact ikm.bgk@unesco.org for further information.

Technical editing: Martijn R. Manders and Christopher J. Underwood

Copy-editing: Sara M. Mabelis

Design/Layout/Illustration: Warren Field

Cover photo: Artificial seagrass placed on a test site during the Advanced Course on *In Situ* Preservation.

© UAD/ Arpakorn Kiewmas

Printed in Thailand

CLT/12/OS/015

UNIT 9

Contents

Core Knowledge of the Unit	2
Introduction to the Unit	2
1 <i>In Situ</i> Preservation	3
2 Why <i>In Situ</i> Preservation?	3
3 Threats to Underwater Archaeological Heritage	6
4 Measuring the Extent of Deterioration	14
5 Examples of Techniques used for <i>In Situ</i> Preservation	20
6 Conclusion	28
Unit Summary	28
Suggested Timetable	29
Teaching Suggestions	30
Suggested Reading: Full List	32

UNIT 9

Author Martijn R. Manders

In Situ Preservation

Core Knowledge of the Unit

This unit introduces students to *in situ* preservation, what it means and the techniques that can be used to preserve underwater cultural heritage sites from deterioration.

Upon completion of the *In Situ* Preservation unit, students will:

- Have an understanding of the principles of *in situ* preservation.
- Gain basic knowledge on when to use it.
- Gain basic knowledge on how to apply it.
- Be able to evaluate of different techniques that are used around the world.

Introduction to the Unit

In situ preservation is the number one Rule in the UNESCO Convention on the Protection of the Underwater Cultural Heritage (Paris 2001). It is important and should be considered as the first option. However, to be able to apply *in situ* preservation, one must first know what is meant by this. Does it mean leaving sites at the place they have been found? Or do the sites also require physical protection? What about excavations; are they still possible? Once preserved *in situ*, what is the next step? This unit will discuss all of these aspects and explore different techniques that can be used to physically protect underwater sites.

1 In Situ Preservation

Over the past few decades, maritime archaeology has evolved from an object related profession, into one that encompasses underwater cultural heritage; a non-renewable resource that provides a unique opportunity to investigate and learn from our past. Shipwrecks are essentially time capsules (closed finds) and their informative strength is the assemblage value of all the associated objects; ship, inventory, personal belongings and cargo collectively. Every shipwreck has its own unique story to tell.

This source or resource has to be managed in a responsible and sustainable manner. Management means that sites or information from these sites, are being secured over a long period of time. Sites have to be investigated according to international standards such as the UNESCO Convention for the Protection of the Underwater Cultural Heritage (Paris 2001). Archaeologists, conservators and policy makers are now all involved in the management of underwater cultural heritage. The *in situ* preservation of sites is an integrated component of this management process.

Recent international standards state that *in situ* preservation should be the first option to be considered when managing a site. However, what does *in situ* preservation of underwater heritage sites mean? Why should we protect them with this method? How can sites be physically protected underwater and against what threats?

2 Why In Situ Preservation?

There are many reasons why *in situ* preservation is given priority by international standards.

- Need to preserve the heritage site for the future
- Well developed protection system by law
- Enormous amount of newly discovered sites
- Cost effectiveness
- Time gap between discovery and excavation
- Lack of conservation knowledge

Over the years, the *in situ* preservation of archaeological sites has become increasingly important. This is also the case for those sites underwater. The reasons to do so are pragmatic or based on philosophic thoughts on how to manage our common maritime heritage.

A representative proportion of our maritime past has to be preserved for future enjoyment and research. The 'stock' of archaeologically interesting shipwrecks is immense and unarranged. It is therefore important to know what is where underwater and to investigate their probable meaning for maritime archaeology. This can be achieved by evaluating these wreck sites. Following evaluation, the state or condition of these selected wrecks should be preserved, as without active safeguarding, many excellent examples of maritime heritage will be lost forever.

The first physical protections *in situ* were carried out in the 1980s and were specifically implemented to leave something for future generations. Due to projects like MoSS (Monitoring of Shipwreck Sites) and BACPOLES, it is known that *in situ* preservation is a method to slow down degradation. However, it is

impossible to totally halt the deterioration of shipwrecks (this is also the case for shipwrecks preserved *ex situ*). It is therefore important to know how long a wreck can be preserved underwater by taking certain kinds of measures. The idea is to create an archive underwater that is accessible and to make sure that the 'files' are kept as intact as possible until they are finally opened. For this reason it is important to have an idea how long the protection has to be effective; for 5 years, 20 years or 100 years. The protective measures have to be selected in such a way that deterioration of the site can be brought down to a minimum and that it is still possible to access the site in the future for archaeological research.

Since it is important to know what will be protected or preserved, a non intrusive assessment on the site is executed. This assessment will give answers to some basic questions such as the extension of the site, the condition of the environment and the object, how old the wreck is and whether it has a cargo on board. The information is very helpful if, in the future, it is necessary to look for an object to answer a specific scientific question.

Most countries nowadays have a well developed law and regulation system concerning the protection of maritime archaeological heritage. This is a precautionary principle. It means that these countries take the responsibility to preserve not only their own, but also common maritime past. The *in situ* preservation is a logical method to do so for such scope of safeguarding.

Some international regulations concerning the protection of maritime heritage underwater go even further by stating that the conservation *in situ* should be the first option. The best examples of these regulations are UNESCO Convention on the Protection of the Underwater Cultural Heritage (Paris 2001) and the ICOMOS Charter on the Protection and Management of Underwater Cultural Heritage (Sofia 1996).

The amount of shipwrecks discovered grows fast and there is not enough capacity to do the research. Not only on land, but also underwater archaeological sites are getting more easily accessible. Nowadays diving is not an exceptional hobby. Equipment that can look through water of even the lowest visibility (side scan sonar and multibeam sonar) has been rapidly developed, as well as equipment that can penetrate into the seabed (sub-bottom profilers). This has caused a rise in the amount of archaeologically interesting shipwrecks that are listed in monument registers and other archaeological databases all over the world. These more advanced survey methods make it possible for almost everyone to explore the underwater world at a reasonable cost. This sudden availability of our maritime past has created an immense problem; to be able to keep pace between the amount of wreck sites reported every year and the ones that can be investigated, the maritime archaeological community would need a lot more workforce to achieve so.

The excavation of an underwater wreck is very expensive. Even though diving is not so exclusive pastime anymore, all interventions underwater are still costly. It is still necessary to use special equipment and to be able to work accurately, it is crucial to spend a lot of time underwater. In some countries, the underwater archaeologists need special training and licences. This makes an underwater excavation far more expensive than a regular excavation on land.

Even if a wreck is likely to be excavated, there is usually a prolonged period of time between the discovery of objects and the actual excavation.

The following necessary points need to be fulfilled before excavation can be started:

- There has to be a non intrusive assessment
- There has to be a project design
- There has to be funding in advance for the entire project
- There has to be a timetable
- There has to be research objectives.
- Details of the methodology and techniques to be employed must be set out in the project design
- The investigating team must be competent, appropriate to the task and have the right qualifications
- Sometimes political or legal issues have to be solved (for example, the ownership of a wreck) before an excavation can commence

See the Rule 10 of the Annex of the UNESCO Convention for the Protection of the Underwater Cultural Heritage (Paris 2001).

The research objectives of an excavation are essential. If something is excavated it will never again attain its original form, as excavation in itself is destructive. This is the basic premise on why all these rules have been laid out to regulate archaeological excavations. It will be impossible to attain all information that is enclosed in a wreck site. For example, studying a cargo or a construction of a ship could well bring about hundreds of questions. Yet by excavating the cargo and trying to answer a few questions, you remove the source and make it impossible to answer other questions that could have been asked and answered just as well. It is therefore important to know the field of research and to orientate before starting an excavation. In this way you might be able to ask (and answer) the most essential questions for that moment.

Not all wrecks are selected to be physically protected. Some natural environments are very stable and large scale physical protection is not necessary, such as at the *Vrouw Maria* site in the Baltic Sea (Finland). Alternatively, some environments are very hostile to archaeological sites underwater and much effort has to be done to try to stabilize the site, such as at the BZN 10 site (Netherlands) or the *Avondster* wreck site in the Bay of Galle (Sri Lanka). Some sites might not be considered worthy of spending that much time, effort and money on physical protection. If this is the case with a wreck site, the choice can be made to leave a wreck unattended, i.e. not physically and not legally protected. This selection of wreck sites is pragmatic and the efforts for doing research and preserving wrecks *in situ* should always be balanced.

