A MARITIME RESEARCH PROJECT FUNDED BY THE EUROPEAN UNION CULTURE 2000 PROGRAMME

MACHU Final Report

Nr. 3 www.machuproject.eu

Managing Cultural Heritage Underwater

MACHU FINAL REPORT NR. 3 - Managing Cultural Heritage Underwater

THE NETHERLANDS
The National Cultural Heritage Agency
Rijksdienst voor het Cultureel Erfgoed (RCE)
P.O. Box 1600, 3800 BP Amersfoort
T +31 (0)33 42 17 421
F +31 (0)33 42 17 799
E info@cultureelerfgoed.nl
www.cultureelerfgoed.nl

THE NETHERLANDS
Directorate IJsselmeer,
Region Rijkswaterstaat (RWS) IJsselmeergebied
Rijkswaterstaat IJsselmeergebied, Meet- en Informatiedienst
Zuiderwagenplein 2, PO Box 600, 8200 AP Lelystad
T +31 (0)320 29 89 98 *Main office*
+31 (0)320 29 76 63 *Secretariat*
F +31 (0)320 23 43 00
E wim.dijkman@rws.nl / herman.hootsen@rws.nl
www.rijkswaterstaat.nl

BELGIUM
The Flemish Heritage Institute
The Maritime Archaeology and Heritage Afloat Unit
VIOE: Vlaams Instituut voor het Onroerend Erfgoed
Koning Albert II-laan 19, Bus 5,
B-1210 Brussels
T +32 (0)2 553 16 50
F +32 (0)2 553 16 55
instituutonroerenderfgoed@vlaanderen.be
www.vioe.be

GERMANY
The Roman-Germanic Commission (RGK) in cooperation with the Authority for Culture and Protection of Monuments in Mecklenburg-Vorpommern
Römisch-Germanische Kommission des Deutschen Archäologischen Instituts
Palmengartenstrasse 10-12, 60325 Frankfurt a. M
T +49 (0)69 97 58 180
F +49 (0)69 97 58 18 38
info@rgk.dainst.de
www.dainst.de/abteilung.php?id=268

POLAND
The Polish Maritime Museum in Gdańsk
Centralne Muzeum Morskie
Olowianka 9-13, 80-751 Gdańsk
T +48 (0)58 301 86 11 *Main office*
+48 (0)58 320 33 58 *Secretariat*
F +48 (0)58 301 84 5 info@cmm.pl www.cmm.pl
The Polish Geological Institute - National Research Institute
Państwowy Instytut Geologiczny - Państwowy Instytut Badawczy
Subcontractor to the museum
Rakowiecka 4 Str., 00-975 Warszawa
T +48 (0)22 849 53 51 sekretariat@pgi.gov.pl
F +48 (0)22 849 53 42 http://pgi.gov.pl/pgi_en/

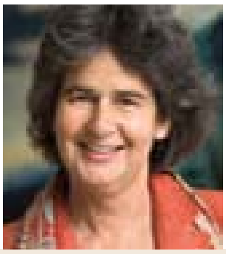
UNITED KINGDOM
English Heritage, Maritime Archaeology Team
Fort Cumberland, Fort Cumberland Road,
Eastney, Portshmouth, PO4 9LD
T +44 (0) 9285 6735
F +44(0) 23 9285 6701
E maritime@english-heritage.org.uk
www.english-heritage.org.uk/maritime

PORTUGAL
The Nautical and Underwater Archaeology Division
Divisão de Arqueologia Náutica e Subaquática (DANS)
Avenida da India 136, 1300 300 Lisbon
T +21 36 16 546
cnans@ipa.min-cultura.pt
www.ipa.min-cultura.pt/cnans

SWEDEN
The National Maritime Museums
P.O. Box 27131, 102 52 Stockholm
T +46 8 519 549 00
F +46 8 519 548 94
registrator@maritima.se
www.maritima.se

MACHU (Managing Cultural Heritage Underwater) was a three-year project involving seven countries (see above) sponsored by the European Union's Culture 2000 programme.

The primary goal of the MACHU project was to find new and better ways for effective management of our underwater cultural heritage and to make information about our common underwater cultural heritage accessible to researchers, policymakers and the general public. This was achieved through the construction of a web-based GIS application (for management and research) and an interactive website designed to increase access to our underwater cultural heritage for the general public, the citizens of Europe, thereby enhancing public support for the protection of sites underwater. Furthermore, by tackling the issues in a multi-country approach, MACHU promoted greater mobility of both data and researchers working on our common underwater cultural heritage. We believe that the project also contributed to cultural dialogue between and a mutual understanding of the culture and history of the countries involved. The MACHU project ran from September 2006 to August 2009.



FOREWORD

JUDITH VAN KRANENDONK

DIRECTOR-GENERAL CULTURE AND MEDIA, THE NETHERLANDS

For many years now, my job as Director-General for Culture and Media has occasionally brought me into contact with the cultural heritage underwater. Whenever something is brought to the surface, it usually makes the news. It is then that I am reminded that there is an entire world beneath the water, a world that takes us straight back to the past, our glorious maritime past. Like many other people here and all over the world, I associate underwater archaeology with the exciting and the unexpected - with the unknown, in other words.

But as well as being exciting, the unknown and the unexpected can also be a problem, for out of sight can mean out of mind. In a changing society where the sea bed is being exploited more and more, we sometimes forget about the unknown.

So it is very important that we gain more idea of the rich archaeological resource that lies beneath the water. And not only the very best bits - what we need is a good overview of what we are likely to find there, from prehistoric dugout canoes to Second World War submarines. This information will allow us to manage this unique part of our heritage properly and effectively. And it will enable us to persuade others to take it into account in their activities.

The European MACHU project aims to develop methods and techniques for more effective management of the underwater cultural heritage. It focuses above all on developing methods to give us an insight into the wealth of heritage sites under water, and on passing this information on to academics, policymakers and even the public at large, in Europe and also beyond. These methods include using new techniques to take a closer look at and in the sea bed, and using digital tools to link data and make them widely available to others.

Many stakeholders are involved: besides my own Ministry of Education, Culture and Science and the other seven partners in the project, these include geological and oceanographic institutes, universities, fishermen, sport divers and amateur archaeologists.

It was also decided that the project should be used to create more support for the management and protection of the cultural heritage underwater. A great deal of effort has therefore gone into presenting this often poorly visible heritage in an attractive way, a way that brings objects and wrecks to life, and gives them meaning. When this is done well, we find that a pile of wood can suddenly tell a story.

With this goal and approach, the MACHU project ties in seamlessly with the Ministry's objectives, as set out by the Minister, Ronald Plasterk, in Art for Life's Sake: Dutch cultural policy in outline. I should like to quote from this policy document to clarify my point:

> 'Culture contributes to making the Netherlands an innovative country. That contribution has become even more significant thanks to digitisation and mediatisation. It is important, however, that parties in the cultural sector work with one another and with others outside the sector.'

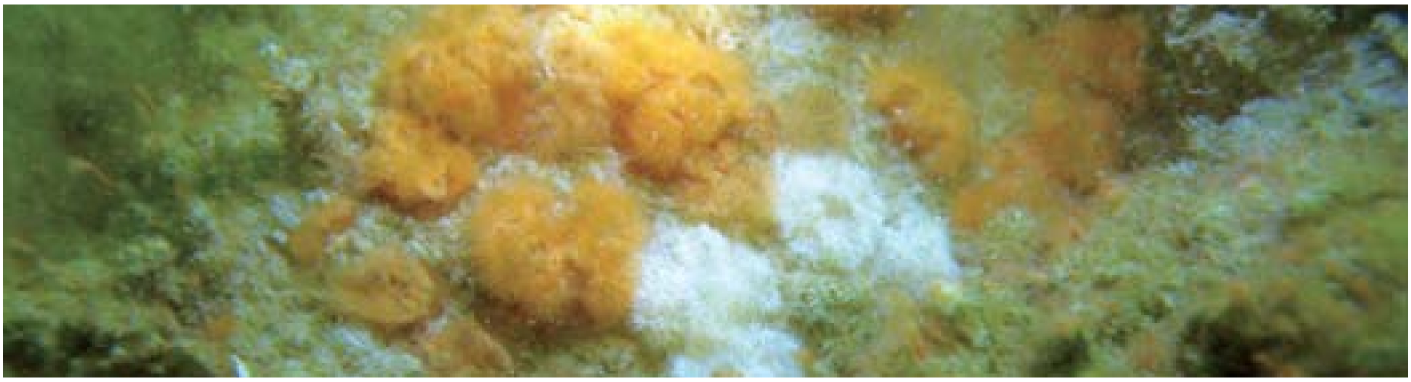
And:

> 'Digitisation [...] offers the culture sector opportunities in abundance for [...] opening up access to culture, and for enhancing its public appeal, with the younger generation using existing cultural resources in new ways.'

I am very pleased to learn of the excellent cooperation on this project between the Directorate-General for Public Works and Water Management and the Cultural Heritage Agency. Management has to be a joint effort, and both these departments at different ministries are important players when it comes to preserving and managing the cultural heritage underwater. Their collaboration has been entirely in the spirit of the agreement my fellow Director-General Bert Keijts and I signed in November 2007. I therefore have no doubt that, as the project results are consolidated and applied, this partnership will remain intact.

MACHU has done groundbreaking work on the management of and policy for the cultural heritage underwater. I should therefore like to congratulate everyone who has worked on the project on the results. I am convinced that, over the coming years, others will derive great benefit from what you have achieved. And I am not just talking about the research results. The strength of European projects lies in collaboration between different partners in different countries, with different cultures and knowledge and backgrounds. Make sure you keep up those contacts! ■

CONTENTS



STAKEHOLDERS, PARTNERSHIP AND INTERDISCIPLINAIRY RESEARCH: CASE STUDIES

MANAGEMENT OF THE UNDERWATER CULTURAL HERITAGE: NATIONAL PRACTICE

APPENDICES

INTRODUCTION

This is the final publication of the MACHU project. Over the last three years we have been searching for better ways to manage the underwater cultural heritage and to share it with a large group of interested people. The primary focus has been on finding solutions on a European scale. However, we think that the results can be used at all levels: local, regional, national, and even global.

All the partners in the project – most of them government agencies – have an official and central role to play in the management of the underwater cultural heritage. We are however very much aware of the fact that we cannot do this on our own or in isolation. Data we need for a better understanding of the natural environment are collected by other organisations.
The same goes for information about planned infrastructural projects that may cause a threat to archaeological sites underwater. Sites are constantly discovered and visited by other stakeholders, including sport divers. The national institutes also need each other, not only for projects like this, but more especially for the exchange of information on sites, because they are all part of one European heritage, and because many of them have a direct verifiable link to several countries. It is therefore interesting and also important to build relationships with each other, between professionals, and between professionals and amateurs.

MACHU has served as a network for cooperation and exchange. Exchange of data and information has occurred face to face, person to person, and also using more advanced techniques like an interactive website and a Geographical Information System (GIS). The information exchanged has been multidisciplinary, ranging from archaeological to geological and from geophysical to spatial planning. The MACHU project has made it possible for the partners, sub-contractors, assisting organisations and individuals to learn from each other and to improve their knowledge, and our overall knowledge, of the management and protection of the underwater cultural heritage.

New techniques for assessing and monitoring archaeological sites and their environment have been introduced and evaluated. Optical dating (OSL) was used successfully for the first time on sediment deposited underwater. Methods for predicting and monitoring erosion and sedimentation have been introduced and evaluated.

We are extremely satisfied with the results of the project and this final report is our way of sharing the knowledge gained.
This is the third MACHU report. Report 1 was published in January 2008 and Report 2 in January 2009. Both are still available as PDF files on the MACHU website.

We hope that the information gathered in the MACHU publications and on the website will be read and built upon in the management of the underwater cultural heritage and future collaborations in Europe. The MACHU GIS and the website will both continue to be used over the coming years. We will investigate the possibilities of continuing the cooperation we have established in another European project, but only then when there is a strong feeling that it would be useful, and we have good research questions to address. This will take some time. However, I should like to invite other institutes to contact us so that we can keep on building a network in Europe and use it as a basis for joined-up protection and management of our common underwater cultural heritage.

It only remains for me to wish you a pleasant read!

MARTIJN MANDERS
MACHU project leader

Structure of the MACHU project

MACHU was a three-year, EU-funded pilot project (Culture 2000: Grant agreement No. 2006-116) to find better ways to manage the underwater cultural heritage and to make data and information on this resource available to scientists, policymakers and the general public. The project started in September 2006 and ended on 1 September 2009. Because the underwater cultural heritage is by its nature an international matter, from the outset MACHU involved a group of Europe-based maritime partners or co-organisers: Belgium, Germany, England, Poland, Portugal, Sweden and the Netherlands. The Netherlands was project leader, responsible for overall organisation, and the project language was English.

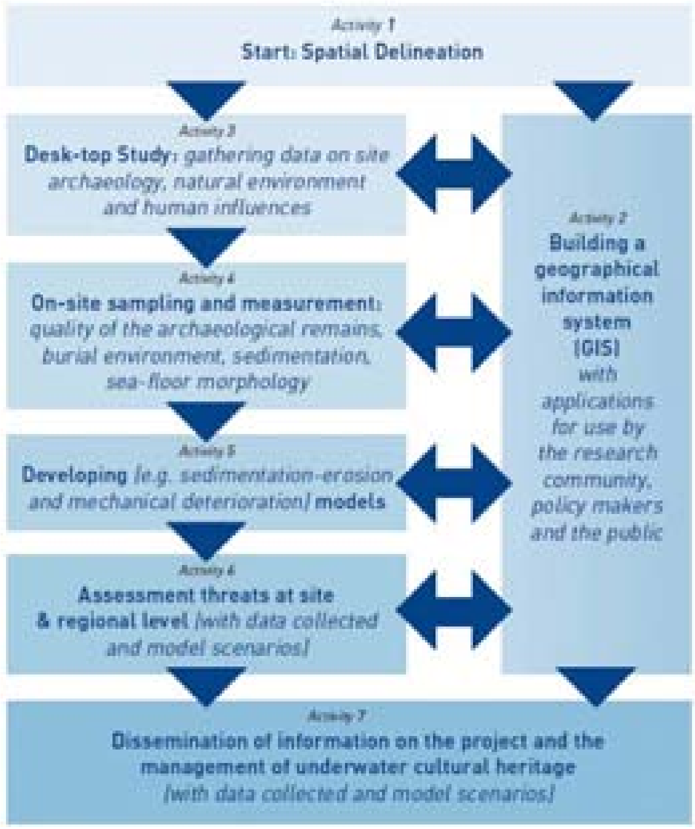


FIGURE 1 STRUCTURE OF THE MACHU PROJECT. SOURCE: MACHU

MACHU GOALS FROM THE OUTSET AS SET OUT IN THE EU PROPOSAL

GIS-BASED DECISION SUPPORT SYSTEM

MACHU had a set of objectives that were set out at the beginning of the project. The primary goals of the project were to find better ways to manage the underwater cultural heritage and to make data and information on this resource available to scientists, policymakers and the general public. This would be achieved through the construction of a GIS-based Decision Support System which would simultaneously act as a database for research and as a web-based interface for increasing awareness of our underwater cultural heritage among the general public, the citizens of Europe, all at low cost.

The specific benefits to the academic community would be to aid the exchange of data and information and thereby help develop research networks between different countries. On a broader European basis, the condition of sites on the seabed and information about research project development would become available to the academic community, helping to avoid duplication in research. One benefit to policymakers would be to develop best practice for the implementation of European Directives, such as the 1985 EIA[1] and 2001 SEA[2] Directives.

INFORMATION ACCESSIBLE TO THE GENERAL PUBLIC

Since a large proportion of the damage done to underwater sites is invisible to the general public, it is difficult to obtain support for protective measurements. Making site information accessible to the public would therefore inevitably engender a greater public commitment to the protection of sites, thus enhancing protection of our underwater cultural heritage. Furthermore, by tackling this issue on a multi-country basis, MACHU would inherently promote greater mobility of both data and researchers working in the field of our common underwater cultural heritage. The project would therefore also contribute to cultural dialogue between and mutual knowledge of the culture and history of the countries involved.

COLLECTING DATA

The GIS application would combine archaeological and historical data from sites and areas with information on the burial environment (including geophysical, geochemical, sedimentological and oceanographic data) and possible threats to the sites in the short term (e.g. erosion, infrastructural works, mining and fishing) and the longer term (e.g. increased erosion due to climate change and chemical degradation). Data were to be acquired both by desk-based studies of extant resources and by the acquisition of new data using new technologies and models that, until now, have been used only sporadically in the cultural sector.

MODELLING

Particular emphasis was to be placed on the physical influences on site formation and management, including the development of erosion-sedimentation models. These models would be developed on both a regional scale (via the manipulation of the data within the GIS system) and a site scale (through calibration of existing laboratory models using in situ data). The results from both would be iteratively fed back into the GIS application throughout the project.

FIGURE 2 The third MACHU meeting in October 2007 at the Polish Maritime Museum in Gdańsk. Source: WB.

MACHU ACHIEVEMENTS

GIS-BASED DECISION SUPPORT SYSTEM

The first objective: 'to create a GIS-based Decision Support System which will simultaneously act as a database for research' was partially achieved. The GIS application combines archaeological and historical data from sites and areas with information on the site environment.

The plan to develop a separate DSS – as an early warning system for possible threats to the sites in the short term (e.g. erosion, infrastructural works, mining and fishing) and the longer term (e.g. increased erosion due to climate change and chemical degradation) – was abandoned because the GIS system also functions as such. A MACHU GIS system was developed and is now fully operational. This system serves as a DSS, but the final decisions are left to the users of the GIS (researchers and policymakers). However, they can now access all the available data and are therefore better equipped to might the right choices.

The initial idea of automatically harvesting data needed for the GIS at source proved unrealistic, for several reasons. Though it is technically possible, to develop software to extract data and serve them in the MACHU GIS would be a project in itself. Besides the political and legislative complications it raises, it also falls outside the scope of this project. So the MACHU partners chose to deliver the data for the GIS from one central database. One drawback of this approach is that the continuous input of data is completely dependent on the willingness and efforts of the individual partners.

The database behind the GIS can also function as a database for scientific research by the international partners. To create a database to provide input for the GIS the MACHU partners had to design a framework. Using this framework, the MACHU GIS can easily be used in a broader network of future maritime partners all over the world.

INFORMATION ACCESSIBLE TO THE GENERAL PUBLIC

To facilitate the MACHU GIS a special MACHU website was created that can function as a platform for underwater cultural heritage for the benefit of the general public.

The website also gives extra information for policymakers and the scientific community: the flesh on the bones of the scientific data that are provided through the GIS. The GIS viewer is available on a limited-access part of the website. Besides the GIS and the extra information, the also website functions as a communication platform for the MACHU partners.

WORK AND ORGANISATION

A project combining many different fields of research needs to be well planned and designed in advance. The structure of the project, rules and responsibilities, contracts, the project proposal, work formats and budget planning were all included in the MACHU Handbook that was handed out to the partners at the start of the project. The MACHU project was structured as seven work packages or activities, according to a predefined plan.

ACTIVITY 1: SPATIAL DEFINITION

Objective: To have a well-defined plan for achieving realistic goals under the three-year programme.

The first activity was the organisation of the project. The lead organisation and coordinator was the Dutch Cultural Heritage Agency[3]. To monitor the project, every six months a meeting was held to discuss the progress and objectives of the project as a whole, progress with the MACHU research, and the progress made by individual MACHU partners. The first meeting was held in the Netherlands, the second in Portugal, the third in Poland, the fourth in Germany, the sixth in the UK and the seventh in Belgium. The final meeting was held after the final symposium held in Amersfoort, the Netherlands, on 4 June 2009. At least two staff involved in the project from each country had to be present at each meeting for decisions to be taken.

Each country also provided an activity report and a financial overview every six months to allow the progress of work on the project to be monitored at the level of the participating partners.

This made it easy to foresee problems. The system of evaluating and monitoring the project every six months meant definition was an ongoing process, and details could be changed in order to come up with the best and most realistic solutions. The close contact throughout the entire project with the EACEA (Education, Audiovisual & Culture Executive Agency), which audited the project at European level, was also important.

ACTIVITY 2: BUILDING A GEOGRAPHICAL INFORMATION SYSTEM

Objective: To create a working GIS as a tool for the management of the underwater cultural heritage, facilitating scientific data exchange and site management.

To create an internationally usable system the MACHU partners spent several meetings thoroughly discussing what should and should not be depicted in the MACHU GIS. Because a GIS viewer has to harvest data from a database, the database itself had to be described. Defining the records and fields in the underlying database was an important but difficult process. The final changes to the formats were made at the Poland meeting in October 2007, the outline of the formats having already been agreed at the meeting in Lisbon in

March 2007.

In accordance with the plan, the actual building of the GIS was put out to tender. Grontmij, a sub-contractor, was eventually commissioned to build the GIS viewer according to MACHU specifications. Development of the GIS started in the second half of 2007 and was finished by May 2008. RWS coordinated the technical side of the operation. All partners have agreed that, with a code of practice, the MACHU GIS (plus sedimentation-erosion models) can function as a framework for a DSS[4].

Results: The objective of delivering a working GIS with several layers of underwater cultural heritage features was successful, and the system is now up and running. RWS is currently working on version 2.0.

ACTIVITY 3: DESKTOP STUDY

Objective: To gather the relevant data on degradation, protection, monitoring and overall management of the cultural heritage underwater and make it available for the GIS

Because of the physical extent of the underwater world and underwater cultural heritage sites, the project was limited from the start to specific (small) test areas designated by the partner countries. A desktop study was performed to identify what kind of data were already available for the MACHU project. All wrecks and sites within these areas were to be described thoroughly, in archaeological, historical, biological, geological and other terms, to create an overall picture of threats and opportunities in the test areas. All the data were collected and entered in the MACHU GIS.

Results: The available data on degradation, protection, monitoring and overall management of the cultural heritage in the designated areas have been collected. Data and information have been made visible in the MACHU GIS and on the website.

ACTIVITY 4: ON-SITE SAMPLING AND MEASUREMENT

Objectives: To gather the data on the burial environment, degradation and the impact of erosion and sedimentation necessary for the protection, monitoring and overall management of the cultural heritage underwater. The information on erosion and sedimentation will also be used to validate sedimentological models.

Shipwrecks have been monitored in studies of various factors (salinity, flow current) at several sites (i.e. the Wadden Sea, Baltic Sea) in other projects, including MoSS and BACPOLES.[5] These studies were performed to estimate the influence of the parameters measured on the degradation of wrecks. The studies proved successful at a lower level, and the idea was to incorporate such data, gathered with dataloggers, into the MACHU project. However, the practical implications of this became quite clear when we started actual work on the MACHU project. Dataloggers are not only rather expensive to buy and maintain, installation using professional archaeological divers is also a costly activity. It was therefore decided that we would not use dataloggers in the MACHU project, and would leave it to the individual partners to establish how data about the environment could be extracted from other sources.

Several new and existing techniques for on-site sampling were used. Specific research was conducted on site: mainly bathymetric measurements (e.g. side-scan sonar, multibeam, seismic), but also coring and other forms of sampling. The results were used to model sedimentation and erosion to provide input for the GIS and the website, and to evaluate different techniques for monitoring and assessment.

ACTIVITY 5: DEVELOPING MODELS

Objectives: To be able to predict changes in certain areas for a proactive approach to protecting the underwater cultural heritage. To use data from the past and present to predict sedimentological and mechanical deterioration in the future.

New techniques have been developed and tested in the MACHU project. The development of a sedimentation-erosion model has provided an interesting and useful tool for managing the underwater cultural heritage in the future. Large-scale and site-level models

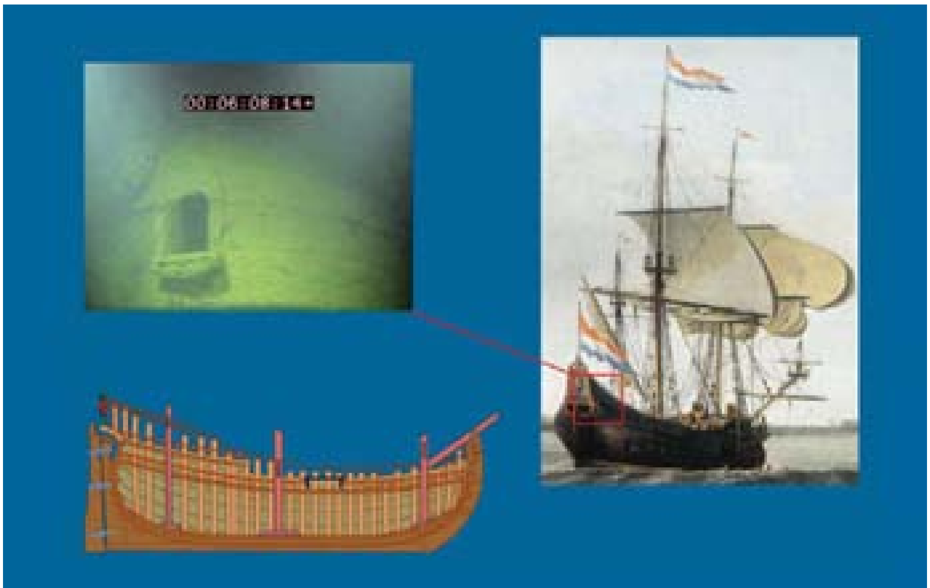


FIGURE 3 Collecting data is an ongoing process, depicted: to the left a ROV image of the Ghostwreck to the right a painting of a fluytship left bottom line drawing of a fluytship. Source: MACHU website

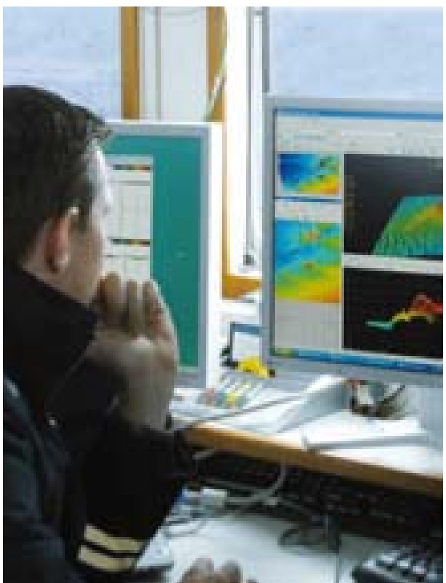


FIGURE 4 Specific research was conducted on site: mainly bathymetric measurements. Source: MACHU

were investigated, with varying degrees of success (see p. 48 and 54). OSL was applied not only to coastal sediments on land, it was also used for the first time in a submerged environment, to investigate sand layers that have formed underwater.
Historical maps have been digitized and geo-referenced and entered in the MACHU GIS. These maps can now be used to predict where to expect wrecks and other archaeological sites, on the basis of sediment movements in the past. Poland, in particular, has already input an extensive range of maps of the Gdańsk Bay area (see p. 85).

Results: On a regional scale a sedimentation-erosion model for the southern part of the North Sea has been developed and incorporated into the MACHU project. The use of site-level models was investigated using the wrecks on the Burgzand sandbank in the Wadden Sea. They were evaluated by multibeam recording. A start has been made on inputting the historical maps of the Gdansk Bay area in Poland and parts of the Netherlands (Wadden Sea and Zeeland). The first results are visible in the GIS.

FIGURE 5a A historic map of the Gdańsk harbour area from 1674.

ACTIVITY 6: ASSESSMENT OF THREATS AT SITE AND REGIONAL LEVEL

Objective: To be able to predict the severity of threats to underwater cultural objects or areas, and establish the urgency of protective measures.

Field sampling and assessments were carried out at the sites chosen in the various countries as test locations. Site sampling and measurements were planned to obtain an up-to-date picture of threats to underwater sites and the influence of geological, biological and human interference. Archaeological monitoring surveys were performed by the partners themselves.[6] But by no means all these research activities were carried out by the partner institutes. One important objective of the MACHU project was to use data from and cooperate with third parties and stakeholders, including avocational divers, and navy or hydrographical institutes, which provided multibeam and side-scan sonar data. The Swedish MACHU partner conducted a survey to establish which wrecks were visited by scuba divers in the Stockholm archipelago. On the basis of this survey, fieldwork was organised in order to assess the most frequently visited wrecks, to establish the impact of diving activities on wrecks.

Most countries took bathymetric measurements using multibeam, side-scan sonar and sub-bottom profiling to assess threats to the underwater cultural heritage. The final report includes articles on this work from the Netherlands (Manders, p. 59 and p. 71), Portugal (p. 108), and Belgium (p. 56). Large-scale models of the Goodwin Sands were also used (See Dix et al., p. 51).

Results: An evaluation of threats to underwater sites and the results of different kinds of research are presented in the Research layer of the MACHU GIS. The widespread use of multibeam surveys by hydrographical and other institutes can be a very useful and cost-effective way of monitoring wrecks and sites.

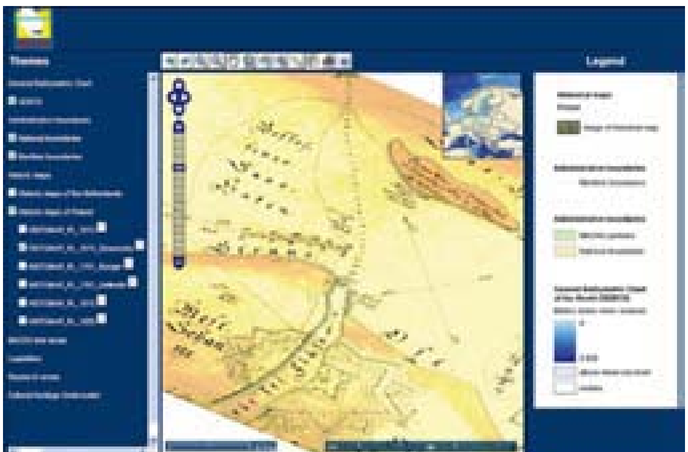


FIGURE 5b A geo-referenced historic map of the Gdańsk harbour area in the MACHU GIS. Source: MACHU GIS

FIGURE 6 Cooperate with third parties and stakeholders, avocational divers.

ACTIVITY 7: DISSEMINATION OF INFORMATION ON THE PROJECT AND MANAGEMENT OF THE UNDERWATER CULTURAL HERITAGE

Objectives: To inform the scientific community, policymakers and the public about the project. To build and maintain a website to inform people about the project and the progress made. To produce a publication detailing the progress made over the three years of the project. To publish a general and a scientific final report.

The MACHU website has been created to function as a platform for the underwater cultural heritage. News items and information on wrecks, sites and the project have been published on the site. Three MACHU reports have also been published, presenting information on the project, objectives and work carried out. Other publications have been produced in the partner countries. There was media interest, and several publications, radio and television stations have carried items on the project. Articles, films and radio interviews can be downloaded in the publications section of the website. The site also has many links to items on various aspects of the underwater cultural heritage in all the partner countries. MACHU has also been mentioned in several other articles, books and incorporated into undergraduate research at universities/university degree courses[7]. A book on underwater archaeology for children called Martijn en de Geheimen van het Scheepswrak ['Martijn and the Secrets of the Shipwreck'] has also been published. It is currently available only in Dutch[8].

MACHU has been presented as a useful international uniform method for describing and exchanging data on the underwater cultural heritage at a number of important archaeological and maritime symposia (World Archaeological Congress in Dublin, European Maritime day in Rome). To gather information and data on the underwater cultural heritage is one thing, but to get the word across is another very important aim of the MACHU project. A lot remains to be done.
Results: The MACHU website has been designed as a platform for the research community, policymakers and the public. The GIS is available, and a DSS has been published on the website in the form of a code of practice.

CONCLUSION

Most of the objectives of the MACHU project have been achieved, but some had to be changed during the project so as to make them more useful and bring them into line with the rest of the project. There is a working GIS with several layers describing the underwater cultural heritage in detail. The internationally agreed uniform formats used to built the GIS are unique. A DSS based on a piece of software to be developed together with the GIS proved to be a bridge too far for this pilot project. The GIS and the MACHU project as a whole can be seen as a DSS, with best practice available on the website for stakeholders.

The collaboration between European countries, with so many differences and similarities, was very inspiring, and sometimes difficult. The time chronology of historical periods was, for example, a difficult issue. Sweden has no Roman period, for instance.

Other more general difficulties included language, division of responsibilities, cultural differences, and differences in communication and approaches to problems.
We noticed during the project that there is clear pressure on cultural heritage agencies in this age of privatisation, economic crisis, and the introduction of Malta archaeology throughout Europe. The project had to deal with reorganisations, changes in the names of institutes, in personnel and responsibilities, and in government structures. Since 2006 the institutes involved have come under increasing pressure to get more done, and bring in more money from other (non-governmental) sources, all with fewer people. This observation has given us cause for concern.

NOTES

1 Council Directive of 27 June 1985 on the assessment of the effects of certain public and private projects on the environment (85/337/EEC).
2 Council Directive on the assessment of the effects of certain plans and programmes on the environment (2001/42/EC).
3 The Agency was called the RACM until 2009, and resulted from a merger between the former Department for Conservation (RDMZ), and the National Service for Archaeological Heritage (ROB).
4 See also MACHU Report No. 2, p. 24, The concept of Decision Support Systems, and relevance to the MACHU project.
5 See for the MoSS projectwww.mossproject.com and BACPOLES www.bacpoles.nl.
6 See for the results MACHU Reports 1 & 2.
7 See the publications section of the MACHU website.
8 Martijn en de Geheimen van het Scheepswrak (Amsterdam 2008). ■

FIGURE 7 Explaining MACHU fieldwork on Dutch television. Source: MACHU

FIGURE 8 A travelling exhibition; buckets full of stories; MACHU at the maritime & jutters museum Texel. Source: MACHU

DATA EXCHANGE: A GEOGRAPHICAL INFORMATION SYSTEM AND A WEBSITE

To establish whether a site is in danger of deterioration or not, or if a site is of major archaeological importance, one needs to take a lot of information into consideration. So it would be ideal to have a single system at our disposal that contains all the information we need and presents it in a structured way. This is what we had in mind when we started developing a Geographical Information System as part of the MACHU project: a platform and a tool to combine and interpret data from archaeological sites underwater.

The GIS soon became an important part of the project. From the start in 2006, a great deal of effort went into developing the building principles, identifying the functional needs, specifying the necessary map layers and data formats, collecting and processing data, constructing web services and actually building the MACHU GIS web application. Earlier articles in MACHU reports I and 2 focused on the process. Here we present the final results achieved over the project period. The GIS will continue to be developed after the project, as we continue to learn by using the system. What we have learned during the project may be of use to future researchers planning to do the same kind of thing or, even better, to build upon what we have learned.

More information on the GIS can be found on the MACHU website: www.machuproject.eu/gis.htm.

The MACHU GIS consists mainly of objective data that still need to be interpreted. It is not a tool for addressing the public and creating awareness of our underwater cultural heritage. The MACHU website was created for this purpose. Besides explaining more about the MACHU project, the site also present tales of our common maritime history, using all sorts of visual communication methods.
The article on the MACHU website describes how the website evolved and what theoretical knowledge was taken into account, as well as describing the eventual result. ■

Building a Geographical Information System in MACHU

BUILDING A PLATFORM

One of the biggest issues in managing the cultural heritage underwater is how to combine all the data and information that is needed to manage this resource in a responsible way. Obviously this was also a key issue when we started the discussions about the MACHU project in 2005. It was decided to create a kind of exchange platform. This platform had to be able to view all the data linked to a geographical location no matter where the original data was stored. And so the idea of the MACHU GIS was born. It also needed to have the functionality to query the data based on its geographical location or administrative characteristics. A theoretical solution to access data was found. For the presentation of information ('translated' data for specific purposes and stakeholders), we came up with a connected website full of stories and visual aids (See also *Machu as a gateway to the Underwater Cultural Heritage*, page 31-36).

But why would we as MACHU partners and stakeholders want to combine all this data and information? What is the advantage of such an exchange platform?

There are several reasons why we need a platform for exchanging data and for making information about our cultural heritage underwater available:

FIGURE 1
Main water systems of the Netherlands.

- Governments are responsible for the management and protection of their underwater cultural heritage (UCH). They need to have access to the data and information that is important in executing this task.
- It is not easy to create an instant overview of the amount, quality and accurate position of the UCH. In fact, the sites underwater are highly invisible. Not only because they lie beneath the water surface, but also because many – if not most – of these sites are presently buried in the seabed. It takes a lot of creativity and circumstantial information to predict the possibility of finding archaeological sites in the seabed.
- The Treaty of Malta involves many different stakeholders in the protection and management of the UCH. Lots of data are collected and stored in different places. Much of it could be used for other (research) purposes too. However, until now, most of this valuable information has remained inaccessible.
- It is hoped that access to data about the underwater cultural heritage will encourage more stakeholders to acknowledge the need to protect this resource, or at least manage it responsibly.
- The seabed can be extremely dynamic. It is therefore important to have recent data available all the time. These data also need to be managed by the organisations that have a responsibility to do so. Information about shipping lanes, for example, needs to be managed by the Dutch *Rijkswaterstaat* (RWS)[1] and similar authorities in other countries. They often have the latest information which they can immediately (and automatically) present to others.
- Having the right information available in decision-making processes (political, policy and infrastructural, for example) will ensure that the right decisions are made and the cultural heritage is automatically considered in the process, rather than at too late a stage or not at all (which might frustrate the economic processes and the stakeholders involved).
- Having a platform for data exchange is also cost-effective, since it will diminish the likelihood that data, such as multibeam echo sounder recordings, are collected twice.

The exchange platform that we as MACHU partners wanted to create would be a Geographical Information Systems (GIS). A GIS is a system that can capture, store, analyse, manage and present all kinds of data that are linked to a location (see for further information *'Geographical Information System'*, p. 20). As part of the system we needed a GIS viewer for comparing different kinds of data at one location, for example near a wreck or site.

Within the MACHU project, RWS was assigned responsibility for actually building such a GIS viewer. RWS not only had the required knowledge and expertise, more importantly, it would also benefit from the information the viewer could present. In contrast with the other MACHU partners, RWS is not the national authority responsible for the cultural heritage. Its main responsibility is the management of the Netherlands' infrastructural facilities and, as such, RWS is the largest manager of underwater beds in the Netherlands. This means that it shares a responsibility (with the RCE) for most of the Dutch cultural heritage underwater.

Some examples where RWS might use such a GIS viewer are large-scale infrastructure projects like the wind farms in the North Sea or land reclamation work, as in the second Maasvlakte project to extend the Port of Rotterdam. These projects need a lot of research and planning at the beginning, addressing questions such as 'what is the best place?', 'where do we build?', 'where do we extract sand from the sea?' etc. A MACHU GIS viewer could compare all the data, propose the most suitable places to carry out work and identify the implications of doing so.
Another specific example where RWS might use the GIS is in the dredging of the North Sea channel or the Western Scheldt: shipping lanes that have to be deepened to create access for larger vessels. We know where to dredge, but what can we expect? Obstacles? How many? Any of archaeological importance? Other things, like gas pipes or peat? It is important to know about the latter because there is the possibility of upwards movement of the deeper soil.

If governmental organisations like RWS have access to as much information as possible about the cultural heritage underwater, it will certainly save the taxpayer money.

Due to the success of MACHU, *Rijkswaterstaat* agreed to continue its involvement in the MACHU GIS viewer and its further development. Moreover, by way of an even stronger commitment, RWS will integrate the MACHU GIS viewer into its own architecture. This guarantees the continuation of the MACHU GIS viewer after the project ends, and even more functionalities and data will become available in the future. It agreed to remain involved because of its firm belief in the product. To guarantee the involvement of the other current and future partners, a functional management group will be set up. See 'Application management' for further information p. 27. ■

SOME FACTS ABOUT RIJKSWATERSTAAT

Source: Annual Report Rijkswaterstaat 2008

Rijkswaterstaat is the executive arm of the Dutch Ministry of Transport, Public Works and Water Management. On behalf of the Minister and State Secretary, *Rijkswaterstaat* is responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands.
Rijkswaterstaat manages the country's main road network, main waterway network and main water systems. It is responsible not only for the technical condition of the infrastructure but also, and especially, for its user friendliness. It facilitates the smooth and safe flow of traffic, keeps the national water system safe, clean and user-friendly and protects the country against flooding.

LAND-BASED INFRA-STRUCTURE UNDER RIJKS-WATERSTAAT MANAGEMENT

- Lanes under management (in km) 5,734
- Road traffic control centres 6
- Tunnel complexes 14
- Rush-hour, buffer and additional lanes 25
- Movable bridges over water 59
- Fixed bridges over water 658
- Other bridges 2,539

WATER-BASED INFRASTRUCTURE UNDER RIJKSWATERSTAAT MANAGEMENT

- Main water system (in km^2) 65,250
- Dikes, primary water defences (dikes, dunes, dams, engineering structures, foreshores) (in km) 325
- Storm-surge barriers (in km) 4
- Waterways (in km) 4,378
- Coastal waterways managed in North Sea (in km) approx. 4,100

FORMATS FOR COMMUNICATION

As stated in the introduction, MACHU is a platform for exchanging information on our common underwater cultural heritage.

An important part of this information is embedded in data files, collected and stored in many different places and in different data formats. These data formats could be considered the language of the data, which enables us to define and understand its content. It is only possible to communicate if we use the same language.

In this section we focus on the use of data formats that have been developed for the exchange of information through a 'Geographical Information System' (GIS).
The MACHU GIS itself will be discussed in the section entitled 'Geographical Information System' (p. 20).

WHY USE MACHU DATA FORMATS?

Data formats are used for regulating the flow of information. Data formats make it possible to harmonize the content of exchanged information and to implement the technical requirements necessary to process the data in a GIS.
Defining data formats for MACHU makes it possible to register information that is com-

monly felt to be of importance to the management of the cultural heritage underwater. In 2004, the Culture 2000 MoSS project,[2] set up with the aim of monitoring, safeguarding and visualizing shipwrecks, provided a template for storing management information. This template has served as an important source of information for defining the content of the MACHU data formats.

The use of MACHU data formats is very different from that in the MoSS management plan template. Like the MoSS Management plan template, the MACHU data formats help to collect and record important management information. This information is however stored in a format that includes a spatial reference. It can therefore be combined and studied with other data, in terms of their spatial relationship.

As more information comes available and can be studied in this way, so we will gain more insight into the circumstances of the cultural heritage and useful information on which to base management decisions.
The development of the data formats has been tied closely with the development of a Geographical Information System for MACHU.

MAIN CHARACTERISTICS

The data formats for MACHU have been constructed for use as layers in a GIS platform. This means that the formats share some common characteristics.

Map layers in a GIS represent real world features. These features are commonly presented in two abstractions: discrete objects (e.g. wreck sites) stored as vector data (points, lines or polygons), and continuous data (e.g. seabed elevation) stored as raster data. Each feature should be represented by a suitable abstraction. The information related to these features can be stored in attribute tables (or cell values in the case of raster data). The way attribute tables are built up influences the potential uses of the data in a GIS. For example, the format of the attributes determines storage capacity (data type) and, therefore, the potential for querying the data or using the content for presentation. To provide better data query possibilities, it is useful to standardise values of attributes that represent the same features but are created by different partners. These values are laid down in domain tables.

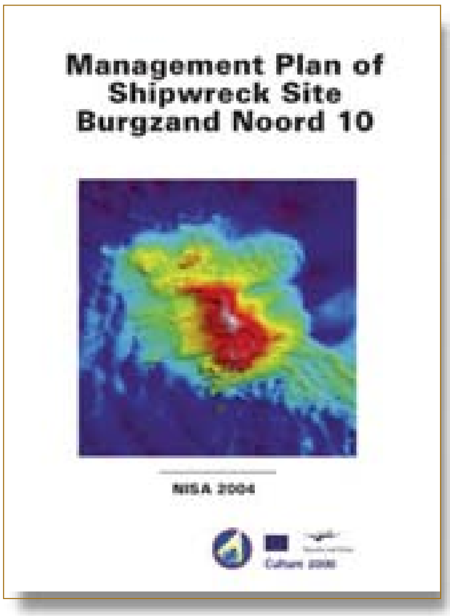


FIGURE 2 Example of a MoSS Management Plan.

To present features in a GIS they have to be geo-referenced and presented in a common reference coordinate system. All data in MACHU are referenced according to the World Geodetic System (WGS84) dating from 1984 (revised in 2004). WGS84 is the reference coordinate system used by the Global Positioning System (GPS) and commonly used for nautical charts all over the world. Using a global position system also provides the opportunity to incorporate data beyond European borders.

The MACHU formats as described are based on the use of the ESRI shapefile format[3] (for vector data) and GeoTIFF[4] (for raster data). Examples and pre-shaped shapefiles have been made available for partners on the MACHU website. The MACHU data formats were based on these file formats because they can be used within, or created by, many widespread GIS platforms (e.g. ArcGIS (ESRI),[5] Mapinfo (Pitney Bowes),[6] GRASS (OSGeo).[7] The use of these single file types was intended to give partners the possibility to exchange data easily at an early stage of the project.

The MACHU data are only complete when they also contain metadata. Metadata is information on the dataset itself, like a content description, information on data quality, restrictions on use and contact information. MACHU complies with the INSPIRE implementation rules for metadata (see 'Building principles', p. 21).

FORMAT DESCRIPTIONS

Given the time constraints and technological limitations of the individual partners, the scope had to be reduced to a limited number of GIS layers. As a result, it was decided to start focusing on the establishment of the following layers:

- Archaeology (Cultural Heritage Underwater), containing information on cultural heritage sites underwater;
- Research areas, representing the available research data;
- Legislation, containing legislative information related to cultural heritage management;
- Bathymetry, presenting the bathymetry of the seabed;
- Administrative boundaries on land and at sea;
- Sediment mobility, presenting sedimentation and erosion on the seabed based on a model developed within the MACHU project.

The layers represent important management information. The available information on most of these subjects is recorded differently in each country. In order to be able to merge the information from different sources into single GIS layers, and to be able to update the data on a regular basis, common data formats are crucial.
Not all layers needed a detailed data format description. After the desired content of each layer was clear, it was found that some of the layers could be covered by existing datasets, coming directly from expert institutes. The use of these datasets provided good-quality and up-to-date information for all countries, and made it possible for partners to focus on the remaining layers.

ARCHAEOLOGY FORMAT

The archaeology layer contains information on archaeological sites or objects. These sites are geographically recorded as point features, based on an xy-coordinate pair (in WGS84). A point represents the location of the centre of the site.

The attributes of the archaeology format are mainly based on a collection of information elements originating from the MoSS management plan. The format now consists of 30 attributes, including descriptive information on the site, assessment information, competent authorities, geographical coordinates, protection, threats, and information references (for instance to its management plan). Each site location has been given a unique identification number that should support communication but also create the opportunity to establish a relationship with other data sources in the future.

A special symbol set has been created for this layer to present sites based on object type and degradation status in the GIS.
A complete format description and a list of domain values can be found in appendix 1.

RESEARCH AREAS FORMAT

The Research area layer contains information on research areas, these being areas where research has taken place whose results are expected to be significant for the management of the cultural heritage underwater. Research areas are recorded as polygon features, where each research area is presented as a separate polygon (or several polygons if one study covers a dispersed area).

Research results often consist of huge data files (e.g. multibeam readings) that cannot easily be exchanged through a web-based GIS. The research area layer should therefore make it possible to indicate the availability of research information, rather than presenting the source data itself. Source information (metadata) should make it possible to recover the actual source data when needed. Because an area might be the subject of more than one study, polygons in the research area may overlap.
The format consists of eight attributes containing a brief description of the kind of research and research period. It also contains a reference to an image that can be used to present the results of the research in the GIS. The images should be geo-referenced (e.g. as GeoTIFF) and made available together with the research areas dataset.
A complete format description and a list of domain values can be found in appendix 1.

LEGISLATION FORMAT

The Legislation layer contains information on rules and laws pertaining to the cultural heritage underwater. Legislative areas are recorded as polygon features, where each rule or law is presented as a separate polygon (or several polygons if a rule or law applies to a dispersed area).
Legislative areas can cover legislation on international, European, national and sub-national level, and the polygons in the legislation layer may overlap. The legislative datasets of each country (partner) are limited to the area within its maritime and terrestrial boundaries.
The format consists of ten attributes containing information on each specific rule or law, its status, the competent authority and a brief description of its content.
A complete format description and a list of domain values can be found in appendix 1.

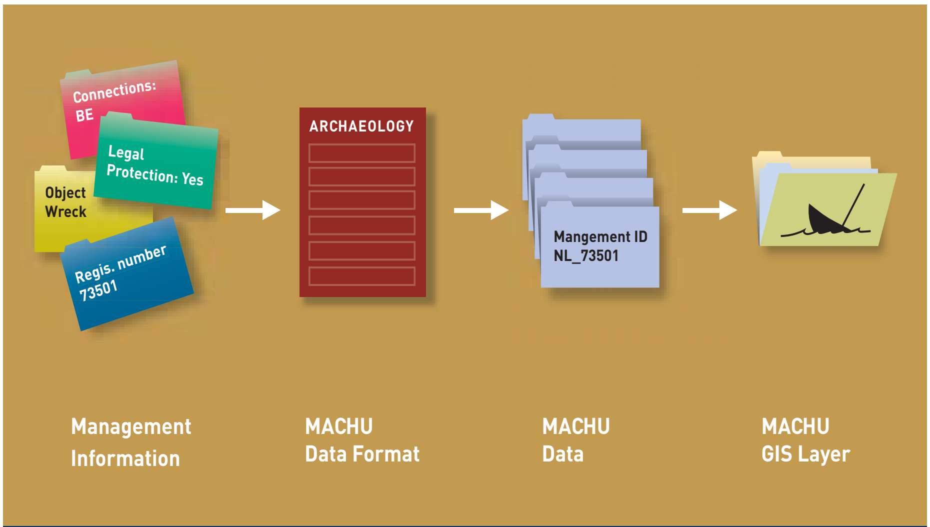


FIGURE 3 Using MACHU data formats to organise management information.

BATHYMETRY FORMAT

Bathymetry should be made available on two different levels: general bathymetry on a broad scale, and more detailed bathymetry on a local (site) scale.
On a local scale, this information can be made available in the Research area layer, using the Research area format. As explained in the section on the Research area format, bathymetric data can consist of huge files that are not easy to exchange through a web-based GIS. As an alternative, bathymetry measurements can be added to the Research area layer and bathymetry charts can be presented as images. Because there can be a great deal of variation in bathymetry at different locations, it is not practical to create one common legend for all these images. Instead, it has been agreed that suppliers will use a logical colour range to present different depths. Bathymetric data should be presented in rainbow colours, using dark red for shallow waters (high values) to dark blue for deep waters (low values). There is also an option to add the local legend to the image, preferably using Lowest Astronomical Tide (LAT) as a common reference. More information on the original data sources should be made available through the metadata.

The overall bathymetry should give an indication of the bathymetry on a broad scale, and can therefore be presented with less detail. This layer is covered by the General Bathymetric Chart of the Oceans (GEBCO), distributed by the British Oceanographic Data Centre (BODC)[8] on behalf of the Oceanographic Commission. The GEBCO is a One Minute grid, meaning that it provides bathymetry data on a global grid with a one arc minute spacing. The grid is a continuous digital terrain model for the ocean and land. Using this grid, it will be possible to identify depth (metres below mean sea level) in the GIS.

ADMINISTRATIVE BOUNDARIES FORMAT

The administrative boundaries layer should contain information which allows the user to identify national administrative boundaries (terrestrial and maritime) for orientation.

The most practical way to achieve matching boundaries for different countries was to obtain them from a single dataset. The best freely available dataset found was the Global Administrative Unit Layers (GAUL)[9] dataset of the United Nations Food and Agricultural Organization (FAO), which contains national boundaries worldwide.

The best available dataset that was found for representing national maritime boundaries was the Maritime Boundaries of the Oceans dataset distributed by Flanders Marine Institute (VLIZ).[10] This dataset contains the Exclusive Economic Zone (EEZ) of each country worldwide.
The administrative boundaries are also used by some partners to represent some of their legislative boundaries in the legislation layer.

SEDIMENT MOBILITY FORMAT

There is no format available yet for the sediment mobility layer. This layer will contain results from the hydrodynamic model developed for MACHU by the University of Southampton. (See 'Sedimentation-erosion modelling' p. 56). The model produces a motion picture of seabed movements. This will provide insight into the risk of sedimentation and erosion processes (on a broad scale) at sites on the seafloor. Snapshots of the seabed in motion, comparable to bathymetry images, can be taken at specific intervals and presented in the GIS. The exact format that can be used will depend on the results the model produces. As work on the model is still ongoing, this layer has not yet been established, but it is expected to be available in the last quarter of 2009. At this stage, the model covers an area including the North Sea, the Channel and part of the seas surrounding Ireland and Great Britain.

OTHER DATA FORMATS

A temporary format was created for the MACHU test areas. The MACHU test areas layer is used to display the areas where each partner focused their research during the initial phases of the MACHU project. Concentrating data collection into specified areas was necessary to make sure that the data collected would have a spatial correlation. This layer will fulfil no purpose after the project.

New formats could be created if partners wish to combine information on new issues in new layers or if present formats need to be updated. At the end of the project some new layers with historical maps were added. Because it was not possible for the partners to deliver this information in a common way at that time, no format description was made and the layers are presented differently by the individual partners.

GEOGRAPHICAL INFORMATION SYSTEM

MACHU & GIS

Much of the information that is important for the management of the cultural heritage underwater has a spatial component and is therefore related to a specific location or area. This again means that it is possible to link this information to other area-related subjects.

For example, a shipwreck is located at a certain location on the seabed. Depending on the location, there may be conditions that directly affect the state of the shipwreck, like human activities (e.g. shipping, dredging, fishing, construction of wind farms, looting) or natural processes (e.g. sedimentation-erosion of the seabed, biological degradation by shipworm). The state of the shipwreck might also be subject to indirect influences, such as legislation concerning the surrounding area or measures taken to preserve the wreck site. The location of the ship remains combined with information on historic events, or environmental conditions in the area may help to reveal the history of the ship and how it came to its end.
Besides the available information on the wreck itself, all these area-related factors should be taken into account when decisions are made on the management of a wreck site. It is therefore necessary that this information can be combined and consulted with reference to its spatial correlations. This can be done using a Geographical Information System (GIS). Recognising the significance of a GIS for cultural heritage management underwater, one should also be aware that a GIS is a concept that encompasses a wide range of geographical data processing, up to highly sophisticated data editing and analysis. Within the MACHU project the focus was on creating a tool that would allow cultural heritage managers to exchange, combine and consult relevant information.

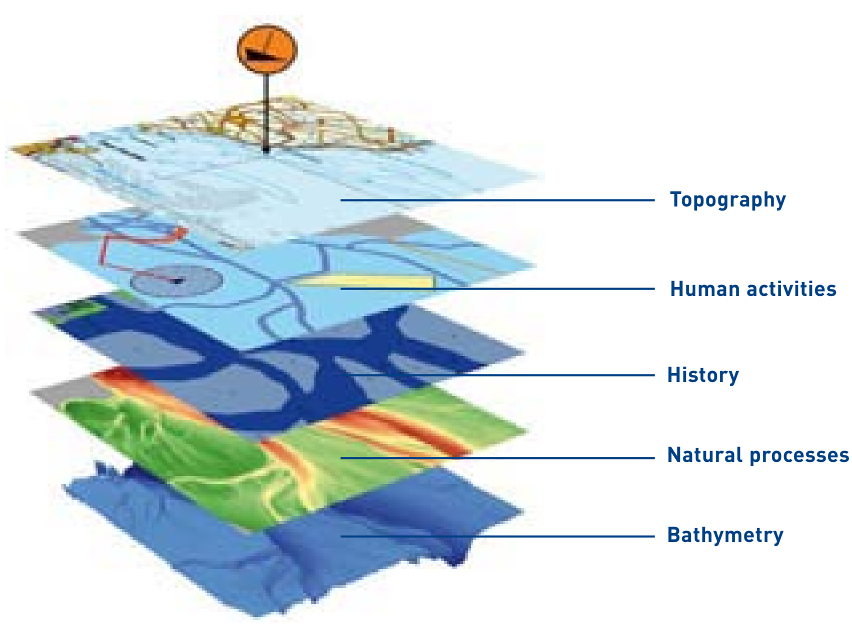


FIGURE 4 Example of spatial relationships between a shipwreck and its surrounding area, presented as map layers in a GIS.

In creating a GIS that can serve this purpose on a European level and for a considerable period, there is a lot to be considered, including how to make the tool accessible to many users in different organisations across Europe, the functional needs of the users, what data it should contain and how to organise maintenance of the system. These are subjects that will be discussed in the following sections. The MACHU GIS was set up as a prototype to be created during a three-year project with the objective of ongoing maintenance and development.

BUILDING PRINCIPLES

Before the actual building of a GIS could start, the building principles had to be clearly defined. The basic ideas on how a GIS for MACHU should work would have to be supported by all partners. This paragraph contains a summation of the main issues.

INSPIRE, THE EUROPEAN FRAMEWORK

To be able to exchange information, it is necessary to use a common exchange platform. From the beginning it was clear that the MACHU GIS, being a European platform, should be based on European standards. It was therefore clear that MACHU should join another European initiative aiming to create a European framework for the exchange of spatial data, known as INSPIRE.[11]

INSPIRE stands for 'Infrastructure for Spatial Information in Europe'. It is a European Commission initiative to build a European spatial data infrastructure (ESDI) that allows a variety of users to identify and access spatial data from a wide range of sources across Europe. The INSPIRE objective is to establish an ESDI through the use of integrated spatial information services (geo-services), based upon a distributed network of databases, linked by common standards and protocols to ensure compatibility. The MACHU basic principles appeared to correspond very well to this INSPIRE objective.

Since the INSPIRE directive came into force in May 2007 and the implementation rules were still evolving during the MACHU project, MACHU was one of the first European projects to attempt to establish an exchange platform according to INSPIRE principles.

A WEB-BASED SYSTEM

The MACHU GIS had to be an easily accessible platform. The creation of a web-based system seemed to provide the best possibility of offering users an easily accessible user interface without the need to install GIS software locally. Using a web-based system also offers good opportunities to create a flexible system where changes can easily be made to both system and data.

DATA MANAGEMENT AT SOURCE

The MACHU GIS had to allow information to be shared. At the same time the MACHU partners wanted to stay in charge of their own data, to keep control of its availability and secure its maintenance by retaining control of data management. This matches an important INSPIRE key principle that states that spatial data should be collected once and maintained at the level where this can be done most effectively. It means that the MACHU GIS should not require a central database to store combined data but that partners should use their own data storage facilities.

EXCHANGING DATA USING GEO-SERVICES

Since the ambition is to maintain data at the source, the MACHU GIS should be able to handle multiple source input. Translating the data into web-services – or geo-services when referring to spatial data – based on international standards makes it relatively simple to exchange data online and combine it in a web-based GIS. INSPIRE prescribes the use of geo-services based on the specifications of the Open Geospatial Consortium (OGC).[12] The use of geo-services in combination with data management at source implies that partners should be able (in time) to serve their own data.

RESTRICTED ACCESS TO PROTECTED INFORMATION

For some partners there are legal restrictions or policies that place constraints on public access to information on the cultural heritage underwater. In order to make exchange of this protected information possible in the MACHU GIS, access had to be restricted to partners directly involved in the management of the underwater cultural heritage.
The establishment of access restrictions to the application through user accounts and passwords seemed the most practical solution. While it is acknowledged that security could be improved, for instance by introducing access restrictions on a geo-service level (which could also open up the possibility of a more publicly-accessible application), given the time available this had to remain a subject for future development.

AVAILABILITY OF SOURCE INFORMATION

The exchange of information starts with its recovery. For MACHU, it had to be possible to recover data useful for the management of the cultural heritage underwater and determine its usability. The data shared also have to be well-documented, therefore. This source information is also known as metadata. INSPIRE provides implementation rules for metadata pertaining to geographical data, based on the standards of the International Organization for Standardization (ISO).[13] Metadata had to be made available within the MACHU GIS as well as in a separate metadata catalogue open to both professionals and public.

GIS FUNCTIONALITY

Once the information is made available in the GIS, the application would have to provide several possibilities for users to access the data. These could to a large extent be standard functionalities available in many known GIS applications. For example, it should be possible to select, combine and view map layers, identify map objects, read object information and perform data queries. It also should be possible to store the outcomes of queries as printed maps or exported data files. Because it was agreed upon that data management should take place at source, there was no need for an editing functionality.

One important feature of the GIS would be the possibility to explore information on common subjects from different partners (as laid down in the MACHU data formats), not only by visualizing the datasets together in a map, but also by querying the information as a whole. This, together with some other functional requirements, meant a special GIS system would ideally have to be developed for MACHU. The desired functionality of the GIS was specified in a functional design.[14,15]

USE OF OPEN SOURCE SOFTWARE

Instead of using commercial software, the MACHU project preferred to use open source software to build the MACHU GIS. Open source software is computer software whose source code is freely accessible and not subject to any licence restrictions on redistribution or further development. Using open source software means that one does not have to

INSPIRE KEY PRINCIPLES

- SPATIAL DATA SHOULD BE COLLECTED ONCE AND MAINTAINED AT THE LEVEL WHERE THIS CAN BE DONE MOST EFFECTIVELY.
- IT SHOULD BE POSSIBLE TO COMBINE SEAMLESS SPATIAL DATAFROM DIFFERENT SOURCES ACROSS THE EU AND SHARE IT BETWEEN MANY USERS AND APPLICATIONS.
- IT SHOULD BE POSSIBLE FOR SPATIAL DATA COLLECTED AT ONE LEVEL OF GOVERNMENT TO BE SHARED BETWEEN ALL DIFFERENT LEVELS OF GOVERNMENT.
- SPATIAL DATA NEEDED FOR GOOD GOVERNANCE SHOULD BE AVAILABLE ON CONDITIONS THAT ARE NOT RESTRICTING ITS EXTENSIVE USE.
- IT SHOULD BE EASY TO DISCOVER WHICH SPATIAL DATA IS AVAILABLE, TO EVALUATE ITS FITNESS FOR PURPOSE AND TO KNOW WHICH CONDITIONS APPLY FOR ITS USE.

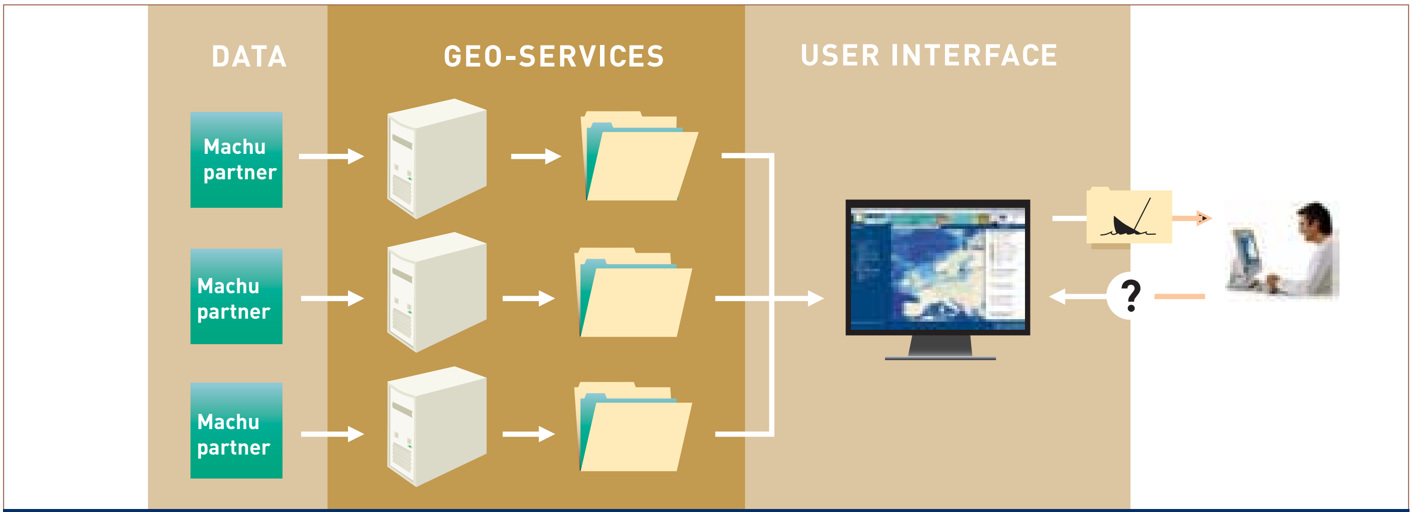


FIGURE 5 MACHU GIS Principle Model.

dependent on a single contracting party for future development, and that no licences have to be purchased. The use of open source software is not an INSPIRE objective but its use is supported by the European Commission in a number of other initiatives.[16]

STANDARD PLATFORM LANGUAGE

As a European platform, both the system and the information had to be understood by all partners. Because the creation of a multilingual system did not seem to be a realistic target for the three-year MACHU project, it was decided that the MACHU GIS should be in English, as this was already the official language of the MACHU project.

It should be noted that in the initial phases of defining the building principles, existing web GIS applications provided a source of inspiration. Two deserve a special mention. The first is the MESH WebGIS system of the Mapping European Seabed Habitats (MESH) project,[17] which influenced the way the research data are implemented and the map layers are managed on different levels in the viewer, for example. The second one was a predecessor of Mapviewer from *Rijkswaterstaat*, which served as an example of how to provide geo-services in a web-based GIS application. Mapviewer will become the base application for MACHU GIS II. (See 'Application management', p. 28).

THE MACHU GIS PRINCIPLE MODEL

Based on the building principles, a simple 'principle model' was created for the MACHU GIS. This model consisted of three major components, representing the three important stages in dataflow:

DATA

Data files contain the information to be exchanged through the MACHU GIS. Data are to be provided by individual sources (partners) and stored and managed on local storage facilities, e.g. a database or warehouse.

GEO-SERVICES

Data are to be exchanged through geo-services created by a local server.

USER INTERFACE

Geo-services are linked and visualized as map layers in a user interface hosted by one of the partners. The user interface should make it possible for a user to interact with the available geo-services as specified.

THE MACHU GIS APPLICATION

A prototype application, MACHU GIS I, was built by Grontmij Nederland b.v. and was ready for use in the summer of 2008. MACHU GIS I can be regarded a 'proof of concept' for the exchange of MACHU data through a GIS platform.

To establish a MACHU GIS that can be maintained and managed for an extended period, it was necessary to develop a second version, MACHU GIS II. This application, which will become the operational version, is now under development at Rijkswaterstaat and will be available in the last quarter of 2009.

In this section, the prototype version MACHU GIS I will be described on the basis of the three components of the 'principle model': user interface, geo-services and data. It will be followed by a section on application management, including the main differences that will be introduced in MACHU GIS II.

USER INTERFACE

The MACHU GIS I application consists of two components:

- **The administrator's module**
  The administrator's module allows an administrator to add geo-services to the MACHU GIS viewer, to classify geo-services by theme or layer and to manage the visibility of the map layers at the opening stage of the application. The legend is served separately and also added here by the administrator.
- **The MACHU GIS Viewer**
  The MACHU GIS Viewer is the user interface where users can interact with the geo-services.
  The *viewer* consists of four main sections: *(See figure 9)*

1. Table of Contents (TOC)

Geo-services are presented in the TOC on three different levels. The actual geo-services are presented on a sub-layer level. Sub-layers are combined into map layers and map layers are grouped into themes. The TOC allows users to add and remove services in the Map Area.

The MACHU GIS application differs from other GIS web applications in that it is able to combine data from different geo-services into a single map layer. This allows the user to access multiple source data (data provided by different partners) as if it originated from one data source. For example, data served from different sources but combined in one map layer can be queried in a single operation. To enable the application to perform this way, data formats were developed for the main map layers and each contributor of data commits to using these formats. *(See 'Formats for communication', p. 17).*

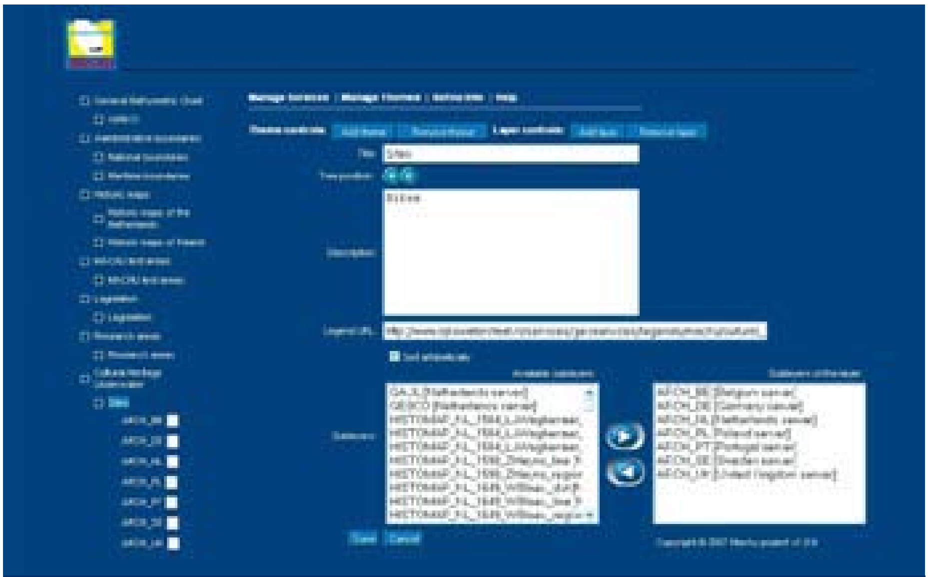


FIGURE 6 Screenshot of administrator's module, showing geoservices being added to a map layer.

FIGURE 7 Screenshot of a query and results.

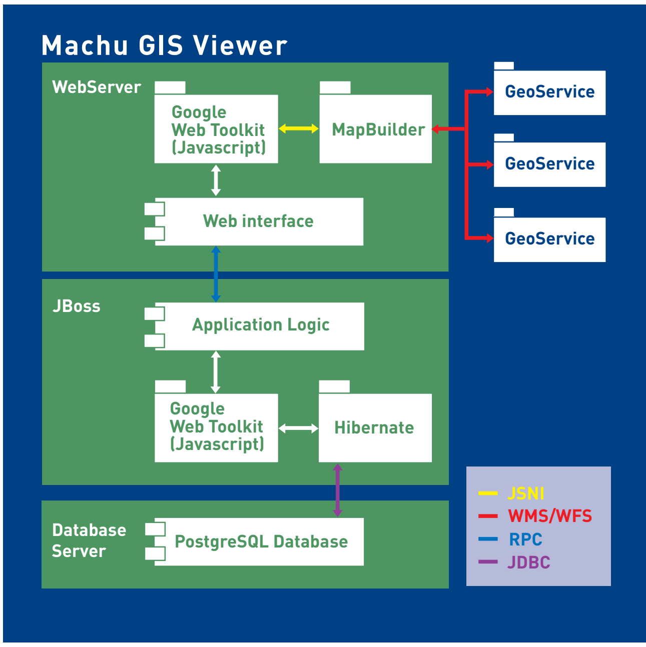


FIGURE 8 Component diagram of MACHU GIS I
MACHU GIS I uses MapBuilder to provide the functionality of the Interface and Map Area segments and Google Web Toolkit (GWT) to create the TOC and Legend elements. GWT is also used to manage the interaction between the client and server and the connection between the server and the database via a secondary library: Hibernate.
Source: MACHU GIS Application. Technical design of the MACHU GIS Viewer. August 11, 2008. Grontmij Nederland bv.

The TOC also provides the possibility of accessing the metadata of the map layers (on a sub-layer level).

2. Map Area

Selected map layers are presented in the Map Area. The Map Area is an interactive map which can be used to select and identify features. Detailed information on selected or identified features is shown in a pop-up window. The Map Area contains several navigation options, including a scale bar and navigation buttons. It also contains an overview window that can be switched on and off and be used for navigating through the Map Area. As the cursor is moved across the map its geographical position is shown at the bottom of the Map Area, where there is also a scale bar showing the current map scale.

3. Function Buttons

The viewer contains a series of function buttons that allow the user to navigate through the Map Area, identify map objects, query map layers and perform some additional functions like measuring map distances and exporting maps.

When the query function is used, a pop-up window appears which allows the user to select the map layer to be queried. A query can then be performed by selecting features geographically on the map or by entering a query statement. Query results will be shown in the pop-up window.

When the identify option is used, results will again be shown in a pop-up window. In this case, all active map layers present in the identify location will be added to the results.

The results can be used to navigate to a selected feature (by using a 'zoom to' button), or link through to additional information. In the Research area layer, it is also possible to use the results to add images of the original research data to the TOC and Map Area. Finally, the results may also be exported to a data file.

4. Legend

The Legend explains the symbols used in the visible map layers. In MACHU GIS I, each legend is derived from a separate image service.

GEO-SERVICES

Data in the MACHU GIS are exchanged through geo-services. Geo-services should be created, when possible, at source. This means that each MACHU partner should be able to produce their own geo-services. Because most of the partners did not have this capability at the start of the project, it was decided that *Rijkswaterstaat* would temporarily collect and serve the data for each partner. This way the project would not have to depend on different local conditions for the development of the data formats and the MACHU GIS application.

According to the INSPIRE principles, MACHU data should be served as OGC Web Mapping services (WMS) and Web Feature Services (WFS). These are international standards used to exchange geo-spatial information. *Rijkswaterstaat* has provided a description of how to generate these geo-services using the UMN Mapserver.[18] This document is available on

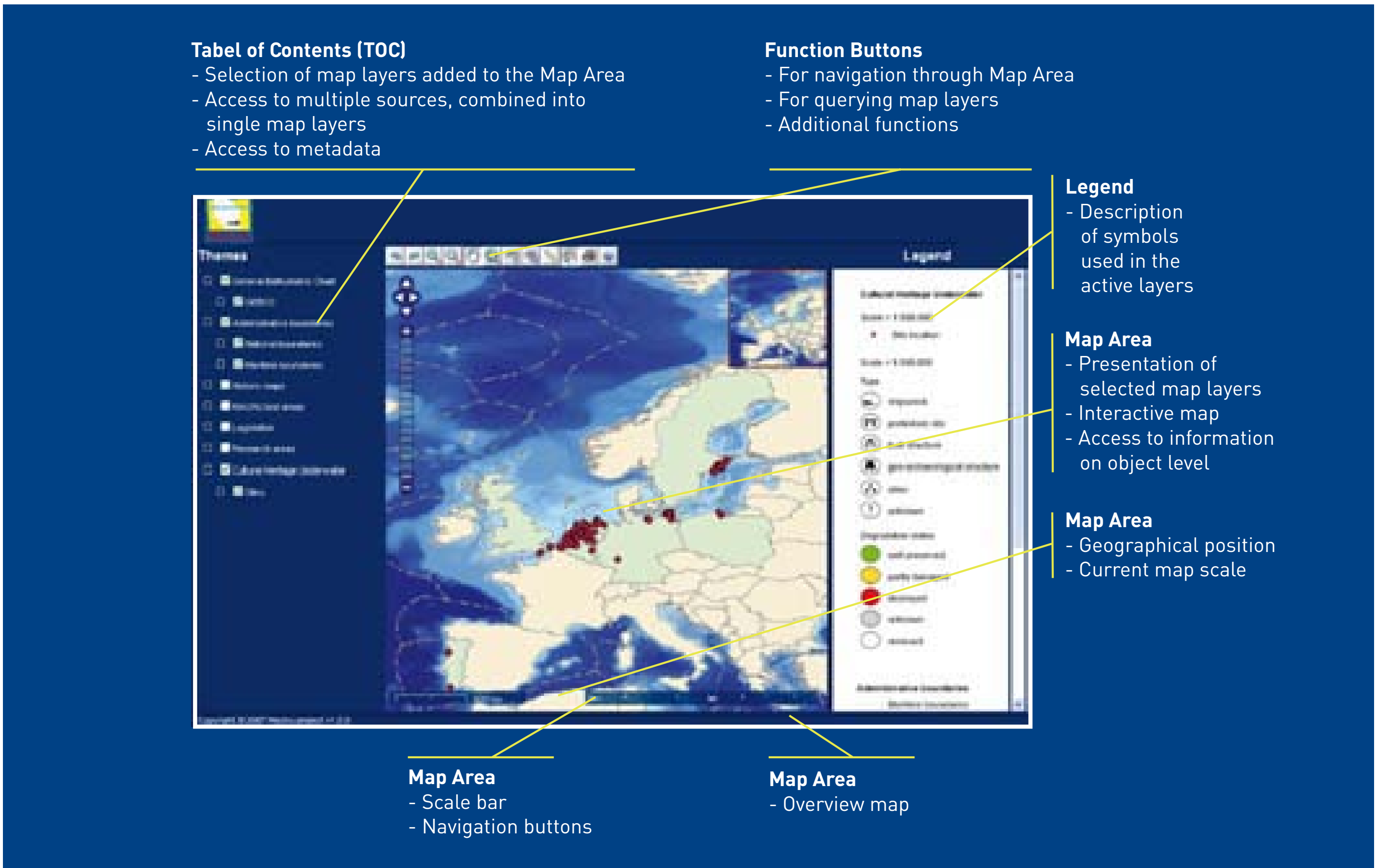


FIGURE 9 Screenshot of MACHU GIS viewer presenting its main components.
Source: MACHU GIS Application. Technical design of the MACHU GIS Viewer. August 11, 2008. Grontmij Nederland bv.

```
LAYER
    DATA 'shapes_machu_services/LEGIS_NL'
    DUMP TRUE
    METADATA
        'wfs_featureid' 'LEG_IDENT'
        'ows_srs' 'EPSG:4326 EPSG:28992'
        'ows_title' 'LEGIS_NL'
        'wms_style' 'default'
        'wms_style_default_legendurl_href'
        'http://localhost/machu/legends/machu/legislation.png'
        'wms_style_default_legendurl_format' 'image/png'
        'wms_style_default_legendurl_width' '218'
        'wms_style_default_legendurl_height' '78'
        'WMS_METADATAURL_TYPE' 'TC211'
        'WMS_METADATAURL_FORMAT' 'text/xml'
        'WMS_METADATAURL_HREF'
'http://localhost/machu/metadata/machu/LEGIS_NL.shp.xml'
        'gml_include_items' 'all'
        'gml_LEG_IDENT_alias' 'Identifier'
        'gml_LEG_NAME_alias' 'Legislation_name_English'
        'gml_LEG_NAT_alias' 'Legislation_name_original'
        'gml_LEG_TYPE_alias' 'Legislation_type'
        'gml_LEG_ENF_alias' 'Level_of_enforcement'
        'gml_LEG_LEV_alias' 'Level_of_agreement'
        'gml_COUNTRY_alias' 'Country'
        'gml_COM_AUTH_alias' 'Competent_authority'
        'gml_LEG_DESC_alias' 'Description'
        'gml_LEG_REMARK_alias' 'Remarks'
    END
    NAME 'LEGIS_NL'
    PROJECTION
        'init=epsg:4326'
    END
    STATUS OFF
    TEMPLATE 'query.html'
    TOLERANCE 8
    TYPE POLYGON
    UNITS METERS
    CLASS
        STYLE
                #TRANSPARENCY 100
                OUTLINECOLOR 231 215 203
                SYMBOL 0
        END
    END
```

FIGURE 10 Example of MAP file syntax (for the Legislation layer).

the MACHU website.

