Preserving a layered history of the Western Wadden Sea

Managing an underwater cultural heritage resource

Martijn René Manders

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Managing an underwater cultural heritage resource

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Foreword

Foreword

In 1988, I started my study of archaeology at the University of Leiden. Actually, I wanted to become a palaeontologist and Leiden wasn't my first choice, but I unraveled the mysteries of archaeology with great interest in that first year, with approximately 60 other students. Not long after that, an issue of the UNESCO *Courier* caught my eye. It was completely devoted to underwater archaeology[1] and from that moment on I wanted to become an underwater archaeologist. I took the train to Alphen aan den Rijn to visit the Afdeling Archeologie Onderwater (AAO: Department of Underwater Archaeology) of the Ministry of WVC (Department of Culture), which was headed by Thijs Maarleveld. I told him what I wanted to do and he told me what I would need to pursue my dreams. My diving experience was no more than a basic course I had completed in Marseille in 1987, and Thijs advised me to take more diving lessons before joining them in their annual fieldwork on Texel. Underwater archaeology is a technical profession with a safety-first attitude!

Jef van den Akker, originally a sociologist and one of the underwater archaeology team members, introduced me to his dive club Espadon in Utrecht. This was not only the start of my new career and devotion, but also that of wonderful lifelong friendships and professional respect. I redirected my field of study from the Archaeology of South-Southwest Asia to free doctoral study of underwater archaeology at the Faculty of Prehistory, led by Professor Louwe Kooijmans. In 1990, I was ready to join the team. Except for 1995, the year the team went to Terschelling and I worked on my Master's Thesis and acted as a medieval cooper at ARCHEON, I stayed with the group. Eventually, we left Alphen aan den Rijn and moved to Lelystad, where we were incorporated into the Netherlands Institute for Ship and Underwater Archaeology (NISA).

In 2003, I took another step in my career, moving from Lelystad to the headquarters of the Rijksdienst voor het Oudheidkundig Bodemonderzoek (State Agency for Archaeological Heritage, ROB), which was subsequently merged into the National Service for Archaeology, Cultural Landscapes and Monuments (RACM) and is now the Cultural Heritage Agency of the Netherlands (RCE). The move was part of a change in focus from pure science-based archaeology towards a more inclusive cultural heritage management approach.

This thesis is a reflection of the work I have been involved in over the past years, always with the aim of making a valuable contribution to the protection of our underwater cultural heritage. By heading the Maritime Programme (2012–2016) and the Maritime Programme Overseas (2016–2020) at the RCE, I am close to fulfilling the dreams I have always had: making maritime heritage visible, ensuring its inclusion in overall heritage management and making a difference. My work at the University of Leiden, Saxion University of Applied Sciences in Deventer and the UNESCO Fieldschool have given me the great pleasure of teaching students about maritime and underwater archaeology and management. The students have also allowed me to reflect on my work, which I treasure. After 27 years, the passion is still there, and although many people have left, other new colleagues and friends have arrived. Thijs Maarleveld moved to Denmark to set up a faculty for underwater archaeology at the University of Southern Denmark, Boudewijn Goudswaard set up his company in archaeological management and advice, Arent Vos remained in Lelystad when I left for Amersfoort, and Ron Strötbaum became a successful cameraman and film editor. My friends, colleagues and 'seniors in the trade', Jef van den Akker and Peter Stassen, moved to Amersfoort as well, even before me. They passed away far too soon, in 2009 and 2013, respectively. I still miss them a lot. Although I have met many people since in my professional career, the people mentioned above have left an 'imprint' on me which still feels like family, with all the similar ups and downs. They have partly formed and informed my way of working and thinking. I will always be indebted to them.

From my first year of fieldwork in 1990 onwards, the Western Wadden Sea has taken a prominent place in my underwater archaeology career. I have made hundreds of dives there, on many of the wrecks, such as the *Scheurrak* SO1 and the *Burgzand* wrecks. My research shifted from pure science to a focus on the management of shipwreck resources, including the vital but sometimes difficult relationship and cooperation with other stakeholders, such as the fishing community, sports divers and the municipalities in the area. It was for this reason that during the writing of my thesis about in-situ management I came up with examples and questions that were primarily focused on the Western Wadden Sea. Although my first thought was to concentrate on in-situ management in general, my thesis ultimately turned to the management of the submerged or underwater cultural heritage (UCH) in the Western Wadden Sea area. Since 2000, I have been responsible for the execution of a series of European projects (MoSS, BACPOLES, MACHU, WreckProtect and SASMAP, more information about these projects can be found in this thesis) in the Netherlands, for which the practical work was executed in the Wadden Sea, where I learned much about the natural conditions, the threats to underwater cultural heritage (UCH) and the ways we could protect and monitor the sites. This longstanding research now forms the basis of my thesis.

Much of the work presented in this thesis has been done in conjunction with many other people. The results from European projects, for example, are due to the efforts of many from within and beyond the Netherlands. Some of the chapters or sections in

[1] UNESCO 1987.

this thesis are based on previously published articles, as will be mentioned at the start of each particular chapter or section. None of the previously published work has been included without modification. As the core of what I want to say may, however, still be the same, the former co-authors should and will be mentioned.

Since I started my research on the management of underwater cultural heritage in the Wadden Sea a lot has changed. This is, of course, also inherent to the time it has taken me to finish this thesis. In recent years, however, much of this change has been triggered by new regulations in Wadden Sea and heritage management. The Wadden Sea has become a world heritage site, the management of cultural heritage has been decentralized and the Monuments Law has become the Heritage act, with specific consequences for underwater cultural heritage. These developments have shifted the positions of several stakeholder groups and led to a change in attitudes. Maritime and underwater archaeology are currently the central focus for archaeologists, the general public and politicians. It is now the time to make changes and improve the management of underwater cultural heritage based on real data and decisions made by multiple stakeholders. I hope my thesis will contribute to this goal.

1. General introduction

wreck on the island of Terschelling. Photo: M. Manders.

1. General introduction

Much of what has been produced and used by humanity has been lost, thrown away or left behind under water. Sometimes this has happened on purpose, such as the dumping of waste, sometimes by accident, such as the loss of ships. The Netherlands is blessed with a tremendous amount of maritime and underwater cultural heritage, hidden in the North Sea, the Dutch rivers and lakes, in reclaimed land, in former river branches, in estuaries and tidal inlets that have become silted up and, last but not least, in the large tidal basins of the Wadden Sea and the Southern Delta region. However, this resource is primarily invisible to most of us. With a largely 'land-based' archaeological community, there is a bias towards looking at Dutch history from the land towards the water and not the other way around. The – often muddy – waters of the Netherlands, the difficulty of executing archaeological research under water and the tight budgets for cultural heritage management in general have resulted in this enormously rich and often well-preserved resource being largely neglected by archaeologists, historians and cultural heritage managers.

However, over the last three decades, and in cooperation with a more substantial international community of professional and avocational maritime and underwater archaeologists, our insights into this rich underwater resource and the opportunities to research and protect it have improved considerably. Building upon this experience with the underwater resources, I have seen and experienced many of the changes in underwater archaeology and the management of underwater cultural heritage. The changes have been both for the better and the worse, forced by developments inside and outside the profession, from the local to the international scale. In the meantime, many new sites have been discovered and dealt with. This thesis presents an analysis and evaluation of what has happened over the years, what we have gained and what we have lost. New ways to deal with underwater cultural heritage will be proposed. The thesis, therefore, focuses on this one primary question:

How can we manage the underwater cultural resource?

I hope this research will be useful for maritime and underwater cultural heritage managers, archaeologists and policymakers as a background study for their own use and to stimulate discussions about the future value (and non-value) of the management of underwater cultural resources.

Fig. 1.1 A historic replica of a three-masted ship on the Texel Roads. Photo: Paul Voorthuis, Highzone Fotografie.

Fig. 1.2 The Scheurrak SO1 excavation 1989–1997. Photo RCE.

1.1 Introducing underwater archaeology and underwater cultural heritage management in the Netherlands[2]

Although still a relatively young discipline, underwater archaeology and cultural heritage management has come a long way since its cautious beginnings almost 50 years ago. This development can be divided into roughly four stages:

1970s: a nascent interest in diving on shipwrecks and a growing interest to learn more from them, initiated by adventurers and volunteers
1980s: professional interest (archaeology and history) and growing interest from the field of heritage management
1990s–2007: formative phase, with specialized professionals being educated and trained by the Dutch government. Underwater archaeology and management is systematically integrated into national heritage management.
2007–present: decentralization of responsibility in heritage management.