It is not always easy to ascertain what is important in the selection procedure to determine which wreck should be actively preserved and which should not. Important factors, however, are the age and the level of preservation, the condition of the site and the level of integrity (Is it undisturbed? Does the ship still have its cargo?). See Unit 3: *Management of Underwater Cultural Heritage*.

Declaring a wreck archaeologically interesting and worthy of protection means that responsibility has to be taken for its preservation. This is not exclusively the task of maritime archaeologists, but also of the policy makers. Therefore, one of the best ways to safeguard our maritime past is to engender public interest and support.

Additionally, a reason to preserve archaeological sites *in situ* is the lack of knowledge on how to treat certain processes of deterioration.

Recent cases that support this reason are, for example, the sulphur problems threatening the hulls of the *Vasa* and the *Mary Rose*. See Unit 11: *Conservation and Finds Handling*. See *Additional Information 1*.

 **Suggested Reading**

- Sandström, M., Fors, Y. and Persson, I. 2003. *The Vasa's New Battle: Sulphur, Acid and Iron*. *Vasa Studies 19*. Stockholm.

ADDITIONAL INFORMATION

1 The majority of text in this section is taken from: Manders, M. 2004. *Why do We Safeguard Shipwrecks*. *MoSS Newsletter*. 3/2004, pp. 4-6.

3 Threats to Underwater Archaeological Heritage

Some of the primary threats to underwater archaeological heritage are:

- *Physical-mechanical*
- *Biological*
- *Chemical*
- *Human*

Why is it so important to physically protect archaeological sites underwater? Legislative protection is important against human threats, but insufficient, because there are also physical, chemical and biological threats which are ongoing.

In fact there are many factors influencing the course of deterioration over time. Muckelroy (1975) developed a model on the process of deterioration that still stands, but more have also been developed (e.g. Ward 1999). The models are there, but observation and monitoring are required in order to determine the most important threats to a particular site.

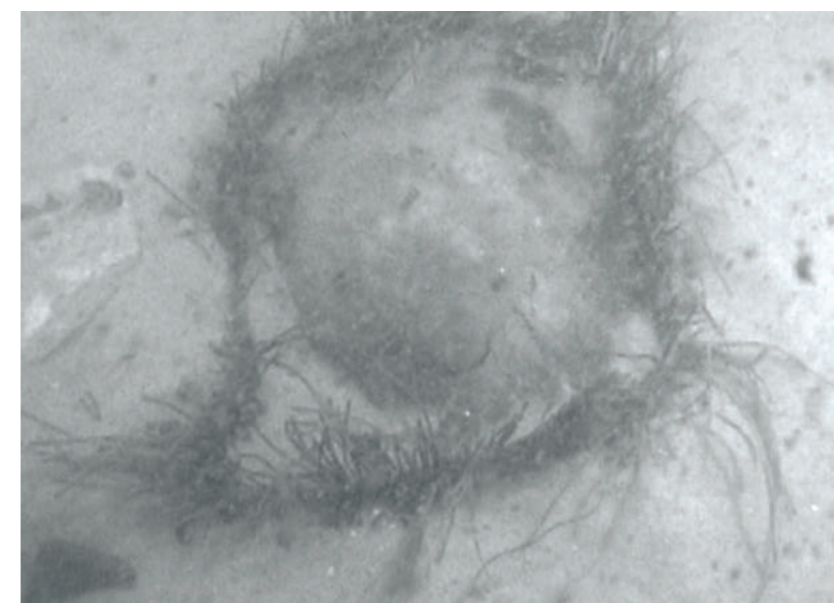
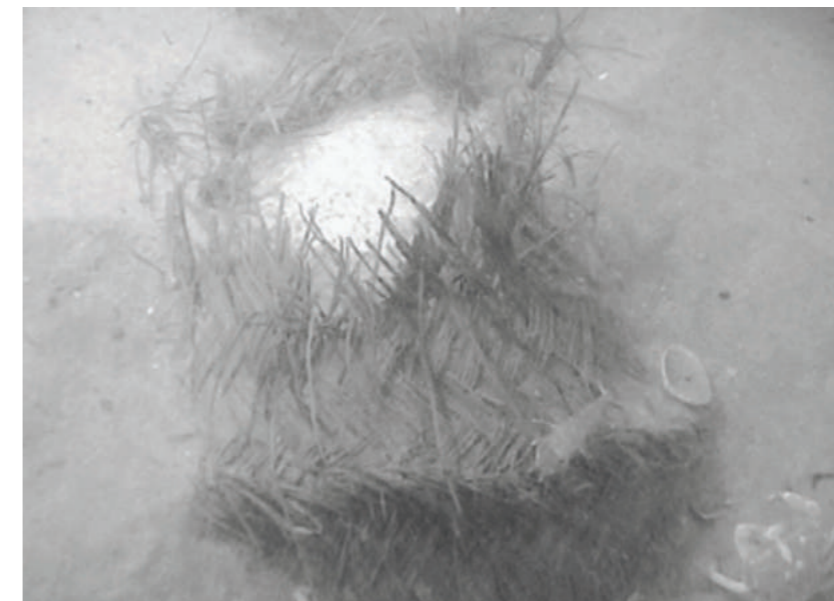
3.1 Physical-mechanical Threats

- *Erosion and abrasion by currents, tidal movements or changes in water circulation.*
- *Erosion or mechanical deterioration due to dredging, fishing or anchoring.*

All of these result in objects being removed and displaced. Objects becoming exposed are therefore more vulnerable to mechanical and other forms of deterioration. Surfaces of objects are eroded and parts of the site disappear.



Mechanical deterioration of a basket around an Iberian jar (BZN 10 wreck, the Netherlands). Within a few hours, due to the abrasive effects of currents caused by the tidal flow, the basket disappears.
© RCE



3.2 Biological Threats

The biological threats to *in situ* underwater sites are, for the most part, dependent on the presence of oxygen. Examples of biological deterioration (in decreasing order of severity) include:

- Marine Borers (especially *Teredo navalis* or shipworm)
- Fungi
- Bacteria

Research in the Netherlands and Australia has shown that shipworm can deteriorate wood within a few months. The shipworm is also one of the biggest biological threats in Asia. Research on the *Avondster* wreck in the Bay of Galle in Sri Lanka has shown the disastrous effects on exposed wood.

The shipworm is dependent on saline and aerobic water of higher temperatures. The effect of gribble (*Limnoria lignorum*) is generally less destructive than that of *Teredo navalis* (which also requires a similar environment), but over an extended period of time wood strength can be compromised and important archaeological information may be lost.

Usually, above water the most severe attackers of wood are fungi: Soft rot, Brown rot and White rot. The underwater environment in contrast, is not favourable for most fungi and it rarely exists, especially in saline waters, however, sometimes Soft rot does occur. In some instances old fungi that were still present in the timbers of a ship when it sank become active again once they are taken from the seabed into the dry, oxygen rich environment.

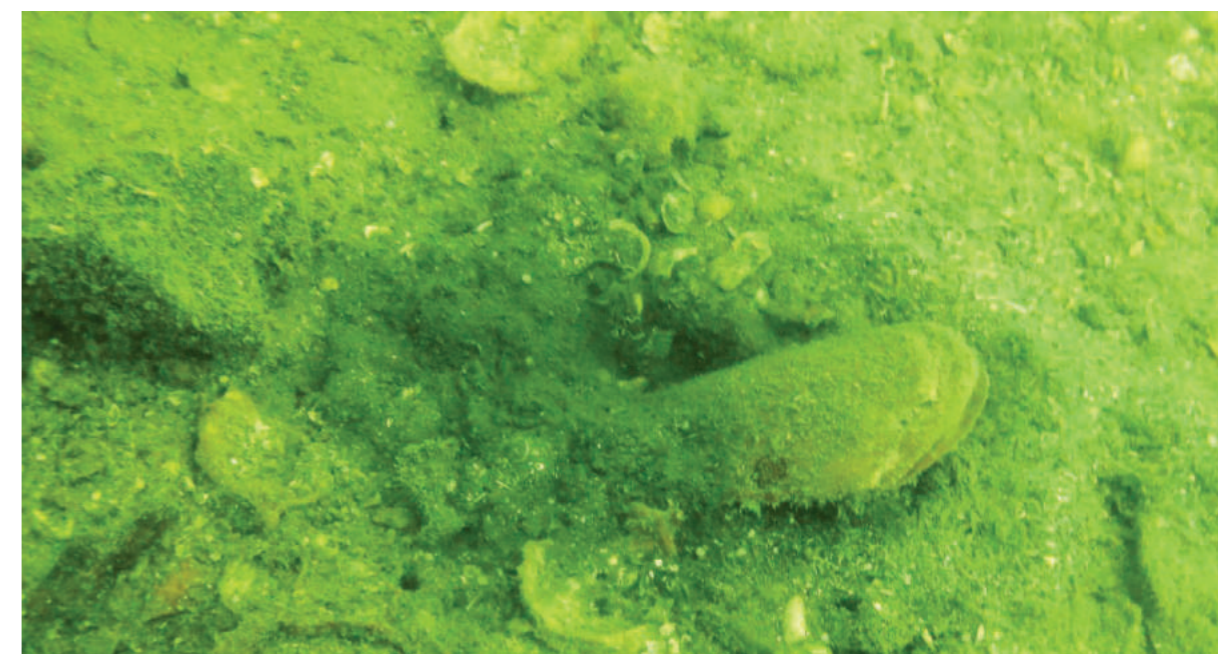
Tunnelling bacteria may attack wood when the conditions are still slightly aerobic. As timbers or parts of timbers become buried in the sediments, they will be degraded by organisms that require less and less oxygen until they are only subjected to the relatively slow action of (near) anaerobic erosion bacteria, in both fresh and marine environments.