UMN Mapserver is an open source web mapping engine.[19] It was originally developed by the University of Minnesota and is now a project of the Open Source Geospatial Foundation (OSGeo),[20] It uses a 'Mapfile' to create a geo-service. The Mapfile is the basic configuration file for data access and styling with Mapserver. The file is an ASCII text file made up of different objects for which a variety of parameters are available. The Mapfile makes it possible to define how a user can 'communicate' with the data and how data should be presented in the web GIS application. It contains, for example, the location of the source data, title of the layer, references to a template for querying the data, aliases used in the attribute table and definitions that provide the classification or symbology of the layer.

DATA

The data in the MACHU GIS are presented as map layers. The data formats used are discussed in the section 'Formats for communication', (p. 17-19).

As we have said, there are a lot of activities and processes important to the management of the cultural heritage underwater that could be added as layers in a GIS. It is not possible to collect and present information on all of these subjects in a short period of time. The availability of information in the MACHU GIS should therefore grow in time as more data and services become available, for example as a result of infrastructural projects and cooperation with other stakeholders.

The map layers currently available (October 2009) in the MACHU GIS are:

■ Cultural Heritage Underwater (Sites)

The Cultural Heritage Underwater layer contains combined information on archaeological sites provided by MACHU partners. Sites are presented as dots on large-scale maps and as more complex symbols on smaller-scale maps. The complex symbols represent information on object type (symbolisation) and degradation status (symbol colour). The symbolisation used is derived from a true type font created specially for MACHU.

■ MACHU Test Areas

The MACHU Test Areas layer contains combined information provided by MACHU partners on the areas where each of them focused their research during the initial phases of the MACHU project. Data were collected in these areas in such a way as to ensure that

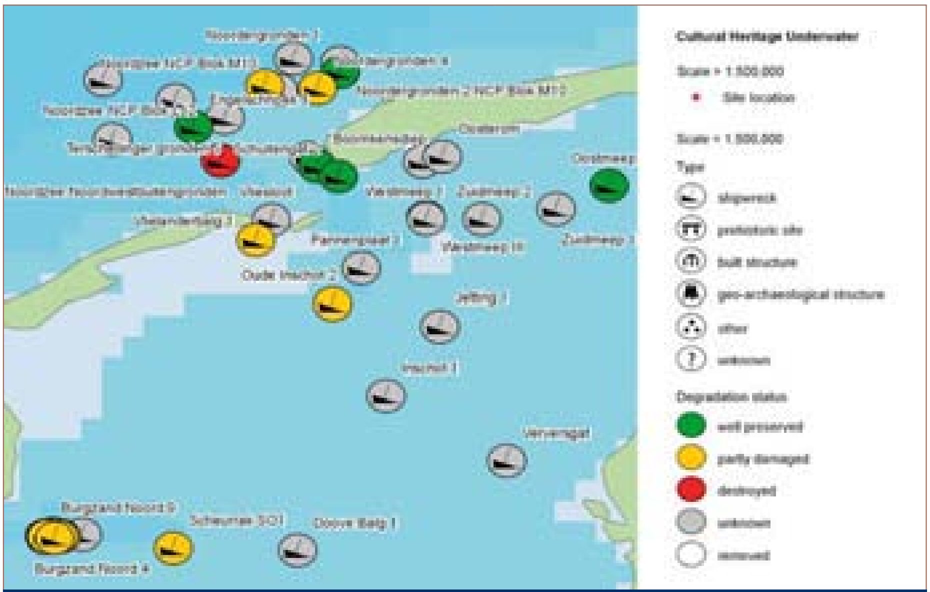


FIGURE 11 Cultural Heritage Underwater layer.

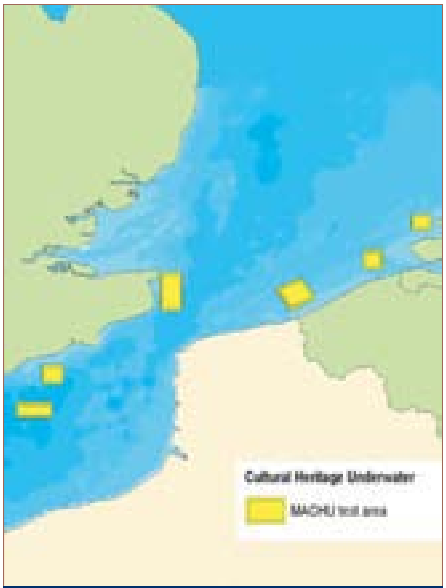


FIGURE 12 MACHU Test areas layer.

data with a spatial correlation would be available. This layer therefore fulfilled only a temporary role. The MACHU GIS now also contains data outside these test areas.

■ Research areas

The Research areas layer contains combined information provided by MACHU partners on the availability of research data. The layer presents areas where research has taken place whose results are expected to be significant for the management of the cultural heritage underwater. Each area represents a different study. The data from the research are not presented here, but they can be obtained using the metadata of each individual study (see also Research images layer).The research areas are presented with different shadings for each research method. The number of methods displayed in the legend can be extended when new methods become available within the layer.

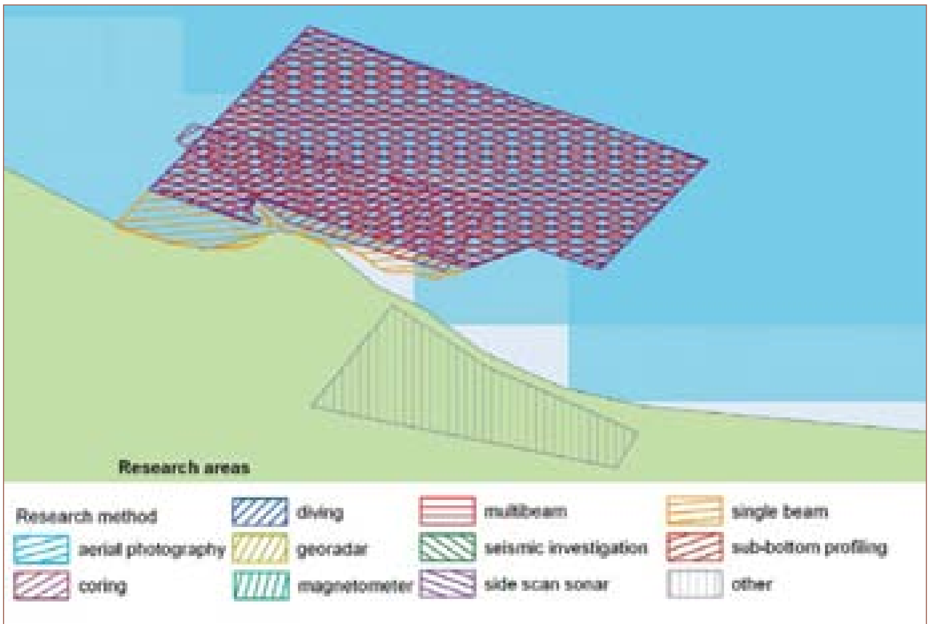


FIGURE 13 Research areas layer.

■ Research images

Research images represent the original data sources of the Research areas layer. The research images can be added interactively through the Research area layer. The presentation type for these images depends on availability. Because legends can differ per image, these are not added to the legend in the viewer, but legends can be made available with the image itself. The Bathymetry format description contains extra instructions on the presentation of bathymetric images. The images can be used to obtain metadata for the original research data they represent.

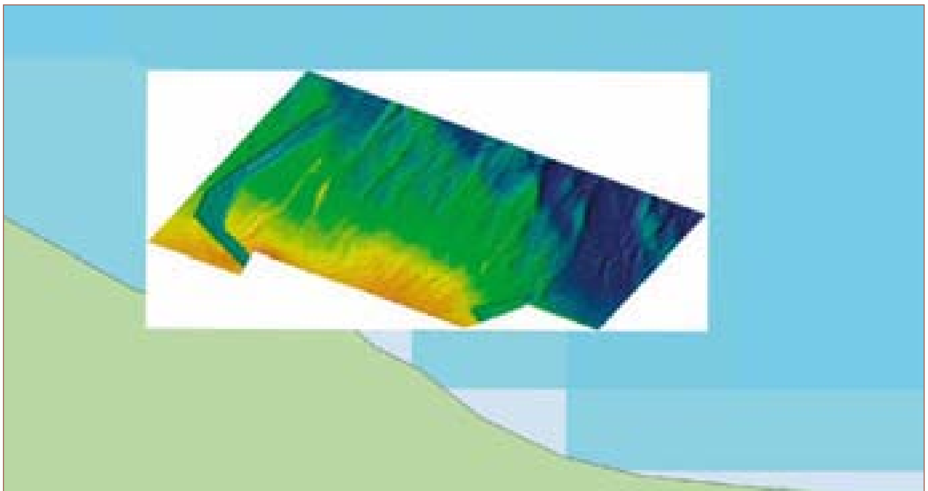


FIGURE 14 Research images layer.

FIGURE 15 Legislation layer.

FIGURE 16 Administrative boundaries.

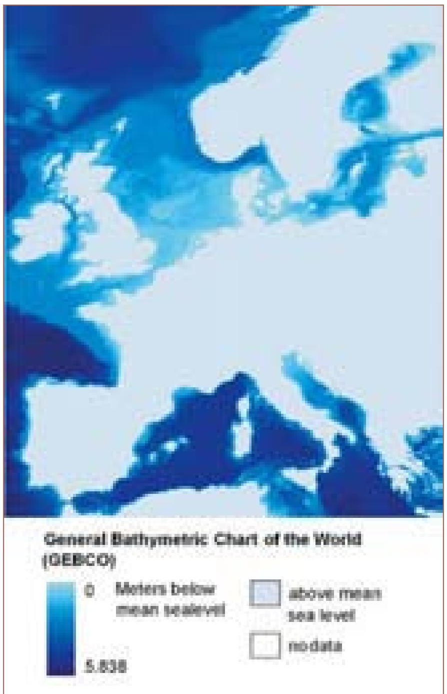


FIGURE 17 General Bathymetric Chart of the Oceans layer.

FIGURE 18 Historical maps layer (The Netherlands).

■ Legislation

The Legislation layer contains combined information provided by MACHU partners on legislation related to the cultural heritage underwater. Legislative areas are presented as transparent areas made visible by their boundaries. Each partner presents the legislation that applies within their own national maritime and terrestrial boundaries.

■ Administrative boundaries (maritime and terrestrial)

The administrative boundaries theme contains two map layers, one containing world maritime boundaries derived from the Flanders Marine Institute (VLIZ)[21] and presented as a dotted line, the other containing the Global Administrative Unit Layers (GAUL) derived from the EC-FAO Food Security Programme,[22] showing national boundaries on land. (MACHU partners are presented as green areas.)

■ General Bathymetric Chart of the Oceans (GEBCO)

The GEBCO layer contains a subset of the General Bathymetric Chart of the Oceans, One Minute Grid, distributed by the British Oceanographic Data Centre (BODC)[23] on behalf of the Oceanographic Commission. The GEBCO One Minute Grid provides bathymetric data on a global grid with one arc minute spacing (this corresponds to a cell size of approximately one square kilometre in the North Sea region). The data represent different depths.

■ Historical Maps

The Historical Map theme currently contains two map layers, historical maps of the Netherlands and historical maps of Poland. The format of historical maps depends on availability.
The Dutch partners provided several digitized historical maps, presented in separate sublayers for areas, linear elements and point objects.
The Polish partners provided scanned and projected images of historical maps.
See MACHU Report 2 'Historic maritime maps in GIS' (p. 26 - 28) for comment on both presentation types.

Not all the envisaged layers could be realised during the project, and some are still under construction. In the final phase of the project and in the months following, efforts will be made to realise a number of new layers:

■ Sediment mobility

This layer will contain snapshots of the seabed in motion, taken from the hydrodynamic model developed for MACHU by the University of Southampton. *(See the article on 'Sedimentation-erosion modelling', p. 48-53).* This layer will provide insight into the risk of sedimentation and erosion processes (on a broad scale) at sites on the seafloor.

■ Unverified submerged objects

This layer should contain archaeological sites that cannot yet be verified by the competent authorities. This information could for example come from diver communities. To distinguish this information from information that is already validated, it should be presented in a separate layer.

Topography

Several layers with topographical information

FIGURE 19 Historical maps layer (Poland).

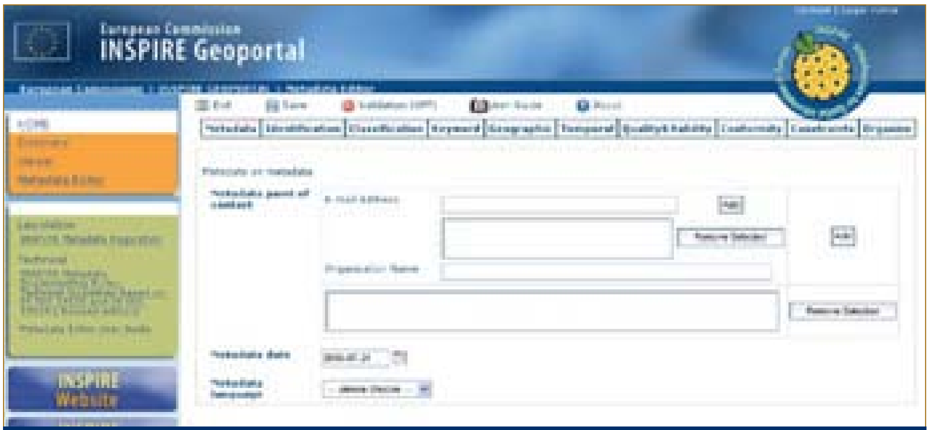


FIGURE 20 Screenshot of the Inspire Metadata Editor.

FIGURE 21 Example of metadata (here presented in Dutch Rijkswaterstaat style sheet).

should allow better orientation. The following are under development:

- Rivers, containing linear features.
- Sea areas, containing polygon features to be used for labelling sea areas.
- Places or cities, containing point features for orientation on land.

The possibility of adding digital hydrographical maps will also be examined.

Threats

Although very important for MACHU, the GIS still lacks layers that represent different kinds of threat to the cultural heritage underwater. Because so many threats need to be taken into account, the realisation of these layers will take a lot of effort. Examples of layers presenting threats include:

- human influences (pipelines, dredging, fishing, wind farms etc);
- geological influences (e.g. seabed conditions);
- geochemical influences (e.g. water quality);
- climatological influences (e.g. waves);
- biological influences (e.g. presence of shipworm).

METADATA

Along with the data, the MACHU GIS should provide metadata, which contain source information on the data (and services) used in the MACHU GIS.

Metadata should be provided in accordance with the INSPIRE metadata implementation rules. INSPIRE prescribes the use of ISO 19115 (metadata profile for geography) and ISO 19119 (metadata standard for services). (See also 'Building principles', p. 29).

To create metadata files, one needs a special metadata editor that can generate the metadata using the right syntaxes and store the metadata information in XML-format (Extensible Markup Language). In the first phase of MACHU, a Dutch metadata editor from *Rijkswaterstaat* was used. This editor was able to produce metadata according to the Dutch profile (containing all core metadata elements of the European metadata standard as well as additional Dutch metadata elements). Unfortunately, this editor could not be made available in English during the MACHU project. In the final phase of the MACHU project, the INSPIRE metadata editor[24] was ready for use. This can be used by all MACHU partners to create metadata com-pliant with INSPIRE formats.

Because metadata are stored in XML-format, a style sheet is used to present the data in a user-friendly way. In MACHU GIS I this is a Dutch style sheet version from *Rijkswaterstaat*. An English version is under construction and will be integrated into MACHU GIS II.

The possibility of providing metadata information through a metadata catalogue, to allow data outside the MACHU GIS to be recovered, is still being investigated and this feature is expected to become available in the last quarter of 2009.

APPLICATION MANAGEMENT

MACHU GIS II, the follow-up version to MACHU GIS I, is being constructed at *Rijkswaterstaat*. The goal is to integrate the MACHU GIS into the geo-architecture of *Rijkswaterstaat* to guarantee maintenance and application management in the long term.

MACHU GIS II will be based on the *Rijkswaterstaat* Mapviewer.[25] Mapviewer is a web GIS application based on OpenLayers, an open-source JavaScript library for web mapping. It is a *Rijkswaterstaat* general application for viewing web services and the base application for many of *Rijkswaterstaat*'s more customised applications. The latest version of Mapviewer, suitable for integrating the MACHU GIS, became available in spring 2009.

MAINTENANCE AND DEVELOPMENT

Integrating the MACHU GIS into the geo-architecture of *Rijkswaterstaat* means this organisation can guarantee maintenance of the system. A MACHU GIS based on Map-viewer will benefit from ongoing developments as *Rijkswaterstaat* keeps its Mapviewer up to date. For example, the performance of MACHU GIS I might already be affected by the introduction of a new web browser, Internet Explorer 8, and new efforts are needed to guarantee the accessibility of the system.
Once MACHU GIS II is launched, *Rijkswaterstaat* can provide manpower and technical requirements to maintain both the system and the geo-services. Of course the integration of the MACHU GIS into the geo-architecture of *Rijkswaterstaat* will also help *Rijkswaterstaat* to improve the incorporation of cultural heritage management into its own activities.
To guarantee ongoing involvement by the partners in the use and development of the MACHU GIS, they have been invited to join a user group to give directions to the functional application manager, who will be stationed at *Rijkswaterstaat*.
System management will be directed by the Centre for Data and ICT of *Rijkswaterstaat*. This department will secure the hosting of the application and geo-services. Partners are expected to realise their own geo-services in time, so their data will be hosted only temporarily. No specific agreement has yet been reached on this subject, however.

NEW FUNCTIONS

The standard Mapviewer application already contains most of the functions provided by MACHU GIS I. Functions that are not available in the standard Mapviewer will be added to MACHU GIS II. The standard Mapviewer also contains extra functions, some of which were required by MACHU but could not be realised in the prototype application. Examples of possible improvements include:

- Users should be able to add (local) services as map layers themselves.
- Possibility to change the presentation order of map layers by moving layers up and down.
- Map layers made transparent for comparison with underlying layers.
- Viewer settings (e.g. additional map layers) stored and re-used.
- Better possibilities for viewing, identifying and querying results.
- Possibility to rescale windows.

The standard Mapviewer allows user profiles to be integrated. This can for instance be used to generate an administrator's profile, adding management functions to the viewer.

CONCLUSION

The establishment of the MACHU data formats enhances the possibilities for exchanging information (spatial or otherwise) on the cultural heritage underwater. The formats offer cultural heritage managers a structure for storing and exchanging information on a scale that transcends national boundaries. Once the institutes involved in the management of the cultural heritage underwater adapt and implement these formats, it will become easier to find, combine and explore joint information resources. This, in turn, will create better foundations for management decisions.
The MACHU GIS application has become a platform that can be used by cultural heritage managers as a tool for exchanging and exploring this information. More importantly, however, this information should now become available and be shared between organisations working towards the common goal of preserving our cultural heritage underwater.

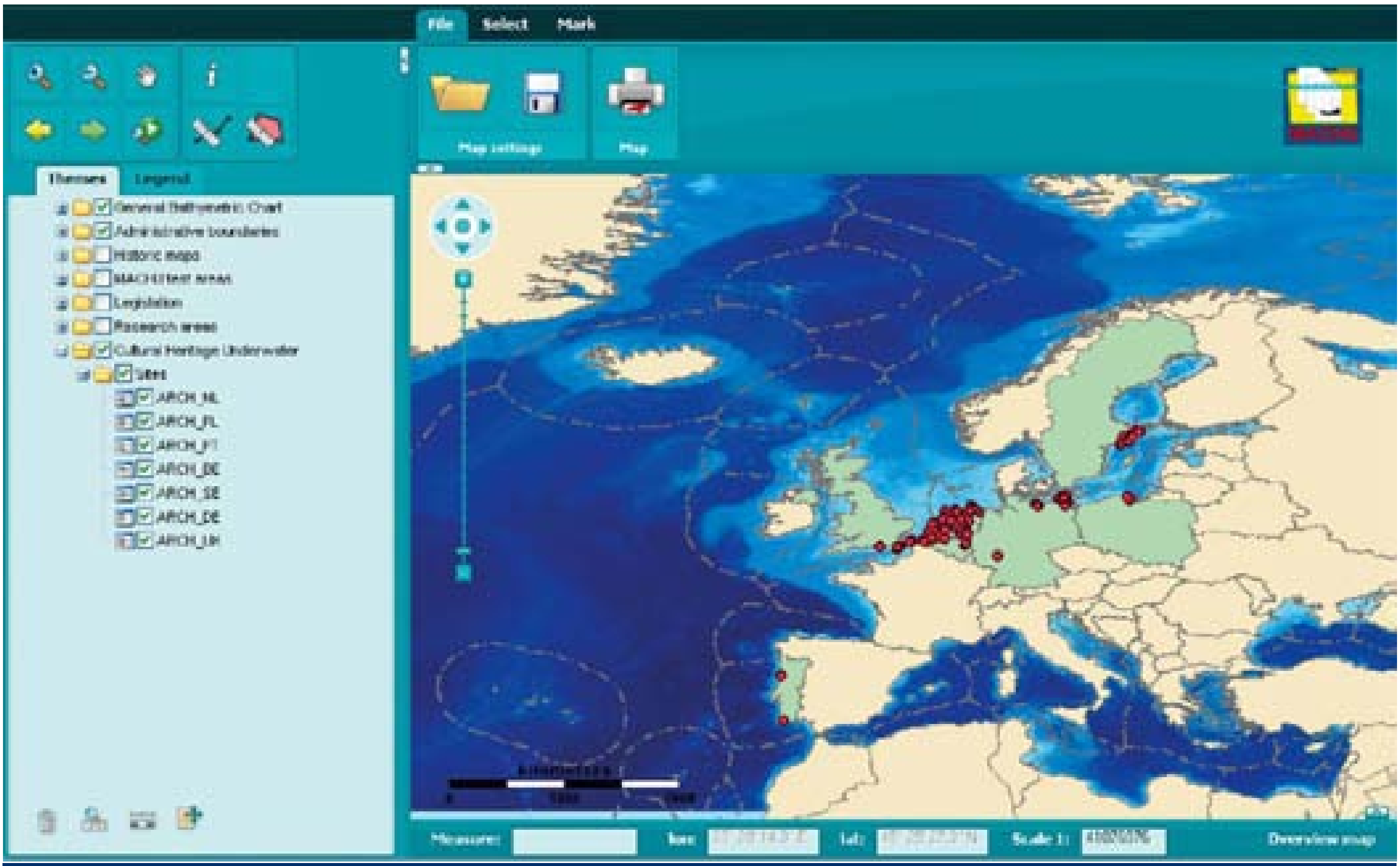


FIGURE 22 Screenshot of MACHU GIS II under construction.

EVALUATION

During the three years of development in the MACHU project, several issues arose that influenced development processes and decision- making on data formats and the MACHU GIS application. Some of these issues have already been mentioned in this article. Since MACHU will continue to develop, it is important that the experience and knowledge gained during the project be preserved. This evaluation therefore contains a selection of additional findings and considerations which might prove useful for future developments.

TECHNICAL CAPABILITIES

The assumption that all partners could provide data in a shapefile or GeoTIFF format, proved to be too optimistic. Many partners appeared to have problems producing data this way. They did not have the necessary software available in their organisation or were unable to find local assistance. It is important for partners who want to keep improving their data processing and exchange to recognise the importance of their technical capabilities.
As a concession to partners without the necessary capabilities, a web form was created to allow them to create data according to MACHU formats. This web form could be used to enter information on an archaeological site according to MACHU attributes and send it to RCE for further processing. This is not a permanent solution, however, as it involved a great deal of work.

Thus far, MACHU data have been created and stored in a shapefile format. In future, it might be wise to look at the possibility of storing MACHU data on local geo-databases instead. A geo-database could offer advantages over single data file formats when it comes to storing and managing the MACHU data. For example, it would become easier to avoid errors when entering data (a persistent problem during the MACHU project) because domain values could be incorporated into the database. Using a database might also make it possible to es tablish new relationships between data sets (tables). And, when needed, it would still be possible to export data in an single data file format.

FORMATS

The centres of archaeological sites are recorded as point features. There has been some discussion of the possibility of recording sites as linear and polygon features too. This could provide an opportunity to add more detailed spatial information on a site. During the MACHU project, there was only time to focus on features representing site locations, as the 'anchor point' for all information related to a site. In the MACHU GIS, there is however already a possibility to add more information through the Research area layer, where research images can present more detailed information on a site.

In the Archaeology format it is not easy to add information on shipwrecks whose location is still unknown. Sometimes a ship's position can be narrowed down to a certain area that could be presented in a layer. The creation of such a layer remains a matter for further investigation.

In MACHU GIS I, a direct link from a feature in the Archaeology layer to a site management plan was established through the attribute management_id. For this, the management plan had to be stored in PDF on a central location of the MACHU website. Central storage of the management plans causes extra work and it became clear during the project that not all partners were able to submit their management information in this way, or preferred to use the attribute 'references' to link to their own websites, which also contain management information. To create a clear access point for MACHU GIS users, it is preferable that just one attribute be used to link to management plans. Therefore, in MACHU GIS II, the link to a management plan will only be established through the attribute 'references'. One disadvantage is that this link will not always lead directly to a management plan. A better way to establish direct links to management plans should be considered during future developments.
Both the Archaeology and Research areas formats now contain a link to other resources by a 'references' attribute containing a URL. It might be worth considering adding a reference attribute to the Legislation format too. Because of the limits on the textual content of an attribute in a shapefile format, the format could only contain a brief description of the legislation. Using a reference attribute creates the possibility of linking through to more detailed descriptions.

BUILDING PRINCIPLES

Some thought has been given to the development of more sophisticated GIS functionalities. As mentioned in 'Formats for communication' (p. 17-19), there is a close relationship between the development of data formats for MACHU and the MoSS management plan template. The information topics described in the management plan will to a large extent be made available through the MACHU GIS. One tempting idea was therefore to create a system that would be able to create management reports directly by using the information available in the MACHU GIS. This was not however a realistic goal for the three-year MACHU project, and must remain an option for future development.
Another close relationship might be created between the MACHU GIS and the development of a Decision Support System (DSS). The MACHU GIS provides information on which to base management decisions. The idea of using the information available in the MACHU GIS to automatically generate DSS output was raised during the MACHU project. This idea could not however be elaborated during the project. The interpretation of the information in the MACHU GIS in support of management decisions therefore remains a manual task for managers.

DATA

The Research area layer displays research areas. A research image is used to present research data on a particular area and can be added interactively through the Research area layer. In MACHU GIS I, the images are also used to link through to the metadata of the research data. An image is not available for every research area. In these cases an 'empty image' (showing the MACHU logo and text 'no image') is used to create a link to the metadata. This 'empty image' has to be processed like other images and therefore be geo-referenced and displayed in the related research area. Although no better solution could be found at the time, this feels like a complicated and time-consuming way to link through to the metadata of research areas. Other potential solutions may emerge with the development of MACHU GIS II.
Data added to the MACHU GIS should preferably be derived directly from the geo-services of professional institutes. For example, hydrographical data should come directly from a hydrographical institute. This should allow this data in the MACHU GIS to be kept up to date. With the growing influence of INSPIRE regulations, these services might become more common and available to the MACHU GIS in time.

METADATA

MACHU users can now use the INSPIRE metadata editor to create metadata compliant with European standards. The MACHU project started, however, with the intention of using a Dutch metadata editor which was already available at the start of the project, though not in English. The Dutch metadata profile consists of the European core metadata elements plus additional Dutch elements (ISOcompliant). This means that the Dutch metadata profile contains more metadata elements, for example on data quality, than the European metadata standard. Once the Dutch editor becomes available in an English version, as is expected, data providers will be able to choose which editor they want to use. The MACHU GIS application will be provided with a style sheet that allows users to read the European metadata elements as well as the additional Dutch elements. With the growing influence of INSPIRE regulations, more metadata editors are likely to become available in due course.

GEO-SERVICES

During the project, data were served by Rijkswaterstaat. In order to make the MACHU GIS work as intended – as a tool for exchanging information originating from different data sources – it is important that partners make arrangements to produce their own geo-services compliant with the MACHU definitions.

Rijkswaterstaat uses a Mapfile to present geoservices. To make it possible to combine the from of different partners into a single layer, those data must be in the same format. This can be achieved by using the same Mapfile. It is possible to provide Mapfiles as a template to partners (e.g. via the website). It might be even better, however, if it were eventually possible to use a central 'Mapfile' for all services.

Not all the data are accessible to the public. The establishment of access restrictions through user accounts and passwords seemed the most practical solution for preventing unauthorised access. However, as we have said, security could be improved. *Rijkswaterstaat* is currently investigating the possibilities. Once security on geo-service level is achieved, this will also open up the possibility of using the MACHU GIS itself on a more public level. In MACHU GIS I, the legend is built up of images (png files) of each map layer. These legend files are served separately from the data, in order to make sure a legend is presented only once, even though map layers are built up from multiple sources. One disadvantage of presenting the legend in this way, instead of using automatically generated legends, is that it involves extra work to produce and serve each separate legend file. The advantage is, however, that using images produces clear legends. The use of separate legend files will be continued in MACHU GIS II.

MACHU GIS II

GIS web applications and geo-services are evolving rapidly. When the MACHU project started, it seemed that the development of a new GIS web application would offer the best possibility of creating an exchange platform as MACHU intended. Joining ongoing projects like the development of Mapviewer at Rijkswaterstaat could not guarantee that a working system would become available in time, potentially slowing down other developments within the project. By the time the prototype MACHU GIS I was ready, Mapviewer had also evolved into a tool that – after some additional development – could function well as an exchange platform for MACHU. More importantly, though, Mapviewer offered better potential for maintenance in the long term. It was therefore decided to put extra effort into preparing this second platform for MACHU, instead of further developing the MACHU GIS I prototype.

APPLICATION MANAGEMENT

It is not yet clear which department within the Rijkswaterstaat organisation will be responsible for the functional management of MACHU GIS II. A transition is currently in progress, with many tasks previously performed by regional departments being transferred to national departments. The aim is to create uniform procedures throughout the organisation. The most likely candidate for the functional management of the MACHU GIS at this moment is the Directorate Traffic and Shipping (DVS).

The MACHU GIS has become a system that provides access to data from all EU partners, managed at a single, central location. The question of whether this tool could also be used on a more local scale, for example to support local projects, has been raised. In MACHU GIS I, this would mean separate applications having to be installed and managed locally. MACHU GIS II might come with a feature that allowed users to add local services themselves. This would open up the possibility of using a centrally managed application for local projects. It would provide shared information as well as locally added information, while the management of the application itself could remain at a single, central location.

NOTES

1 Directorate General for Public Works and Water Management.
2 Monitoring, safeguarding and visualizing North-European shipwreck sites; MoSS; http://www.mossproject.com/.
3 www.esri.com/library/whitepapers/pdfs/shapefile. pdf.
4 http://trac.osgeo.org/geotiff/
5 www.esri.com/
6 www.mapinfo.co.uk/
7 http://grass.osgeo.org/
8 British Oceanographic Data Centre (BODC): www.bodc.ac.uk
9 United Nations Food and Agricultural Organization (FAO): www.fao.org
10 Flanders Marine Institute (VLIZ): www.vliz.be
11 INSPIRE: http://inspire.jrc.ec.europa.eu/
12 Open Geospatial Consortium (OGC): www.opengeospatial.org/
13 International Organization for Standardization (ISO): www.iso.org/iso/home.htm
14 Functioneel ontwerp GIS MACHU, RWS IJsselmeergebied, 10 juli 2007. (Applies to MACHU GIS I)
15 *Functioneel Ontwerp (FO) Machu GIS, Rijkswaterstaat, data en ICT Dienst, Afdeling IAPD, 1 juli 2009.* (Applies to MACHU GIS II)
16 Free and open source software activities in European Information Society initiatives; http://cordis.europa.eu/fp7/ict/ssai/fosshome_en.html
17 Mapping European Seabed Habitats (MESH): www.searchmesh.net/
18 Serving MACHU data using UMN Mapserver; Rijkswaterstaat, 14 augustus 2009.
19 Mapserver: http://mapserver.org/
20 Open Source Geospatial Foundation (OSGeo): www.osgeo.org/
21 Flanders Marine Institute (VLIZ): www.vliz.be
22 EC - FAO Food Security Programme (ESCGSDRN): www.fao.org
23 British Oceanographic Data Centre (BODC): www.bodc.ac.uk
24 European Commission Geoportal: www.inspire-geoportal.eu/
25 *Technisch Ontwerp GeoServices en Mapviewer2, Rijkswaterstaat,* April 7, 2009. ■

MACHU as a gateway to the underwater cultural heritage

FIGURE 1
The HMS Victory in Portsmouth Historic Dockyard.

Part I Cultural heritage in the real and virtual worlds

CULTURAL HERITAGE IN THE REAL WORLD

We are living in a rapidly changing world. Certainty and stability are constantly under threat. Economic crisis, social disorder and personal upheaval are never far away. Understandably, perhaps, there is a desire for balance and stability, for a shared identity. This is one of the factors fuelling interest in the cultural heritage – the historical and/or archaeological heritage that can give us a sense of common identity through a connection with the past.

There is a growing awareness and appreciation of the cultural heritage in general, and underwater cultural heritage museums are particularly popular among the general public. Visitor numbers to museums and cultural heritage sites in the EU continue to grow. Here, I am referring to real-world sites of cultural interest such as the Acropolis in Athens, or museums like the Louvre in Paris.[1]

People who are frequent visitors to museums of 'fine art' also visit virtual cultural heritage sites on a regular basis. Though the 'old media' (newspapers, magazines, books) still dominates the information output on the cultural heritage, its share is declining. We are in a period of transition from the old media towards a new media dominated by television and, increasingly, the Internet. The new media is catching up fast. However, there tends to be a difference between the proportion of people interested in the cultural heritage (27%) and users of cultural heritage-related websites (7%). This seems to be due to the fact that cultural heritage lovers tend to be older, and are not completely familiar with the digital world.[2]

CULTURAL HERITAGE SITES: WHO VISITS WHAT?

Besides actual historic sites, there are also museums of historic interest and, to a lesser extent, theme parks, some of them combined with actual archaeological sites.[3] The top cultural heritage sites are those that combine several factors of cultural interest: history, culture and pure tourism.[4] In this respect, a city like Paris ranks very high, with the Louvre, the Eiffel Tower, Ile de la Cité, Centre Pompidou and much more. Millions of people, often referred to as tourists, are willing to spend time, effort and money visiting places of cultural interest.[4] Sometimes this is their primary goal, but more often it is a secondary goal. When on holiday, besides lying on the beach, almost everyone will make one or two excursions to experience the culture of the country they are visiting. A lot of tourists who visit Estartit, Rosas or Llorett de Mar (Costa Brava, Spain) end up in Figueres visiting the Dali Museum, or even the archaeological site of ancient Ampurias (the Greek Massaliot colony of Emporion). Even in a culturally poor environment such as a mass tourism destination, most people will try to feed their cultural appetite. If it's there, it will be visited.

For obvious reasons, the underwater cultural heritage is more difficult to access in the real world. However, the few sites that combine the underwater cultural heritage with a museum or a replica of a real historic ship attract huge attention from the general public. One of the best examples is the Vasa Museum in Stockholm, which has the highest visitor numbers of any museum in Sweden. Here, one can come face to face with the flagship of the Swedish navy in 1628. Wrecks in the Stockholm archipelago are also visited very frequently by a growing army of sport divers who (as explained elsewhere in this volume) create other, quite serious problems for the management of the underwater cultural heritage.

When it is brought to life, the underwater cultural heritage has one big advantage over any other form of cultural heritage. A wreck is by its very nature a time capsule, sealed by nature, preserving everything that was in the vessel when it sank. In this respect it gives us an actual insight into the period of the ship in question. Wrecks are actually working time machines. It is impossible to get closer to the past than this. In Portsmouth Historic Dockyard you feel and touch maritime cultural heritage. There are three historic ships to visit, the HMS Victory the flagship of lord Nelson (18th century), HMS Warrior (19th century) and the Mary Rose flagship of Henry the VIII (16th century).

This is the appeal of the underwater cultural heritage. The thoughts and ways of the ordinary man, so often beyond our grasp, come to life through an artefact like this. The poem from the Scheurrak SO1 wreck – a poem by

SCHEURRAK SO 1 WRECK

It is often the small and trivial object that attracts attention and makes a connection through time. The Scheurrak SO I wreck is an artificial name for an excellent excavated wreck in the Wadden Zee, the Netherlands. The ship probably sank in a severe storm on Christmas Night 1593.

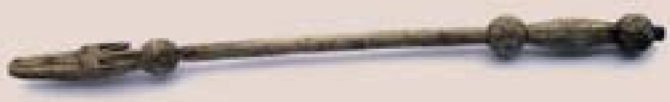
It can teach us a lot about shipbuilding techniques, late 16th-century social and economic history, trade, weaponry, etc. But the extraordinary thing about such a wreck and its inventory lies in the fact that the personality of a sailor is sometimes still there. And that is what makes the underwater cultural heritage so special and irreplaceable.

For example, a linstock was found in the Scheurrak SO1 wreck. A linstock (from the Dutch lontstok, 'lint stick') is a staff with a fork to hold a lighted match, used for discharging cannons on a ship. This one is special because it is has a small poem on its rim, and we have the name of the poet, or at least the owner of the linstock.

In old Dutch, the poem reads: '*Die avent en die muierghen zyn niet even goet – den moerghen moet sorghen dat den avent niet – en doet voude den avent sorghen – als den morghen doet – daer soner menigh ryen die nu gaen tefoet* – bymy Cornelis Clasoon van Block Dick ffff anno 1590'.

'*The evening and morning are not equally good / The morning has to make/do what the evening does not / Should evening make/do what morning does / Then many would ride who are now on foot / Made by me Cornelis Claaszoon van Blokdijk in the year 1590.*[5]

In Blokdijk, a small village near the town of Hoorn, lived a sailor whose name was Cornelisz. Claesz of Westerblokker, aged 23. He was a constable (bosschieter). So it is very likely he was the owner of the linstock.



FIGURES 2a-b Linstock from the Scheurrak S01 wreck – Part of the stern.

an ordinary sailor – is like a 16th-century YouTube movie. We know how the rich and famous thought, but the ideas and writings of ordinary people are rare in history. We want to know how they lived. To see, wonder and learn that our identity is linked to a past that is understandable.

So where can we find this masterpiece of common poetry? The answer is that we cannot. It is not on display in any museum. At this moment resides in the repository of the Dutch Cultural Heritage Agency in Lelystad. This small item from a shipwreck illustrates the value and extra dimension of digitizing the cultural heritage for the future, to disclose it to a worldwide audience.

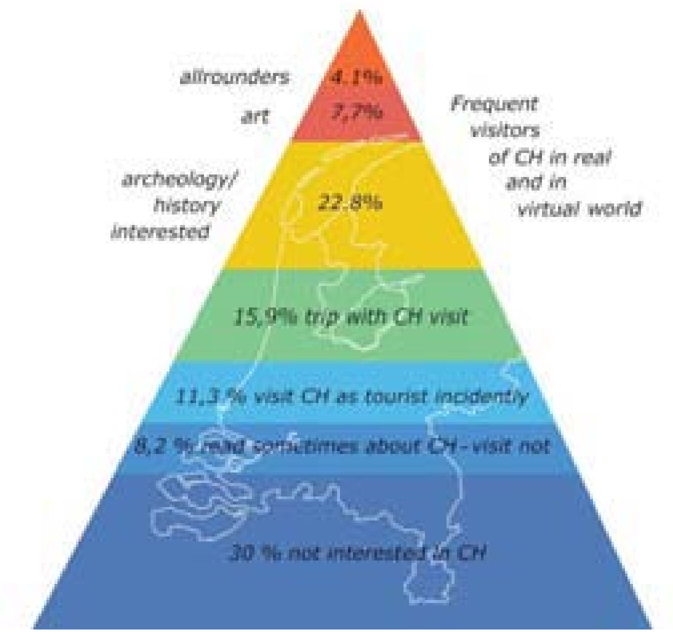


FIGURE 3 Sociodemographic characteristics of the Dutch population clustered into seven profile groups.
Source: SCP

B. VISITING CULTURAL HERITAGE SITES IN THE VIRTUAL WORLD

It is clear that actual cultural heritage sites are still much more popular than their virtual counterparts. The actual experience of being near 'the action' is the extra thrill. Information about and access to 'the action' in written and digitized form can never be more than second best. But again, change is afoot. The computer as a window on the world is becoming a reality in the first decade of the 21st century. Homo sapiens in the real world has also become a *homo digitus* in a virtual world. The web has grown very rapidly, especially with the rapidly growing potential for data exchange in recent years. From small children to senior citizens, everybody uses the Internet as a source of information guide on almost everything. There is already a generation that has never experienced a world without the Internet. For that generation, communicating and experiencing the world through the computer is normal. Social behaviour, contact and personality are highly influenced by sites such as MSN, MySpace, YouTube, LinkedIn and the like. Without friends on LinkedIn or MySpace you do not exist as a person. One's digital personality is almost as important as one's real personality.

Actual cultural heritage sites attract many visitors, and surveys conducted at heritage sites indicate that the management of such attractions is important to visitors. On the Internet, however, the ordinary visitor is not actually present, and does not experience the need to manage a digital archive.[6]

The first three profile-groups (34.6%) are frequent visitors to online cultural heritage sites. 7.7% are interested in art, but not in the historical or archaeological heritage. 30% of the population have no interest in the cultural heritage at all. The group (35.4%) who occasionally visit virtual heritage sites, a vast group of potentially interested visitors who are interested in the cultural heritage and visit at least one real-world cultural heritage site a year, do not yet visit cultural heritage sites on the Internet. However, we can see a trend towards wider use of the Internet (EU-wide) among all groups. So the cultural heritage will benefit automatically from the sheer growth in the number of Internet users. However the possibilities offered by the virtual world are often not exploited to their full potential. In the virtual world there is much to be gained, and it is the 35.4% who are occasional visitors who are an interesting group to target.

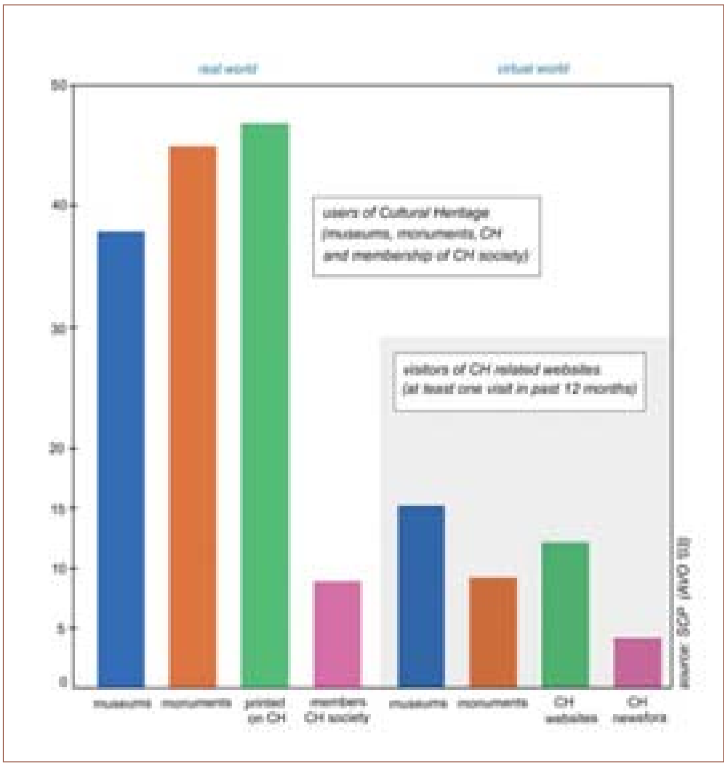


FIGURE 4
Frequent visitors to cultural heritage sites in the real and virtual worlds.
Source: SCP 2006

FIGURE 5
Multi media news on the MACHU website.

WHAT ASPECTS OF CULTURAL HERITAGE TO PRESENT?

One of Europe's key information society policy objectives is to make the content and digitally preserved materials of archives, museums and libraries more widely available.[7] The digitization of the cultural heritage is underway. All over Europe, archives and museums are busy digitizing their collections. There is much discussion as to what aspects of the cultural heritage should be presented and how. Should all the raw data be presented, or at least made accessible, without filters or restrictions, or should a representative proportion be fully digitized, with additional information made available to those who are interested?

WHY PUT DATA ON THE NET? WHO TO ADDRESS?

There is a lot to be found, but consistent treatment is relatively rare. Studies have found that visitors to online cultural heritage resources complain about information often being very scanty. Illustrations accompanying the text are small and information of a more specialist nature is often repeated over and over again on different websites. In other words, the cultural heritage presented is in many ways a little dull, especially if we consider that we want to attract also a younger generation to the cultural heritage. This new group of young Internet surfers are used to an image-driven media: television and YouTube (if it's not on YouTube it's not real… at least not interesting enough to be real).

It is also difficult to ascertain the reliability of information presented on the web. And it is of course very important to know that your information source is trustworthy. It is illustrative to consider how Wikipedia is rated, for example. In some studies it is said to be as good as or better as the Encyclopaedia Britannica. In others, it is scorned as being unreliable due to its open source character.

HOW TO PRESENT THE CULTURAL HERITAGE

The discussion on how to present the cultural heritage is less topical, and yet it is very important to at least try to appeal to a substantial proportion of the public.
Putting a database with raw data on a site and waiting to see what happens is not likely to be an effective way of presenting and promoting

CASE STUDY: THE ARMADA AND THE GIRONA

Take the exploits of the Spanish Armada and the planned invasion of Albion in 1588. This was not just an English-Spanish conflict, but a wider international conflict in which many European regions played a role. On the Spanish side there were Spanish, Italian (Venetian) and German Hanseatic ships. The English were reinforced by Dutch ships.

The Spanish fleet was to accompany and facilitate an invasion of England by Spanish troops from Flanders (the most important city in the Low Countries, Antwerp, had just been conquered by the Spanish). Philip II's main goal was not to conquer Britain but to divide and isolate the Protestant rebels in Holland and punish their allies in Britain with an invasion.

Say you are interested in the Armada, and want to know more about the ships used by the Spanish in that period and what became of the Armada. Or how many Armada wrecks have been located and excavated. You can use Google to find information. Your Google search entry might be something like: '*Spanish Armada, Armada Felicisima, Spanish galleon.*'

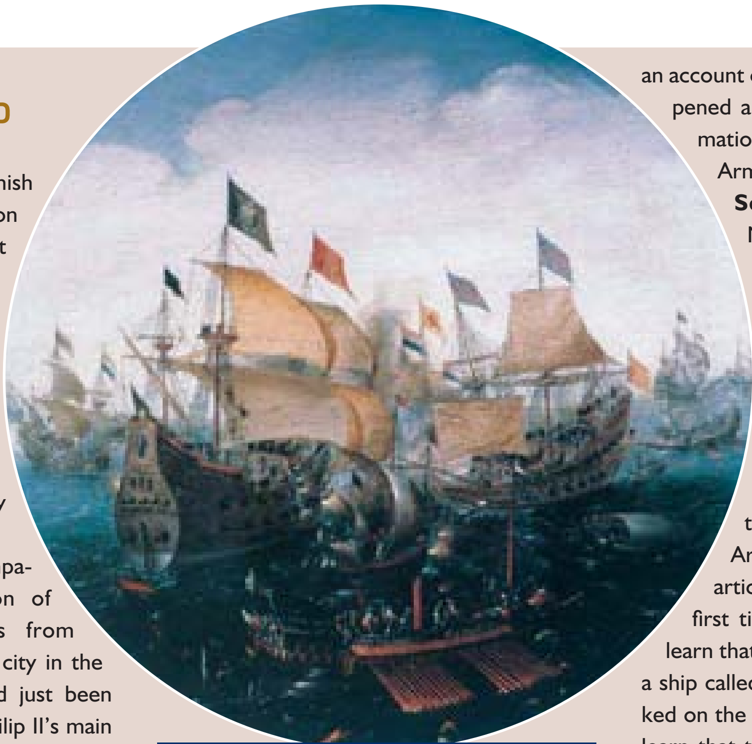


FIGURE 6 An English and a Dutch Ship Attacking a Spaniard ca. 1610.
By Anthonisz,. Aert (1579-1620)[8]

First hit: the site of the National Maritime Museum in Greenwich, London[9], which gives an account of who was involved, what happened and why. But there is no information on the ships used by the Armada.

Second hit: History on the Net.[11] This also gives an account of the invasion with only a headline story.

Third hit: Wikipedia[12]: We find an extended account of the whereabouts of the Armada and, hidden in the text, a link to the Armada in Ireland, but no specific link to ships and the whereabouts of the Armada. But in the Wikipedia article we do at least find for the first time some names of ships. We learn that the greatest loss of life was on a ship called the Girona, which was wrecked on the north coast of Ulster. We even learn that the Girona is depicted on sterling banknotes issued by the First Trust bank in Northern Ireland.[13]

It is interesting to see the different 'historical' interpretations of the Spanish Armada in the different national Wikipedia entries.[14]

FIGURE 7
The Girona depicted on Sterling banknotes.

the cultural heritage. Connectivity and getting the story across are key components of presenting the cultural heritage in data form. We know that visitors want to feel a connection with the cultural heritage and the past, and that means presenting stories about the cultural heritage, pictures, artist's impressions, and also film. Access to and the speed of the Internet increase every year. This also has implications for what we present and how. For instance, Internet film has become a major and important medium. YouTube has grown from obscurity to a kind of video Internet standard.

Stories on the general and the underwater cultural heritage are important and must be presented in Internet formats. This calls for a different type of presentation than in the old media. Concise stories, pictures and film combined with links to related information are very important for Internet visitors, especially since in time, they will become very familiar with the Internet.

WHAT ABOUT THE UNDERWATER CULTURAL HERITAGE IN PARTICULAR?

There is a lot to be found on the cultural heritage online. There is even a lot to be found on the underwater cultural heritage. The problem is that much of the information is scattered and not easy accessible. There is as yet no pan-European underwater cultural heritage website. There is no central information portal on European maritime history, for instance, or on archaeology and the management of the underwater cultural heritage.

To get a comprehensive overview of international maritime history and archaeology you have to browse the net intensively, and then repeat your search. The underwater cultural heritage is by its very nature an international affair, and it should be treated that way. Ships travel from port to port, and tend to be lost in foreign waters. That makes management and disclosure of the underwater cultural heritage an international matter. The presentation of the underwater cultural heritage on the Internet should also be a combined international effort. We need a portal where visitors can find everything they ever wanted to know about wrecks and the stories behind them on one officially authorised international site.

Intensive browsing can unearth information on the subject, but it is not easily accessible. More disturbingly, one finds the same pieces

of information over and over again, often with no means of verification or source.
Although there are many sites providing information on the underwater cultural heritage, it is relatively meagre information, and often seems to come from relatively limited sources repeated over and over again. One very important online source is Wikipedia. This is an open source encyclopaedia so – although interesting – Wikipedia is not a verifiable source of information on the underwater cultural heritage.

Part II The MACHU website as a gateway to the underwater cultural heritage

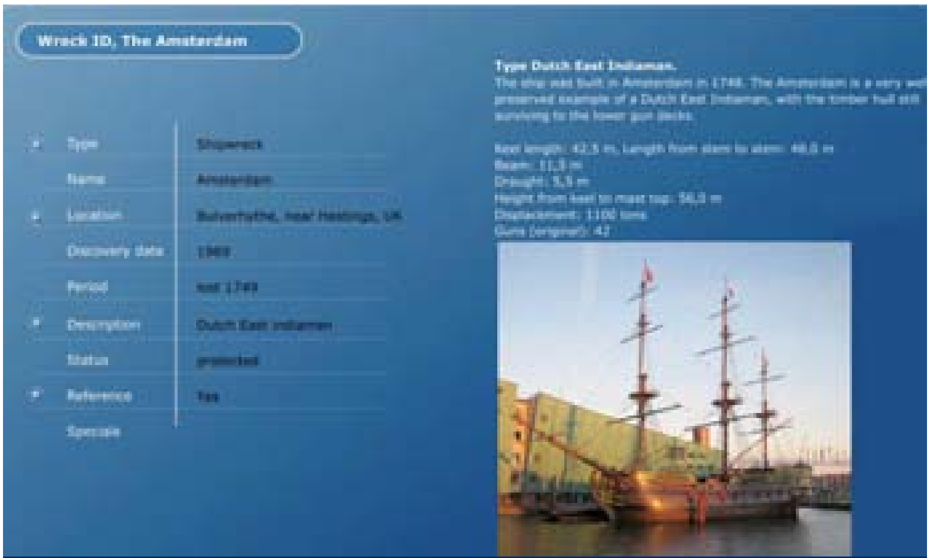


FIGURE 8 The wreck ID of the Amsterdam. Source: MACHU website

FIGURE 9 A virtual archaeological diving experience. Source: MACHU website

We have already observed that information on the underwater cultural heritage in the virtual world is scattered and not easy accessible. But above all – and despite the open source character of the information on sites like Wikipedia, which have attracted a great deal of praise – it is not historically validated information. In my view, a centrally managed international (European) portal on maritime history and the underwater cultural heritage should be launched.
A platform exists that could be used as a portal for this purpose. That platform is the MACHU website. Seven international maritime institutes are already working together in the MACHU consortium, collecting and entering data on the underwater cultural heritage into the MACHU GIS and, to a lesser extent, on the regular website.

MACHU is all about managing cultural heritage underwater, and its first objective was to describe the variety of underwater cultural heritage sites and wrecks. The GIS has proved to be a powerful management tool where researchers and planners can find basic spatial information on the underwater cultural heritage, details of legislation pertaining to it, methods of preservation (in situ) and a code of good practice on the underwater cultural heritage and its management.
All aspects of managing the underwater cultural heritage are explained on the MACHU website. This is the corporate information. But this primary information – however important – is not descriptive in an historical and archaeological sense. It has nothing to do with storytelling. The cultural aspects of the sites are not extensively described in the GIS. And let us be honest, the general public will not be very interested in the management of the underwater cultural heritage in itself. However, they will be drawn to the subject of management indirectly if it is incorporated into stories about sites and wrecks.

INFORMATION ON WRECKS AND SITES ON THE MACHU WEBSITE

In analysing information MACHU uses a number of criteria defined in best practice guidelines for the use and digitization of the cultural heritage on the Internet. These guidelines were drafted as part of several European projects, and represent an attempt to standardise the minimum requirements for presenting the cultural heritage in digitized form.[15] The description of the wrecks in the public part of the MACHU site sticks to the formats agreed on by the MACHU partners for the information in the GIS.

The left side is the actual record, setting out what you might call the database information.
Type: shipwreck, site, structure
Object name < scientific >
Name <name of ship/ popular name>
Location < country, region, place> no coordinates given
Date <period> lost /or
Discovery date < modern>
Description <yes>
Status <(well) preserved ex/ in situ, excavated, partly >
Links <external, in print or virtual>
Picture <images, >
Specials <maps, video, sound >

The fields also function as buttons. Click on 'Description', and the available information will appear on the right. The right side is reserved for the extras activated by clicking a field on the left. The Type entry tells you more about a given ship type (if possible). The description part gives information on the archaeological background of the site, stories associated with it and/or historical information. Impressions of how a ship might have looked (artist's impression, movie) can be added in the 'Specials' section. Subjects like navigation, ordnance and maritime warfare in relation to the wreck can also be discussed.

This extra feature, combining a database with special features, is what makes this method of presenting the underwater cultural heritage potentially a very powerful tool in the race for visibility. Visibility on the web depends to a large extent on such extras that can attract an audience. If a wreck or object can be seen in its historical and archaeological context, it will be much more appreciated.

ADDRESSING THE PUBLIC

One important aspect of the MACHU website is that it not only addresses people who are already interested *(see figure 2)*. It can address a much wider audience with the way it represents the underwater cultural heritage. It allows more scope for the story behind it, lets images and film speak, and tries to tell the story of the underwater cultural heritage in normal language, in an attempt to draw the general public to the subject. MACHU is especially keen to address students and children, providing them with additional information on maritime history. There is a segment on the website where, in a game-like environment, visitors can actually have a virtual diving experience as an underwater archaeologist. It also has items on ship types through the ages and on terminology for parts of old sailing ships. Such educational features must be presented in more languages, to serve the needs of individual EU partners, especially since it is best to address children in their native language. With online presentations, it is fairly easy to adapt the subject according to the region (language) or individual (education level). This will make the appeal of the underwater cultural heritage more accessible to a wider public than any other form of presentation.

CONCLUSIONS

Europeans are interested in the cultural heritage in general, and in the underwater cultural heritage. The public will support the management and protection of the underwater cultural heritage. But they must first be made aware of its existence, vulnerability and richness. Presentation of this part of our cultural heritage online is currently scattered and diffuse at best. A central platform on the underwater cultural heritage would meet the need for easily accessible information in plain language with visual extras, all monitored by an international conglomerate of national maritime institutes, and serving as a portal for all stakeholders: the scientific community (both GIS and wreck IDs alike), policymakers (GIS) and the general public.

NOTES

1 Frank Huysmans, Jos de Haan, *Het bereik van het verleden, Ontwikkelingen in de belangstelling voor cultureel Erfgoed, Het culturele draagvlak deel 7.* SCP (Den Haag, december 2007) p. 127. Eurobarometer 56.0 is a survey of public opinion in the European Union. An additional study was CC-EB2003.1, which also investigated interest in archaeology among citizens of the EU member states.

2 Ibid. p. 153.

3 ibid 64% of visits are combined with a non-cultural activity such as outdoor recreation or visiting a city. p 125 table 5.4.

4 Cultural heritage is defined as: '*Traces of the past visibly and tangibly manifest in the present. These may be objects in museums, archaeological finds, archives, monuments and historic buildings, or landscapes, as well as the customs and narratives associated with them. A distinction is thus drawn between the material and non-material heritage.*' (source: www.cultuurnetwerk.nl). '*Digital heritage*' is information on the cultural heritage available in digital form.

5 www.machuproject.eu/wrecks/

6 Henrieke Wubs, Frank Huysmans, *Klik naar het verleden, Een onderzoek naar gebruikers van digital erfgoed* (Den Haag 2006) pp. 30-31.

7 www.numeric.ws/ The Numeric Study aims to measure the progress of the digitization of Europe's cultural heritage. One of Europe's key information society policy objectives is to make the content and digitally preserved materials of archives, museums and libraries more widely available. Across Europe, these institutions are converting their 'analogue' collections into digital form, thereby creating new opportunities for all interests to benefit from improved and convenient access to these resources. NUMERIC is a European Commission project that defines the empirical measures for digitization activities and establishes the current investment in digitisation and the progress being made by Europe's cultural institutions.

8 Source: National Maritime Museum, Greenwich, London.

9 www.nmm.ac.uk/

10 www.nmm.ac.uk/explore/sea-and-ships/facts/navies-and-warships/the-spanish-armada

11 www.historyonthenet.com/

12 http://en.wikipedia.org/wiki/Spanish_Armada

13 http://en.wikipedia.org/wiki/Spanish_Armada_in_Ireland

14 I did only very brief research, but it seems that information on the Internet is often neither validated nor free from bias.

15 http://dublincore.org/documents/usageguide/ It defines conventions for describing things online in ways that make them easy to find. Dublin Core is widely used to describe digital materials such as video, sound, image, text, and composite media like web pages. Dublin Core is defined by ISO in ISO Standard 15836, and NISO Standard Z39.85-2007.
See also www.minervaeurope.org/, MINERVA Project: MINERVA EC, MInisterial NEtwoRk for Valorising Activities in digitisation, eContentplus

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– *Het bereik van het verleden, ontwikkeling en de belangstelling van Cultureel Erfgoed* (Den Haag 2007).
– Colin Martin, Full Fathom Five (London 1975). ■

Investigating the hypothesis 'High diving frequency equals increased deterioration'

How does scuba diving affect shipwrecks in the Stockholm archipelago? Testing a GIS model

Our goal was to develop a GIS working model that allows us to generate an overall picture of the condition of the underwater cultural heritage and to predict various future scenarios.

WHY USE GIS?

All our statistical data are connected to a geographical position (geographical relevance). While it is important to understand the process of ongoing deterioration, it is equally important to know where deterioration takes place. This gives us a better chance of understanding the causes of the deterioration and a better grasp of how we can best manage the underwater heritage.

Processing real-world data, GIS creates features on a map. Each feature comprises data that can be used for depiction or analysis. GIS data are often referred to as 'layers', and this article is no exception.

The GIS model is designed to analyse the general condition of the underwater heritage. This means that the model does not determine whether individual wrecks are at risk, but rather whether whole areas that include many wrecks are under threat. Furthermore, the GIS model is designed to provide us with indicators for future scenarios.

This should help us identify exposed water areas and predict the vulnerability of the underwater cultural heritage. It will also help us preserve and manage our common heritage under water, by making it accessible in the form of diving parks, for example.

To achieve these goals, the GIS model needs to provide answers to the following questions:

- Under which circumstances does deterioration take place?
- To what extent does recreational diving contribute to the deterioration/damage (looting)?
- What factors promote recreational diving? Which shipwrecks have the highest diving frequency?
- How will the trend in recreational diving affect the underwater cultural heritage in the future?

DATA AND VARIABLES

There are three different causes of deterioration:

- Natural causes
- Recreational diving
- Human activities other than diving

Unfortunately, GIS could not help us determine natural causes, as there are not yet enough accurate data to run a GIS analysis. More basic research is required to explore the natural causes of deterioration. The data on natural deterioration employed in our study were almost exclusively based on our fieldwork.

In order to determine statistical relationships and to make the model work, the variables need to:

- be objective and suitable for statistical use;
- allow monitoring over a certain period of time;
- provide information that can be used for predicting effects on the underwater cultural heritage;
- be at least partly suitable for external validation.

STATISTICS AND WEIGHTING

To be able to translate diving frequency into a deterioration factor (or an effect index), we validated several variables. We determined the statistical relationships between the variables that influence recreational diving and the exploitation pressure *(see figure 3)*. We also had to understand how the variables related to each other, as well as the impact of every single variable (weighting).

We determined the current diving frequency from the diving logs of the online diving community www.dykarna.nu. Information on diving frequency over time was obtained by means of a questionnaire (see article by Göran Ekberg), which also gave us information about the divers' reasons for recreational diving and their diving behaviour on wrecks. Establishing diving behaviour was very important, as our goal is to predict objects or areas that are likely to be vulnerable in the future.

The analytical process comprised several steps *(see figure 4)*. Step one was to establish the actual deterioration process. This analysis was based on the results from the GIS analysis of the digital map layers, the diving frequency and the results of our fieldwork. The potential

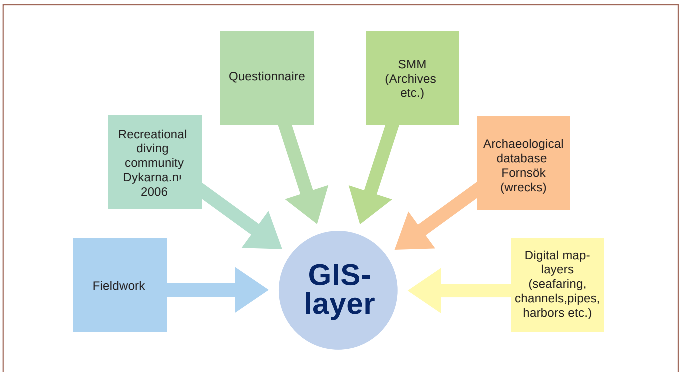


FIGURE 1 The data processed in the study are from different sources and in different formats. The data is presented as an attribute to the object (wreck) or to an area (usually the nautical mile grid) in a GIS vector layer.

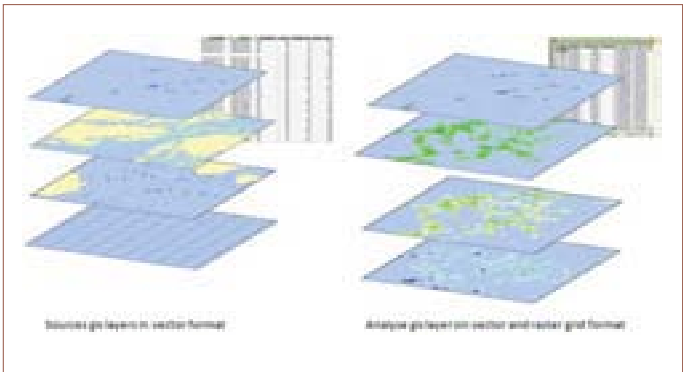


FIGURE 2 The features in vector layers are linked to the data by a common Id number and to the nautical mile grid through the Id of the common square. This allows GIS maps to be dynamic, as the data is displayed to meet different purposes and different scales.

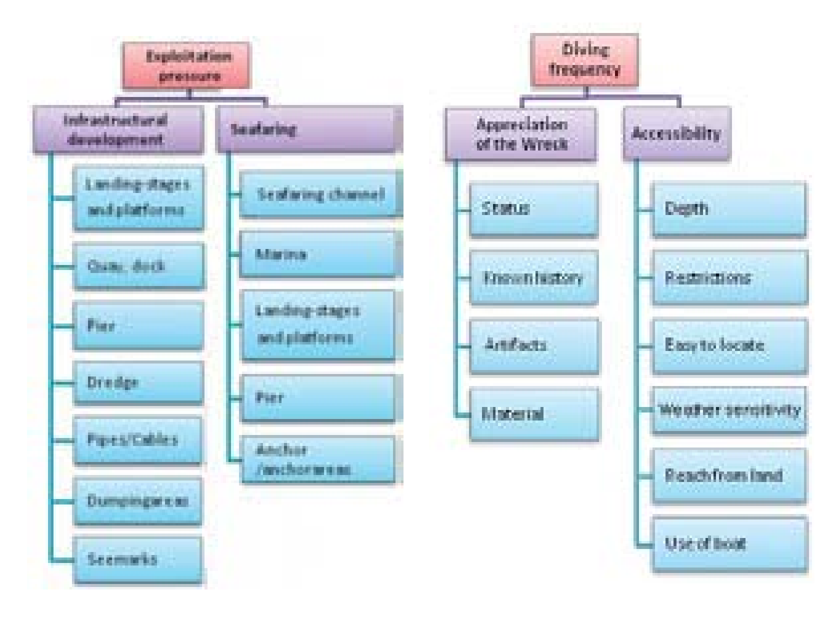


FIGURE 3a-b Effect variables on exploitation pressure and diving frequency (digital map layers to the left and various sources to the right) used in the study. Variables concerning deterioration - see article by Jim Hansson (p.90 - 92).

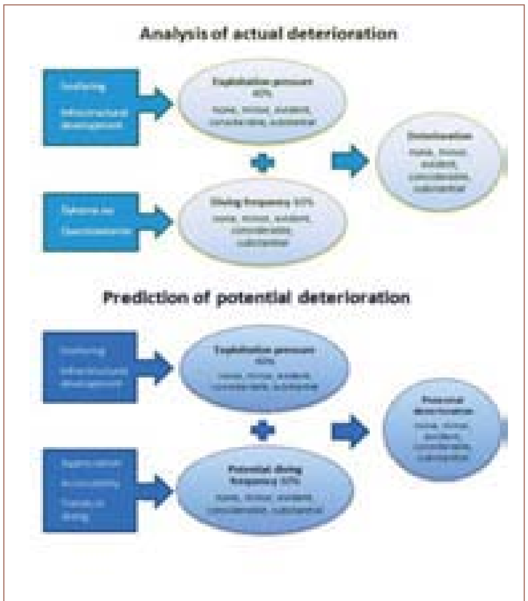


FIGURE 4 Analytical process: We determined the actual deterioration process based on the results from the GIS analysis and fieldwork. The potential deterioration data is based only on the GIS analysis. For further analysis, the different results are presented as GIS layers: exploitation pressure, diving frequency, deterioration, potential diving frequency (or diving interests) and potential deterioration.

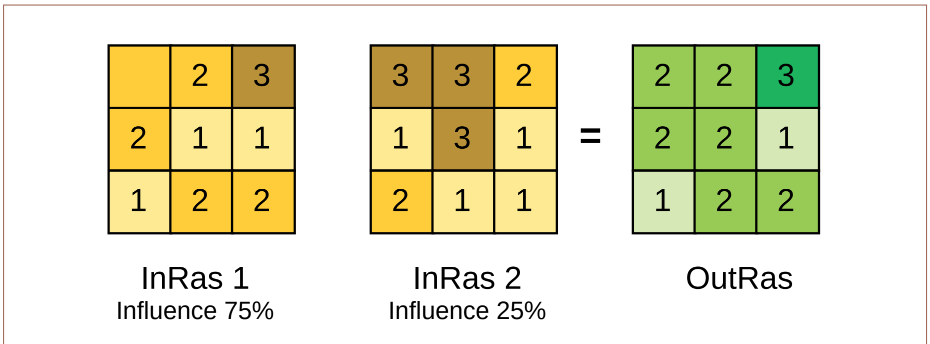


FIGURE 5 Principle of weighted overlay analysis.

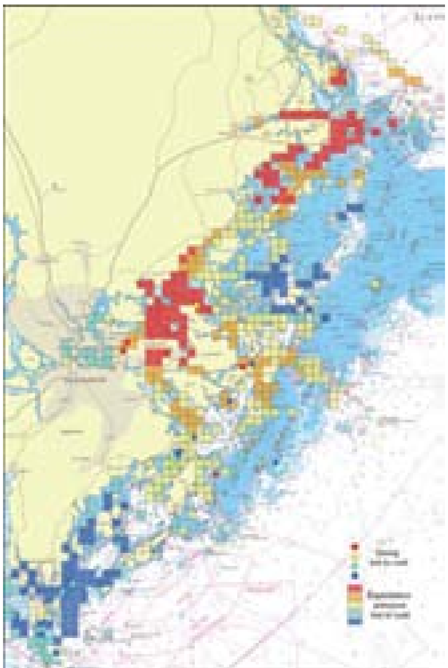


FIGURE 6 Hot Spot analysis.

deterioration was derived exclusively from our GIS analysis. For further analysis, the results are presented as a number of GIS layers: exploitation pressure, diving frequency, deterioration and potential diving frequency (or diving interest) and potential deterioration.

GIS ANALYSIS

The GIS environment is based on both vector and raster layers. We used two different methods to analyse the data:

1. The vector analysis focused on the objects and their attributes: location, status, quantity, and other attributes that refer to an object or area.

2. The raster analysis allowed us to transfer our analysis from a single wreck to the scale of an entire area using the nautical mile grid and the ID of the common square *(see figure 2)*.

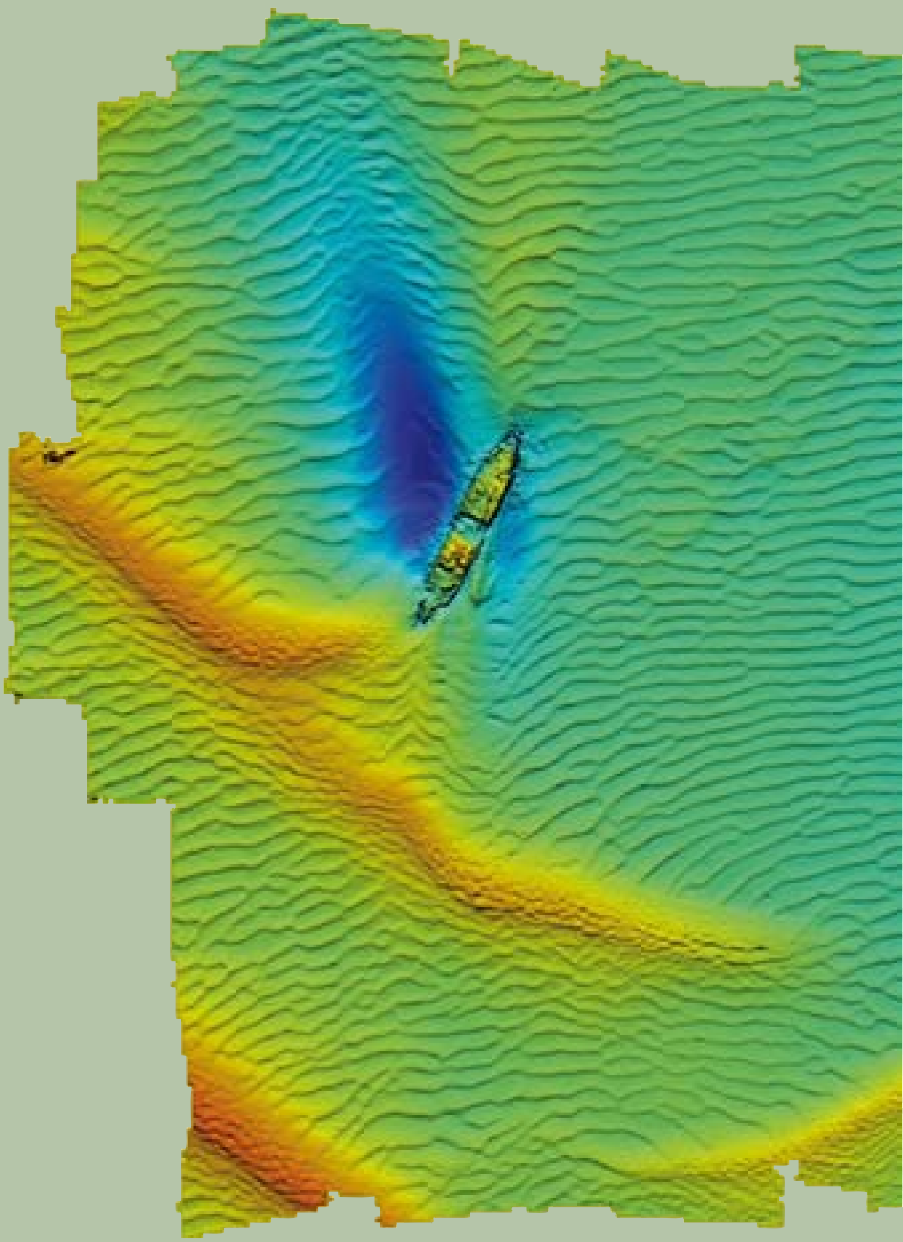
The nautical mile grid was analyzed in raster, for example: Hot Spot analysis and Weighted overlay. Weighted overlay superimposes several rasters using a common map scale and weighting according to the individual raster's importance.

The Hot Spot Analysis tool calculates the (Getis-Ord Gi*) statistic for each feature in a dataset. The result reveals where features with either high or low values are spatially clustered. This tool works by looking at each feature within the context of neighbouring features. A feature with a high value is interesting, but may not be a statistically significant hot spot. To be a statistically significant hot spot, a feature must have a high value and be surrounded by other features with high values.

A WORKING MODEL THAT WORKS

Our study established that recreational diving causes deterioration of the wrecks (see article by Jim Hansson). The predictive modelling is based on a number of statistical-spatial relationships estimating the deterioration pressure and diving frequency at wreck sites within a reference area (i.e. the model area). The model area is then extrapolated to a larger-scale analysis. Our GIS model allows us to locate water areas with potentially high pressure, thus helping us to predict 'danger zones' and to indicate particularly vulnerable wrecks or other remains. ■

INNOVATIVE TECHNIQUES FOR ASSESSMENT AND MONITORING



The MACHU project used and evaluated some fairly innovative techniques for management of the underwater cultural heritage (see also MACHU Reports 1 and 2).

The innovative element lay in some cases in the introduction of a new method or technique being used for the first – or nearly the first – time in connection with the underwater cultural heritage. Sometimes, however, the innovative part lies in the fact that information is being collected, combined and presented in a way that has never been done before, as in the MACHU GIS. These new techniques are being introduced not just for the sake of it, but to meet the goal of achieving better and more effective management.

The following articles all talk about combining and retrieving data and information from the sites and their environment. The environment is extremely influential for the condition of the sites and must therefore be assessed and considered. These articles clearly show that changes in the environment and the condition of individual sites will have a major influence on the management of the underwater cultural heritage. A good understanding of the condition and archaeological value of sites and the processes that influence them will make overall management more accurate and cost-effective. ◻

Optical dating: potentially a valuable tool for underwater cultural heritage management

INTRODUCTION

The management of the underwater cultural heritage raises many challenges. The resource is largely invisible and its environment hostile to investigators and the site itself. Sediment dynamics may have a positive effect, bringing about the rapid burial of a sunken wreck, for example, but may also cause periodic or ongoing exposure of the site. The causes of such sedimentation changes can be natural, such as a change in currents, or human, such as sand extraction or even the removal of sand during archaeological investigations. The exposure of a site triggers several deterioration processes – including abrasion, attack by shipworm, fishing nets getting caught up in ship parts – thus diminishing the archaeological value of the site. Obviously, the archaeological value of shipwrecks largely depends on their state of preservation.

It is therefore important to know the post-depositional processes at an archaeological shipwreck site, from the moment it was wrecked until the present. MACHU aims to find effective methods of underwater cultural heritage management. Within this project we have for the first time (as far as we know) used optically stimulated luminescence dating (OSL) for archaeological shipwreck assessment underwater. In addition, we combined OSL research with grain size analysis and the use of stable lead isotopes and geochemical analysis. The dating of sediments covering a shipwreck can be used to determine the burial history and to identify possible deposition (sedimentation) and exposure (erosion) phases. Details of the optical dating method, and an introduction to this study, including a description of the fieldwork, site and aims of the OSL research, have already been published in MACHU Report 2 (Manders et al. 2009, 40-42). In this article, the final results of this research are presented.

In this study we applied optical dating, grain size analysis and geochemical analysis to two cores taken near shipwreck BZN 10 in the Wadden Sea. The aim of our research was to determine when the sand below, beside and on top of the shipwreck was deposited. The reasons for this will be explained below. Finally, we also wanted to establish whether the method of physical *in-situ* preservation applied at this site was working. Studying sediment transport and burial rates allows preservation methods, such as the polypropylene netting used here, to be evaluated and or improved.