Starting tentatively with professional underwater archaeology and underwater cultural heritage management in the early 1980s, since the mid-1980s – when the work was finally taken up more seriously – until now, the number of underwater sites that have been annually reported in the Netherlands is about 50 to 100. Quite a few are of specific archaeological importance and still of high integrity. This means that large parts of the ships, as well as cargo, inventory and personal belongings, are often well preserved.
As part of this rich resource had become known through the intensification of recreational diving in the late 1970s and early 1980s,[3] it was decided that it would be sensible to focus on rescue research of newly discovered sites. In addition to negotiating mitigatory research associated with large-scale public works,[4] attention focused on the more dynamic tidal basins and especially the Wadden Sea. There was no way everything could be done, not even in these tidal basins, and so the work concentrated on a few marvellous excavations, such as the sixteenth-century grain trader called the *Scheurrak* SO1 (Fig 1.2) and a large seventeenth-century trader, the *Aanloop Molengat*, with a cargo of half-products.[5] This focused approach had its advantages. With limited energy and investment on the government side,[6] but the help of many people, mostly recreational divers and colleagues from abroad, good results were produced.

During the early period of professional underwater archaeology in the Netherlands, which roughly covered the period from the late 1980s to the early 1990s, the two above-mentioned sites were also used to develop strategies and techniques for dealing with the difficult natural conditions predominating in the area, such as strong currents and bad visibility. By excavating the sites, a 'window' on the potential of underwater heritage was gradually opened for a wider public.

The decision to focus on these excavations was made in the context of earlier developments. The first semi-archaeological research in the Netherlands on historical shipwrecks was undertaken in the 1970s, but the government only seriously took up its responsibilities for underwater cultural heritage in the mid-1980s.[7] The fact that underwater archaeology received a crucial stimulus at that time was due to several reasons. One of these was the fact that in 1986, Christies auction house had sold gold and porcelain from the wreck of the VOC ship the *Geldermalsen* for approximately 40 million guilders.[8] The

[2] Parts of this chapter were published by Manders & Maarleveld (2006). All the information has been updated and the text has been rewritten considerably
[3] See the first three annual reports by Maarleveld (1982, 1983 and 1984). These reports show the dependence of the government on the recreational diving community. Up until the last two annual reports of the NISA (Morel & Oosting 1994, 1995), the research results from the professional and the amateur underwater archaeological community were published together. This tradition has finally started again. For 2005, the ROB is preparing a new publication in collaboration with the LWAOW.
[4] The Slufter project (Adams, Van Holk, Maarleveld 1990).
[5] Aanloop Molengat (1987–1992 and 2000). See for an overview, Maarleveld 1993(1) and Maarleveld & Overmeer (2012) and Scheurrak SO1 (1989–1997), see for an overview Manders 2003 (2).
[6] The Afdeling Archeologie Onderwater or department for underwater archaeology (AAO/WVC) existed until the mid-1990s, after which, this executive department for underwater archaeology became part of the NISA (Netherlands Institute for Ship and Underwater Archaeology, ROB/NISA).
[7] Normann 1987.
[8] Jörg 1986.

Geldermalsen sank on her homeward voyage in 1752 with over 150,000 pieces of porcelain on board. It was discovered near Indonesia in 1985 by Captain M. Hatcher. Although the salvaging of the objects was not seen as the ultimate example, or 'best practice', of how to conduct archaeological research under water, it appealed to the imagination of the wider public and therefore made underwater archaeology a subject of general discussion. Never before had maritime cultural heritage shown its richness in such a public way and, even 'better', everybody was able to buy a piece of it! The *Geldermalsen* and other salvage projects were hot issues for journalists.[9] It now became important for the archaeological community to show that 'sound' archaeological research under water could help us to make an even better reconstruction of the past, if it was executed in 'the right way'.[10]

Although the tensions between commercial salvers and maritime archaeologists was not only a Dutch issue, these salvage operations can be seen as a driving force for change in the Netherlands. In response to the sales of the mid-1980s, a Commission of the Royal Netherlands Academy of Arts and Sciences[11] was established which had the task of investigating the current situation in underwater cultural heritage management in the Netherlands. The Commission concluded that 'the Dutch government failed in its policy because of its lack of interest in cultural heritage on the seabed'.[12] The Commission also stated that 'there is a serious lack of tradition in the country concerning maritime archaeological research'.[13] The overall conclusion of the Commission was that something had to be done immediately to safeguard this rich resource.[14]

In the same period, and not completely by chance, the Dutch national Heritage act was being revised. In 1985, it was determined that the Dutch Monuments Law also applied to its underwater cultural heritage. At the end of that year, the Dutch Monuments Law of 1969 was updated, although it was only to be implemented some years later in 1988.

It was felt that the updated law not only provided an opportunity to change the rules but also to change attitudes.[15] On 15 March 1985, a symposium entitled 'Verantwoord onder water' was organized by the KNOB in Den Helder, at the southern-most tip of the Wadden Sea. It was one of the first times that different views on how to conduct research on shipwrecks were presented in order to initiate a true debate.[16] One year later, on 17 September 1986, a second symposium was organized by the Nederlandse Museumvereniging, entitled 'Plundering, of verrijking van de scheepvaartgeschiedenis' (Plunder, or enrichment of the maritime past). This conference aimed to gather and discuss various opinions and views on the salvaging of the *Geldermalsen*. Public opinion was mobilized through the media to appeal for the protection of underwater maritime heritage.[17] It is interesting to see that, according to public opinion at the time, the best way to safeguard underwater cultural heritage was to excavate it.[18] The pressure from all sides led to the establishment of a small archaeological diving unit and the political and public support to start the above-mentioned long-term excavations on the *Aanloop Molengat* and *Scheurrak* SO1 sites.[19] With these excavations, the subsequent governmental underwater archaeological agencies have proved the richness of our underwater cultural heritage. These underwater archaeological excavations also proved that this was not just something for the Mediterranean, but that it could even be done in the dark and murky waters of the Netherlands.

The focus on excavation was adopted, in an attempt to avoid the traps of protection for the sake of protection.[20] A focused approach was needed in order to develop adequate underwater archaeology practices under the prevailing conditions, without being distracted by the continuous flow of sites being discovered. Therefore, at that time, it was consciously decided not to follow exactly the same path as terrestrial archaeology, where, since the mid-1970s, the notion of preserving archaeological resources for future use was growing, questioning the impact of any disturbance.[21]

In the second half of the 1990s, it became clear that the approach to underwater cultural heritage needed to change. Through excavation, knowledge had improved and ambitions had changed. Underwater heritage management was becoming an accepted public responsibility and, more than before, there was a

[9] See Volkskrant, 23 July 1985.

[10] Regteren Altena 1987, 13: 'The Netherlands can contribute to the effective protection of historical shipwrecks by developing a vision on underwater archaeological policy that is focused on "excellent research"'.

[11] The 'Commissie Normen Onderzoek Scheepswrakken' was installed in 1985 by the KNAW (Koninklijke Nederlandse Akademie van Wetenschappen: Royal Netherlands Academy of Arts and Sciences) and had two members, Prof. J.R. Bruijn and Prof. H.H. van Regteren Altena.

[12] Rapport van de commissie Normen Onderzoek Scheepswrakken KNAW 1985, 26.

[13] KNAW 1985, 16.

[14] See KNAW 1985.

[15] The symposium 'Verantwoord onder water' (KNOB 1986). The symposium 'Plundering, of verrijking van de scheepvaartgeschiedenis' (Brand et al. 1987).

[16] KNOB 1986.

[17] Meijer 1986, Hansen 1986(1), Hansen 1986(2), Hansen 1986(3), Ridderikhof 1986.

[18] Eelman 1986, Hansen 1986(4) and KNOB 1986, 53.

[19] Jesserun 1991, 19–21.

[20] Maarleveld, 1993 (2). The protection of a site might be solely done for pragmatic reasons to postpone making decisions as to what to do with it in the future. However, protecting a site means that responsibility is taken for its future welfare. This means that protective measures are meaningless if they are not accompanied by a management plan. The time frame should also be part of the management plan.