The European Union (EU) funded project, Preserving Cultural Heritage by Preventing Bacterial Decay of Wood in Foundation Poles and Archaeological Sites (BACPOLES) revealed that bacterial decay of wood in marine sites is often less than in fresh water environments.

Generally, due to the manner of anaerobic bacterial attack of organic materials, very little archaeological information is lost; it is mainly the strength of the organic structure that is reduced.

Research (MoSS project) investigating the deterioration of modern wood blocks buried in marine sediments, showed that burial 10 cm under the surface of the seabed is usually sufficient to prevent the action of wood boring organisms and fungi. However, shipworm can be 40 cm long and it only needs to have a small part of its body in the open water. In theory therefore, it can attack wood at deeper levels.

At a depth of 50 cm microbiological activity is significantly reduced. In a stable environment, only the first few millimetres of sediment is usually aerobic and below this level more anoxic conditions prevail, but the size of the aerobic/anaerobic range is very dependent on the sediment type. However, irrespective of sediment type, bioturbation, scour, erosion by currents and tidal movements or human action, can expand the aerobic zone and consequently increase degradation. Therefore, burial of a site under at least 50 cm of sediment, where stable, anoxic conditions prevail and which excludes the effect of wood boring organisms, is generally recommended for the long term preservation of underwater cultural heritage sites that contain large quantities of organic structural and artefactual materials.



TOP: Wood from the *Avondster* ship (Galle, Sri Lanka) severely attacked by the shipworm. © MAU

ABOVE: Bioturbation in the first few centimetres of the seabed: the Fan clam digs itself into the soil and therefore causes disturbance of possible find layers (Mannok site, Thailand). © UNESCO

LEFT: The *Teredo navalis* or shipworm. © D. Gregory



Rust is a form of chemical deterioration (Mannok site, Thailand). © UNESCO

Examples of human threats:

- Treasure hunting
- Sports diving
- Fishing
- Dredging e.g. mineral extraction
- Large infrastructural/development works
- Pollution
- Ship movements
- Archaeology

3.3 Chemical Threats

Chemical processes can also affect the integrity of archaeological objects. One of the most common processes is the corrosion of iron and other metals, which happen especially in oxygen rich environments. Generally, the less oxygen, the less corrosion occurs. However, even under anaerobic conditions, corrosion of iron can occur, producing reduced iron corrosion products, such as iron sulphides. These can diffuse into the degraded structure of organic materials, such as wood, that are lying in close proximity to the corroding iron. Also, iron sulphides and other sulphide species can be formed by sulphate reducing bacteria under low oxygen conditions. Once the organic materials are recovered from a site the incorporated sulphides may be oxidised in the presence of free oxygen. These oxidation reactions produce acidic iron sulphates and other sulphate species, such as sulphuric acid that destroy cellulose, lignin and collagen by assorted chemical reactions. These processes have occurred on several ships recovered from the seabed, such as the *Vasa* in Sweden, the *Mary Rose* in England, the *Batavia* in Western Australia and the BZN 3 and BZN 15 wrecks from the Wadden Sea, the Netherlands. See Unit 10: *Conservation and Finds Handling*.

3.4 Human Threats

The threat of man to the underwater cultural heritage is enormous. One clear problem is that of treasure hunting, through which much data and information about the underwater cultural heritage is lost without having been researched thoroughly. It also has high exposure and therefore, is sending the wrong message to the public. However, other threats are just as destructive as treasure hunting, especially when the quantity of sites being disturbed or even lost is considered:

Suggested Reading

- Gibbs, M. 2006. Cultural Site Formation Processes in Maritime Archaeology: Disaster Response, Salvage and Muckelroy 30 Years on. *The International Journal of Nautical Archaeology*. 35.1, pp. 4-19
- Hamer, M. 2002. Ships Wrecked. *New Scientist*. 5 October 2002, pp. 38-40
- Huisman, D.J., Manders, M., Kretschmar, E., Klaassen, R.K.W.M. and Lamersdorf, N. 2008. Burial Conditions and Wood Degradation on Archaeological Sites in the Netherlands. *International Biodeterioration and Biodegradation*. No. 61, pp. 33-44.
- Manders, M. 2004. Protecting Common Maritime Heritage. The Netherlands Involved in two EU-Projects: MoSS and BACPOLES. *Mediterraneum*, Vol.4. Fabio Maniscalco (ed.), pp. 279-292.
- MoSS. 2004. Monitoring Newsletter. *MoSS Final Report*, 2/2004.
- Muckelroy, K. 1975. A Systematic Approach to the Interpretation of Scattered Wreck Sites. *International Journal of Nautical Archaeology*. No. 4, pp. 173 - 190
- Sandström, M., Fors, Y. and Persson, I. 2003. The *Vasa's* New Battle: Sulphur, Acid and Iron. *Vasa Studies* 19. Stockholm.
- Ward, A. K., Larcombe, P. and Veth, P. 1999. A New Process-based Model for Wreck Site Formation. *Journal of Archaeological Science*. No 26, pp. 561-570

This site is covered with trapped fishing nets, cables and wires (Mannok site, Thailand). © UAD, Thailand



A fish trap placed alongside the Mannok wreck site © UAD, Thailand



In Thailand, approximately 500,000 recreational divers are active each year. This is a huge stakeholder group to be considered. They can form threats for the underwater cultural heritage, but can also be beneficial for the protection of it. © Christopher J. Underwood



A fish trap being placed on the seabed. © Christopher J. Underwood

4 Measuring the Extent of Deterioration

4.1 Monitoring

When archaeological sites are preserved *in situ*, they should be monitored for changes that might occur to the condition of the site, in order to measure the effectiveness of the chosen protection strategy and to be able to act on any possible detrimental changes. Although often forgotten, monitoring is a critical part of the overall management programme.

The extract below was taken from an article written by the author for the EU-MoSS project (See *Additional Information 2*) and illustrates the role that monitoring plays in the management process.

The MoSS project consists of three research aspects: monitoring, safeguarding and visualising. Why was this approach chosen? And what is the value in combining these three aspects? The whole project is designed to find effective ways to preserve our common maritime heritage underwater. This not solely the concern of maritime archaeologists, but is also a much broader public issue. Our heritage is only well protected if it has extensive public support. The public should consist of scholars, decision-makers and the people who consider these shipwrecks as part of their own history. For them it has to be clear what can still be found underwater, how these finds can be used to reconstruct the past, why wrecks are deteriorating, how these processes can be stopped or slowed down, and at what cost. In other words, the shipwrecks on the seabed and their threats have to be investigated and visualized to create understanding and arouse public interest.

If a site is to be successfully protected, it is important to first know what is threatening it. This requires observing and recording what is happening to the site over an extended time period, in order to understand any damaging effects. By systematically observing wrecks (monitoring) it is possible to understand more about the major degradative processes. If, for example, it is possible to mitigate the major factors that degrade wood, it is obvious that the degradation rate would decrease. Safeguarding therefore, depends to a great extent, on the information gained from monitoring wrecks. After safeguarding a wreck it is also important that monitoring continues to keep track of the development of the site and the effectiveness of the protective measures.

Visualization is an important part of documenting and investigating a site. Wrecks underwater are usually not easily accessible and research on these sites is usually concentrated over a very short period of time. The visualization of excavation, monitoring and safeguarding, enables scientists to do research even when they are not physically present on the site. Since archaeological research can take years to complete, visual documentation is essential to keep track of everything that has been carried out. Visualization also enables the opening up an archive of archaeologically interesting shipwrecks to a wider audience. There are many ways to do this. The *Vrouw Maria* wreck (Finland) and the *Eric Nordevall* (Sweden) are so well

ADDITIONAL INFORMATION

2 Manders, M. 2004. *Combining Monitoring, Safeguarding and Visualizing to Protect our Maritime Heritage. MoSS Final Report*, pp. 74-76.

preserved, that although other methods have been utilised, the conventional ways of documenting a site by photography and video registration have been enough to create widespread public interest and to highlight the importance of these wrecks for reconstructing our past.