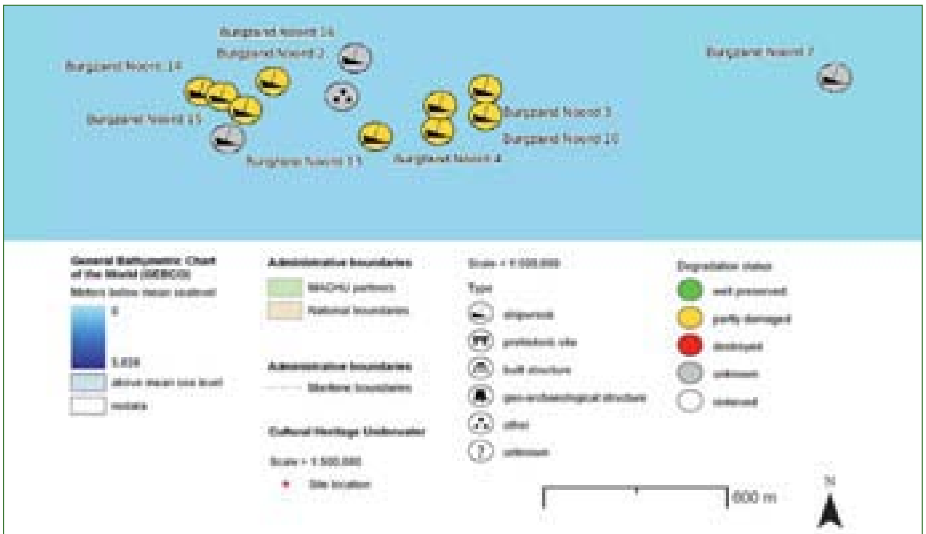


FIGURE 1 The BZN 10 wrecksite between the other known Burgzand sites in the Wadden Sea. Source: MACHU GIS

The specific aims of this study were:

- to investigate the application of OSL dating to sediment transport and deposition in the Wadden Sea and to evaluate the application of OSL dating to shipwrecks in a dynamic environment;
- to date sand layers below, in and on top of a physically protected shipwreck (BZN 10). By accurately dating sand, the age of a wreck can be narrowed down, making identification easier. In addition, transport of 'bleached' sand after the sinking of the ship can give us an indication as to when and how fast the ship was buried. Furthermore, if younger sand is found in or below a shipwreck, it is likely that the wreck moved after sinking. Also, the environment may be highly dynamic, causing the ship to be repeatedly exposed. This can be important for assessment of the value or significance of ship and cargo, and for determining whether to preserve in situ or ex situ (through excavation);
- underneath the wreck: to test the hypothesis that shipwrecks sink into the Holocene sediment of the Wadden Sea, which appears to be less consolidated than the hard Pleistocene subsurface;
- in the wreck: to use drilling to find *in-situ* shipwreck-related debris and sediment layers. In this way, it may be possible to establish if a site contains relatively undisturbed sediment layers that may contain artefacts from the wreck site;
- above the wreck: to investigate the relative intactness of the site and, in the case of physically protected sites, to investigate the effectiveness of *in-situ* preservation in the Wadden Sea. Five shipwrecks in the Wadden Sea have been physically protected *in situ* with polypropylene nets.[1] These nets can be used as an independent age marker and thus serve as a control for the OSL dating.

In this article the OSL results will be evaluated by comparing them with the lithological and sedimentological results as revealed by grain size and geochemical analysis. Studying grain size distribution allows us to address questions such as 'Is sedimentation continuous or does it occur during events?', 'Are there any

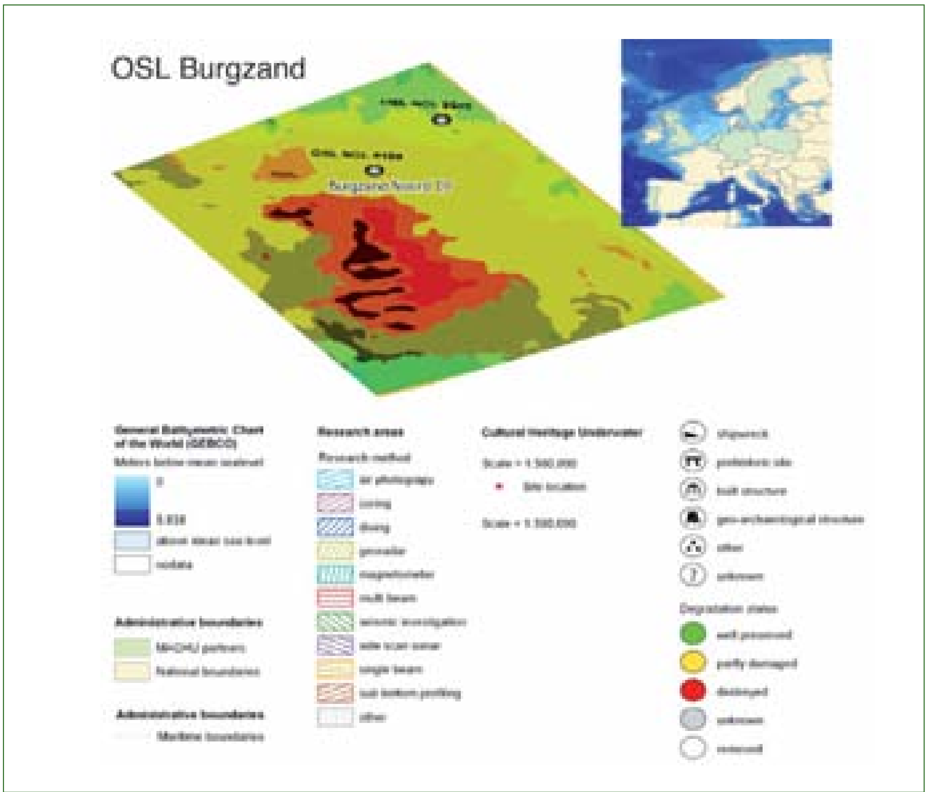


FIGURE 2 The two Ackermann cores 9108 (inside the wreck) and 9208 (just outside the wreck). Source: MACHU GIS

FIGURE 3 The Ackermann tubes are 350mm long and 66 mm in diameter. The samples are undisturbed and completely sealed off to prevent light coming in.
Photo: P. Voorthuis/Highzone Photography.

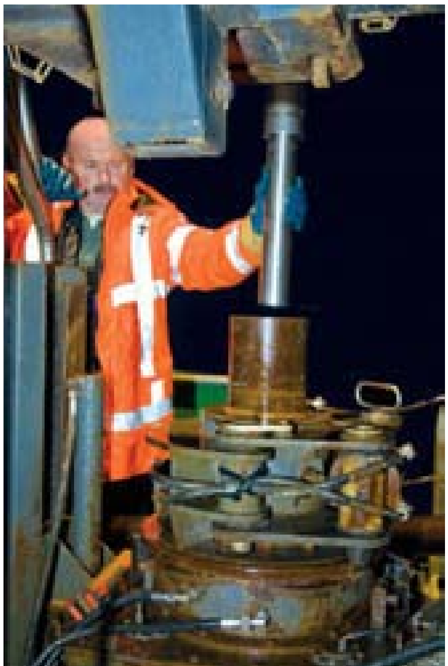


FIGURE 4 The cores were taken with an installation placed at the stern of the research vessel.
Photo: P. Voorthuis/Highzone Photography

gaps in the sequence?', 'Is sediment transported through waves (fining upward sequences) or during periods of low energy?'. To further unravel the past sediment dynamics of the Wadden Sea, major element and anthropogenic trace metal concentrations and stable lead isotopes were analysed.

Stable lead isotopes can be used to fingerprint the provenance of anthropogenic lead. From 1950 to 1983 lead was added to petrol as an antiknock agent (Walraven et al. 1996). This lead originated from Broken Hill, Australia, and had a lead isotopic ratio very different from European industrial lead and natural lead. By studying metal profiles in the sediment, it is possible to identify the onset of the industrial revolution, the introduction and use of antiknock agent, and the last 20 years. In addition, if the metal profiles and stable lead isotopes can be used to identify sedimentation events, this could provide useful information such as the rate and frequency of burial or erosion events at shipwreck sites in dynamic sandy environments in shallow (less than 30 m) continental seas. Erosion events may also be marked by changes in grain size and heavy mineral concentrations that may be indicated by trace elements such as REE, Zr and Ti.
Major element concentrations and carbon and sulphur contents reflect lithological changes (such as calcium carbonate and clay content) and can therefore add to our understanding of the sedimentation history.

METHODOLOGY

THE SITE LOCATION

This study concentrated on the Burgzand Noord 10 (BZN 10) wreck located on the Burgzand sandbank in the Wadden Sea, east of the Dutch island of Texel (*Figure 1*). The BZN 10 was a 17th-century trader of possible Northern German origin carrying a cargo from the Iberian Peninsula (Manders 2002, 2003, 2006, Manders & Kuijper 2003, Van Holk 2003).

The site was selected for this research for several reasons. The wreck is situated in one of the initial MACHU test areas, it is physically protected *in situ* (Manders 2004) and extensive information about the site, the ship and its environment is already available (see references above).

THE FIELDWORK

The samples were taken from the site on 27 November 2007. Two Ackermann cores were drilled, one through the wreck (no. 9108) and one just next to it (no. 9208) (*figure 2*). The aim was to go through the whole Holocene layer and one or two metres into the Pleistocene sediments below (for more information about the sampling see MACHU Report 2: Manders et al., 2009). We were hoping that the core through the wreck site (no. 9108) would strike timbers from the ship structure. This could then be used as a reference point for dating the sediment.
The Ackermann cores consist of RVS tubes 350 mm long and 66 mm wide (*figures 3 & 4*). No light can get to the undisturbed samples that together make up one continuous sample. The core taken outside the wreck (9208) was almost six metres long and consisted of 17 separate samples. The core inside the wreck was almost nine metres long and consisted of 25 samples. Unfortunately, the last core never hit the ship structure. It probably passed between two parts of the wreck. However, parts of the protective nets were present in the samples.

OPTICAL LUMINESCENCE DATING

Optical dating is the most versatile tool available for determining the time of deposition and burial of sandy deposits (see also Manders et al. 2009). However, application of the method to sediments in the Wadden Sea is not straightforward matter, because light exposure of the grains prior to deposition and burial may be too limited to completely reset the OSL signal ('set the OSL clock to zero'). Any remaining OSL signal will result in a positive age offset; the OSL age of such deposits overestimates the true burial age. To counteract such problems, one can use the part of the OSL signal that is most light-sensitive (i.e. has the best chance of being reset), and one can try to use only those grains for which the OSL signal was reset (i.e. the grains or subsamples giving the youngest results). Both approaches have been successfully used to determine the age of fluvial deposits. They had never previously been applied to Wadden Sea sediments, however.

To select a suitable sampling depth for full OSL dating analysis, some 20 samples from the two cores were examined in a 'quick and dirty' investigation. Unfortunately, the results were too scattered to convincingly guide sample selection (*see figure 5*). After discussion between the NCL and the Dutch Cultural Heritage Agency, ten samples were selected for full analysis (see the list of dated samples that have been subject to full analysis in *figures 8 and 9*).

RESULTS

OSL RESULTS EQUIVALENT DOSE

Suitable parameters for the SAR protocol were determined on the basis of the sample characterization tests.[2]

There were no signs of contamination with feldspar so no infra-red (IR) bleaching was needed prior to the OSL measurements.

Based on the scan test and information on the sample origin it was decided to cover the centre 2 mm of each aliquot with quartz grains.[3] Results of the preheat plateau tests and thermal transfer tests indicated that the equivalent dose was independent of the preheat temperature in the region 180° C to 220° C for 10s. Based on the thermal transfer tests a 10s preheat of 200° C was selected with a cutheat of 200° C for all subsequent measurements. The net signal used for analysis was obtained by subtracting the background signal (0.8 - 1.6 s) from the initial signal (0.0 - 0.8 s) (early background subtraction method, Ballarini et al., 2007). The SAR procedure applied is described in Wallinga et al. (2009). Results of the equivalent dose determination for all samples from cores 9108 and 9208 can be found in *figure 6*.

Once all measurement parameters had been determined and the protocol tested, measurements were taken to determine the equivalent dose of all samples. Measurements were repeated until at least 24 aliquots per sample had given results that passed the rejection criteria. A suitable method for sample equivalent dose measurement was selected, depending on the depositional environment and the observed spread in single-aliquot equivalent doses (Galbraith et al., 1999; Lian and Roberts, 2006; Wallinga, 2002). Because the deposits are very young and equivalent dose results are widely scattered for most samples, the PDF fitting method developed by Wallinga et al. (in press) was used to determine the burial dose from the equivalent dose distribution.[4] This method assumes that the spread in the single-aliquot equivalent dose values measured is dominated by incomplete resetting of the OSL signal in some grains at the

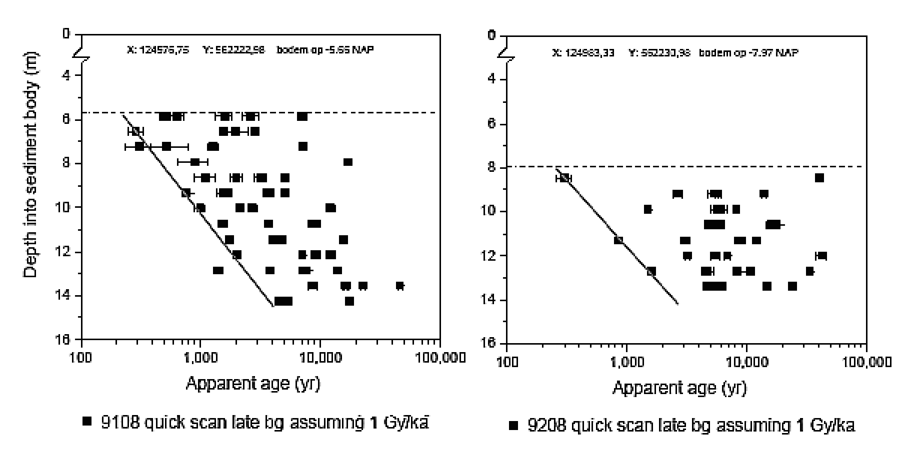


FIGURE 5 Preliminary OSL age estimates using 'quick and dirty' methods. Note that the results are too scattered to convincingly guide sample selection for full OSL analysis.

Sample NCL	Preheat (°C)	Equivalent	(syst.)	(rand.)	Aliquots all	iterated	Recycling point		Recuperation point		Dose recovery Dose (Gy)	Ratio	IR red. (%)	Comments (De)
NCL-9108001	200	0.207 ± 0.031	0.004	0.031	33	25	1.01 ± 0.02	R2	0% ± 1%	N	2	0.97 ± 0.03	3%	De from PDF analysis
NCL-9108003	200	0.055 ± 0.018	0.001	0.018	25	19	1.03 ± 0.02	R2	-2% ± 1%	N	2	0.99 ± 0.04	2%	De from PDF analysis
NCL-9108005	200	0.234 ± 0.030	0.005	0.030	27	23	1.03 ± 0.02	R2	-2% ± 1%	N	2	0.97 ± 0.00	3%	De from PDF analysis
NCL-9108010	200	0.256 ± 0.024	0.005	0.023	24	19	1.00 ± 0.02	R2	-1% ± 1%	N	2	1.04 ± 0.09	1%	De from PDF analysis
NCL-9108013	200	0.631 ± 0.024	0.013	0.020	29	23	0.98 ± 0.01	R2	0% ± 0%	N	5	0.92 ± 0.04	-2%	De from PDF analysis
NCL-9108017	200	0.631 ± 0.042	0.013	0.040	27	22	1.03 ± 0.02	R2	-1% ± 1%	N	5	1.12 ± 0.07	2%	De from PDF analysis
NCL-9108023	200	0.740 ± 0.040	0.004	0.040	24	18	1.02 ± 0.01	R2	0% ± 0%	N	15	0.95 ± 0.07	1%	De from PDF analysis

Table 8 2 Summary of equivalent dose results 9208

Sample NCL	Preheat (°C)	Equivalent	(syst.)	(rand.)	Aliquots all	iterated	Recycling point		Recuperation point		Dose recovery Dose (Gy)	Ratio	IR reduction (%)	Comments (De)
NCL-9208026	200	0.083 ± 0.005	0.002	0.005	29	23	1.02 ± 0.01	R2	0% ± 1%	N	5	1.03 ±	1%	De from PDF analysis
NCL-9208030	200	0.715 ± 0.025	0.014	0.021	27	21	1.03 ± 0.01	R2	0% ± 1%	N	5	1.05 ± 0.10	2%	De from PDF analysis
NCL-9208039	200	1.328 ± 0.030	0.027	0.014	21	17	1.05 ± 0.02	R2	0% ± 1%	N	5	1.06 ± 0.05	5%	De from PDF analysis

FIGURE 6 Results of equivalent dose determination. 7 samples are from core 9108, 3 from core 9208.

time of deposition. The burial dose is therefore expected to be at the lower end of the equivalent dose distribution. We obtained palaeodose estimates for our samples by fitting a Gaussian to the lowest peak in the distribution;[5] a second Gaussian was fitted to the remaining data to aid the fitting procedure. Due to the extreme spread in equivalent dose estimates for some samples, the burial dose estimates may not be valid in all cases. The implications for the optical ages obtained are discussed below. After calculation of the sample equivalent dose an associated random uncertainty was added through error propagation to allow for uncertainties in the dose rate of the beta source used for the measurements (Bos et al., 2006). Equivalent dose results and additional information on equivalent dose estimation for all samples are listed in *figures 6 and 7*.

DOSE RATE

Radionuclide concentrations of the samples showed no sign of secular disequilibrium. For calculation of the environmental dose rate we assumed a water content of 20% by weight (typical of sandy deposits). Organic contents were well below 1% by weight and were not taken into account. For calculation of the cosmic dose rate we assumed the samples were gradually covered by younger sediments after deposition, and we took attenuation by the water column into account. Dose rates from 0.73 to 1.06 Gy/ka were obtained, which is in line with results on other samples from similar environments.

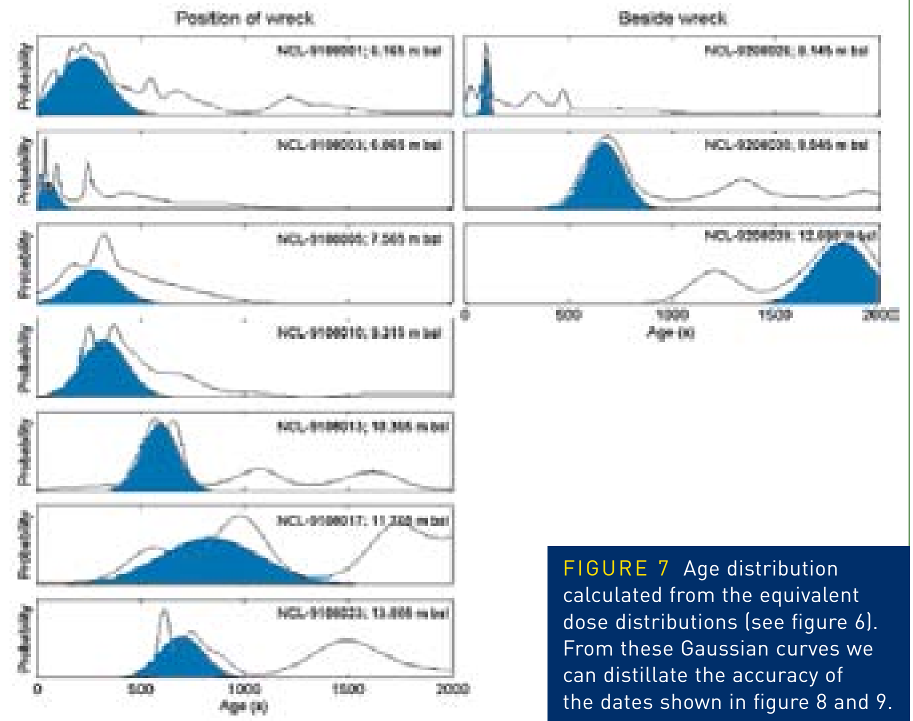


FIGURE 7 Age distribution calculated from the equivalent dose distributions (see figure 6). From these Gaussian curves we can distillate the accuracy of the dates shown in figure 8 and 9.

OPTICAL AGES

Optical ages are calculated by dividing the sample equivalent dose by the sample dose rate. For each sample, the validity of the optical age estimate is ascertained on the basis of the single-aliquot equivalent dose distribution and the consistency of ages obtained from samples taken at different depths in a single core. This judgement is based on expert opinion, and is thus subjective. For both cores, the spread in single-aliquot age estimates for samples from the upper metre below the seabed precludes reliable dating (see for the datings figure 8 & 9). However, the age of these sediments is very likely to be 100 years or less. At the location of BZN 10 (9108) the results from underlying sediments (1.5 - 3.5 m below the seabed) indicate an age of around 300 years; these age estimates are likely to be valid. Hence, optical dating

Sample NCL	Client	Location X	Location Y	Location Depth (m)	Equivalent dose (Gy)	Dose rate (Gy/ka)	Age (ka)	Validity	Age (AD)
NCL-9108001	Z39	124976	562222	0.175	0.207 ± 0.031	0.929 ± 0.031	0.223 ± 0.034	Maximum age	1785 ± 34
NCL-9108003	Z42	124976	562222	0.875	0.055 ± 0.018	0.984 ± 0.034	0.056 ± 0.018	Maximum age	1952 ± 18
NCL-9108005	Z75	124976	562222	1.575	0.234 ± 0.030	0.820 ± 0.029	0.285 ± 0.038	Likely OK	1723 ± 38
NCL-9108010	Z122	124976	562222	3.325	0.256 ± 0.024	0.788 ± 0.027	0.325 ± 0.032	Likely OK	1683 ± 32
NCL-9108013	Z155	124976	562222	4.375	0.631 ± 0.024	1.062 ± 0.037	0.594 ± 0.030	Likely OK	1414 ± 30
NCL-9108017	Z176	124976	562222	5.775	0.631 ± 0.042	0.755 ± 0.027	0.836 ± 0.063	Questionable	1172 ± 63
NCL-9108023	Z179	124976	562222	7.875	0.740 ± 0.040	1.062 ± 0.037	0.697 ± 0.045	Likely OK	1311 ± 45

FIGURE 8 Dating results from core 9108 (in the wreck).

Summary Table Dating results project 9208

Sample NCL	Client	Location X	Location Y	Location Depth (m)	Equivalent dose (Gy)	Dose rate (Gy/ka)	Age (ka)	Validity	Age (AD)
NCL-9208026	Z34	124983	562230	0.175	0.083 ± 0.005	0.786 ± 0.029	0.106 ± 0.008	Maximum age	1902 ± 8
NCL-9208030	Z110	124983	562230	1.575	0.715 ± 0.025	1.058 ± 0.036	0.675 ± 0.033	Likely OK	1333 ± 33
NCL-9208039	Z40	124983	562230	4.725	1.328 ± 0.030	0.729 ± 0.025	1.821 ± 0.076	Questionable	187 ± 76

FIGURE 9 Dating results from core 9208 (outside the wreck).

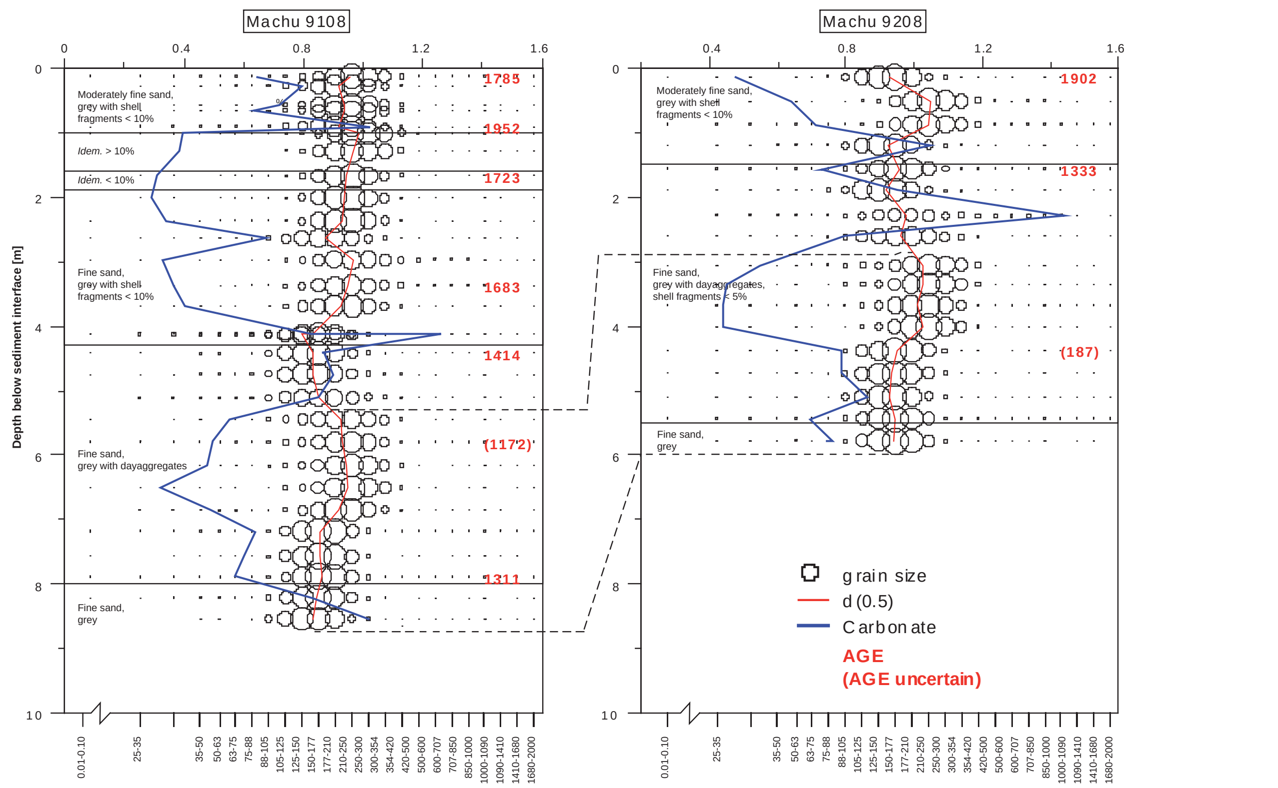


FIGURE 10 Grain size distribution for both cores. The distribution of every sample isrepresented as a collection of circles at the same depth. The sum of all circles at each line is 100% of the grain size fraction. The grain size classes are plotted on the lower x-axis. The red line represents the median grain size value. The blue line represents the Ca (%) content (scale at the top). Most samples fall in a narrow range of grain size fractions. Several groups can be described, distinguished by their difference in median values (d50). The net was found at a level of 40 cm below the surface in core 9108. The OSL age is plotted in red. The dotted lines connect the intervals with similar grain size distribution. Note that the age (187) of core 9208 is uncertain for this interval.

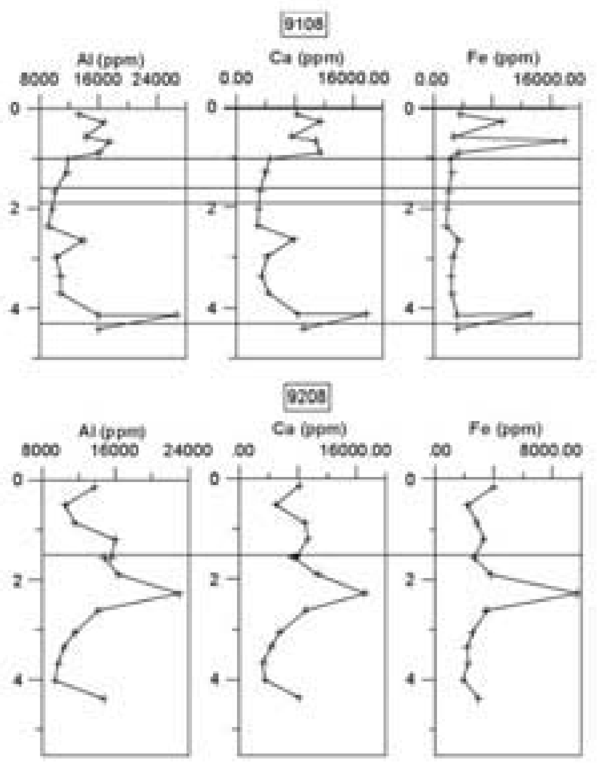


FIGURE 11 Major element variations in both cores. Note the different element range on the x-axis variation in iron.

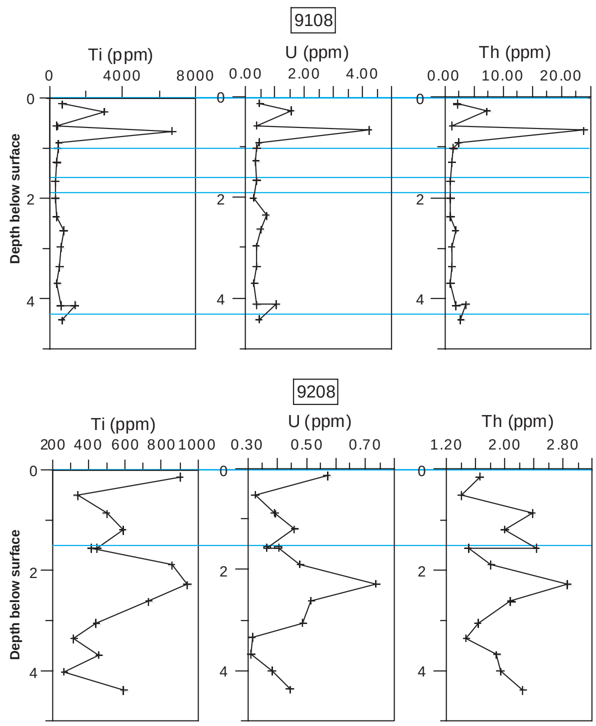


FIGURE 12 Indicator elements for heavy minerals. Accumulations of heavy minerals were found at the top of core 9108, indicating winnowing, whereby quartz and feldspars are transported as heavy minerals lag.

suggests these sediments are of a similar age to the BZN 10 wreck. The optical age obtained from a sample from the other core (9208) at a similar depth (1.6 m below the seabed) gave a much older age (~ 700 years). The samples from more than 4 m below the seabed at the wreck position (9108) indicate ages between ~ 600 and 800 years, with the results on the oldest sample likely to be unreliable. We conclude that the core did not penetrate the entire Holocene sedimentary body and that Holocene sediments are present below the wreck.

GRAIN SIZE AND METAL RESULTS

Both cores – core 9108, taken in or very close to the wreck and core 9208, taken outside the shipwreck as a reference – were investigated. The wreck was covered with a polypropylene net in 2000, 2001 and 2003. In core 9108 the net from 2000 or 2001 was found at a depth of 40 cm.[6]

Figure 10 shows that grain size follows the lithology reasonably well. Distinct regions of similar grain size distributions can be recognized in both cores. In core 9108, in addition to the clay lenses occurring four metres below surface, clay lenses were also found in the interval from three to four metres below surface. The pattern of median grain sizes and distribution between approximately four metres below surface in core 9108 seems to correspond with the level below approximately 1.5 metres in core 9208. This again corresponds with the measurement data from both cores. 9108 was taken at -5.66 m, while 9208 was taken at -7.97 m of water depth, giving a height difference of 2.31 metres.

The deposition of the upper three metres of core 9108 was possibly related to the sinking of the ship. This would have caused lower water velocity and the deposition of sand, which buried the wreck. The grain size distribution of this sand does not differ much from the deeper sand and the sediment in core 9208. The sediment in core 9108 thought to have been deposited after the placement of the in situ preservation netting (upper meter in core 9108) is characterized by a similar grain size distribution to the rest of the core. However, the carbonate (shell) content seems to be somewhat higher. The higher carbonate content at the top of core 9108 coincides with the heavy mineral-rich layer (see below). This suggests that high carbonate contents correlate with a more dynamic environment.

GEOCHEMICAL RESULTS

The observed changes in grain size distributions are also reflected in the geochemical patterns. At the top of core 9108 the clay mineral content is somewhat higher, as also reflected in the finer grain size. At the top of core 9208 there is an increase in the d50 of the sand fraction recorded as a decrease in the Al content (*figure 11*). The high iron content at the top of core 9108 is accompanied by an increase in Ti, lanthanides, Cr and U and Th (*Figure 12*). This indicates an increase in heavy minerals like ilmenite, magnetite, zircon and chromite in this core. Such an increase can be brought about by sorting and winnowing caused by dynamic sedimentological conditions. It is interesting to note that the increase in heavy minerals coincides with the in-situ preservation net. It is possible that the currents preferentially caused movement of lighter quartz and feldspars grains which eventually led to a relative enrichment with heavy minerals. These enriched heavy mineral layers are therefore indicative of erosion events.

Anthropogenic metals generally show almost no trend going from the top to the bottom of the cores (*figure 13*). The content of these metals are however very low and fall in the natural range for these elements, suggesting that the date of the sediment is after 1850, or that all the sediment is of local unpolluted origin. Anthropogenic metals are transported as very fine clay particles, often associated with organic matter, which only settle under very

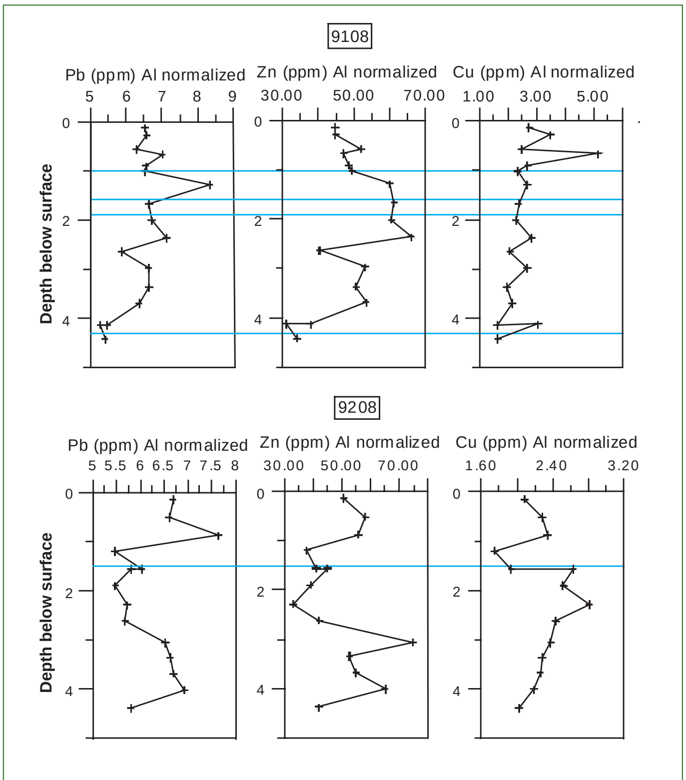


FIGURE 13 Al normalized metal profiles in cores 9108 and 9208. Variation mainly coincides with Fe2O3 content. Note that contents of Pb, Zn and Cu are very low and most likely not enriched by anthropogenic influences.

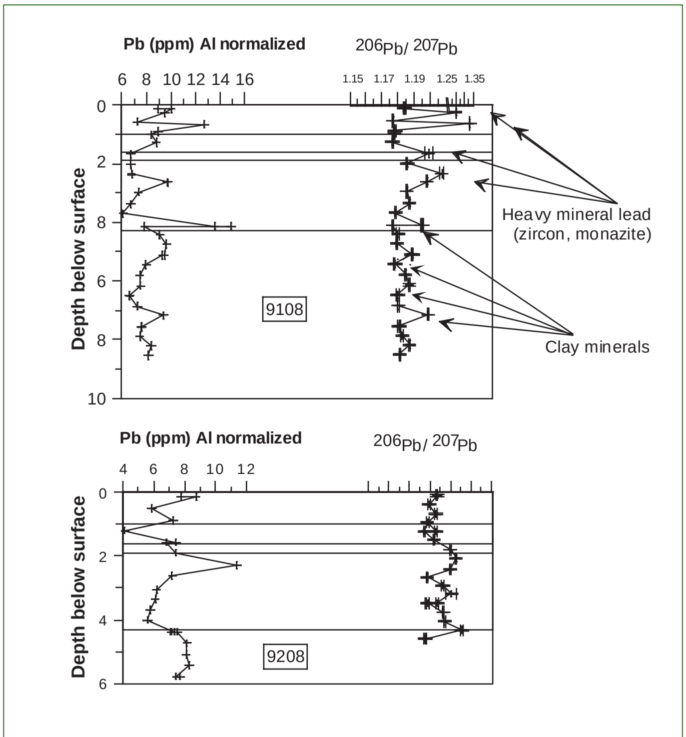


FIGURE 14 Al normalized Pb and 206Pb/207 Pb versus depth plot for cores 9108 and 9208. Pb isotopic compositions in core 9108 are mainly influenced by heavy minerals (zircon, apatite) and clay minerals. No indication was found for petrol lead (206Pb /207Pb < 1.10) or industrial lead (206Pb /207Pb between 1.15 and 1.17).

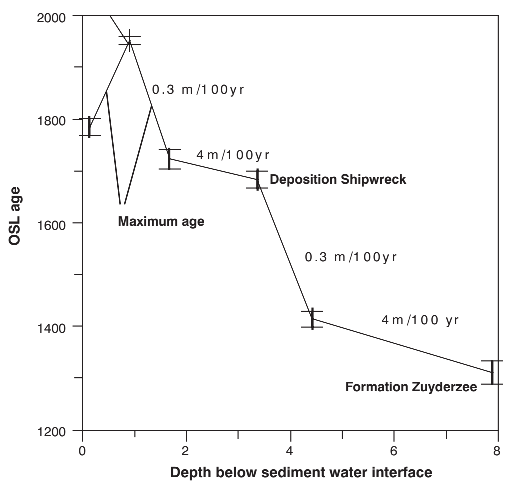


FIGURE 15 Depthversus age plot for core 9108. The plot shows two periods of rapid deposition (1300-1400 and 1650-1700). In the intervals between and after these periods, sedimentation rates were much lower, and might even be erosional.

low energy conditions. Only during events when mixing of sand and clay occurs in the water column, such as heavy storms, may such particles be trapped in the sediment.

LEAD ISOTOPES

Lead isotopic ratios in core 9108 (*figure 14*) show some very radiogenic values (between 1.22 and 1.35), especially at the top. These values indicate the presence of the parent isotopes U and Th. The high values for the 206Pb/207Pb ratio coincide with high values for REE, Cr, Fe, Zr and Ti, which indicate the presence of heavy minerals such as chromite, ilmenite and zircon, and phosphate minerals such as monazite and xenotime. Sands containing percent-level values of these minerals are known to occur on the Wadden Islands (De Meijer et al., 1996). These minerals, especially the phosphates, are known to contain high concentrations of U and Th, which would explain the radiogenic lead isotopic values. In the deeper parts of both cores, higher values for the 206Pb/207Pb ratio between 1.19 and 1.22 coincide with an Al content which is indicative of clay mineral content. Clay minerals also have higher levels of U and Th than quartz grains.

No industrial-age 206Pb/207Pb ratio values were found (values lower than 1.175), indicating that anthropogenic lead from after 1850 is not present. Nor were any petrol-derived 206Pb/207Pb ratios observed, indicating that the fine fraction of the sediment is certainly pre-1950.

OVERALL CONCLUSIONS AND DISCUSSION

The OSL research at the Burgzand Noord 10 site has shown that it is possible to use optical dating in a highly dynamic submerged environment, specifically the Wadden Sea. However, one has to take into account that there maybe an incomplete resetting of the OSL signal in some grains at the time of deposition. Although 'quick and dirty' analyses of the samples did not give any useful results, full analyses were successful.

The two cores were taken 8.75 m (9108) and 5.95 m (9208) into the seabed respectively. The aim for core 9108 was to go through the wreck site, and include evidence of the polypropylene nets (the protection layers), structural timbers and, finally, Pleistocene sediment in the samples. The aims for core 9208 were to include the whole Holocene sediment layer and to finish one or two metres into the Pleistocene sediment layer. The OSL dates show that neither core reached the Pleistocene sediment. This in itself is interesting. First of all, it means that the wreck parts are lying in and on Holocene sediments. The general idea up until now was that shipwrecks in the Wadden Sea sink down into the soft Holocene sand until they rest upon the much harder Pleistocene layer. This is certainly not the case with the BZN 10 wreck. The sediment – particularly that in the wreck – is well graded, with layers of coarse and fine sand and clay. It consists of compact Holocene sediment in several layers. Considering the long cores that were taken, the Holocene layer is extremely thick at the Burgzand location. From this we can conclude that wrecks are very likely to be found at a greater depth under the seabed surface. These sites may be older, since the OSL dating tells us that at four to eight metres, the sediment was last uncovered in the 14th and 15th centuries. Historic maps, for example, tell us that shallow areas – sandbanks – have always existed in the Burgzand area, but they have changed their form and location over time (Oost 1995, Kosian 2009). Parts of these old sandbanks may still exist at greater depths. These relics of the ancient maritime landscape may not have been uncovered for centuries by changing current patterns, and are therefore likely to contain wrecks of high archaeological value. We believe this is certainly the case in the eastern part of the Wadden Sea, which is dominated by strong sedimentation, and where large areas fall dry at low tide.[7] The present study suggests, however, that this might be also be the case in the more eroded western part of the Wadden Sea.

Core 9108, which was taken at the wreck location, gives a sediment dating of 1723 +/- 38 (between 1685 and 1761) 1.575 m under the seabed. At 3.325 m the sediment is dated 1683 +/- 32 (between 1651 and 1715). Below that level, at 4.375 m, the age increases to 1414 +//- 30 (between 1384 and 1444) (*figure 15*). Although we have to be careful not to jump to conclusions on the basis of only a few datings, we may conclude that there is a 'find layer' that dates from around the time of the wreckage between approximately 1.5 and 3.5 metres below the seabed that was not subsequently eroded. It consists of fine sand with shells.[8] According to the OSL dates, the two-metre thick layer of sand was deposited between 1650 and 1700. This information is important for establishing the value of the site. The existence of a sediment layer from around the time of the wreckage allows us to conclude that the protective layer in the BZN 10 wreck has not completely eroded away over time. Parts of the ship structure may therefore still be in excellent condition and it can be assumed that part of the cargo and inventory still lie undisturbed in the wreck. This is also confirmed by the archaeological assessment performed in 1999, when parts of the cargo, inventory and ship were surfacing the seabed. However, we also know now that at some locations on the site, almost two metres of practically undisturbed contemporary sediment is still present. The older date at almost 4.5 metres deep shows that, from that point at least, no finds from the wreck can be expected.[9] The OSL dates from outside the wreck (core 9208) show a considerable increase in age at a relatively low depth (at 1.575 m 1313 +/-33 = 1280-1346). This can tell us something about the extent of the site.

The two cores show a striking similarity between the pattern in median grain sizes and distribution of the layer four metres below the surface in the wreck and the layer 1.5 metres below the surface outside the wreck.

The depth at both locations also differs by approximately the same amount (2.31 metres). We can therefore assume that these two layers are the same.

If we assume this, then our conclusion is that a considerable amount of the top sediment outside the wreck has been disturbed over time and affected by heavy erosion. This can be confirmed by the analyses of the multi-beam echo sounding sequence taken at this site. The deepening of the seabed around BZN 10 has been continuous, at an average rate of almost 10 cm per year.

Thus, OSL can add to our understanding of site formation processes and can also help us to determine the quality of the archaeological resource without using excavation.

Another aim of this research was to investigate the use of OSL for monitoring the in situ protection method used on the BZN wrecks. The results from this research – consisting of only two cores – are not however good enough. From the cores itself we can measure the amount of deposition under the nets. OSL allowed us to determine the age of the sedimentation as recent, but we were not able to distinguish recent age differences in sufficient detail to establish sedimentation rates and events over a few years. However, a comparison between sedimentation layers in and outside the wreck shows clear erosion outside, with older sedimentation layers protruding from the surrounding seabed at the protected wreck site. In addition, in the first metre of core 9108, carbonate- and heavy mineral-rich deposits were found, suggesting that although netting works, there still is movement of sand, and dynamic sedimentary conditions prevail. This shows the effectiveness of in situ preservation with polypropylene nets in the Wadden Sea, but also that the sediment steady state is still fragile and can easily become unbalanced. Multibeam echo sounder surveys should therefore be performed regularly to monitor this.[10] If monitoring reveals a sharp decline in the protection of the wreck, action should be taken to reapply in situ preservation methods or, if important archaeological values are lost, to launch an excavation of parts of the wreck.

NOTES

[1]These are BZN 2, 3, 4, 8 and 10. BZN 9 has been partly protected.

[2]A modified single-aliquot regenerative-dose (SAR) protocol for OSL dating of individual grains from young samples (<300 years) using dose-recovery tests. See also Ballarini et al. (2007). This involves exposing one grain to a small amount of radiation (light).

[3]Aliquot: an aliquot part (or simply aliquot) of an integer is any of its proper divisors. This is the smallest quantity of something.

[4]PDF fitting method: See Wallinga et al. (in press).

[5]Gaussian: a model for statistical distribution. See for example http://science.widener.edu/svb/mathcad/pdf_docs/gausian.pdf or http://en.wikipedia.org/wiki/Gaussian_function.

[6]The net from 2003 was removed before coring.

[7]In December 2008, M. Manders (RCE) and M. Dominguez (RING) investigated and dendro-dated an old wooden ship frame dredged up several years ago from great depth in the eastern Wadden Sea, and now exhibited at the Shipwreck Museum in Terschelling. This frame from a clinker-built ship turned out to be from the 14th century (after 1321) RING Internal Report number: 2009023, 2009.

[8]Whether these are shells of creatures that lived on the site or were transported into the wreck at a later stage remains uncertain.

[9]Only ten OSL measurements were taken, so we cannot establish at exactly what depth the sediments predate the shipwreck. Nor can we precisely establish erosion-sedimentation cycles, although the method seems to be suitable for this purpose.

[10]See also Manders (2009) in this volume.

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Sedimentation-Erosion Modelling as a tool for Underwater Cultural Heritage Management

An understanding of the dynamics of underwater archaeological sites has been a primary research aim of marine archaeologists for the last four decades. To develop a viable sediment dynamic model for artifact based sites is crucial in terms of site formation process study; a priori archaeological investigation; and the effective management of marine sites to ensure their future stability. As part of the MACHU project an attempt has been made to develop a tiered approach to investigating such archaeological site dynamics. The developed approach requires three phases:

1. A desk based analysis of sediment mobility at regional scales using numerical modelling (using industry standard packages) and limited, publically, available environmental data. If successful this should represent a cost and time efficient method of large area, coarse resolution (tens to thousands of metres), assessment of the current seabed conditions. Such an approach also has the potential for predicting the impacts of future large scale change in the seabed dynamics in response to either climate change or the construction of major offshore and coastal structures.
2. Physical modelling of specific archaeological sites in their regional context. Such an approach requires access to specialist laboratory facilities and expertise but could still provide a more cost effective approach than long term *in situ* measurements of multiple sites. Further, successfully calibrated physical models also has the capacity for predicting change in response to changing flow conditions, sediment budgets and large scale structural changes of the archaeological objects.
3. Detailed *in situ* measurement of sedimentation and erosion as part of a comprehensive field site investigation. This is still an important component of the management of underwater cultural heritage, as it provides detailed real-time and historic measurements of the site dynamics, but it is expensive and logistically complex. Further, other than qualitative assessment on the basis of the site investigators the outputs from this approach can only give a predicted assessment when the data is fed back into phases 1 or 2.

The work during the course of the MACHU programme has focused primarily on the development of a robust, coarse resolution, numerical model for the North-west European Shelf, with a higher resolution nested domain centred on the Goodwin Sands, in the Dover Straits, an area that contains five UK Designated Wreck Sites. The outputs from this work have also been added to the MACHU GIS to show the potential for their use across the continental shelf.

RATIONALE OF THE NUMERICAL MODEL

The purpose of the numerical sedimentation-erosion model is to provide a regional scale backdrop of seabed conditions to cultural managers of archaeological sites, for use in conjunction with and as a context for guidelines developed for site scale management. The final outputs from the model are a description of the net sediment transport pathways and the nature of gross and/or sudden changes in seabed level (erosion or accumulation) as a response from either ambient tidal and wave conditions or extreme conditions (the passage of a storm through the area).

These outputs are derived from calibrated modelling of the direction and magnitude of tidal and wave induced currents and there interaction with different sediment fractions on the seabed. This project has used the Danish Hydraulic's Institute MIKE 21 2D hydrodynamic and sediment transport soft-

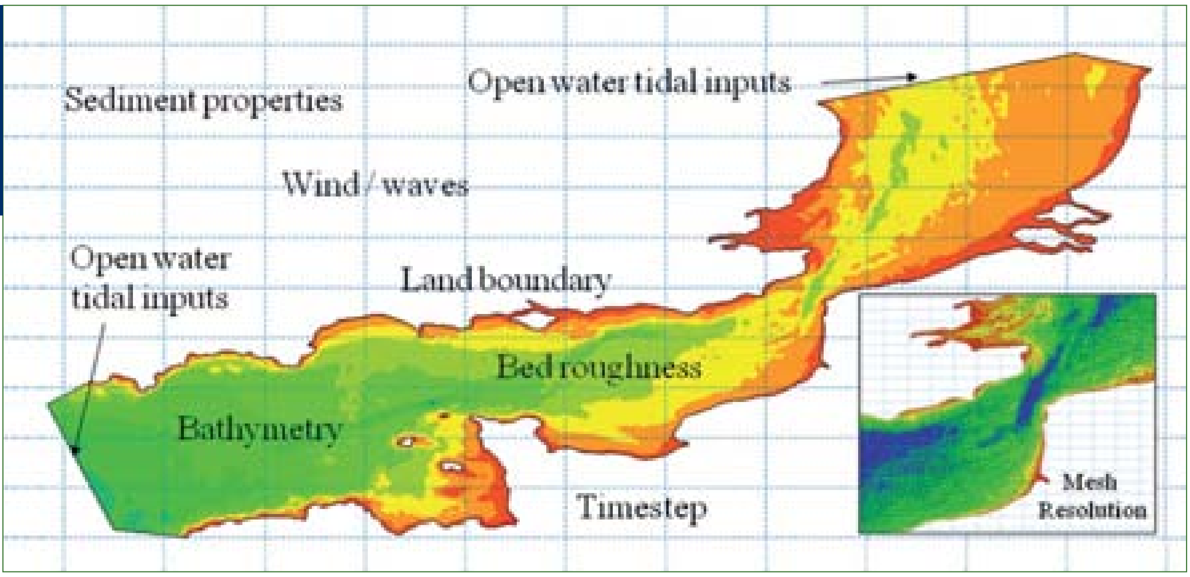


FIGURE 1
The core inputs for the numerical hydrodynamic and sediment transport models used in this study.

ware, but the approach taken could be applied to a range of commercially available modelling products. The MIKE 21 model used in this study is composed of a decoupled hydrodynamic model and sediment transport model (i.e. the output from the hydrodynamic model was exported and then used as input conditions to the sediment model. A coupled hydrodynamic-sediment approach is available (i.e. the two models run interactively) but the run times are considerably longer so were not used in this instance.

Two versions of the hydrodynamic model were developed: a tidal current only version and a tide and wave current version. Irrespective of the particular approach chosen, all the numerical models (hydrodynamic and sediment transport) require similar stages of development:

■ Model design

The model design phase needs to account for a number of different inputs and starting parameters including: the land boundaries; bathymetry; open water tidal inputs; the seabed sediment distribution; the 'roughness' of the seabed (a composite parameter of the small scale seabed morphology – e.g. ripples and sand waves – and surface grain size); the wind/wave regime; the mesh resolution to define the spatial output of the calculated hydrodynamic and sediment dynamic properties; and the time steps and time period over which the model should run *(figure 1)*.

The variable resolution described in *figure 2* was designed to provide the greatest resolution in the English Channel and the very southern most parts of the North Sea, which were to be the location of the case study nested domains undertaken as part of the MACHU project. The typical model runs were 4033 time steps of 300 seconds each, which corresponds to a 14 day run period and so covers a full spring-neap cycle. The default, boundary, tidal elevation parameters from the MIKE 21 predictive 'KMS' model were used to drive the tidal component of the hydrodynamic model. The KMS global tide model data represents the major diurnal (K1, O1, P1 and Q1) and semidiurnal tidal constituents (M2, S2, N2 and K2) with a spatial resolution of 0.25° x 0.25° based on TOPEX/POSEIDON sea surface altimetry data. Because the KMS model includes only a finite number of tidal constituents, adequate distance must also be allowed between the open boundaries and the region of interest to allow higher harmonics to be developed, and hence further supporting the need to develop a model domain that encompassed the whole shelf.

■ Desktop study

Across the European Union the availability of spatial and temporal oceanographic, bathymetric and geological information is highly variable due to a combination of both a lack of a priori data and financial and legislative restrictions on the data that does exist. The ultimate accuracy of the model inevitably depends on the resolution and quality of the input data and so each of them need to be assessed in turn. The first essential component is the definition of both 'closed' land boundaries for the domain, in this instance these were obtained from NGDC 'Global Self-consistent Hierarchical High-resolution Shoreline Database' (www.ngdc.noaa.gov), and 'open' sea boundaries which were defined by the approximate location of the shelf break and an arbitrary boundary at the entrance to the Baltic. The bathymetry that these fixed boundaries enclosed was based on a combination of publically available GEBCO bathymetry (www.gebco.net), with an original resolution of a depth point every 1 arc minute (which at this latitude gives a bin size of c. 1.85 km x 1.155 km) and CMAP bathymetric data, purchased under license, at an original resolution of an average depth point every 0.43 arc minutes (equivalent to a bin size of c. 0.5 km x 0.8 km).

These data were both referenced to a 'mean sea level' vertical datum, and combined to produce a new bathymetric model based on the variable mesh grid shown in *figure 1*.
If higher resolution bathymetric sources (e.g. swath bathymetry data) are available they can be integrated in to a new mesh, particular in the form of smaller nested domains, and if this is done it will inevitably enhance the accuracy of the final outputs. However, as part of the aim of the MACHU project is to construct a model based on easily accessible data, the

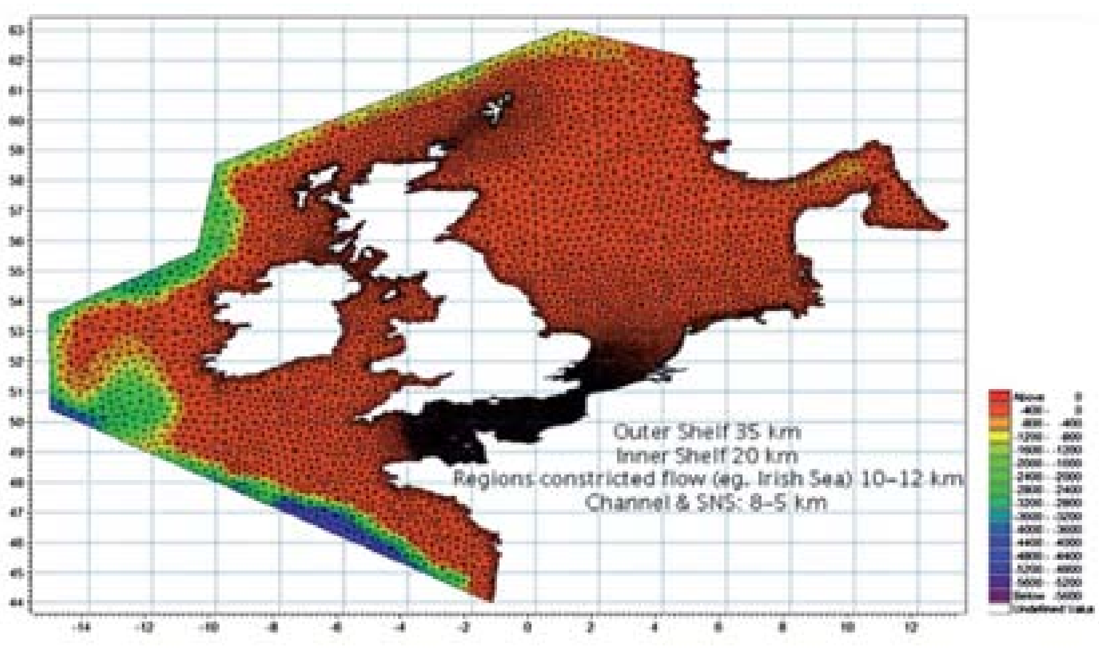
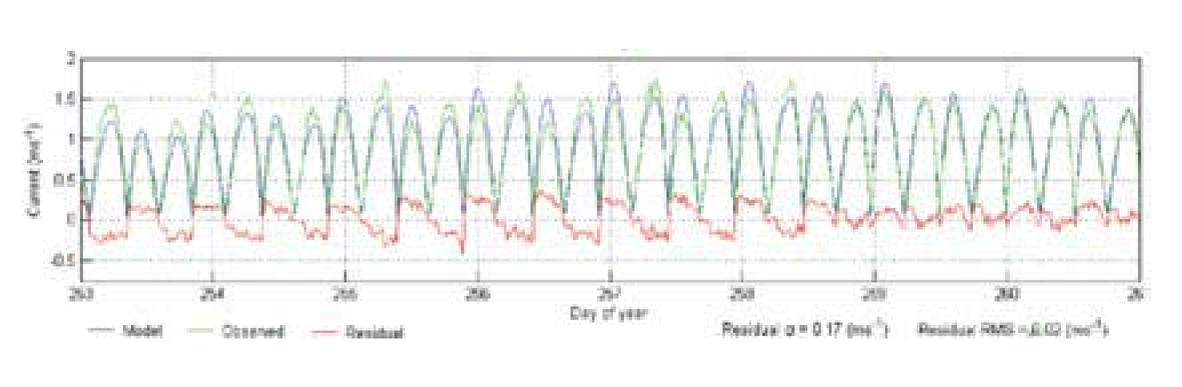


FIGURE 2
The model domain and variable mesh resolution for the large scale MACHU numerical model.
The mesh resolution varies from being:
- 35 km at the Outer Shelf;
- 20 km through the Inner Shelf;
- 10-12 km in regions of constricted flow (e.g. Irish Sea and the waters between the Scottish mainland and the Shetland Isles);
- 8-5 km in the Channel & Southern North Sea.

FIGURE 3
Depth Averaged Velocity calibration for observed data located in the Southern North Sea and modelled data at a mesh resolution of ca. 7 km.



final results presented here do not include any higher resolution data.

Within the sediment transport equation it is possible to define a spatially variable grain size parameter within the entire model domain. Compared to the bathymetric data, there are relatively limited sources of the spatial variability of sediments on the shelf beyond the maps created by the British Geological Survey (www.bgs.ac.uk) and the Bureau de Recherches Géologiques et Minières, Centre National pour l'Exploitation des Océans (www.brgm.fr), the data from both only being available for use under license. A coarse resolution map of sediment distribution was therefore created from the limited number of published scientific papers in order to enable the production of a large scale, shelf wide, sediment transport model. However, with in situ data available for the nested models it was possible to do additional runs with more specific sediment input data and so enhance the quality of the output in these focus areas.

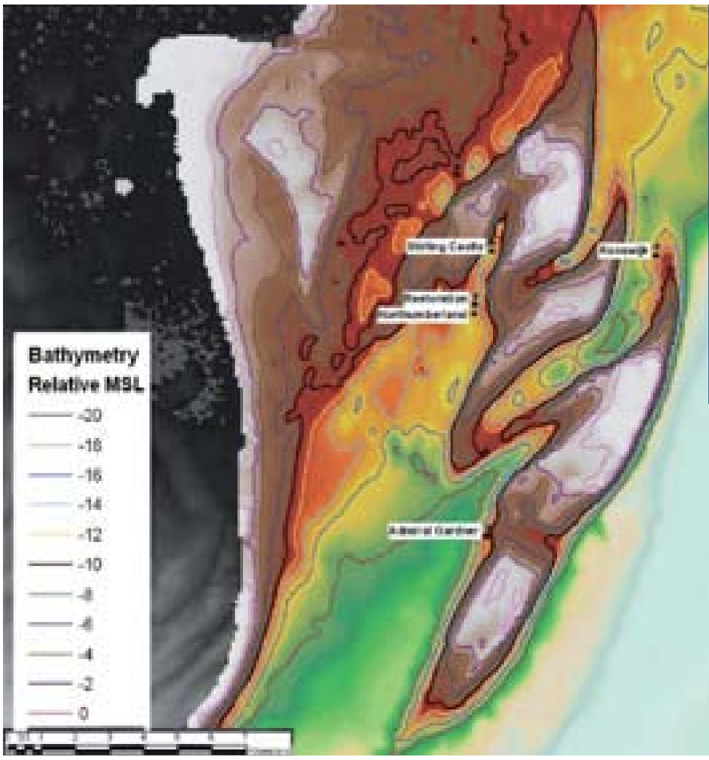


FIGURE 4
The location of the five designated wreck sites located on the Goodwin Sands off the East Kent coast, UK. Bathymetry relative to mean sea level, with the 10 m contour highlighting the general shape of the bank system.

Once the main model parameters are set, as described above, the ability to control the flow and sediment transport outputs is through the variation of the bed roughness. The bed roughness element of both models can be set independently and is characterized by a parameter known as the Manning's number which is effectively a method of retarding or accelerating the flow through the application of friction on the overlying water column. To find the appropriate solution two approaches can be taken: firstly the calculation of the Manning Number directly using an equation based on the grain size and the small scale seabed morphology [e.g. ripples and sand waves]; secondly the Manning value can be iteratively changed to identify the value that gives the optimum outputs when compared against real hydrodynamic data acquired from the model domain.
In this project the Manning's number for the hydrodynamic model was iteratively determined (a final value of M=40 providing the optimum data output), whilst in the sediment transport model of the nested domain, the Manning's Number was calculated from the known grain sizes and seabed topography.

The final component of the model input was to construct a wave regime. Again this can be done in two ways: firstly a wind field can be placed in the model which effectively drives the production of artificial waves and their associated currents which need to be calibrated against extant data within the model domain; alternatively we can input a direct wave field and for the MACHU project this is the approach we took. In order to provide the best inputs we statistically analysed wave data acquired close to the nested domain sites (in this case the Goodwin Sands) and produced an ambient wave field and a storm wave field that could be applied to the tidally driven hydrodynamic model.

MODEL CALIBRATION

An essential part of the modelling process is to undertake calibration in order to tune the model so the outputs agree as closely as possible with in situ field data. Calibration is undertaken primarily in the hydrodynamic domain and on three key parameters: tidal elevation, depth averaged tidal current speed and direction. A total of 56 sites spread throughout the entire shelf model domain were used to calibrate tidal elevation (21 being in coastal locations and 35 in offshore locations). Current speed and direction was calibrated against 21 sites all within offshore locations focused in the Eastern English Channel and the Southern North Sea. All of these data were obtained from publically accessible sources including the British Oceanographic Data Centre and the Proudman Oceanographic Laboratory. These represent a subset of the data available with selection being based on: overlapping data records (as the time of the model run period has to coincide with the time of observed data); and the quality of the *in situ* data. Once run, the model output was cross-correlated with the in situ data so a quantitative assessment of the calibration could be made.

As an example of this process *figure 3* represents the velocity calibration for a site near to the Goodwin Sands sub-domain, it clearly shows that model is replicating the real current speeds to within < ±20 cms-1 which is the acceptable error bounds for hydrodynamic modelling as defined by the UK Environment Agency. It is important to recognize that the observed data represents measurement of depth averaged flow at a single point whereas the outputs from the model are representing depth averaged values for an area covering several kilometres depending on mesh size. A number of hydrodynamic models were iteratively run until the best combination of input parameters were found so as to optimize calibration.

MODEL SUB-DOMAINS - THE GOODWIN SANDS

During the course of the MACHU project a number of smaller scale nested domains, all within the Eastern English Channel, have been studied including: the Hastings Bank (a large sand and gravel bank 13 km south of Hastings); and the aggregate licensing area 473E in the central Eastern English Channel: both of which have been reported in previous MACHU seminars and publications. The ultimate aim of the project, however, was to produce a high resolution model of the Goodwin Sands, a pair of sandbanks, North and South Goodwins, which are located c. 4-8 kilometres off the East Kent Coast and cover an area of approximately 22,000 hectares. The banks are in relatively shallow water, drying out at low water, and represent the accumulation of sand, under dominantly tidal influences. Folklore has it, that the Goodwins represented the ancient Island of *Lomea* or alternatively the '*Infera Insula*' which was, as recorded in the Anglo-Saxon chronicle, drowned during a great storm in 1099.

However, more recent work, suggests that they consist of c. 25 m of unconsolidated sandy sediments resting on incised chalk bedrock, a scenario which would suggest creation during the middle to later part of the Holocene marine transgression. Work in the 1950's by Cloet demonstrated that the banks undergo slow seasonal to centennial rotation in an anti-clockwise direction, with periods of minor reversals. This results in a general wes-

FIGURE 5a-b
Bed level change for the Goodwin Sands under an ambient wave and tidal regime condition (a) and storm conditions (b).
In both images the banks are outlined by the -10 m relative to mean sea level contour.

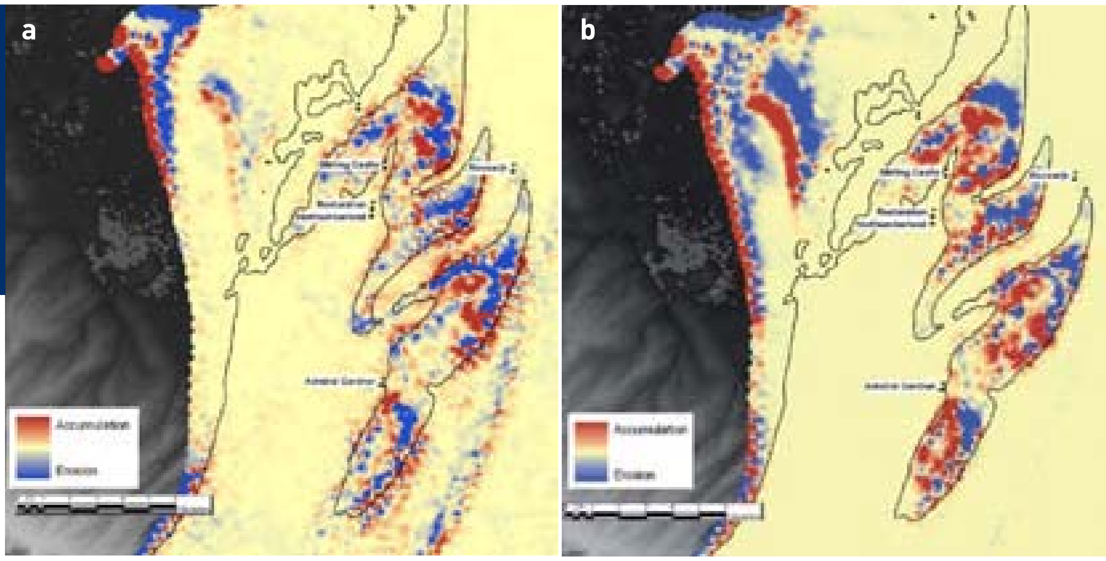


FIGURE 6a-b
Residual sediment transport vectors for the Goodwin Sands under an ambient wave and tidal regime condition (a) and storm conditions (b). In both images the banks are outlined by the -10 m relative to mean sea level contour. In both images the residual sediment transport vectors are superimposed on the corresponding bed level change contour plots as seen in figure 5.

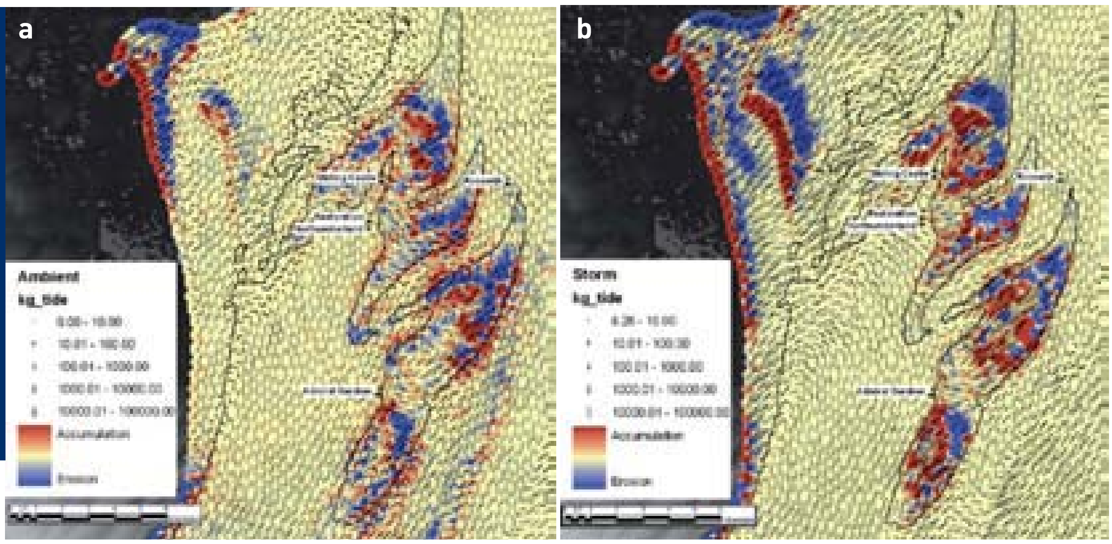
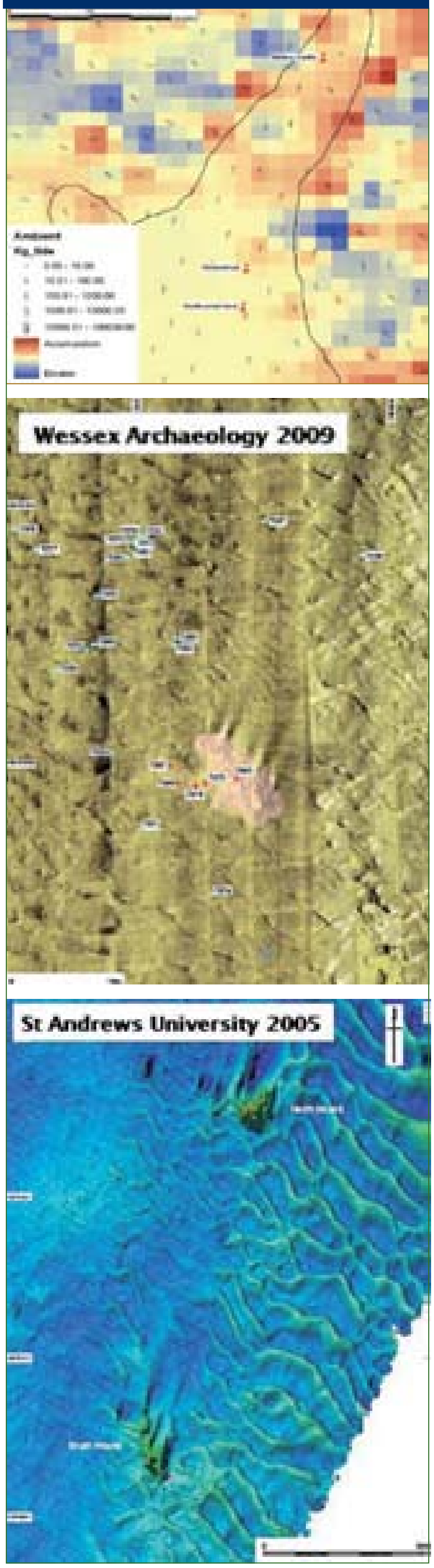


FIGURE 7a-b-c
(a) Bed level change and residual sediment transport vectors for the southern margin of the North Goodwin's, an area containing the Protected Wreck sites of the Stirling Castle, the Restoration and the Northumberland. Swath bathymetry data of the Northumberland (b) and the Restoration (c), both showing flow normal bedforms indicating North-North-Easterly sediment transport.



terly movement of the western edge of the North Goodwins and the eastward movement of the South Sand Head at the southern tip of the South Goodwins. The acquisition of bathymetry, funded over the last decade by English Heritage, at a number of wreck sites on the Goodwins, also demonstrate bed mobility through the presence of metre to decametre scale bedforms.

The Goodwin Sands have presented a hazard to safe navigation since at least the mid 1500s, and they are commonly referred to as the 'shipswallower' in the belief that an entire vessel, if trapped on the Sands, may become completely buried. Consequently, they represent a region with a very high density of shipwrecks, including five wreck sites *(figure 4)* designated under English legislation (the Protection of Wreck Act 1973):

- The Stirling Castle, a 'third rate ship of the line' was lost while at anchor on the Goodwin Sands during what became known as the 'Great Storm' of 27th November 1703. The wreck of the Stirling Castle was first reported in 1979, but shortly afterwards was re-engulfed by sand and was not reported again until 1998 and presently lies at a depth of 12 m in a shallow gully.
  The effect of tidal flow around the exposed wreck and sand wave movement led to substantial exposure, but reports since 2003 (www.st-andrews.ac.uk/rasse/) indicate that sandwave migration is, once more, covering the wreck.
- The Northumberland, also a 'third rate' was lost with all hands in the same storm as the Stirling Castle. The wreck was first reported in 1980 with the site described as a low mound, but it is thought that the wreck remains are vulnerable to dynamic seabed conditions as noted in dive investigations conducted under the Government's contract for Archaeological Services in the 1990s.
- The Restoration, was a further 'third rate' naval vessel lost in the Great Storm of 1703 and recent dive investigations have revealed the wreck, thought to lie in two sections, to be almost entirely buried.
- The Rooswijk was recorded as a vessel of the Verenigde Oostindische Compagnie (Dutch East Company) and was lost on the Goodwin Sands in 1793. The wreck is believed to lie in two sections with reports indicating that exposed sections of hull and internal structure are in good condition with substantial sections presently buried.
- The Admiral Gardner was an English East Indiaman vessel on passage to India when she was wrecked on the Goodwin Sands in January 1809 during a storm. She was discovered in 1983 and subject to salvage with the site designated finally in 1990. Recent site investigation has revealed the recorded position of the wreck to be entirely covered by a sandbank.

The Goodwin Sands nested model was created with a mesh size of 500 m, with sediment transport calculations based on a single grain size of 0.4 mm (representative of the dominant sediment fraction of the Goodwins), using a Mannings number of 40, and run for two basic scenarios:

1. An ambient condition which combined both a calibrated tidal component and an ambient wave regime (statistically calculated from observed data adjacent to the study area), which had a significant wave height of 0.8 m, a wave period of 4 seconds, a direction of 255° (c. WSW), and with a model run period of 14 days;
2. A storm scenario, with a significant wave height of 2.975 m, a wave period of 5.785 seconds and the same direction as the ambient condition and a model run period of 24 hours.

The sediment transport model outputs were then presented in two ways: bed level change maps and maps of residual sediment transport vectors. Bed level change data was contoured within ArcMAP and presented as simple erosion and accumulation plots, rather than presenting absolute values. This enabled the identification of zones susceptible to: net erosion, net accumulation or net stability over a spring-neap cycle *(figure 5a)* or a storm *(figure 5b)*. Residual sediment transport vectors were recalculated to show kg of sediment moved per individual tide and are presented on a scale covering five orders of magnitude *(figures 6a and 6b)*.

Indirect, regional scale calibration of the sediment transport results was also undertaken through comparison of these data with published maps of sediment transport direction, derived from the interpretation of bedform asymmetry as determined from sonar records. These qualitative comparisons demonstrated strong agreement between the output from the MACHU model and the extant data. An additional calibration factor can be seen in *figures 5a and 6a*, as the pattern of erosion and accumulation, and direction of residual sediment transport, clearly demonstrates the potential anti-clockwise rotation, under ambient conditions, of the banks as suggested by Cloet. In both *figures 5a and 6a*, the general westerly movement of the western edge of the North Goodwins and the eastward movement of the South Sand Head at the southern tip of the South Goodwins are identified.

Comparisons between the ambient conditions and the passing of a single storm suggest that at depths greater than ca. -10 m the effect of the storm seems to be negligent and the pattern of residual sediment transport seems to be similar to the ambient condition if not slightly ameliorated. Whilst on the actual banks, during the storm period, bed level change is clearly enhanced and unsurprisingly focused on the very shallowest sections of both North and South Goodwins. These changes represent in some localities, 2-3 orders of magnitude greater movement of material during a single days storm than is found over a full spring neap cycle. The overall direction of sediment transport also changes, with a very strong south-westerly dominating sediment transport direction over the Goodwins, developing presumably in response to the waves refracting around the headline at Dover.

The true capabilities of the model can be demonstrated though by the ability to predict the conditions of the five designated wreck sites that are found on the margins of the slopes. For the purposes of this analysis we can group the wrecks in to three broad geographical regions: the southern margin of the North Goodwins (the location of the Stirling Castle, Northumberland and Restoration); the northern tip of the South Goodwins (the Rooswijk) and the south-western margin of the South Goodwins (the Admiral Gardner). Analysis of the residual sediment transport vectors for these three sites *(figure 7a)* suggests that the bed is mobile and the dominant transport direction is to the north-north-east, with similar flow vector orientations being present under both ambient and storm conditions. Swath bathymetry data presented in the recent Designated Site Assessment Reports of the Northumberland and the Restoration (Wessex Archaeology) show the presence of significant large scale flow normal bedforms which indicate a similar north-north-easterly transport direction *(figures 7b and c)*.

At the Stirling Castle flow normal bedform orientations, as described in the RASSE project, suggest transport to the north-east a transport direction difference of only ca. 20°. The bed level change values for all three sites suggest they are in zones of slight accumulation, and in close proximity to a bank margin with the potential for westerly migration. This bank margin migration direction ties in with the anti-clockwise seasonal rotation described earlier and has also been identified from the analysis of time-lapse swath bathymetry of the adjacent area to the Restoration.

Approximately, 6.5 km to the south of this cluster of wrecks the Admiral Gardner is located on the western margin of the South Goodwin's, in a region, suggested by the model, of localised higher sediment accumulation, with sediment being brought in from both the south and east under both ambient and storm conditions. Interestingly, this direction of sediment movement is against the overall anti-clockwise rotation and suggests a westerly spreading of the bank in this area. Interestingly, the most recent archaeological survey suggests the site has been totally buried since its discovery in the early eighties and designation in 1990. Finally and by comparison to the sites described so far the Rooswijk lies on the northern tip of the South Goodwin's and appears to be in a zone of slight erosion with the residual sediment transport being very strongly from the north under both ambient and storm conditions.

The latest archaeological assessment by Wessex Archaeology (2007) describe a potential scattered debris site with anecdotal evidence to suggest the wreck is lying on a potentially very thin layer of sediment and may indeed be resting directly on the chalk bedrock. As with the other sites there are numerous bedforms suggesting extensive sediment mobility, albeit those described are significantly smaller in dimensions than the other sites. Again there appears to be broad agreement between the model output and the most recent environmental assessment.

CONCLUSIONS

The shelf scale and nested domain sedimentation-erosion models (especially that of the Goodwin Sands), developed as part of the MACHU project, and calibrated against site scale conventional marine archaeological assessment clearly illustrate the potential of well constrained carefully constructed numerical models to aid the heritage management process. These models can never replace the need for *in situ* archaeological investigation using either remote sensing and/or diver techniques but can play an important role as part of a three-tiered approach to site management. This again can be clearly illustrated at the Goodwin Sands, as although the five protected sites have been the focus of in situ study, it is highly unlikely that anything other than a very small fraction of the several hundreds of wrecks also believed to be located on the Goodwins can be investigated in similar detail. Consequently, a combination of the sedimentation-erosion model outputs and an assessment of the known archaeological record can be used to narrow down the sites of highest archaeological potential that are most at threat.

The shelf model now having been fully developed, the ability to construct further nested domains is relatively straightforward and so could be used to aid management decisions throughout the North-west Europe peninsula. There is also the potential to develop the modelling approaches to look at the evolution of submerged landscape archaeological sites under a transgressing sea and to assess their current site dynamics.

Finally, the outputs from this model have been constructed in such a manner that they can be easily manipulated in standard GIS packages but most importantly that they can be fully integrated in to the MACHU GIS package.

FUTURE WORK

As with all projects there is always potential for future development. In the case of the sediment-erosion model there are a number of future developments that could be undertaken, including: enhanced calibration of the shelf model using novel numerical approaches and further datas
ets; reducing the mesh size of the nested domains to <50 m (an issue primarily of computing power); develop both shelf scale and nested models with variable sediment grain size and Manning's Number; produce wind driven wave fields to enable the modelling of the growth and decay of storms; to extend the calibration of the model outputs against a greater number of archaeological sites; and finally to continue to find dissemination routes (such as MACHU) through which the approaches developed here can reach the greatest number of heritage managers.