[21] Lipe 1974, Green 1984.

need for an overall assessment of resources. Significance assessments were undertaken and, through various European projects, cooperation between several countries led to research on the deterioration and in-situ preservation and protection of shipwreck sites.[22] With an increasing focus on and stability in budgets (albeit temporary), staff, credibility and support in the following decade, it was possible to investigate what our rich underwater maritime heritage had to offer and to open this archive for investigation and enjoyment.[23] The sites were and still are today primarily being inventoried, assessed and monitored; as well as valued and compared. In doing so, we are grasping the extent of the resources, we know the existence of.

In summary, there has been a shift from focused archaeological excavations to managing the resource.[24] For underwater archaeology, this means more emphasis on making an inventory of all the sites that have been discovered and producing some sort of overview of the potential of Dutch underwater cultural heritage.

Until recently, our knowledge of the underwater resource was completely based on incidence: a wreck was discovered and something had to be done with it. This incident-driven approach has been viable and accepted for a long time, as in fact it has been on land as well. In addressing the new ambitions of gaining better knowledge and an overview, however, it was essential to ensure that management was not incident-dependent. Starting from scratch, new techniques needed to be developed to assess the volume, quantity and quality of maritime heritage we were potentially dealing with. With the information that the national cultural heritage agency and others have since collected, it has become possible to roughly estimate what might potentially still be found.[25] To obtain an even better idea about what is left in the seabed, this information was translated into predictive models and combined with information from dry areas. In this way, the importance of specific areas and sediment layers that we had no solid information on has been assessed. Based on such predictions, a very general management tool was developed: the indicative map of archaeological values (IKAW). Since then, even more accurate and detailed methods have been established.[26] In the first half of the 1990s, management thus shifted from a short-term (excavation) to a long-term approach (inventory, monitoring and safeguarding; building up and maintaining an archive under water).

The Dutch Government, through its cultural heritage agency, has also positioned itself differently since the mid-1980s. This has slowly but steadily created opportunities for others (besides the national government) to do research, gain overviews and further support the management of archaeological heritage.[27] Until 2006, the national government was the only professional actor in underwater maritime heritage management. In that year, the first ever development-led excavation was carried out by a commercial party.[28] In early 2017, there were five commercial parties with an excavation licence for archaeological work under water.[29]

Building an inventory of what we know means that we can selectively protect sites for the future, while in theory it may also be possible to choose exactly the right site to excavate in order to fill a gap in our knowledge or to contribute to solving a research question set out in a research agenda.[30] By doing so, it is no longer necessary for chance finds to dictate the research and a problem-oriented approach can be taken. Sites with a high research value are being well protected and managed to safeguard the resource for future research. Research may therefore shift from excavations led by chance and intuition, to question-based research led by rules, guidelines and scientific programmes, or what should be 'best practice' in archaeology. I

[22] These were the MoSS, BACPOLES, MACHU, WreckProtect and SASMAP projects. See further in this thesis for more information about these European projects.

[23] E.g. Daalder et al. 1998.

[24] ROB 1995, ROB n.y.(1), ROB n.y.(2)

[25] Maarleveld 1995, 1998. Deeben et al. 2005.

[26] Deeben et al. 2002, also Lauwerier & Lotte 2002. IKAW (Indicatieve Kaart Archeologische Waarden) was designed for both land and underwater terrain. For underwater terrain, it can only roughly tell us something about the possibility of finding sites in certain areas. It lacks information about sediment build up, erosion and other natural and human threats, but also information about current and past land/water use. This makes it a good basis for the prediction of prehistoric sites under water, but not particularly for shipwrecks. Although superficial, the overview created has been of assistance in convincing other stakeholders to care for our maritime heritage. The static overview, which does not represent the dynamics of the Dutch seabeds, has led to the development of a new system: the Historical Geomorphological Map set. See also Chapter 2.

[27] Archaeological Management Research.

[28] ADC ArcheoProjecten.

[29] ADC, RAAP and Archol have a licence for both underwater and land research, while ADT and Periplus Archeomare only have a licence for underwater excavations. The City of Amsterdam (within its municipal borders) and the RCE also have a licence for underwater excavation. On 1 June 2015, licences for archaeological excavation were held by 4 universities, 41 companies, 21 municipalities and 1 for the national government (RCE) (http://erfgoedmonitor.nl/indicatoren/opgravingsvergunningen-aantal-uitvoerder, accessed 7-10-2015). On 30 October 2016, this had not changed, except for the growth in the number of municipalities with an excavation licence from 21 to 25 (http://erfgoedmonitor.nl/indicatoren/opgravingsvergunningen-aantal-uitvoerder, accessed 29-01-2017). The system of archaeological excavation licences will disappear with the implementation of the new Heritage act in 2017 and a system of personal certification is being put in place and will be active from July 2017 onwards (http://cultureelerfgoed.nl/dossiers/erfgoedwet/archeologie-en-de-erfgoedwet, accessed 29-01-2016).

[30] A new national research agenda has been drafted, which includes maritime and underwater cultural heritage: http://cultureelerfgoed.nl/sites/default/files/downloads/dossiers/g02-026_rapport_noaa_2_0_def.pdf (accessed 29-01-2017). See also https://cultureelerfgoed.nl/nieuws/nieuwe-nationale-onderzoeksagenda-archeologie-online, accessed 29-01-2017).

deliberately say 'may', because at the moment (2017) archaeology and archaeological heritage management in the Netherlands are still – and probably will be for a long time – dictated by a prevailing in-situ preservation policy strongly linked to the 'disturber pays principle,' as laid out in the Treaty of Valletta (1992). This was put in place to protect archaeological sites from being excavated without proper preparation, plans, resources or an overall rationale for why the excavation is necessary. Although excavations do occur, a proper discussion of the functionality of excavations in general remains limited and driven more by the practical circumstances (mitigating a 'problem' for the client) than by a well-argued scientific or societal reason (the need to learn about the past).[31]

Changes in policies, laws and regulations thus change the approach to how work is executed. Another example of this is the change in the mid-1990s in dealing with the participation of other stakeholders in archaeological dive projects. Until 1995, the national government (at that time the ROB) was able to dive and excavate with few legal restrictions. However, in December 1994, a new law 'Besluit Arbeid Onder Overdruk' (The Law on Hyperbaric Labour, working under excess pressure) was implemented. This law stipulates that anyone who works under water must possess a specific professional diving licence.[32] Archaeology students and colleagues in other countries, however, generally make do with other qualifications, such as sports diving certificates. Thus, it has become very difficult for them to participate in underwater research with the Cultural Heritage Agency under this new law. Fortunately, soon after the introduction of the dive law, an exception was made to allow, in specific circumstances, students to participate in the work as long as they had 'sufficient' experience in diving. Unfortunately, the medical check for these students has to be done on a professional level which is another financial obstacle.[33] This law also remains an obstacle for joint diving between avocationals and professionals, which has a strong effect on the participation of other stakeholders, including local communities, in underwater cultural heritage management.[34]

For a long time, well into the 1990s, underwater archaeologists did not have a specific academic archaeological background but came from a diving community or other scientific disciplines such as maritime history and oceanography.[35] It is only more recently that university-trained underwater archaeologists have begun to do the work. Contacts and connections with various stakeholders is therefore traditionally very strong in underwater cultural heritage management.
Since the implementation of the European Valletta Convention (Treaty of Valletta, 1992) in Dutch law in 2007, cultural heritage management has been decentralized and in many cases has become the direct responsibility of the municipalities, rather than the national government.[36] What many of them may not have realized is that this responsibility also stretches to the water, including rivers, lakes and seabeds. The desire to also manage this heritage has slowly awoken and led to a degree of critical evaluation of the system as implemented in the Monument Law.[37] The question is whether these municipalities are up to their tasks.