The Darsser Cog site (Germany) is the oldest of the investigated wrecks, although requires some more work to make the wreck accessible to a wider audience. This particular site has been documented and visualised by photographic mapping. The BZN 10 wreck (the Netherlands) is also well preserved, as at least half of the ship is still protected in the sediment. Despite the fact it has been broken up, the remains can still be reconstructed by the scientists and translated to the public.

Not long ago there was only one kind of visual monitoring. Back then, the only information about the condition of a shipwreck were the written accounts of what had been seen by the researchers. It is still important to register these visual changes, but now there are many more techniques to quantitatively measure the condition of the wreck. These methods, like the use of a data logger to measure the environmental conditions, are potentially more objective and can be more easily compared. It is however, very important that this data is accessible and can be understood by more people than just the researchers working on the site. To do this it is important to illustrate these numbers by using, for example, graphics.

The safeguarding of shipwrecks is a long term process and does not simply stop after physical protection. Over the years, the situation in and around a wreck site can change or protective measures may become ineffective. For example, if there is heavy erosion on a site, the wreck can be physically protected by covering the site in sediment. This has been achieved with polypropylene nets at the BZN 10 and other sites in the Wadden Sea. This method is very effective, however, the erosion in the vicinity of the site continues. After a long period of time, the seabed around the protected wreck can be extensively eroded, so much so, that sand starts to flow away from under the protective nets. Regular monitoring can identify this threat at an early stage and other measures can be implemented to ameliorate this problem.

In conclusion, monitoring helps to select the right measures to safeguard a site. Safeguarding a site is a long term process. This process has to be monitored to ensure that the measures taken are still valid after many years. The monitoring can also provide new information that may force a change to the mitigation strategy applied to protect the site.

Raw data gained from the monitoring can be made visual for a wider audience, such as other scientists, policy makers and the general public. It is important for them to know why and how wrecks are threatened, what kind of measures have been taken to preserve maritime heritage, and at what cost.

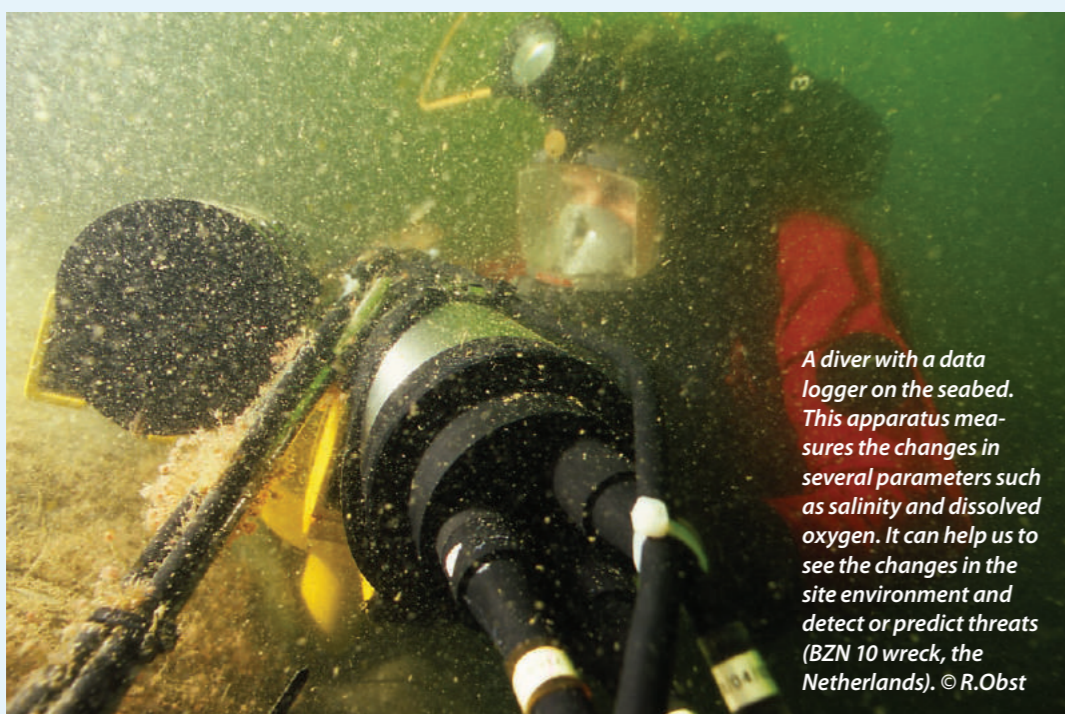
Monitoring should always be compared to baseline data. The most ideal procedure would be to have data prior to undertaking physical *in situ* preservation. Then after installation the same data is collected and a time line for further monitoring is developed. This time line is an indication of how often a site is going to be monitored in the future. However, this can change over time for a number of reasons, (e.g. new information might indicate that severe changes are occurring and the site has to be visited more often)

4.2 Open Seawater

In open seawater parameters such as dissolved oxygen, salinity, temperature and depth will all affect colonisation of exposed timbers by wood borers. However, this data also provides a picture of the environment. When the condition of the site changes, it is necessary to be able to compare that change with the change in the environment.

This data can be obtained from:

- Technical devices such as data loggers. These are pieces of equipment that may contain several sensors to collect different data (for example salinity, temperature and dissolved oxygen) over long periods of time. A data logger automatically records the data once it is installed and can be retrieved when the data logger itself is collected or through a wireless connection with the device.



A diver with a data logger on the seabed. This apparatus measures the changes in several parameters such as salinity and dissolved oxygen. It can help us to see the changes in the site environment and detect or predict threats (BZN 10 wreck, the Netherlands). © R.Obst

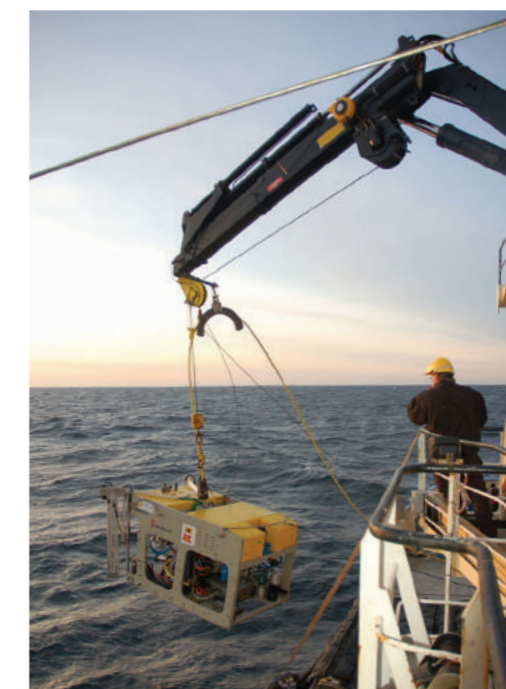
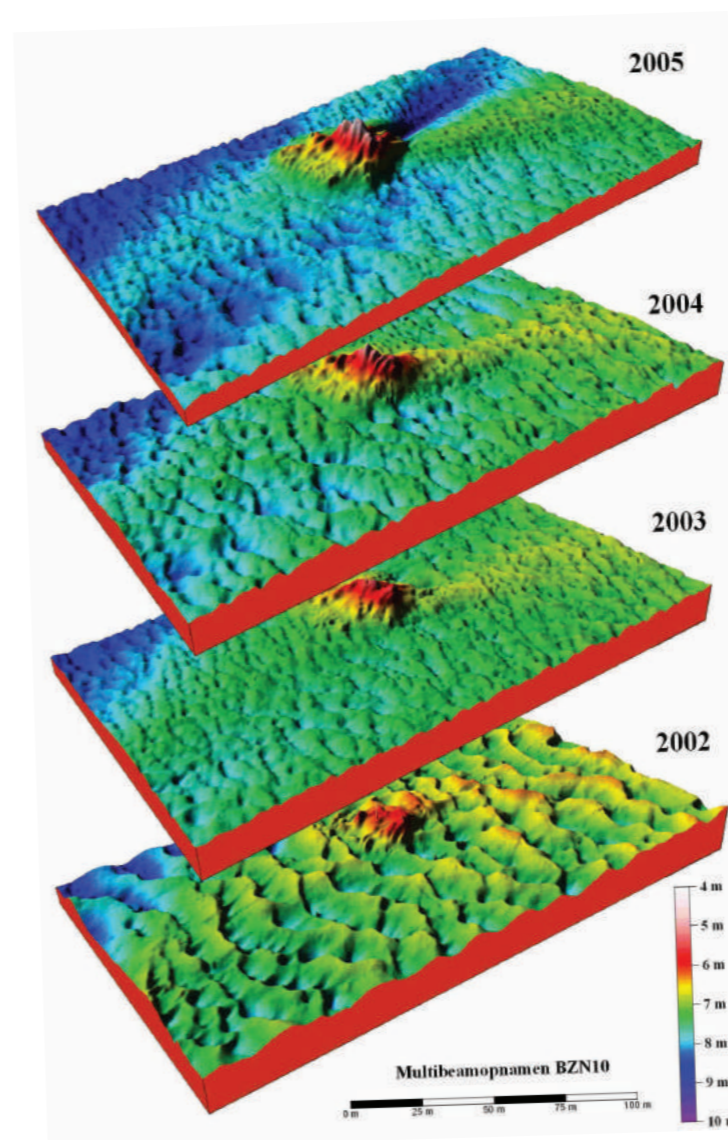
- By obtaining information from large (oceanographic) institutes that are measuring useful parameters for other purposes. The advantage of having your own measuring devices is that it can be placed anywhere (e.g. on a wreck site) and the archaeologist can choose what parameters to measure. The disadvantages are that these installations are usually very expensive to buy and especially difficult to maintain. The advantage of obtaining data from other institutes is that it is usually inexpensive (often free of charge) and it establishes cooperation between different stakeholders, however, it is often difficult to influence the positioning of these data loggers and the parameters they are measuring.
- Another way to measure the characteristics of the water column is to place sacrificial objects in the water and measure their deterioration rate over time. Taking water samples and post recovery analysis.