THE AUTHORS

***Justin Dix, Pierre Cazenave** and **Tim Rangecroft** work at the School of Ocean & Earth Science, University of Southampton, National Oceanography Centre, Southampton.*
***David Lambkin** works for the ABP Marine Environmental Research Ltd, Suite.*
***Chris Pater and Ian Oxley** are from English Heritage, Maritime Archaeology Team, Fort Cumberland, Portsmouth.*

Physical Modelling as a tool for Underwater Cultural Heritage Management

As described in the companion article on numerical modelling for underwater heritage conservation, physical modelling of specific archaeological sites should be considered an essential part of a tiered approach to investigating the dynamics of submerged archaeological sites. To complement the development of the numerical sedimentation-erosion model, a short physical modelling study for the MACHU project work has been undertaken. This project built directly on recent research conducted at the University of Southampton. Within the MACHU project we aimed to undertake three components of further research:

1. To undertake uni-directional flow experiments of erosion and accumulation around a generic ship model placed on a scaled mobile bed following the method previously developed by the University of Southampton team. The results from these experiments to be recorded using a laser scanner, so as to produce accurate, quantitative, digital terrain models of the developed erosion and accumulation patterns. This new ability to measure the developed morphological surfaces would enable more accurate intra-model run comparisons and quantitative comparison between model runs and high resolution (decimetre in x,y and z) prototype scale swath bathymetry measurements of shipwrecks from the marine environment.
2. To undertake initial bi-directional flow experiments on an identical generic ship model to assess the importance of asymmetric residual sediment transport patterns on the site dynamics of archaeological wreck sites.
3. To undertake a comparative study of one of the MACHU study site, the Burgzand wrecks in the Wadden Sea, Netherlands (Manders, this volume). This site has excellent time-lapse swath bathymetry datasets, which would provide a detailed calibration dataset of annual changes in sedimentation and erosion on a single site for a bespoke model experiment.

THE PHYSICAL MODEL

Through a series of integrated experiments spanning: in situ measurements of a single submerged wreck site (a prototype scale); wind tunnel experiments (laboratory scaled but operating under physically comparable flow conditions); and water flume tank experiments with a scaled mobile bed (laboratory scale but with scaled flow conditions); researchers at Southampton had already been able to demonstrate were able to demonstrate the ability to model at laboratory scale sediment accumulation and erosion patterns around individual three-dimensional objects (specifically shipwrecks) under uni-directional flow. However, the analysis of the products of this original modelling work was only a series of low resolution topographic representations and non-rectified photo-imagery. This qualitative approach suggested quite subtle topographic features were being successfully replicated but were difficult to quantitatively assess. Consequently, the MACHU project provided the opportunity to extend this

FIGURE 1a-b Bi-directional pump system and the placement of the model vessel on the mobile bed. The coins and blocks represent reference points to enable stitching of laser scans so larger surface areas can be recorded.

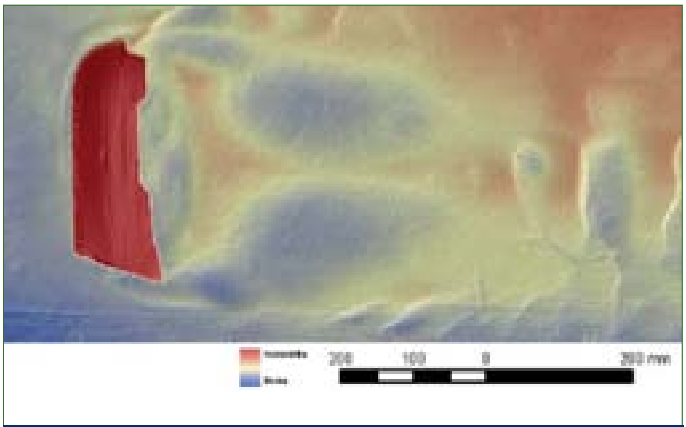


FIGURE 2 Figure 2: Sedimentation pattern generated under uni-directional conditions.

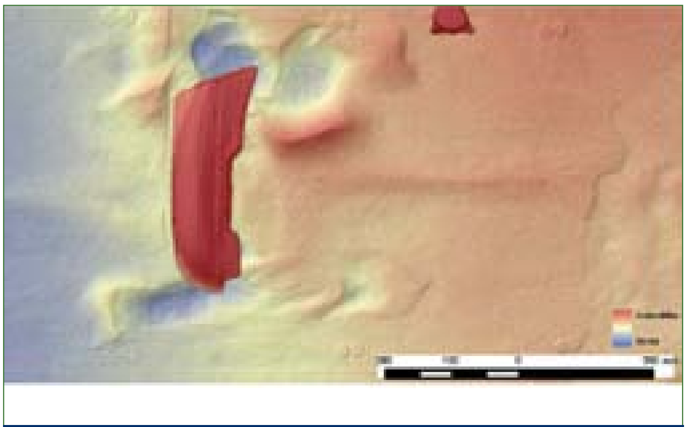


FIGURE 3 Sedimentation pattern generated under bi-directional conditions.

preliminary work such that the effect of bi-directional currents could be assessed and quantitative topographic measurements could undertaken for both uni-directional and bi-directional runs.

Key to the success of undertaking such experiments was the accurate calibration of the flow tank, which requires the extensive mapping of the flow, using a high resolution Acoustic Doppler Velocimeter, capable of measuring the flow speed and direction at any point in the tank at a resolution of > 0.1 cms-1. The criteria required for successful modelling included developing an effectively homogenous flow field in cross-section and a working area of greater than 1 metre along the tank where a fully developed boundary layer had been created. For the MACHU work it was also essential to create a flow tank set-up that was capable of operating in a bi-directional mode such that these conditions were satisfied for water flowing in both directions within the tank during the same This all had to be achieved at a flow speed that ensured clear water scour (i.e. the bed was not in motion under normal flow conditions). This was a significant challenge but a fully functioning tank set-up was developed during the course of the project *(figure 1a)*.

The modelling work was undertaken at a scale of 1:119 which enabled us to model the sediment accumulation patterns for a thirty metre vessel in medium grained sand. Every model was run for a twenty-four hour period for the uni-directional models, with these experiments representing a strongly asymmetric residual sediment transport direction typical of many parts of the UK shallow continental shelf. The bi-directional experiments were run for a forty-eight hour period, with flow being passed for a twenty-four hour period in each direction. These latter runs reflected a more symmetric tidal flow scenario. On completion of each model run the tank was drained and the resultant surface was laser scanned using a Konika Minolta VI-910 laser scanner *(figure 1b)* with a spatial resolution of < ± 0.22 mm in x,y and z. The generated x,y,z data was processed in ArcGIS to produce a range of contour, slope and aspect plots at 1 mm resolution.

RESULTS

A total of 16 experiments (12 Uni-directional and 4 bi-directional) were undertaken during the course of the MACHU project in order to assess the effectiveness of the modelling approach and the critical parameter of wreck orientation to flow on the corresponding patterns of sediment accumulation and erosion.

As can be seen in *figure 2 and 3*, the detail provided by the laser scanner enables unprecedented quantitative analysis of the morphology generated by the enhanced turbulent flows created by the interaction of the flow and the shipwreck. The zones of erosion and accumulation can be clearly identified even in these simple hillshade and coloured contour plots. In particular, the two prominent scour pits, separated by a thin accumulating high, downstream of the vessel, and offset from the main structure are clearly visible in the uni-directional model oriented at 90o to the flow (Figure 2). A series of replicate experiments demonstrated that all of the key morphological features developed, in almost identical localities and with similar dimensions, and so illustrated the reproducibility of this approach.

Figure 3 shows a similar orientation to flow (90°) but the pattern created has been generated from a bi-directional current. At the bow end an almost symmetrical pattern of scour has developed, as has as central linear thin ridge which can be seen protruding both sides of the mid-ship position. In this model there is a slight regional gradient (dipping gently left to right) which accounts for the overall bed level differences between each side. Of particular, interest in figure 3 is the impact of the more complex stern structure which has produced quite a distinctly different pattern of scour on either side of the vessel showing, the localised impact the detailed.

Unfortunately, despite a number of efforts we were unsuccessful in our attempts to model the Burgzand site primarily due to the low aspect ratio (height:width) that the wreck site expresses at the prototype scale. However, with the techniques and approaches developed during MACHU, we are continuing to work on this problem beyond this programme. The data obtained from the range of generic model orientations in both uni-directional and bi-directional experiments is now being quantitatively compared with swath data from a range of wrecks, in what will be the final stage in determining the validity of this approach to understanding marine site dynamics.

THE AUTHORS

***Justin Dix**, **Tim Rangecroft** and **Richard Sullivan** are from the School of Ocean & Earth Science, University of Southampton, National Oceanography Centre, Southampton. **David Lambkin** works for the ABP Marine Environmental Research Ltd, Suite B, Waterside House, Town Quay, Southampton. **Chris Pater** and **Ian Oxley** work for the English Heritage, Maritime Archaeology Team, Fort Cumberland, Portsmouth.* ■

Sedimentation-erosion study and future modelling

INTRODUCTION

During MACHU project research, the VIOE and the Renard Centre of Marine Geology at Ghent University (RCMG) worked together on specific wreck sites. High-resolution seismics and side-scan sonar measurements were taken. The results are presented on page 67. These geophysical surveys were organised and coordinated by the RCMG. The data gathered were discussed in the presence of both parties in order to obtain the most realistic interpretations.

Information was been derived from the sediment samples taken at and near wreck sites during archaeological surveying. This information has been analyzed at the Department of Marine Biology (Ghent University).

PhD research currently being conducted at the RCMG is studying small-scale sediment dynamics near objects and structures on the seabed. This involves detailed morphological, hydrological and sediment-dynamics investigations to allow prediction of burials in the sandy seabed of the Belgian Continental Shelf. High-resolution time series of sediment dynamics have been obtained using state-of-the art technology. Towed and autonomous sonar and profiling systems have been used, mainly to monitor tidal influences on sand transport capacity under fair weather conditions, whilst more energetic weather conditions (waves, storms) have been recorded with *in-situ* autonomous dataloggers (burial registration mines and 'SeaGrass' rods). The latter have been developed in-house and were specifically designed to monitor the potential for burial and exposure of shipwrecks. The 'SeaGrass' dataloggers are used mainly to measure nearbed sediment load concentrations and the changing seabed-water interface in both time and space (i.e. four dimensions).[1] The 'SeaGrass' project of the same name was carried out by the VIOE and the RCMG working in collaboration, as archaeological wreck sites are suitable for this type of research, and the project goals coincided with those of the MACHU project.

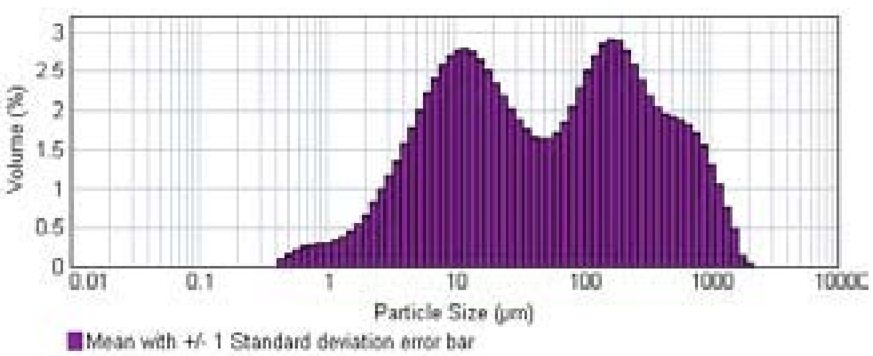


FIGURE 1 BIMODAL GRAIN SIZE DISTRIBUTION OF SEDIMENT WITHIN WRECK B125/306B, SAMPLE 2A 30/07/2008 © MASTERSIZER2000

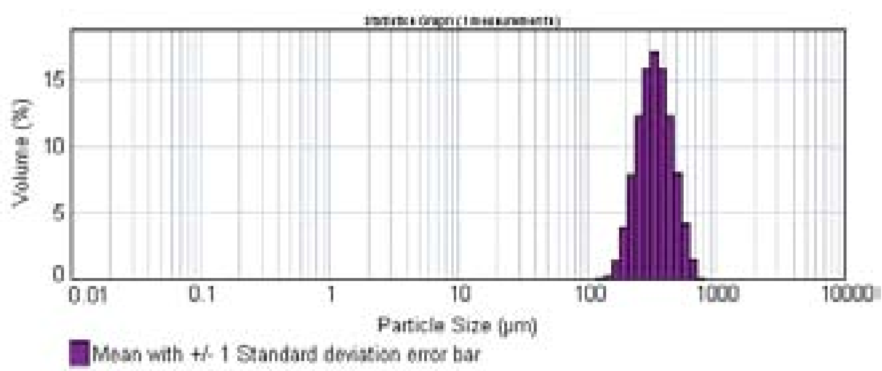


FIGURE 2 UNIMODAL GRAIN SIZE DISTRIBUTION OF SEDIMENT OUTSIDE T-319 B112/238 WRECK, SAMPLE B 20/03/2009 © MASTERSIZER2000

SEDIMENT ANALYSIS

Sediment samples were systematically taken by divers during VIOE diving prospections at 32 different wreck sites over the past three years. Samples of the superficial sediments were taken both inside and outside the wreck as far as possible.

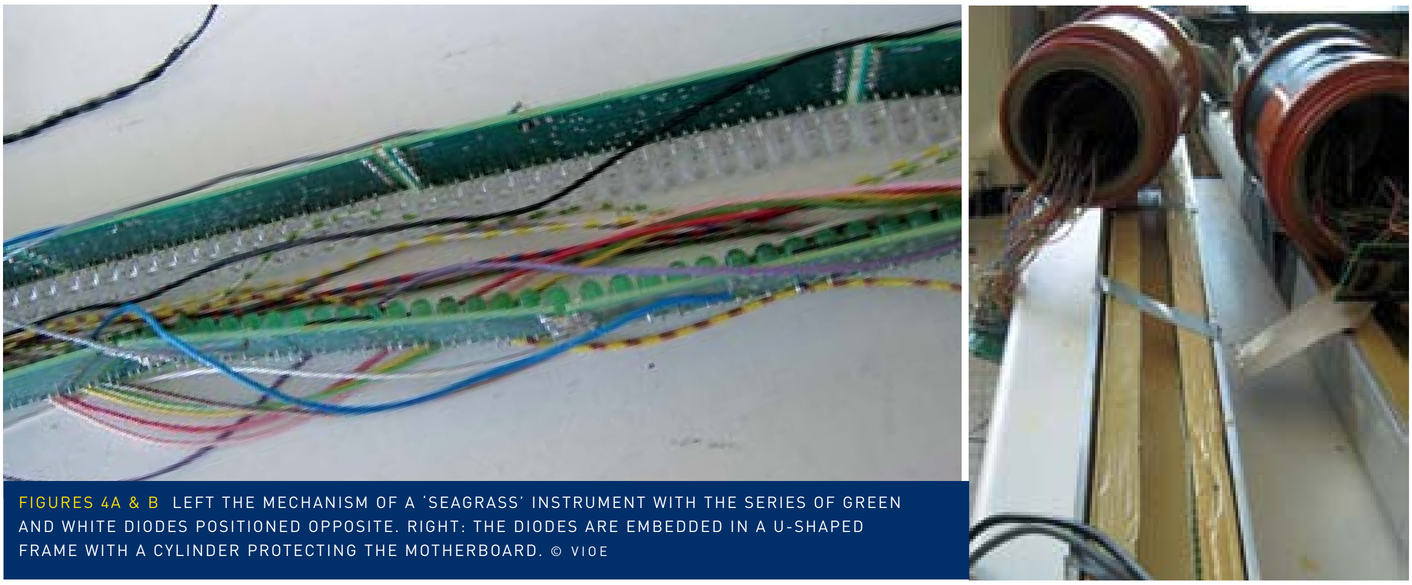
A total of 67 samples were analyzed using a 'Malvern Mastersizer 2000'[2]. Grain size analysis was performed on the sand and silt fractions in the samples.

Four wreck sites that yielded a useful amount of referential sample material have so far been investigated in more detail (18 samples). In most of the samples, no particles larger than 1600 µm were found in the 1600 µm-sieve.

A clear difference was identified in the grain size distribution of samples taken at the wreck site compared to those taken off-site. Other observations from this small number of samples include:

- Inside the wreck, sediments have a heterogeneous character *(figure 1)* and are characterized by a wide grain size distribution (less sorting). Some of the sediments are bimodal[3].
- Furthermore, samples taken off-site seem to be more uniformly distributed and well sorted *(figure 2)*. No bimodal sediments are present.
- Finally, looking at the smallest grain size fraction (d10), the median grain size (d50) and

FIGURE 3 LEFT: LAB TESTING OF THE 'SEAGRASS' INSTRUMENT IN SEDIMENT FLUMES (FLANDERS HYDRAULICS RESEARCH). RIGHT: THE PLACING OF A MEASURING ROD OFF-SHORE © RCMG



FIGURES 4A & B LEFT THE MECHANISM OF A 'SEAGRASS' INSTRUMENT WITH THE SERIES OF GREEN AND WHITE DIODES POSITIONED OPPOSITE. RIGHT: THE DIODES ARE EMBEDDED IN A U-SHAPED FRAME WITH A CYLINDER PROTECTING THE MOTHERBOARD. © VIOE

the largest grain size fraction (d90)[4], the different samples taken inside the wreck show greater variation over time than those outside the wreck. This proves the dynamic character of sedimentation and erosion at wreck sites.

In spite of the under-sampling, the varying (non-specific) locations of the samples at the wreck sites and the limited time-dependency (irregular and non-systematic sampling over time), there is a general trend present in the sediment distribution. The wrecks seem to gather and trap different kinds of sediment fractions, whereas the adjacent seafloor (close to/outside the wreck) is characterized by a fine distribution. Sedimentation of coarse sands is more obvious inside the wrecks than outside.

SEAGRASS' DATALOGGERS

The 'SeaGrass' PhD study is focused on one of the historic wreck sites: the 'Buiten Ratel wreck', or B114/230a (see above), on the western flank of the Buiten Ratel sandbank within the MACHU Buiten Ratel test area. The site has an active hydrodynamic character which results in erosion and sedimentation patterns[5].

The ongoing research on the burial potential for sea mines, pipelines and shipwrecks involves development of low-cost dataloggers for sand level and turbidity. The 'SeaGrass' dataloggers were developed in-house (RCMG-UGent), and are still at the prototype stage. Nevertheless, they have been successfully tested in sediment flumes and silt tanks (Flanders Hydraulics Research), and once off-shore, deployed on a tripod frame (*figure 3*).

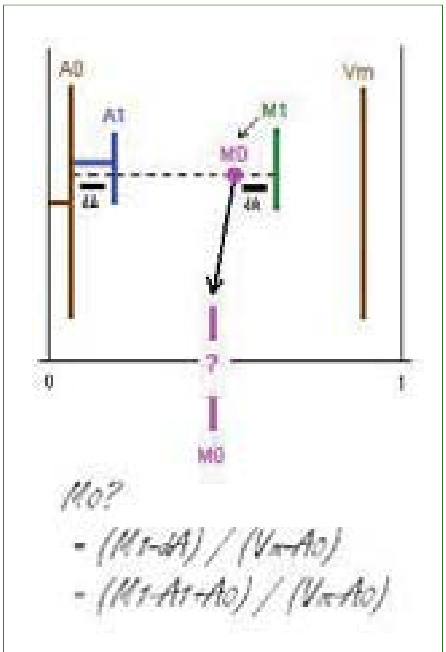


FIGURE 5 Normalisation of the values measured by each pair of diodes.

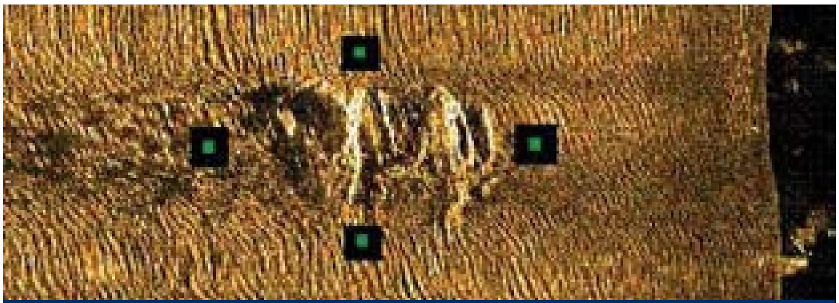


FIGURE 5 Side scan sonar image (Klein 3000, RCMG) of the Buiten Ratel wrecksite (B114/230a) with an indication of the planned location of 4 'Sea Grass' instruments. © RCMG

The principle of measuring is optically based. Visible light emitting diodes are lined up in a single array (with a resolution of 0,50 cm) opposite an array of photodiode receivers. A U-shaped frame is vertically positioned in the sea bottom (*figures. 3b & 4*). If the sand level rises, the sediment will block the corresponding couples of diode pairs and no light will propagate through the sediment, giving a zero value. In the water column sediment is in suspension, and will partially block the propagating light, depending on the concentration. The theoretical range of intensities measured by the photodiodes depends on their sensitivity.

Recordings taken every 60 seconds for example (adjustable recording frequency), will include two values: the background light (A1) without an activated LED and the real measurement (M1) when the LED is activated. Taking into account the difference between these values, interference by daylight or biofouling can be filtered out (M1-A1) *(figure 5)*. To reconstruct profiles of sediment concentration in the water, the pairs of diodes need to be calibrated and the maximum range (Vm) of each pair needs to be defined (Vm-A0). Each instrument with an array of 256 diode pairs is therefore measured in the absence of light. The theoretical maximum range is 0-1024, but for most pairs it is less. Finally, recordings from the individual pairs can be corrected and compared with each other.

So far, no data time series have been collected for the Buiten Ratel wreck site. A possible deployment near the wreck might involve four 'SeaGrass' instruments in order to identify seabed changes over time in three dimensions *(figure 6)*.

The successive 'SeaGrass' time series recordings should give an insight into the migration and development of sand dunes and ripples, the degree of erosion and sedimentation due to storm activity in the vertical and turbidity (i.e. sediment in suspension).

FUTURE

The sediment analysis revealed some preliminary interpretations, though it was based on only a few sediments. More samples must be analyzed in order to obtain statistically well-founded conclusions.

The 'SeaGrass' measuring rods will be deployed at the wreck site in autumn 2009, and the PhD project will be finished by the end of 2011. This project deals with formulae for bed load transport, which will be tested against all the field data. A burial prediction model and risk maps covering the Belgian Continental Shelf will also be produced.

The high-resolution datasets of cyclic burial changes will be correlated with the direction and strength of the sand transporting agents (e.g. wind, waves, currents). It is hoped this will provide sand budget calculations for the Buiten Ratel wreck site.

The results are expected to give more insight into the sedimentation-erosion processes at this wreck site and indicate the potential of these techniques for other underwater sites.

NOTES

[1] Research along the same lines as the 'Quest 4D' Research Project *('QUantification of Erosion and Sediment patterns to Trace natural versus anthropogenic sediment dynamics')* under the *'Science for Sustainable Development'* programme (2005 – 2009), www.vliz.be/projects/quest4D/).

[2] The Mastersizer Malvern 2000 has a grain size measurement range of 0.02µm – 2000µm. 72 samples have been taken (untill 1 August 2009). Sediment analysis was performed in June and July 2009.

[3] A sediment is bimodal when two groups of grain sizes are dominant within the sample, in other words there is a clear presence of two peaks in the grain size distribution, in contrast with the uniform distribution of a unimodal sediment type (1 peak) (see also figures 1 & 2).

[4] The first 10% of all grains in the grain size distribution of one sample are smaller than d10. The other 90% is indicated as d90. The median grain size is d50.

[5] Several aspects of this sandbank (i.e. sedimentology, morphology, hydrodynamics) have been studied in detail in the past. The sandbank itself is a stable system, whereas the superposed bedforms (e.g. sand ripples and sand dunes) are very dynamic. Sedimentation occurs mainly in the defined convergence zones on top of the sandbank. The Buiten Ratel wreck site is located on the lower part of the flank, which is covered by flood-dominant bed forms (wavelength 2 m, height 35 cm) (Baeye 2006).

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Multibeam recording
as a way to monitor shipwreck sites

INTRODUCTION

The main focus of the MACHU project was to find better ways to manage the underwater cultural heritage (UCH). UCH management comprises all the steps needed to preserve or investigate archaeological sites underwater in the best possible way. It involves making choices between excavation and in situ preservation, and taking measures to ensure the quality of underwater cultural heritage resources over a longer period of time. And here, in particular, lies a threat: the 'maintenance' of our UCH involves a lot of time, people and money. This is the 'downside' of extensive inventories and a preference for preserving sites *in situ*.[1]

The more sites we know about, the more sites will be marked as being of national or even international importance (and therefore declared monuments). The more sites we preserve in situ, the more time and money have to be allocated to their preservation and maintenance. This message is not very popular with government agencies, but it is a direct consequence of the policy developed by them, and therefore extremely important.

There is still not a widely accepted protocol on how to monitor archaeological sites underwater, either nationally or internationally.
There are also no rules about what constitutes best practice in monitoring. We are still in fact seeking acknowledgement of the fact that monitoring is an important part of cultural heritage management, even more so given that preservation in situ is to have precedence over excavation.

HOW CAN WE MONITOR ARCHAEOLOGICAL SITES?

Monitoring is observing. In UCH we in fact regard it as observing the changes – both current and future – at an archaeological site. Observation has to be scientifically based in order to be able to develop methods to minimise any negative effects and also because it provides the baseline for the next round of monitoring. It is important to produce a baseline study of the physical condition of the archaeological site. This should ideally be included in the evaluation, thus immediately connecting the archaeological value of the site with its state of preservation. As soon as the condition of the site declines, its value may decline too.

What are the key things to measure when monitoring the condition of the site and any changes occurring now or in the future? This depends on the budget and staff available, the number of sites that have to be monitored and the level of detail required. It is essential that monitoring be executed in a structure that is more or less the same at all sites. It also depends on the context: sites in active, hostile environments need to be monitored more closely than those in stable environments.
Information that is always needed to assess the current and future state of an archaeological site includes its present archaeological value or significance (as established in an evaluation), its size, the relationship between the site and its environment, its current condition, roughly which materials are present, and an overview of present and future threats.
When monitoring it is important to relate the information collected to the baseline study. The newly gained information can influence the archaeological value and should provide some insight into immediate and potential future threats.

This information should also provide input for an ongoing monitoring programme for the site. All monitoring programmes together should provide the input for an overall monitoring programme for an entire state or country with a longer-term focus.
Underwater archaeological sites can be monitored in different ways. Underwater monitoring can, for example, be performed by divers, remote operated vehicles (ROVs) or dataloggers. From the water surface, geophysical methods or coring can be used, or a combination of these methods.[2] By using a combination of methods, different elements of a site can be investigated: the site in its larger context, its natural environment and

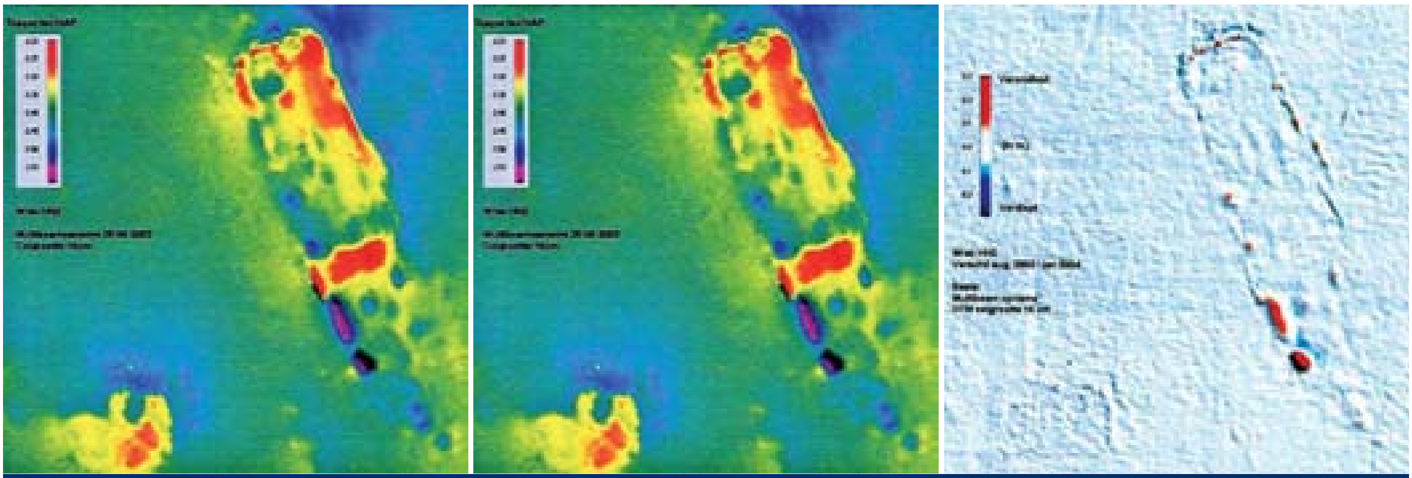

FIGURE 1a-b-c An 18th century shipwreck Hoornsche Hop 2 monitored with high resolution multibeam echo sounder (grid 15 x 15 cm). The difference map August 2003-January 2004 shows no sign of illegal digging. In fact small sounding pits of earlier archaeological investigation have been filled with sediment. SOURCE: RWS the condition of the wreck site and the materials it consists of. One method of monitoring that has been tested in UCH management in the Netherlands for a number of years is the multibeam echo sounder.

THE USE OF MULTIBEAM ECHO SOUNDERS IN MONITORING

The multibeam echo sounder is an instrument used in hydrography to plot the seabed. It sends multiple sound pulses to the seabed in a narrow path under the ship, accurately measuring depth. Usually, the higher the frequency, the better the accuracy.[3] At the moment, in ideal conditions, some systems can produce images as good as the side-scan sonar.[4] One advantage, however, is that a multibeam recording consists of actual depths. It is therefore ideal for monitoring the seabed and the archaeological sites in it – or actually just on the surface of it. The data gathered allow us to calculate such things as depth changes over time and how much sediment has been deposited or eroded.[5]

Multibeam is very useful for mapping an area of the seabed rapidly and can be used for the detection of shipwrecks on the seabed. It does not cover as much seabed as a side-scan sonar in one single track, but it does give an accurate overview of an area in actual depths in just a short period of time. Since it produces actual depth measurements, it can quantify environmental changes like sedimentation or erosion processes. It is therefore a cost-effective method for monitoring sites – including their environment – underwater.
Multibeam data can also be processed in such a way as to create a three-dimensional image, or even film. This is highly effective for research, making it possible for a researcher to virtually swim around the wreck site and understand issues in 3D. In an age where visualisation is becoming more and more important, these kinds of images can also be very useful in communicating with a broader audience.

The multibeam echo sounder can be a highly effective tool for regular monitoring. Due to its highly accurate positioning and depth measurements, it has also been used for other purposes. One example was an investigation of the possible looting of a site near the Dutch town of Hoorn *(figure 1)*. The Cultural Heritage Agency had been informed by local divers that looters were active at an 18th-century shipwreck, looking for Makkum earthenware that was known to be part of the cargo. However, comparison between an earlier multibeam recording and one made just after the information was given revealed that the site had not been touched for a while. Divers can never obtain such a quick and accurate overview in such murky waters.

At the Banjaard, the other Dutch MACHU test area in Zeeland, old wreck positions have been reanalysed on the basis of new multibeam recordings. The 19th-century 'spot by 11' wreck, for example, was found to be approximately 100 metres south of its original position.[6]

The multiple depth measurements taken with multibeam can also be used as input for sedimentation-erosion models on a regional as well on a larger scale, such as that produced by Southampton University (UK) for the Burgzand Area of the Wadden Sea (NL) and the southern North Sea basin.[1]
A coring plan for optically stimulated luminescence dating (OSL) was also developed as part of the MACHU project on the basis of the multibeam recordings of the BZN 10 site in the Wadden Sea.[8]
Another use for multibeam is in archaeological evaluation and excavation. Its good positioning and the depth measurements and overview it provides give an accurate basis for site plans, not only saving valuable time, but also often proving more accurate than measurements taken by hand. This application is not within the scope of this article, however.[9]

The multibeam echo sounder is used by many organisations whose remit includes managing the waters and seabeds of Europe. In the Netherlands they include Rijkswaterstaat (the Directorate-General for Public Works and

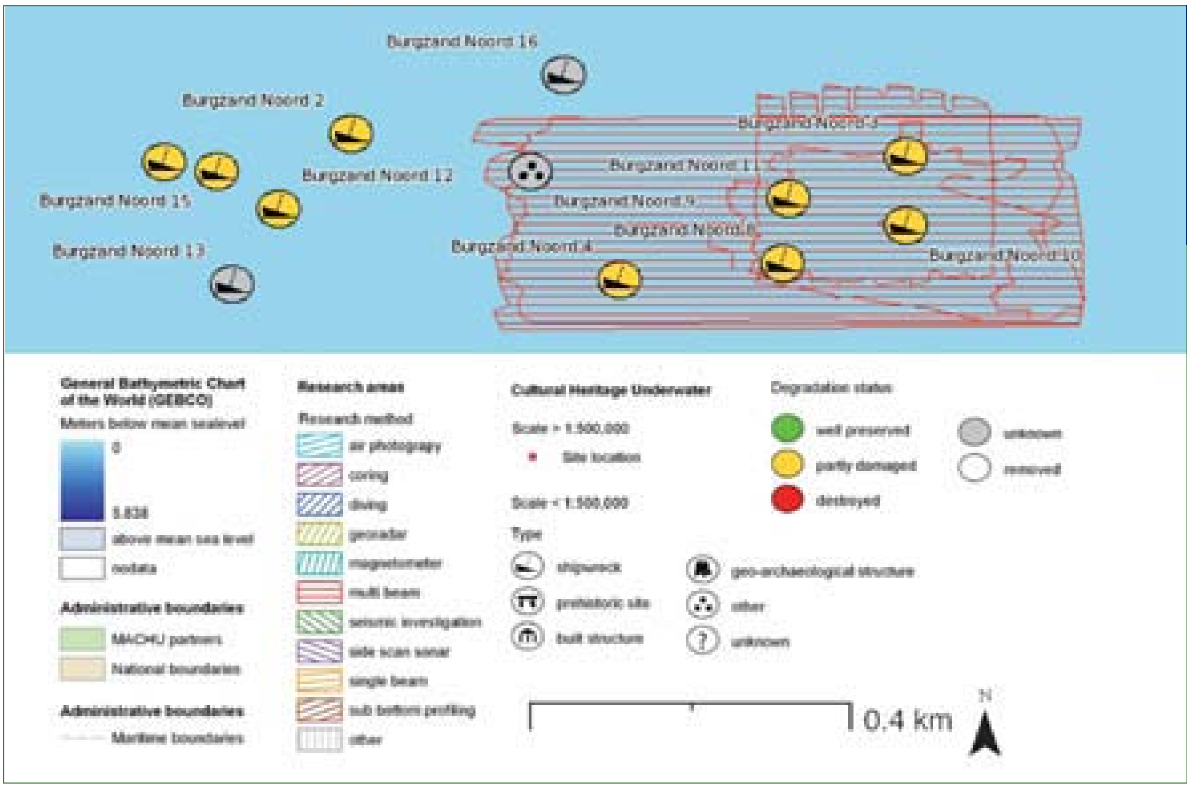

FIGURE 2
Research area Burgzand in the Wadden Sea, The Netherlands with the 4 monitored shipwreck sites.
SOURCE: MACHU GIS

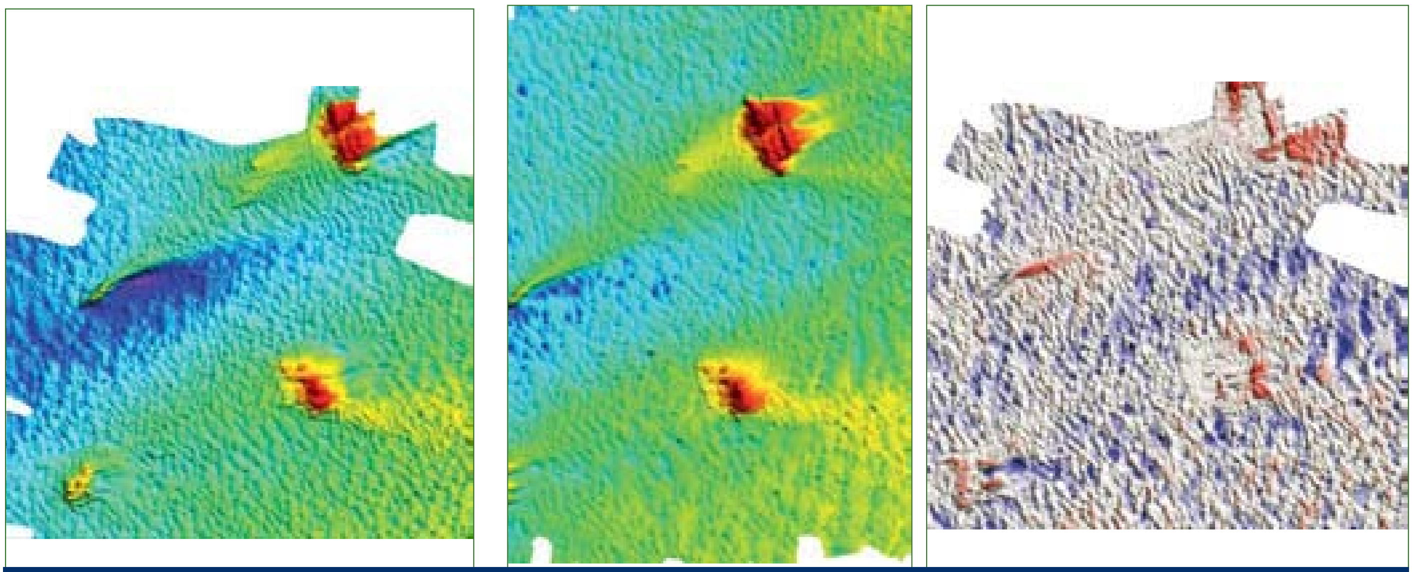

FIGURE 3 Multibeam echosounder overview images of the whole research area. On the left 2003, middle 2004 and the difference map (grid 50 x 50 cm). SOURCE: RWS

Water Management, or RWS) and the Ministry of Defence's Hydrographic Service.[10] Data they collect for other purposes can – in many cases – be used for archaeological monitoring. The rough data, that is, though sometimes they have to be processed slightly differently, with a higher resolution.[11]

In conclusion: multibeam echo sounders can be used to create an overview of a site and its immediate environment, with accurate depths in a high resolution, in just a short period of time. This makes it a cost-effective instrument for archaeological monitoring.[12] Furthermore, data can be collected by many different stakeholders.[13] And harvesting of information from third parties makes monitoring even more cost-effective.

RESULTS OF MULTIBEAM MONITORING

THE BURGZAND NORTH AREA

With this in mind, the Burgzand area – one of the MACHU test sites – was extensively monitored using a multibeam echo sounder *(figure 2)*. In 2002 and 2004 the system used was a Reson Seabat 8101, in 2003 and from 2005 onwards the equipment used was a Reson Seabat 8125, a top-of-the-range system.[14] It has an operating frequency of 455 KHz that can cover a 120° swathe of the seafloor with 240 dynamically focused beams. This means that 240 depth measurements are taken with each pulse. Every second the multibeam sonar can give 40 pulses. The 8101 has a lower resolution, measuring with 101 beams. From 2002 onwards the monitoring was performed in collaboration with RWS, the main management agency for waterways in the Netherlands.[15] The first recordings (2002 to 2005) were made for another EU project known as MoSS (Monitoring of Shipwreck Sites), and were later taken over by the MACHU project.[16] This large series has given us detailed knowledge of what is happening on the seabed in this area. The multibeam recordings were made each year, without taking into account specific events like storms that can have a strong sudden impact on the seabed. The reason for this is that we specifically wanted to monitor the long-term effects on the sites, and we therefore had more flexibility when it came to the availability of the surveyors and their equipment.

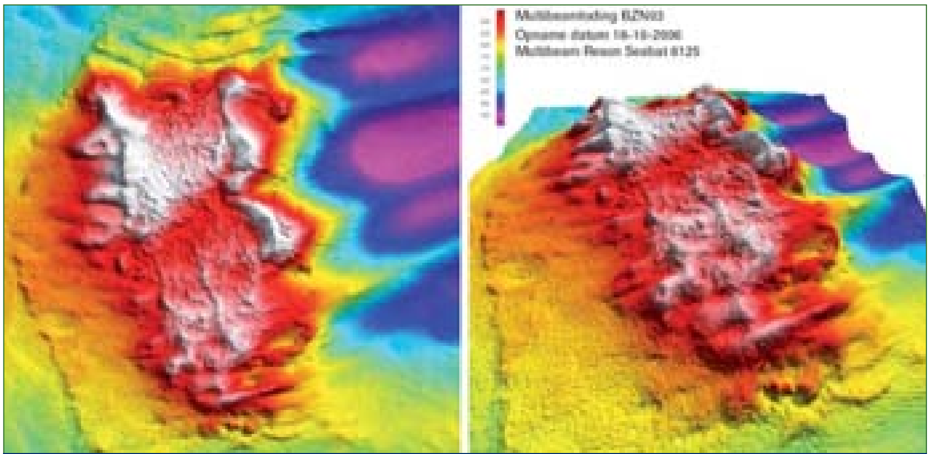

FIGURE 4 High resolution multibeam images from 2006 of the BZN 3 wreck. SOURCE: RWS

Four archaeological shipwrecks are known to lie in an area of 200 by 250 metres – the heart of the former Texel Roads. They are referred to as BZN 3, 8, 10 and 11.[17] These sites have all been archaeologically assessed and dated to the second half of the 17th century. BZN 3, 8 and 10 are physically protected. BZN 3 was the first wreck to be covered in 1988, with more than 6000 sandbags and polypropylene nets. In 2001 and 2003 the protection was extended by another method, using only the nets. BZN 8 (2003) and 10 (2000, 2001, 2002, 2003) were also covered using this last method. BZN 11 has deliberately not been physically protected and is used as a benchmark for measuring the effect of non-protection in this area *(figure 3)*.[18]

The shallow Burgzand area is extremely dynamic, influenced by tidal movements and large amounts of water being pressed through narrow gullies. At high tide water moves from west to east.

The natural environment is one of the biggest threats to the sites, causing strong erosion that uncovers the wrecks, making them

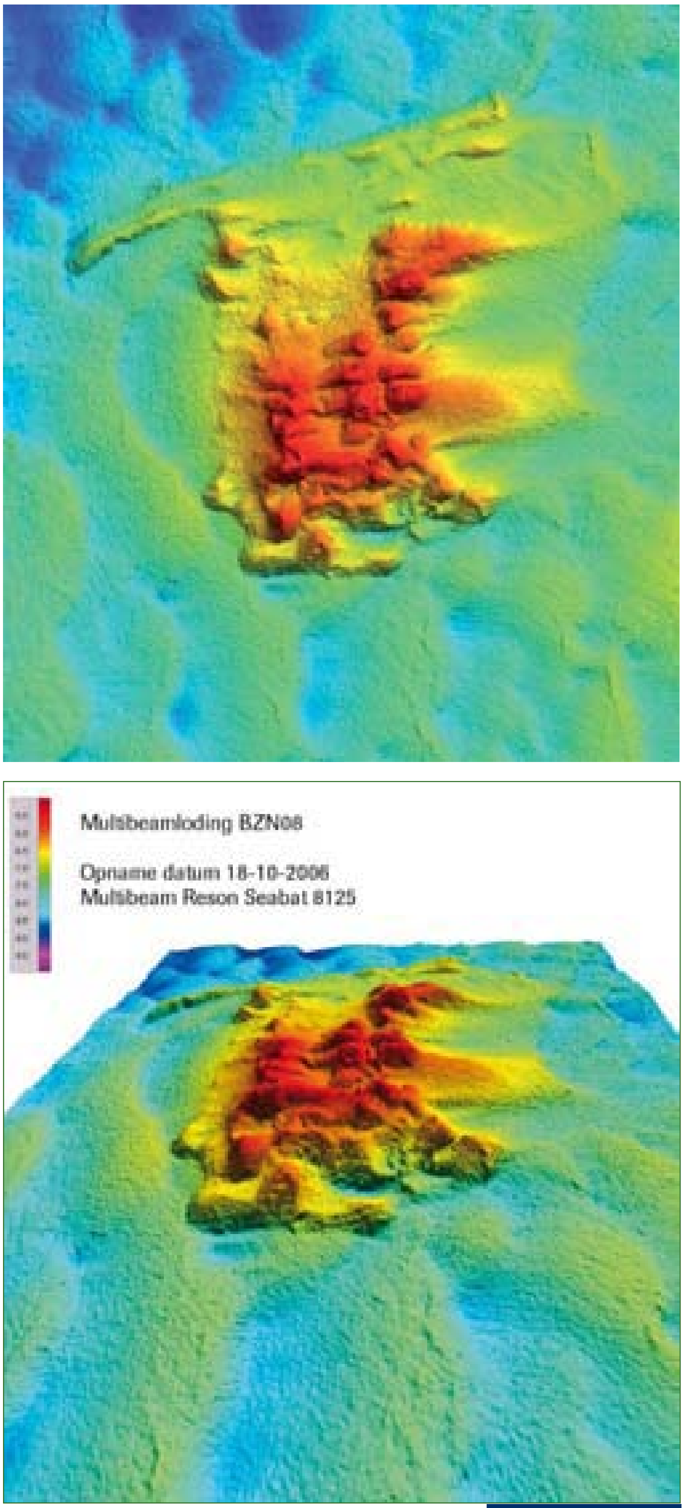

FIGURE 5 High resolution multibeam images from 2006 of the BZN 8 wreck. SOURCE: RWS

vulnerable to bio-attack by organisms like shipworm (Teredo navalis). But as quickly as the wrecks can be uncovered, they can be equally quickly covered again with a protective layer of Holocene sand. However, mainly due to the construction of the Afsluitdijk - causeway in 1932, the seabed as a whole is eroding in this area and the prognosis is for this to continue for at least a few decades.[19]

A number of conclusions have been drawn from systematic analysis of the multibeam recordings.[20]

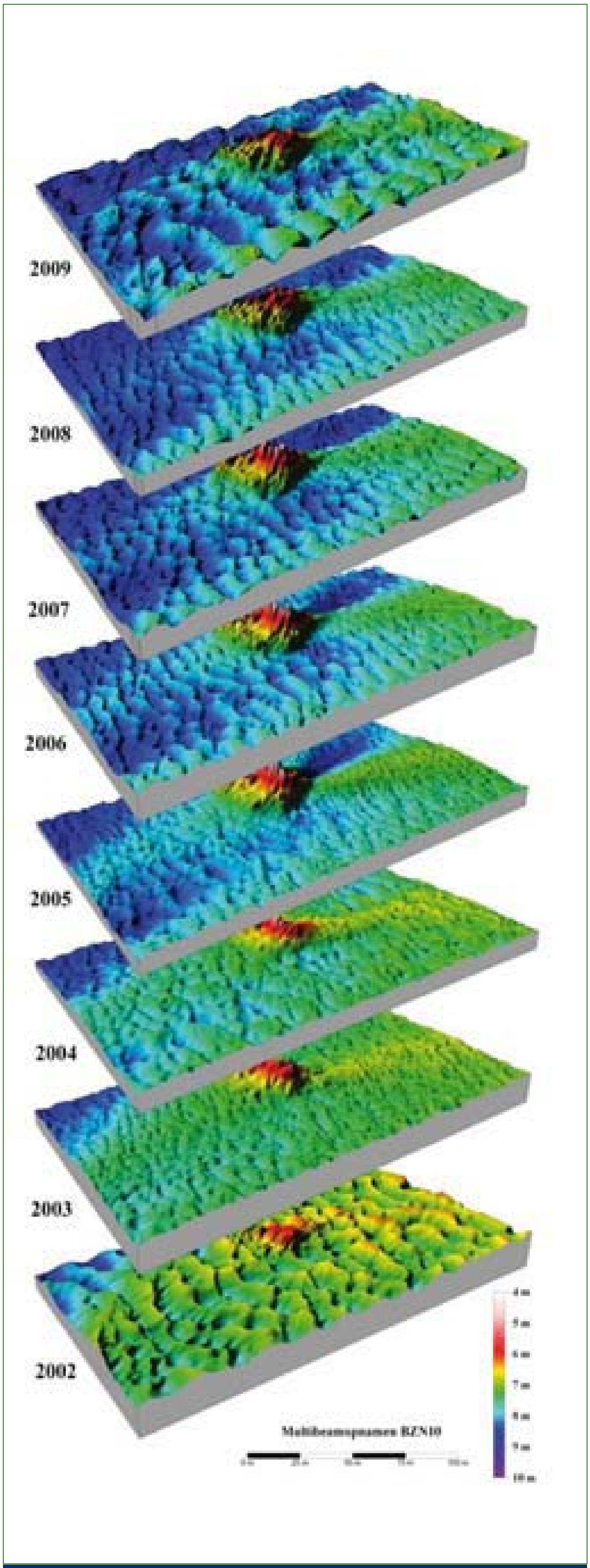

FIGURE 6 Sequence of multibeam images from the BZN 10 wreck 2002-2009. SOURCE: RWS/SEGER VAN DEN BRENK, PERIPLUS-ARCHEOMARE

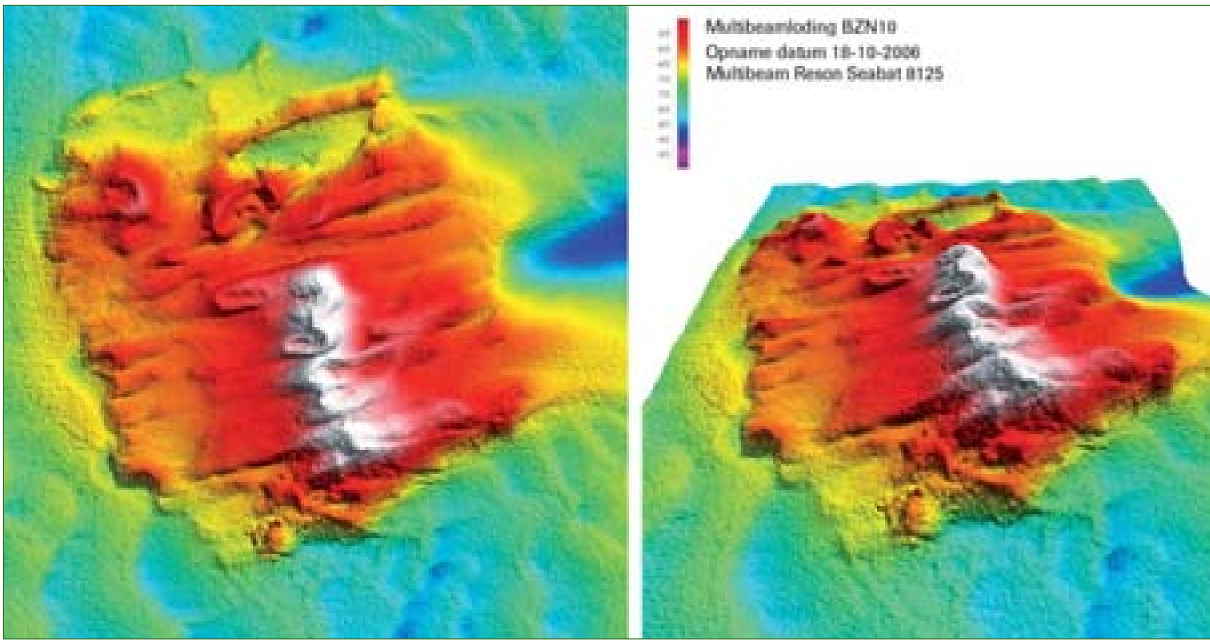

FIGURE 7 High resolution multibeam images from 2006 of the BZN 10 wreck. SOURCE: RWS

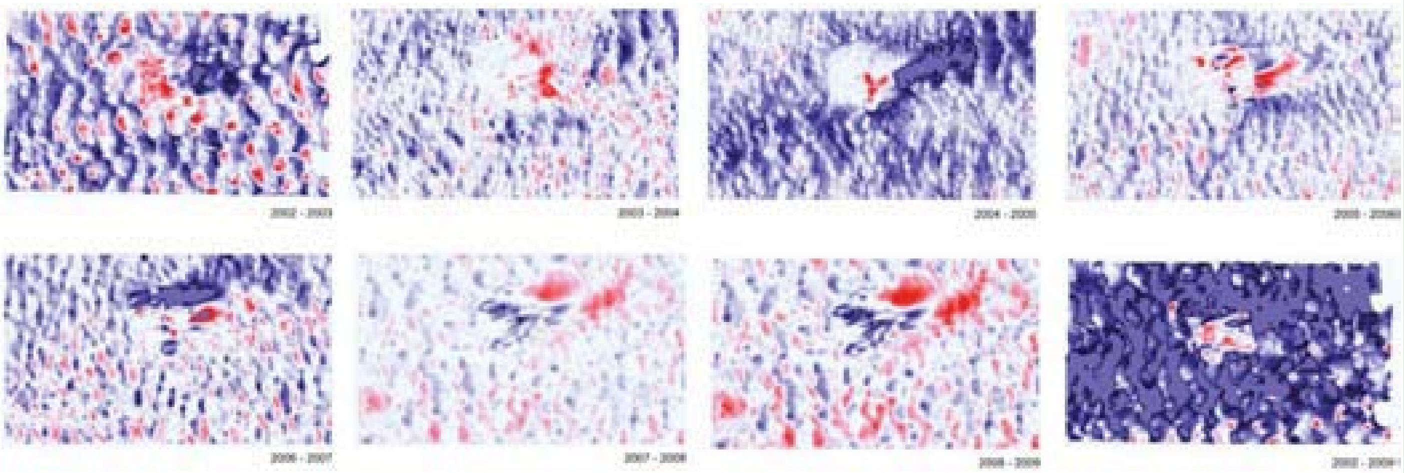

FIGURE 8 Differences maps from the BZN 10 wreck 2002-2009 (grid 100 x 100 cm). Bottom right the differences map for the whole period showing strong erosion around the physically protected site. SOURCE: RWS

BZN 3

In 2003 the site was protruding from the seabed over an area of approximately 50 metres by 50 metres. The multibeam data showed a clear edge on the west side from where the net protection starts. Sediment had been deposited on the east side.

In the middle of the wreck a small channel was visible running from west to east. In the south a small part of the wreck seemed to have become separated from the main protected part. Archaeologists from the Dutch Cultural Heritage Agency identified this as the bow section of the ship, which was not yet visible when the wreck was discovered in the 1980s. In 2001 the bow had provisionally been covered with polypropylene nets and just before the 2003 multibeam recording, the protection was reapplied in a better way. However, in that year, the data still showed individual wreck parts, which means that this part of the site was not yet buried under a layer of sand.

The 2003 image also showed the individual strips of netting starting as much as 60 metres outside the wreck to the west. There was also some indication of large objects or wreck parts in the area.

In 2004 the whole site seemed to be level. A great deal of sand had been caught in the nets. The west-east channel in the middle of the wreck was slowly disappearing and, one year after the covering was applied, the bow section also seemed to be covered in sand. Sedimentation was visible on both the west and east side of the wreck mound. From the middle of the wreck, this was the case for up to 60 metres to the west and also approximately 60 metres to the east.[21] In some places small erosion pits were visible, probably due to bad connections between the strips of netting. The sedimentation-erosion map produced for the period 2003 - 2004 clearly shows the deposition of sediment around the older protection of 1988 as a result of the new protective measures. While the height remained the same in the area of the original wreck mound, in newly covered areas more than a metre of additional deposition had occurred. The multibeam data from 2006 show the existence of deep erosion pits on the east side of the wreck *(figure 4)*. The height differences from the top of the wreck mound to the deeper areas on the east side were now 5 to 6 metres.

A sediment build-up at least 85 metres long on the west side of the wreck seen in 2009 was probably caused by the BZN 11 wreck, which lies approximately 180 metres west of this wreck.
On the east side of the wreck, sediment build-up has occurred over approximately 60 metres measured from the middle of the wreck mound. However, there is also a continuation of erosion on that side between the strips of netting.
Sand ridges over 200 metres long have formed on the north and south sides of the wreck mound.

BZN 8

In 2003, the wreck site was approximately 20 metres wide and 30 metres long. The maximum height differences inside and outside the wreck were 2.5 to 3 metres. On the southwest side sharp edges had formed around the polypropylene nets. Before the physical protection the stern part to the south was already the most protruding feature. Strong erosion here posed a major threat to the whole site.
In 2004 the protective layer was clearly catching sand, and most height differences in the wreck had levelled out. However, in the southeast and northwest area some individual uncovered ship parts were being revealed and east of the wreck mound a large erosion pit approximately 40 by 8 metres was becoming visible in the middle of the wreck. Also east of the wreck mound, in the north and south region, more sand had been deposited and two large sand ridges had formed.
In 2006 sand seemed to have been successfully caught at the wreck site. On the west side the edges of the protective nets were clearly covered with sand *(figure 5)*.
In 2008 the erosion pit in the east had deepened (see above in 2004).

In 2009 the wreck site is approximately 22 metres wide - with some strips of nets stretching for more than 40 metres – and 40 metres long. Erosion on the east side continues.
Inside the wreck the mound is levelling out due to sediment build-up.

BZN 10

Multibeam recordings of the BZN 10 wreck since 2002 were available for this research *(figure 6)*. The first one was produced for the MoSS project and focused only on this wreck site.[22] The physical protective nets are clearly visible. The site was still relatively flat, but some archaeological features were still protruding, including a cannon to the north of the site. On the edges of the nets, on the north, south and west sides of the site, sharply defined edges were visible. In areas with clear signs of strong erosion, archaeological features were also surfacing on the seabed.
In 2003, after extension of the covering, the site was 30 metres wide, with strips of netting extending a further 10 metres on the east side. The length of the site as 40 metres.
More sediment had settled on the wreck,

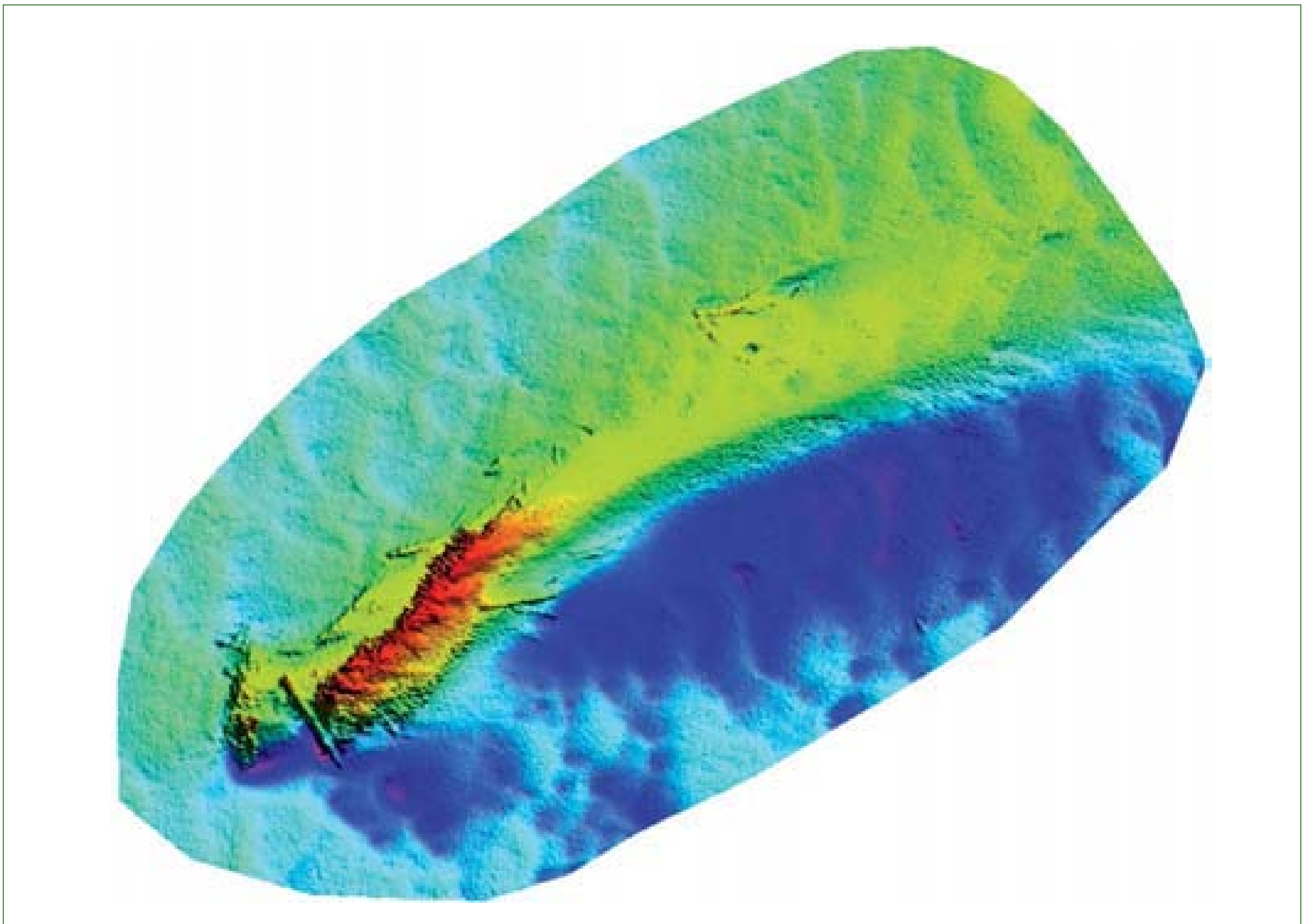

FIGURE 9 High resolution multibeam images from 2006 of the BZN 11 wreck. SOURCE: RWS

covering all the archaeological material. From the west side to the middle of the wreck mound we measured 20 metres, from the middle of the mound to the east as much as 40 metres. In the south a sand ridge had formed, extending towards the east.
In 2004 the site was 45 metres wide and 47 metres long. More sediment had been caught in the wreck and the sand ridge in the southeast was extending. The edge of the protective nets to the west was becoming more visible, due to the lowering of the seabed around the wreck site.

This was even more pronounced in 2005. More sediment had been caught on the east and (to a lesser extent) the west side of the wreck. However, in the middle part east of the wreck mound, an area outside the protective nets had deepened severely.
In 2006 parts of this erosion pit had been filled with sand again. Erosion continued in the north and south, however. The erosion in the east was worst in the middle of the wreck site. In the north individual ship parts were becoming visible. In the area around the wreck site, the seabed had deepened further *(figure 7)*.
By 2007 the situation had worsened. On the north-northeast side a strong erosion gulley had formed and more individual ship parts were being revealed.
A slight sedimentation ridge had become visible in the middle part of the west side as a result of wreck BZN 8, which lies 180 metres west of BZN 10. The proximity of this same wreck has however exposed the seabed to stronger erosion on the south side of BZN 10. The seabed at and immediately surrounding the BZN 10 wreck site deepened by an average of over 80 cm between 2002 and 2009.[23] The deepening has been much greater in the surrounding seabed if we take into account the fact that the physically protected part of the site has gained more sediment over that same period. The most severe deepening took place in 2004-2005. The average deepening in that year was approximately 34 cm.[24] But strong erosion also occurred in 2003-2004, 2006-2007 and 2007-2008. A small positive sedimentation rate was detected in 2007-2008 and 2008-2009, mainly due to the filling of some deep erosion gullies in the east and north. Strikingly, however, in these two years the area on top of the wreck site seemed to lose sediment for the first time. The reason for this is not clear at present, but it may be that sand flows away from under the protective nets in some areas. This must be investigated in the next planned monitoring dive *(figure 8)*.[25]

BZN 11

The BZN 11 wreck has not been physically protected in situ and therefore serves as a benchmark for the protected wreck sites. It is oriented west-east, with the bow very probably in the east. The other three monitored sites were all oriented north-south. The wreck site consists of the bottom part of a wreck (keel, frames and planks) and, in the west, a small section of the port side (from a higher part of the structure). In 2003 the site was approximately 25 metres long and 8 metres wide.[26] There was a strong erosion gulley on the south side of the wreck.
By 2004 the site was only 5 metres wide. The length remained the same, but a large ridge at least 50 metres long was forming to the east. From 2004 on the deep erosion gulley levelled out.

This was still the case in 2006, but in the southwest some strong erosion pits seemed to be undermining the ship's structure (figure 9).
In 2008 and 2009, the site was still as large as in 2004, but the seabed around it had flattened out further. The wreck seems to be slowly disappearing, probably because it is falling apart. Evidence of this can also be found in the multibeam data. While in 2003 the height difference between the wreck and the surrounding seabed was still approximately 1.40 metres, in 2009 the wreck was protruding above the seabed by only 10 cm.

CONCLUSIONS

Overall, it is clear that the physical protection of the BZN 3, 8 and 10 sites has been effective, especially when we compare these sites with the unprotected BZN 11 site. The extensions over the years have also been necessary and effective.

A 2003-2004 sedimentation-erosion map of the whole BZN area shows a flattening of the sand waves. The total research area is 79,800 m^2. From 2003 to 2009 the average deepening of the seabed was 53 cm, which means there has been a loss of 31,849 m^2 of sediment from this area.[27] Here, too, the most pronounced deepening occurred between 2004 and 2005, by some 50 cm in just one year[28] *(see also figure 3)*. On the west side of the BZN 3 site sediment continues to build up. This also seems to be the case at BZN 8 and 10, albeit to a lesser extent. Overall sedimentation on the west side of the wrecks can be as much as 1.5 metres in one year. At all three sites the edges to the west of the protection have become clearly visible. The straight lines indicate however that the protection is still very much intact. The nets clearly protrude above the seabed because they catch sand, and because the surrounding seabed is eroding. However, these parts of the protection have to be monitored regularly, including by divers, because there is a risk of severe underscouring.

On the east side of the sites deep erosion pits have become visible. These pits pose a threat to the wreck sites and their protection. Small irregularities or damage detected occasionally in the protective layers may in the long run cause extreme erosion pits and must therefore be repaired at an early stage.
Although the *in situ* method tested seems to be effective, it remains unclear how long it will continue to have a positive effect on the site and how intensive maintenance of each individual site will be. Since 2003, attempts have been made to set up a regular monitoring programme, including diving inspections. Due to budgetary constraints and different sets of priorities, however, we were only able to continue multibeam echo sounder recording over the full period thanks to project funding.[29] It was not possible to set up a full diving programme to support the monitoring by multibeam. The series of multibeam data has proved extremely valuable in creating an overview of the site, the area and the potential threats. However, these have to be followed up with diving inspections. Using the data collected and the exact positions, divers could effectively repair the protection and identify the cause of the irregularities at the sites detected with the multibeam.
The multibeam echo sounder cannot look into the seabed. This is not a problem, however, when monitoring erosion-sedimentation and the physical protection of wreck sites.

Over the coming years, RWS and the Dutch Cultural Heritage Agency will continue to monitor the sites at Burgzand and other sites elsewhere in the Netherlands. These two government agencies are together responsible for most of the archaeological heritage sites underwater. An agreement between them has guaranteed their continued collaboration in the future.[30] The MACHU GIS can be used as a platform for the exchange of multibeam data recorded by RWS and other parties, often for other purposes. These data can then be used by archaeologists for desk-based monitoring of underwater archaeological sites. Tests using the Research layer of the MACHU GIS as a platform for multibeam data exchange have been conducted as part of the project. These tests were successful, but need to be repeated with a larger number of images.[31]

NOTES

[1] Considering in situ preservation is stipulated as the first option in the Treaty of Valletta 1992 (the European Convention on the Protection of the Archaeological Heritage) and in the UNESCO Convention on the Protection of the Underwater Cultural Heritage 2001.

[2] Some experience of monitoring has been gained in European collaborations, including the Culture 2000 MoSS project (www.mossproject.com) and Bacpoles (www.bacpoles.nl) under the EU's 5th Framework Programme.

[3] The highest resolution in the Burgzand research was 10 x 10 cm.

[4] A side-scan sonar also detects obstacles on the seabed using sound frequencies. However, this system sends out the sound waves at an angle and, instead of measuring depths, creates an image of hard reflections, soft reflections and shadows.

[5] See also the final report of the Rasse project (Bates et al. 2007) and the article by Mayer et al. (no date) for their conclusions on the use of multibeam for underwater cultural heritage management.

[6] The site was wrongly registered in Archis. Its position was corrected after the multibeam recording of the site in 2008 (Konsberg EM 3002D).

[7] See Dix et al. (2009), this volume.

[8] See Manders et al. (2009) this volume.

[9] The use of multibeam as a basis for making site plans is becoming standard practice. In the Netherlands, multibeam formed the basis of the archaeological recordings at the first excavation underwater executed by a private archaeological company in 2006: the excavation of the ship 'De Jonge Jacob' (1858). See Waldus (in prep.)

[10] In Belgium the Flanders Marine Institute (VLIZ), coordinator of scientific research in the North Sea, and Flemish Hydrography, serve as centres of expertise for this kind of work. See also Demerre (2009).

[1v] When multibeam is used for the monitoring of shipping lanes, the main focus is to detect any obstacles, like protruding shipwrecks or shallow seabed, that might endanger the ships passing through. The maps produced of these usually quite large areas are of a lower resolution than is needed for archaeological assessment or monitoring.

[12] Or at least part of the monitoring. The use of multibeam echo sounders in underwater cultural heritage management was also promoted in the IMAGO project (innovative measuring of sunken objects). See IMAGO (2002)

[13] It is therefore important to focus on ways of making these multibeam recordings – and data obtained by other geophysical methods – available to the archaeological community. MACHU also focused on this issue. See Dijkman & Hootsen (2009), this volume.

[14] Talbot (2005).

[15] RWS has responsibility for waterways in the Netherlands, while the Dutch Cultural Heritage Agency is responsible for managing the cultural heritage (including the cultural heritage underwater).

[16] See also Van den Brenk (2003).

[17] The Texel Roads was the place where, in the 16th to 19th centuries, ships were anchored waiting for the right wind to enable them to set sail or for their cargo to be loaded or unloaded (mainly for the Amsterdam market).

[18] Besides these four wrecks, other wrecks in the Burgzand area include BZN 2, 4 and 9 which have been completely or partly (BZN 9) covered with polypropylene nets. BZN 12, 13, 14, 15 and 16 are not physically protected, like BZN 11. Vos (2006).

[19] Oost (1995), Vos (2003)

[20] The images from the multibeam data were analysed using MACHU GIS.

[21] Strong sedimentation over at least 40 metres and slight sedimentation another 20 metres further east.

[22] See www.mossproject.eu and Van den Brenk (2003).

[23] This has been calculated from the sedimentation-erosion difference maps produced for this purpose. The calculations were performed using a 1 by 1 metre grid.

[24] 7958 m^3 of sand was lost in an area of approximately 25000 m^3. The standard deviation average difference (95%) in that year was as much as 51 cm. This means that, for the purposes of calculation, the 5 % highest and lowest values were disregarded.

[25] The RCE will execute the next monitoring dive at the site in late September, early October 2009.

[26] Approximately 30 metres to the East some other parts of the wreck were located and investigated during the evaluation of the wreck. These parts have not been taken into account here.

[27] The standard deviation average difference (95%) was in fact 67 cm.

[28] Standard deviation average difference (95%).

[29] The multibeam recording was funded by RWS and the European MoSS (www.mossproject.com) and MACHU (www.machuproject.eu) projects.

[30] Agreement between RWS and RACM (now the RCE) signed on 7 November 2007. See for more information: http://eb.sdu.nl/sduwebdata/op/SC86082.pdf

[31] It has been decided to show only the images (Tiffs) produced with the multibeam data and not the data itself. This is to prevent the system from overloading. The real data can be acquired through the metadata shown.

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TINE MISSIAEN RCMG UGENT

An interesting tool for better management of valuable areas of underwater cultural heritage

Seismic imaging in marine archaeological site investigations

Over the last few decades, marine acoustic techniques have become a successful tool for the visualization and monitoring of the *in situ* heritage underwater. The most commonly applied techniques involve using side-scan sonar and multibeam systems to identify archaeological artefacts lying on the seabed. However, the main disadvantage of these techniques is that they cannot penetrate the subsurface. Given its penetration capacity, the marine seismic method allows us to detect and image submerged archaeological objects. Steady development towards very high and ultra-high resolutions has made the seismic technique a major asset in site-specific archaeological research.

One of the major applications concerns the study of buried wooden shipwrecks. Since the late 1980s there has been a sharp increase in research on archaeological shipwrecks using marine seismic techniques. In Belgium, however, little attention has been paid to the potential of seismic techniques for marine archaeological studies. Thus far, the bulk of archaeological research on the Belgian Continental Shelf (BCS) has been focused on exposed shipwrecks.[1]

In recent years, the Renard Centre of Marine Geology (RCMG, Ghent University) has been involved in seismic studies of marine archaeological sites.[2] The VIOE therefore contacted the Centre for a further testing of the potential of these techniques as an instrument for monitoring wreck sites *in situ*. Two sites were selected within the MACHU test areas:

1. An exposed 18th-century shipwreck on the Buiten Ratel sandbank; and

2. The buried 18th-century wreck site of the VOC vessel 't Vliegent Hart, in the Vlakte van de Raan area. Interpretation and data processing of the latter site are still in progress.

MARINE SEISMIC IMA GING

In marine seismic imaging, an acoustic source and receivers are towed behind a ship. The source emits an acoustic pulse that travels through the water and is reflected from the seabed and subsequent layers of the subsoil. The reflected signals are recorded, and as the ship constantly moves, this results in a vertical cross-section through the seabed. So-called reflectors on the seismic image mark the boundary between two distinct subsurface layers.

In order to image the shallow subsurface in the greatest possible detail (and to allow the detection of small buried objects) a high vertical resolution is needed. This implies the use of high-frequency acoustic sources, such as the parametric echosounder. The latter emits two sound signals with different frequencies (100 kHz and 8-12 kHz). While the high-frequency signal allows a very detailed image of the seafloor, the low-frequency signal gives a detailed image of the underlying structure (decimetre resolution). The fast pulse rate also results in a high lateral coverage.

The ability to image buried wooden objects, such as wooden shipwrecks, depends on the type of wood, the level of decay, and the density of the surrounding sediment. On the whole, oak and pine artefacts are acoustically detectable in a wide range of marine sediments, with sandy sediments generally giving a better contrast than sand-silt-clay mixtures.[3] The wavelength of the seismic signal should not be much greater than the size of the wooden boards. In our case, working with acoustic signal frequencies well over 3 kHz, this should not be a problem. The sediments surrounding a shipwreck are also often marked by scour features, often much larger than the wreck itself. In time these scour features may become filled in and buried.

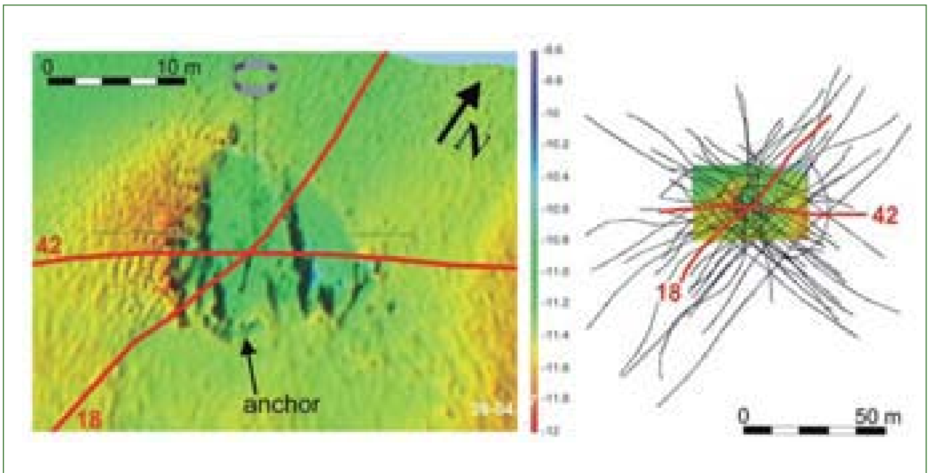

FIGURE 1 Left: Multibeam image taken in 2007 over the wreck site on the Buiten Ratel sandbank © MDK - Coastal Department - Flemish Hydrography The two large wreck pieces can be clearly observed. The red lines mark the location of the seismic profiles shown in figures 2 and 3. Right: Entire seismic network recorded at the same wreck site, plotted against a multibeam background. © RCMG

SEISMIC IMAGING OF AN EXPOSED SHIPWRECK B114/230A, BUITEN RATEL WRECK

(BUITEN RATEL TEST AREA)

In October 2007 a seismic survey was carried out over the Buiten Ratel shipwreck. A few months earlier the wreck had been surveyed using multibeam by the Flemish Hydrography. The image shows that the wreck has broken into two pieces and a partly exposed anchor is clearly visible (figure 1-left). During the seismic survey a parametric echosounder source was used. This was attached to a long iron pole at the side of the ship and a motion sensor was used to filter out the wave action. Positioning was done using a DGPS antenna (of 1 m accuracy).

In total 44 short profiles were recorded, crossing the wreck at different angles (*figure 1-*

right). Due to strong tidal currents it was not always possible to sail in a straight line.

Figures 2 and 3 each show two examples of seismic profiles (top=10 kHz, middle=100 kHz, bottom= interpreted line drawing). In general the wreck is observed more sharply on the high-frequency data. The low-frequency data have deeper penetration and allow identification of buried objects. The wreck outline (bright red or yellow reflectors) and the sediment cover that spreads over the wreck surface (blue or blue-green reflectors) can clearly be distinguished in the seismic images. The thickness of the sediment cover ranges from a few centimetres to 50 cm or more. The low amplitudes of the sediment cover, compared with the high-amplitude seafloor reflection, suggest the presence of relatively soft cover sediments (e.g. increased silt and/or mud content), in contrast with the surrounding sandy seafloor.

Although the different wreck parts stand out sharply on many profiles *(e.g. figure 3)*, the distinction is a lot less clear when it comes to the sediment cover. The wreck contours are sometimes distorted *(figure 2)*, most probably due to side reflections caused by curved or protruding wreck parts. Local sedimentation has often silted up the gap between the wreck parts. The height of the wreck above the seabed is less than 1 m. The depth below the seabed remains unknown because the acoustic signals cannot penetrate through the wreck. Only a few small buried objects were observed near or under the wreck (figure 2). But this may present a distorted view of the actual situation – the likelihood of identifying such objects is relatively small, given the large profile spacing.