It was due to this decentralization and the changing role of the national government in underwater cultural heritage management that the need to develop tools for management and to build capacity for the execution of it – once again – by different stakeholder groups became urgent. As a direct consequence of this, the Maritime Programme was established in 2012.[38] Its establishment was decided on at ministry level after the evaluation of the implementation of the Valletta Treaty in the Dutch Monuments Law. This evaluation made the lack of integration of maritime cultural heritage management into overall cultural heritage management very clear.[39] The primary task of this programme was to have a basis for maritime and underwater cultural heritage management in place by mid-2016.[40] The integration of underwater and maritime archaeology, including maritime and underwater cultural heritage management within the management structures of the Cultural Heritage Agency of the Netherlands (RCE), was largely established in March 2016.[41] Tools for other actors have been developed and made accessible.[42]

Although stepping away from its former responsibilities in many cases, there are some exceptions in which the national government remains the lead management organization for underwater cultural heritage: the North Sea is still managed nationally and the government has a direct responsibility in other national waters

[31] See also Fontijn 2017.
[32] HSE 1 and the Dutch equivalents NDC duikarbeid A and B.
[33] See also Vroom 2017.
[34] Efforts have been made to also create exceptions within the dive law for archaeological dive training by professionals for avocationals, and for field cooperation. To date (January 2017), this has unfortunately not led to any changes in the law.
[35] Alexander McKee, discoverer of the Mary Rose near Portsmouth was, for example, an historian (McKee 1982).
[36] Wet op de Archeologische Monumentenzorg (WAMZ) 2007. http://wetten.overheid.nl/BWBR0021162/2008-01-01.
[37] Idem.
[38] http://cultureelerfgoed.nl/dossiers/maritieme-archeologie/maritiem-programma (accessed 29-01-2017).
[39] Tweede Kamer, vergaderjaar 2011–2012, 33 053, no. 3
[40] See www.maritiem-erfgoed.nl (accessed 19-1-2017).
[41] This was according to the plans made in 2012.
[42] www.maritiem-erfgoed.nl (accessed 19-1-2017).
[43] See e.g. Rijkswaterstaat 2012, 99 &150.

Fig. 1.3 This is what people usually see when looking at the Wadden Sea: the water surface and what lies above it, not below. Photo M. Manders.

and nationally initiated projects.[43] In all other cases, there is a strong need to cooperate with new competent authorities and other stakeholders in underwater archaeology research and cultural heritage management. The knowledge gathered over the years should be transferred to those who now have (or should have) the responsibility for the resource.

1.2 Research problem

As we have seen, since the early 1980s, we have learned a lot about underwater cultural heritage in the Netherlands, both in terms of the resource itself and the relevant research issues and heritage management. It is abundant, often rich and extremely well preserved. It is also constantly threatened and is the responsibility of several governmental agencies on the regional and national levels. Due to new laws and regulations, this responsibility has increasingly become the task of local government – the municipalities – who often need more knowledge and facilities to be prepared for this new role. Diving regulations have become more strict and cooperation between professionals and amateurs has become more difficult as a result. At the same time, underwater cultural heritage management has shifted from an incident-driven task to at least exhibiting the willingness to undertake long-term management. The problem, however, is that the amount and quality of archaeological remains and the immediate danger they are in, urge us to act quickly to save valuable resources at sites under threat. At the same time, there is also urgency to act in a responsible way and to determine which sites are still in real need of investigation and preservation. The tension between the two issues is evident. However, with a more active and intense use of the water by more stakeholders and the responsibility for cultural heritage placed in lower level government bodies, it has become more urgent to start thinking about the way we can establish longer term and integral management of the resources of our sea, river and lakebeds.

Underwater sites are often situated in a hostile environment and are thus invisible to most people (Fig 1.3). This alone creates many management issues that specifically relate to underwater resources. As a result, they are often not taken into account prior to or even during development activities in an area. Thus, a necessity has arisen to develop effective ways to make underwater cultural heritage visible to non-specialists, such as land archaeologists, experienced divers, planners and other stakeholders who need to be involved in the management. By making this resource visible, it becomes more realistic that a joint effort can be made to take care of it. As the development of ways to mitigate against threats to the underwater cultural heritage resource has to date been limited in its scope and evaluation, the time is ripe to achieve more.

Gaining a good understanding of what resources remain and what can still be found is essential for land-use planning, construction, infrastructure planning and the sustainable exploitation of maritime resources, tourism and recreation (Fig 1.4 presents an overview of the sites discovered on and in Dutch seabeds). Cultural heritage, although a blessing for many culturally minded people,[44] is, however, often a curse for others, such as project developers and spatial planners. The high costs and delays associated with archaeological projects have to be mitigated to meet the interests of the latter. The sooner the 'problem' is known, the better the solution can be sought. Realizing that cultural heritage values are not always perceived positively – especially when high levels of investment are involved – has been a real eye-opener to many archaeologists who made the step or career move from primarily being an archaeologist to working in the societal and spatial setting of cultural heritage management or policy planning. Even within governmental agencies, the differences in stakeholder attitudes towards underwater cultural heritage within infrastructural projects is a well-known and recognized issue. This means that the rationale for protecting underwater cultural heritage has to be evaluated and communicated clearly and repeatedly. Out of sight too often seems to mean also out of mind.

As we have seen in the preceding section, underwater archaeology has painstakingly and slowly developed from an adventurer's

[44] Or others with a profit to make from cultural heritage.

profession – which focused primarily on the retrieval of objects – to a systematic and scientifically justifiable archaeological investigation of shipwrecks focused on retrieving data through excavation. Much of the work executed in underwater archaeology and cultural heritage management has been a direct response to incidental discoveries that resulted in ad-hoc solutions, restricted by the financial means and capacity available. Underwater archaeology is expensive and requires specialists to execute it. Even now, when an underwater site is discovered, a discussion amongst terrestrially orientated archaeologists arises concerning whether to treat it differently than we would do a terrestrial site. The recovery of all the beautiful finds then often prevails over fact-finding through proper underwater archaeological excavation.[45] In the meantime, it has proven to be necessary to develop specialized methodologies for doing archaeological research in dark, muddy and often inhospitable contexts. In the process, underwater archaeology has been looking for branch-specific solutions, proving its right to exist alongside mainstream terrestrial archaeology.

With the signing and ratification of the Treaty of Valletta (1992), greater emphasis has been placed on the management of archaeological resources in general, including underwater resources. By placing the responsibility partly outside the archaeological community, on local governments and those who intend to disturb the site, the urgency to do something with the resource has increased. The 'disturber-pays-principle', which is one of the basic principles of the Treaty of Valletta, ensures the attention of these stakeholder groups. In-situ preservation, as the first option to consider, is an important rule in the Treaty and other subsequent conventions and guidelines for underwater cultural heritage management such as the ICOMOS charter for the protection and management of underwater cultural heritage (Sofia, 1996) and the UNESCO Convention on the Protection of the Underwater Cultural Heritage (Paris, 2001). This has induced a shift in activities towards cultural heritage management, with in-situ management as the primary focal point. It is questionable, however, whether in-situ preservation of underwater sites is always the most logical option, and for underwater cultural resource remains especially, this should be carefully examined.

While the changes in rules and regulations first led to the exclusion of specific actors and stakeholders, for example due to stricter diving regulations, in recent years there has been more inclusion, due to more general regulations that support participation. Stakeholders such as sports divers and source communities need to be included in underwater heritage management. The issue is how to realize this. More stakeholders also means an acceptance that cultural heritage has different values. A site or an object can be perceived and interpreted differently by different groups within society, depending on cultural and social background and political context. It will be interesting to see how this growing diversity has implications for how we will or should use this heritage now and in the future. Participation in the decision-making process and activities related to cultural heritage management by different individuals and groups will only increase in the coming years. Thus, it will also be interesting to see what the consequences are for archaeologists and cultural heritage managers, who need to prepare themselves and start thinking about what role they should and are willing to play.

The effects of infrastructure projects and other human interventions on the seabed are substantial. It is not only the short-term effects that threaten archaeological sites but also long-term deterioration and erosion. However, this is still rarely taken into account when permits are granted for infrastructure projects. Only after decades do we see the long-term and delayed effects.[46] These can be severe, but responsibility for the consequences is always a complicated issue, especially after many years. This should be regarded as one of the major downsides of the implementation of the Valletta Convention in the Netherlands and many other countries in Europe (see for more on these threats, chapter 3).