4.3 The Seabed

Erosion or sedimentation of the seabed can assist in determining whether a site is in danger and to decide whether to measure only the site itself or also to monitor the surrounding seabed over a larger area. They are both important to monitor. Measuring a larger area can provide information about the overall seabed changes occurring in an area due to, for example, changes in currents or large infrastructural works in the area. Measuring the seabed at site level can provide information about erosion on the site. Erosion can be caused by the fact that a physically protected site may provide a hard surface, an obstacle on the seabed, from which toe scouring can occur around the edges.

The seabed can be measured in a few ways.

- Visually, underwater by divers and Remotely Operated Vehicles
- From the water surface with geophysical methods like single beam, multibeam, side scan sonar.
- From the water surface with traditional sounding (sounding lead).
- From the air with laser, aerial photography and satellite.



ABOVE: Remotely Operated Vehicles or ROVs can be our eyes at great depths (Ghost wreck, Sweden). © Martijn R. Manders.

LEFT: A sequence of recordings of the seabed with multibeam sonar helps us to detect and visualise changes in the seabed morphology, for example, due to sediment erosion processes (BZN 10 wreck, the Netherlands). © RCE/RWS/Periplus

4.4 (Marine) Sediments

Marine sediments are usually very low in oxygen except in the first couple of centimetres and this concentration decreases rapidly with increasing sediment depth, until anaerobic conditions are attained. However, due to changes in the seabed, caused by erosion, this may alter. Also, as previously mentioned, deterioration can still occur under close to anoxic conditions.

The effect the burial environment has on the deterioration of materials can be measured by:

- Placing microelectrodes in the seabed, connected to a data logger
- Using sacrificial objects, which are buried in the seabed and measured for deterioration over time
- Sampling and analysing original elements, objects and sediments recovered from the site

In the future, it will be important to develop quality standards for different materials and to make an effort to apply these standards at a universal level. In this way, comparisons crossing administrative borders could be possible as well as assisting in the prioritization of sites in a broader setting. Some standards can be copied from terrestrial archaeology, whilst others will have to be developed specifically for underwater archaeology.

The parameters that have to be measured may differ, however there is some critical data for sediment and water.

Sediment:

- How easily it changes from oxygen rich to anoxic (redox potential)
- pH
- Bio turbidity
- Chemical pollution
- Sulphur content

Water:

- Salinity
- Water transport
- Temperature
- Dissolved oxygen
- Turbidity

4.5 The Object

Overtime the object can be monitored in a general way. Archaeologists can consider: Is the overall condition of the site deteriorating? Are elements falling apart? Is the relationship between the components weakened?

When monitoring different materials that an object is constructed from, it is important to consider the following indicators:

Wood

- Measuring the water content as an indicator of the deterioration of the wood
- Visual deterioration (e.g. due to borers or abrasion)

Iron

- Amount of iron left in the object
- Visual deterioration (amount, shape and colour of the corrosion)

 **Suggested Reading**

- Vroom, L. and Koppen, F. 2003. On the use of the Data Logger System, Water Watch 2681 at Marine Archaeological Site BZN 10. *MoSS Newsletter*. 4/2003, pp. 12-14.
- Gregory, D. 2004. Data loggers. *MoSS Newsletter*. 2/2004, pp. 8-9.
- Manders, M. 2003. Safeguarding: the Physical Protection of Underwater Sites. *MoSS Newsletter*, 4/2003, pp. 18-21.
- Manders, M. and Lüth, F. 2004. Safeguarding. *MoSS Final Report*, p. 63-74.
- Manders, M. 2004. Combining Monitoring, Safeguarding and Visualizing to Protect our Maritime Heritage. *MoSS Final Report*, pp 74-76.
- Manders, M. 2004. Why do we Safeguard Shipwrecks? *MoSS Newsletter*. 3/2004, pp. 4-6.
- Manders, M. 2004. The Safeguarding of BZN 10. *MoSS Newsletter*. 3/2004, p. 6-8.
- Manders, M. 2005. Site 13. Burgzand Noord 3 (BZN 3) Wreck, Wadden Sea, the Netherlands. Preserving Cultural Heritage by Preventing Bacterial Decay of Wood in Foundation Piles and Archaeological Sites. *Final Report EVK4-CT-2001-0004*. Dr. René Klaassen (ed.), pp. 55-64.
- Manders, M. 2005. Site 12. Burgzand Noord 15 (BZN 15) Wreck, Wadden Sea, the Netherlands, Preserving Cultural Heritage by Preventing Bacterial Decay of Wood in Foundation Piles and Archaeological Sites. *Final Report EVK4-CT-2001-0004*. Dr. René Klaassen (ed.), pp. 45-54.

5 Examples of Techniques used for *In Situ* Preservation

5.1 Sandbags

Advantages

- Protection against looters
- Probably encourages the formation of an anaerobic environment
- Long term preservation
- Material easy to obtain

Limitations

- High labour costs
- Difficult to monitor
- Weight on the wreck site
- Strong scouring around the protected site
- Some types of sandbags might deteriorate easily (e.g. natural materials like canvas)



5.2 Polypropylene Debris Netting:

Advantages

- Easy to create anoxic environment
- Inexpensive
- Easy to install
- Nature does the work
- Material easy to obtain
- Easy to remove with proper equipment
- Easy to monitor (in and outside the mound)
- Becomes part of the environment

Limitations

- Works only in specific environments
- Works only on wrecks that don't protrude extensively above the seabed
- Can be easily and quickly damaged after installation
- Organic growth may make it less effective
- Has to be installed in a specific way
- Research on the environment has to be carried out in advance
- Some scouring may occur around the edges



Advantages:

- A combination of methods, tailored to that one site

Advantages (Cuijk example):

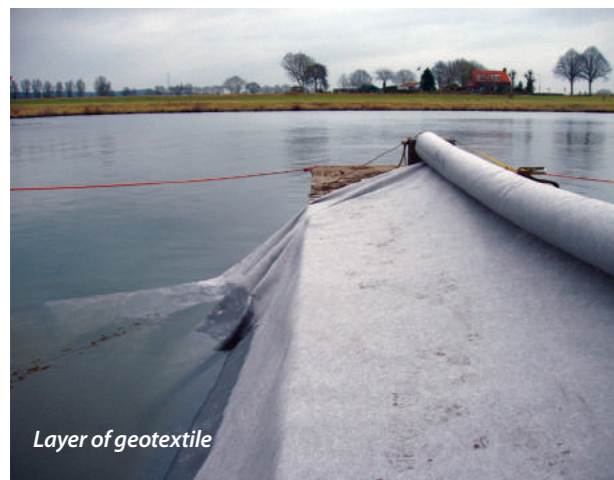
- Good, strong protection
- Anaerobic conditions
- Archaeological layers and later deposited sediment separated
- No organic transport between layers
- Easy monitoring

Limitations:

- It is tailor made for a specific site so may not be suitable for other sites

Limitations (Cuijk example):

- High costs for installation
- Scouring around the protected area may be severe



Layer of geotextile



Layer of clay



Usually we have to tailor our methodologies to protect sites underwater. We can, however, base our solutions on methods tried somewhere else. Here, a Roman quay in the River Meuse in the Netherlands is being protected with a layer of geotextile (above, left) followed by a layer of clay (above), debris nets with strong galvanised wire connected to it (left) and sandbags. © RCE

5.3 Specific 'Hands On' Solutions

It is important when applying an *in situ* preservation method to focus on the needs of the site. The parameters on why to protect, what the threats are, and what the most important features of the site may be different. A customized or 'hands on' solution is therefore always good to consider. These may be a combination of methods already known or the development of completely new ones.