SEISMIC IMAGING OF WRECK SITE B129/306B, 'T VLIEGENT HART

(VLAKTE VAN DE RAAN TEST AREA)

The 18th century VOC (Dutch East India Company) merchant ship 't Vliegent Hart was wrecked near the Vlakte van de Raan in 1735 shortly after leaving Zeeland for Batavia

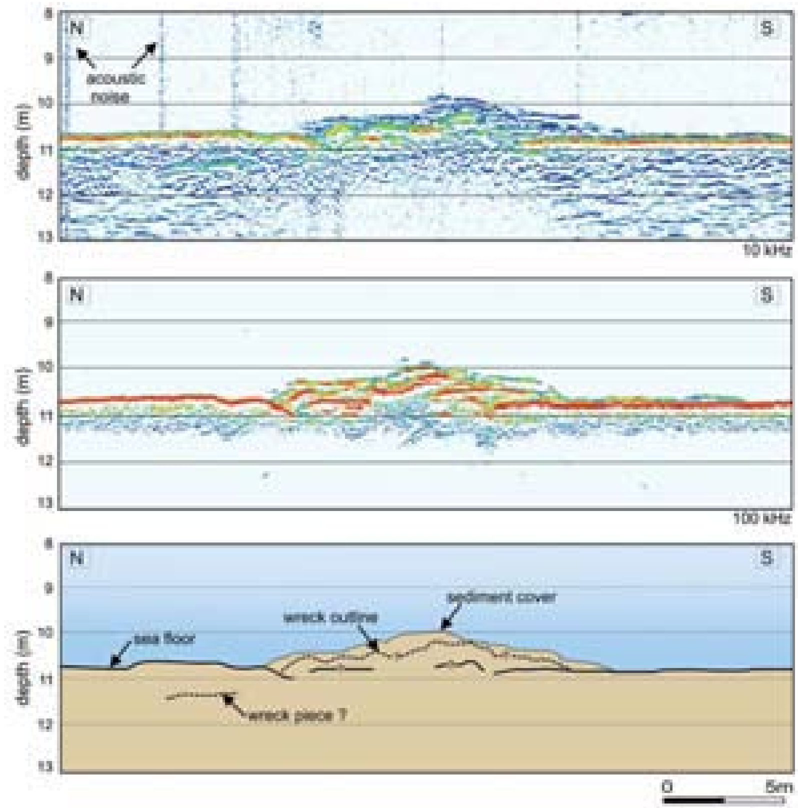

FIGURE 2 Seismic profile 18 over the Buiten Ratel wreck site (for location see figure 1). Top: 100 kHz image. Middle: 10 kHz image. Bottom: Interpreted line-drawing (Depth below the water surface in meters). The different wreck parts do not stand out clearly. Probably this is due to the fact that the profile only crosses over the edge of the northern wreck part. A buried object can be observed, most likely a small detached wreck piece. The thin blue lines on the high-frequency image are probably due to acoustic noise related to the equipment. © RCMG

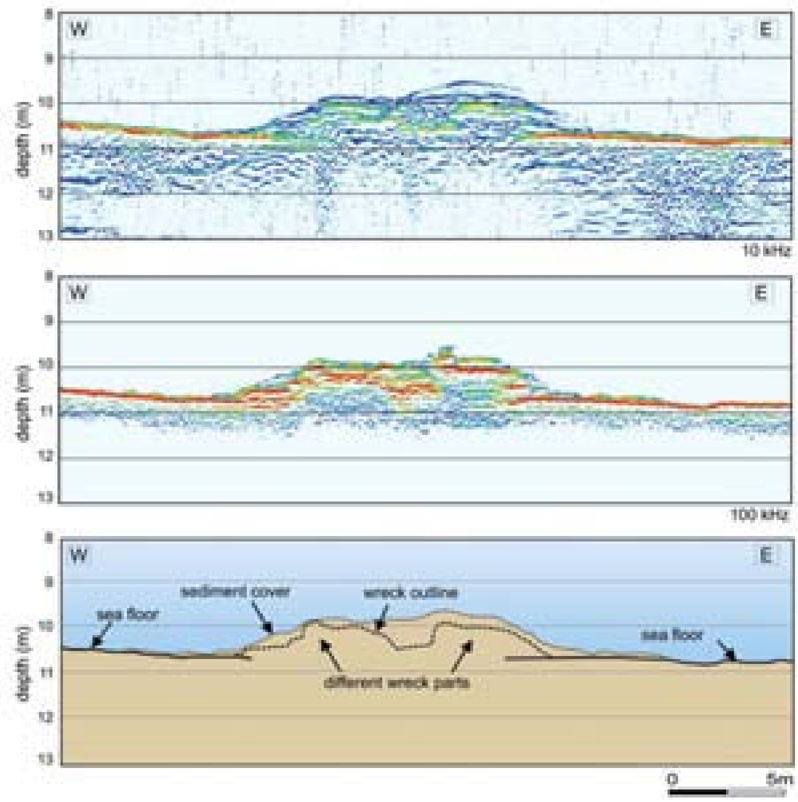

FIGURE 3 Seismic profile 42 over the Buiten Ratel wreck site (for location see figure 1). Top: 100 kHz image. Middle: 10 kHz image. Bottom: Interpreted line drawing (depth below the water surface in metres). The wreck is covered by a thin layer of sediments, no more than a few dm thick. The different wreck parts can be clearly distinguished. The thin blue lines on the high-frequency image are probably caused by acoustic noise related to the equipment. © RCMG

(Indonesia).[4] Several salvage attempts were made in the 18th century, but gradually the wreck was forgotten. In 1961 the wreck was rediscovered, and since 1979 it has been dived on and excavation works were carried out until 2000.[5] Since then the wreck site has been unofficially 'visited' by 'wreck hunters'.

A first attempt was made early in 2009 to visualise the current state of the wreck site. Side scan sonar images produced by RCMG (Ghent University, see also page 56) allowed the visible parts of the wreck site to be located more precisely. In addition, Flemish Hydrography produced 2D and 3D multibeam images of the site. Both (side-scan and multibeam) showed only small fragments visible above the seabed. The majority of the wreck is completely buried.

In May 2009 a seismic survey was carried out by RCMG over the wreck site with the aim of acquiring more information on the buried remains of the wreck and its current condition. A parametric echosounder source was used for the survey (see also previous section). Positioning was done using DGPS (1 m accuracy). In total, 78 short profiles were recorded, crossing the wreck at different angles. Wind, waves and strong tidal currents made it difficult to sail in straight lines.

An initial rough analysis of the seismic data was performed. The data agree well with the side-scan sonar and multibeam images. The exposed wreck parts – wooden beams, possibly also cannons – were clearly visible on the seismic data (even if the objects were a few metres away from the profile), mostly in the form of large hyperbolic diffractions *(see figures 4 and 5)*. The sediment layer that largely covers the wreck seems to be very thin, at places only a few centimetres. As in the Buiten Ratel study, here too the depth of the bottom of the wreck remains unknown. Hull fragments were identified down to a depth of 2 m below the seabed *(see figure 4 bottom)*, but the wreck is likely to extend much deeper. The seismic data also agree well with the information obtained from the excavations. The extent of the wreck confirms the drawings that were made in the late 1990s *(figures 4 and 5 top right)*. Towards the west of the wreck a large, shallow depression seems to be filled with recent sediments (alternating thin silty and sandy layers?). The bottom of this depression might be the original seabed at the time of wreckage. Inside the wreck itself a number of very strong reflectors can be observed, especially on the port side *(see figure 4)*. These may well correspond to the different brick layers that were found inside the hull. The seismic data also reveal a few strong, very shallow reflectors east of the wreck. The excavations suggest that this area is characterised by a few thin, highly compact organic and sandy layers. However, some relation to wreck debris cannot be excluded.

SUMMARY AND CONCLUSIONS

Marine seismic techniques provide a fast and efficient tool for archaeological studies. This has been illustrated again by two case studies within the Belgian MACHU test areas on the wooden wreck remains of two 18th century vessels, both exposed and buried. The results demonstrate that a careful survey design is essential, combining high spatial survey accuracy with dense line spacing adapted to the site. The latter is especially important in the case of buried objects.

To provide better results and to allow more precise interpretation, additional investigations are needed at these sites and existing archaeological and historical data should be gathered and studied in more detail. The use of complementary methods, such as coring and other geophysical measurements (e.g. electric or electromagnetic methods) could also provide more information. The big challenge in the future also lies in the detection of objects whose existence is not suspected beforehand. This opens up new prospects for

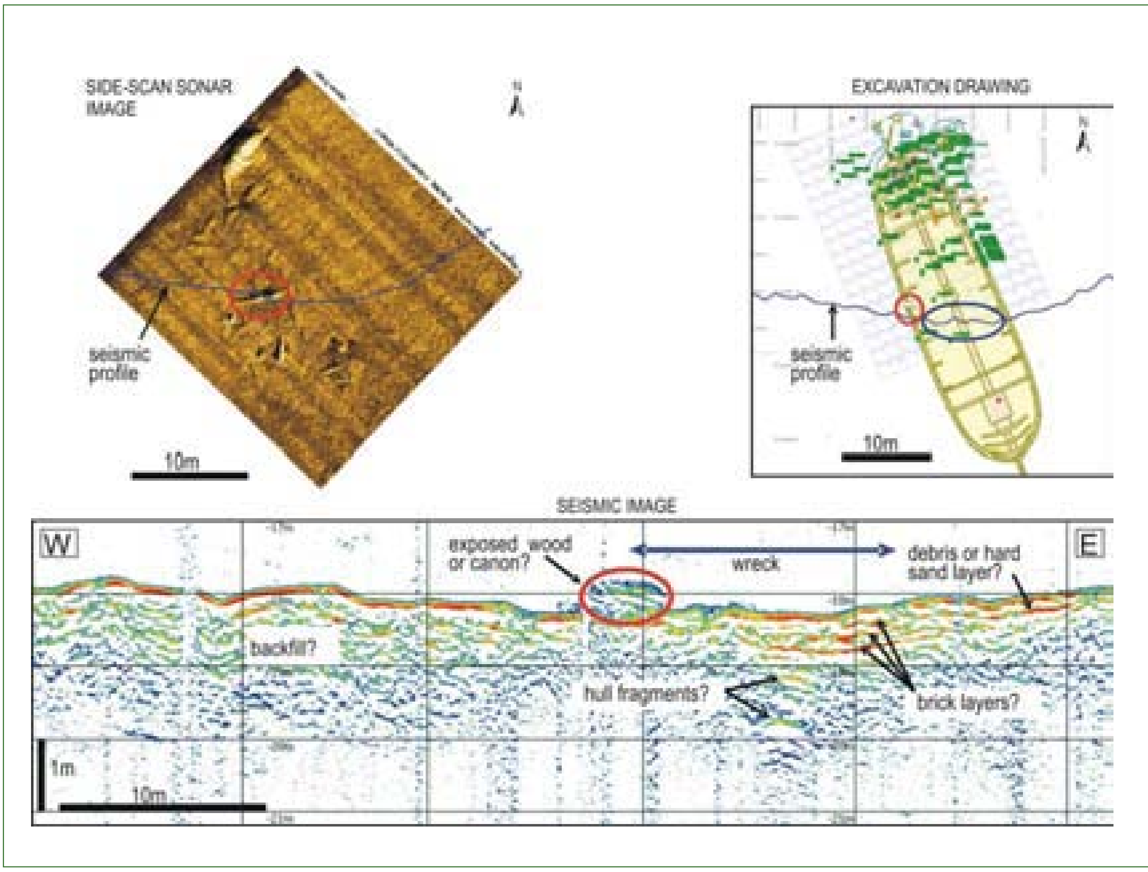

FIGURE 4
Seismic profile 30 over 't Vliegent Hart wreck site.
Top left: side-scan sonar image © RCMG.
Top right: excavation drawing © 3H Consultancy Ltd.
Bottom: 10 kHz seismic image (depth below the water surface in metres). The exposed beam (cannon?) is clearly visible. Strong reflectors inside the wreck are possibly due to bricks. Deeper reflectors (hull?) have also been observed. Recent backfill sediments can be seen to the west. The shallow reflectors to the east may be due to compact sand layers or wreck debris. © RCMG

the use of geophysical techniques in marine archaeological site surveys.

NOTES

[1] So far 278 wreck sites have been localised in the BCS. Some wreck sites in the Buiten Ratel sandbank area and Vlakte van de Raan area were studied in more detail (Demerre & Pieters 2008:15-17, Demerre & Zeebroek 2009:8-11, Pieters et al. n.d., Pieters et al. 2008, Zeebroek et al. 2006, Zeebroek et al. n.d. & Zeebroek et al. 2009: 77-78.)

[2] Missiaen 2008 & Missiaen n.d..

[3] Arnott et al. 2005.

[4] Van der Horst 1991.

[5] Van der Horst 1991, Hildred 2001, Pieters et al. 2008 & the 'Zeeuws Maritiem MuZeeum Vlissingen' archives.

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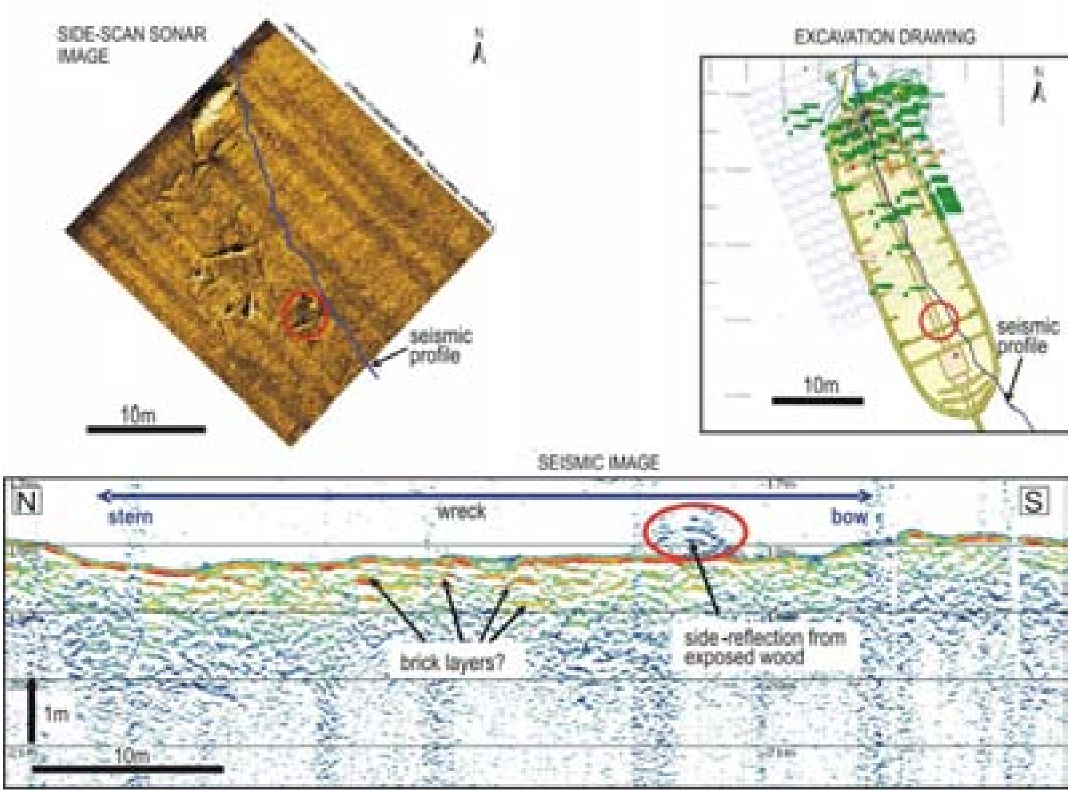

FIGURE 5
Seismic profile 24 over 't Vliegent Hart wreck site.
Top left: side-scan sonar image
© RCMG.
Top right: excavation drawing.
© 3H Consultancy Ltd.
Bottom: 10 kHz seismic image.
Depth below the water surface in metres.
The side-reflections from an exposed wreck part (beam?) a few metres from the profile are clearly visible. The reflectors inside the wreck are possibly due to bricks.
© RCMG

Chirp and Sonar

Another piece of geophysical research conducted on the Burgzand was a try-out using seismic chirp sub-bottom profilers in combination with side-scan sonar. The primary reason for this research was to investigate the use of these techniques in monitoring, and especially to see whether these systems could detect disturbances in sedimentation processes on the seabed due to the Burgzand sites. The second reason was to map the thickness of the sand layers that have settled on the physically protected wreck sites.

The work was performed by Deltares of the Netherlands using a CM2 system from C-MAX, with a frequency of 325 kHz, a resolution of 0.1 m and a search path of 100 m. The sub-bottom profiler used was an SB-0512i system from Edgetech. This seismic chirp system can easily distinguish different sediment layers and other distortions within the first 15 metres of the seabed. Different frequencies can be used in the Wadden Sea, between 0.5 and 7.2 kHz. A measurement was taken every 0.75 m.[1] The side-scan and seismic chirp data were processed using Petrel (3D modelling software) to visualise the results in 3D.

Unfortunately, due to the presence of sport divers, it proved impossible to investigate the whole area. Only a few measurements were taken at the BZN 3 and BZN 10 wrecks.

The following conclusions can be drawn from the data collected:

- The BZN 3 site is clearly visible on the side scan as well as in the chirp data. The chirp profile shows us a sedimentation layer of approximately 0.5 m on top of the wreck mound. This means that the protection measures put in place in 2003, with polypropylene nets on top of the old protective layer of sandbags, has managed to hold another half a metre of sand. On the flanks of the mound, as much as 1.5 m of sediment has been caught with this new protection system. This is the area where no sandbags had previously been deposited (in 1988).
- The chirp data from the BZN 10 sites show relatively sharp flanks with low reflections in places. Does this mean that there is less sediment under the polypropylene nets? In other words, are there areas where the protective nets are more or less hanging loose? Or is there only minor sedimentation on these flanks? These questions can only be answered by divers. Measurements with the sub-bottom profiler show a sediment layer at least a metre thick on top of the wreck.

It is difficult to base conclusions on only these two profiles, but it seems that seismic chirp data can also help us to monitor physically protected wreck sites. The data allow us to monitor the amount of sediment caught in the polypropylene nets. More research is needed over the coming years, combining information from the multibeam monitoring with that from the sub-bottom profilers, and with control observations by divers.

NOTE

[1] Two measurements per second at a sailing speed of 3 knots (1.5 m/s).

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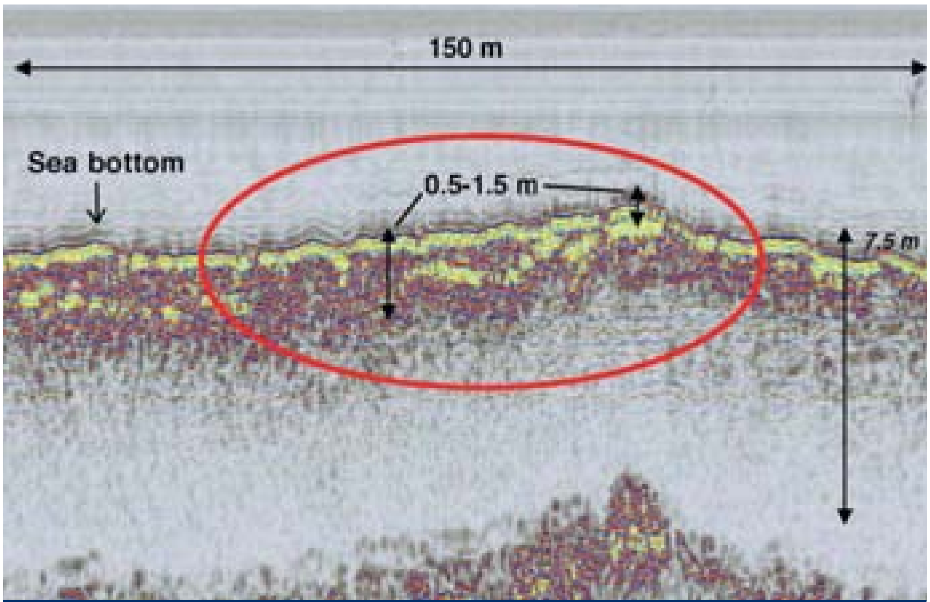


FIGURE 1 Sub bottom chirp profile from the BZN 3 wreck. Picture: Deltares

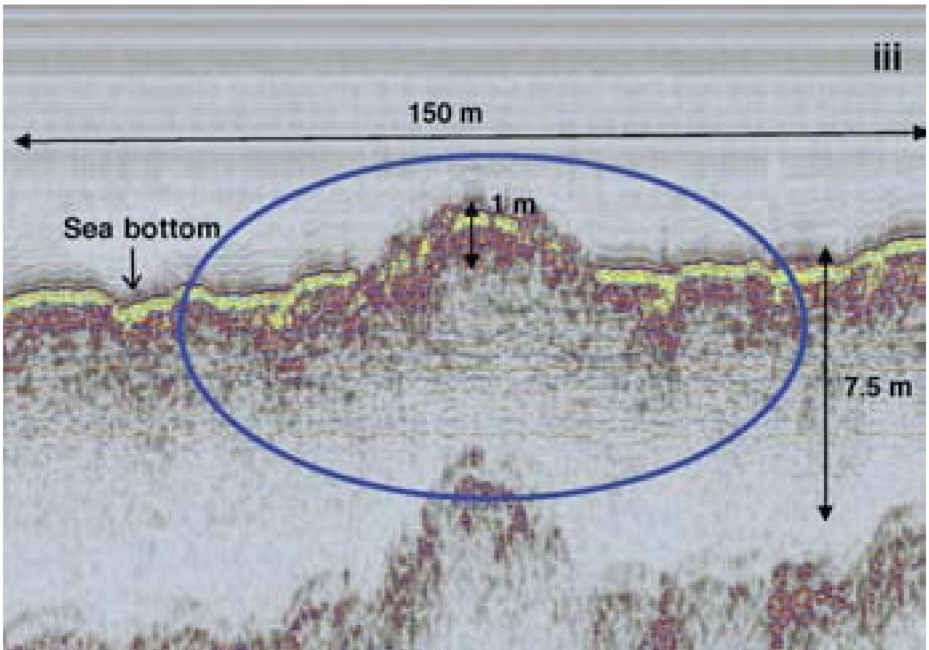


FIGURE 2 Sub bottom chirp profile from the BZN 10 wreck. Picture: Deltares

OVERVIEW

Wave climate in the Gulf of Gdańsk

Management of the underwater cultural heritage located on and in the seabed is very much dependent on wave fields. Puck Bay, in the western part of the Gulf of Gdańsk, where the test site for the MACHU project in Poland is located, has a very specific wave climate. In this paper an overview of the wave climate will be given based on in situ measurements and data derived from numerical modelling. In addition, a monitoring programme for a specified location will be proposed.
Puck Bay is uniquely located, since it is protected from the open Baltic by the Hel Peninsula. This protection undoubtedly has an impact on the improved wave conditions inside the bay compared with those of the open sea. However, the protection is incomplete, and waves from the open sea also reach the sheltered basin.

Information requirements for modern coastal management require statistical characterisation of the prevailing environmental conditions. The impact of a storm on the heritage site will be primarily related to the combined influence of surges, sea surface waves and currents. There is therefore a need for long-term statistical information on meteorological and sea state parameters. A high-resolution homogeneous dataset was generated in the framework of the EU's HIPOCAS research project (see Guedes Soares et al. 2002). A number of statistics essential to almost all marine activities have been obtained from this dataset.
Wave forecasts by meteorological offices usually consist of sea state parameters like significant wave height and mean wave direction. To forecast the corresponding information for the occurrence of extreme individual waves is a difficult task. Some progress in this field has been achieved through analysis of datasets of reliable measurements. Such a set of time series of free-surface elevation measurements, obtained by Directional Waverider buoy, is available at the Institute of HydroEngineering of the Polish Academy of Sciences in Gdansk (IBW-PAN). The database can provide some useful information on extreme waves and wave events in Puck Bay. Extraordinarily large water waves with heights more than double the significant wave height were selected. The results were used to indicate periods and areas where extreme waves occur more frequently.

MODELLING WAVES IN THE BALTIC SEA

The waves that occur at the heritage area itself depend on what is happening throughout the Baltic. Therefore, the first step in obtaining information essential to the design and exploitation of such an area is to model waves throughout the basin.
The phenomenon of sea waves is a difficult process to describe. Non-stationary and non-homogeneous wind fields over the sea generate waves that vary both spatially and temporally. The waves that are generated are modified by the shape of the basin, by the bottom topography and type in the shallow water, and by sea currents.
The wave model should incorporate all the physical processes that impact the development, distribution and dissipation of waves. In order to model waves, it is key to describe wind fields, which are the input data. Simultaneously, well-documented, wide-ranging wave measurements are essential for the verification of the model.

DESCRIPTION OF THE BALTIC WAVE MODEL

The Institute of Hydroengineering of the Polish Academy of Sciences (IBW PAN) uses the WAM4 spectral wave model to model and forecast waves in the Baltic Sea. This model is widely used throughout the world. A description of it can be found in Marine Engineering and Geotechnics.
The WAM4 wave model is based on the energy balance equation. The statistical properties of a free surface are characterised with the aid of wave spectra. The equations describe wave propagation in an environment that is non-homogeneous in terms of sea currents and bottom topography. They take into consideration the following physical processes that impact on waves:

- energy flow from wind to waves;
- dissipation due to whitecapping;
- nonlinear energy transfer between component waves.

CALCULATION GRID

The modelled area included the entire Baltic Sea and the Danish Straits. The calculation grid in the spatial domain is rectangular in sperical, rotated coordinates. The grid was

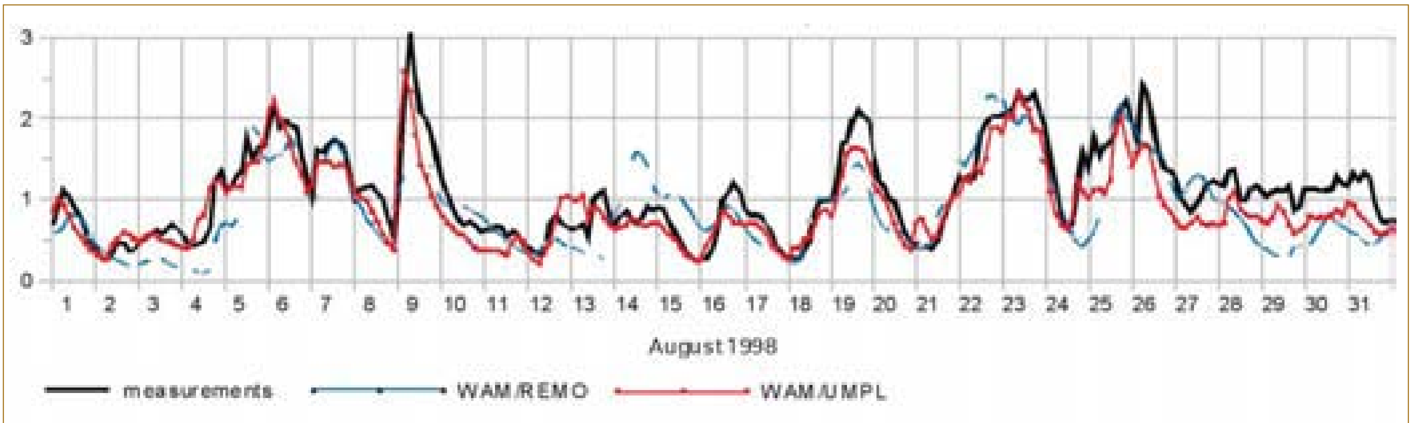


FIGURE 1 Significant wave height in August 1998. Comparison of the results of measurements taken with a Directional Waverider buoy and WAM4 model data driven by winds from the REMO and UMPL models.

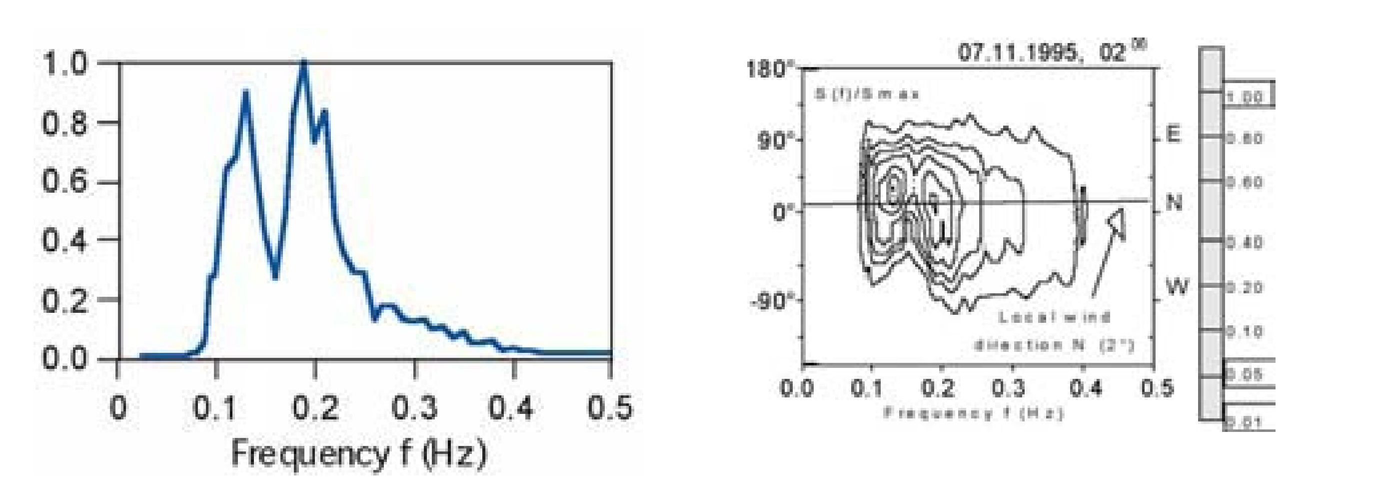


FIGURE 2 Dimensionless wave frequency spectrum (left) and directional wave distribution (right) measured on 07.11.1995 at 2.06 pm. The water depth at the measurement points was 15 m, and the significant wave height was Hs = 2 m.

rotated in such a way that the equator of the rotated configuration was located in the centre of the modelled area.

The grid size depends on the size of the basin studied and the scale of the meteorological and oceanographic processes being predicted. It is usually a compromise between the accuracy requirements of the results, the available computer power, and calculation time. Thus, different spatial grids of varied resolution are applied depending on the purposes of modelling:

1. 9' × 9' (about 16 km)
2. 5' × 5' (about 9 km)
3. 1.8' x 1.8' (about 3 km)

The spectral grid consists of 25 frequencies ranging from 0.05054 Hz to 0.497855 Hz, which corresponds to wave periods from 2 s to 19.8 s and 24 directions at an angular resolution of 15°.

INPUT DATA FOR THE WAVE MODEL: WIND FIELDS AND BALTIC ICE COVERAGE

The input data for wave models are wind fields. Thus, wave modelling is fully related to wind modelling and the quality of the results obtained depends largely on the quality of the generated wind fields.

UMPL, a mesoscale atmospheric model, has been in operation at the Interdisciplinary Centre for Mathematical and Computational Modelling (ICM) since 1998. In operating mode, this model produces 48-hour forecasts of winds over the Baltic Sea on a spatial grid with about 16 km steps. These wind forecasts are used to forecast waves on a daily basis (http://new.meteo.pl) and wind analyses are used to model waves in different historical scenarios.

Two centres in the United States – the National Center for Environmental Prediction (NCEP) and the National Center for Atmospheric Research (NCAR) – collaborated on a database that contains records of the global reanalysis of atmospheric fields over a period of 51 years (1948-1998). The NCEP database provided the input data used in the REMO regional, which allowed wind fields over the Baltic to be obtained at a resolution of 50 km and one-hour time steps. These fields were used to reconstruct waves in the Baltic during the period 1958-2001.

Ice coverage has an important impact on Baltic waves. Sea ice coverage limits the wave generation area, which in turn influences waves even in areas distant from the ice pack. Information on Baltic ice coverage was therefore also incorporated into the model.

VERIFICATION OF MODEL RESULTS

Since even the best model does not fully reflect reality, it is very important to evaluate modelling results prior to their analysis or their use in creating designs *(see figure 1)*.

Wave measurements in the southern Baltic were introduced only recently and are conducted on a fairly irregular basis. The IBW PAN has taken measurements with a Directional Waverider buoy in several areas of the southern Baltic Sea including the Bay of Pomerania and Puck Bay and in the open sea near the IBW PAN Coastal Research Station at Lubiatowo. The measurement series were taken over periods lasting from several months to several years.

RESULTS OF WAVE MODELLING

The results of calculations from the wave model produce a frequency-directional wave spectrum on calculation grid points. This allows a number of wave parameters to be calculated, including:

- significant wave height, H_s
- mean wave direction, $_m$
- mean wave period, T_{02}
- wave component period in spectrum peak, T_p
- swell height, H_{swell}
- mean swell direction, Θ_m^{swell}
- mean wind wave direction

WAVES IN PUCK BAY

As mentioned in the introduction, Puck Bay in the western part of the Gulf of Gdańsk is uniquely located since it is protected from the open Baltic by the Hel Peninsula. This protection undoubtedly has an impact on the improved wave conditions inside the bay compared with those of the open sea. However, the protection is incomplete, and waves from the open sea also reach the sheltered basin. The best way of learning about waves is to conduct in situ measurements. Unfortunately, the waves of Puck Bay have not been measured systematically. The only wave measurements available were taken by IBW-PAN using Waverider buoys. The measurements were taken over a period of just a few months at two measuring sites.

Wave modelling allows the entire basin. The WAM4 model was applied to model the waves in Puck Bay.

WAVE MEASUREMENTS: WAVE SPECTRA IN PUCK BAY

The results of the spectral analyses of waves in Puck Bay show their complex character. The wave spectrum generated by northwesterly winds has two peaks. *Figure 2* presents the two-peak wave spectrum measured using Waverider buoys outside Port Północny. The high-frequency peak in the spectrum contains wave components generated by prevailing winds from Puck Bay. The wave period at the peak is about 5 s. Waves generated in the open Baltic are responsible for the low-frequency peak, which has a period of about 8 s. Thus, the waves in the vicinity of the heritage site are wind waves generated with both small wind fetch in Puck Bay and significant fetch from over the Baltic.

WAVE MODELLING: WAVES GENERATED BY STATIONARY WINDS

Puck Bay is partially sheltered by from open Baltic waves by the Hel Peninsula. Numerical calculations were made with the aim of verifying how the waves generated in the open Baltic reach the protected area beyond the peninsula. The WAM4 wave model was used for modelling.

Figure 3 presents the results of the numerical calculations. In the first experiment, the waves were generated as a result of the action of a homogeneous and stationary wind field that blew at a speed of 20 m/s from a northerly direction for 24 hours over the Baltic Sea and Puck Bay. In the second experiment, the same wind blew over the Baltic Sea, but it was calm over Puck Bay.

The spatial distribution of significant wave height shows to what extent open sea waves reach the vicinity of the Tri-Cities.

WAVES DURING THE EXTREME STORM ON 23-24 NOVEMBER 2004

A heavy storm occurred on 23-24 November 2004. The wind blew from the north with gusts of 25 m/s in Kołobrzeg, 30 m/s in Ustka, and 31 m/s in Gdańsk. The storm caused significant damage, including to the pier in Sopot. The results of modelling indicate that the significant wave height near Sopot pier during the storm reached 2.3 m (*figure 4*). Simple estimations suggest that an individual wave with a height of about 4.6 m might have occurred.

The spatial distributions of significant wave height and the mean wave period in Puck Bay during the greatest storm power are presented in *Figure 5*.

NOTE

[1] Instytut Budownictwa Wodnego – Polskiej Akademii Nauk (IBW-PAN), Institute of HydroEngineering – Polish Academy of Sciences.

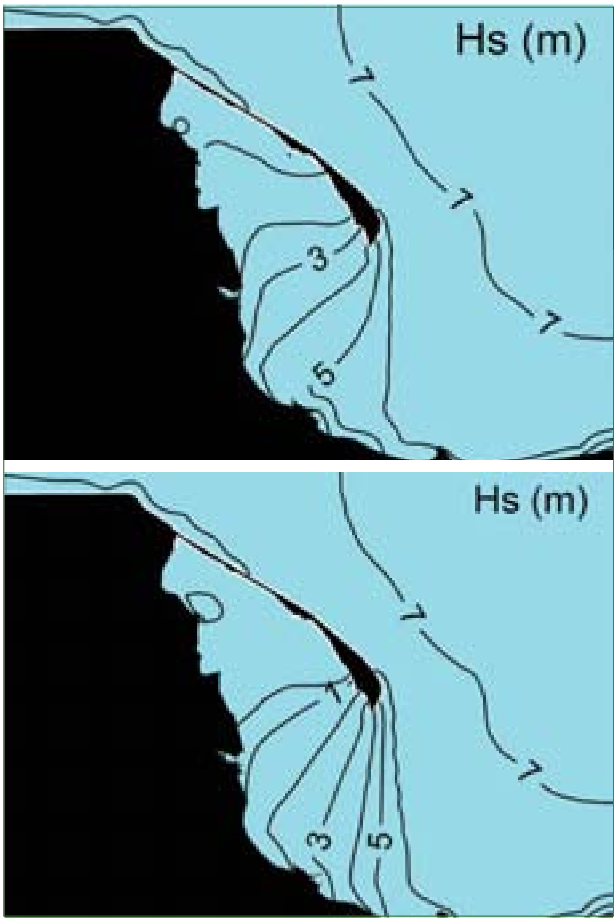


FIGURE 3 Results of numerical experiments: wave fields generated by a homogeneous and stationary wind fields. Spatial distribution of significant wave height Hs (m).

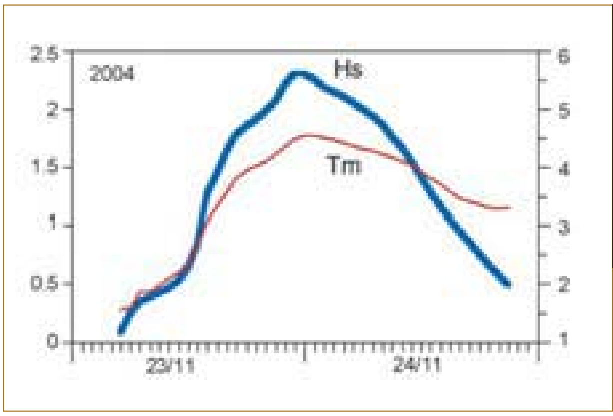


FIGURE 4 Change in significant wave height Hs (m) and mean wave period Tm (s) during a storm near the Test area. The results obtained are from the numerical WAM4 model driven by winds from the UMPL atmospheric model.

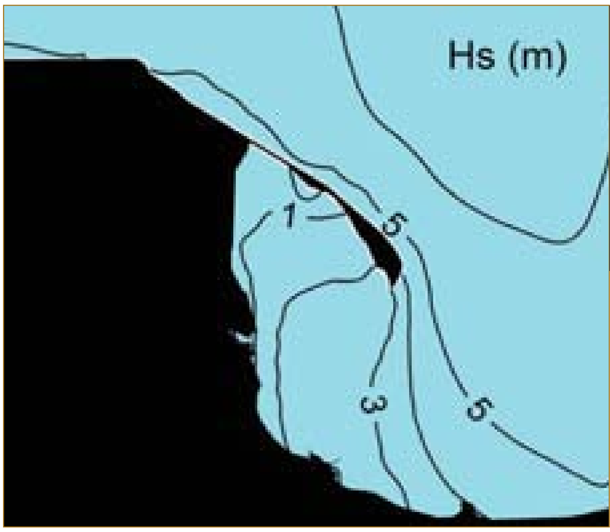


FIGURE 5 Spatial distribution of significant wave height Hs (m) on 24 November 2004 at 00 UTC. The results obtained are from the numerical WAM4 model fed with winds from the UMPL atmospheric model.

DR. MAŁGORZATA ROBAKIEWICZ IBW-PAN[1]

Part II[2]

Hydrodynamics in the Gulf of Gdańsk

The existing knowledge of hydrodynamic conditions in the Gulf of Gdańsk is based on *in situ* observations carried out regularly for over 50 years, plus some ad hoc measurements taken as part of scientific and commercial projects. This article presents new results on the hydrodynamics of the area.

A summary of the measuring techniques used and an historical overview of measurements will be presented below. Results of analyses of salinity, temperature and current variations in time and space will then be presented.

FIELD MEASUREMENTS OF HYDRODYNAMICS IN THE GULF OF GDAŃSK

In situ measurements are the basic source of information on dynamics in the water body analysed. The quantity and quality of the data available often define the limits of our understanding of natural processes there. For a better explanation of the present state of our knowledge it makes sense to take a closer look at measuring techniques and their potential and limitations.

MEASURING METHODS

In situ measurements of hydrodynamic conditions can be performed using a variety of different methods. Taking into account the spatial aspect of planning, we can distinguish:

- the Euler method and
- the Lagrange method.

In the Euler method measurements are recorded in several selected fixed locations. In such cases, the registered information represents changes in a parameter (e.g. in the case of currents, their magnitude and direction) over time, with a frequency dependent on the instrument used.

In the Lagrange method measurements track a floating object. Only currents can be registered using this method.

In terms of the length of measurements, we can distinguish:

- *short-term* registrations (e.g. seconds, minutes);
- *long-term* registrations (e.g. hours, days, months or even years).

We can also distinguish the following methods of measurement:

- *direct* (e.g. water temperature, traditional water level gauges);
- *indirect* (e.g. salinity using conductivity gauges, water level using pressure gauges, satellite images, etc.).

From this general overview of the potential of *in situ* measurements in terms of coverage of the area of interest in space and in time, it is quite clear that to obtain a spatial distribution of any parameter it is necessary to have a number of instruments running simultaneously. In practice it is not possible to cover the Gulf by a set of instruments running in parallel for a certain time (e.g. weeks or months). Satellite images are a good alternative as they deliver a picture of a certain space. However, we have still problems with the interpretation and accuracy of data from such images. Their availability is also limited for technical and meteorological reasons. All this explains why we still encounter problems presenting a well-documented picture of temporal and spatial changes in hydrodynamics in the Gulf of Gdańsk region.

MEASURING TECHNIQUES MAGNITUDE AND DIRECTION OF CURRENTS LAGRANGE METHOD

The first measurements of currents were taken by tracking floating objects. By measuring time between successive locations of the floating object it was possible to estimate water velocity. The floating objects can be used to record the trajectory of average water movement. Usually, the surface layer is observed using this technique. Recently this type of measurement has been modified by using GPS systems to track floating objects. Nowadays the floating objects are designed in such a way that they can deliver parameters of flow at a chosen depth.

The tracing method is quite similar to observation of floating objects. It is possible to trace water movement using a special substance known as a tracer (preferably a substance that is neutral in the natural environment to which it is discharged, e.g. rhodamine). However, to obtain detailed information using this method, special gauges must be used to measure concentrations of the tracer.

MAGNITUDE AND DIRECTION OF CURRENTS EULER METHOD

Currents are generally measured using current meters. A number of technical solutions to measure currents have been applied in recent decades. In the past, rotor-type current meters were often used. Later, electromagnetic current meters started to be produced. At present the most advanced technique uses Acoustic Doppler Current Profilers (ADCP). The advantage of ADCP gauges lies in the fact that they can measure velocity in the whole water column divided into a pre-defined number of layers.

All of the above types of gauges can currently be found in field experiments. All of them can be used to measure currents in a fixed location; most of the instruments can work autonomously for several days, weeks or even months, depending on the available source of energy. In addition, some ADCP-type current meters are also tailed to work in the moving mode, which means we about information about currents in ship tracks. Measurements of this type are fairly difficult to interpret, however, because they cannot be treated as a picture of a specific time.

SALINITY AND TEMPERATURE

In the past salinity was measured using laboratory methods. Nowadays water conductivity is the basic method used to measure salinity. Temperature is also measured using modern techniques involving special transducers. In the past classical (mercury) thermometers were used. Nowadays the most common instrument used to measure salinity and temperature is the CTD (conductivity, temperature, density) gauge. This instrument allows registration of these three parameters simultaneously in a vertical profile. Measurements take as much time as is necessary to lower and/or lift an instrument.

HISTORICAL OVERVIEW OF IN SITU MEASUREMENTS IN THE GULF OF GDAŃSK

In situ measurements of hydrodynamics in the Gulf of Gdańsk started in the earlier part of the 20th century (in the 1920s). The first publi-

cations (e.g. Viweger, 1926; Kijewski 1937, 1938; Borowik 1939), acknowledged by Młodzińska (1974), date from that period.
After the Second World War numerous *in situ* measurements were carried out in the Gulf of Gdańsk. It is very difficult to enumerate all of them, mainly due to a lack of published material. Only some are recalled below to illustrate how changes in knowledge follow changes in measuring techniques.
Młodzińska's investigations (1962) of the chemical composition of Vistula river water were pioneering. Analysis of long-term changes in water salinity at coastal stations started in the 1970s using *in situ* observations (e.g. Młodzińska 1974; Kiermut 1974; Majewski 1979). Those analyses allowed scientists to conclude that conditions at Władysławowo station are similar to those in the open sea, and that Hel and Gdynia stations represent conditions in the Gulf of Gdańsk, while Gdańsk is very much influenced by the Vistula river.
In the 1970s and 1980s the Vistula river outlet to the Gulf of Gdańsk attracted a great deal of interest. Numerous measuring campaigns of varying spatial and temporal scope were carried out during that period (e.g. Tarnowska 1977; Majewski, Bogacka 1983, Bogacka et al. 1983). Field observations allowed the circulation patterns close to the river outlet to be characterised.
Very interesting measurements were taken by Tarnowska in the Vistula river outlet in 1977. Water currents, wave characteristics and sediment transport in the vicinity of the Vistula river bar were measured using direct and indirect methods.In the 1990s *in situ* measurements in the region were performed as part of the RODEX (RODamine EXperiment) experiments carried out by scientific institutions located in the tri-city agglomeration (Gdańsk-Sopot-Gdynia). Three sets of measurements were taken, in 1996, 1997 and 1998. They recorded salinity, temperature and currents at a number of locations over a period of more than two weeks (Bulletin…, 1997, 1999).

WATER TEMPERATURE - CHANGES IN TIME AND SPACE

Water temperature changes seasonally in the Gulf of Gdańsk. However, it is not uniform throughout the whole water body, which has a layered temperature structure. The upper layer reaches the bottom in the shallow parts (i.e. in the coastal zone), while in the deeper parts its boundary is located at a depth of 40-60 metres, sometimes even reaching 70 metres. Between this and the lower layer, which extends to the bottom, is the intermediate layer, characterised by a minimum water temperature. The intermediate layer most commonly appears at a depth of 60-80 metres, but can sometimes reach 90 metres.
In the upper layer changes in water temperature are closely related to seasonal changes in meteorological parameters (e.g. air temperature, solar radiation), and are modified by vertical processes (i.e. convection, mixing due to wind, mixing due to Vistula river inflow). Based on observations carried out at the coastal stations it was found that the largest differences in water temperature in the basin are observed between Hel and Świbno stations. The biggest differences at these stations can be observed in the period April-July. Detailed analyses of *in situ* data for 1980-1984 carried out by the Institute

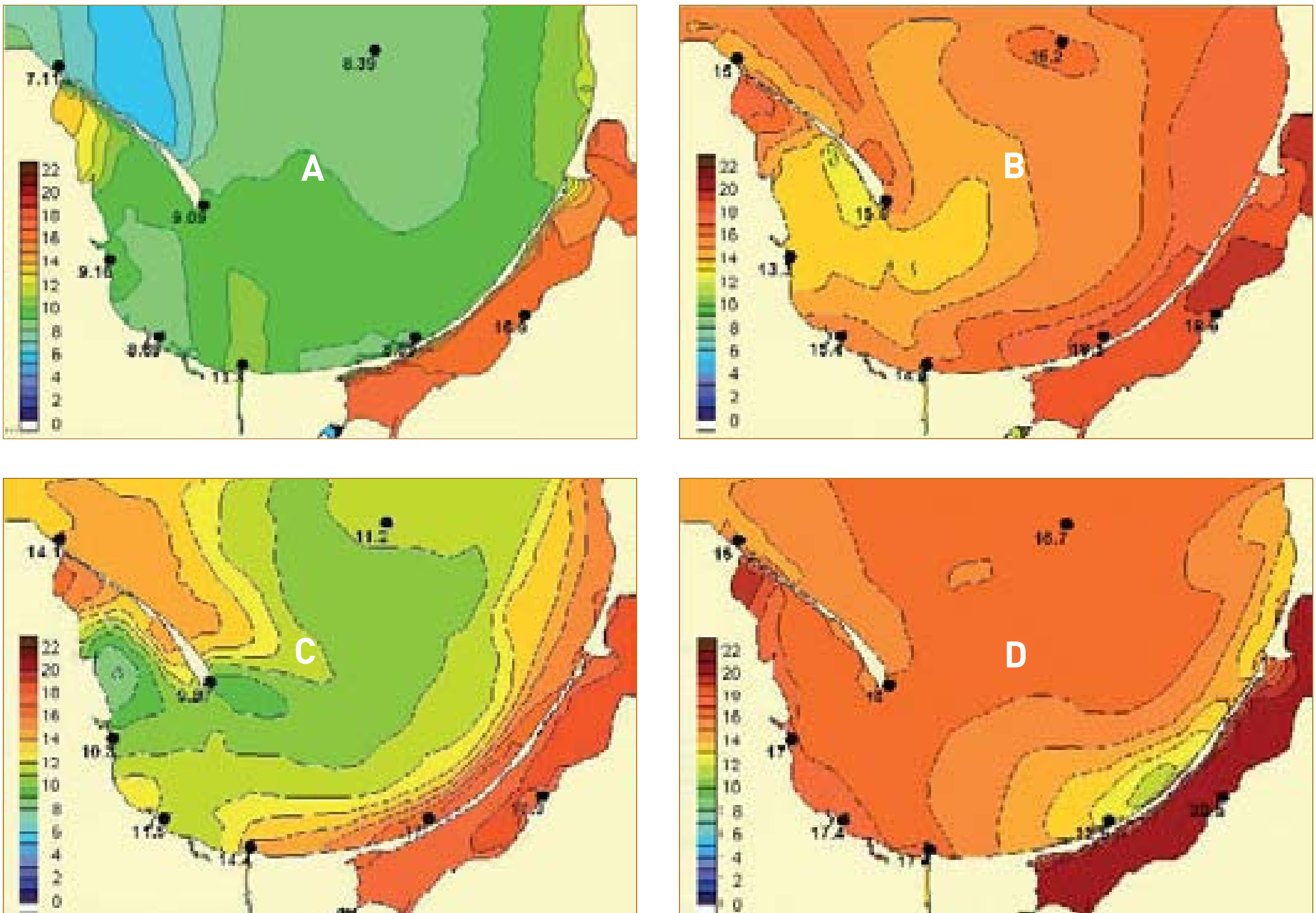


FIGURE 1 Surface temperature Gulf of Gdańsk at selected points in time (Data from UG model).

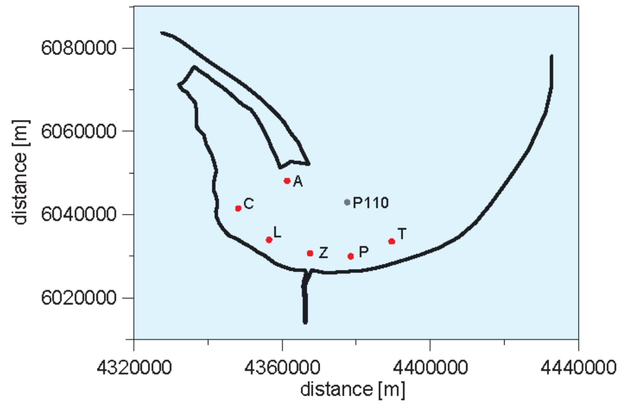
of Meteorology and Water Management (IMGW) have shown a maximum difference of 6.8° C, encountered in July 1980.
Based on water temperature measurements taken in 1950-1975 as part of a monitoring programme, IMGW prepared maps of mean monthly surface temperature. Pronounced differences can be seen between the coastal zone and the deepest part of the Gulf. The lowest water temperature was observed in the Vistula River mouth in January (i.e. 0.1 - 2.0°C) and the northeastern side of the area (close to Vistula Spit, 1.4 - 2.2°C), and in February in the shallow parts of the Gulf (approx. 1°C) as well as the deeper part (2.5°C). The smallest year-on-year differences in surface temperature were observed in February.

In the springtime water temperature increases due to the increase in solar radiation. In this period the temperature difference between the extreme values can be as high as 7° C. Characteristically, in spring a distinct increase in water temperature tends to be observed in the Vistula River mouth. As a consequence, the water surface temperature in the southern part of the Gulf also increases. In summertime water surface temperature differences between various parts of the Gulf decrease; in August they become quite uniform (differences reach only 2.3° C). At the same time the water temperature reaches the maximum absolute value of the year (16.1-18.4° C). In the southern part of the Gulf, which is very much influenced by the Vistula river, the maximum temperature is observed in July. In the northwestern part of the Gulf (the Puck Bay region) the maximum is observed in September.
Water temperature starts to decrease in September. The most dynamic decrease is observed in the shallow parts of the Gulf. The most pronounced decrease is seen in November.

Mean monthly water surface temperatures vary over the year in the range 14.3 to 17.1°C. In the deepest part of Gulf (below 80 m) water temperature shows a slow increase to the maximum temperature. Since the deep water has no contact with the atmospheric temperature, the water temperature does not follow the seasonal changes observed in the upper parts of the water column. The annual variation in temperature there is related to the inflow of water from other regions of the Baltic Sea.
Very distinct short-term water temperature changes in the surface layer are a localised phenomenon in the Gulf of Gdańsk. They are mainly due to wind action which in certain conditions pushes the surface water seaward while, at the same time, to compensate, inflow of deep water is observed at the surface. As mentioned above, the water temperature in the deepest part of Gulf is low, so occasionally patches of cold water are observed in the coastal zone. This phenomenon is known as upwelling. It is very difficult to detect using traditional measuring techniques (i.e. point measurements). However, satellite images and numerical modelling have added greatly to our knowledge of this phenomenon (Kowalewski, 1997). The results of the predictive hydrodynamic model developed by the University of Gdańsk show that upwelling can be observed in some locations in the Gulf *(figure 1)*, on the:

- northern side of the Hel Peninsula *(A)*
- southern side of the Hel Peninsula *(B)*
- southwestern coast of the Gulf *(C)*
- southeastern coast of the Gulf *(D)*

FIGURE 2
Location of modelled sites in the Gulf of Gdańsk in the 1994 reanalysis.
Robakiewicz, 2007



Point measurements taken using CTD instruments can deliver interesting information about the region. Results from three locations in the Gulf obtained in the POLRODEX'96 experiment can be cited as an example *(see figure 2)*. The data come from the cross-section located from the Vistula river mouth northward. They clearly show that in the summer temperature in the deeper part of the Gulf mainly varies in the surface layer due to variations in solar radiation, whereas in the deepest layers (below 60 metres) temperature becomes constant, and is much lower than at the surface. In the shallower parts variations in temperature can be observed close to the seabed. They are related to water circulation in the entire area as described above, leading in extreme cases to upwelling.
It is also worth mentioning that the water temperature in the southern part of the Gulf, and especially in the vicinity of the Vistula river mouth, is very much dependent on the volume and temperature of freshwater inflow. Such information can be analyzed using *in situ* measurements in conjunction with results from hydrodynamic numerical modelling of the region. One example was the reanalysis of hydrodynamics in the Gulf of Gdańsk in 1994 based on a numerical model (Robakiewicz, 2007). The increased river discharge observed in the spring is due to melting snow. Spring floods are often observed on the Lower Vistula river. The seasonal changes in water temperature in the river are quite well-correlated with solar radiation. Some of the time shift between extreme values is related to the amount of water to be warmed (discharge). When we compare water temperature in the river and in the southern part of Gulf we are struck by the fact that, starting in spring, the water temperature in the river exceeds that in the Gulf; in the autumn and winter, the opposite is true. In the 1970s it was proposed that surface water temperature be used as an indicator of riverine water in the Gulf. This indicator cannot however be regarded as universal, so its applicability is questionable.

SALINITY IN THE GULF OF GDAŃSK - CHANGES IN TIME AND SPACE

Measurements of water salinity in the Gulf of Gdańsk are generally taken in conjunction with water temperature measurements. Analysis of salinity in the Gulf is based on measurements taken by IMGW, some measurements taken on an ad hoc basis, and on knowledge derived from numerical modelling. IMGW measurements cover stations at sea and also coastal stations. Comparisons of the mean monthly differences in salinity over the period 1951-1980 (Majewski, 1990) have shown that the highest salinity can be observed at Władysławowo (7.52‰) and Hel (7.32‰), while lower values are found in the southern part of the Gulf, at Gdynia (7.30‰)

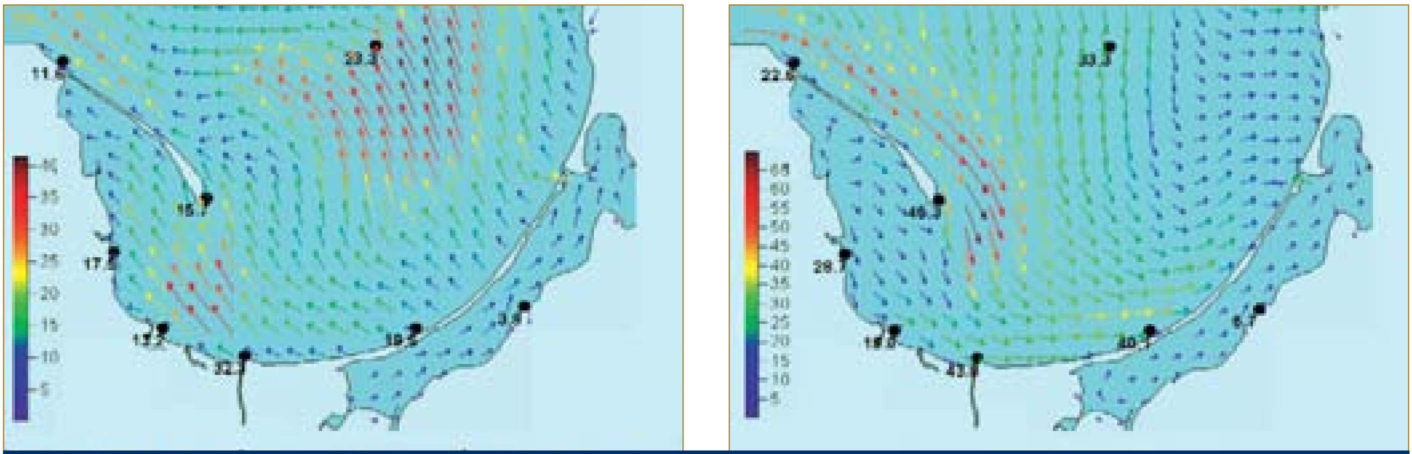


FIGURE 3 Surface currents obtained using the numerical model developed by the University of Gdańsk (sample results).
Left: Mai 24, 2006 / Right: September 1, 2006 Source: UG website

and Gdańsk (5.99‰). We have to consider these results an 'estimate' of the real values, as no automatic instruments able to measure continually with very high frequency were available in that period (1951-1980). From more recent measurements it is known that at some locations large variations can be observed over a short time scale.

Spatial differentiation in salinity is very much dependent on morphological conditions. In this respect we can identify some fairly major differences between the coastal zone, deep parts of the Gulf, and the Baltic proper. The shallow part of the Gulf is very much dependent on the Vistula River; in that region salinity is below 7‰. Influence of riverine water is observed in the surface layer in the deeper parts of Gulf; in extreme cases it can be measured close to Hel Peninsula.

It is known from field observations that, when the wind blows from the W, N and E riverine water cannot spread easily into the Gulf, and therefore spreads along the coast. When there is a NE wind water moves westwards, while a NW wind will cause it to move towards the east. Wind from the S and SW allows riverine water to spread freely in the Gulf. It is also well known that weak winds (not exceeding 2-3 m/s) support spreading of riverine water, whereas strong winds induce mixing close to the river outflow.

The statistics available (1980-85; see Majewski 1990) indicate that spreading towards the east and northeast is dominant (50% of time), while northward spreading accounts for about 25% of the time, and for 16% of the time water spreads on both sides of the river outflow.

Seasonal changes in river outflow have a direct influence on seasonal salinity changes, especially in the surface layer in the coastal regions. The lowest salinity is observed in spring-summer, i.e. periods of the highest river discharge (e.g. 4.5‰ in May, close to the Vistula river outlet), while in winter in the coastal zone it is an estimated 6‰.

As in the case of temperature, we also observe salinity stratification. There is a surface layer where salinity can have gradients of 0.25‰ - 0.35‰, an isohaline layer with no gradients (salinity 7-8‰), and below that a bottom layer where salinity can reach an average 8-11‰.

WATER CURRENTS IN THE GULF OF GDAŃSK

In the Gulf of Gdańsk wind is the main generator of water motion. Wind-driven currents are generated as a consequence of wind stress acting on the free surface. This force makes the surface move, and energy-momentum causes it to transfer to the deeper parts. Wind stress generates drift currents. Wind-driven currents develop relatively quickly in steady wind conditions. It has been suggested by some authors that after about 48 hours of steady wind, currents in the Gulf reach a steady state. However, *in situ* observations and numerical modelling do not confirm this hypothesis.

Gradient currents are generated by wind sustained for long periods. In such cases the water level increases in some parts of the water body, while in others it decreases. This creates horizontal pressure gradients which are the mechanism behind these currents. Gradient currents develop slowly; they decrease similarly slowly.

Density currents are also observed in the Gulf of Gdańsk. They are created in the event of non-uniformity of water density. The density difference in the Baltic Sea is due to exchange of water masses between the Baltic and the North Sea. In the Gulf of Gdańsk, however, the main 'source' of density differences is Vistula river inflow. Density currents are weaker than those of wind origin, though they should not be overlooked.

In practice, *in situ* measurements include all types of currents without distinction by origin.

The flow pattern in the Gulf is rather complicated to measure and interpret. Currents differ substantially in space and in time, so *in situ* measurements can provide only a rough picture. Nowadays only numerical models can identify the spatial distribution of currents. Two selected results of flow pattern in the surface layer derived from the model developed by Gdańsk University are shown in *figure 3*. As can be seen, the topography of the area plays a very important role. We can clearly see that flow close to the Hel Peninsula is directed along it. We must bear in mind that the accuracy of any model is very much related to the horizontal and vertical discretization used to represent the modelled area. The results obtained deliver averaged conditions in the area covered by the individual grid cell of the model.

Let us consider *in situ* measurements from the region to obtain an idea of the actual situation. An example of long-term measurements in a selected location is presented in *figure 10*. Substantial variability over time and differences between currents in the same location but at different depths (13 m; 75 m) can clearly be seen. We can see that even in the deep region, velocities can vary substantially. Due to local variations in currents, model results are not currently able to represent the real situation with a very high degree of accuracy.

This means that an extensive monitoring programme is needed for the management of the underwater cultural heritage in this area. None of the existing models can tell us in enough detail how salinity, temperature and currents develop in the area. By systematically collecting data during the monitoring programme, we might in the future be able to gain a better understanding of the natural changes in this area. The data can then be used for a model of the area, and presented as an extra layer in the MACHU GIS.

MONITORING PROGRAMME

Lack of *in situ* data characterising site-specific hydrodynamic conditions at the proposed underwater cultural heritage sites in the Gulf of Gdańsk has prompted a proposal that a monitoring programme be set up to fill the gap. For a complete picture of hydrodynamics in the area velocities, salinity and temperature need to be recorded. Together, they represent the hydrodynamic climate of the site of interest.

The destructive role of flow is associated with velocities:

1. Sediment movement leads to coverage of historical objects by a layer of seabed sediment – this process depends on the bed material (the finer the sediment on the seabed, the smaller the velocities required to start this process)
2. Mechanical destruction of objects by high velocities – depending on the resistance of objects.

Salinity and temperature, especially temporal changes in them, can have a negative impact on the cultural heritage. This impact may be associated with these parameters either directly (as in the case of corrosion due to salinity changes) or indirectly (due to changes in biodiversity, for example).

As shown above, the Gulf of Gdańsk is characterised by high variability in natural conditions, from very gentle to very severe. To cover the full spectrum of conditions, long-term measurements are recommended, e.g. one to two years of continuous registration. If it is not possible to carry out continuous measurements on such a time-scale, shorter periods will have to suffice. However, deciding the most appropriate period is no simple matter. In such circumstances analysis of the available long-term wind data is very helpful, as wind is one of the most important parameters characterising climate severity in this region. Thanks to long-term wind statistics for 1951-1975, the fact that in the inner part of the Gulf of Gdańsk (stations: Gdynia, Gdańsk, Świbno, Krynica Morska) the wind is weaker than outside the bay is well-documented. This is closely related to the presence of Hel Peninsula. Mild conditions dominate at all stations during May - August, while severe wind conditions dominate in November - March. Analysis of data as a series of continuous observations highlights the fact that the winter months are the most appropriate for measurements of severe conditions. One disadvantage of taking measurements in the Baltic Sea in winter, however, is the occasional presence of ice cover, which can be dangerous for instruments installed close to the shoreline.

It is recommended that autonomous instruments be used for monitoring, with online data transmission if possible. Currents should preferably be measured in the whole water column (e.g. using an ADCP current meter). If this is not possible, one level close to the bottom would be the absolute minimum. Salinity and temperature should be measured close to the bottom, preferably at the same level as currents.

NOTES

[1] Instytut Budownictwa Wodnego - Polskiej Akademii Nauk (IBW-PAN), Institute of HydroEngineering - Polisch Academy of Science.
[2] See for part I Machu Report 2 p. 43-45'

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Reconstruction of the palaeo-land scapes of the southern Baltic

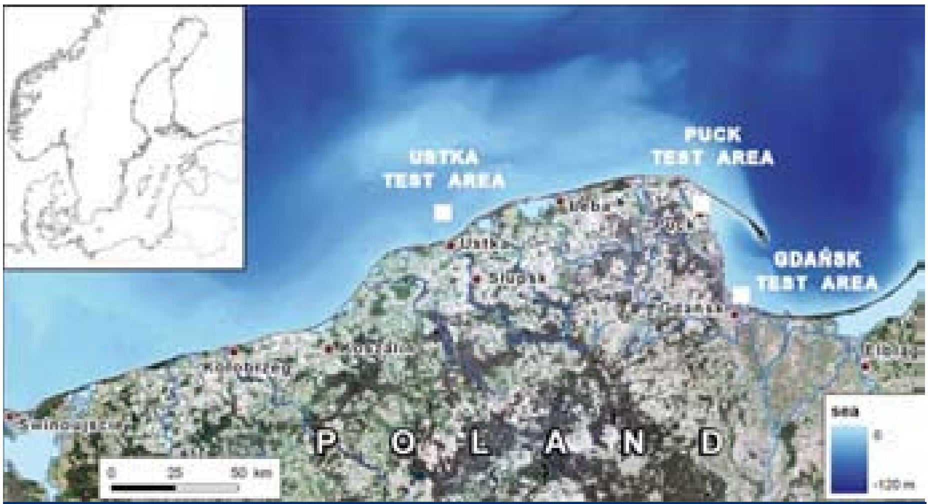


FIGURE 1 The location of the test areas.

The reconstruction of the palaeo-landscapes of the southern Baltic was based on the results of investigations of the three MACHU test areas: Ustka, Puck and Gdansk (*figure 1*).

PALAEO-LANDSCAPE OF THE USTKA TEST AREA

The area, covering 15 square kilometres (5 x 3 km), is located approx. 8-10 km north of Ustka, at a depth of 20-27 metres (*figure 2*). In 1999-2003, during the underwater fieldwork conducted by the Maritime Museum in Gdańsk, rooted tree trunks and peat sediment outcrops existing *in situ* were found on the seafloor.

The results of seismoacoustic profiling (*figure 3*), palynological sediment research and radiocarbon dating of the pine-tree trunk – taken from the seabed – delivered information about the palaeogeographical development of the Ustka area. The seismoacoustic profiling analysis showed the existence of 34 metres of denivelations in the top of the boulder till (*figure 4*). The analysis of palaeo-surface relief, arrangement and glacial marginal lake and lake sediment thickness deposited in the water reservoirs of a depression enabled us to determine the range of these reservoirs. Though the range has undoubtedly changed over time, we can assume that in the Late Glacial and Early Holocene these reservoirs covered areas no bigger than those shown in blue in *figure 4*. The areas marked brown were situated above the level of the lakes at that time.

It is known from previous research (Uścinowicz 2003) that in the Late Glacial and Early Holocene, depending on changes in sea level, the test area was located at various distances from the coast and at different heights relative to the then Baltic sea level. About 9500 years BP, which is the period of radiocarbon dating for the pine-tree trunk (*figure 5*), the Baltic was shifting from the Yoldia Sea phase to the Ancylus Lake phase. In the first stages of Ancylus Lake, the water level was approx. 37 - 33 metres lower than today.

The Ustka test area was then located about 30 km from the coast of Ancylus Lake and approx. 15 metres above its current level (*figure 6a*). The water level of Ancylus Lake rose by approx. 40 mm a year (Uścinowicz 2003), so about 9200 years BP the Ustka test area would have been located by the shore of Ancylus Lake (*figure 6b*). The Litorina Sea appeared in the region c. 8200 BP, when the water level was about 25 metres lower than

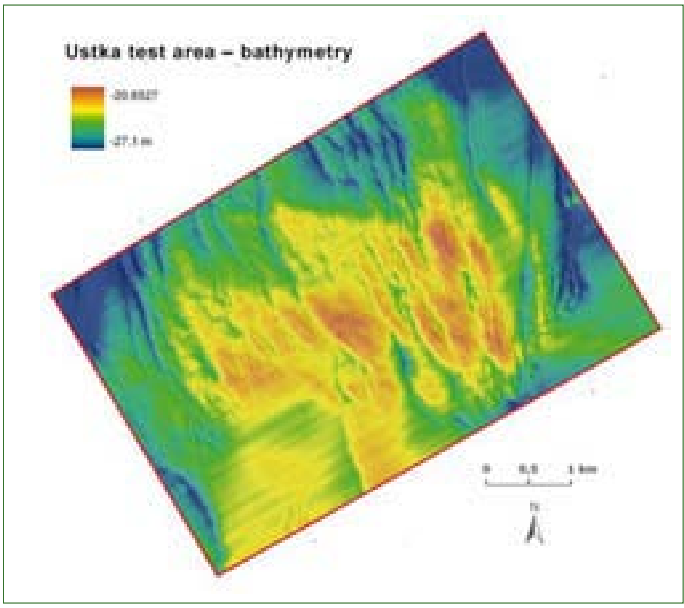
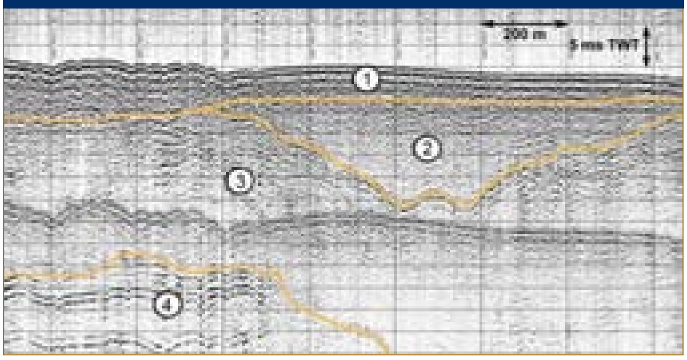


FIGURE 2 Bathymetric map (DTM) of the Ustka test area.

FIGURE 3 Fragment of seismoacoustic (boomer) records with geological interpretation. 1 - marine sand, 2 - lacustrine silt and sand, 3 - till, 4 - pre-Quaternary (Miocene?).



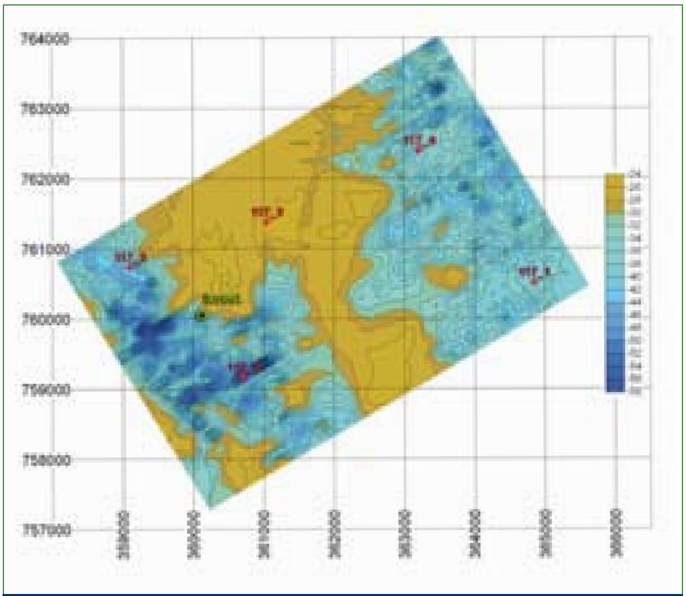


FIGURE 4 Palaeo-surface of limnic and marine sediment deposition - relief of the till surface; (red cross -coring site with core number).

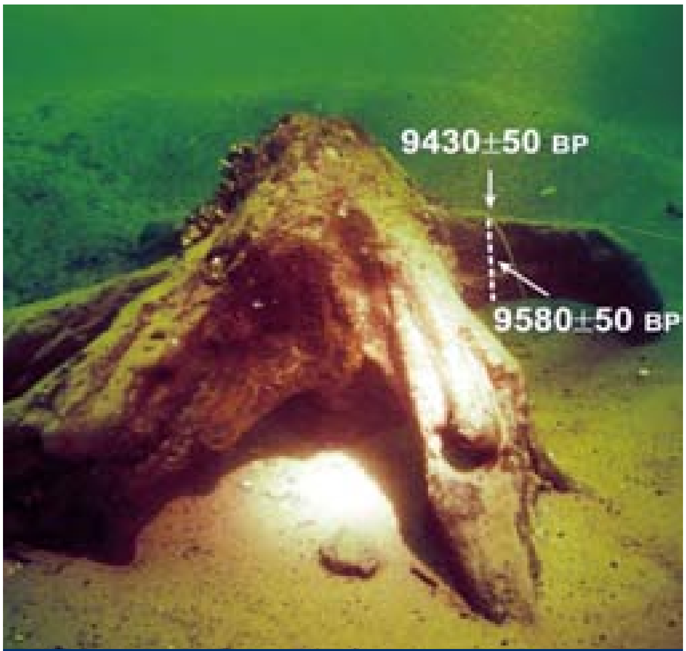


FIGURE 5 Tree stump rooted in the ice-marginal lake silt.

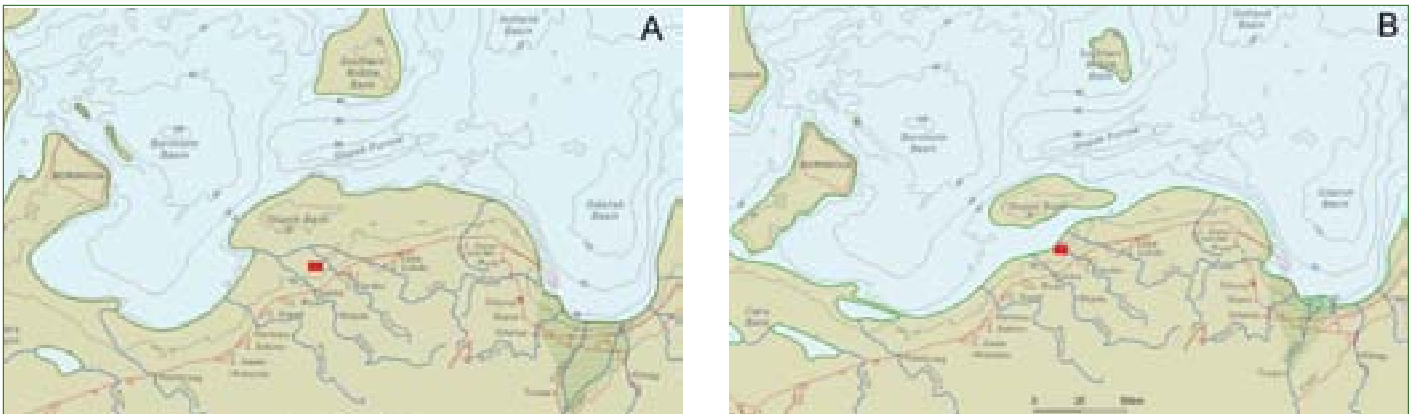


FIGURE 6 The position of the southern Baltic shoreline: A - about 9500 years BP, B - about 9300 years BP (red rectangle - the location of the Ustka test area; red line - the present-day shoreline).

the current level of the southern Baltic (*figure* 7). The shallow water area of the southern Baltic, situated below 25 metres, developed into land from the period of deglaciation until the Litorina Sea (Atlantic) transgression. The specific shape and development of the shore-line constrained the processes of erosion accompanying the transgression, enabling sediment relics of terrestrial environments, such as tree trunks rooted in the bottom, to be preserved in this area.

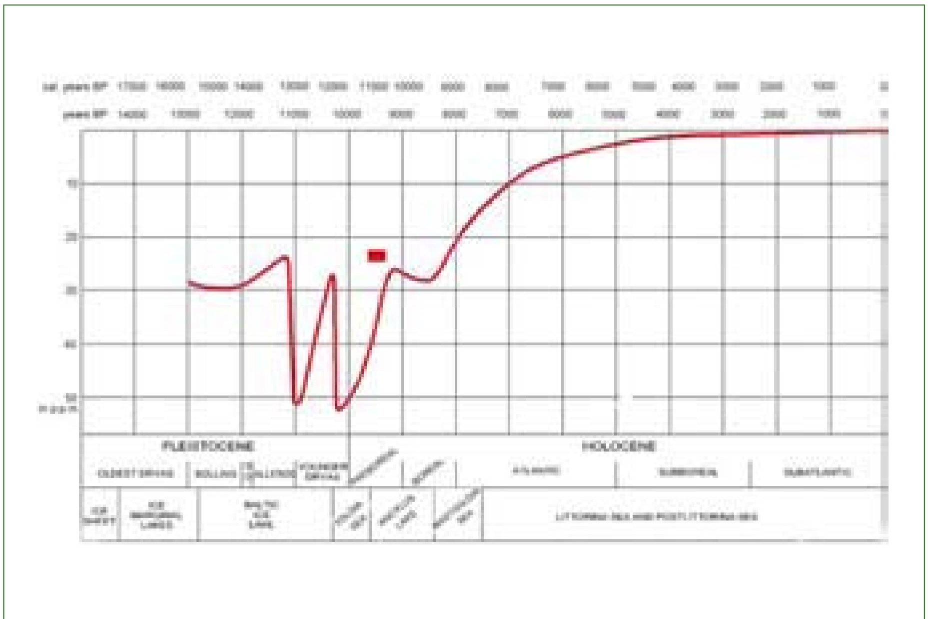


FIGURE 7 RSL curve for the southern Baltic with the position of the Ustka test area.

PALAEO-LANDSCAPE OF THE PUCK TEST AREA

The Puck test area, measuring 1.2 x 0.5 km and with a surface are of 0.6 square km - (*figure* 8), is located in Puck Lagoon and stretches from the coast to an area approx. two metres deep, including an underwater archaeological site with relics of the Medieval harbour. Puck Lagoon now covers 102.69

FIGURE 8 Location of the Puck test area (red squares - coring sites).