The fact that, today, municipalities are being asked to take care of their own heritage also poses multiple difficulties. Just to name a few: firstly, underwater cultural heritage is 'invisible', so who wants to protect it?; secondly, municipalities have never felt responsible for underwater cultural heritage and therefore have no tradition to fall back on;[47] and thirdly, the dynamics of heritage management can be completely different on the local level than on the national level. Local communities and stakeholder groups are socially and politically close to the decision-makers and, therefore, may have more influence, convincing them of their interests. This may be contradictory to the aims, intentions and ambitions of national authorities such as the RCE, or the wider professional archaeological community. The primary aim of local stakeholders might be to make underwater cultural heritage more visible and accessible, which may be done by excavating the remains rather than through in-situ preservation. The latter can be seen by these local communities as a way of avoiding responsibility.[48] Also, the view about what is important to 'keep' (ex or in situ) may well be different from a local perspective, in comparison to the view of a national institute that is concerned about the 'stepping stones' of Dutch maritime history.[49]

[45] See also https://muablog.wordpress.com/2010/05/17/the-advisory-council-on-underwater-archaeology-by-matthew-a-russell/ (accessed 23-1-2017).

[46] One example of this is the Afsluitdijk, which was built in 1932 to close off the Zuiderzee from the Wadden Sea. Its long-term effects are still visible in the Wadden Sea. See also Elias et al. 2012.

[47] See, for example, also http://www.oudhoorn.nl/archivering/kroniek/2014/kroniek_2014_februari.php (accessed 29-01-2017).

[48] See, for this expression, also Manders et al. 2009 (1), 179.

[49] Manders 2015(1).

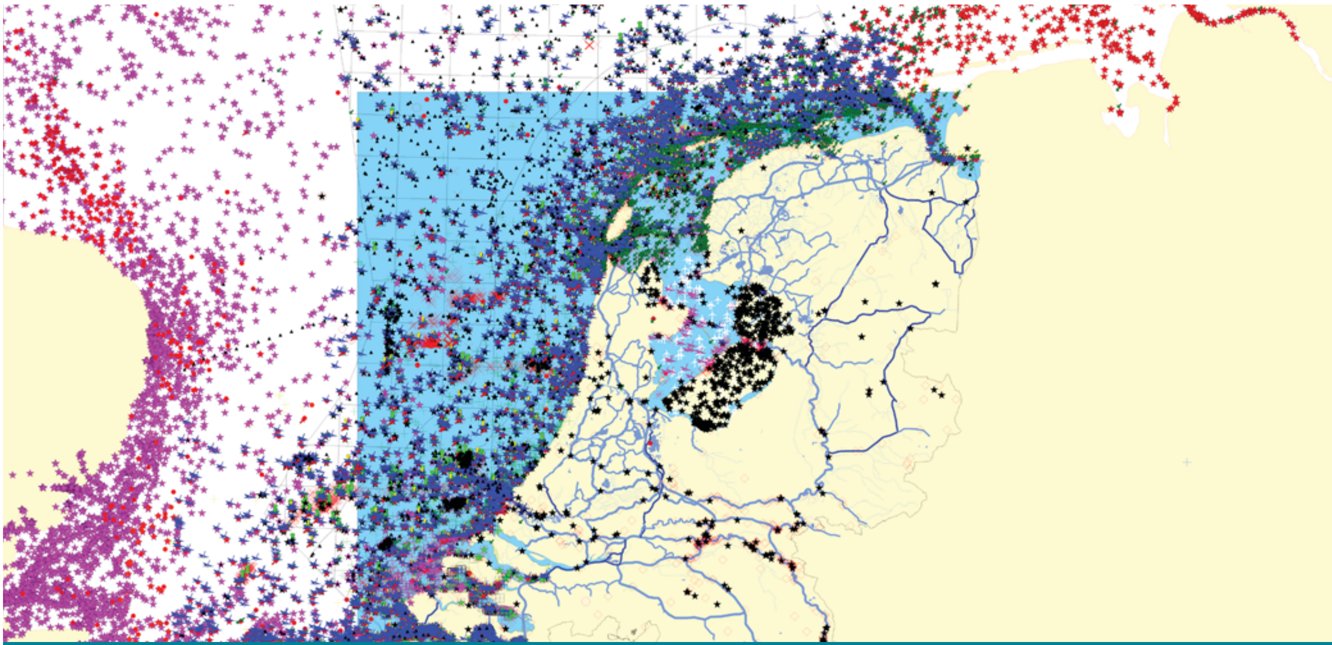


Fig. 1.4 More than 60,000 locations on Dutch seabeds. This is a view of all the known locations recorded in the Archis 2, Hydrographic Office, RWS and amateur archaeologist databases combined. Figure: courtesy RCE.

All these discrepancies in perspectives may lead to different views on what is regarded as valuable and important, and of what needs to be maintained or researched and what should not. One could argue, of course, that such a dialogue or even controversy could, in the end, be advantageous for cultural heritage management. On a management level, diverse interests, on various levels, of different stakeholder groups, may well strengthen common management goals. Fishermen may want to preserve shipwrecks because they are important due to the amount of fish that inhabit them. For divers, enjoyment is often the primary reason to preserve wrecks. A holistic approach that looks at the significance of different sites for different stakeholders is therefore the only proper way to ensure the long-term preservation of underwater cultural heritage.

In archaeological heritage management, in-situ preservation is now considered to be the first option. This is also true for underwater cultural heritage management. This has been made explicit in a few prominent laws and policy papers.[50] But why is this the case? Why has it become such an important part of heritage management in general? Is it because it is a panacea – a wonder pill – for cultural heritage management? Does it provide solutions to most of the problems that arise? And is it the most convenient for most of the stakeholders involved?

These became urgent questions for the author after becoming actively involved in the negotiations of the UNESCO Convention on the Protection of the Underwater Cultural Heritage (Paris, 2001). It has triggered thinking on how we should preserve our rich cultural heritage in an inclusive way: not by considering the sites one at a time, but taking this heritage as an integral and meaningful whole that needs to be responsibly, systematically and proactively managed. Many of the questions above were posed in relation to this principle. Project after project was designed to come up with answers. The test locations in the Wadden Sea were selected with the aim of designing practical solutions. It is for this reason that the focus of this study is geographically on the western part of this area, including the Burgzand.[51] However, the question remains: Is the key to managing our underwater cultural heritage through in-situ preservation?

1.2.1 Summary of the research problem

Over the years, the focus on underwater cultural heritage has shifted from object-related archaeology to underwater cultural heritage management. This shift has occurred due to the sheer plenitude of the resource, as well as changing legislation, but also due to growing knowledge, the development of new research methods and techniques and the participation of an increasing number of stakeholders. However, as underwater heritage management is still mainly incident-driven, this has led to the question of whether long-term sustainable management under water is viable and, if so, how this can be approached more systematically and proactively, including the more active involvement and participation of stakeholders. More specifically, the extent to which in-situ preservation should be the main goal of the management of the underwater cultural resource requires thorough investigation, given the many natural and anthropogenic threats to which it is and will be exposed.

1.3 Key concepts and outline of the research

The growing notion that there is cultural heritage under water must be dealt with carefully, thoughtfully and systematically. Moreover, the increasing decentralization of responsibilities demands a change in approach, encouraging the shared responsibility of different stakeholders – perhaps no less than a paradigm shift. The questions of how, under these circumstances, we should manage our underwater cultural heritage and what a firm basis for maritime and underwater heritage management might be, are not strictly ‘archaeological’. Cultural heritage management (CHM) is not just about doing archaeology. CHM works with the same sites and objects, but within different

[50] See, for example, the Treaty of Valletta (Valletta 1992), The Icomos Charter for the Protection and Management of the Underwater Cultural Heritage (Sofia 1996), and the UNESCO Convention for the Protection of the Underwater Cultural Heritage (Paris 2001).

[51] For the description of the Burgzand area, see Chapter 3.

theoretical and societal frameworks, with different goals in mind and with different sets of questions and research methodologies. Rather than asking ourselves what the past looked like, this CHM looks ahead and tries to picture what the past will look like in the future under different scenarios. CHM tries to share these visions and aims to negotiate a shared view with other stakeholders. Although CHM relies on archaeology and archaeological and historical research to understand the past, it takes a step further by evaluating and managing heritage for future society and science. This thesis starts from this CHM point of view.

Underwater cultural heritage management consists of many tasks, complex decisions to be made and includes – as part of archaeological monument care (in Dutch: AMZ-cyclus[52]) – desktop study as well as in-situ preservation and excavation (Fig. 1.5). Due to the strong bias towards in-situ preservation in archaeological heritage management, this thesis will primarily focus on this element of management. Maritime cultural heritage relates to the history of interaction between human societies, and water as the connection between those societies and as a means of living. As such, it informs us about an important dimension of various people's former natural and cultural environments.[53] It may consist of tangible heritage (such as ships, harbours or landscapes) and intangible heritage (such as traditions, social memories and narratives), which can be found in the water or on land or be preserved and transmitted by communities (in the case of intangible heritage). In this study, the focus is predominantly on cultural heritage as a material witness of the past, which society consciously recognizes as a part of its cultural legacy and is therefore willing to preserve for the future.