The solution for a Roman Quay in Cuijk in the Netherlands, for example, consists of a combination of established techniques. This particular site is threatened by currents of the river as well as by large river barges that destroy the riverbed with their engines. The site had to be protected for only a maximum of three years, before it was planned to be excavated.

First a layer of Geotextile to cover the exposed archaeological layer was placed over the site, then a layer of clay, then a layer of debris netting with galvanized steel entwined in it and finally some sandbags to keep everything down.

5.4 Sand Deposition

Advantages

- Inexpensive
- Product easy to obtain
- Can be deposited in many ways .e.g. water dredge and ship
- Natural product

Limitations

- The physical environment remains the same, so in cases of erosion, this method can only be effective for a very short period.
- Sand may be eroded (by currents) and deposited somewhere else, where it is not wanted
- Sand from another place is introduced on the site

5.5 Road Barriers

Advantages

- Strong structure
- Possible to get good anaerobic/anoxic environment
- Easy to overcome height differences

Limitations

- Expensive
- Not easy to handle
- Not easy to install
- With the use of sandbags, is it easy to create an anaerobic environment?
- Big threat of toe scouring

5.6 Artificial Sea Grass

Advantages

- Works well to create an anaerobic environment
- Looks natural, if natural colours are used
- Has nature do the work after installation
- Can be installed easily

Limitations

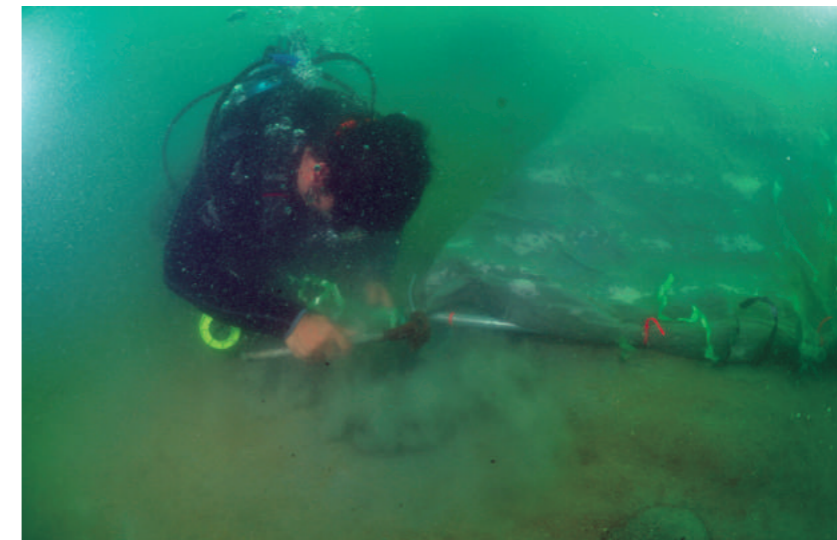
- Very expensive if bought on the market
- Labour intensive when self fabricated
- Very sensitive, it may work for a short period until the fronds become overgrown with algae and then settle flat on the seabed
- Has to be installed carefully
- No possibilities to overcome significant height differences
- Scouring may occur under and around the mats



Artificial seagrass can be bought or made by hand. Here, the UAD in Chanthaburi are making their own seagrass by assembling large (approximately 1 metre) fronds on fishing nets. © UAD



Like debris nets and geotextile, it is easier to install the artificial seagrass on the seabed when it is fixed to a heavy iron pole. © UAD



Artificial seagrass is being installed on the seabed. This self-made grass is temporary covered with a sheet to prevent the fronds from floating up while installing it. © UAD



Artificial seagrass placed on a test site during the In Situ Advanced Course of the UNESCO field school in Thailand. © UNESCO

5.7 Covering with Geotextiles

Advantages

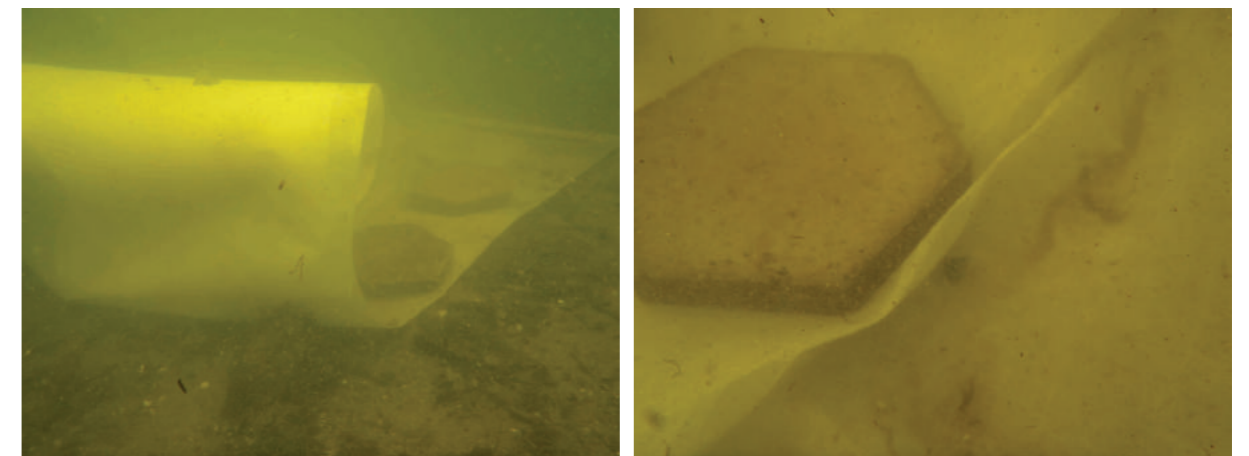
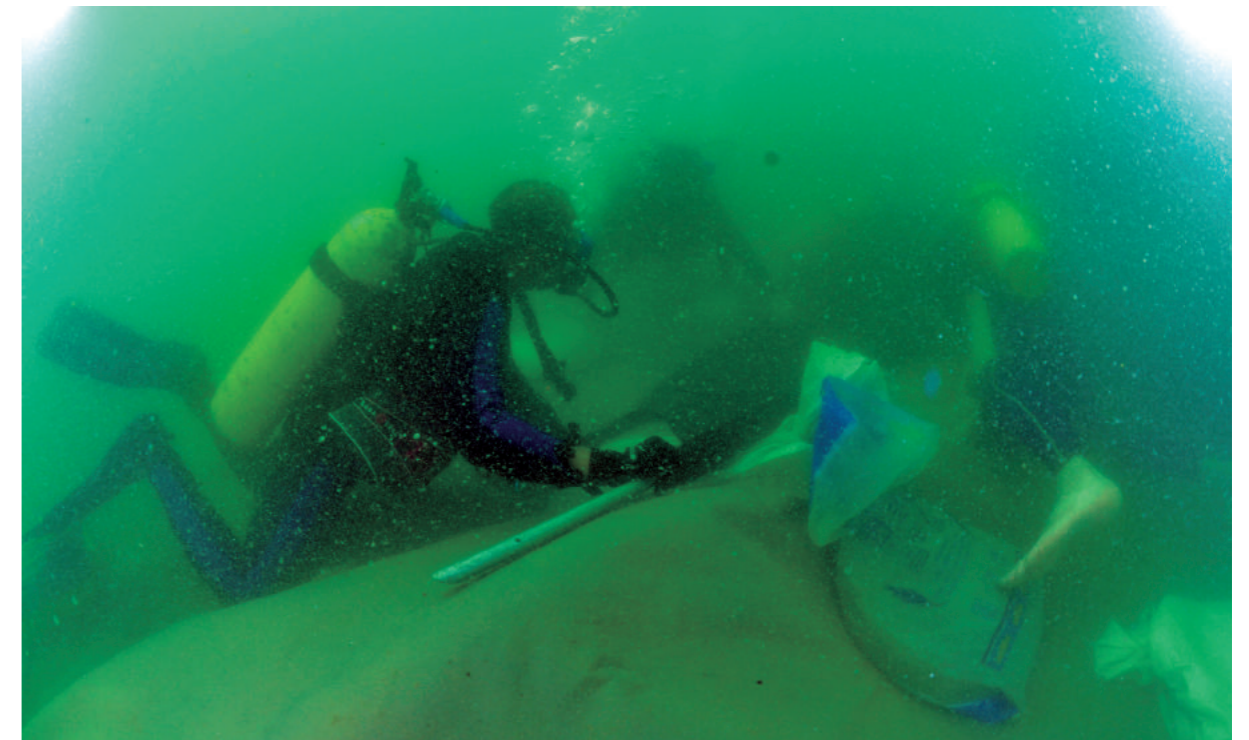
- Easy to buy
- Different types available
- Protection against *Teredo navalis*
- Protection against abrasion
- Some types of textiles can seal off the site, while some can be penetrated by fine sediment