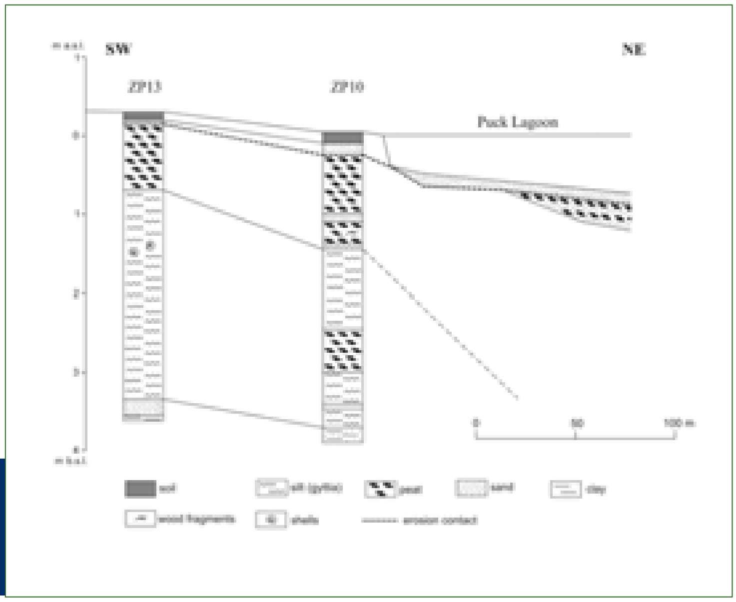


FIGURE 9 The lithology of the coastal zone of Puck Lagoon.

square km, with an average depth of 3.13 metres and a maximum depth of 9.4 metres. About 30 % of the lagoon bottom area is located in the depth range of 0 - 2 metres.

The Puck test area, like the whole of Puck Lagoon, was covered by peatlands, swamps and lake reservoirs in the Early Holocene (Uścinowicz, Miotk-Szpiganowicz 2003). The diversified seabed morphology meant that the marine environment influenced different parts of the lagoon at different times. It is therefore difficult to define when the brackish lagoon appeared in the area of Puck Lagoon (Witkowski, Witak 1993, Kramarska et al. 1995, Witak 2002, Miotk-Szpiganowicz, Uścinowicz 2003, Uścinowicz 2003, Uścinowicz et al. 2007).

In the deepest part of Puck Lagoon the beginning of lagoon sediment deposition is marked by the sand layer lying on top of Preboreal peat, 11.85 metres below the sea surface, which suggests that the first inflows of marine water in this part of lagoon occurred no earlier than 7200-7000 years BP, when the water level in the Gulf of Gdańsk was approx. 13 - 12 metres lower than it is today (Uścinowicz 2003). The shallower areas of Puck Lagoon were at that time characterised by peatlands and freshwater reservoirs that were not influenced by the Baltic. The gradual transformation of these areas into the brackish lagoon probably did not begin earlier than 5500 years ago (Miotk-Szpiganowicz, Uścinowicz 2003). This lagoon was protected from marine influences by the sandy barriers of what is now Hel Peninsula on one side, and by Rewę Mew (Seagull Reef) on the other, which limited the intensity of the erosion processes, although erosive contact is clearly visible at the top of the peat sediments (*figure 9*). Due to the thin lagoon sediments, the bottom of present-day Puck Lagoon is also a palaeo-surface dating from before c. 5500 years ago.
As the water level in the southern Baltic rose, the area of the lagoon also gradually increased. It acquired more or less its current shape and range at the end of the Subboreal Period. The curve of relative changes in water level for Puck Lagoon is well-documented for the last 3000 years (*figure 10*). According to this curve, the average water level in the lagoon 3000 years ago was approx. 1.2-1.6 metres lower than it is nowadays; 2000 years ago it was approx. 0.8-1.2 metres lower; and 1000 years ago it was approx. 0.4-0.8 metres lower. The analysis of diatom and palynological data and radiocarbon datings indicates that transgression-regressional cycles lasting approx. 1000 years, with an amplitude of approx. 0.5 metres (*figure 10*), overlapped the long-term trend whereby the water level slowly rose (Uścinowicz et al. 2007).
The comparison of the current shoreline with the topographical map from the end of the 19th century shows that the shoreline has retreated approx. 20-30 metres (*figure 11*) along almost the entire section. This allows us to define the average rate of peat shore

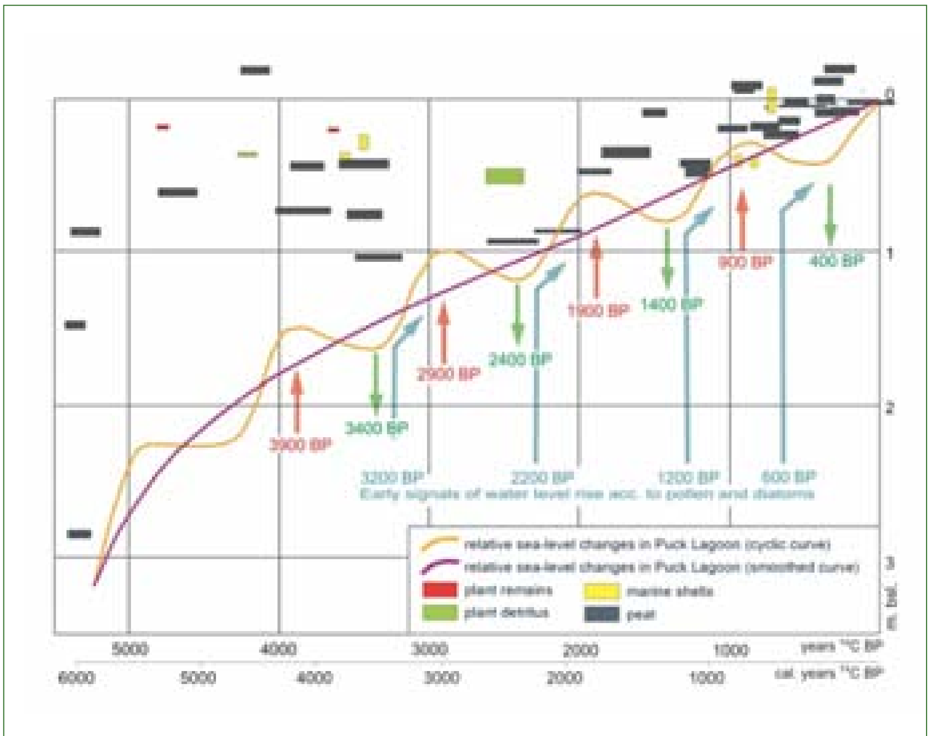


FIGURE 10 Relative sea-level (RSL) curve for the Puck Lagoon (according Uścinowicz et al. 2007).(RSL) curve for Puck Lagoon.

erosion as approx. 0.2-0.3 metres per year. The only place where the shore is growing nowadays is near the mouth of the Pútnica river, which has been located in its current position for about 150 years. Sediments of older mouth cones have been eroded. It may be assumed that during the Middle Ages the average sea level was approx. 0.5 metres lower than its current level, and the shoreline was 100-200 metres closer to the lagoon than it is today.

PALAEO-LANDSCAPE OF THE GDAŃSK TEST AREA

The area, measuring 5.5 x 6.5 km, and with a surface area of 35 square km, is located in the southern part of the Gulf of Gdańsk (*figures 1, 12*), which covers a total of 5000 square km and has a maximum depth of 100 metres. The area extends from the shore to the area with a water depth of 17 metres, and includes the underwater part of the Martwa Wisła (Dead Vistula) mouth cone.

In the Late Pleistocene or the first half of the Holocene the Gulf of Gdańsk, like the whole southern Baltic, was developing under the influence of rapid changes in sea level. When the water level was lower the shoreline was located many kilometres north of its current position. At the end of the Atlantic Period, when the level of the southern Baltic was approx. five metres lower than it is nowadays, the shape of the shore was slightly different than today, and the shoreline was probably located approx. 1-2 km further north. In the southwestern part of the Gulf of Gdańsk the transgrading sea entered a large depression and extended approx. 0.5-1.0 km beyond the present shoreline, as evidenced by the location of the present dead cliff. In the area of what is now the Martwa Wisła (Dead Vistula) mouth cone the marine ingression reached further inland, as evidenced by the floor of marine deposits 7 - 5 metres below the present sea level (*figure 13*).

In the second half of the Holocene, while the sea level was coming closer to its present state (*figure 14*), the shoreline in the region of Gdańsk was also changing. In the most southerly part an intensive expansion of an accumulation platform at the foot of the cliff caused it to transform into a fossil cliff (Rosa 1963, Mojski 2000). Along the southern borders of the Dead Vistula mouth cone, at a distance of approx. 3 km from today's shoreline, marine sands can be found on the surface (Mojski 1977). The oldest dune ridges (*figure 12*), oriented W-E and WSW-ENE, are connected with these marine sand ranges.

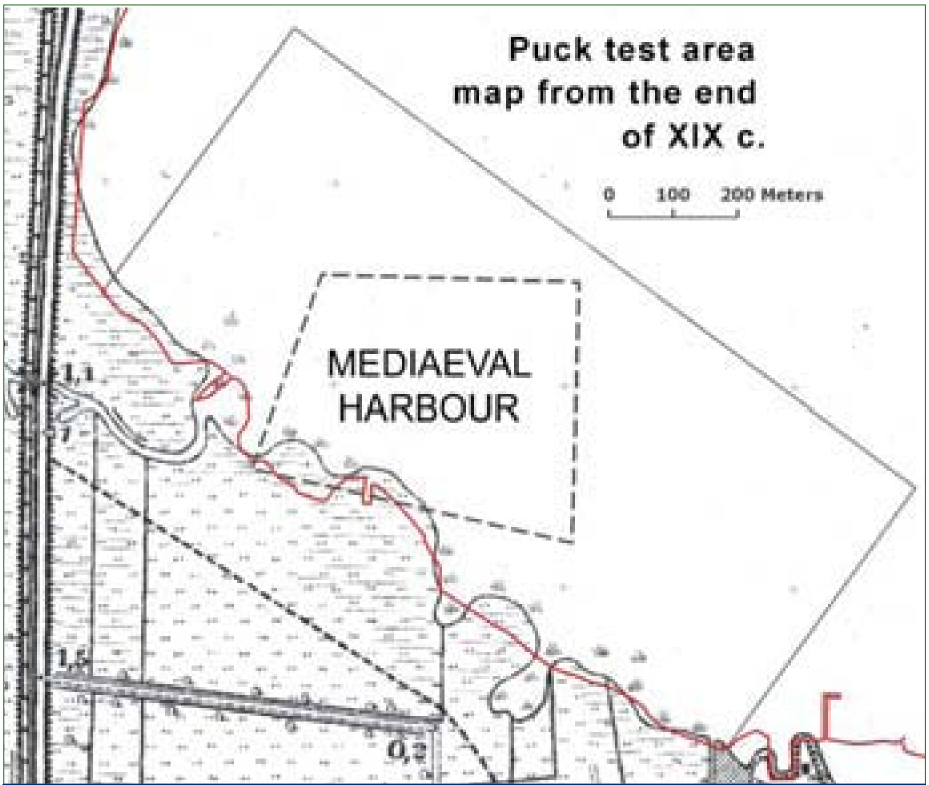


FIGURE 11 The changes in the shoreline of Puck Lagoon (red line - the present day shoreline).

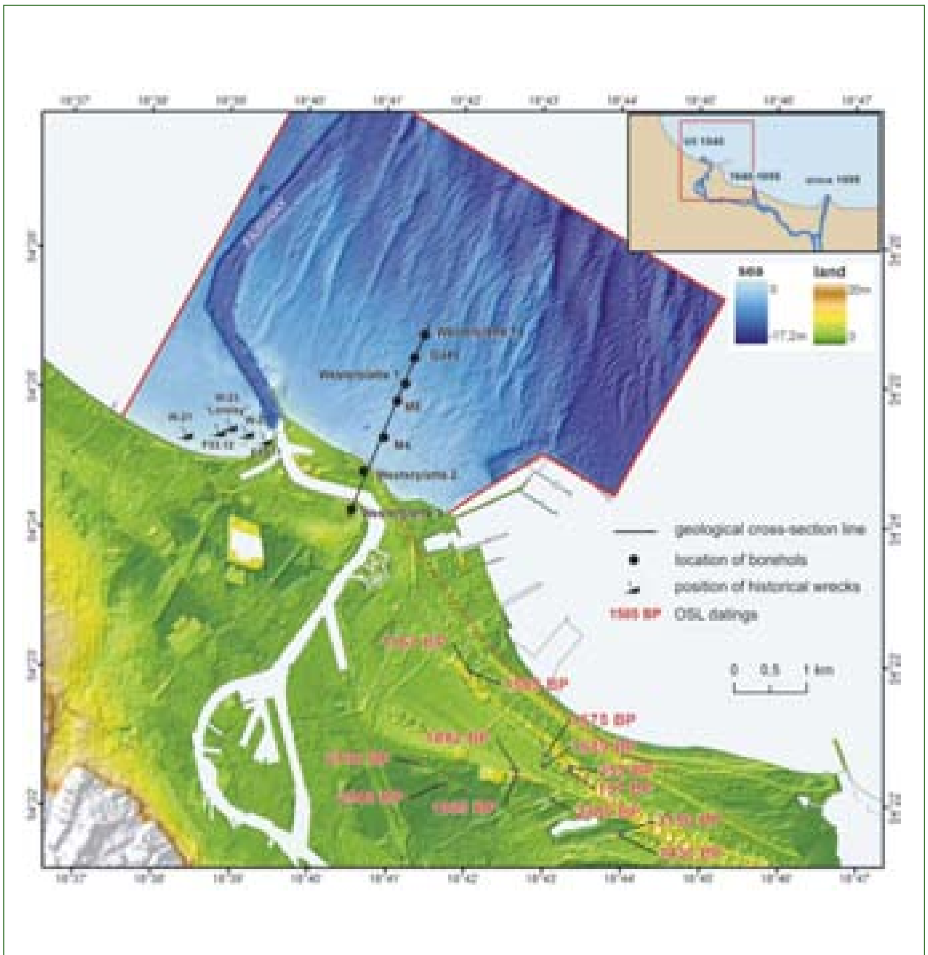


FIGURE 12 Location of the Gdańsk test area with the geological cross-section line and borehole location, the results of OSL datings and the position of the historical wrecks.

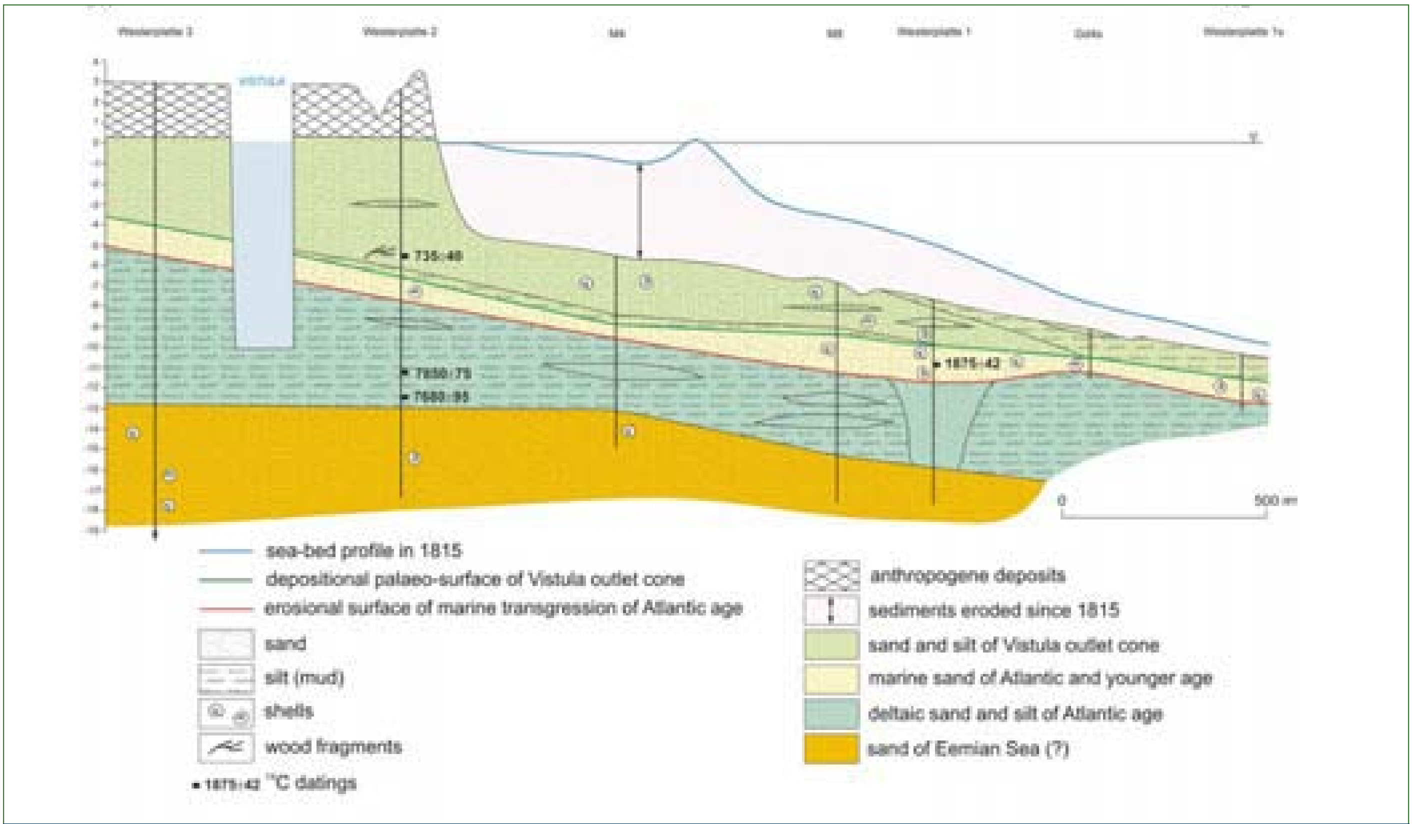


FIGURE 13 Gdańsk test area - geological cross-section.

The oldest dune ridge stabilised in the Subboreal Period (OSL dates - 3430 and 3150 years BP). Younger dune ridges located closer to the present shore (*figure 12*) changed their orientation from ESE - WNW, moving gradually to NW. We can conclude that, along with the gradual expansion of the seashore and the formation of a younger generation of dunes, the older generation was stabilising, in a development similar to the aeolian processes observed today. According to OSL dates, the change in the orientation of the dune ridges occurred at the end of the Subboreal Period, about 2760 - 2540 years BP (*figure 12*), when the oldest dunes of the new orientation stabilised. The shoreline in the Martwa Wisła (Dead Vistula) mouth region is bent to the sea in a characteristic way. It is a shoreline shape typically caused as a river forms a mouth cone. Younger generations of dune ridges relate to the present shoreline and indicate that the Martwa Wisła mouth cone developed sequentially (*figure 12*). The dune ridge, which today lies at a distance of approx. 1-2 km from the present seashore, has been dated (OSL) to 1865 and 1882 years BP. The subsequent dune ridge generations, dated (OSL) to 1675, 1689 and 1505 and 1161 years BP, are located approx. 1.3 km from the shore (*figure 12*).

The present shoreline of the Martwa Wisła (Dead Vistula) mouth cone is located between 2 and 3 km from its root, i.e. from the former shoreline of 2000-3000 years ago. For over 2000 years the cone expanded rapidly, reaching its maximum range in the first half of the 19th century. The rate of expansion was not regular. The historic maps analysis indicates that, from 1840, the cone was subject to intensive erosion, which caused the shoreline to recede landwards by 100-200 metres in some places. Deposits from the Dead Vistula mouth cone that can be found today in the test area are from the lower, older part, and their age is difficult to estimate.

The test areas were marked out on the basis both of the presence of sunken wrecks, and of the occurrence of tree trunks in the area of the southern Baltic. Comparing the development and character of palaeo-landscapes in the test areas, we can conclude that the present landscapes formed in different periods, at different rates, but always directly connected with the development of the Baltic and with changes in its water level. ■

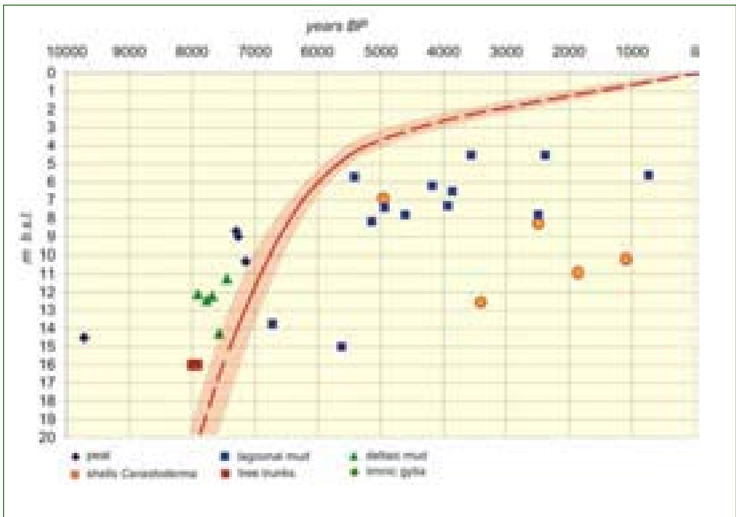


FIGURE 14 Relative sea-level (RSL) curve for the Gdańsk area.

The use of historical maps in Poland

The bathymetric maps of the period from the end of the 16th century to the first half of the 19th century provide excellent documentary material describing historical coastal development in the mouth of the Martwa, Wisa (Dead Vistula). These maps were created in order to determine safe routes for ships entering the port of Gdańsk. The oldest preserved map dates back to the year 1594. New maps were produced almost every year after that, with scales ranging between 1:1500 and 1:6000. The 'Gdańsk rod' (Dantziger Ruthen) was used as a unit of square measure, and the depth of the water was measured in feet. Several dozen maps were analyzed, and maps from the years 1613, 1674, 1701, 1761, 1815, 1829 and 1898 *(fig.1 to 7)* were chosen for comparative analysis using GIS technology. The changes in the shoreline on the historical maps were compared with the shoreline on the 1:10000 topographical map from 1997 *(figure 8)*.

The comparison shows that the outlet cone, especially its underwater part, was formed in a very dynamic way. The oldest bathymetric maps show the shoreline, and the range and shape of sandy banks and water distribution channels, which changed frequently, some as often as every year. The natural water distribution channels were several metres deep and their shape suggests that they might have been artificially deepened and widened from the beginning of the 17th century.

The sea shore did not grow evenly *(figure 9)*. In some periods it showed stagnation or even receded, possibly due to periodic differences in the quantity of transported material, changeable vulnerability to storm activity in the area characterized by slight denivelation or differences in the sea level at the time when measurements were taken. From the end of the 16th century to the year 1824, when the furthest extent of the land section of the cone was documented, the shoreline moved about 850 metres. The formation of the outlet cone mouth cone of the Dead Vistula finally ended in 1840 when, as a result of an ice jam, the waters of the Vistula created a new mouth.

In the absence of clastic material delivery, the outlet cone was subject to erosion and, as a result, the offshore parts of the cone were degraded and the shoreline needed artificial protection. The comparative analysis of maps allows us to estimate that, over the last 150 years, the sediment layer of approx. 1 - 5 m thick was degraded, and the shoreline receded in some places by 100 - 200 m *(figure 9)*.

CONCLUSION

1. Historic maps and bathymetric plans of good quality are available for the area of Dead Vistula outlet since XVI century.
2. Changes in coastline, rivers, depth etc, can be identified from this source with good accuracy.
3. This information can help us to:
- understand the maritime landscape.
- place archaeological sites (now underwater) in their historical context.
- predict the value of an area for UCH.
- find new archaeological sites.
4. The knowledge about the changes of coastal area could be used as a auxiliary information to design the spatial developing plans of the area with the special attention to protection UCH. ■

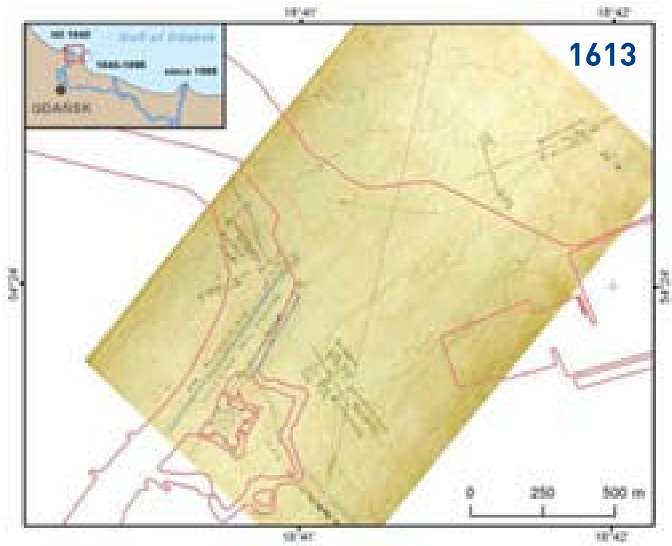
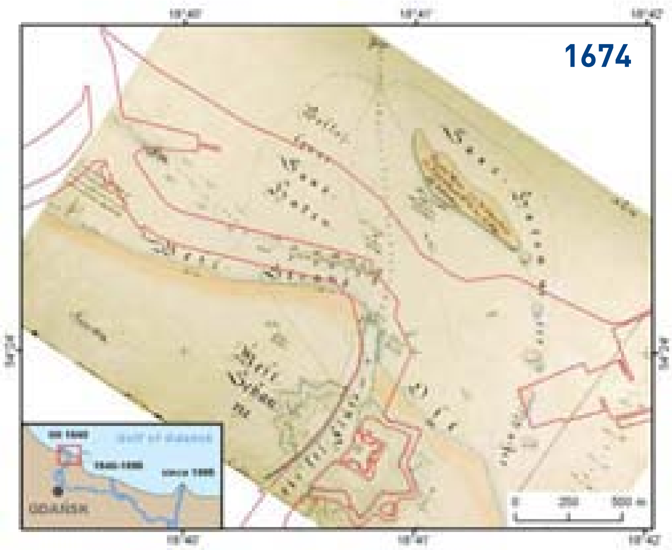
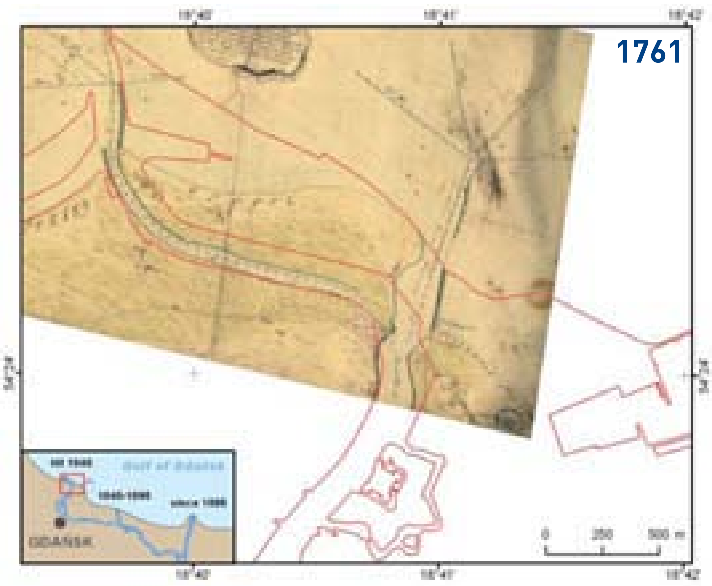


FIGURE 1-7 The historic bathymetric maps from 1613 - 1898 (red line - the present day situation).





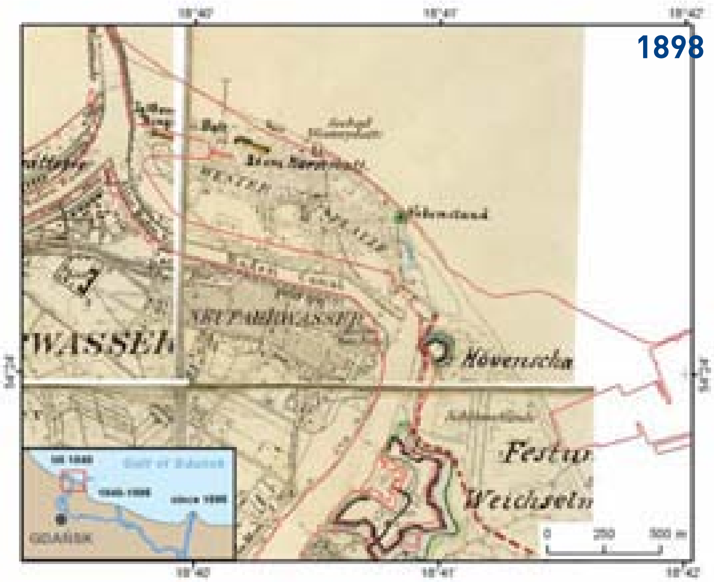


FIGURE 8 The 1997 topographic map, scale 1:10000

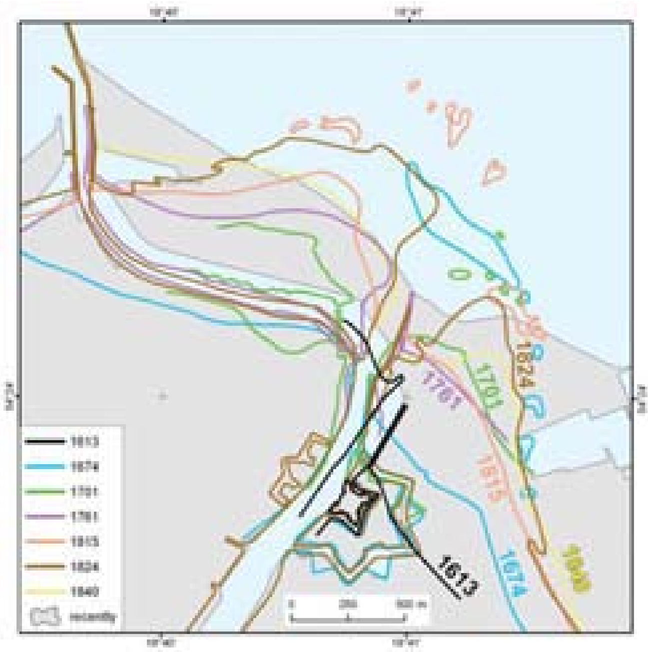


FIGURE 9 The reconstruction of the shoreline migration basing on the historic bathymetric maps (according to: W. Jeglinski).

STAKEHOLDERS, PARTNERSHIP AND INTERDISCIPLINAIRY RESEARCH: CASE STUDIES

Underwater cultural heritage should not only be there to be enjoyed by many, our vision is that many different stakeholders should also play a role in its management. Sport divers and amateur archaeologists, for example, are the ears and eyes of underwater archaeology, and they have their own reasons for protecting and preserving this rich resource so they can enjoy it in the long term.

Over the coming years more input is needed from such stakeholder groups to create awareness of the management and protection of the underwater cultural heritage, to engender the idea of shared responsibility and to keep this idea alive. Information from all sources should be incorporated, weighted and evaluated in order to create a more complete overview of what is out there, and how we can best protect and investigate it.

The aim of MACHU was to set up partnerships between the government agencies responsible for management of the underwater cultural heritage and different stakeholder groups. Many such partnerships have been established in the partner countries, both formally (under agreements, for example) and informally (by launching debates and exchanging information, for example). Joint efforts were made on a local, national and international scale.

There remain some issues that could potentially block closer and continued cooperation between different stakeholders in the underwater cultural heritage, connected with the ownership and protection of data (see also 'Some final remarks and discussion of the future of MACHU', this volume p. 131-134). But who owns the data? Who is allowed to know where cultural heritage underwater is to be found and, consequently, enjoyed? Is there any effective system of enforcement to punish those who break the rules?

In the following articles we will focus on some examples of cooperation and interdisciplinary research in the field of underwater cultural heritage management in the MACHU project. Cooperation took place between avocational and professional groups, and also between different research disciplines, such as cultural heritage and geosciences.

More examples of cooperation can be found at the MACHU website *www.machuproject.eu* and in MACHU Reports 1 and 2.

Questionnaire on recreational diving in Sweden

The aim of this study was to analyze recreational diving as a cause of shipwreck deterioration. For this purpose, we designed a questionnaire. Our prime motive was to generate valid data about recreational diving and how this type of diving affects the cultural heritage underwater. The data was mainly intended for the Swedish contribution to the MACHU project. Our questions touched upon a number of different subjects connected to the cultural heritage underwater, such as diving habits, knowledge of cultural heritage legislation, attitudes towards the cultural heritage underwater as well as how and where diving occurs. Furthermore, we were hoping that the survey would give us the opportunity to establish contact with the recreational diving community.

The questionnaire was published on the Swedish national maritime museum's website from March to May 2008, with three different diving forums linking to it. At the time, one of these forums, www.dykarna.nu, had nearly 18,000 members. Our target was to obtain around 250 responses, but in the event we were pleased to receive as many as 308. 168 responses came from divers living in our test area, the Stockholm archipelago. The other 140 responses were sent in by divers from other parts of the country. The latter responses were very useful as comparison.

DIVERS

The divers who responded to our questionnaire showed a very good age distribution as well as a wide geographical spread. They also represented a good distribution of level of experience and number of dives per year. However, these 308 divers are just a small proportion of all the active divers in Sweden. Although our results provide us with some insight, it would be premature to jump to conclusions and extrapolate our results to the entire diving community.

RESULTS

The following three sections present some of the results from the questionnaire:

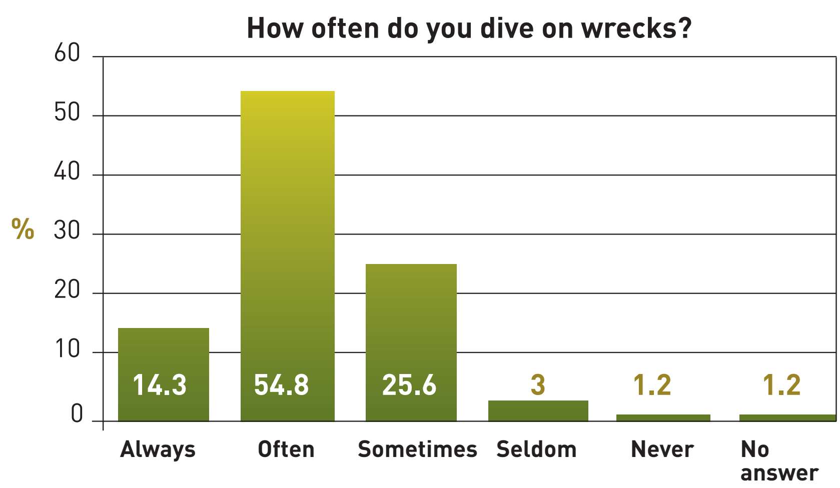


FIGURE 1 Responses from the 168 divers in our test area.

EDUCATION AND SKILLS

Our questionnaire revealed that divers are in general very well educated in the skills of diving. The average diver has completed 3.7 courses. 60% of the recreational divers who responded to the questionnaire had taken a nitrox course. The recreational divers spend a large amount of money on diving courses, chartering boats and, most of all, on equipment. Divers are generally very actively involved in their hobby. They dive very frequently and spend a lot of time and – as mentioned above – a lot of money on it.

On the east coast of Sweden, wrecks are the main attraction for divers. The primary reasons for taking up diving are adventure seeking, an interest in nature and wrecks, and for some an interest in wrecks and history. It also seems that general interest in wrecks and the stories behind them increases as divers become more experienced. In several cases, wrecks are the main reason why people continue diving. See *figure 1*.

We also found that many divers – many more than we thought, in fact – dive very deep. 65.4% of the divers answering the questionnaire have a maximum diving depth of 40 metres or more, 23.5% have 60 metres or more as their limit and 5% have a maximum depth of 90 metres or more. Under professional diving legislation, archaeologists at the National Maritime Museum are only permitted to dive to a maximum of 40 metres. This means that more than 50% of recreational divers dive much deeper than the archaeologists of the Swedish maritime museums.

CULTURAL HERITAGE LEGISLATION

Several of our questions dealt with knowledge of and attitudes towards cultural heritage legislation. It turned out that many of the divers responding to the questionnaire had a very good knowledge of the law applying to the underwater cultural heritage and its

implications for recreational diving. 84% of the divers knew how the legislation protects wrecks and 76% knew that it protects isolated finds, cultural layers and remains other than wrecks. 93% consider the protection afforded by the legislation as good.
Despite this good level of knowledge about heritage legislation, there is a need to educate recreational divers regarding our underwater cultural heritage. Quite a few divers expressed a need for more information about the law and how to act when visiting a cultural heritage monument.

WHERE AND WHY

The results of our questionnaire gave us a fairly good picture of where, how and why recreational divers dive. We selected 30 wrecks of different types, age and depth for our questionnaire and asked the divers how many dives they had made on each wreck and why they had dived there.

Summarizing their answers, we found that 'our' 308 recreational divers had made 8.727 dives on these 30 wrecks. The most visited wreck was the motor ship Harm, lost in 1969, with 1.427 dives; the least visited was a very broken up, little-known wooden wreck with only 13 dives. Using the 308 divers as an index, it is easy to see just how much diving occurs in the Stockholm archipelago. The diver's forum 'Dykarna.nu' currently has 19.433 members, for example. Applying the above-mentioned index, we calculated that these 19.433 divers have made nearly 550.000 dives on the 30 wrecks This is, of course, a hypothetical example, but it still gives us an idea of the amount of diving on wrecks in the area around Stockholm. We also have to bear in mind that we cannot be certain that these 308 divers represent the average of divers in Sweden.

REVIEW OF THE QUESTIONNAIRE DESIGN

A variety of methods are available for collection of data and the chosen method can always be implemented in different ways. However, once data collection is completed, it is important to consider whether relevant questions were missing or if questions could have been phrased differently. Though we obtained a large amount of interesting and valid information from our questionnaire, we are certain that the next time we choose to conduct a survey, we will do it differently. Here are a few thoughts on our questionnaire.

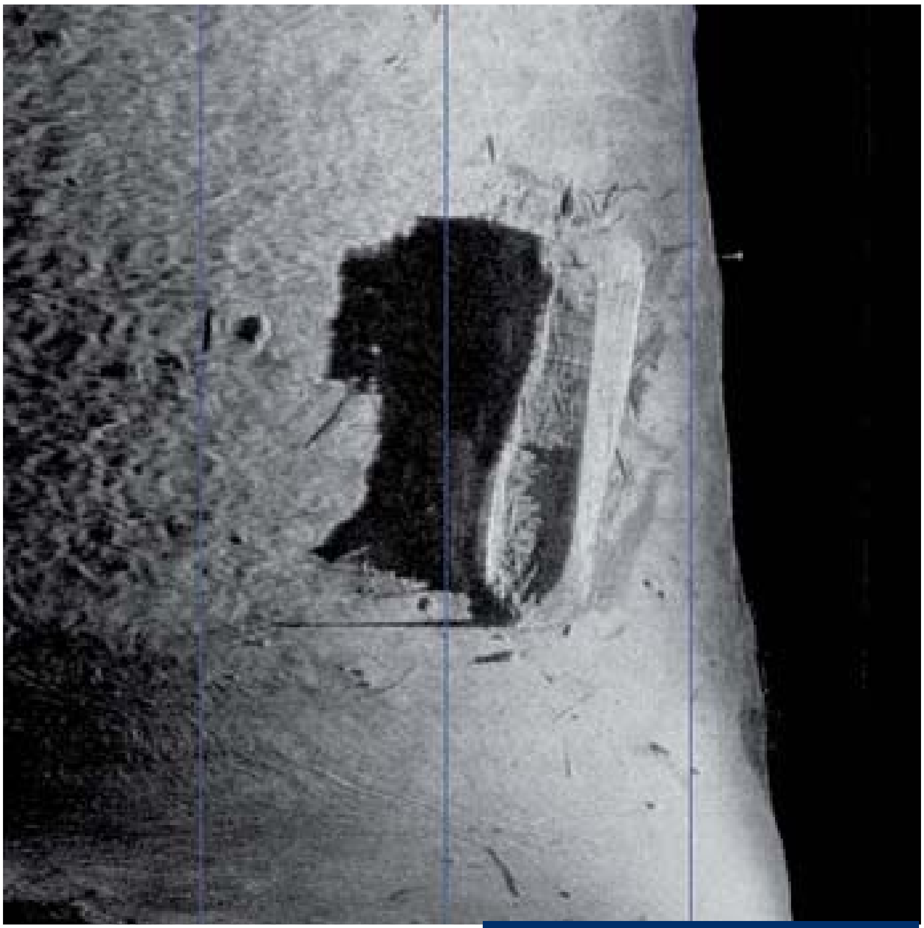


FIGURE 2 Side scan sonar image of one of the 30 wrecks in our study, the Anna-Maria, which sank in 1709.
PHOTO: SMM

- Some of the questions could have been phrased in a better and more specific way. Some questions left room for misunderstanding and the result has therefore not been as good as possible.
- We could have had more follow-up questions, giving the divers a better opportunity to express more personal opinions.
- We could have reached out to more divers to obtain more valid data.

CONCLUSION

Having obtained more responses than we initially expected, we are very satisfied with the outcome of this study. Our questionnaire helped us to increase our knowledge about the habits and skills of recreational divers. We were able to generate a large amount of information for our contribution to the MACHU project and to establish and improve our relations with the recreational diving community. ■

How does scuba diving affect our wrecks?

As part of the Swedish contribution to the MACHU project, fieldwork was conducted to determine the changes to our underwater cultural heritage caused by natural processes and human activity – especially recreational diving. We also wanted to develop a method for analyzing the cause and extent of deterioration at a specific site. The results of the fieldwork also gave us an idea of the ongoing deterioration at the sites visited.

We also wanted to develop a model for use on wrecks which can also be used in the future to identify effects on and deterioration of the shipwrecks. Our method involved the collection of new data and the subsequent estimation of the status of the shipwrecks through comparison with earlier data.
This article presents a sample of our fieldwork results.

Out of 30 wrecks, we selected 15. Our selection criteria were that they should be similar wrecks in different environments, with different diving frequencies. Our goal was to investigate these wrecks during two field seasons (2008-2009). Visits to 13 of them yielded ample data. Thanks to our documentation of these wrecks, combined with information recovered in earlier fieldwork, GIS modelling will be able to show changes or influences that have already damaged or might potentially damage the remains. The methods used during the fieldwork included video documentation, photo documentation and control measurements of data. The photographs, videos and measurements were taken from predetermined positions on the wrecks, allowing us to return to the same positions in the future.

SS INGRID HORN VERSUS SS HANSA

To illustrate our results, the following section introduces four of the 13 wrecks investigated.

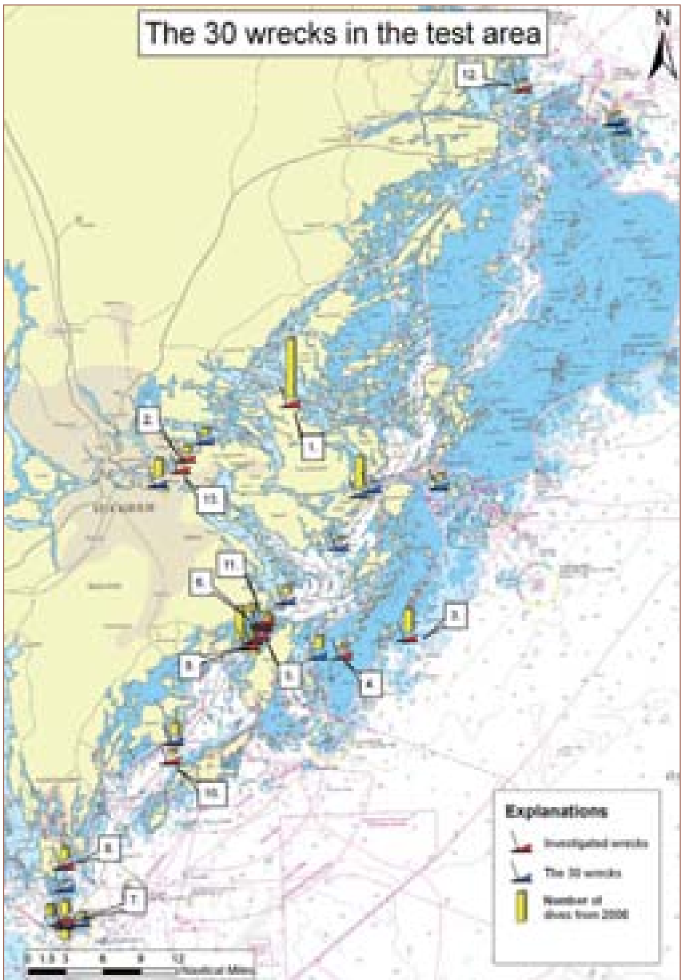


FIGURE 1 Map of the test area indicating all 30 wrecks, including the 13 wrecks we investigated as well as the number of dives to each wreck. The number tags refer to figure 2.

	Wreck name and date		*Material*	*Visited*	*Deterioration level*
1	Harm	1969	Steel	Yes	Minor
2	The Käppala wreck	c. 1850	Wood	Yes	Minor
3	Sappemeer	1969	Steel	Yes	Minor
4	The Björns wreck	c. 1740	Wood	Yes	Evident
5	Riksäpplet	1676	Wood	Yes	Evident
6	Anna-Maria	1709	Wood	Yes	Evident
7	SS Hansa	1917	Steel	Yes	Considerable
8	Margaretha Af Vätö	1898	Wood	Yes	Evident
9	SS Ingrid Horn	1917	Steel	Yes	Evident
10	The Koster wreck	c. 1750	Wood	Yes	Evident
11	The Bellevue wreck	c. 1550	Wood	Yes	Minor
12	The Idö wreck	c. 1850	Wood	Yes	Minor
13	The Kungshamns wr.	1361	Wood	Yes	Evident
14	Concordia	1754	Wood	No	
15	Jurgen Fritzen	1940	Steel	No	
16	The Maderö wreck	c. 1550	Wood	No	
17	Gröna Duvan	c. 1700	Wood	No	
18	Paula Faulbaum	1941	Steel	No	
19	Fyrspännaren	c. 1770	Wood	No	
20	Ibex	1892	Steel	No	
21	Oleg Koshevoi	1946	Steel	No	
22	Nepolina	1913	Wood	No	
23	The Jutholms wreck	1702	Wood	No	
24	Gröna Jägaren	1676	Wood	No	
25	The Svartfots wreck	1960	Wood	No	
26	Harburg	1957	Steel	No	
27	The Nackastrand wr.	c.1950	Wood	No	
28	Tyr	2001	Steel	No	
29	Fringilla	1930	Steel	No	
30	The Dalarö wreck	c. 1650	Wood	No	

FIGURE 2 A table showing the selected wrecks.
The classification is described at the end of the article.

FIGURE 3a-b The intact sternpost of the 90-metre wreck of SS Ingrid Horn is almost covered in sediment. We can also see that the wooden structures are almost entirely intact. Photo: Jakob Selbing

FIGURE 4a-b Photo of the bilge pump of the Björns wreck from 2003. The picture taken in 2008 shows its subsequent collapse, probably due to divers or anchoring.
Photo: Mirja Arnshaw and Patrik Höglund, SMM

The ***SS Ingrid Horn***, loaded with iron ore, sank in 1917 to a depth of 27 metres. She is frequently visited by divers and her position is sheltered from strong winds. Furthermore, she is partly buried in a mud layer, which protects the wreck from rapid deterioration. Our comparison between the SS Ingrid Horn and the ***SS Hansa***, also loaded with iron ore, which sank in 1917 to a depth of 25 metres, revealed major differences. The SS Hansa's position is far more exposed to winds, ice and waves than that of the SS Ingrid Horn. Taking a closer look at the exploitation pressure, it was obvious that the SS Ingrid Horn owes her current good condition to the fairly sheltered environment in which she is situated. As a result, she has been only slightly affected. We determined some damage due to recreational diving, e.g. to some parts of the structure (especially smaller parts like railings, stairs etc.) caused by the divers' lack of buoyancy. Furthermore, a large number of artefacts are missing due to looting. However, in general, the SS Ingrid Horn is fairly intact.

If we compare the SS Ingrid Horn with the SS Hansa, we are struck above all by the differences in the preservation of the hull structure. Sketches and pictures from the late 1960s, when the SS Hansa was found, show that she was very well preserved, with her entire structure almost intact.

THE BJÖRNS WRECK VERSUS THE KOSTER WRECK

The Björns wreck has been dated to approximately 1740 and lies at a depth of eight metres. She has been affected by recreational divers in terms of the disappearance of artefacts due to looting, tying of ropes (for buoys) and anchoring of diving boats. The fact that the wreck is situated in a natural harbour, which is a very popular anchoring place for regular boats, has also affected its condition.

We compared the Björns wreck with the Koster wreck, which has quite a short history as a diving site. It was found in 1995 and has

been roughly dated to 1750. The Koster wreck is almost intact up to the railing.
We had extensive data on the Koster wreck which we could compare with our new documentation. The geographical location of the Koster wreck could hardly be more different to that of the Björns wreck. The diving depth is 36 metres, in the middle of a major shipping lane. Despite its location, the wreck has not been affected by shipping or strong wave action. But in terms of the impact from recreational diving and anchoring, we found that the wreck had been strongly affected over just 15 years. We noticed impact from recreational divers (bad buoyancy), the moving of artefacts around the wreck, heavy damage from the diving boats' anchors and the disappearance of artefacts due to looting. In the case of the Koster wreck, we have a strong impact from recreational divers, and almost none from natural causes.

FIGURE 5 Part of the collapsed starboard side of the wreck of the SS Hansa. One of many ropes from old buoys fastened onto the wreck is also visible. Photo: Jim Hansson, SMM

A FOUNDATION FOR THE FUTURE MONITORING OF SHIP WRECKS

To record our observations, we used a form that was filled out after each dive. The purpose was to note all the information and to create an archive for each wreck for the purposes of future research. The data from the forms will be incorporated into our monitoring plan, thus enhancing our knowledge of our underwater cultural heritage.
The results will be fed into our GIS tool and then analyzed. Our approach is to set up a plan for each wreck to make sure that we can preserve it in the best possible condition for the future and to take preventive measures. The form uses a classification scale with three levels (none-low-high) to grade the damage to the wrecks on the basis of six different variables.

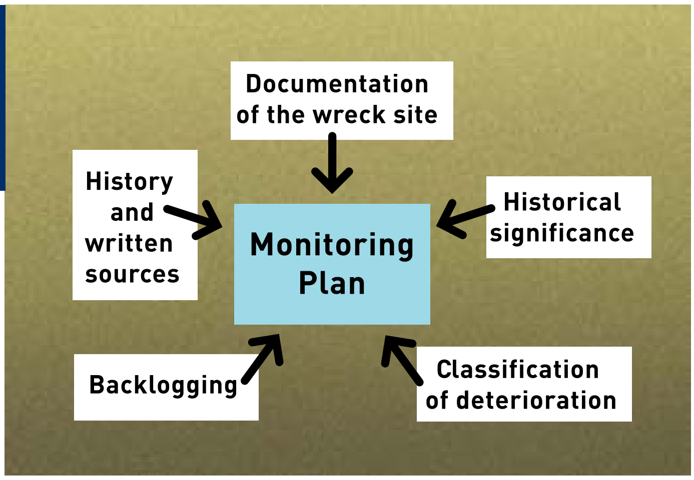
CONCLUSIONS

Despite the difficulty of determining natural causes due to lack of proper information on waves, winds, sediment transportation etc., we are satisfied with the results. We can clearly see the deterioration caused by recreational divers at the sites. We managed to identify diving patterns. Certain objects such as the railings, fragile details in general and of course artefacts are almost always destroyed or removed. In most cases this will not be done deliberately. Bad buoyancy is one of the main factors today compared with the earlier history of recreational diving. In the past, it was more acceptable to take home a 'souvenir' or move deck planking, for example. Today's recreational divers are more aware of our underwater cultural heritage, though they still cause a great deal of deterioration other ways. They apparently still regard it as acceptable to touch or grab artefacts or sensitive details on wrecks.

Our fieldwork yielded very valuable information and our method proved very successful. In the course of this project, we developed a way to locate and predict impacts on and deterioration of our shipwrecks, as well as a method that can be used in other geographical environments along the Swedish coast. The GIS tool we developed as part of the MACHU project will serve as an excellent basis for our future work on locating and preserving our underwater cultural heritage. ■

FIGURE 6 The Koster wreck. The picture shows the bollard on the port side near the stern in its correct position on the railing. Photo: Jim Hansson SMM. Sketch by Göran Ulrich.

FIGURE 7 Our monitoring plan will help us protect and preserve historical remains under water.



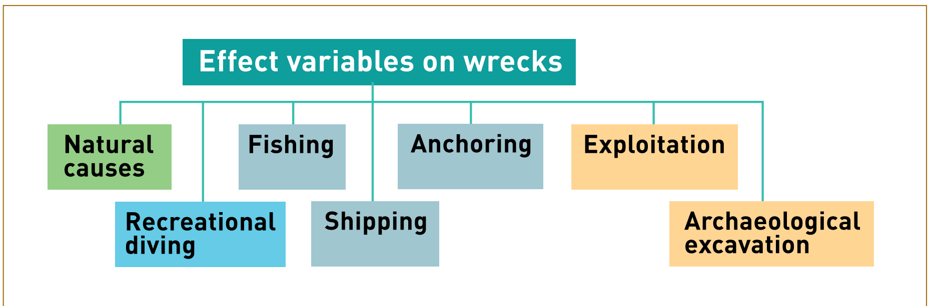


FIGURE 8 The six effect variables used in the studies.

An example of the impact of infrastructural works on the management of our cultural heritage underwater

Russian gas and a Swedish ship barrier of 1715

Maritime archaeology is international. In the case of ship archaeology, this could hardly be otherwise. Ships are moving objects. They were made to sail from one port to another and in many cases they were lost in foreign waters. Trade and warfare connected their history to different places in the world. Even today, in the age of the global economy the recent history of archaeological sites can take on an international dimension. Ships might still be owned by the countries they originally came from or sites may be threatened by international infrastructural works. Europe is increasingly becoming one, and there is a growing need for transport connections and energy, not only within the EU. International construction projects connect the world, creating transport routes and supply lines for today and for the future. This has already had an impact on our cultural heritage. Taking this into consideration, the management of our cultural heritage underwater must be seen from an international perspective.

The story of the ship barrier of 1715 was an international one from the very beginning, and remains so to this day. Many countries have a connection with its history and today investigation of this monument has an international dimension because of the plan to build a gas pipeline from Russia to Western Europe *(figure 2)*. It is situated on a natural shoal at the Eastern entrance to the Bay of Greifswald between Mönchgut peninsular on the island of Rügen to the NorthWest and the small island of Ruden to the SouthEast *(figure 3)*. Here, 14 wreck sites stretch in a line for almost a kilometre from West to East *(figure 4)*. The ship barrier is regarded as Germany's most impressive visible underwater monument. In fair weather it is easily visible to a depth of 3 to 4 m.

FIGURE 1 Divers of the Authority for Culture and Preservation of Monuments in Mecklenburg-Western Pomerania prepare for survey of a wreck of the 1715 ship barrier in Greifswald Bay. Picture: Nord-Stream

FIGURE 2 The planed gas pipeline through the Baltic Sea from Vyborg/ Russia to Lubmin at Greifswald Bay/Germany. Picture: Nord-Stream

THE GREAT NORTHERN WAR

The wrecks commemorate a very important event in the history of Northern Europe. They are a monument to the struggle for

FIGURE 4 The ship barrier of 1715 from above. Almost one kilometre long and visible from above in the shallow water of the bay. Picture: Otto Braasch, Landshut, Landesamt für Kultur und Denkmalpflege, Archäologie und Denkmalpflege, Luftbildarchiv, Schwerin.

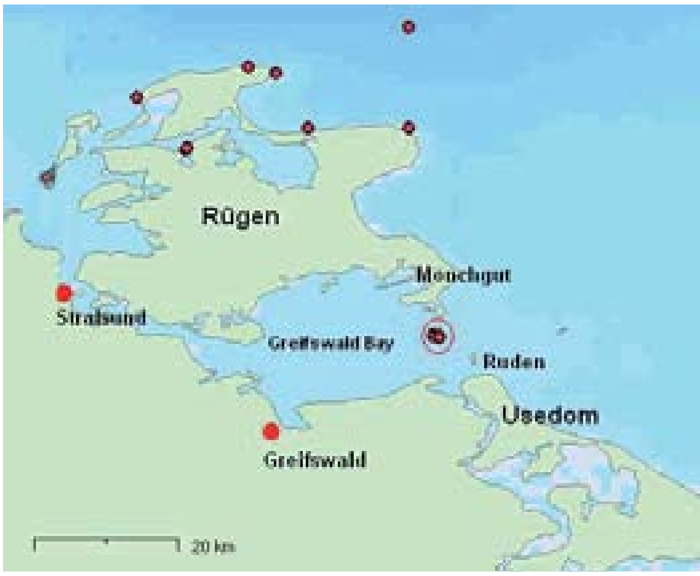


FIGURE 3 The MACHU showing the ship barrier of 1715 at the Eastern entrance of Greifswald Bay. Picture: MACHU Project GIS

FIGURE 5 Infrastructualconstruction work and archaeology in Wismar Bay. During dredging work for a sport boat harbour a 15th century ship wreck was found and excavated by the Authority for Culture and Preservation of Monuments (Förster 2000). Picture: Landesamt für Kultur und Denkmalpflege, Archäologie und Denkmalpflege Schwerin.

supremacy in the Baltic Sea during the Great Northern War, which lasted from 1700 to 1721. In this period the Russian Empire fought alongside Saxony-Poland and Denmark-Norway against the Kingdom of Sweden. During that time, Sweden ruled large parts of Pomerania. The fighting took place first and foremost in and around the Baltic Sea, reaching Pomerania in August 1711 when Danish troops entered the country from Mecklenburg. Later, these forces where joined by troops from Saxony and Russia, who outnumbered the Swedish troops. This forced the Swedish troops to concentrate on defending the fortresses of Stralsund and Stettin and the island of Rügen. The Swedish fortress of Stralsund was subsequently subjected to four sieges by the allied troops. The besieging armies had serious problems with supplies and the transport of heavy siege artillery. The harbour at Greifswald was at that time the place where the necessary artillery could be brought ashore, but it was still blocked by the Swedish, who had control over the Bay of Greifswald. After the fortress of Stettin was forced to surrender in September 1713, only Rügen and Stralsund remained in Swedish hands. The final siege of Stralsund began at the end of 1714.

This time, troops from Denmark, Russia, Saxony and Prussia, which had recently joined the conflict, tried to break the Swedish defences. The Swedish still had Rügen under control to defend the waterways giving access to the town of Stralsund from land using heavy gun batteries. This strategic advantage also prevented the landing of the urgently needed artillery. Heavy artillery was positioned at the narrow western entrance to the Strelasund between the mainland and Rügen, but the situation was more complicated at the Eastern entrance to the Bay of Greifswald. Guns were placed on the Mönchgut peninsular on Rügen, the small island of Ruden and at the NorthWestern tip of the island of Usedom. Between the Mönchgut peninsular and the island of Ruden natural shoals make the water very shallow.

In 18th-century sources these shoals are also referred to as the Ruden reef. Larger ships could only enter the bay via a few passages. One of these passages, known as the 'Mitteltief' (middle deep), was out of range of the land batteries.

For this reason, in 1715 the Swedish decided to block this passage with an artificial barrier to force every ship to pass into the bay within range of their guns. They requisitioned several small and medium-sized vessels from the harbours in the area, paying the owners a small amount of money for their property. The ships were loaded with cobblestones and sunk across the Mitteltief passage together with several large anchors.

In July 1715 the Danish fleet approached and attacked this defence system for the first time but they were beaten back by the artillery on the island of Ruden. The Swedish plan seemed to be working, but this was soon followed by another attack in September 1715. According to some historical sources, a local pilot who was treated badly by the Swedes defected to the Danes. He guided the Danish ships to a secret passage in the barrier. During the night, the Danish dragged their ships through the barrier using anchors that were brought out by the ships' boats. This sudden change in the situation caused confusion among the commanders of the Swedish ships in the bay. Some tried to flee towards Sweden, while others burned their ships to prevent them being captured by the Danes. The heavy siege artillery was then brought ashore at Greifswald harbour and positioned in front of the besieged fortress of Stralsund. In November 1715 the island of Rügen was conquered by a joined Danish-Prussian army.

The fortress of Stralsund surrendered in December 1715, just one day after the Swedish King managed to escape secretly from there to Sweden. After the war was over the barrier was slowly forgotten. The anchors were most probably salvaged but the shipwrecks with their cargo of stones remained a hazard to shipping until at least the mid-19th century. They were then forgotten for the next 150 years, until they were rediscovered in 1996 (see: Förster et al. 2002; Frost 2000; Krüger 2002; Scherer 2003).

MANAGEMENT AND PROTECTION OF UCH TODAY

The remains of the ships are regarded as a unique archive of local shipbuilding traditions in the late 17th and early 18th century. They are also an important European historical monument and as such have enjoyed statutory protection under the Monument Protection Act of the German state of Mecklenburg-Western Pomerania for the past 16 years. Until 1990 this part of Germany belonged to the territory of the former GDR. Diving in the coastal waters of the German Democratic Republic was very limited because of very strict border regulations. For this reason the underwater heritage remained almost undisturbed until the early 1990s. After the political changes, activities of all kinds increased in the waters of Mecklenburg-Western Pomerania, so legislation was urgently needed. Today the state's Monument Protection Act also covers our cultural heritage underwater *(figure 2)*. Furthermore, *figure 6* stipulates that the costs of any disruption to a monument and the related costs of maintenance, professional restoration, recovery and documentation of the monument must be borne by the party causing the disruption.

After the reunification of Germany an infrastructural network needed to be established in the East. The legislation proved its worth, because wherever building took place archaeological sites were found on land and under water *(figure 5)*. In the beginning, it was difficult to achieve acceptance of archaeology as a component of planning. Today the State Authority for Culture and Preservation of Monuments has a permanent role in planning processes for all construction activity in Mecklenburg-Western Pomerania and is widely accepted by the public.

One of the main tools for the management of cultural heritage underwater in the state of Mecklenburg-Western Pomerania is a GIS database for the collection of all available data. The data are drawn from historical archives, other water-related authorities, aerial photography, information from the public and the work of the Mecklenburg-Western Pomerania Society for Underwater Archaeology.

The Society for Underwater Archaeology is an association of sport divers and amateur archaeologists which works very closely with the Authority. Together with archaeologists, members of the society participate in surveys and small excavations. All data collected by the Society are added to the database.

The main source of data on potential archaeological sites in the waters of Mecklenburg-Western Pomerania is the aerial survey of the coast. Due to the geological conditions on the southern Baltic shore, soft sediments create long beaches and shallow waters with shifting sands.

These circumstances have caused many ships to founder on the shoals. Today the light sandy ground enables archaeologists to identify wreck sites from above *(figure 6)*. Shipwrecks and other anomalies down to a depth of six metres can be traced from a height of about 300 metres. Today the number of potential archaeological sites underwater in the database exceeds 1400.

MANAGING UCH, THE SHIP BARRIER

Fourteen of these sites form the ship barrier created in 1715. It remained undisturbed for

FIGURE 6 Many wreck sites along the coast of Mecklenburg-Western Pomerania are discovered by aerial survey. This wreck could be identified as the British Brig Water Nymph (1840/1875) due to archaeological work prior to planed beach restoration (Auer and Belasus 2008). Picture: Otto Braasch, Landshut, Landesamt für Kultur und Denkmalpflege, Archäologie und Denkmalpflege, Luftbildarchiv, Schwerin.

FIGURE 7 A geophysical survey was carried out at the site of the ship barrier in 2006. Picture: Mike Belasus, Landesamt für Kultur und Denkmalpflege, Archäologie und Denkmalpflege Schwerin.

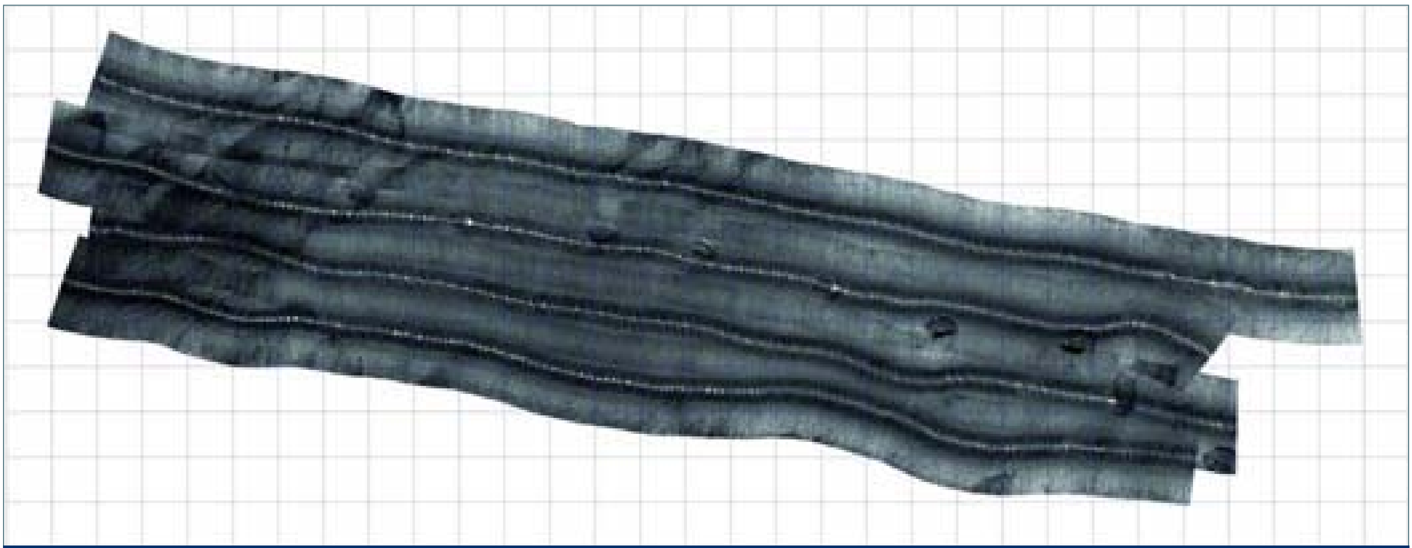


FIGURE 8 A side scan overview of a part of the ship barrier of 1715 in Greifswald Bay.
Picture: INNOMAR Rostock, Landesamt für Kultur und Denkmalpflege, Archäologie und Denkmalpflege Schwerin.

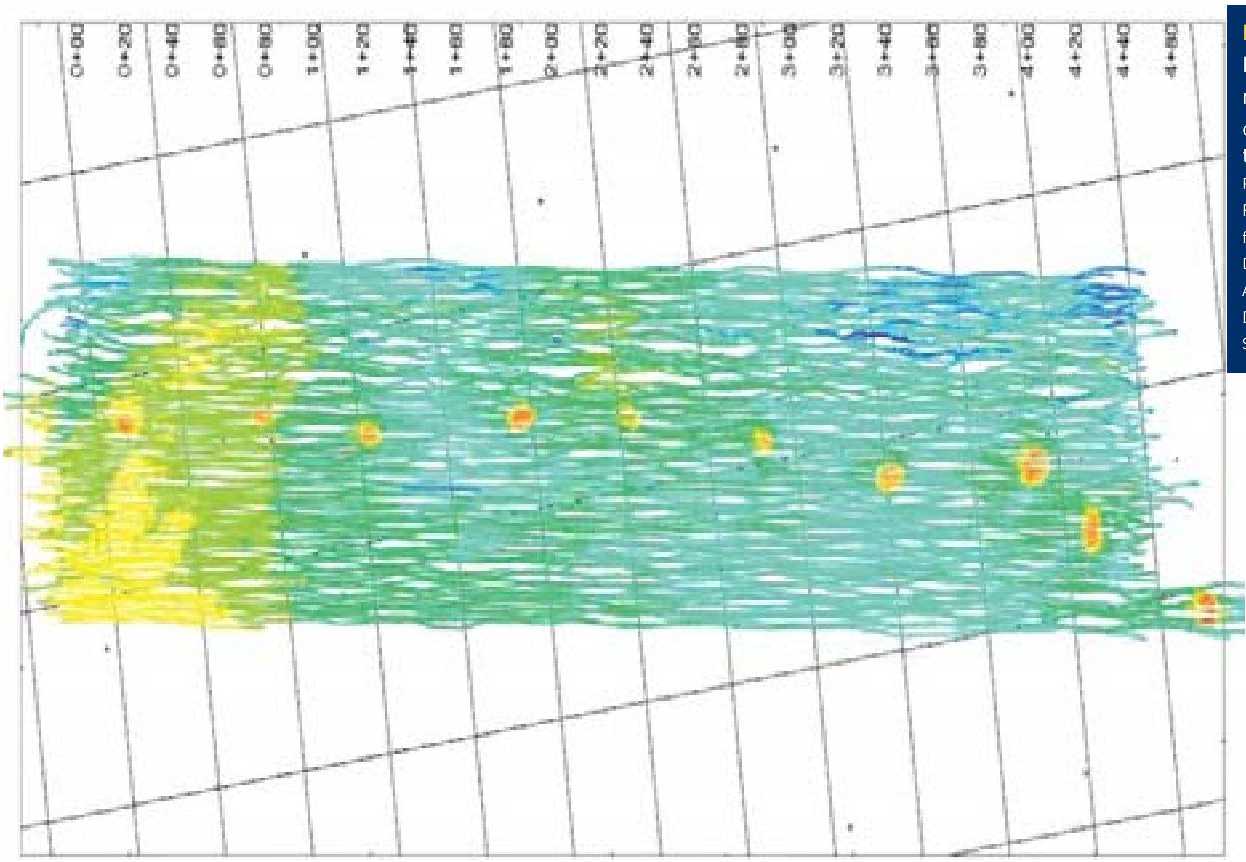


FIGURE 9 Bathymetric mapping carried out with seismic technology.
Picture: INNOMAR Rostock, Landesamt für Kultur und Denkmalpflege, Archäologie und Denkmalpflege Schwerin.

almost 300 years. However, given that the barrier is almost a kilometre long, and was created to close an important shipping passage, it was only a matter of time before it was disturbed by infrastructural works.

The pipeline planned as part of the North-European gas pipeline (NEGP, Nord Stream) will stretch 1220 km through the Baltic Sea, connecting Russia and Germany from Vyborg to Lubmin on the Bay of Greifswald. The modern shipping canal at the eastern entrance of the bay and nature reserves leave just enough room for the pipeline through the ship barrier. The planned construction of a double pipeline will have an enormous impact on the seabed. As in the other countries through which the pipeline will pass (Finland, Sweden and Denmark), the State Authority for Culture and the Preservation of Monuments in Schwerin, Germany, has been involved in the negotiations since the beginning. Necessary actions were planned at a very early stage, in consultation with the contractors. This included a survey of the entire pipeline route in German waters to identify any unknown potential archaeological sites and determine what archaeological activities would be needed. Thanks to the database, some areas of archaeological significance, like the ship barrier of 1715, were already known of beforehand and initial steps could be taken at an early stage.

EXCAVATION OF THE SHIP BARRIER

In 2006 a fieldwork campaign was launched to obtain more detailed information on the barrier in the area of the pipeline corridor. This campaign concentrated on geophysical and diving surveys of the wrecks *(figure 7)*. The goal was to find out if there was a possibility for the pipeline to pass the monument without causing any disturbance and, if not, how the disruption could be limited. For this purpose, side-scan data were gathered to give an overview of the sites *(figure 8)*. A seismic survey with two different frequencies was performed to give more information about bathymetry, the precise position and parts of the barrier that might be hidden in the sediment *(figure 9)*. Having considered all the data, it was decided one of the wrecks should be recovered to guarantee better protection of the adjacent wrecks. To keep the disruption to a minimum the smallest and probably most disturbed site was selected for excavation and recovery.

In 2008 a second fieldwork campaign was launched to gather further information from the site chosen *(figure 10)*. The site was documented in detail and test trenches were excavated *(figure 11)*. The examination of the site revealed the remains of one side of a ship 9 m long and 4.7 m wide. The wreck lies on top of the sediment protected only by a ballast mound of cobblestones. Most of the ship is gone. Parts of the outer planking, frames and ceiling planking have survived under the ballast, but there were no signs of the keel, keelson or posts. The hull of the vessel was made from oak using the clinker technique.

In summer 2009 the full excavation of the site was carried out and all timbers were recovered from the wreck. During the work it turned out that a second layer of planks joined butt edge-to-edge had been added to the clinker planking of the hull. For this purpose, the steps in the lap strake planking had been smoothened. While the planks within the strakes of the clinker planking were joined by 20 to 25 cm lashes, the planks of the outer carvel planking were butt-end joined within the strakes. Each timber was documented in detail on a 1:1 scale after recovery. Among the scarce finds were part of a leather shoe representing life on board and a bar shot as evidence of warfare (Heinze 2009).

After the recovery and detailed documentation the timbers now await reburial in an old water-filled gravel pit near Demmin in Mecklenburg-Western Pomerania, in order to preserve them for the future. An archaeological underwater museum is to be developed at this site where sport divers can also see the remains of other ship finds already stored in the artificial lake. To prevent a loss of information through possible accidents during the building process the adjacent wrecks of the barrier on both sides of the planned pipeline were documented *in situ*. During construction work in the vicinity of the monument the adjacent wrecks will be marked with buoys. Archaeologists will be on site to observe the proceedings. After the pipeline is finished the sites next to the pipeline will be surveyed. To preserve the visual effect of this unique monument for the public, the shape of the wreck site will be reconstructed to show the external appearance of the entire barrier as visible from the air before construction of the pipeline.

CONCLUSION

In the last few years public awareness of the underwater cultural heritage in Mecklenburg-Western Pomerania has increased. The data that have been collected so far suggest there is a vast archaeological resource beneath the state waters of the Baltic Sea. However, we have few details about the individual sites at this juncture. The little information we have clearly shows that there are sites of great significance for our understanding of the past. The fact that we do have some data is thanks largely to public involvement in the manage-

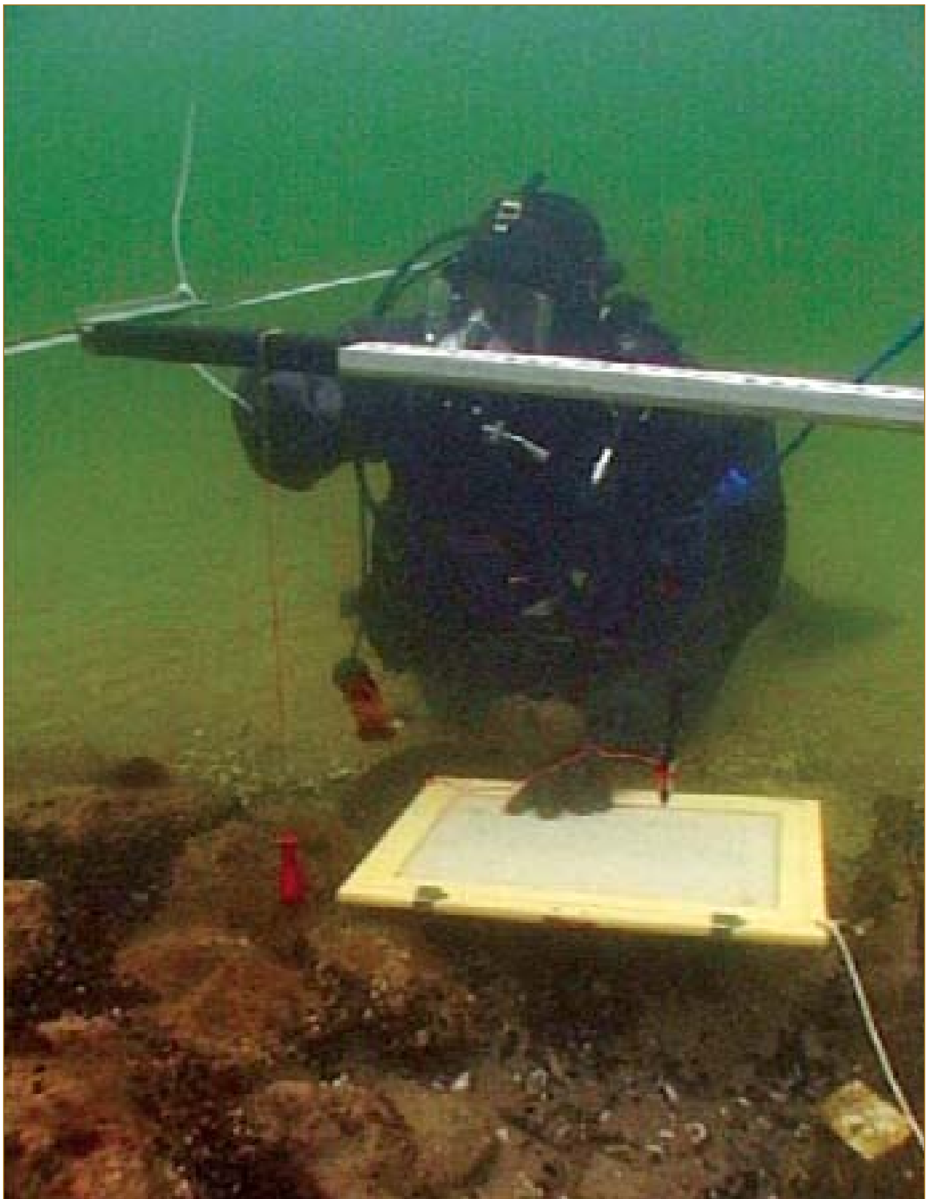


FIGURE 10 Detailed documentation of the site Mönchgut 67 chosen for recovery.
Picture: James McClean, Landesamt für Kultur und Denkmalpflege, Archäologie und Denkmalpflege Schwerin.

ment process. In a state without any regular funds for underwater archaeology, no permanent diving team within the authority and no scientific institution specialized in the underwater heritage, a regulatory link between infrastructural processes and management of our cultural heritage under water is essential. Today, archaeology – even underwater archaeology – is a permanent feature of the infrastructural planning process throughout the state and is widely accepted by the public.

The ship barrier of 1715 is a good example of how this synergetic effect can work. Besides practical work on site presentations for the public, information was also disseminated to the media and articles prepared. This was always supported by the contractors, and made people understand the importance of the past and their own history and culture. Furthermore, new data will continue to be collected and made available for archaeological and historical research. To keep this system of awareness and acceptance running, permanent contact must be maintained with the public and decision-makers. At times of economic recession, this will be no easy task.

A site like the ship barrier in the Bay of Greifswald consisting of several wrecks from one period and one place is scientifically important not only for Germany but also for other countries in Europe. The data acquired during the research have therefore been integrated into the MACHU GIS and made accessible to a larger group.