Maritime heritage can also be found on land, and include harbour structures and shipwrecks in former sea and river beds, such as in the IJsselmeerpolders.[54] Underwater cultural heritage, however, not only consists of shipwreck material or maritime infrastructures, but also of the remains of prehistoric settlements and inundated buildings that were 'flooded' and are presently situated under water.[55]

Fig. 1.5 Diver preparing for underwater protection measures. See the polypropylene nets for covering sites, front-left of the picture. Photo: Paul Voorthuis, Highzone Fotografie.

[52] Archeologische Monumenten Cyclus (AMZ).

[53] I am well aware that there is no common definition of 'heritage' (Ome Baron 2008, 9; Vecco 2010) or 'maritime cultural heritage'. However, 'tangible maritime heritage' can be defined here as: the material witness of the maritime past which a society wants to preserve for the future.

[54] Reclaimed land in the former Zuiderzee in the Netherlands.

[55] See Chapter 2 for in depth explanation of the definitions of underwater and maritime cultural heritage.

Fig. 1.6 Frames of the BZN 3 wreck before protection. Photo: M. Manders/RCE.

This study is devoted to maritime heritage that belongs to both categories, but it mainly consists of shipwrecks situated in an underwater environment. Thousands of ships have been lost in Dutch waters (Fig 1.6). Some private researchers, most of them active divers, have built databases recording tens of thousands of these shipwrecks.[56] In total, the databases of the Cultural Heritage Agency of the Netherlands consist of no less than 60,000 locations under water (Fig 1.4). This represents the combined knowledge accumulated by different stakeholders, ranging from the Hydrographic Office to sport divers and fishermen.[57] A few hundred underwater archaeological sites (including shipwrecks) are located in rivers. The nature of these river sites are diverse, including bridges, submerged built constructions, settlement relics and religious sites, which have all been recognized and investigated.[58] The same variety can be expected in other water regions in the Netherlands, such as the Wadden Sea. The reason for this is that there are few areas within Dutch territorial waters that have not been dry land during some period of the Pleistocene or Holocene. Moreover, the opposite is also true, with many 'dry' areas in the Netherlands once river or seabeds.

Although this thesis is focused on underwater maritime heritage, we can also learn about our maritime past from terrestrial research. Extensive research on shipwrecks has been undertaken on dry land, in particular in the Flevopolders. Here, 450 shipwrecks were located when the area was reclaimed from the sea during the 1960s and 1970s.[59] The Noordoostpolder and Flevopolders give us an indication of the number of shipwrecks that might still be lying on the bottom of the nearby Markermeer and IJsselmeer. Other wrecks on dry land have been found in former river branches, such as the Roman barges of Zwammerdam and Vleuten-de Meern.[60]

As a first delineation to its scope, this research will focus mainly on the Western Wadden Sea in the Netherlands, due to the number and condition of the underwater sites in this area. The extensive research done during the previous four decades in this area will provide the necessary data to answer the questions in this thesis.

The second delineation concerns limiting the time frame for new information used to describe natural and human processes in the area of the Western Wadden Sea and developments in law and law enforcement. This has been set – completely arbitrarily – at 1 January 2017, the moment when it became clear I was about to round up the writing of this study.

In summary, this study will analyse and discuss the methodology and future development of underwater CHM in the western part of the Dutch Wadden Sea, focusing on the material maritime heritage of this area that has been investigated more or less systematically until 2017.

1.4 Research questions

Starting from the problem definition, key concepts and delineation of the scope discussed above, the research for this thesis was driven by one central question and a limited number of more specific research questions:

The central question of the thesis is: 'How can we manage the underwater cultural resource?'
The sub-questions are:

1. If possible, how can we gain knowledge about the presence of underwater cultural heritage, and of maritime underwater heritage, in particular, in the Western Wadden Sea?
2. If possible, how can we develop an approach to co-create this knowledge by means of desktop research that can serve as a basis for heritage management?
3. Shipwrecks are often found by accident. How can we better predict our chances of finding them?

[56] Oral communication P. de Keijzer, 'de Pluvier' diving team, Scheveningen.

[57] The combined databases that the RCE manages range from objects registered in ARCHIS2, the Hydrographic Office database, RWS and even that of amateur archaeologists. It is not always clear whether these locations are correct or contain sites of cultural significance.

[58] Some investigated examples: bridges such as the Roman bridges of Cuijk (Goudswaard 2000) and Maastricht (Vos 2004); submerged built structures such as the Castle of Elsloo (Soeters & Stassen 2002, Stoepker & Soeters 2005); the village of Beulake (Verlinde 1979); and religious sites (Stassen 2005). The largely by avocationals executed project 'Expeditie Over de Maas' (http://www.overdemaas.com/nieuws/expeditie-over-de-maas (accessed 20-12-2017)) shows the potential of (former) riverbeds.

[59] Some wrecks have been published. See, for example, the Flevoberichten issued by Rijkswaterstaat Directie Flevoland.

[60] See, for example, the overview articles by Brouwers et al. (2013 & 2015).

Fig. 1.7 The Wadden Sea at sunset. Photo: Paul Voorthuis, Highzone Fotografie.

4. Is it possible to preserve 'unknown resources' in situ?
5. What is threatening the shipwrecks in the Western Wadden Sea?
6. Is in-situ preservation a panacea for underwater cultural heritage management in general? What are the alternatives?
7. Is in-situ preservation the solution for cultural heritage management in the Western Wadden Sea? What are the alternatives?

1.5 Objectives

This research focuses on the management of underwater maritime heritage and the potential of applying in-situ preservation to this heritage in the Western Wadden Sea (Fig 1.7). This will be done through the analysis of data gathered over the past four decades and on the basis of recent and current (published) debates regarding this objective, both in the study area and in other areas around the world with underwater environments that are rich in maritime cultural heritage.

The specific objectives are to analyse and discuss the possibilities and impossibilities of in-situ management of archaeological sites under water and specifically the shipwrecks in the Wadden Sea (Fig. 1.8 shows the full archaeological heritage cycle, of which in-situ preservation is one option).

The aim is to dissect the most prominent issues, such as the spatial distribution and extent of underwater cultural heritage, its condition, the natural and cultural threats to which it is, and will be, exposed, the ways to protect this heritage and the effectiveness or not of protective measures. The possible ways to preserve underwater maritime heritage in situ will primarily be investigated in an evidence-based manner and from a science-based perspective, rather than on the basis of the motives, emotions and ideas expressed in public debates between different stakeholders. Nonetheless, a separate discussion about the importance of including non-scientific stakeholders in the process will be included at the end of the thesis (Chapter 7).