Limitations

- Expensive
- Requires knowledge on suitable types of geotextile for different circumstances
- Difficult to install, especially in areas with currents and waves



Geotextile is being fixed to a heavy iron pole before taken into the water, which reduces the buoyancy.
© UAD



TOP: Geotextile has been installed on a wreck (Advanced In Situ Course test wreck, Thailand). © UAD

ABOVE LEFT: Geotextile used on a shallow site of a log boat near Roskilde, Denmark. © WreckProtect Project.

ABOVE RIGHT: Geotextile used on a shallow log boat site in Denmark. Due to its buoyancy the textile needs to be weighted down. In this example, a tile is used. © WreckProtect Project.

Suggested Reading

- Camidge, K. 2005. *HMS Colossus Stabilisation Trial Final Report*. CISMAS.
- Camidge K. 2008. *HMS Colossus Stabilisation and Recording Project Report*. CISMAS.
- Coroneos, C. 2006. A Cheap and Effective Method of Protecting Underwater Cultural Heritage. *Heritage at Risk Special Edition*. Grenier, R., Nutley, D. and Cochran, I. (eds.). ICOMOS, pp. 55-58.
- Godfrey, I. M., Gregory, D. Nystrom, I. and Vicki Richards. 2004. *In Situ Preservation of Archaeological Materials and Sites Underwater*. *Mediterranean*, Vol.4. Fabio Maniscalco (ed.), pp. 343-351.
- Godfrey, I.M., Reed, E., Richards, V.L., West, N.F. and Winton, T. 2005. The *James Matthews Shipwreck – Conservation Survey and In Situ Stabilisation*. *Proceedings of the 9th ICOM Group on Wet Organic Archaeological Materials Conference, Copenhagen*. P. Hoffmann, K. Strætkvern, J.A. Spriggsa and Gregory, D. (eds.). The International Council of Museums, Committee for Conservation Working Group on Wet Organic Archaeological Materials, pp.40-76.

- Heldtberg, M., MacLeod, I.D., Richards, V.L. 2004. Corrosion and Cathodic Protection of Iron in Seawater: a Case Study of the *James Matthews* (1841). *Proceedings of the ICOM-CC Metal WG Interim Meeting METAL*, pp. 75-87.
- Manders, M. 2004. Safeguarding a Site: the Master-Management Plan. *MoSS Newsletter*, Vol. 3/2004, pp. 16-20.
- Manders, M., Gregory, D. and Richards, V. 2008. The *In Situ* Preservation of Archaeological Sites Underwater: an Evaluation of Some Techniques. *Heritage Microbiology and Science. Microbes, Monuments and Maritime Materials*. Eric May, Mark Jones, Julian Mitchel (eds.). The Royal Society of Chemistry, pp. 179-204
- Staniforth, M. 2006. *In Situ* Site Stabilization: The William Salthouse Case Study. *Heritage at Risk Special Edition*. Grenier, R., Nutley, D. and Cochran, I. (eds.). ICOMOS, pp. 52-54.
- Winton, T. and Richards, V. 2005. *In Situ* Containment of Sediment for Shipwreck Reburial Projects. *Proceedings of the 9th ICOM Group on Wet Organic Archaeological Materials Conference, Copenhagen*. The International Council of Museums, Committee for Conservation Working Group on Wet Organic Archaeological Materials, pp.77-91

6 Conclusion

Presently, not many sites in Asia have been physically protected. In Sri Lanka a part of the *Avondster* shipwreck (Dutch East Indiaman) has been protected against deterioration covered with polypropylene nets. Effectively protecting the underwater cultural heritage is a process of trial and error. By testing out different methods, archaeologists can learn more about the environment and decide which method can be best used in which area, or for which kind of site. Trial and error implicitly also means that mistakes will be made, but there should be room to do so.

Suggested Reading

- Manders, M.R., Chandraratne, W.M., Dayananda, A.M.A., Muthucumarana, R., Weerasena, K.B.C. and Weerasingha, K.D.P. 2004. The Physical Protection of a 17th Century VOC Shipwreck in Sri Lanka. *Current Science*. 86, 9, pp. 101-107.
- Manders, M. and Weerasinghe, P. 2007. Protecting the *Avondster*. Excavation Report of the VOC ship *Avondster* (1659). Parthesius (ed.). *Centre for International Heritage Studies Special Publication*. No. 1, pp. 157-166.

Unit Summary

In situ preservation is the first rule in the UNESCO Convention on the Protection of the Underwater Cultural Heritage (Paris 2001) and is promoted as the first option for archaeologists to consider. *In situ* preservation means many things and although it is easily pronounced, it demands legal and specific physical protection of the site. Deciding to protect a site gives a responsibility to preserve it for a (long) period of time. This may be done for several reasons, be they scientific or for enjoyment. The reasons for protecting a site often have some bearing on the preservation methods that need to be used. When for enjoyment, we may not want to cover a whole site up as would be done, perhaps, when we preserve it for scientific reasons.

Different threats also determine the way sites are protected. If the site has to be protected against shipworms, it is necessary to create an anaerobic environment on the site. However, if the site is protected to prevent looting, then the physical protection should be as non-penetrable as possible and legal protection should also be in place which also includes some law enforcement.

Involvement on the site does not end when the *in situ* technique has been applied; periodical monitoring of any changes on site is also required in order to be able to preserve the heritage site to perpetuity.

Suggested Timetable

15 mins	Introduction
45 mins	<p>Why <i>In Situ</i> Preservation?</p> <ul style="list-style-type: none"> - Preserve for the future - Well developed protection system by law - Enormous amount of newly discovered sites - Cost effective - Time gap between discovery and excavation - Lack of conservation knowledge
	Break
90 mins	<p>Threats to Underwater Archaeological Heritage</p> <ul style="list-style-type: none"> - Physical - Chemical - Biological - Human
	Break
90 mins	<p>Measuring the Extent of Deterioration</p> <ul style="list-style-type: none"> - Monitoring - Evaluating and acting on it
	Break
90 mins	Examples of Techniques Used for <i>In Situ</i> Preservation
	Break
90 mins	Practical Session
10 mins	Concluding Remarks and Closure

Teaching Suggestions

Throughout this unit students are provided with an introduction to *in situ* preservation, what it means and the techniques that can be used to preserve underwater cultural heritage sites from deterioration. To help deepen student's understanding of the topics presented, a selection of teaching suggestions are included below.

1 Introduction

When introducing *in situ* preservation, it is important to give a brief overview of management of the underwater cultural heritage. Trainers should explore aspects such as surveying, assessment, selecting sites, excavation, etc. See Unit 3: *Management of Underwater Cultural Heritage*.

It is also useful for trainers to present and explain the UNESCO Convention on the Protection of the Underwater Cultural Heritage (Paris 2001), the ICOMOS Charter on the Protection and Management of Underwater Cultural Heritage (Sofia 1996), and any relevant local or regional agreements such as the European Convention on the Protection of the Archaeological Heritage (Valletta 1992).

2 Why In Situ Preservation?

During this section it is important to provide examples of underwater cultural heritage that are either close to the trainer or the student's own practice

This section is also particularly useful for connecting conservators to the topic of *in situ* protection. With the knowledge and/or the prediction about the state of the archaeological site and its individual objects, a conservator can develop their conservation plan and select the most effective strategies for removing the objects from the seabed.

3 Threats to Underwater Cultural Heritage

This section is best illustrated by a series of visual examples of potential Asian threats and how they have caused the destruction of particular sites. It is important to emphasize that fishing activities might be one of the biggest threats of all to the underwater cultural heritage.

5 Examples of Techniques Used for In Situ Preservation

The techniques discussed during this section are focused primarily on archaeological sites. It may be useful for trainers to expand on this and also discuss aspects such as preserving metal wrecks, objects using zinc anodes (anodizing) or other sacrificial methods.