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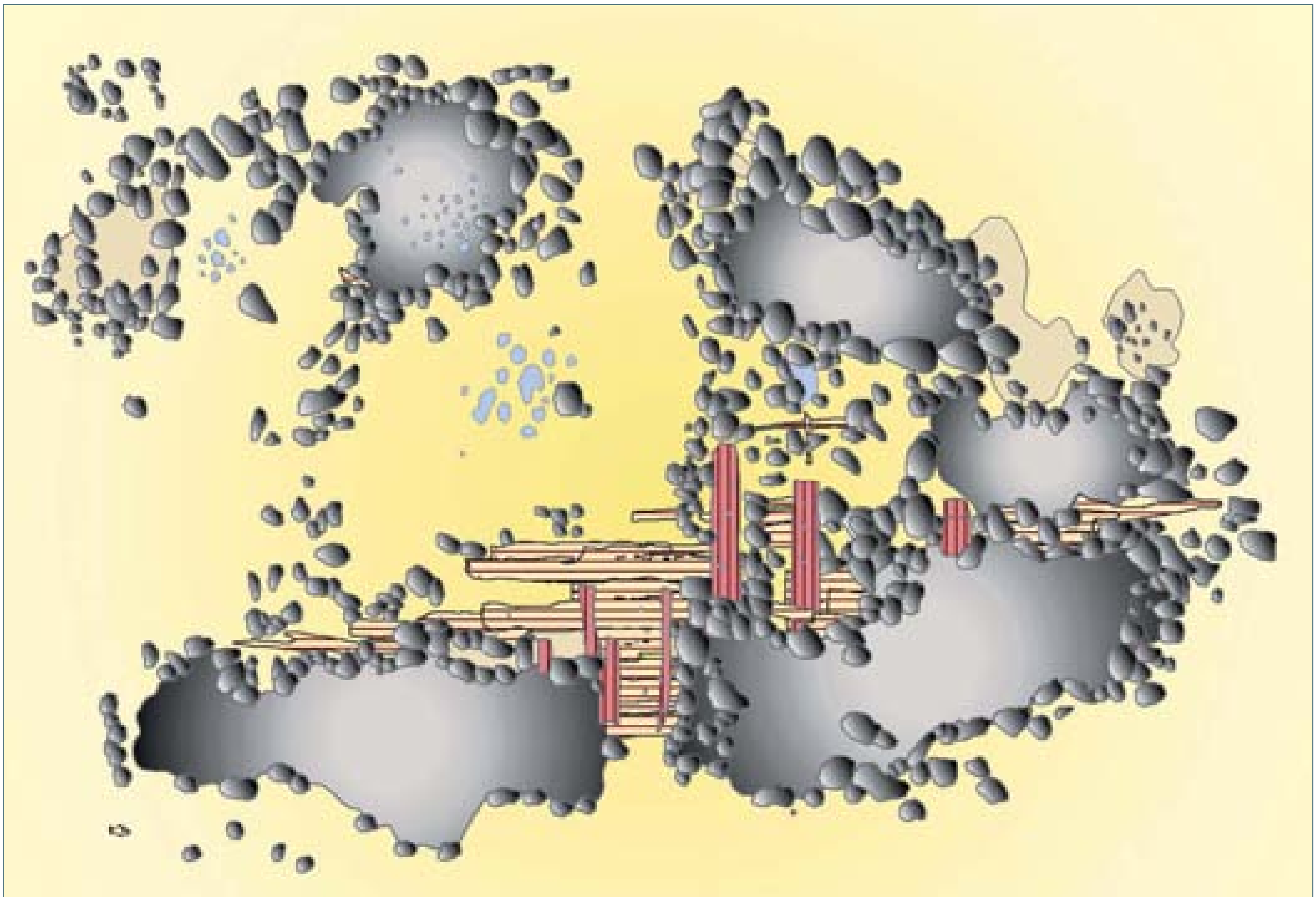

FIGURE 11 Plan of the wreck site Mönchgut 67. Frederik Feulner, Landesamt für Kultur und Denkmalpflege, Archäologie und enkmalpflege Schwerin.

An investigation of the wreck of an eighteenth-century ship

The 'Buiten Ratel' case study

FIGURE 1 Marine plants, including *metri-dinum senile*, cover most of the exposed parts of the shipwreck. © VIOE

The wreck of an eighteenth-century wooden vessel located in the MACHU Project 'Buiten Ratel' test area (so called as a result of its proximity to the Buiten Ratel sandbank) has become known as the 'Buiten Ratel wreck'. The 'Buiten Ratel' test area occupies 225 square kilometres in the western part of Belgium's territorial waters and contains 21 known wrecks or wreck sites of archaeological interest[1].

The 'Buiten Ratel' wreck lies nine miles off-shore from Nieuwpoort at a depth of between seven and eight metres GLLWS (average low water level at spring tide). The wreck was frequently but irregularly visited by a group of amateur divers from 1996 onwards. These divers belonged to a non-commercial association called North Sea Archaeological Team Aquarius (NATA). They collected numerous artefacts from the wreck, including pottery, weapons, tools, kitchen utensils, personal items, and wooden objects. Although the presence of certain prominent elements such as anchors and a large wooden beam were noted, no systematic observations were made regarding the wreck as a whole.

The site was selected by the VIOE for investigation for a number of reasons: the presumption that the wreck of an eighteenth-century wooden vessel would be of research interest, the rarity of such a site (no similar example is known in Belgian waters), the wealth of artefactual material; divers' familiarity with the site, and the presence of threats to the wreck, both from human interference and from the natural environment. There were also a lot of gaps in the knowledge of the condition of the shipwreck and the need for preservation of the artefacts.

FIGURE 2 Measuring an anchor shank, 30 July 2008. © VIOE

In collaboration with a number of institutions, researchers, and divers, the VIOE set up an investigation programme, carried out in 2007 and 2008, which involved:

- a site survey to gather information regarding the state of preservation of the wreck and to identify threats to its survival;
- the capture of a picture of the site by means of seismic imaging techniques (see 67);
- sediment sampling and analysis (see 56);
- multidisciplinary research into the artefacts taken from the wreck in order to assess the ship's origin and wreck date.

SURVEY OF THE WRECK SITE

In the course of 2007-2008, the VIOE carried out seven diving expeditions to the wreck[2]. The VIOE dive team was fortunate enough to enjoy the assistance and expertise of experienced North Sea divers, who participated in the project on a voluntary basis. The diving survey was intended to gather information on:

- general diving conditions;
- the size of the site, including the height to which the wreck protrudes above the sea-bed;
- orientation and description of the wreck, as well as of its more prominent features, and of remaining artefacts;
- the state of preservation of the wreck;
- the extent to which the wreck is exposed;

- marine life at the site;
- general observations of the site.

Diving conditions were generally difficult. For the most part, visibility varied between 0.2m and 2m, with 6m being the best recorded. On two occasions survey work could not proceed because visibility was too poor.
The wreck protrudes to a height of approximately 1.5m from the seabed. During one dive the extent of the wreck was measured at 150m^2 (10m x 15m), although this measurement remains to be verified. The wreck lies in a SE-NW orientation, and it is assumed – on the basis of the position of three anchors – that the bow is pointing towards the coast and towards the edge of the Buiten Ratel sandbank.

Exposed elements of the wreck include a wooden beam (0.4m / 0.5m by 8.8m) lying along the length of the wreck with a small 'kidney'-shaped impression (0.3m-0.4m). Other wooden planks are also visible. Two large anchors have been identified, although one of them remains partly buried. A smaller anchor lies underneath one of the two larger anchors. At its northwestern end (thought to be the stern) the wreck is more completely buried in the sand of the seabed. The timbers appear to be well preserved, although closer investigation is required. Some lead bullets and bar shot, which had become encrusted together, were found next to the long wooden beam.

Potential threats to the wreck were monitored in the course of the diving survey. Parts of the wreck were more exposed at times, notably in August 2007 and February 2008. The figure of 150 square metres proposed for the surface area of the wreck[3] corresponds to the part of the site which is generally exposed and therefore most easily recognisable for divers.
The exposed parts of the wreck have been colonised – and largely covered – by sea creatures, including sea dianthus *(Actiniaria)*, sea anemone *(Metridinum senile)*, and polyps. A large number of fish have been observed at the site. There are only a few fishing nets snagged on the wreck.

The wreck sits on rippled sand, although there is an area to the southwest of the wreck which is scoured by the current. There is a sand extraction zone some 3.5 - 4km to the north east of the wreck site,[4] but this presents no direct threat. Sediment samples were taken from inside and outside the wreck (see page 56).

In addition to the gathering of this information, the site was used as a test area for an undergraduate research project investigating the corrosion of different metals in a wreck.[5] The project involved the installation of samples of five different metals in the seabed and above the seabed at the wreck site. After a period of two months all of the samples which were recovered bore traces of corrosion. This project may provide a useful starting point for the further investigation of the impact of marine conditions on metal objects.

The diving survey provided a useful means of identifying threats to the wreck and permitted monitoring of the site over a period of time. Poor visibility under water emerged as the most significant factor hampering the survey work. It was observed that the extent of the exposed section of the wreck varies. It is hoped that greater understanding of sedimentation-erosion processes at the site will emerge from a doctoral research project being undertaken – using the Buiten Ratel wreck as a study area – by Matthias Baeye of the Renard Centre of Marine Geology at the University of Ghent (RCMG – see below)[6]. Much of the exposed part of the wreck is covered by marine plants. The surviving timbers of the wreck seem reasonably sound, but one must also take into consideration the exposure of the wreck to erosion and to potentially damaging marine life[7]. Such factors as these need to be given further consideration before conclusions are drawn regarding the site as a whole.
A significant variety of marine life has been recorded at the site, ranging from plants to fish. Many of these seem at first sight to pose no threat to the wreck, but their presence may restrict assessment of its extent and condition.

The wreck site was measured as covering an area of approximately 15 metres by 10 metres. The ship itself must have been longer than 15 metres. It is probable that much of the wreck is buried, and this hypothesis is supported by observation of the stern (at the northwestern end of the site) and of the anchors. It seems likely that the 150 square-metre area represents the part of the wreck most frequently exposed above the seabed, or covered by only a thin layer of sediment. The seismic survey carried out at the site seems to support this hypothesis (see below).

MULTIBEAM AND SIDE-SCAN SONAR SURVEY OF THE BUITEN RATEL WRECK SITE

In 2007 a multibeam survey was carried out over the wreck site by the Flemish Hydrographical Service (Coast Department, Agency for Maritime and Coastal Services). The multibeam image, taken using an EM 3002, shows that the wreck extends over an area of 11m by 13.5m, but that it is in two

FIGURE 3 Samples of different metals were buried at the wreck site in an attempt to measure rates of corrosion. © VIOE

pieces. The partly exposed anchor is clearly visible on the multibeam image. The side-scan sonar image, produced using a Klein 3000 is less clear. This could mean that the wreck was buried deep below the sand. The Fund for Sand Extraction (Federal Government Economic Service) has also carried out multibeam survey work on the wreck and in the surrounding area.

The multibeam and side-scan sonar imaging was complemented by imaging based on high-resolution acoustic techniques undertaken by the RCMG at the University of Ghent, one of the project partners. Detailed results of this survey are set out in section on page 67. The general findings were that the wreck site is buried under a layer of sediment of between a few centimetres and half a metre in depth. The sediment that covers the wreck is soft, like silt or mud, in contrast with the sandy sea bottom on which the wreck rests.

SEDIMENT SAMPLES

As well as the sedimentation-erosion study, work was also carried out at the RCMG (in collaboration with the Department of Marine Biology at the University of Ghent) on the sediment samples taken from wreck sites investigated in the context of the MACHU Project. Six sediment samples were taken at the Buiten Ratel site, four from outside and two from inside the wreck itself. True grain size analysis was performed on the samples using the Mastersizer Malvern 2000. and it emerged that there was indeed a marked difference between the sediments inside and outside the wreck.

ARTEFACTS FROM THE BUITEN RATEL WRECK: A MULTIDISCIPLINARY ANALYSIS

The collection of artefacts which had been recovered from the site of the Buiten Ratel wreck before the MACHU Project began formed the subject of a multidisciplinary investigation which yielded significant information regarding the origin of the ship and the date on which it sank[8]. Among the artefacts were objects made from a range of materials which would have served a range of purposes. They included parts of the ship; sailing tackle and stores; weapons and ammunition; cargo; personal items; fragments of artefacts; and objects of unidentified function. Analysis was undertaken by specialists in areas including archaeology, history, natural sciences, and food science.

The artefacts themselves, including clay pipes, glass objects, iron tools, weapons, ammunition, and pewter objects, were studied by the appropriate experts. Most of the artefacts were dated to the mid-eighteenth century. Additional dating evidence came from dendrochronological analysis of wood from three barrels. The most recent of the felling dates identified for the trees used to make the barrels was 1735. Investigation of stamps on several objects and of stylistic elements of a gold pocket watch from the wreck site has led to the identification of 1741 as the earliest possible year for the sinking of the ship.
Coal taken from the wreck was examined by the Laboratory of Palaeobotany, Palaeopalynology and Micropalaeontology at the University of Liège, and it was discovered that it had been mined in England.

An onion-shaped glass bottle which was recovered from the wreck contained a fluid which was sent for analysis to the Department of Nutrition and Food Science at the University of Barcelona. The fluid was found to be white wine, although its origin has not been determined.
A clump of red metallic material was analysed and found to be cinnabar. It could not have been used on board in this form, as it would need to be processed into a powder, which was used as a dye in the eighteenth century.

Numerous objects found at the wreck site suggest that the vessel may have had a link with the Netherlands. They include, for example, a gold pocket watch from Amsterdam; a tobacco box with an inscription in Dutch; clay pipes from Gouda; and two pewter spoons from Amsterdam. Parallels have been proposed with the groups of artefacts found in the wrecks of the 'Hollandia' and the 'Amsterdam', and also with the items listed in an inventory of equipment for an eighteenth century ship from the Dutch East India Company (VOC). These parallels suggest that the Buiten Ratel wreck may have been of similar origin and date.

The investigation of the artefacts demonstrated that the ship cannot have sunk until 1741, and produced evidence suggesting that she was from the Netherlands. The significance of the wreck is apparent even from the dating evidence alone, as it reveals the wreck to be among the earliest to be studied in Belgium to date.

CONCLUSION

The various surveys carried out at the wreck site during the MACHU Project, together with the study of existing data and material which had previously been recovered, have yielded a considerable body of information about the wreck.

FIGURE 4a-b Pewter spoon and detail showing the mark indicating manufacture in Amsterdam, one of the clues suggesting the origin of the ship. © VIOE

The main threat to this site comes from its own natural environment. The wreck is not in fact in immediate danger from such activities as sand or gravel extraction, but sections of it are exposed above the seabed and are therefore subject to erosion caused by the movement of the water and of the sediments it carries. Analysis of one of the barrel staves showed that there may also be / have been a threat from Teredo *navalis*.

The large collection of artefacts already recovered from this and other wreck sites, together with the general awareness and interest that this brings, make the Belgian North Sea an attractive area for wreck divers. An important part of the VIOE's role is therefore to promote awareness among the diving community of the problems which can arise as a result of the retrieval of artefacts without contextual information, and without the resources and knowledge necessary for conservation. Protection and further scientific research *in situ* are needed for better knowledge of the site.

The wreck needs to be monitored in order more fully to assess its state of preservation, observe its varying exposure on the seabed and monitor its degradation. A programme for the monitoring of the sedimentation-erosion process (cfr. page 48) and an interpretation of the preliminary results of the seismic imaging of the wreck and its surroundings (cfr. page 67) are presented later in this report. The wreck site itself remains the subject of study, in collaboration with specialists.

NOTES

[1] Demerre & Pieters 2008: 15-16.
[2] www.maritime-archaeology.be & Demerre 2008: 21, 24-25.
[3] VIOE 2006: Database Maritime Archaeology online: www.maritime-archaeology.be (consulted 10th August 2009).
[4] The sand extraction zone is situated 3.5 - 4 kilometres northeast of the site.
[5] Biront 2006-2007.
[6] Page 56-58 this volume.
[7] Such as the teredo navalis, traces of which were discovered in one of the wooden barrels recovered from the ship by NATA divers (Zeebroek et al. n.d.)
[8] Based on the preliminary results of these studies, to be published at a future date (Zeebroek et al. n.d.).

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FIGURE 5 Dendrochronological analysis of wood from a barrel provided a terminus post quem of 1735 for the sinking of the ship. © VIOE

FIGURE 6 Clump of cinnabar found in the wreck. © VIOE

Cooperation between the government and amateur archaeologists in Zeeland

Almost archaeology...

The southwestern part of the Netherlands, Zeeland, like most areas of the Netherlands, has always been influenced by the sea and its tidal regime. The river Scheldt has always been an important route for maritime traffic to the inland cities of Western Europe. In the past the outlet was the Eastern Scheldt; in more recent times, the Western Scheldt. Besides an abundance of shipwrecks, the waters of Zeeland also yield enormous numbers of other archaeological/historical sites. They range from lost cargoes and aircraft wrecks to submerged terrestrial structures such as buildings, dikes and even whole villages, inundated as a result of fluctuating sea levels and flooding caused by storms.

Considering the high potential for archaeologically interesting sites in this area, the Cultural Heritage Agency (RCE) was very interested when the Directorate-General for Transport and Public Works (*Rijkswaterstaat* - RWS) in the Zeeland area contacted it in mid-2009 to say that intriguing structures had been found at the bottom of the Eastern Scheldt. This new site was found by monitoring the topography of the seafloor. Because of the dynamic nature of the sea bottom due to the high velocity of the tidal flows, RWS checks the shipping lanes regularly using single- and multibeam recordings. New recordings in the vicinity of the Eastern Scheldt storm surge barrier (which closes the Eastern Scheldt estuary to prevent flooding) showed clear man-made structures. These large structures with a length (NW-SE) of 87 metres and a total width (NE-SW) of 85 metres had emerged because of erosion in the area. With these large rectangular structures at the edge of a river outlet known to have been used in the past, and the submerged Roman temple of the local goddess Nehallenia approximately 6.5 kilometres east of this location, a lot of people hoped they would turn out to be the remains of a possible Roman harbour.

The RCE decided to investigate the site in collaboration with a local group of amateur archaeological divers. The cooperation between local archaeological communities and the RCE is part of a deliberate policy to integrate amateur archaeologists into cultural heritage management and give them a role as caretakers, and the ears and eyes of underwater archaeology in their region.
In spite of the restrictions and preference for in situ preservation, amateur archaeologists can still be helpful in archaeological research. The task of the RCE as a central administrative body is to obtain a general overview of archaeology (including maritime archaeology), check the quality of observations/reports and devise suitable policies for the protection of the cultural heritage. But the RCE also improves the quality of the observations made by the amateur community in a number of ways:

- In collaboration with the Dutch Society of Avocational Underwater Archaeologists (LWAOW [cf. national practice Nederland]), the RCE runs courses on underwater archaeology, equivalent to the NAS I and NAS II courses in the UK.[1]
- The RCE agrees procedures and roles with the various stakeholders (governmental and non-governmental) involved in the management of underwater cultural heritage management.
- In association with the course on underwater archaeology, RCE archaeologists join amateurs at different sites to give them on-site instruction.

The collaboration between the RCE and the Nehallenia Archaeological Diving Team and the Roompot Wreck Diving Association (WDSR)[2] are good examples of how regional archaeological communities participate in research into their local cultural heritage. Both diving teams are part of the LWAOW and have collaborated with the RCE in the past. By way of a contribution to the MACHU project, they investigated several wrecks and performed hundreds of dives in Zeeland in order to monitor the different sites.[3]

Since the site with the intriguing structures is located in the official shipping lane and near the storm surge barrier, a lot of agencies needed to give their authorisation for the proposed diving activities. The Cultural Heritage Agency notified the different partners and obtained the clearances needed. This first prospection would be a short project

FIGURE 1 The province of Zeeland in the Netherlands.

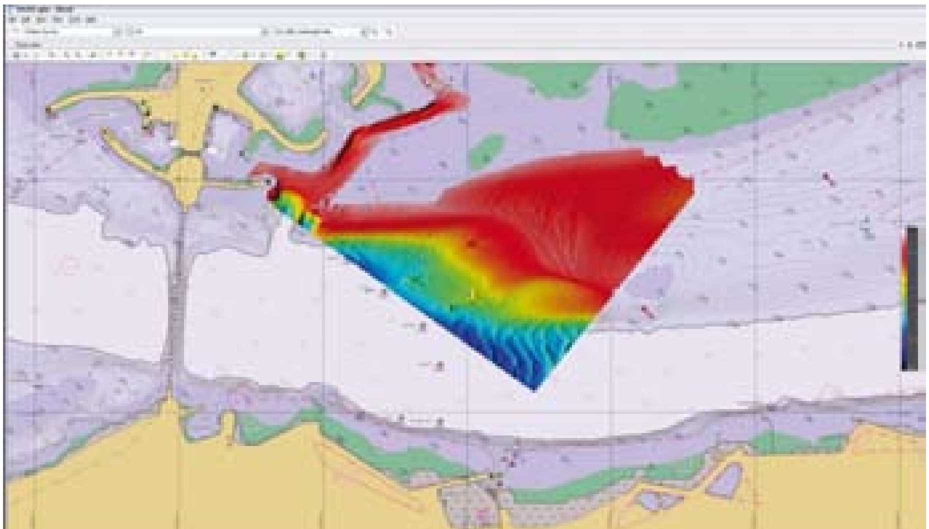

FIGURE 2 FIGURE 2: The area of the site in the Eastern Scheldt. Source: RWS.

involving the Cultural Heritage Agency, RWS, the Archaeological Agency of the Province of Zeeland (SCEZ), the shipping control operators in Wemeldinge and the local diving community.

Apart from the hazardous location, the currents and the notoriously bad visibility make this site difficult to examine. Another complicating factor is the weather. Strong winds, high waves (mainly with N - NW winds) and currents restricted our opportunities for examining this newly-found site, and it is always up to the captain of the ship to give the go or no-go (mostly just 12 hours beforehand).

We were finally given the 'go' for our investigation on a Sunday, with a light wind (force 1 to 2), clear sky and a slack tide, so there would be a minimal current. The exact position provided by RWS and the availability of Humminbird side-scan sonar equipment on the ship – owned by the amateur archaeologists – made the fairly large site easy to find. The depth reader showed an average of 15m and the ship dropped anchor in the middle of the site.

After the standard safety procedures (anchor sign, alpha/diving flag, notification of the shipping control operators, diving safety procedures, emergency procedures, equipment checks, equipment rechecks…) a diving team consisting of an RCE archaeologist and a local diver jumped into the water and started their descent to the bottom. The current was not so strong and the visibility fluctuated between good (3m) and bad (0.15m) depending on the changing currents. On arrival at the seafloor we hooked our reel to the heavy anchor chain and started our exploration, swimming circles of different diameters centred on the anchor chain. The undulating topography consists of a succession of sand plains and fairly high dunes (up to 2 metres), but we came across the much-discussed obstructions fairly quickly. They were protruding 0.2m to 0.5m from the seafloor and were made of… jute canvas and concrete triplex! We thoroughly investigated the area for the next hour at a depth ranging between 18m and 14m. Although the site was clearly man-made, there was no doubt that it was recent.

Later meetings with RWS revealed that, when the storm surge barrier was built in the 1970s, they first laid a 'carpet foundation' of concrete triplex and jute filled with sand. Before actual work started on the barrier, they tested the system with an experimental run some distance away, which actually showed up almost 40 years later.

We were just a few decades too early: in the Netherlands the legislation on monuments and historic buildings stipulates that a site or object is part of the cultural heritage if it is more than 50 years old and of particular cultural or historical importance.[4]

This is in contrast to the UK, where there is no age restriction and sites like this can be regarded as part of the cultural heritage.

This is nevertheless a good example of how government agencies and local diving communities/amateur archaeologists can work together on the management of cultural heritage. This project also demonstrates how unpredictable archaeology can be!

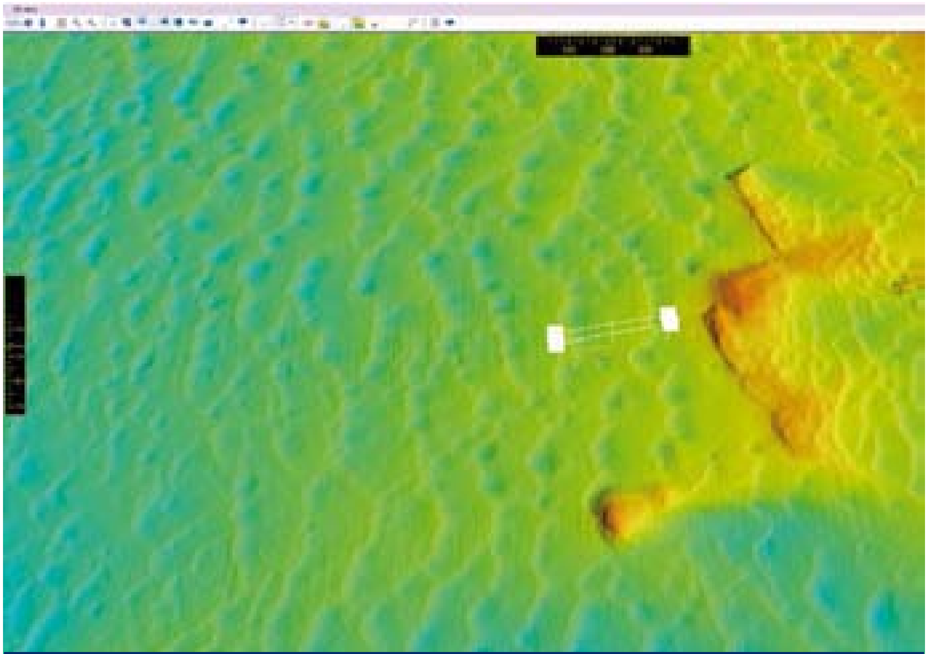

FIGURE 3 A multibeam image of the site showing clear man-made structures. Source: RWS

FIGURE 4 Collaboration between amateur divers of the Nehellenia Foundation and the RCE: divers prepare to go into the water. Photo: Will Brouwers

NOTES

1 www.nasportsmouth.org.uk/ and www.lwaow.nl/

2 For more information on these local archaeological diving teams go to: www.nehallenia.com/index.asp and www.wdsr.nl/

3 See the MACHU website for an impression of a day with the diving team and a MACHU team on a monitoring trip this summer (www.machuproject.eu/documenten/Machu%20-%20Eastern Scheldt.pdf). Also see Machu Report No. 2, Will Brouwers, Test areas Burgzand Noord and the Banjaard.

4 See the Legislation section of the MACHU website at www.machuproject.eu/legislation.htm ■

MACHU and the Genealogy of the Portuguese Underwater Cultural Heritage Inventory

Memories of the present

In 1959, when I obtained my first scuba diving permit on the very first course given in Portugal, I was far from its long term consequences and I had no idea what it would lead to. The reason was that the last test dive of the course was near to the Lusitanian-Roman site of Troia in the mouth of the Sado river, twenty miles south of Lisbon, the largest and most important western and Atlantic centre for fish processing in the Roman world. This was also the first dive made in Portugal for archaeological purposes. Manuel Heleno, Director of the Portuguese Museum of Ethnology (now the National Museum of Archaeology), supervised the fieldwork, in spite of being a non-diver, as Lamboglia and Benoît had some years earlier, in the very early days of Euro-Mediterranean underwater archaeology. It was an unforgettable dive amidst a forest of amphorae and shards, which soon unfortunately became a desert, as commonly happened throughout the north Mediterranean coastal region over the following two decades.

The memory of this dive has stayed with me ever since, and has made me ponder the question: how can we perpetuate, share and manage these memories?

I found the answer in Paris in the early 1970s, when Olivier Büchsenschutz, Assistant Professor of Archaeology at Jussieu and Michelet Paris VII University (today Paris I), invited me to integrate the 'Carte Archéologique du Cher' project team (with Jean Dorion and Armelle Querrien). This project aimed to catalogue the archaeology of France, in the early years of computing in archaeology. It was in fact a pioneering, high-profile project which began with the systematic collection of site data, mainly from Buhot de Kersers's Statistique Monumentale du Cher. To this were added aerial photographs that had

FIGURE 1 The author with Maria-Luísa and Jean-Yves Blot at MNA in the 80ies of the 20th century. PHOTO: DANS

FIGURE 2 World map with Portuguese shipwreck locations. PHOTO: DANS

already been interpreted, and field plans based on military maps on a scale of 1:25 000. Two teams of archaeologists driving old Renault 4s belonging to the IGN (Institut Geographyque National) then spent two weeks a month visiting each canton of the Bourges region to carry out detailed investigations. The other weeks were devoted to desk work in Paris, organising the data collected in the field, which were finally stored on perforated cards used by the giant IBM computers at Paris' Faculté de Droit, near the Panthéon National.

The fieldwork always began in the archives of the Musée de Bourges, the main antiquities institution of Cher provincial capital, to complete the project data for each canton, site-by-site, in a rigorously selected order. The nest step was to drive to the mairie of each canton to analyse the Napoleonic cadastral map (the world's oldest, completed in 1812). This analysis had two objectives: first, to collect all data concerning significant ancient toponyms, topography and roads, and to make copies on transparencies of all selected topological, toponymic and geographical details; second, to compare it with the current cadastral map and make selected photocopies, all this new data being incorporated into 1:25 000 map. Then, interviews were conducted, to collect information from shepherds, hunters, antiques collectors, physicians and old families in the canton. They were easily contacted through local bars (les bistrots du coin). Once this preliminary phase was complete, our cantonal data archive was updated, and the field visits planned.

The field visits were always unforgettable experiences, which always resulted in sketches, drawings, plans, photographs and topographical data. As a result of this 1974 mission, 40% more archaeological sites were discovered, and for each one of us, this phase of the project was a memorable scientific and human experience.

From 1976 to 1980 I led the first Portuguese archaeological urban rescue project at Braga town, the Octavian Bracara Augusta (which led to the creation of the first large permanent professional archaeological team in Portugal). For a number of reasons, this work was extended to sixteen surrounding municipalities in this province north of Oporto, bordering the Galicia region of Spain. This was another unforgettable experience, in which we tested and adopted a fiche filing card for archaeological sites and data inventory, literally adapted from the model used in the Carte Archéologique de la France project. Some years later, it came as no surprise to learn that this filing card model had been adopted by everyone in the Portuguese archaeological community.

In 1980, when I was invited to direct the National Museum of Archaeology (MNA), marking my return to my home town after a fifteen-year European 'pilgrimage', I immediately introduced two new areas at this hundred-year-old institution: palaeoecology and nautical and underwater archaeology, headed by José Mateus (Utrecht University PhD) and myself, respectively. The first initiative undertaken in the latter area was the launch of a national underwater cultural heritage inventory, which over the years was fortunate enough to enjoy input from Jean-Yves[1] and Maria-Luísa Blot[2], Paulo Monteiro[3], João Pedro Cardoso and Patrick Lizé, and also involved the creation of specific infrastructures, both home-based and field-targeted (file archive, library, lab conservation for artefacts from wet contexts, survey and excavation equipment and logistics). In fact, it was a national centre for nautical and underwater archaeology avant la lettre, with very close ties with the scuba diving community. This public, open style of management at the MNA led in 1992 to the creation of a specific ONG, Arqueonáutica-Centro de Estudos, which had a fundamental role in educating the public and raising awareness of the underwater cultural heritage, a role that became decisive during the public debate on the treasure hunting law introduced in 1993. Fortunately, this legislation was revoked in 1995, anticipating Portugal's ratification of the UNESCO Convention on the Protection of Underwater Cultural Heritage in 2006, and meanwhile leading (in 1997) to the creation of the CNANS as part of the Minister of Culture's new Portuguese Institute of Archaeology.

During those fifteen years at the MNA the national underwater cultural heritage inventory collected around 4,500 records of artefacts and site references, from both archaeological and written sources, mainly since the Age of Discovery (*figure 1*). The data came from two different sources because they referred either to underwater cultural heritage remains in Portuguese waters or to Portuguese ships lost in other parts of the world (*figure 2*). In fact, the national underwater cultural heritage inventory records shipwrecks of 47 flags in Portuguese waters, and Portuguese ships lost in the waters of 54 countries on all continents.

The four tools used for the CNANS/DANS inventory were:

1 The 'new register', an official classified book in which each line corresponds to an entry (a site context or a single find with no located site context) and which has some basic shot descriptors: number, name (if available), date or chronology, brief description, operator and observations (*figure 3*).

2 The fiche filing card system, directly adopted

from the Carte Archéologique du Cher model, obviously with appropriate and specific fields (*figure 4*).

3 The 'corresponding-to file', which includes all related documents or notes in other archives (*figure 5*).

4 The database, whose fields correspond more or less to those of the fiche filing card system (*figure 6*).

At the MNA there was also a single large wall panel with a map showing the whole of the southern Algarve on a 1:25 000 scale, covered by PET film onto which numbered tags (corresponding to the inventory) were glued (*figure 1 and 2*)[4]. This first phase of the inventory (MNA) can be considered almost quantitative, even though it did allow some initial qualitative analysis[5].

of CNANS, the number of records has doubled (to approx. 9,200). This has allowed us to raise our level of ambition, but it has also revealed the limitations, making us aware of the fact that we need to migrate to a GIS environment. This has thus become a prime objective in terms of national heritage management. Nevertheless, the present phase can already be called qualitative, in two senses, due to the interactive relationship between the basic management aim (underwater cultural heritage management and protection) and the research background[6]. Recently this need improvement took on extra urgency in Portugal with the advent of a government agenda based on an interministerial approach to the management of maritime resources, both natural and cultural[7].

In this sense, in spite of the difficulties at CNANS/DANS in recent years, their participation in EU projects like FEMAM, ANSER, ArcheoMed, MoSS[8] and, more especially, MACHU has provided important opportunities to share experiences for the upgrading of Portuguese underwater cultural heritage management. And the challenge was ultimately a very positive one.

NOTES

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[3] IPA was replaced in 2007 by IGESPAR (Instituto de Gestão do Património Arquitectónico e Arqueológico, I.P.), and CNANS by DANS.

[4] Alves, F., [2001], *Para uma Carta Arqueológica do património náutico e subaquático em qualquer parte do mundo. Arqueología Subacuática - II Jornadas Latinoamericanas - Inventarios y Cartas Arqueológicas aplicados al Patrimonio Sumergido* (Santiago de Chile, 22-24 de octubre).

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[7] In the framework of several national project groups, continental shelf research (EMEPC), maritime security (CIAM-GT Surveillance), and development of a GIS based on a sustainable and coordinated perspective of maritime space management (POEM).

[8] For which the author was an external auditor. ■

FIGURE 3-6 The Portuguese UCH inventory in CNANS: The registration book (1st), fish filling card (2nd); documentation archive (3rd); data base (4rd). PHOTOS: DANS.

Geophysical and geological missions conducted in 2009 in the context of the EU-MACHU Project

DANS, the Portuguese partner in the MACHU project, has conducted a number of field missions in the Ria Aveiro with the aim of monitoring the Aveiro A, B, C, D, E and H wreck sites and verifying silting levels at each site to find out if there was any threat of erosion, as well as to identify any hitherto undetected anthropogenic threats. The first mission described here was executed on 10 and 11 March 2009 by Hélder Tareco, a geophysics expert, and Miguel Aleluia, a DANS assistant archaeologist. They used a 6.2m fibreglass cabined boat, the Circe, adapted for geophysical surveying, and a Klein side-scan sonar to scan the seabed.

The survey of the Ria de Aveiro sites B, C, D and H began at low tide, in ideal conditions. Due to the absence of wind, the Ria was a mirror, which obviously facilitated navigation, especially as it is usually very difficult to drive a boat at slow speeds due to the local tide flow in the Ria channels. Several trails could be covered at sites B, C and D, giving total coverage without any problem. Special attention was focused on the Ria de Aveiro H site ('Tile Boat 1')[1], which is very difficult to capture on sonar due to its special environment characterised by a tile tumulus obscured by molluscs and algae.

Ria de Aveiro sites A and E were surveyed at high tide because they are almost exposed at

FIGURE 1 The survey vessel 'Circe'. PHOTO: DANS

FIGURE 2 Survey of the Ria de Aveiro sites at low tide. PHOTO: DANS

low tide (usual tide amplitudes in Portugal are approx. 3 to 3.5m) and the higher water level gives the best sonar performance.
This side-scan sonar mission showed no clear unsilting of the sites, nor any threats related to this as yet. Nevertheless, at Ria Aveiro A the thin silt covering gives some cause for concern, and more frequent monitoring is recommended.

This observation was subsequently confirmed by a direct land survey at very low tide, during the geological mission (see below). A mission was conducted in the same area on 19 and 20 August 2009 with the aim of taking sedimentological-stratigraphical soundings to characterise the Ria de Aveiro A wreck site. The work was executed by Miguel Aleluia, an assistant archaeologist at DANS, in conjunction with a team from the Faculty of Sciences at Lisbon University consisting of Prof. Conceição Freitas, Prof. César Andrade, Rute Ramos, Tânia Ferreira, Pedro Costa and Carlos Janardo.

The equipment used for the soundings belongs to the university. A digital camera (Olympus), ruban meters and inox pegs were also taken along for the purposes of making sounding profiles.

FIGURE 4 Taking sediment samples at the Ria de Aveiro sites. PHOTO: DANS

First of all, on 19 August, profiles were marked underwater using inox pegs, as the tide was not very low (0.7m) on this first day and it was preferable to take soundings ashore. The second day would then be used to take soundings at the wreck site itself, which is located at a lower level. In fact, it proved necessary to make preliminary site preparations and mark out the area on the first day (peripheral buoys repositioned, stakes cleared of molluscs), followed by cleaning of algae. This preliminary operation allowed better positioning of the sounding profiles.

The soundings were then taken in a westerly direction, following a profile marked by stakes every 10m. Stakes I, II, IV,VII, VIII and a point 0 (zero) were positioned by DGPS (differential GPS). Their height was measured at the top and bottom, to allow DANS to precisely measure the local sedimentation variation at the site.

This second mission in the same area focusing on measuring the sedimentology in and around the Aveiro A site through sounding and specially prepared stakes, placed and observed by divers, verified that the southern part of the site was at the same level as it was during the last excavation phase, approximately five years ago. Neither erosion nor sedimentation had therefore taken place.
This method of sounding was successful but only gives a good view of the higher sediment levels on the wreck. The university team concluded that, to sound deeper and obtain better results, it will be necessary in the future to try other equipment that can look deeper into the seabed and is better adapted to the specific field conditions (e.g. sediment) in Aveiro. However, cooperation on the monitoring of archaeologically interesting sites has been established between IGESPAR/DANS – responsible for the management and protection of the underwater cultural heritage – and other stakeholders, including the Faculty of Sciences of Lisbon University, as part of the MACHU project. This is good news for the future of the overall management of the underwater cultural heritage in Portugal, because this should always be a joint effort.

NOTE

[1] The ‘Tile boat 2’ in Portugal is located in Sesimbra Bay (in the Sado bar, south of the Tagus/Lisbon river) at a depth of approx. 60 metres. This site of a shipwreck loaded with tiles is very interesting, containing as it does a number of stone balls of different calibers. She was surveyed and fully examined by photogrammetry in 2007 as part of the EU-VENUS Project (see http://piccard.esil.univmed.fr/venus/index.html). ■

FIGURE 3 Carefully packing of the sediment samples. PHOTO: DANS

Management of underwater cultural heritage

ANDREA OTTE RCE

National practice – Some examples

The MACHU project brought together seven countries that share a rich European maritime heritage, but with regional differences in underwater heritage management and legislative frameworks. These different frameworks do not always make it easy to work together, but they also can be inte resting and info rmative. We asked the MACHU partners to complete a questionnaire about how the underwater cultural heritage is managed in their country. The information provided by the Netherlands, Belgium, the UK and Poland in response to the questionnaire is published below in narrative form. The response from Portugal is published here in their entirety.

The articles and questionnaires give an insight into the national practice of underwater heritage management within the MACHU area, with central, regional and local government all playing different roles, reflecting different national approaches to government.[1] In Poland and Portugal, for example, all responsibility for the underwater heritage lies with the national authorities, while in Germany (Mecklenburg-Vorpommern), at a regional level, the Bundeslaender (states) are almost exclusively responsible for archaeological heritage management.[2]

Legislation on the underwater cultural heritage tends to be a rather recent development. Although some countries, such as Belgium and Sweden, had regulations concerning ownership of salvaged ships as far back as the fourteenth century,[3] legislation for the protection of the underwater heritage has developed only over the last four decades. In most cases, the existing heritage legislation has been rewritten to include the underwater heritage, as is the case in Germany (Mecklenburg-Vorpommern), Portugal, Poland, the Netherlands and Sweden. In the case of Belgium and the UK, separate legislation exists for wrecks. This legislation is limited to wrecks, however, and does not cover other underwater heritage such as prehistoric remains, bridges and drowned settlements. Most legislative frameworks have instruments for scheduling underwater sites. These sites may not be disturbed or altered in any way without a permit from the competent authorities. Besides protection for sites, there usually is a general obligation to report new finds to the authorities and a prohibition on searching for archaeological remains without permission. Sweden has a true system of blanket protection, under which all archaeological remains, including shipwrecks more than 100 years old, are protected directly by law.[4]

All the MACHU partners have ratified the Valetta Convention, although there is, of course, variation in the way it has been implemented nationally. In a few cases, the implementation of Valetta with regard to the underwater heritage is not yet on an equal footing with land-based archaeology. Commercialisation, which has been so rapid in land-based archaeology, is now slowly starting to develop in maritime archaeology, as can be seen in Portugal and the Netherlands. There are also some interesting variations in GIS systems. In most countries there is a legal obligation to keep a register of archaeological sites (in some cases only protected sites). All countries have a database that registers maritime data, in many cases with a GIS. The accessibility of the information differs. In Sweden, for example, all information is accessible by law. The same is true of information on listed sites in the UK. The German state of Mecklenburg-Vorpommern takes another approach, however. Here, information on archaeological sites is accessible only to people who can show they have good intentions. These are just some swift conclusions that can be drawn from the articles below. Most notably, however, there is a growing awareness in all the MACHU countries that the underwater cultural heritage must be managed in a sustainable way to safeguard it for future generations. Hopefully, the MACHU project has helped bring us closer to this goal.

[1] Besides the four papers in this publication, additional information on National practice in all MACHU countries can be found on the MACHU website: www. machuproject. eu
[2] Denkmalschutzgesetz (DschG M-V), 1998
[3] Adlercreutz , p. 155. 4 Adlercreutz 1999, p. 158.

Management of the underwater cultural heritage in Belgium

ADMINISTRATIVE STRUCTURE

LEGISLATION

The organisation responsible for the management of the cultural heritage on Flemish territory[1] is the Flemish Agency for Spatial Planning and Heritage[2] (RO-Vlaanderen), part of the Flemish Government's Department of Spatial Planning and Heritage. Within the same department, the Flemish Heritage Institute (Vlaams Instituut voor het Onroerend Erfgoed - VIOE) researches and catalogues monuments, landscapes, archaeology and heritage afloat. It makes the research results available to the management unit, scientific researchers and the public.[3]

The management of the underwater cultural heritage in the North Sea is slightly different. Responsibility for the archaeological heritage on land and the heritage in seas and rivers (below the high tide level) exists at two levels of government. The competent authority within Belgian territorial waters is the Federal Government and the competent authority for the archaeological / cultural heritage is the Flemish (regional) government. A cooperation agreement signed in 2004 between the Federal Minister of North Sea Affairs and the Flemish Minister of Spatial Planning and Heritage regulates management of the underwater cultural heritage in Belgian territorial waters (*figure 1*). This agreement has made better communication possible, for instance during the planning of economic or infrastructural works at sea, and both archaeological finds on land and at sea require must now be reported.

Within the VIOE, a unit set up in 2003 in close cooperation with the Province of West Flanders is responsible for cataloguing and researching the maritime heritage (archaeology and heritage still afloat). It also acts as a point of contact on the maritime cultural heritage for the public.

In 2007 legislation was passed regulating the ownership of wrecks and wreck parts in the Belgian territorial sea. It also creates a legal basis for the protection of shipwrecks or wreck parts of archaeological and historical value within the Belgian territorial sea. So far, however, no order implementing the legislation has yet been put in place, so any offence under this law will have no legal consequences. In the meantime, wreck sites in particular can be protected under regulations governing other matters (mainly environmental).

The Management Unit of the North Sea Mathematical Models (MUMM) is responsible for the management of the marine environment in the Belgian part of the North Sea, under the authority of the Federal Minister of Science. Some areas within Belgian territorial waters are for instance protected by law, mostly because of the bird species present there, or for the conservation of the natural habitats of fauna & flora,[4] which affords the heritage in these areas some indirect protection against the destructive impact of human activities.

FIGURE 1
A representative of the Flemish Minister of Spatial Planning and Heritage and the Federal Minister of North Sea Affairs sign the cooperation agreement (Raversijde, October 2004). © VIOE

In due course the VIOE, with its Maritime Heritage Research Unit, can act as an advisory body on the protection of the underwater cultural heritage, offering its services to scientific institutes, developers, policymakers and society. It will also retain its role as the point of contact for finds and information on the heritage, and in raising public and stakeholder awareness of the importance of this heritage. In other words, the only protection of the underwater cultural heritage achieved so far is the duty to report archaeological finds (found by chance), and the indirect protection of certain areas under environmental legislation (*see above*).

Outside the territorial waters (in the Exclusive Economic Zone or the remaining part of the Belgian Continental Shelf)[5] there is no national legal protection or management of the underwater heritage. Although the UNESCO Convention of 2001 (*see below*) contains some regulations on the cultural heritage in this area,[6] Belgian legislation on wrecks applies only to its territorial sea. There has therefore been no active policy of *in situ* protection, or any deliberate physical protection of wreck sites on the Belgian Continental Shelf (or in its territorial waters). However, under the Wrecks Act of 2007, wreck sites within Belgian territorial waters can be protected for historical or archaeological reasons.[7] Policymakers have been advised on valuable wreck sites eligible for possible *in situ* protection under the implementing order. Age is not a criterion, as protection of the cultural heritage in the Flanders region is always based on archaeological or historical value. World War I and II wreck sites, or even more recent wrecks of particular historical, architectural or archaeological importance, are not excluded.

ORGANISATION OF UNDERWATER HERITAGE MANAGEMENT AT THE NATIONAL LEVEL

The Flemish Heritage Institute (VIOE), part of the Department of Spatial Planning and Heritage, researches and catalogues monuments, landscapes, archaeology and the heritage afloat. It makes the research results available to the scientific community and the wider public. The VIOE's Maritime Heritage

Unit currently employs three maritime heritage researchers (one specialised in the heritage afloat) and five technicians providing practical support for research.
Except for the VIOE, as far as is known, no other organisation in Belgium is professionally involved in the management of the underwater heritage in the North Sea.

As said earlier the main task of the VIOE's Maritime Heritage Unit is to catalogue and research the maritime heritage. It does so mainly through an interactive database, www.maritime-archaeology.be, to promote cooperation with volunteers and other scientists and to return information to the public. This database, in four languages, promotes international information exchange. It operates alongside the Central Archaeological Inventory (CAI)[8], the main database of known archaeological sites in Flanders. It is GIS-based and can be accessed interactively by several partners. It also serves as a reporting medium for finds.
Plans for a revamped CAI include better correlation with the maritime archaeological database. Data relevant to both will be linked (e.g. maritime archaeological structures on land).[9]
For the underwater heritage, the MACHU GIS database is a very welcome initiative, which will undoubtedly also prove useful in future national and international cooperation.
Organisation at the regional and local level
Even though there is close cooperation between the VIOE and the Province of West Flanders at Walraversijde Archaeological Museum (Ostend), no responsibility for maritime archaeological research exists at a lower administrative level. Nevertheless, the provincial authority was until recently involved in the presentation of the maritime heritage on land and is also involved in an international maritime project.[10]

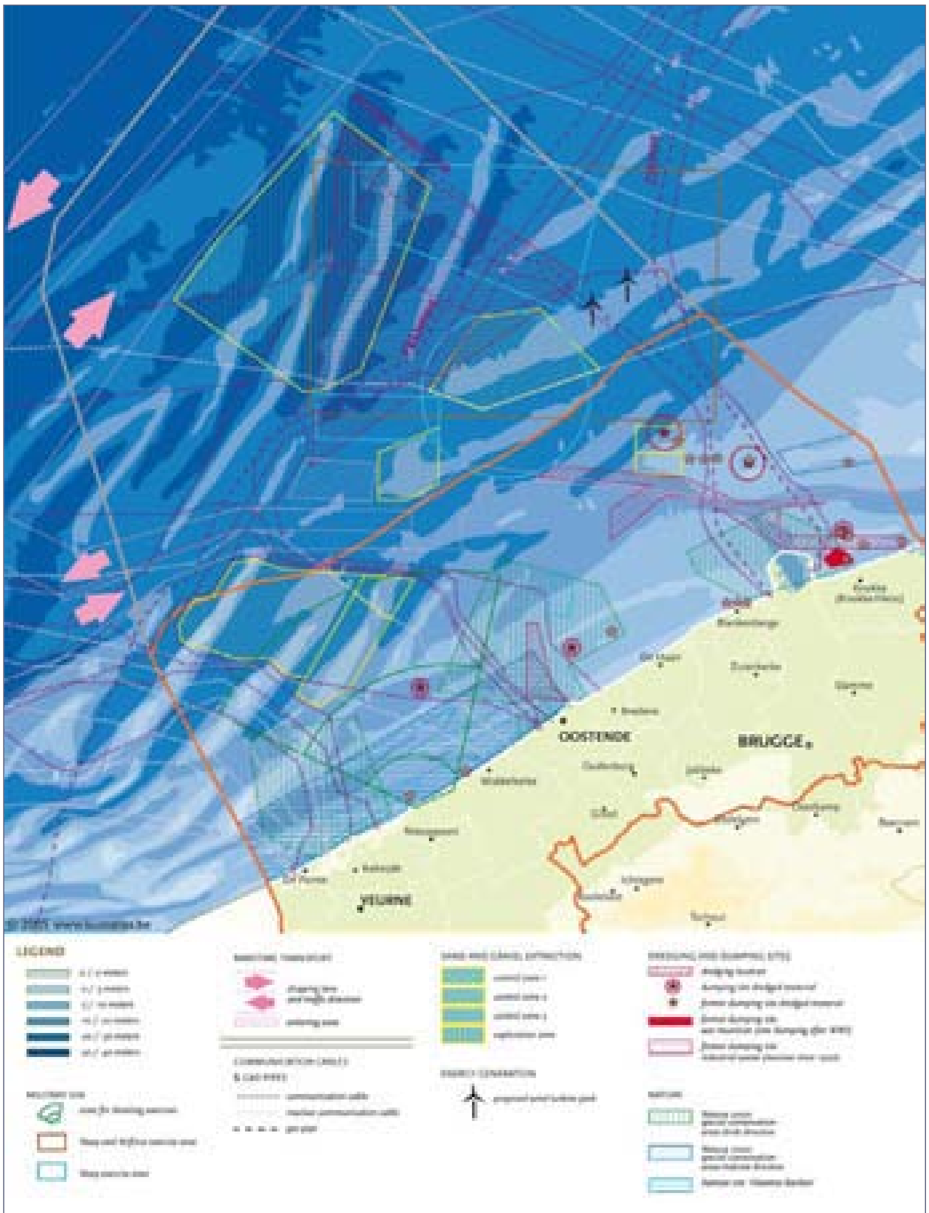

FIGURE 2 Map showing zones of multifunctional use of the Belgian Continental Shelf.
© Belpaeme & Konings 2004

COOPERATION WITH OTHER STAKEHOLDERS

The knowledge and expertise of other disciplines and stakeholders are indispensable for good results in maritime archaeological research. Some research performed for other purposes can be shared at little or no cost for archaeological research, ensuring that work is not duplicated. The VIOE works with several governmental services on the basis of a voluntary agreement. They include the Province of West Flanders (see above), the Flemish Marine Institute (VLIZ), the Flemish government shipping agency (DAB vloot) and Flemish Hydrography (Department of Coast, Agency for Maritime and Coastal Services)[11].

It cooperates on an ad hoc basis with other stakeholders, including the Fund for Sand Extraction (Federal Public Service for the Economy, SMEs, Self-employed and Energy – Continental Shelf), the Maritime Access Division of the Flemish Ministry for Public Works, the Renard Centre of Marine Geology (Department of Geology and Soil Sciences, Ghent University) and the Royal Belgian Institute of Natural Sciences (KBIN). Some of the non-institutionalised collaborations are to be placed on an official footing soon.
Alongside these partnerships the VIOE works with the amateur diving community, mostly for wreck surveying and exchange of information. Official contacts with the central federation are to be arranged.
There is no direct cooperation with the fishing community, although information about finds and wreck locations in the North Sea is often exchanged through unofficial contact with fishermen. Some private ship owners have provided transport for archaeological research.
A few months ago the Flemish Marine Institute founded an association to organise contacts between the scientific world and the offshore and nearshore industry. The VIOE took an interest in this initiative.
In the meantime, initial contacts have been made with the Fund for Sand Extraction and the Maritime Access Division (see above) and offshore contractors sometimes consult the maritime archaeological database.

MALTA PRACTICE

Belgium has adopted the Treaty of Malta (Valletta) in principle but it has yet to be

implemented by the Flemish parliament. Implementation is expected to be completed shortly, however, along with a review of the archaeology decree.[12] A quality control system is in the making and will be included in the decree. Meanwhile the Flemish Agency for Spatial Planning and Heritage (see above) operates in the line with the Treaty in the archaeological management operations.
The regulations apply on Flemish territory only up to the high-tide level. The new archaeological heritage decree will however include the principles of the 2001 UNESCO Convention (see below).

SCIENTIFIC PRACTICE

The monitoring of wreck sites through diving and sediment sampling is now one of the core tasks of the VIOE's Maritime Heritage Unit, mainly thanks to the MACHU project. For the moment, the VIOE collaborates with the amateur diving community on a voluntary basis for diving operations in the North Sea. Over the next few years, efforts will be made to set up an additional in-house archaeological diving team at the Institute.

THE UNESCO CONVENTION FOR THE PROTECTION OF UNDERWATER CULTURAL HERITAGE 2001

The UNESCO Convention of 2001 has not yet been signed by Belgium. The procedure for a general archaeological heritage decree has priority, but it will incorporate the principles of the 2001 Convention (see above).

PUBLIC AWARENESS

The number of publications about the underwater cultural heritage is growing even though they do not yet appear on a regular basis. Nevertheless, publications for the scientific community and the general public are two of the main priorities on the research agendas of the VIOE and the Maritime Heritage Unit.[13] A series of publications have been written about coastal archaeology, including some about the maritime heritage produced in collaboration with Walraversijde Archaeological Museum.[14]

In 2008 the maritime archaeological research conducted in 2006 - 2007 was presented in a monograph[15], and the plan is to produce similar reports on a regular basis. Some articles about the maritime heritage are to be published in Relicta, a scientific journal about heritage research in Flanders.[16] The results of maritime research are regularly presented to the public in temporary exhibitions (mostly at Walraversijde Archaeological Museum)[17] and also in small articles in maritime journals[18]. Finally, as mentioned above, the VIOE has a web-based maritime database (www.maritime-archaeology.be). The site regularly carries news items. The awareness on the underwater cultural heritage in general is rather poor in this country. Even though the input is still in a first stage, general interest in the maritime heritage is starting to grow.
In 2004 the research on an 18th-century shipwreck on the Buiten Ratel sandbank (in Belgian territorial waters) was brought to the attention of the wider public in a documentary for the series *Overleven* on the Belgian television channel Canvas.[19.]

FIGURE 3 The VIOE was contacted by the Maritime Access Division for advice during the salvaging of a World War I wreck which was causing an obstruction in an inner harbour sluice in Zeebrugge. © VIOE

NOTES

[1] Including the heritage on its river beds.
[2] *Acting under the Decree on the Protection of the Archaeological Patrimony,* 1993 (Belgisch Staatsblad 15.09.1993, 08.06.1999 and 24.03.2003).
[3] www.vioe.be
[4] Ramsar Convention, 1971 protection of wetlands (coastal banks of international importance for birds) & NATURA 2000 (EU Directive on the protection of wild birds, 1979 – special protected areas – and EU Directive on the conservation of natural habitats and of wild fauna & flora, 1992 – special areas of conservation – (www.mumm.ac.be/EN/ Management/Atlas/list.php).
[5] United Nations Convention on the Law of the Sea (UNCLOS), 1982.
[6] UNESCO Convention, 2001, art. 8 - 10.
[7] Wrecks Act 2007: art. 16 - 17 (Belgisch Staatsblad 21.06.2007).
[8] http://cai.erfgoed.net/cai_publiek/index2.html
[9] Plans have also been made to correlate the other heritage databases of the VIOE. The three main databases are the Central Archaeological Inventory (CAI), the Database Inventory of the Built Heritage (DIBE) and the Atlas for Landscapes. Other specialised databases also exist (http://www.vioe.be/nl/inventarisatie).
[10] Under the Interreg IV programme West Flanders is participating in the '2 Seas' programme for cross-border cooperation (France, Flanders, England and the Netherlands).
[11] Demerre 2009:30-31.
[12] Since October 2009 the draft has been approved by the parliament.
[13] www.onderzoeksbalans.be
[14] Zeebroek I., Pieters M. & Gevaert G. (eds.) 2007 & Kightly, C., Pieters, M., Tys, D. & Ervynck, A. 2000.
[15] Demerre I. et al. 2008.
[16] Missiaen T. n.d.; Pieters M. et al. n.d. & Zeebroek I. et al. n.d.
[17] '*Drowned Past'* (in Bruges, Nieuwpoort, Brussels, Raversijde, De Panne, 2006-2007); *'Wrecked and Balanced'* (in Raversijde, Koksijde, 2007-2009); '*Destination Harstad?'* (in Raversijde, 2008) and '*Porcelain from the east, cork from the south…'* (in Raversijde, 2009).
[18] E.g.: *Ruimschoots (magazine voor klassieke scheepvaart)* and *De Grote Rede* (News about our Coast and the Sea).
[19] Servaes J.; Deckers O. 2004. This research is the result of a collaboration between the not-for-profit organisation of North Sea divers (NATA vzw) and the VIOE. ■

FIGURE 4 Diver observing remaining tiles on wreck site B141/237, Callisto. © VIOE Allan Soreyn

FIGURE 5 The exhibition 'Wrecked and Balanced' about the research on the 18th century Wrecksite on the Buiten Ratel sandbank and its find collection, presented in the Provincial Museum of Raversijde (Oostende) (2007-2008). ©Province of West-Flanders

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EXHIBITIONS

– *'Drowned Past ['Verdronken Verleden']* (Provincial Museum, Raversijde 2006), with reference to the 2nd International Colloquium on Maritime and Fluvial Archaeology in the southern North Sea area (in Bruges, Nieuwpoort, Brussels, Raversijde, De Panne, 2006-2007).

– *'Wrecked and Balanced. Study of an 18th century wreck site on the Buiten Ratel bank.' ['GeWrakt en Gewogen: Onderzoek 18de eeuwse wraksite zandbank Buiten Ratel']* Raversijde, Koksijde, 2007-2009.

– *'Destination Harstad? The wreck of the Belgica discovered on the bottom of a Norwegian bay' ['Eindbestemming Harstad? Het wrak van de zuidpoolvaarder Belgica ontdekt op de bodem van een Noorse baai.']* Raversijde 2008.

– *'Porcelain from the east, cork from the south… Archaeological traces of imports in Walraversijde' ['Porselein uit het oosten, kurk uit het zuiden… Archeologische sporen van import in Walraversijde en Oostende.']* Raversijde, 2009. ■

Management of UCH

National practice in the Netherlands

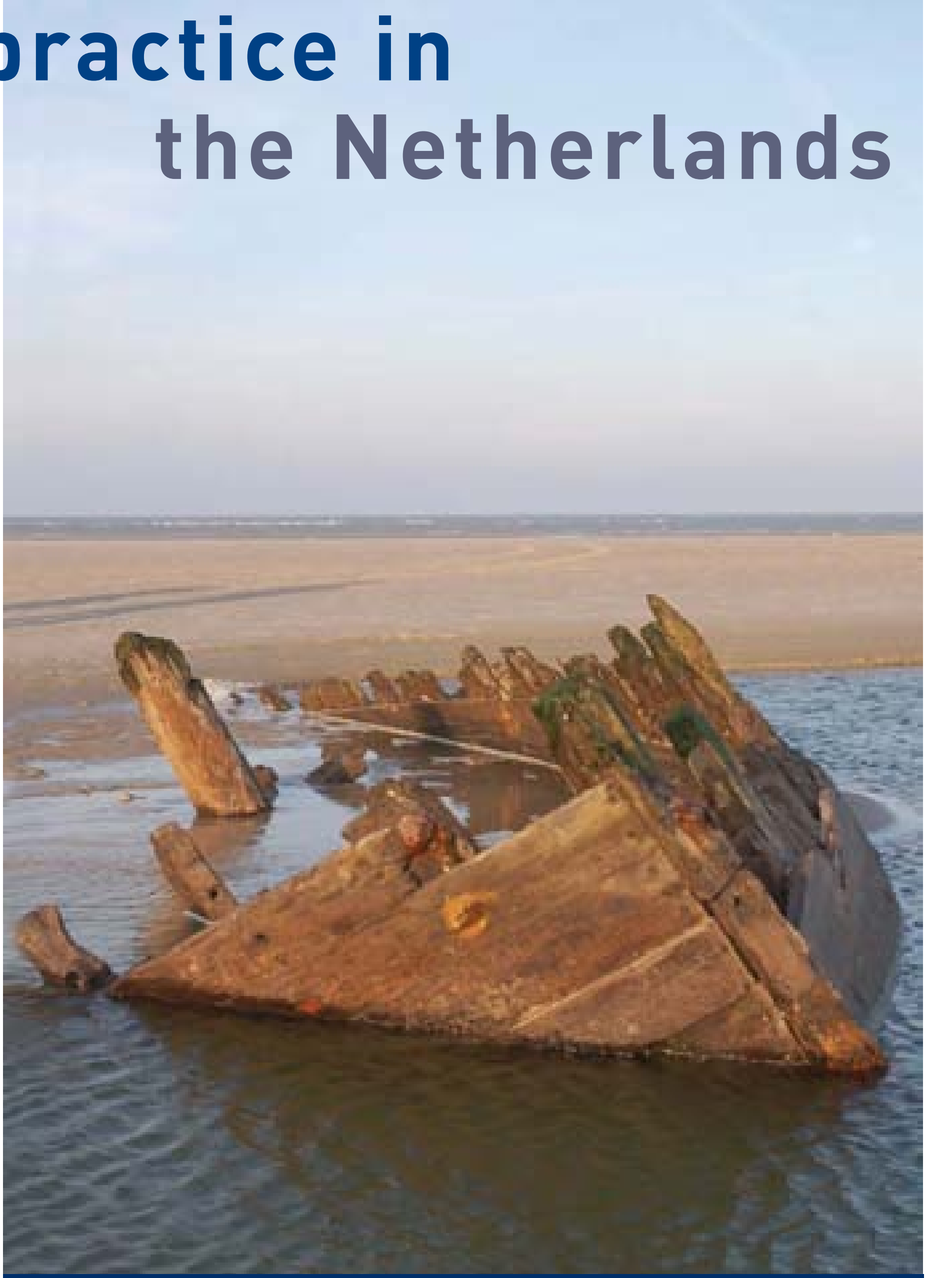

FIGURE 1 Wreck in the tidal zone on the Frisian Island Terschelling. Photo: Martijn Manders, RCE

ADMINISTRATIVE STRUCTURE

In the Netherlands, responsibility for the management of the cultural heritage is shared by national, regional and local government. In principle, this also applies to the management of the underwater cultural heritage, but in practice the situation is somewhat different. Since most of the Netherlands' waters are either outside local and regional borders (the North Sea) or have been designated *'Rijkswateren'* (waters that are managed by central government), management of the underwater heritage occurs to a large extent at national level.

LEGISLATION

The first Monuments and Historic Buildings Act (*Monumentenwet*) was introduced in 1961. At that point there was hardly any awareness of the underwater archaeological heritage, so the legislation made no provision for these sites. Although the underwater heritage was not excluded as such (the definition of an archaeological monument applicable then, and indeed still used in the present legislation, includes all man-made objects at least 50 years old that have a scientific value, cultural heritage value or aesthetic value, and this evidently also includes shipwrecks and other phenomena found underwater), but as a result of some crucial powers being given to local authorities, areas outside local boundaries could not be protected. This was remedied in the new Monuments and Historic Buildings Act 1988, which included provisions for areas outside municipal boundaries.

Sites are considered to be of archaeological importance if they are at least 50 years old and are of general interest because of their beauty, their scientific significance or their cultural heritage value. The Monuments and Historic Buildings Act 1988 gives all archaeological sites a basic level of blanket protection. This protection consists of two things:

a. a banning order on excavation of these sites (excavation is defined as disturbing the soil with the purpose of finding archaeological remains);
b. an obligation on anyone who makes a chance discovery of artefacts of archaeological interest to report them to the local authorities or (outside local boundaries) to the Ministry of Education, Culture and Science within 48 hours.

In addition to these general protection measures, the Minister of Education, Culture and Science has the option of officially designating archaeological sites. The Netherlands has approximately 1800 designated archaeological monuments, six of which are situated underwater. Any activities that may in any way alter these sites require a licence from the Minister. Scientific institutions, public authorities and professional archaeological organisations are eligible for such a licence.

The Minister of Culture pursues an active policy of scheduling archaeological sites. The current policy aims for a list of protected monuments that represents a cross-section of the archaeological values that can be found in or on the Dutch soil.[1] Since underwater sites are currently under-represented on the list, this category will be one of the key focuses of our policy over the coming years.

The Monuments and Historic Buildings Act has full force in Dutch territorial waters. In the contiguous zone its enforcement is limited to the blanket protection. Archaeological sites in this zone cannot be scheduled.

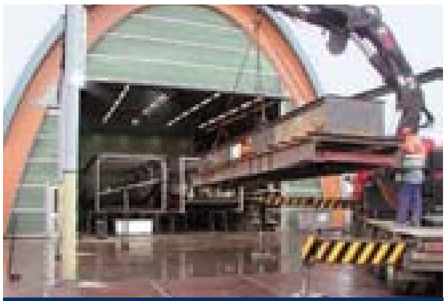

FIGURE 2 Transport of a dug-out canoe to the national repository for ship finds (RCE-Lelystad). Photo: RCE

The sphere of influence continues on the rest of the Continental shelf. Licences for the exploration of gas and oil fields and the extraction of sand and gravel include a reference to the Monuments and Historic Buildings Act, to allow its provisions to be applied here too.

In 2007 the Monuments and Historic Buildings Act underwent considerable changes as a result of the Valetta Convention. In this connection, not only the Monuments and Historic Buildings Act, but also the Spatial Planning Act (*Wet Ruimtelijke Ordening*) and the Earth Removal Act (*Ontgrondingenwet*, which regulates sand and gravel extraction) have been amended. An assessment of the archaeological importance of the area has to be made at an early stage of planning. Subsequently, every attempt must be made to execute the plan in such a way that disruption to archaeological sites is kept to a minimum. If that is not possible, an archaeological excavation must be carried out to ensure preservation of the archaeological information *'ex situ'*. The cost of both the preliminary archaeological work and the conservation measures or excavation should be an integral part of any development project.

ORGANISATION OF UNDERWATER HERITAGE MANAGEMENT AT THE NATIONAL LEVEL

The authority responsible for the underwater cultural heritage at a national level is the Ministry of Education, Culture and Science. Its Directorate-General for Culture and Media has a unit for Cultural Heritage, which is responsible for policymaking and the drafting of legislation. Everyday responsibility for heritage management lies with the Dutch Cultural Heritage Agency, however. It is concerned with management of the historic environment as a whole, i.e. archaeology, the built heritage and cultural landscapes. It performs the tasks arising from the Monuments and Historic Buildings Act and national policies, such as the licensing of activities at scheduled sites. But the Agency also acts as a centre of expertise for heritage management (both terrestrial and underwater heritage). In this capacity, the Agency performs research to determine which aspects of our historic environment should be preserved and how this can be done. It also manages a national repository for ship finds.[2]

The Cultural Heritage Agency has approximately 250 staff, 22 of whom are involved in maritime archaeology (both sites underwater and shipwrecks on land). A considerable proportion of them work on the conservation and management of the maritime artefacts in the national repository for ship finds managed by the Agency. The Agency has four positions for maritime policy officers and one information manager. They work at its central offices in Amersfoort. Their work consists of providing information in support of national legislation and policies, advising on spatial planning projects, enforcing the Monuments and Historic Buildings Act and managing maritime sites of national and international importance. The remaining staff involved in maritime heritage management are located at the offices in Lelystad, where the national repository is also housed.
The agency currently employs five professional divers, but only two of them (one diving researcher and one support diver) actually have diving in their job descriptions. The others may join in diving activities, but not on a regular basis. Additional diving capacity therefore has to be hired in to complement this two-person diving team.

BUDGETS

The Cultural Heritage Agency currently has an annual budget for maritime heritage management of 200,000. Approximately 135,000 of this is intended for underwater research (assessments, surveys, monitoring etc). Since the Agency's own diving capacity is limited, it has to hire in commercial diving capacity.

GIS

One of the tasks of the Cultural Heritage Agency is to keep a national database of all archaeological sites, including underwater sites, to provide all organisations involved in heritage management with information. The system is fully web-based, powered by Java and open GIS-compliant. The data are stored in an Oracle database. Both administrative and spatial information are linked, and can be viewed on map layers. Depending on their authorisation, users can access specific tables of information. They include research reports (approx. 9000), archaeological observations (approx. 60000) and archaeologically assessed sites (approximately 13,000, about 1800 of which enjoy statutory protection). The GIS also contains many topographical and other layers, including a predictive model layer for the whole of the Netherlands (the IKAW).

In addition to this general GIS, the MACHU GIS will function as a specific GIS for the underwater heritage. It is equipped to store information related to the management of underwater sites, such as management plans and sedimentation and erosion models. Since it contains management information at an international level, it is well suited to support further international cooperation on maritime heritage management and to underpin international (European) maritime policies.

ORGANISATION AT THE REGIONAL AND LOCAL LEVEL

In the new legislation much of the responsibility for the archaeological heritage has been handed over to regional and local authorities. This is because of the way spatial planning is organised in the Netherlands. With the advent of the Valetta Convention, management of archaeology has become more and more integrated into the spatial planning system. As in other countries, archaeological sites have become a permanent feature of the spatial planning process. Spatial planning in the Netherlands mainly takes place at local government level, with regional government playing a supervisory role, to make sure that interests that transcend the local level are also taken into account. In practice, this means that local authorities incorporate archaeological sites and zones where there is a high probability of finding archaeological remains in their local zoning schemes. Anyone who wants to perform activities in these zones must apply for a permit. The local authority has to weigh the interests of the applicant against the archaeological interest. It can either grant the permit, grant it with prior conditions/restrictions or refuse the application. Conditions might include an excavation/watching brief, or regulations concerning the location and dimensions of foundations, to limit the damage caused.

Scheduled sites can be included in local schemes, but all activities at these sites will also need a permit from central government (Minister of Culture/ Cultural Heritage Agency). The situation is the same for the underwater heritage, at least in theory. This is not necessarily the case in reality, however, for a number of reasons. First of all, local authorities are often unaware that they have underwater cultural heritage for which they are responsible within their boundaries. This situation is however changing, albeit slowly.

Secondly, the knowledge and expertise needed to manage the underwater cultural heritage is lacking most of the time. To be clear: this expertise is very scarce within the Netherlands anyway (see numbers given above), which makes it hard to come by. One concern is that, although it is possible to take university courses in maritime archaeology, no fully-fledged study programme exists. So, at least in the short and medium term, we will be dependent on people from other countries, or people who studied abroad, to fill this gap.

Thirdly, a large proportion of Dutch waters are the responsibility of central government, including the North Sea, or they are a shared responsibility of central and local/regional authorities. This is true of '*Rijkswateren*' (National Waters), which include all major rivers, the Wadden Sea and the tidal inlets in the southwest Netherlands. In these areas, there may be some doubt as to who is responsible for managing the archaeological heritage

FIGURE 3 Salvage operation of a World War II airplane by staff members of the Dutch Royal Navy and Royal Air Force. Photo: RCE

COOPERATION WITH OTHER STAKEHOLDERS

The major stakeholder in the underwater cultural heritage is Rijkswaterstaat (the Directorate-General for Public Works and Water Management), the agency of the Ministry of Public Works and Water Management that is responsible for managing Dutch waters, including the seabed. Management of the underwater cultural heritage in or on the seabed is considered a shared responsibility of the Cultural Heritage Agency and *Rijkswaterstaat*.[3] Their collaboration is based on a 2007 agreement which regulates information-sharing between the two organisations. This has led to the creation of the MACHU GIS. Other stakeholders include the Ministry of Defence, particularly in the case of World War I and World War II wrecks (both ships and aircraft), although they will also offer material assistance for the management of other underwater cultural heritage on an ad hoc basis.

The Cultural Heritage Agency, as a centre of expertise, has a role in generating new knowledge that benefits archaeological heritage management. In this role it cooperates with other centres of expertise, including Deltares (the Dutch Institute for Delta Technology) and the University of Wageningen. For maritime heritage, new knowledge might for example relate to degradation processes in different materials or combinations of materials (e.g. iron and wood), or predictive modelling of sedimentation-erosion processes in the seabed.

Apart from cooperating with other institutions, the Agency maintains close contacts with avocational wreck divers, especially those who are members of the LWAOW (the Dutch Society of Avocational Underwater Archaeologists). This group is of the utmost importance to heritage management underwater. They are the eyes and ears of the professional heritage managers, and they report many new wreck locations.

They are also often the first to notice if wreck locations are endangered by natural processes or human activities, and report their findings to the Agency.

FIGURE 4 Briefing of avocational divers of the LWAOW during a course. Photo: Martijn Manders RCE

MALTA PRACTICE

Archaeological heritage management in the Netherlands has changed radically under the influence of the Valletta Convention, which the Netherlands signed in 1992. In 2007 the Valetta Convention was ratified and implemented in Dutch law (under the Archaeological Heritage Management Act, or *Wet op de Archeologische Monumentenzorg*). However, actual legal implementation was preceded by a long period during which the influence of its principles were already being increasingly felt. One major change was the introduction of market forces in development-led archaeology in 2001. This resulted in the establishment of a wide range of private archaeology agencies, specialising in consultation, excavation, conservation of artefacts and dendrochronology, for example.

Malta has largely been implemented through the existing spatial planning system. Planning permits, needed to construct buildings and other structures, dig trenches, build roads etc., can now also stipulate that an archaeological assessment must be carried out. If the licensing authority feels it is necessary, it can also attach conditions to the permit, requiring archaeological excavations, watching briefs or measures to ensure the preservation of the site in situ, for example.
In the Dutch spatial planning system it is local government (the municipality) that issues planning permits. This means that, with the implementation of Malta, local authorities have been given a very important role in archaeological heritage management.
Besides the spatial planning process, the procedures for environmental impact assessments and sand/gravel extraction also have a certain level of protection of archaeological values embedded in them. Both can be applied to the Continental Shelf, making it possible to apply the principles of the Valetta Convention beyond Dutch territorial waters.

UNDER WATER

Eight years after the introduction of privatisation in archaeology, the archaeological market has expanded enormously. However, underwater archaeology has lagged behind. Until approximately two years ago there was not a single private agency for underwater archaeology in the Netherlands, but since then two commercial companies have been granted an excavation licence for archaeological work underwater. There is also a company specialising in surveying techniques for maritime archaeology. Although this is a promising start, the situation is still not ideal. The field suffers from a lack of experienced maritime archaeologists, who are very hard to come by. People have to be trained on the job (but by whom?), and to build up a reasonable amount of experience takes several years. The developing market will therefore not be mature for at least a number of years and in the meantime remains very vulnerable indeed. One further threat, not only to the successful privatisation of maritime archaeology, but also to underwater archaeology in a broader sense, lies in the fact that underwater archaeology training and research have not yet been embedded in any of the archaeology degree programmes on offer in the Netherlands.

FIGURE 5
Inside view of the national repository of ship finds (RCE-Lelystad).
Photo: RCE

QUALITY SYSTEM

To make sure that the quality of archaeological work does not suffer due to commercial interests, a quality system has been established. The basis for this system is the *Kwaliteitsnorm Nederlandse Archeologie* (the Dutch Archaeology Quality Standard), a set of standards defined by the archaeological field itself, which has resulted in their broad acceptance. The standard consists of requirements that individuals involved in the archaeological work and the archaeological work itself must meet. The Cultural Heritage Inspectorate has a supervisory role. The quality system has a legal basis due to the fact that an excavation licence is granted only to companies and institutes that meet the requirements.

Organisations can also lose their excavation licence if they do not work according to the quality standard.

UNESCO CONVENTION

The Netherlands has not signed the UNESCO Convention for the Protection of Underwater Cultural Heritage 2001. The reason lies not in the principles behind it, but in the possible conflict between the Convention and the International Law of the Sea (UNCLOS). Like other UNESCO member states, the Netherlands has not committed itself politically to the Annex of the Convention, which sets out rules inspired by the ICOMOS Charter of 1996.[4] Officially, the Dutch government is still considering the possibility of acceding to and implementing the Convention.

PUBLIC AWARENESS

The underwater cultural heritage features regularly in Cultural Heritage Agency publications, which are targeted at all stakeholders in the field of heritage management. Maritime researchers and policy workers at the Agency also contribute to other national and international publications and seminars.

In 2007 the Agency, together with the Dutch Society of Avocational Underwater Archaeologists, published a summary of recent underwater archaeology discoveries in the Netherlands. The publication, called *De Maritieme Bundel*, details 63 new underwater sites, and hopefully will be the first of many.

The Cultural Heritage Agency website does not have a separate section on maritime archaeology, as it is seen as an integral part of archaeology as a whole. There are several items on the maritime activities of the Agency and maritime projects in which it is involved.

NOTES

[1] *Beleidsregel aanwijzing Beschermde monumenten 2009*, 18 december 2008 (WJZ/82097 - 8235).

[2] Under the Monuments and Historic Buildings Act, archaeological finds from excavations within provincial boundaries become the property of the province in question (and in some cases the municipality concerned). An exception is made for maritime finds. The Minister of Education, Culture and Science can decide to assign maritime finds to the national repository for ship finds, if they come from outside provincial boundaries (territorial waters), or if a ship find is of national or international interest or would require expert care that is available only at the national repository.

[3] Convenant RWS en RACM 2007, *Samenwerkingsovereenkomst tussen Rijkswaterstaat en de Rijksdienst voor Archeologie, Cultuurlandschap en Monumenten betreffende archeologisch onderzoek en het aantreffen van vondsten bij werken.*

[4] ICOMOS: International Council on Monuments and Sites.

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National practice in Poland

INTRODUCTION

Poland is a typically agricultural economy, but it also has a rich maritime history. The Polish coastline is peppered with shipwrecks dating back to at least the Early Medieval period. There is also believed to be considerable archaeological potential in territorial waters as far as non-wreck remains are concerned, particularly in the Mesolithic and Neolithic landscapes beneath the Baltic Sea.
The process of affording the underwater cultural heritage legal protection started around ten years ago. A new Act for the Protection of Monuments with special provisions for underwater sites was finally introduced in 2003[1]. The present legal status of these sites does not raise any difficulties in interpretation.

ADMINISTRATIVE STRUCTURE

The Minister of Culture is responsible for the management and protection of monuments. The Monument Protection Act is administered by the State Service for the Protection of Monuments. It consists of two administrative levels supervised by the Minister of Culture: the regional inspectors, who are answerable to the General Inspector of Monuments. Decisions aimed at the protection of monuments that are located within Polish waters require the permission of the Maritime Office Director in agreement with the regional inspector. The level of protection also depends on where precisely the heritage is situated within Polish waters: internal waters, the territorial sea or outside Polish territorial waters.