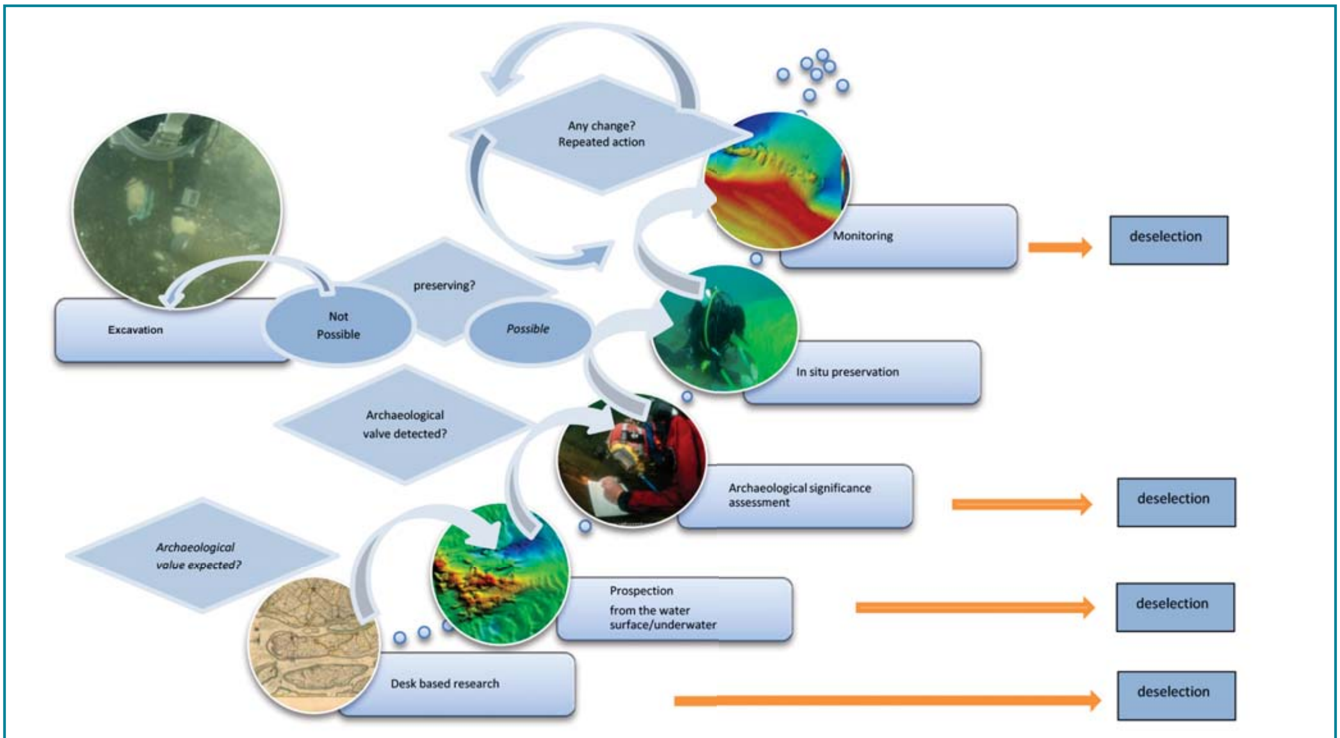


Fig. 1.8 The Archaeological Heritage Cycle. Figure: courtesy M. Manders/SASMAP.

Fig. 1.9 The Wadden Sea Area. Figure: CORINE land-use map, Menne Kosian/RCE.

1.6 A case study approach: the Dutch Wadden Sea

1.6.1 Research area: the Western Wadden Sea

This thesis focuses on the western part of the Dutch Wadden Sea and the former location of the Texel Roads in particular, with the Burgzand area at its centre. Historically, this is where ships were loaded and unloaded, primarily for the Amsterdam market.[61] Much about the geological development of the Western Wadden Sea area has already been described in a series of publications, of which *De Convexe Kustboog* (the 'Convex Coastal Arch'), by Henk Schoorl, from 1999,[62] deserves specific mention. Intensive archaeological research has also been done on the Texel Roads, mainly by government archaeologists, who have focused on the many well-preserved shipwrecks that have been discovered over the decades.[63] Historians have paid special attention to the role of this area in the Golden Age and the Dutch East India Company (Vereenigde Oostindische Compagnie or VOC).[64] However, the importance of the area as a roadstead is much greater and stretches over a longer period of time. It was not only used by ships going to the East and West Indies, but also by warships, merchant ships heading for or returning from the Baltic and elsewhere, and it functioned as such from at least the sixteenth to the twentieth century.

The Wadden Sea is an intertidal zone in the southeastern part of the North Sea. It stretches from the northern Netherlands coast to Germany and the western part of Denmark and consists of a shallow body of water with tidal flats and wetlands. The Wadden Sea is separated from the North Sea by a series of barrier islands with tidal inlets in between. It is also a UNESCO World Heritage Site. The Dutch and German territories were recognized in 2009, and it was extended in 2014 with the recognition of the Danish territory (Fig. 1.9).

In several areas, the Dutch part of the seabed of the Wadden Sea is very dynamic. Processes of sedimentation and erosion alternate at different rates.[65]

[61] See also Chapter 3.

[62] Schoorl 1999/2000.

[63] See, for example, Vos 2012.

[64] See, for example, Roeper & Vonk-Uitgeest (eds) 2002.

[65] Considerable research has been conducted regarding the sea floor in the Wadden Sea area. See also: Oost 2009, Manders 2009(2), Elias et al. 2012, and Brenk & Manders 2014, Manders et al. 2014.

Fig. 1.10 The Afsluitdijk, Photo: Courtesy RCE.

The Wadden Sea is especially susceptible to these processes, as is the North Sea.[66] In the Wadden Sea, gullies can move or change direction over time under the influence of tidal currents.[67] These channels leave traces in the landscape down to the Pleistocene substrata.[68] In some places, Pleistocene sediments are exposed on the surface of the seabed, while in others the Pleistocene strata have disappeared and been eroded by channels or covered with a layer of Holocene sand several metres thick.[69]

Just as the area is constantly being shaped by nature and by humans, so is the seabed. One particular human activity that had a direct and substantial effect on the seabed was the construction of the Afsluitdijk in 1932, between the provinces of North Holland and Friesland (Fig. 1.10).[70] This construction blocked the dominant currents, which rapidly changed the pattern of channels and plates.[71] In addition, by building the dike, the IJsselmeer and Markermeer were isolated from the effects of ebb and flow currents. Since the 1930s, no major changes have subsequently taken place on the former seabed in these lakes except for a massive amount of silt that has settled on the former seabed deposited by the rivers.[72]

The dynamics of the mobile Holocene top strata largely determine whether any heritage has been preserved in the soil, as well as the condition of that heritage at any moment.[73] It is therefore important to gain insight into the condition of the sediments, as well as how they have moved over the past centuries.

The focus in this thesis will be on wrecks submerged at all times. However, it is inevitable that the Wadden Sea *Area* as a whole needs to be taken into account. This area extends from the waters of the Wadden Sea itself far inland, to the point where the influence of the sea disappears.[74] Human and natural processes occurring in the sea and the land adjacent to it play an important role in the decision about what and how to manage and when to preserve sites in situ. People affect management, land affects water; a site is influenced by its context and vice versa.

1.6.2 A short history of the Wadden Sea

The current Western Wadden Sea was only created in the late twelfth century.[75] Before then, the area consisted largely of more or less inhabitable land.[76]

[66] See, for example, Eelkema et al. 2012.

[67] On the moving of gullies in the Wadden Sea, see, for example, the studies by Schoorl 1999 (Part 1, 14–34) and Oost 1995.

[68] See Figs. 1.8 and 1.17 A.

[69] See Fig. 1.20.

[70] See, for example, CPSL 2010, 41.

[71] See Fig. 1.27.

[72] Wiersma & Verweij 2012, 4. Prior to the construction of the Afsluitdijk, the area had been subjected to the same sea-floor dynamics as the Wadden Sea, especially in the immediately adjacent northern section. See also Schoorl et al. 1999.

[73] See also Chapters 2 and 3.

[74] See, for example, Wadden Sea Plan 2010, 5 and Frederiksen n.y.

[75] See for a detailed description of the early development: Schoorl 1999, part 1.

[76] Schoorl 1999, part 1.

Starting in the twelfth century, the Wadden Sea became an easily navigable waterway due to the large breakthrough of the North Sea into the area.[77] From the sixteenth century onwards, the western part of the Wadden Sea became part of the economic heart of the Netherlands, with a strong connection to the international harbour of Amsterdam, and the Texel Roads as the point of departure and destination for voyages to the colonies in the East and West.[78] Dozens of ships would regularly remain anchored in the Roads, waiting for fair winds.[79] This lively and hectic environment, combined with the strong and treacherous currents, the shallows and poor weather conditions, earned the Western Wadden Sea a reputation as an area with a high density of shipwrecks.[80] It now contains many maritime archaeological remains dating from the sixteenth to the twentieth centuries, especially shipwrecks.[81] The tides and subsequent erosion and sedimentation patterns make shipwrecks regularly disappear and reappear again.