Practical Session

Students should be given a practical task that utilizes the knowledge gained during this unit. One useful test to set students, used during early foundation courses, was to develop an *in situ* preservation strategy for one of the below archaeological shipwreck sites in Thailand:

The Ruea Mail or Mannok Shipwreck Site near Mannok Island: this is a (river) steam boat. It dates from the early twentieth century and is an iron ship with possible Asian features. It contains material from as well the French Colonial Period as typical Asian artefacts.

The Ruea Rang Kwian Shipwreck Site: this is a fourteenth century Chinese or Thai junk. During the first investigation in 1989, as part of a cooperative effort between the Thai and the Australians (Western Australian Maritime Museum), the ships' hull was recorded. The hull was investigated again at the SEMEO Regional Centre for Archaeology and Fine Arts (SPAFA) training a few years ago.

The Bangkachai II Shipwreck Site: this is a Chinese junk of approximately 400 years old. The site lies at a depth of not more than 8 metres, near the shore and river outlet. There is often bad visibility. The site has been extensively excavated in five years (between 1993 and 1998) and remarkable well preserved (organic) material has been raised. A one to one scale model is present at the maritime museum. The wreck itself, including one of the three discovered wooden anchors, is still in place.

The Samed Ngam Shipwreck Site: this site consists of a 200 year old dockyard and a shipwreck of an Asian junk. The inside of the ship was first investigated in 1982. The second investigation of the outside of the ship took place during the SPAFA training of 1989. The site now consists of a small part of the dockyard that has been restored and within that dockyard, the remains of the wreck just below the water level. It is now part of a community museum which includes a building that holds an exhibition about the site and the archaeological work that has been executed on it.

The second suggested practical test is similar, but completely focused on developing an *in situ* preservation scheme for the Mannok Island wreck site. This shipwreck is used for the diving practical dive session held during Unit 12: *Practical Dive Session of the Foundation Course, Mannok Shipwreck Site, the Gulf of Thailand*.

This site can play an important role in the discussion on *in situ* preservation. Students can be tasked with developing methods for the site in the light of future use. Does it need to be protected against natural deterioration? Or against looting or fishing?

In prior foundation courses the methods developed ranged between making the site accessible for controlled diving only, to avoiding fishing on the site and full covering of the wreck to create an anoxic environment.



Suggested Reading: Full List

- Camidge, K. 2005. *HMS Colossus Stabilisation Trial Final Report*. CISMAS.
- Camidge K. 2008. *HMS Colossus Stabilisation and Recording Project Report*. CISMAS.
- Coroneos, C. 2006. A Cheap and Effective Method of Protecting Underwater Cultural Heritage. *Heritage at Risk Special Edition*. Grenier, R., Nutley, D. and Cochran, I. (eds.). ICOMOS, pp. 55-58.
- Gibbs, M. 2006. Cultural Site Formation Processes in Maritime Archaeology: Disaster Response, Salvage and Muckelroy 30 years on. *The International Journal of Nautical Archaeology*. 35.1, pp. 4-19.
- Godfrey, I.M., Reed, E., Richards, V.L., West, N.F. and Winton, T. 2005. The *James Matthews* Shipwreck – Conservation Survey and *In Situ* Stabilisation. *Proceedings of the 9th ICOM Group on Wet Organic Archaeological Materials Conference, Copenhagen*. P. Hoffmann, K. Strætkvern, J.A. Spriggsa and Gregory, D. (eds.) The International Council of Museums, Committee for Conservation Working Group on Wet Organic Archaeological Materials, pp.40-76.
- Godfrey, I. M., Gregory, D. Nystrom, I. and Vicki Richards. 2004. *In Situ* Preservation of Archaeological Materials and Sites Underwater. *Mediterraneum*, Vol.4. Fabio Maniscalco (ed.), pp. 343-351.
- Gregory, D. 2004. Data loggers. *MoSS Newsletter*. 2/2004, pp. 8-9.
- Hamer, M. 2002. Ships Wrecked. *New Scientist*. 5 October 2002, pp. 38-40.
- Heldtberg, M., MacLeod, I.D., Richards, V.L. 2004. Corrosion and Cathodic Protection of Iron in Seawater: a Case Study of the *James Matthews* (1841). *Proceedings of the ICOM-CC Metal WG Interim Meeting METAL*, pp. 75-87.
- Huisman, D.J., Manders, M.R., Kretschmar, E., Klaassen, R.K.W.M. and Lamersdorf, N. 2008. Burial Conditions and Wood Degradation on Archaeological Sites in the Netherlands. *International Biodeterioration and Biodegradation*. No. 61, pp. 33-44.
- MoSS. 2004. Monitoring newsletter 2/2004 and *MoSS Final Report*.
- Manders, M. 2004. Protecting Common Maritime Heritage. The Netherlands involved in two EU-projects: MoSS and BACPOLES. *Mediterraneum*, Vol.4. Fabio Maniscalco (ed.), pp. 279-292.
- Manders, M. 2005. Site 13. Burgzand Noord 3 (BZN 3) Wreck, Wadden Sea, the Netherlands. Preserving Cultural Heritage by Preventing Bacterial Decay of Wood in Foundation Piles and Archaeological Sites. *Final Report EVK4-CT-2001-0004*. Dr. René Klaassen (ed.), pp. 55-64.
- Manders, M. 2005. Site 12. Burgzand Noord 15 (BZN 15) Wreck, Wadden Sea, the Netherlands, Preserving Cultural Heritage by Preventing Bacterial Decay of Wood in Foundation Piles and Archaeological Sites. *Final Report EVK4-CT-2001-0004*. Dr. René Klaassen (ed.), pp. 45-54.
- Manders, M. 2006. The *In Situ* Protection of a Dutch Colonial Vessel in Sri Lankan Waters. Robert *Heritage at Risk Special Edition*. Grenier, R., Nutley, D. and Cochran, I. (eds.). ICOMOS, pp. 58-60.
- Manders, M. 2006. The *In Situ* Protection of a 17th Century Trading Vessel in the Netherlands. *Heritage at Risk Special Edition*. Grenier, R., Nutley, D. and Cochran, I. (eds.). ICOMOS, pp. 70-72.
- Manders, M. (ed.) 2011. *Guidelines for Protection of Submerged Wooden Cultural Heritage*. WreckProtect.
- Manders, M. Gregory, D. and Richards, V. 2008. The *In Situ* Preservation of Archaeological Sites Underwater: an Evaluation of Some Techniques. *Heritage Microbiology and Science*. Microbes, Monuments and Maritime Materials. Eric May, Mark Jones, Julian Mitchel (eds.). The Royal Society of Chemistry, pp. 179-204.
- Manders, M. Chandraratne, W.M., Dayananda, A.M.A., Muthucumarana, R., Weerasena and K.B.C. Weerasingha, K.D.P. 2004. The Physical Protection of a 17th Century VOC Shipwreck in Sri Lanka. *Current Science*. 86, 9, pp. 101-107.
- Manders, M. and Weerasinghe, P. 2007. Protecting the *Avondster*. Excavation Report of the VOC-ship *Avondster* (1659). Parthesius (ed.). *Centre for International Heritage Studies Special Publication* No. 1, pp. 157-166.
- Muckelroy, K. 1975. A Systematic Approach to the Interpretation of Scattered Wreck Sites. *International Journal of Nautical Archaeology*. No. 4, pp. 173 – 190
- Sandström, M., Fors, Y. and Persson, I. 2003. The *Vasa's* New Battle: Sulphur, Acid and Iron. *Vasa Studies* 19. Stockholm.
- Staniforth, M. 2006. *In Situ* Site Stabilization: The William Salthouse Case Study. *Heritage at Risk Special Edition*. Grenier, R., Nutley, D. and Cochran, I. (eds.). ICOMOS, pp. 52-54.
- Vroom, L. and Koppen, F. 2003. On the Use of the Data Logger System Water Watch 2681 at Marine Archaeological Site BZN 10. *MoSS Newsletter*. 4/2003, pp. 12-14.
- Ward, A. K., Larcombe, P. and Veth, P. 1999. A New Process-based Model for Wreck Site Formation. *Journal of Archaeological Science*. No 26, pp. 561-570
- Winton, T. and Richards, V. 2005. *In Situ* Containment of Sediment for Shipwreck Reburial Projects. *Proceedings of the 9th ICOM Group on Wet Organic Archaeological Materials Conference, Copenhagen*. The International Council of Museums, Committee for Conservation Working Group on Wet Organic Archaeological Materials, pp.77-91.