SCOPE AND METHODS OF PROTECTION

Article 3.1 of the Monument Protection Act defines an archaeological monument as a movable or immovable object or its constituent parts, or a group of objects, which are man-made or connected with human activity, whose protection is of significant public interest because of its intrinsic historical, artistic or scientific value. Article 3.4 defines an archaeological monument as an immovable or movable monument, underground or underwater remains of activity and human life, associated with cultural layers containing objects or remnants of objects, artefacts that are man-made. Such a monument less than 100 years old can also be protected it is of sufficient historical importance.
Methods of protection are described in - Chapter 2 of the Monument Protection Act as:

- listing of monuments in a register
- recognition as a historical monument
- creation of a cultural park.

Existing protection under local development plans (art. 37a) obliges Directors of Maritime Offices to develop special management plans for sea areas. There is also a clear explanation of what kind of search requires a permit[2].

The consent of the provincial heritage authority is required in order to:

- search for monuments, including archaeological monuments, with the use of electronic, technical and diving equipment;
- search for hidden or abandoned movable monuments, including archaeological monuments, using electronic, technical or diving equipment, which requires the permission of the Maritime Office Director in agreement with the Regional Restorer.

An order issued by the Minister of Culture pertaining to conservation work and other activities involving monuments that have been entered in the register of monuments, archaeological excavations, or searches for hidden or abandoned movable artefacts defines who may carry out work on the underwater cultural heritage[3].
The final area of law relating to protection of the underwater cultural heritage in Poland is maritime law. The Polish Sea Areas and Maritime Administration Act focuses particularly on the protection of wrecks[4].
It stipulates that wrecks and related remains may be sought only with the permission of the Director of the Maritime Office. Such permission will be granted in consultation with:

- the Regional Restorer
- the Commander of the Sea Branch of the Border Guard
- and the Navy Hydrographical Office.

Furthermore, a Maritime Office surveyor may be present during the search. Ships used for wreck searching must depart from and return to a Polish port and all objects that are found and recovered during the search should be kept on the ship for which permission was granted and be submitted to the Director of the Maritime Office.
There is a financial penalty for unauthorised wreck searching, which can amount to twenty times the offender's monthly salary.

The legal protection of cultural objects reco-

FIGURE 1 The Polish Maritime Museum website. The day-to-day management of underwater cultural heritage in Poland.

FIGURE 2 These clothing are samples of the General Carleton wreck (W-32) One of the best documented wrecks in Poland. The general Carleton collection represents the most numerous and securely dated set of ordinary late eighteenth century sailors clothing. PHOTO: CMM

vered outside of Polish territorial waters is much more difficult. Due to the limited size of the Baltic Sea and the shape of its shoreline, the definition of Poland's EEZ has been handed over to the authorities administering international agreements. Nonetheless, it should be noted that, under article 17 of the Polish Sea Areas and Maritime Administration Act, Poland has reserved the right of 'sovereignty' over 'scientific exploration of the sea' and 'protection and preservation of the sea environment' in this zone[5].

ORGANISATION OF UNDERWATER HERITAGE MANAGEMENT AT THE NATIONAL LEVEL

The day-to-day management of the underwater cultural heritage is in the hands of the Polish Maritime Museum. This task is not the core business of the Museum, however. A small unit of three people has responsibility for this task. It operates with an annual research budget of PLN 200,000 (approximately € 47,000)[6]. An active policy on in situ protection is currently being developed. So far, three sites have been protected in situ (by law), but another 12 are awaiting a final decision.

The number of people professionally engaged in underwater cultural heritage management in Poland is also very small, with three at the Polish Maritime Museum and four at Nicolaus Copernicus University in Torun.

Poland does maintain a central database for the underwater cultural heritage. The EPSA database includes the data on underwater monuments catalogued by archaeologists from the Polish Maritime Museum. The system is very simple, and is based on Microsoft Access. Around 70 maritime sites are described, most of which are situated in Polish territorial waters. At this moment no GIS information is linked to the database, but structural cooperation with the Navy Hydrographical Office means access to GIS data is available when required.

ORGANISATION AT THE REGIONAL AND LOCAL LEVEL

In 2002 the working group 'Wrecks' was established, bringing together representatives from governmental and non-governmental organisations with a role in the management of Poland's underwater cultural heritage. One of the main tasks of the group was to create a digital standard for exchange of data on bottom obstacles (mainly wrecks). It meets four or five times a year and the meetings are attended by representatives of various organisations, including the Maritime Offices, the Navy Hydrographical Office, the Polish Maritime Museum, the Marine Institute in Gdańsk, the Sea Branch of the Border Guard and diving associations such as the Baltic Wreck Association. The establishment of 'Wreck' has led to close liaison and collaboration between 'users' and administrators.

Education has been seen to be the key to dealing with the threat posed by recreational diving. We strive to increase access to the underwater cultural heritage as much as possible and to encourage divers to participate in the process of recording new discoveries, surveying sites, excavation, and enforcement. After the first few meetings participants noted the importance of such cooperation as a way of creating a system of protection for the underwater cultural heritage, in collaboration with sport divers and non-governmental organisations.

MALTA PRACTICE

Poland is party to the Revised European Convention on the Protection of the Archaeological Heritage (the Valetta Convention). While the Ministry of Culture and Infrastructure believes that its current legislation is adequate to fulfil its duties under the Convention, there are question marks about this, and much more certainly needs to be done to put the underwater cultural heritage on an equal footing with the terrestrial heritage. We should say that, in daily practice, it does not provide any form of protection for less significant sites, or for the many sites that as yet lie undiscovered beneath the sea. The significance of a site needs to be assessed before it can be designated, and this involves disturbing the site. In light of the fact that there has been no systematic survey of Polish territorial waters to identify wreck sites, sites are only protected when they are drawn to the attention of the authorities, which is a rather piecemeal way of doing things.

SCIENTIFIC PRACTICE

The MACHU project provided the first opportunity to attempt to put in place an active monitoring system. One of the most interesting aspects was cooperation with the team from the Institute of Wood Technology in Poznan. Within the framework of the MACHU project, broader-ranging work aimed at identifying possibilities for using test samples of oak as bioindicators of changes occurring in wood placed in a marine environment was undertaken for the first time in Poland. Changes in physical and chemical properties, loss of mass and susceptibility to decay caused by Basidiomycetes fungi were assessed after wood samples had been removed from the sea. Test samples of oak measuring 250 x 10 x 10 mm were placed in Baltic coastal waters near the Medieval seaport of Puck and in the waters of Gdansk Bay at the same longitude as Or_owo (near the wreck of the Swedish warship Solen). The properties of samples removed from the sea after six and 12 months of immersion were compared with the properties of twin control samples of oak which had not been immersed.

It was found that wood immersed in Baltic waters for a period of six months to a year give the following results in the 10-millimetre-thick zone of wood: decrease in tensile strength (by ~20-40%) and modulus of elasticity of wood (by ~10-36%) connected with mass loss (2.8-14.1%), increase in moisture content to around 120%, decrease in wood density (by ~5-10%), significant increase (20-30 times) in susceptibility of wood to decay caused by Basidiomycetes fungi (white rot fungi, e.g. Trametes versicolor), clear change of wood colour (from light to dark) and surface structure, increase in content of mineral substances (ash-5x), increase in pH value (4 to 6.2), decrease in content of substances soluble in water (by ~40%), ethanol-benzene

mixture (by ~50%) and in 1-percent aqueous solution of NaOH (by ~10%).
The results obtained so far indicate that noticeable, measurable changes in oak immersed in the sea occur in the first year of immersion, and may prove useful for the protection and monitoring of underwater archaeological objects.

UNESCO CONVENTION ON THE PROTECTION OF UNDERWATER CULTURAL HERITAGE 2001

Poland has not yet signed or ratified the UNESCO Convention, but for the last three years extensive efforts have been put into preparing for ratification. It is hoped these will come to fruition in 2010.
The UNESCO Convention 2001 should provide some protection for the underwater cultural heritage beyond the 12-mile limit. Meanwhile, States Parties to the Law of the Sea Convention 1982, which include Poland and most of the Baltic countries, should bear in mind that, under Art. 303(1) of that Convention, they are already under a specific obligation to protect objects of an archaeological and historical nature in all sea areas and to cooperate for that purpose. It would therefore be useful to explore ways of meeting this responsibility.
Poland has not yet taken the step of declaring a contiguous zone under Article 33 of the LOSC.

PUBLIC AWARENESS

Articles and books connected to the underwater cultural heritage are published by the Polish Maritime Museum every year. We also cooperate closely with commercial and public broadcasters. The museum website (www.cmm.pl) has a page on maritime archaeology.

NOTES

[1] Journal of Law.2003, No162,1568.
[2] Chapter 3.36.1 of the Act for the Protection of Monuments.
[3] Journal of Law 2004, No 150, item 1579.
[4] Journal of Law, 2003, No 6, pos.41.
[5] Kowalski 1999.
[6] This has been the research budget for the past two years.

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FIGURE 2 Wreck W-23 Loreley (sank 1887) is situated in Gdansk bay area and there for well protected. PHOTO: CMM

National practice in the English area of the United Kingdom

THE SITUATION IN THE ENGLISH AREA OF THE UK TERRITORIAL SEA

English Heritage is the UK Government's statutory adviser on all aspects of cultural heritage including the English area of the UK Territorial Sea, as provided for under the National Heritage Act 2002. English Heritage is an Executive Non-Departmental Public Body sponsored by the Department for Culture, Media and Sport and we report to Parliament through the Secretary of State for Culture, Media and Sport. In the delivery of our duties we work in partnership with central government departments, local authorities, voluntary bodies and the private sector to conserve and enhance the historic environment; broaden public access to the heritage; and increase people's understanding of the past.

We aim to carry out our duties within the framework of a set of Conservation Principles. These principles apply equally to the marine as to the terrestrial sphere and can be summarised as follows:

- the historic environment is a shared resouce
- everyone should be able to participate in sustaining the historic environment
- understanding the significance of places is vital
- significant places should be managed to sustain their values
- decisions about change must be reasonable, transparent and consistent
- documenting and learning from decisions is essential.

The responsibility therefore for day-to-day management of underwater cultural heritage or historic environment in the English area of the UK Territorial Sea is English Heritage. Within English Heritage, the Maritime Archaeology Team leads on this work with seven staff and an annual budget of £200,000. In addition, we have an annual budget of £340,000 to deliver the UK-wide administration of the Protection of Wrecks Act 1973.

The actual mechanism to protect nationally important heritage sites rests with the Government Department for Culture Media and Sport. Our responsibility under the Protection of Wrecks Act 1973, within the English area of the UK Territorial Sea, is to consider applications and recommendations for designation, re-designation and de-designation of shipwreck sites. On the basis of our advice the government Minister is responsible for designating restricted areas around sites which are, or may be, shipwrecks (and associated contents) of historic, archaeological or artistic importance. The Minister is also responsible for the issuing of licences to authorise certain activities in restricted areas that otherwise constitute a criminal offence.

At the end of the Committee's reporting year in March 2009 there were 46 sites designated within the English area of the UK Territorial Sea (with a total of 61 sites in the UK).

Presently, the Minister also grants the licenses which permits access to sites designated under the 1973 Act, but the administration of those licenses rests with the national heritage agencies within the UK, namely Historic Scotland, Cadw in Wales, Northern Ireland Environment Agency and English Heritage. For example, between January 2003 and December 2098, English Heritage administered 559 new and amended licences which allowed for 3,453 named divers to access designated wrecks. Further information on the designated sites managed by English Heritage is available from: www.english-heritage.org.uk/maritime.

In the English area of the UK Territorial Sea, the Protection of Wrecks Act is the only legislation used to designate shipwrecks of historic, archaeological or artistic importance located within the intertidal zone or on the fully submerged seabed. One other piece of UK legislation exists that could be applied is the Ancient Monuments and Archaeological Areas Act 1979 which is used to designate or schedule sites on land, but which can be used to schedule heritage features such as shipwrecks or aircraft found within the intertidal zone or further offshore, but within the limits of the territorial sea. To date in the UK the 1979 Act has only been used by Historic Scotland to schedule the remaining German naval vessels scuttled in Scapa Flow in 1919; this mechanism allows for unlicensed public access on a 'don't disturb' basis. It is important to add that a new Scottish Marine Bill is presently before the Scottish Parliament which will introduce new legislation for the protection and management for the marine historic environment.

THE MARINE HISTORIC ENVIRONMENT

The number of protected historic shipwrecks is very small (ranging from possible prehistoric seafaring craft with associated cargos through to prototype submarines) and they are only one aspect of promoting the understanding, management and public enjoyment of the historic environment. It is therefore important for us to describe the marine historic environment as also comprising submerged and often buried prehistoric landscape areas and elements, together with archaeological sites and remains of coastal activities (e.g. fish traps) dating from all eras of history. As on land, notably through spatial planning, we consider it essential to ensure the management and use of the full range of the historic environment, is conducted in a manner that best serves the public understanding and enjoyment of the whole, and not just of the designated and protected sites.

To support management of the historic environment the National Monuments Record Centre run by English Heritage provides the national public archive for the historic environment for any area considered to be within England, land and sea. The information (e.g. spatial data, published reports, guidance material, photographs etc.) are available to the general public, researchers and consultants. The National Monuments Record Centre provides the primary source of spatial data for the seabed beyond the administrative boundary of any local government body (e.g. local public authorities responsible for planning matters) which nominally follows the mean low water line on the open coast.

MANAGEMENT OF THE HISTORIC ENVIRONMENT OUTSIDE TERRITORIAL WATERS

At present under the United Nations Convention on the Law of the Sea, the UK cannot directly protect underwater cultural heritage, either by designation or through a licensing regime for sites located beyond the limits of the UK Territorial Sea. However, for UK military vessels and crashed military aircraft located outside the UK it is possible to designate such sites as 'Protected Places' under the Protection of Military Remains Act 1986. For example, the Royal Navy vessels destroyed in the Battle of Jutland in the North Sea in 1916 are designated as 'Protected Places'. For such sites British citizens are not prohibited from diving, but there should be no disturbance. A further initiative to afford protection to a cultural heritage sites located beyond territorial waters is demonstrated by the RMS 'Titanic' Agreement between UK, Canada, USA and France.

MARINE ENVIRONMENTAL MANAGEMENT AROUND THE UK

In 2009 by the UK Government and Devolved Administrations in Wales, Scotland and Northern Ireland published a set of High Level Marine Objectives entitled Our seas – a shared resource which sets out a commitment to an 'effective, integrated and strategic management of human activities in the marine environment…' The importance of these objectives is that they provide an essential first step in the process of actively seeking an integrated approach to marine management, inclusive of cultural heritage.

The next step will be the preparation of a Marine Policy Statement, also to be published by the UK Government and Devolved Administrations, to support the introduction of a number of new marine management organisation, a planning system, development licensing mechanism and conservation measures provided under the Marine and Coastal Access Bill (for Wales and England) and through a Scottish Marine Bill. Consequently, we value the attention paid to marine cultural heritage and that a long term view is taken to promote appropriate management of this resource as a component of a healthy, productive and biologically diverse marine environment. In this regard we are pleased to see compatibility between these high level objectives and continuity in the Government's strategic goal for the marine environment 'to increase our understanding of the marine environment, its natural processes and our cultural marine heritage and the impact that human activities have upon them.' (*source: Defra, 2005 Safeguarding Sea Life: the joint UK response to the Review of Marine Nature Conservation*).

In recent years, much attention has focused on nature conservation protection particularly through designation of European marine sites, such as Special Area of Conservations under the Habitats Directive (Council Directive 92/43/EEC). For these areas it could be possible for indirect protection to be afforded to the historic environment. However, it is also important to realise how such a designation may affect management measures that are proposed for historic environment features with respect to the conservation objectives of such sites. With respect to more direct international measures that promote protection of the historic environment, the UK has ratified the Council of Europe Valletta convention with delivery in part through existing legislative measures.

However, we do find that it is important refer to Valletta Convention particularly when dealing with major marine development (e.g. the ports sector, offshore wind farms etc.) to demonstrate that the UK has ratified an international agreement that addresses archaeological matters. The UK has also recently ratified the Council of Europe Florence convention on European landscapes and English Heritage has published an action plan to inform delivery which provides a link with our on-going programme of historic landscape characterization.

Our approach to characterization includes the marine environment and over the past few years we have commissioned work to develop a methodology for its application. We also anticipate in 2010 further work to support the delivery of the EU Marine Strategy Framework Directive as implemented in the UK with particular attention on assessing 'social factors' inclusive of the historic environment.

It is also important to highlight the importance of the Environmental Impacts Assessment (EIA) Directive (Council Directive 85/337/EEC as amended) and the Strategic Environmental Assessment (SEA) Directive (Council Directive 2001/42/EC) in terms of how development proposals that are subject to EIA and SEA may affect the marine historic environment. Specifically, under UK national legislation, the Food and Environment Protection Act 1985 can be used to set licence conditions on marine development projects as a means to deliver mitigation for any impact on the historic environment.

To demonstrate how the historic environment can be taken into account during development project planning and delviery we have worked with various sectors to produce dedicated guidance such as the British Marine Aggregates Producers Association (BMAPA) and the Collaborative Offshore Wind Research into Environment group (COWRIE).

We also engage on a regular basis with the Crown Estate which leases seabed areas for development within the UK Territorial Sea and adjacent area of Continental Shelf and the Reciver of Wreck within the Maritime and Coastguard Agency.

SCIENCE AND MONITORING

For historic shipwreck sites subject to statutory protection under the Protection of Wrecks Act 1973 we conduct site assessments under a dedicated diving contract, so that through a rolling programme of diving it is possible for each designated site to be revisited approximately once every 6 years. The actual capacity in English Heritage's Maritime Archaeology Team is limited at most to one staff member holding competency to dive under national Health & Safety Regulations ('diving at work'). We have also promoted our program of designated wreck site monitoring within the UK Marine Monitoring and Assessment Strategy (UKMMAS) which is devised to support compliance with a variety of European and international agreements. For further information see www.ukdmos.org Our finding of broadly maritime projects between 2002 and 2007 was in the order of £3.3 million and between 2005 and 2007 directly through the Aggregates Levy Sustainability Fund (ALSF) we spent £2.1 million. In particular the ALSF has provided an essential mechanism to support projects which are particularly themed to assessing the implications of marine aggregate extraction on the historic environment. For example, the work of our MACHU project sub-contractor, Southampton University, was a development of project work initially commissioned through the ALSF on modeling sedimentary dynamics around wreck sites.

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National practice in Portugal

ADMINISTRATIVE STRUCTURE

Legislation Decreto-Lei nº 96/2007, de 29 de Março

Who is responsible for the management of the underwater cultural heritage in your country?

The Ministry of Culture is responsible, and the responsibility is met by the IGESPAR (Portuguese Heritage Agency), which has a Division for Nautical and Underwater Archaeology (DANS) as part of its Conservation and Protection Department.

Is the underwater cultural heritage regulated the same way/by the same legislation as on land?

Yes, under the same principles, and no, because underwater cultural heritage legislation is specific, except in the case of the detailed rules for archaeological fieldwork.

Does national legislative protection consist of one law, or many different laws?

One law for the cultural heritage in general, but with a chapter on Archaeology (with generic references to maritime spaces); one decree pertaining to archaeological fieldwork in all contexts; one decree on the underwater cultural heritage (implementing the principles of the UNESCO Convention, which was ratified by Portugal in 2006).

What about protection/management of the underwater cultural heritage outside territorial waters?

There is one case of international cooperation with Namibia, concerning a 16th-century Portuguese shipwreck in their territorial waters. Portugal has not claimed ownership of the remains because Namibia respects the UNESCO Convention principles, even though it has not yet ratified it.

Is there blanket protection or is there a minimum age for the underwater cultural heritage?

100 years is the age stipulated in the UNESCO Convention. DANS is currently trying to define criteria linking this to the protection of contemporary wrecks (20th C), in connection with the 'wreck diving' issue.

Are other protective legislation methods used (environmental protection)?

Yes, including mitigation references concerning the underwater cultural heritage in several pieces of sectoral legislation (e.g. geological resources, etc.).

Organisation of underwater heritage management at the national level

How many staff at your institute work on the underwater cultural heritage?

Five.

How many maritime/underwater archaeologists?

One.

How high is the budget for managing the underwater cultural heritage roughly?

No budget has been available since 2007. All expenses since then have been authorised (or not) on a case-by-case basis.

How many people are professionally engaged in the underwater cultural heritage in your country?

About 30, including approximately 20 archaeologists.

Is there a central database for the underwater cultural heritage in your country?

Yes, at DANS.

Is it integrated into a database for the overall management of the archaeological heritage, or the cultural heritage in general?
Only for administrative purposes.
Is there a central GIS for the underwater cultural heritage?
No, although the most relevant descriptive elements of specific data are now being entered into the national database with a 'proto'-GIS (because the geo-references are taken from military maps on a 1:25 000 scale and not from the field by GPS).
Are (smaller) specific Geographical Information Systems on the subject of the underwater cultural heritage used at your institute?
No.
Is management of the underwater cultural heritage the core business of your institute?
No.
Is there an active policy on in situ protection?
Yes, but restricted to just a few sites and depending on DANS human resources.
Roughly how many sites are protected in situ?
In the sense of monitoring, fewer than ten, but some of them are included in the monitoring of specific areas, as part of external partnerships or projects (e.g. Ria de Aveiro, Arade estuary, Tagus estuary, Cascais bay, Lagos coastline)

Organisation at the regional and local level

Does responsibility for the underwater cultural heritage exist at a lower administrative level?
Municipalities, provinces, etc. In a very few cases (three), under protocols with municipalities concerning the local underwater cultural heritage inventories in connection with the national inventory (DANS).

Cooperation with other stakeholders

Is there cooperation with other national institutes (navy, maritime authorities (RWS), hydrographical institutes, etc.)?
DANS has institutional connections, but only on an ad hoc basis.
Is the cooperation close, institutionalized (under agreements, for example) or ad hoc?
Ad hoc.
Commercial / amateur diver community:
We have some protocols with diving agencies specifically concerning some managed sites that are open to the public (Océan, Faro A, Thermopylae-Pedro Nunes).
Fishing community?
No.
Offshore industry?
No.
Other?
No.

MALTA PRACTICE

Has the Treaty of Malta (Valletta) been implemented in your country?
Yes.
Is Malta also used for the underwater cultural heritage?
This is not necessary, as Portugal has ratified the UNESCO Convention.
Who is actively involved in execution (private contractors or government institutions)?
Both. Although there are more than 40 private archaeological enterprises, none is involved in the underwater cultural heritage.
How is the quality of the work guaranteed (quality control system)?
In certain complex cases DANS defines the intervention methods to be applied and takes a special note of the quality of the results.

SCIENTIFIC PRACTICE

Is there an active monitoring programme?
Yes, but only or a limited number of sites and always depending on human resources.
Does an archaeological diving team perform research and monitoring in your organisation?
Not since late 2008/early 2009, but DANS-IGESPAR is currently in the process of recruiting three archaeologists.
Are private parties involved in archaeological research/monitoring?
Yes.
If so, does the government agency subcontract parts of its diving work?
Not until now, but two recent protocols with two municipalities employing underwater archaeologists or archaeological divers opens the possibility of cooperation on monitoring tasks.
Is the avocational diving community (sport divers/amateur archaeologists) involved in the work done at your institute?
DANS is recent, but even its predecessor CNANS and, between 1980 and 1995. the National Museum of Archaeology (Lisbon) developed very successful links with those communities, as reflected in the establishment in the early 1990s of ONG (Arqueonútica-Centro de Estudos), which fought very successfully against the 'treasure hunting' law introduced in 1993 and revoked in 1997. The organisation also introduced a training scheme in Portugal inspired by the UK-NAS scheme.

UNESCO CONVENTION

Has your country signed the Convention on the Protection of the Underwater Cultural Heritage 2001?
Yes
Has it been ratified?
Yes, in 2006

PUBLIC AWARENESS

Is there a regular output in publications on the underwater cultural heritage from your institute?
Output is irregular. CNANS and DANS have a series of reports, now with 44 titles, most of them online.
What about the output in your country in general? Does your institute have a website / section devoted to the management of the underwater cultural heritage?
See www.ipa.min-cultura.pt (but now requiring updating in the context of the IGESPAR site).
Is there specific media attention on television: series on the underwater cultural heritage like 'Wreckhunters', etc.?
Yes, occasionally over the past three decades.

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Some recent ones:

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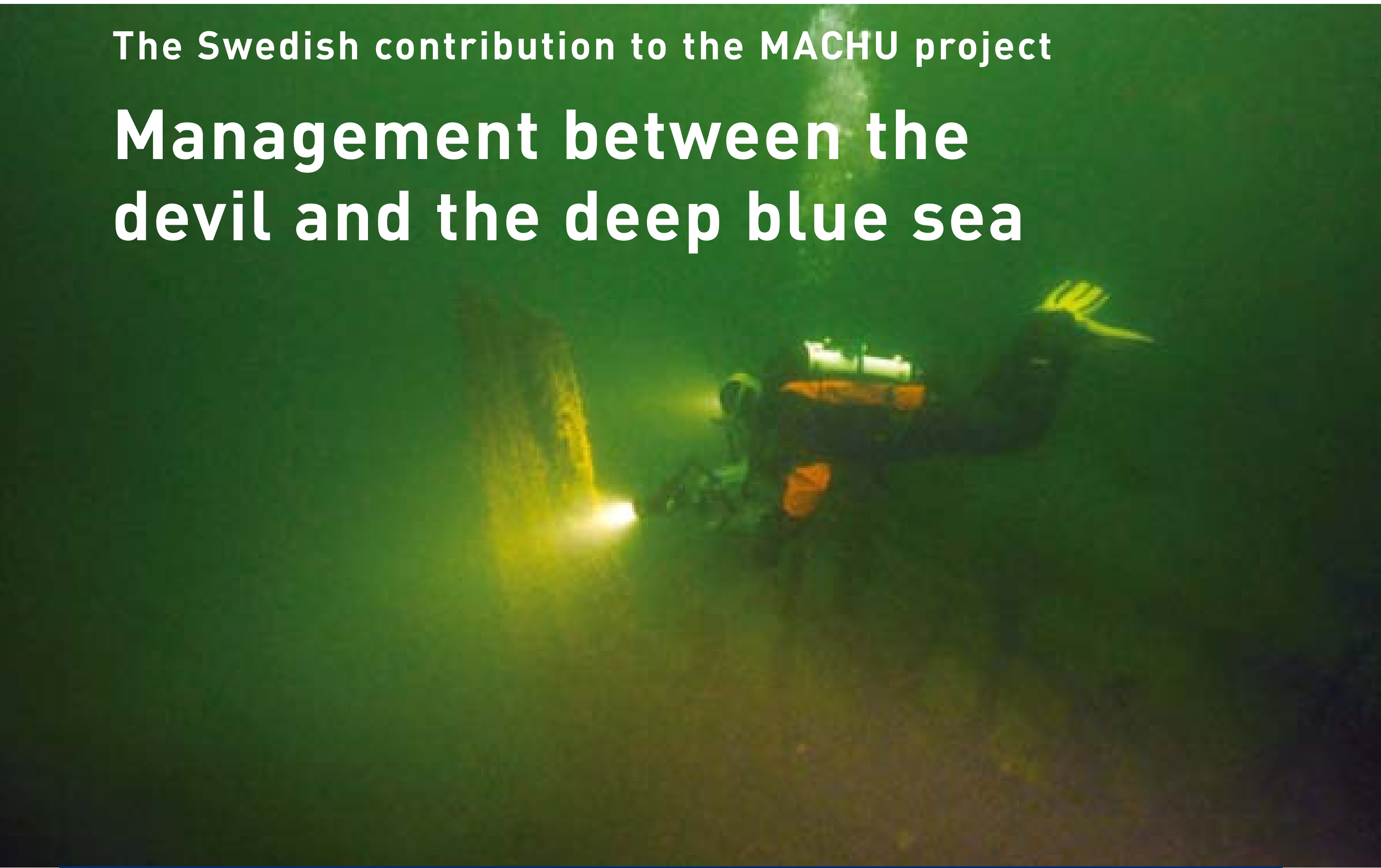

FIGURE 1 MACHU field work at Björns wreck. PHOTO: PATRIK HÖGLUND

INTRODUCTION

The Baltic Sea is an underwater archaeologist's paradise and nightmare. The numbers of wrecks are vast due to an intensive seafaring during a long period of time. Absence of wood boring organisms like the Teredo Navalis, due to the brackish water of the Baltic, leaves us with excellent preservation conditions for wood. From an archaeologist's perspective, management of these wrecks is a great challenge. How do we preserve an intact shipwreck with thousands of visible finds, over time and without limiting accessibility for researchers or the public?

At the same time, these wrecks also leave us with research possibilities that make the Baltic Sea stand out as a global ship archaeological pantry. The Baltic Sea contain all the wrecks we need, from early medieval times and onwards, to understand how seafaring and shipbuilding influenced people and developed our societies in a great part of Europe. It's not surprising that many called for the Baltic Sea shipwrecks to be declared a world heritage.

But there are also other aspects to consider. An intact shipwreck, often described as 'time-capsules', makes us all, researchers and the public, go crazy of curiosity. So far, we haven't been able to keep any of the state-of-the art Baltic shipwreck sites untouched for a longer period of time before divers or archaeologist get too over-excited and start dreaming of a new Vasa.
The pharaonic heritage of Egypt provides a simile. If the wrecks are like Egyptian burial chambers, should we really allow every new find to be opened? Shouldn't a few be left for next generations? The Vasa museum is a fantastic museum, but despite a continuous conservation of the ship, it will eventually deteriorate. Today, we lack the knowledge of how to preserve shipwrecks for a longer time in air. And who knows what methods for accessibility and non-destructive research the future reside?

THE SWEDISH CONTRIBUTION

From a Swedish point of view, when entering the MACHU project, we had expectations of strengthening the UCH management nationally in Sweden. Our own study of the archipelago of Stockholm, our reference area, has, together with the work conducted in other parts of the MACHU project, fulfilled this expectation.

We lacked knowledge of the impact to UCH from recreational diving, by natural deterioration and infrastructural developments. We also lacked strategies and methods for long-term management. After three years we have now earned some of this knowledge, and we have built the foundations for a future management structure. This paper provides a summary of the results. A more detailed understanding of the results and the methods developed by Sweden in this project is provided by Göran Ekberg, Jim Hansson and Anette Färjare in this publication.

The result check-list:

- 30 shipwreck sites have been monitored, whereof fieldwork has been undertaken on14 of these;
- A study of recreational diving through a

questionnaire (habits, diving frequency etc);
- A study of the range and numbers of dive guides and charters;
- Development of a GIS tool;
- Statistics of infrastructural developments
- Buffer zones on the disturbance caused by different infrastructural developments;
- A strategy for future UCH management in Sweden.

RESULTS

We have learnt how to identify damage and wear caused by recreational diving
How do we differ deterioration due to natural causes from deterioration imposed by divers? It is difficult to trace wear from recreational diving on a shipwreck, but our results show it is possible. Comparing old and new photography's and documentation from the very same wreck has given us a picture of how a single site deteriorates over time. Already though this analysis it has in some extent been possible to determine the cause of some deterioration. However, most conclusions are drawn through the comparisons of several similar sites in relation to dive frequency data. Through this systematic approach, we see how divers dive and are able to understand the dive patterns on a specific site, be more effective in the monitoring of a site and foresee where deterioration will occur.

RECREATIONAL DIVING IS A TOURISM INDUSTRY ON A STRONG DEVELOPMENT

The Vasa museum had in July 2009, the same amount of visitors it had in July 1990, when the museum opened. Each year, the number of visitors increases and in 2008 we had 1.1 million people from all over the world.

In the recent years, we have seen shipwrecks occurring more and more in TV and newspapers. Diving in Sweden is becoming synonymous to diving on shipwrecks and most dives are done on shipwrecks. Our questionnaire for recreational divers has shown that although people learn how to dive for the excitement of visiting an underwater world, they keep it up because of their interest of diving on wrecks. Our questionnaire also indicates that the single number of dives on shipwrecks each year can be around 500 000!

In the Stockholm are operates around 15 dive charters. Some of them combine their work with their own diving. A majority of the dive charters don't work full time and have other jobs on the side. It is clear that the number of dive charters has increased in recent years. Recreational diving on ship wrecks is on a strong development today. But this picture is just becoming clear to us. The economical and culture-political possibilities of recreational ship wreck diving are still unknown to most people.

Accessibility is important. The same wrecks are visited again and again. Intact shipwrecks (newly discovered) are popular and technical diving, using mixed gas, is increasing a lot!

Our questionnaire also shows that recreational diving is concentrated to wrecks that are accessible. And these wrecks are visited again and again. New and intact shipwrecks are sought for, but the majority of the divers seem to stick with the same wrecks. This results in more extensive deterioration on certain sites, but it also a knowledge that can help us direct diving to new sites.

FIGURE 2 MACHU fieldwork at Margaretha af Vätö. PHOTO: JIM HANSSON

The diving is also changing in character. Around 40% of the divers are licensed or educated to use mixed gas when diving. This increases the maximum depth and new sites become accessible. Scientific and professional diving in Sweden is behind in this development and has regulations that don't support diving with other gases that air. It is of course problematic that only recreational divers can visit the deeper lying wrecks.

INFRASTRUCTURE

Pressure on the UCH through infrastructural development is extensive. The lack of information regarding UCH in areas with a high infrastructural pressure is problematic

It is hard to keep track of the extent of infrastructural development under water. In recent years, is has become common to lay cables and water pipes on the seabed instead of on land, harbors are being moved to less densely populated areas outside the main cities and wind farms are on a strong development.

We have undertaken a GIS based analysis of the infrastructural development in the archipelago of Stockholm. The pressure is very high. The problem is the lack of knowledge regarding UCH. We have a lot of monuments registered in the Swedish national register (www.fornsok.se), but new monuments are constantly found, suggesting there is a very high dark number. Archaeological surveys are undertaken in connection to the planning of infrastructural development projects in order to avoid shipwrecks and other monuments to be damaged. However, the main tool is supposed to be the existing information, the national register. The infrastructural development projects are only suppose to pay for archaeological surveys when there are very strong indications of monuments occurring. But, the number of surveys undertaken is simply too low.

HOW TO GO ON FROM HERE

There are several subjects within under water cultural heritage management in Sweden that now call for attention. To summon up, we can identify several important strategic directions:
We need to develop monitoring plans on wrecks that are vulnerable, threatened and of high cultural value.
We need to improve our collaboration with the recreational diving community.
Instead of dive prohibitions on wrecks, we need a 'restricted accessibility' strategy to reach a long-term preservation that is supported by recreational diving. Dive parks may be a part of this strategy.

We need to improve our knowledge of the underwater cultural heritage. 'Fornsök', the Swedish national registry is a great asset and a good start, but weneed to register more information. We also need to improve the quality of archaeological research departing from under water cultural heritage.

When it comes to cultural heritage management under water, international cooperation is crucial. ■

FIGURE 3 MACHU fieldwork at the collapsed stern of Hansa. PHOTO: JIM HANSSON

Some final remarks and discussion of The Future of MACHU

The MACHU partners have spent three years finding new and better ways to manage our cultural heritage underwater. The results of this EU Culture 2000 project are presented in this final publication. But are we finished now? Are we done with our work? Is there nothing else to do? In MACHU Report No. 2 we took an initial look at the near future.[1] In this article we review some of the results of the project and discuss their possible use in future initiatives for the management of the underwater cultural heritage.

MANAGEMENT METHODS

The MACHU project has explored and presented new methods, and evaluated existing ones. We can all benefit from this. New methods will help to give us a better understanding of our underwater cultural heritage and help us in our management work. These methods will continue to be evaluated by the MACHU partners and others.

The aim of finding methods that can easily be put into practice (both technically and financially) and can give a clear view of the cultural heritage that is totally submerged (in the seabed), and therefore completely invisible, still applies. Despite large investments in national and international projects over the last decade, we still have no workable method for looking into the seabed on a large scale, to detect sites that are completely covered by sediment. This therefore remains a challenge.

GEOGRAPHICAL INFORMATION SYSTEM (GIS)

However, MACHU has made a clear statement on the need for an interdisciplinary approach to research and management, combining all sorts of information that is potentially relevant. This information then has to be made available to researchers and policymakers. With a modest budget, a Geographical Information System (GIS) has been created that can be used as a platform for data and information exchange. The majority of the work went not into developing the GIS itself, but into creating the formats or metadata. The formats form the basis for data exchange, representing a common language between partners. The format for the description of archaeological sites, for example, contains what we regard as the most vital information.

FIGURE 1 Martijn Manders delive rs a lecture on MACHU at the European Maritime Day (http://ec.europa. eu/maritimeaffairs/maritimeday/ conference_ in_rome_ en. html) Stakeholders Conference, Rome, Italy 19-20 May 2009 held in the Appartamento Principessa Isabella wing of the Palazzo Colonna in Rome. PHOTO: Will Brouwers

By making this information available in a common language and taking into account the international agreements on data exchange (INSPIRE),[2] we have made it possible to exchange data vital to our understanding of our common (European) underwater cultural heritage. Providing data is not in itself extremely difficult; the difficulty lies in agreeing how to do so. This is also the case with legislative or management information or, for example, geophysical data and information, which is available in large quantities, but still poorly accessible. MACHU has created formats accepted by eight partners in seven countries. These agreed formats are extremely important stepping stones towards further cross-border data and information exchange in a European setting. We therefore hope that these results will be incorporated and evaluated in other future (European) initiatives, and not merely forgotten.

The possibility of serving the data at source and viewing them in a single GIS viewer was explored. The viewer has been created, but due to the time and budget constraints, and the legal difficulties of providing access to data which in some countries are still highly confidential. We decided only to investigate the possibilities of harvesting data at source, and to abandon the idea of having this system up and running by the end the project. For the sake of the continuation of the project, a temporary central database has been established for MACHU information, where we can manage access more easily.

We believe, however, that the future lies in serving the information from the original source.[3] This has the advantage that responsibility for the information remains with the organisation where it originated, and that up-to-date information is available at all times.

The fact that, early in the project, it was decided to start with a centralised database, solved the potential problems associated with different languages and differently structured databases, because there were different underlying formats, and these were in English. To serve data from the source in different countries is the real challenge. How can we serve and harvest data from the web and automatically present it in a common langua-

FIGURE 2 Rodi Kratsa-Tsagaropoulou, Vice-President of the European Parliament, delivering a speech in the Sala dell'Apoteosi where the plenary sessions were held.
PHOTO: Will Brouwers

ge and format? How can we arrange data exchange between different countries that even have different scripts? How can we overcome the legislative constraints in some countries, or management measures which limit the public availability of spatial information about the underwater cultural heritage, and so still gain access (albeit limited) to their data?

The initial idea of MACHU was to create a single GIS system (or viewer) for the whole world. This idea has shifted towards the possibility of having different systems that are comparable and compatible. A possible focus in the near future could be the establishment of a range of specialised databases with similar formats that are served according to international metadata standards and can therefore be viewed in personally optimised GIS viewers. Not just one viewer, therefore, but many different viewers designed by and/or for individuals with specific needs.
MACHU has explored the possibilities, set standards and even developed vital basics for future continuation.

WEBSITE

The MACHU website has been designed to serve several purposes. The first was for the exchange of data and information between MACHU partners. This is now possible via a password-protected members page.
Secondly, the website was constructed to serve the general public, people who are interested in learning more about the underwater cultural heritage. It started with an English website for adults, and has now been extended to include a children's page in Dutch. We decided not to create a multilingual website during the project, again due to budget constraints. However, this can easily be done once money is made available for translation. Another highly innovative solution to the language issue was explored, using virtual hosts. Virtual hosts can be customised for a specific group of people, or even a single person. A virtual host can act as a personalised virtual assistant that speaks the language of the visitor, on his or her level, and knows what he or she does or does not like. It can therefore direct the visitor through the website in a comprehensive way, making it possible to store a vast amount of information without losing the clarity of the message that you as host of the website want to put across. Virtual hosts are already available in the banking sector, public transport and other areas.[4] Funding seems to be the only factor hampering the introduction of this customised way of approaching stakeholders in the cultural heritage sector.

Thirdly, the MACHU website has another important role to play: as a portal for scientists giving them access to interpreted data (information) on the underwater cultural heritage and specific sites. This information is based on the scientific data, a lot of which can be collected through the MACHU GIS. The data are validated. It is not easy to find scientifically validated information online. Feedback to the MACHU site has suggested that there is a need for such a portal, whether for trained archaeologists, for amateur archaeologists (who are usually the first to investigate sites), or for archaeology or history students.

REFERENCES TO THE CULTURAL HERITAGE IN THE EUROPEAN MARITIME POLICY GREEN PAPER (2006)

- The continuity between the past, present and future needs to guide and inspire European, national and regional strategies, policies and action related to cultural heritage. (p.48)
- What action should the EU take to support maritime education and heritage to foster a stronger sense of maritime identity? (p. 48)
- European citizens have grown up with tales of the great explorers who first helped us to understand that the globe is round and to locate the continents accurately upon it. (p. 47)
- A sense of common identity may well be one important side effect of bringing stakeholders together to participate in maritime planning processes. (p. 47)
- Member states should be encouraged to sign the UNESCO Convention on the Protection of Underwater Cultural Heritage and the European Convention on the Protection of the Archaeological Heritage. (p. 48)
- Part of an EU Atlas of the Seas databank should be an inventory of underwater archaeological sites (p.47). We would refer to this as taking into account the unknown resource by using other data to predict the probability of finds.

A possible fourth and future option for the MACHU website might be to operate as a news portal on global maritime archaeology. A news page is already available, but needs continuous content updates.

A validated site map (see *Wrecks* on the website) containing all kinds of information and links to further information for a wider public is not yet available on a European or world wide scale. This is partly because it needs well-considered structuring and intensive maintenance. Another obstacle lies in the fact that institutions that collect such information are reluctant to share it, or do not have the time to engage in such collaboration. MACHU has however provided a workable solution, in the form of a platform. The site map shows dots, but not actual positions. It therefore limits the risk of unauthorised diving or looting, which can damage fragile wrecks. The GIS does show actual positions and, mainly for this reason, is for restricted (authorised) use only.

The possibility of having an overview of 'what is there' beneath the water surface is much sought after. If the intention is to showcase the richness of the resource and create support for its protection and responsible management, exact positions are not needed. General locations and interpretative accounts linked to the site will suffice. A map such as that available on the MACHU website serves as an example – or, even better, a platform. Although originally developed as a European initiative, the GIS and the website could serve as a format for data and information exchange on a global level.[5]

MACHU AND EUROPE

MACHU is a European initiative and the aims of the project perfectly coincide with European Union's goal of creating an Integrated Maritime Policy. However, the underwater cultural heritage still has no firm basis in this policy, which focuses mainly on economic growth, renewable energy, climate change and ecology, and is designed to create a maritime spatial planning policy.[6] The MACHU partners find this remarkable, since the Green Paper specifically mentions the cultural heritage (including the underwater heritage) as something to be protected and

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS (COM 575)

This is a vision document from the European Commission following the Green Paper on the European Maritime Policy (2006).
In the Blue Book the Commission makes the following proposals that might benefit the management and protection of the underwater cultural heritage, and MACHU in particular:

- An Integrated Maritime Policy for the European Union, based on the clear recognition that all matters relating to Europe's oceans and seas are interlinked, and that sea-related policies must develop in a joined-up way if we are to reap the desired results.
- The first goal of an EU Integrated Maritime Policy is to create optimal conditions for the sustainable use of the oceans and seas, enabling the growth of maritime sectors and coastal regions.
- The development of the Marine Observation and Data Network will be an important tool for this strategy. The EU has therefore allocated money within the 7th framework research programme for this cause.
- Another important focus in the Blue Book is an emphasis on achieving the highest quality of life in coastal regions.
- The Commission will also launch a European Atlas of the Seas as an educational tool and as a means of highlighting our common maritime heritage.
- It proposes the celebration of an annual European Maritime Day (which was launched in 2008 and is to be celebrated each year on 20 May), raising the visibility of maritime affairs and promoting links between maritime heritage organisations, museums and aquaria.
- There should also be easy access to a wide range of natural and human-activity data on the oceans. This would form the basis of strategic decision-making on maritime policy. Given the vast quantity of data collected and stored all over Europe for a wide variety of purposes, the establishment of an appropriate marine data and information infrastructure is of the utmost importance. This data should be compiled in a comprehensive and compatible system, and made accessible as a tool for better governance, expansion of value-added services and should be sustainable.
- The Commission will take steps (in 2008) towards a European Marine Observation and Data Network, and promote the multidimensional mapping of Member States' waters, in order to improve access to high quality data.

All these statements in the Blue Paper and the Action Plan are highly relevant, and potentially beneficial to the management and protection of the underwater cultural heritage as to other aims like economic growth and protection of the natural environment. The Blue Paper clearly states that: '*[The Integrated Maritime Policy] should also promote Europe's maritime heritage, supporting maritime communities, including port-cities and traditional fisheries communities, their artefacts and traditional skills, and promoting links between them that enhance their knowledge and visibility.*' Unfortunately, after a specific mention in the Green Paper, the management and protection of underwater cultural heritage seems not to have been taken into account any further in the Blue Book. There might be several reasons for this. The underwater cultural heritage is easily overlooked, or is considered (by outsiders) to be of little importance and merely an obstacle to economic growth. Furthermore, cultural heritage organisations, both governmental and non-governmental, have not lobbied effectively and were not active enough in the consultation rounds after the launch of the Green Paper on an integrated maritime policy.

It is vital for the protection and management of the underwater cultural heritage that it be part of the integrated maritime policy. It may not be too late yet, and the institutions involved in the protection, management and investigation of the underwater cultural heritage should join forces quickly and get involved in the European debate on this issue. Soon, it will be too late. After the Blue Book, the next step will be an integrated maritime policy, with or without the underwater cultural heritage.

fostered, and used to create a sense of common identity.[7]

Unfortunately, it has been a continuous fight to keep this subject on the agenda, as illustrated by the fact that the Blue Book, the vision document produced by the European Commission following the Green Paper on the European Maritime Policy, makes no mention whatsoever of the protection of the underwater cultural heritage.

We must bear in mind that the maritime history of many European countries is the true binding factor in the European Union. The waters of Europe have in the past been highways for the transport of people, goods and ideas, and they still are today. Most of the goods traded within or outside Europe leave through seaports and are transported on maritime routes. The cultural heritage is still – at best – used as a nice illustration of cultural diversity, but it is mainly ignored, or literally used to illustrate books, websites and reports. However, failing to take the underwater cultural heritage into account in the European Integrated Maritime Policy will put us on a collision course.

The EU Commissioner for Maritime Affairs and Fisheries, Joe Borg, has stated that '*Any long-term management for the seas and coastal areas needs to take the protection and improvement of the marine eco-system into account. In this regard, maritime spatial planning offers an ideal tool for developing an all-embracing approach to the management of maritime activities in line with these ecosystem-based requirements*'.[8] And indeed it is a big step forward to take ecosystem-based requirements as a basis for further development and economic growth. However, in our opinion, it should not stop there. The European Convention on the Protection of the Archaeological Heritage (Valletta Convention 1992) and the UNESCO Convention on the Protection of Underwater Cultural Heritage (2001) are both highlighted in the Green Paper as being important, and individual countries are urged to ratify them. These two conventions have implications for the management of the European seas, and specifically maritime spatial planning. The archaeological heritage (underwater) should as far as possible be protected *in situ* – at the place where it was found. The protection and management of the cultural heritage must investigated, and the costs borne by the developer.[9] If no research has taken place to establish the impact of a project on the archaeological heritage in the area, the project can be stopped. This would not only be an incredible financial disaster for the developer, it would also be an embarrassment. Furthermore, the EU SEA and EIA directives require an assessment of the cultural heritage and member states are required to apply environmental impact assessment to projects such as offshore wind farms (within any part of the EEZ).[10] Integrated policy means taking into account all aspects of integrated management, including the management of the underwater cultural heritage. This is the only way to make the best choices. We therefore hope that the next European Maritime Day on 20 May 2010 in Gijon, Spain, will include a session specifically devoted to the underwater cultural heritage as part of management.

A SECOND MACHU PROJECT?

Now that we have created a solid basis for future data and information exchange, we believe the results of the MACHU project should be taken up in future projects. With the publication of the final report, the hosting of the GIS by Rijkswaterstaat (the Dutch Directorate-General for Public Works and Water Management) and the website still online with guaranteed content management, it is time to start thinking of how the work can be continued. Over the next few months the MACHU partners will start talking about new possibilities, and will encourage others to do the same. We believe that the MACHU project has set standards for others aiming for the same kind of data and information exchange on a European or global scale. Hopefully, these standards will be used as a starting point for further development.

The challenge is to make data on our underwater cultural heritage generally available for research and management. This can be done through an open system – open-source – that enables us to search the Internet and serve and harvest data that are clearly tagged as validated or unvalidated, in accepted formats to allow them to be compared, as well as data that are managed at source, to ensure that accurate and up-to-date information with clear authorship is available.

Information – the interpreted data – should be widely available online (e.g. on a website like MACHU). Its validity must be clear to visitors, whether scientists, policymakers, students or the general public.
Standardised data and information, whether exchanged top-down, orchestrated through government or non-government agencies, or exchanged bottom-up, influenced by all sorts of direct users and other stakeholders, will be brought together to be used in the management of the underwater cultural heritage, creating greater awareness and moving it up political agendas.

NOTES

1 Manders, Martijn, The Future of MACHU, MACHU Report No. 2, 50.
2 See page 121 for INSPIRE.
3 Where the data were originally stored and are managed. This is usually also the place where authorship is arranged.
4 www.artificialindustry.com/cases.php?itemid=1011&catopen=0
5 The Netherlands collaborates with eight other countries located all over the world (Sri Lanka, India, Indonesia, Ghana, South Africa, Suriname, Brazil, Russian Federation) on the management and preservation of their mutual heritage. The MACHU GIS and website could serve as platforms for the exchange of data and information on the shared maritime heritage (including the underwater cultural heritage) of these countries.
6 http://ec.europa.eu/maritimeaffairs/policy_documents_en.html (10-10-2009).
7 European Maritime Policy Green Paper. Towards a future maritime policy for the Union. A European vision for the oceans and seas- COM 275(2006) (http://ec.europa.eu/maritime-affairs/ policy_en.html. (10-10-2009). A green paper released by the European Commission is a discussion document intended to stimulate debate and launch a process of consultation, at European level, on a particular topic. A green paper usually presents a range of ideas and is meant to invite interested individuals or organisations to contribute views and information. Source: http://en.wikipedia.org/wiki/Green_paper (10-10-2009).
8 Joe Borg: The importance of maritime spatial planning for Integrated Maritime Policy. Speech at the conference on Maritime Spatial Planning. Brussels, 26 February 2009. www.europanu.nl/9353000/1/j9vvh6nf08temv0/vi2whf8k2cu7?ctx=vgny2te26rs8. (Published 26 February 2009, checked 12-10-2009).
9 Article 2 of the *European Convention on the Protection of the Archaeological Heritage* (Treaty of Malta 1992).
10 SEA: Strategic Environmental Assessment. Directive 2001/42/EC. EIA: Environmental Impact Assessment. http://ec.europa.eu/environment/eia/home.htm (Checked d.d. 12-10-2009). EEZ: Exclusive Economic Zone. ■

Appendices

P. VOORTHUIS/HIGHZONE FOTOGRAFIE

APPENDIX 1
Dataformats

COMMON GUIDELINES

Formats described here are to be used as guidelines for preparing data for MACHU GIS. The data formats are based on the use of the ESRI shape file format and GeoTIFF (for images).
All geographic data should be referenced in the WGS84 coordinate system.
Examples formatted empty shape files and domain tables are available at the MACHU website.

DATA FORMATS

Description of the data formats for each layer contains:

- Description of the layer
- Shape of the data set
- Data exchange name
- Description of the attribute table, which contains:
- *Field*
  Contains the name of the attribute field, which is an abbreviation of the content. Using abbreviations in necessary because the number of characters of a field might be limited. ESRI-shape file attribute field names come with a maximum of 10 characters. In MACHU GIS an alias will be used to create readable attribute fields.
- *Description*
  Description of the content to fill this attribute field with. The bold text is used as alias for the attribute field names. If more values have to be added in one field the should be separated by commas.
- *Type*
  Description of notion (like number of characters or digits).
- *Optional/required*
  When marked r adding information is required, when marked o adding information is optional.
- *Domain*
  When marked y, field values should be taken from the domain list.

ESRI shape files actually consist out of a number of data files with different extension like .shp, .dbf, .prj, .shx. When ESRI-shape files are generated, automatically it will generate the attribute files FID and Shape in the dbf-file of the ESRI-shape file. These files are not shown when opening the dbf-file in Excel.

Field	Description	*Type*
FID	Internally generated identification number for each feature (e.g. polygon)	*Number*
Shape	Internally generated text, indicating feature-type (e.g. polygon)	*Text (8)*

METADATA FORMATS

Each dataset (shape file and image) within MACHU should be accompanied by source information or metadata in xml-format (Extensible Markup Language). For the description of metadata files, look for the INSPIRE Metadata Implementing Rules on the INSPIRE website: http://inspire.jrc.ec.europa.eu.
To connect metadata to data in MACHU GIS, metadata files should be named after the source dataset e.g. ARCH_NL.shp.xml for ARCH_NL.shp. For recovery of MACHU datasets, add 'MACHU' as keyword into the metadata.

1. ARCHAEOLOGY LAYER

DESCRIPTION

The archaeology layer contains information on archaeological sites (or objects). These sites are geographically recorded as point location based on a xy-coordinate pair (in WGS84). A point represents the location of (the centre of) a site.

The attributes of the archaeology format are mainly based upon a collection of information elements originated from the MoSS management plan. The format now exists out of 30 attributes, containing descriptive information of the site, assessment information, competent authorities, whereabouts, protection, threats, and information references (for instance to its management plan). Each site location has given a unique identification number that should support communication but also create a future possibility to establish relationship to other data sources.

See Table 1

2. RESEARCH AREAS LAYER

DESCRIPTION

The research area layer contains information on research areas, being areas where research has taken place of which results are expected to be meaningful to the management of cultural heritage underwater. Research areas are recorded as polygons.
Research results often exist out of huge data files (e.g. multi beam readings) that can not easily be exchanged through a web-based GIS. The research area layer therefore should make it possible to indicate the availability of research information, more then presenting the source data itself. Data source information (metadata) should make it possible to recover the actual source data when needed.
The format exists out of 8 attributes containing a brief description of the kind of research and research period. It also contains a reference to an image that can be used to (indicatively) present the results of the research in the GIS and as a link to the research data sources. The images are supposed to be geo-referenced (e.g. as GeoTIFF) and made available together with the research areas dataset.

See Table 2

3. LEGISLATION LAYER

DESCRIPTION

The legislation layer contains information on laws and rules that involve cultural heritage underwater. Legislative areas are recorded as polygons, where each rule or law is presented as a separate polygon (or more polygons in case a rule or law applies to a dispersed area). Legislative areas can cover legislation on international, European, national and sub-national level. This means that polygons in the legislation layer can overlap. The legislative datasets of each country (partner) are limited to the areas of its maritime and national boundaries.
The format exists out of 10 attributes, containing indicative information on each specific rule or law, its status, competent authority and a brief description.

See Table 3

TABLE 1 FORMAT Shape: point Name: ARCH_[country code] e.g. ARCH_NL

Field	Description	Field Type	Optional (o) / Required (r)	Domain
OBJ_IDENT	**Management ID** Used to uniquely identify the site (or object). Proposal: This id could be a 2 letter country code (ISO3166-1) combined with unique number (could be NATREG number or code) e.g. NL_41204.	Text (25)	r	
OBJ_NAME	**Object descriptive name** Name usually a toponym, given in reference to the position of the wreck. In practise this is the name how it is usually described in the databases. E.g. BZN 3 (Burgzand Noord 3).	Text (50)	r	
OBJ_POP	**Object popular name**	Text (50)	o	
OBJ_ORGN	**Object original name** The name can be given when it is known e.g. De Rooswijk.	Text (50)	o	
OBJ_TYPE	**Object type** You can choose between: e.g. shipwreck,prehistoric site, other.			
PERIOD_MIN	**First year dated** E.g. -700 (meaning 700 BC) Number may be used to select object by age.	Nr. signed (8)	o	
PERIOD_MAX	**Last year dated** E.g. 1255 (meaning 1255 AD) Number may be used to select object by age.	Nr. signed (8)	o	
PERIOD_CO	**Archaeological period** Period according to country where object is located, e.g. Viking age 800-1050 AD.	Text (50)	o	y
DISC_DATE	**Discovery date** When first discovered e.g. 1985-07-05 (use January 1st for day and month when only the year is known)	Yyyy-mm-dd	o	
MATERIAL	**Main materials** Most important materials used or transported (e.g. wood, metal)	Text (100)	o	y
ARCH_VALUE	**Archaeological value** High, low or unknown	Text (25)	o	y
UPDATE	**Last update** Last update, changes in data about information on the site (e.g. 2003-05-03)	Yyyy-mm-dd	r	
COM_AUTH	**Competent authority** Full original (national) name of who is approved authority and can decide about the future of the site (e.g. Rijksdienst voor het Cultureel Erfgoed)	Text (100)	r	
LAST_VISIT	**Last visit** E.g. 2005-06-04	Yyyy-mm-dd	o	
NAT_REG	**National registration code** E.g. 41204	Text (50)	r	
LOC_OBJ	**Object location** E.g. Wadden Sea Burgzand, The Netherlands	Text (100)	r	
OWN_TER	**Owner terrain** E.g. Municipality of Texel, The Netherlands.	Text (100)	r	
OWN_OBJ	**Owner object** If known.	Text (100)	r	
LEG_STAT	**Legal status** Is it protected by law? e.g. protected site or not protected site.	Text (25)	r	y
DEG_STAT	**Degradation status** E.g. Well preserved, partly damaged, destroyed, unknown.	Text (25)	r	y
PHYS_PRO	**Physical protection** yes or no	Text (10)	r	y
ACCESS_RES	**Access restrictions** Restricted access for public (diving) e.g. yes/no/unknown.	Text (10)		r y
THREATS	**Threats** E.g. looting, fishing, erosion of seabed, abrasion, biological deterioration, other.	Text (100)	o	y
DEPTH	**Depth** (meters LAT) Minimal Dive depth as known (positive number), in meters LAT e.g. 9,0 or 10,5.	Number (5)	o	
REAS_DATE	**Reassessment date** When should the site be re-assessed? This is part of the planning.	Yyyy-mm-dd	o	

Continued on next page

TABLE 1 *(Continued)*

Field	*Description*	*Field Type*	*Optional (o) / Required (r)*	*Domain*
COUNTRY	**Country** In which country is wreck lying?	Text (25)	r	y
POS_X	**Position longitude** East or West (degrees, WGS84) e.g. written like 4.562279 or negative -4.562279.	String (10)	r	
POS_Y	**Position Latitude** North or South (degrees, WGS84) e.g. written like 53.025038 String (10)		r	
VER_CON	**Verifiable connections** Connections to other countries (full names)	Text (255)	o	
REFERENCES	**References** Link to extra documentation of the object including management plans (website), e.g. www.machuproject.eu	URL	o	

TABLE 2 **FORMAT** Shape: polygon (+ image) Dataset name: RES_[country code] e.g. RES_NL

Field	*Description*	*Field Type*	*Optional (o) / Required (r)*	*Domain*
RES_IDENT	**Identifier** Unique identification number of research area. Might be used to uniquely identify the research area (polygon). Use <2 letter country code (ISO3166-1)>_<ID-code> E.g. for the Netherlands: NL_RA00001. etc.	Text (25)	r	
RES_IMAGE	**Image** Name of the image that represents the research source data. This name should be unique and preferably build like: RES_<2 letter country code (ISO3166-1)>_<year_end>_<year_start>_<method>_<number> e.g. S_DE_2005_mbeam_1 or RES_NL_2005_2006_sss_3 Note: add <year_start> only if different from <year_end> For suggestions on keywords or abbreviations for <method>, see domain list RES_METH	Text (50)	r	
RES_TYPE	**Type of research** Choose one type of research, e.g. archaeological survey	Text (50)	r	y
RES_METH	**Research method** Choose one type of method, e.g. multi beam	Text (50)	r	y
RES_TECH	**Research technique** Additional technical information on research method, for example a specification of used equipment e.g. Seabat 8101 (in case of multi beam).	Text (50)	o	
RES_START	**Research start date** (First) date of research the polygon represent	Yyyy-mm-dd	r	
RES_END	**Research end date** (Last) date of research the polygon represents (identical to RES_START if period is just one day)	Yyyy-mm-dd	r	
RES_REF	**References** Link to a reference (website), e.g. www.machuproject.eu	URL	o	

TABLE 3 FORMAT Shape: polygon Name: LEGIS_[country code] e.g. LEGIS_NL

Field	*Description*	*Field Type*	*Optional (o) / Required (r)*	*Domain*
LEG_IDENT	**Identifier** Unique identification number. Might be used to uniquely identify the feature (polygon) and make it possible to link new information to the object. Proposal: This id could be a 2 letter country code (ISO3166-1 ?) combined with unique number. E.g. NL_12	Text (25)	r	
LEG_NAME	**Legislation name** (English) Name of rule or law in English	Text (100)	r	y
LEG_NAT	**Legislation name** (original) Name of rule or law in national language	Text (100)	r	y
LEG_TYPE	**Legislation type**	Text (25)	r	y
LEG_ENF	**Level of enforcement** E.g. national	Text (100)	r	y
LEG_LEV	**Level of agreement** e.g. European	Text (100)	r	y
COUNTRY	**Country** To which legislation applies	Text (25)	o	y
COM_AUTH	**Competent authority** Full original (national) name. Who is approved authority. Who can decide about archaeology matters e.g. Rijksdienst voor het Cultureel Erfgoed (if more than one, separate by comma).	Text (100)	r	
LEG_DESC	**Description** Brief explanation of rule or law, like Does the rule or law applies purely to cultural heritage or is cultural heritage just touched by it?	Text (255)	r	y (see LEG _NAME)
LEG_REMARK	**Remarks** Remarks on legislation	Text (255)	o	y (see LEG _NAME)

NOTES

[1] In MACHU GIS - I, this attribute is used to connect a site to its management plan, stored as a pdf-document named after the management ID. In MACHU GIS - II, a link to the management plan should be established through the 'references' attribute.

[2] Because the format is based on ESRI shape file format, it is necessary her to always add a full date.

[3] The images should be given unique names as described at field RES_IMAGE and should be delivered with metadata of the research data source. In MACHU GIS -I, the image is used to provide access to the metadata of the research data source. In case no representative image of the research data is available, a standard 'empty' image (containing de MACHU loge and text 'no image') is available at the MACHU website which should be geo-referenced to the location of the research area and used to add on the metadata of the research data source.

[4] For MACHU GIS - I, each rule or law is stored and served as a separate dataset because of technical difficulties to identify overlapping polygons in the application. This means that, until these difficulties are solved, each dataset is give a unique name. Suggested is to compos names as: LEGIS_<country code>_<level of enforcement>_<legislation abbreviation> e.g. LEGIS_BE_E_EUCONV.shp for European Convention within the Belgian boundaries. ■

APPENDIX 2
Domain Tables

1 ARCHAEOLOGY LAYER

The domain table of the archaeology layer present which domain values are accepted in the archaeology format.
All fields of the archaeology format are listed.

Fields without domain values are marked blue.
Note: Fields PERIOD_CO and COM_AUTH have country-depended domain values.

The partners of the corresponding countries supplied these values and agreed on their use. Not all partners provided the necessary information to fill this field.

Field	*Domain values*
OBJ_IDENT	
OBJ_NAME	
OBJ_POP	
OBJ_ORGN	
OBJ_TYPE	shipwreck prehistoric site built structure geo-archaeological structure other loose object unknown
PERIOD_MIN	
PERIOD_MAX	
PERIOD_CO	**Belgium** Paleolithicum: 250.000-12.000 BP Mesolithicum: 10.000-5.000 BP Neolithicum: 5.300-2.000 BC Bronze Age: 2.000-800 BC Iron Age: 750-57 BC Roman period: 57 BC-476 AD Early Middle Ages: 476-987 AD High Middle Ages: 987-1250 AD Late Middle Ages: 1250-1500 AD New Time: 1500 - now Period not known
	Germany Palaeolithicum > 8800 BC Mesolithicum 8800-4000 BC Neolithicum 4000-2000 BC Bronze Age 2000-800 BC Iron age 800 BC -0 Roman periode 0 - 450 AD Early Medieval period 450 - 900 High Medieval period 900 - 1200 Late Medieval period 1200 - 1500 New Time A 1500 - 1700 New Time B 1700 - 1800 New Time C 1800 - now Period not known
	United Kingdom Palaeolithic 500000-10000 Low. Palaeolithic 500000-150000 Mid.Palaeolithic 150000-40000 Up. Palaeolithic 40000-10000 Mesolithic 10000-4000 Early Mesolithic 10000-7000 Late Mesolithic 7000-4000 Early Prehistoric 500000-4000 Neolithic 4000-2200 Early Neolithic 4000-3300 Middle Neolithic 3300-2900 Late Neolithic 2900-2200 Bronze age 2600-700 Early Bronze age 2600-700 Middle Bronze age 2600-700 Late Bronze age 2600-700 Iron age 800 BC - 43 AD Early Iron age 800-300 BC Middle Iron age 300 - 100 BC Late Iron age 100 BC- 43 AD Later Prehist. 4000 BC - 43 AD Prehist.500000 BC - 43 AD Prehist. or Roman 500000 BC - 410 AD Roman 43 - 410 AD Early Medieval 410-1066 Medieval 1066-1540 Post Medieval 1540 - 1901 Early Med. or later 410-1540 20th century 1901-2000 Early 20th century 1901-1932 First World War 1914-1918 Mid 20th century 1933-1966 Second World War 1939-1945 Late 20th century 1967-2000 21st century 2000-2100 Uncertain
	Sweden Paleolithicum (<10000 BC) Mesolithicum (10000-4000 BC) Neolithicum (4000-1800 BC) Bronze Age (1800 BC - 500 BC) Preroman period (550 BC - 0) Roman period (0-400 AD) Folkvandringstid (400-550 AD) Vendel period (550-800 AD) Viking Age 800 - 1050 AD Medieval period (1050-1520 AD) New Time (1520 AD or younger) period not known
	The Netherlands Paleolithicum < 8800 BC Mesolithicum 8800 - 4900 BC Neolithicum 5300 - 2000 BC Bronze Age 2000 - 800 BC Iron Age 800 - 12 BC Roman period 12 BC - 450 AD Early Medieval period 450 -1050 Late Medieval period 1050 - 1500 New Time A 1500 - 1650 New Time B 1650 -1850 New Time C 1850 - now period not known
	PERIOD_PT Period not known
	PERIOD_PL Period not known

DISC_DATE	
MATERIAL	wood iron other organic material other metal other non-corroding material other corroding material ceramic glass flint/stone artefacts bone/antler stone unknown
ARCH_VALUE	high low unknown
UPDATE	
COM_AUTH	**Belgium** Vlaams Instituut voor Onroerend Erfgoed **Germany** State Authority for Culture and Preservation of Monuments, Mecklenburg-Vorpommern **Poland** Centralne Muzeum Morskie **Portugal** Centro Nacional de Arqueologia Náutica e Subaquática **Sweden** Riksantikvarieämbetet **The Netherlands** Rijksdienst voor het Cultureel Erfgoed **United Kingdom** English Heritage
LAST_VISIT	
NAT_REG	
LOC_OBJ	
OWN_TER	
OWN_OBJ	
LEG_STAT	protected by law not protected by law unknown
DEG_STAT	destroyed partly damaged removed unknown well preserved
PHYS_PRO	yes no unknown
ACCESS_RES	yes no unknown
THREATS	looting diving fishing anchoring infrastructural development erosion of seabed abrasion chemical deterioration biological deterioration other unknown
DEPTH	
REAS_DATE	
COUNTRY	The Netherlands Belgium Portugal England Germany Poland Sweden
POS_X	
POS_Y	
VER_CON	
REFERENCES	

2. RESEARCH AREAS

The domain table of the research area layer present which domain values are accepted in the research area format.
All fields of the research area format are listed.
Fields without domain values are marked blue.
Note: Field RES_METH lists all defined research methods plus the keyword or abbreviation that could be used in the image name definition in field RES_IMAGE.

Field	Domain values	
RES_IDENT		
RES_IMAGE	See RES_METH	
RES_TYPE	archaeological survey archaeological monitoring archaeological assessment archaeological excavation other	
RES_METH	**content** aerial photograpy coring diving georadar magnetometer multibeam seismic investigation side-scan sonar single beam sub-bottom profiling other	**keyword or abbreviation for image name** aerphoto coring diving georadar magneto mbeam seismic sss sbeam subbottom
RES_TECH		
RES_START		
RES_END		
RES_REF		

3. LEGISLATION

The domain table of the legislation layer present which domain values are accepted in the legislation format.
All fields of the legislation format are listed. Fields without domain values are marked blue.

Note: A list of international and European legislation is added in a separate table, defining the combinations of LEG_NAME, LEG_ENF, LEG_LEV, LEG_TYPE, LEG_DESC (and an additional reference, momentarily not part of the format).
Descriptions on legislation on national and sub-national level are the concern of the individual partners. They should be added to a national domain list and are not displayed here.
Note: Field COM_AUTH has country-depended domain values. There can be competent authorities on different levels on national and sub-national legislation. Descriptions of these competent authorities are the concern of the individual partners. They should be added to a national domain list and are not displayed here.

Field	Domain values
LEG_IDENT	
LEG_NAME	See legislation list below or national domain list
LEG_NAT	
LEG_TYPE	convention directive law policy
LEG_ENF	national sub-national national territorial sea contiguous zone exclusive economic zone high seas not yet into force
LEG_LEV	international European national sub-national
COUNTRY	Belgium Germany The Netherlands Poland Portugal Sweden United Kingdom
COM_AUTH	See national domain list
LEG_DESC	
LEG_REMARK	

International and European legislation	
LEG_NAME	European Convention on the protection of Archaeological Heritage (revised), 1992
LEG_ENF	national, territorial sea
LEG_LEV	european
LEG_TYPE	convention
LEG_DESC	Convention on the preservation of the archaeological heritage, as a source of knowledge for the common European History, preservation in situ is to be considered as first option.
COM_AUTH	Does not apply
reference	www.conventions.coe.int
LEG_NAME	EU Directive 85/337/EEC (EIA)
LEG_ENF	national, territorial sea, contiguous zone, exclusive economic zone
LEG_LEV	european
LEG_TYPE	directive
LEG_DESC	The EIA directive ensures that environmental consequences (including those for the cultural heritage) of projects are identified and assess.
COM_AUTH	Does not apply
reference	www.ec.europa.eu/environment/eia
LEG_NAME	EU Directive 2001/42/EU (SEA)
LEG_ENF	national, territorial sea, contiguous zone, exclusive economic zone
LEG_LEV	european
LEG_TYPE	directive
LEG_DESC	The purpose of the SEA directive is to ensure that environmental consequences, including those for the cultural heritage, of certain plans and programmes are identified and assessed during their preparation and before adoption.
COM_AUTH	Does not apply
reference	www.ec.europa.eu/environment/eia
LEG_NAME	United Nations Convention on the Law of the Sea (UNCLOS), 1982
LEG_ENF	national, territorial sea, contiguous zone, exclusive economic zone
LEG_LEV	international
LEG_TYPE	convention
LEG_DESC	UN convention to regulate the use of the sea and its natural resources. It states the duty of States to protect objects of an archaeological and historical nature and to cooperate for this purpose.
COM_AUTH	Does not apply
reference	www.un.org/depts/los
LEG_NAME	Unesco Convention on the Protection of Underwater Cultural Heritage, 2001
LEG_ENF	national, territorial sea, contiguous zone, exclusive economic zone
LEG_LEV	international
LEG_TYPE	convention
LEG_DESC	International Convention on the Protection of Underwater cultural heritage, the main issues are the protection *in situ* of underwater cultural heritage and to prevent salvage with commercial objectives (sale of archaeological material).
COM_AUTH	Does not apply
reference	www.unesco.org/en/underwater-cultural-heritage ■

Partners in the MACHU-project

BELGIUM

VIOE (The Flemish Heritage Institute)
The Flemish Heritage Institute (VIOE) is a scientific agency under the aegis of the Flemish Government. The policy of the Institute is to approach the legacy of the past as an integrated whole, encompassing not only archaeology, but also monuments, landscapes and heritage afloat.
Marnix Pieters *project coordination & advise* (left the project end 2008)
Ine Demerre *research coordination & project*
Inge Zeebroek *researcher (reinforced the project in 2008)*
Jan Vertommen *financial advisor*
Tom Lenaert *advisor (2009)*

During the MACHU project research, the VIOE and the **Renard Centre of Marine Geology** of the Ghent University (RCMG) have been working together on specific wreck sites.
Matthias Baeye
Tine Missiaen

ENGLAND

Maritime Archaeological team from English Heritage (EH)
English Heritage is the UK Government's statutory advisor on all aspects of cultural heritage including England's territorial seabed, as provided for under the National Heritage Act 2002.
Ian Oxley *head of the Maritime Archaological Team*
Chris Pater *Marine planner*
David Hilton *GIS expertNational Monuments Record Centre*
Tim Cromack *financial advisor, Environment Commissions*

During the MACHU project sub contractors worked on the development of Sedimentation-Erosion Model.
School of Ocean & Earth Science, University of Southampton, **National Oceanography Centre**, Southampton.
Justin Dix, Pierre Cazenave, Tim Rangecroft and Richard Sullivan
ABP Marine Environmental Research Ltd,
Suite B, Waterside House, Town Quay, Southampton.
David Lambkin

GERMANY

Roman-Germanic commission (RGK), a section of the German Archaeological Institute (DAI). in cooperation with the **Authority for Culture and Protection of Monuments in Mecklenburg-Vorpommern**
Friedrich Lüth *projectleader* (head of RGK)
Harald Lübke *archaeologist* (left the project begin 2008)
Stefanie Klooß *projectmanager* (left the project end 2007)
Katrin Staude *projectmanager* (from end 2007- end 2008)
Mike Belasus *projectmanager* (from begin 2009)

POLAND

Polish Maritime Museum in Gdańsk (CMM), as the leading Polish partner
Iwona Pomian *projectleader*
Waldemar Ossowski *researcher*
Thomas Bednarz *researcher*
Wojciech Jegliński *researcher*

Sub contractor: Polish Geological Insitute (PGI)
Szymon Uscinowicz *researcher*
Grazyna Miotkszpiganowicz *researcher*

PORTUGAL

The Nautical and Underwater Archaeology Division (DANS).
DANS is the Portuguese Centre for Underwater and Nautical Archaeology, integrated in the IPA - Portuguese Institute of Archaeology.
Francisco José Soares Alves *projectleader*
José Antonio Bettencourt *researcher*
João Gachet Alves *researcher* (left the project in 2008)
Patricia Carvalho *researcher*
Helder Hermosilha *researcher*
Vanessa Loureiro *researcher*
Maria Luisa P. Blot *researcher*
Miguel Aleluia *researcher*

SWEDEN

The National Maritime Museums (SMM)
The National Maritime Museums of Sweden (SMM) is a governmental institution with a national responsibility to protect, preserve and animate the maritime cultural heritage.
Björn Varenius *teamleader*
Andreas Olsson *teamleader*
Nina Eklöf *projectleader*
Göran Ekberg *researcher*
Jim Hanson *researcher*
Patrik Höglund *researcher*
Niklas Eriksson *researcher*
Anette Färjare *GIS expert*
Marja Arnshav *GIS expert* (left the project in 2008)

THE NETHERLANDS

The Cultural Heritage Agency *before 2009: The National Service for Archaeology, Cultural landscape and Built Heritage (RACM)*
Martijn Manders *project leader*
Will Brouwers *data manager, research*
Andrea Otte *researcher*
Rob Oosting *researcher*
Arjen Roos *financial advisor* (left the project in 2008)
Aise van Dijk *financial advisor* (left the project in 2009)
Gerjo van der Meulen *financial advisor* (2009)
Paul Boekenoogen *GIS specialist*
Wendy van der Wens-Poulich *researcher*
Menne Kosian *researcher*
Bertil van Os *researcher*
Letty Spieker *secretary, communication*

The Directorate IJsselmeer Region *(Rijkswaterstaat IJsselmeergebied)*, is a regional service of the Ministry of Transport, Public Works and Water Management that manages national waters, roads and waterways in the IJsselmeer region.
Wim Dijkman *projectleader (2007-2009)*
Karen Oostinga *projectleader (2006-2007)*
Herman Hootsen *GIS specialist*
Jeroen Postema *GIS specialist (2007)*
Andre Grul *hydrographic surveyor*
Harry Koks *hydrographic surveyor (2009)*

EU

For the EU representative from Project Agent/Culture Unit EACEA- Education Audiovisual & Culture Executive Agency:
- **Tsirakidis Anastasios** *projectofficer 2006-2007*
- **Paivi Hernesniemi** *projectofficer 2008*
- **Jolien Willemsens** *projectofficer 2009*

We would like to thank them for the cooperation and especially the cooperative thinking when solutions had to be found for organization and budget changes during the project.

SOME OTHER PARTICIPANTS IN THE PROJECT

The MACHU project MACHU has been the fruit of a successful working together of the 8 co organizing partners but also numerous other institutes and people were involved. To mention a few:
- **The Grontmij (NL)** was involved in the actually building of the MACHU GIS viewer.

Important sub contractors in the project for the development of innovative techniques were:
- **The Netherlands Centre for Luminescence dating (NCL)** for performing OSL dating on the Burgzand 10 wreck under supervision of Jakob Wallinga.
- **TNO,** the Netherlands Organisation for applied scientific research unit geology.
- **Deltares,** institute for applied research and specialist advice. Deltares has a unique combination of knowledge and experience in the field of water, soil and the subsurface.
- **The Province of West Flanders Belgium** for financial support and the use of the museum of Walraversijde (Oostende) as congress, exhibition centre and working place.
- **The Flemish Marine Institute (VLIZ)** putting the research vessel 'Zeeleeuw' at the VIOE's disposal for the research of wrecksites by divers.
- **The Flemish Hydrography** simplified the archive study and imaging of wrecksites.
- **The Fund for Sand Extraction (Federal Public Service of Economy)** provided data regarding wrecks and specific mapping for the sediment erosion modeling in Belgium.

COLOFON

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Educom Publishers BV
Mathenesserlaan 347
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T +31 (0) 10 425 6544
F +31 (0) 10 425 7225
E info@uitgeverijeducom.nl
www.uitgeverijeducom.nl

EDITORS

Martijn Manders
Rob Oosting
Will Brouwers

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Paul Voorthuis /
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VIOE
VLAAMS INSTITUUT voor het ONROEREND ERFGOED

Deutsches Archäologisches Institut

Rijkswaterstaat
Ministerie van Verkeer en Waterstaat

Rijksdienst voor het Cultureel Erfgoed
Ministerie van Onderwijs, Cultuur en Wetenschap

CMM
CENTRALNE MUZEUM MORSKIE W GDAŃSKU

MC
Ministério da Cultura

igespar
Instituto de Gestão do Património Arquitectónico e Arqueológico

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