The dynamic sea floor has helped to preserve many of these wrecks and has done so since the moment they arrived there. This has resulted in many still being in a relatively good condition.[82] However, some of this heritage is currently threatened by seabed erosion.[83] Sites protruding from the seabed surface are exposed to a wide range of biological, chemical and mechanical degradation processes.[84]

This huge potential of shipwrecks and their exposure due to erosion of the seabed over centuries has attracted adventurous divers, many from the islands and the mainland adjacent to this sea. The involvement of local stakeholders is very high, as the history of the maritime world and the heritage of maritime ways of life are an integral part of the identity of the communities in the area. Each and every person is strongly connected to the sea and this connection often goes back many generations. Early divers from the islands discovered a vast number of wrecks in the 1970s and 1980s. These formed the basis of a shipwreck inventory in the Netherlands. Many artefacts have been taken from these wrecks and form an important part of the collections of local museums.[85]

This local intervention in and influence on underwater cultural heritage management has in recent years been scaled up to a more regional and even national level, partly due to the decentralization of cultural heritage management to the municipality level, and partly due to the fact that the Wadden Sea has been granted World Heritage status.[86] To manage the area, many decisions on specific maritime activities in the area had to be made at the national level;[87] however, these decisions still required input from the local community.

The Wadden Sea's World Heritage status is based primarily on its natural value.[88] According to the UNESCO, the Wadden Sea is:

> the largest unbroken system of intertidal sand and mud flats in the world. It is a large, temperate, relatively flat coastal wetland environment, formed by the intricate interactions between physical and biological factors that have given rise to a multitude of transitional habitats with tidal channels, sandy shoals, sea-grass meadows, mussel beds, sandbars, mudflats, salt marshes, estuaries, beaches and dunes. The area is home to numerous plant and animal species, including marine mammals such as the harbour seal, grey seal and harbour porpoise. The Wadden Sea is one of the last remaining large-scale, intertidal ecosystems where natural processes continue to function largely undisturbed.[89]

However, people have also lived in the area for many centuries. They have altered and used the space on the basis of what they thought right or what would profit them in one way or another. The area, the landscape, as well as the sea, was shaped and still is being shaped through the interaction of human activities and natural processes.[90] The regional landscape, including the Wadden Sea, therefore, shows clear evidence of how people have used it over time.[91] One collection of such evidence is its shipwrecks.

In almost 40 years of continuous underwater archaeological research in the Wadden Sea, it has become clear that the cultural value of the area, as is also illustrated by the rich archaeological remains, is just as unique as its natural value. Both are an

[77] Schoorl 1999, part 1.

[78] Jacobs 1996, 36, Bonke 2002.

[79] Bonke 2002.

[80] Habermehl 2000, Akker et al. 2007, Koeveringe et al. 2011, Vos 2012.

[81] See e.g. Kleij 1991, Vos 2012, Koeveringe et al. 2011.

[82] Huisman et al. 2008. For a long time, it was thought that shipwrecks in the Wadden Sea would sink into the soft Holocene layers, finally resting on the harder Pleistocene strata. OSL Research in the MACHU project (Manders, Van Os & Wallinga 2009 (1) and 2009 (2)) revealed that this is not true in all cases. For example, after hundreds of years, the BZN 10 wreck ended up on a sand layer from the fourteenth century, possibly an old sandbank.

[83] Os & Kosian 2011, Brenk & Manders 2014. See also Chapter 3.

[84] See also Chapter 3.

[85] See, for example, the collections at Kaaps Kil (http://www.kaapskil.nl/, accessed 29-01-2017) and Wrakkenmuseum Terschelling (http://wrakkenmuseum.nl/, accessed 29-01-2017).

[86] See Willems 1999 and www.waddensea-worldheritage.org (accessed 08-04-2017).

[87] See, for example, Leeuwen et al. 2008 and Ministerie van Landbouw, Natuur en Voedselkwaliteit n.y.

[88] See also Reise 2013.

[89] http://whc.unesco.org/en/list/1314 (accessed 29-01-2017).

[90] See, for example, Vonhögen-Peeters et al. 2013, 1611.

[91] See, for more about the development of the area, Vollmer et al. 2001.

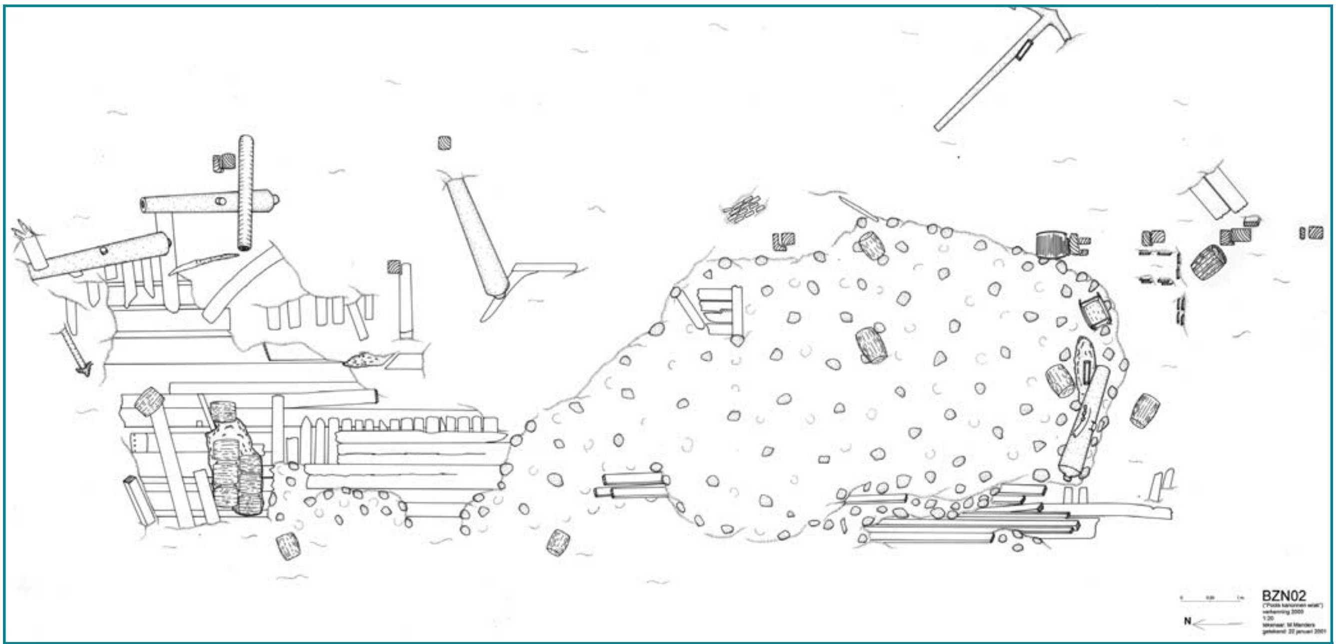


Fig. 1.11 Site plan of the BZN 2 wreck. Figure: courtesy M. Manders/RCE.

important and integral part of the identity or 'DNA' of the area. Even nature has partly been shaped by the activities of people here: it is, for example, one of the most diked seas in the world, with all the geological and natural particularities that accompanied this human intervention.

The aim for many of those who focus on the cultural importance of the area is to preserve the archaeological remains from the violent natural environment. However, the way people want to do this differs from person to person and from stakeholder group to stakeholder group. Some would prefer to remove all the artefacts before they deteriorate too much or even disappear; others would prefer preservation in situ. The latter solution, especially, has gained ground among archaeologists and cultural heritage managers. Professionally, in-situ preservation is the first option and this also counts for the wrecks that have been discovered in the Western Wadden Sea.

1.6.3 The shipwrecks in the Western Wadden Sea

Only the Burgzand wrecks – forming the majority of the shipwrecks in the study area – will be briefly introduced here. I say briefly, because quite a few books and articles have been published over the years with detailed information about the archaeological content and historical significance of the wrecks. The reader is encouraged to turn to these for further information.[92] Information about wrecks outside the Burgzand area used in this thesis will be included when first mentioned.

The Burgzand Wrecks

This thesis heavily builds on information gathered while doing research on shipwrecks in the Western Wadden Sea. Within this area, the main focus of work in recent decades has been on the sites that are located in what is now known as the National Monument of the Burgzand (No. 15660).[93] It consists of fourteen known wrecks from the seventeenth and eighteenth centuries and one possible wreck (BZN 19).

All wrecks have a toponym starting with BZN (Burgzand Noord) and then a number. Not all numbers have been used in order. For example, BZN 1, 5, 6 and 7 do not exist due to the incorrect naming of sites or the merging of different locations which turned out to be one. Initially, national protection was only granted to the site of the BZN 3. The process of protection started in 1988, with registration completed in 1991. However, in 2013, the national monument area was extended to include more wrecks. Those that have been discovered so far are:[94]

BZN 2

The wreck of a mid-seventeenth-century ship was discovered in 1985. It had a cargo of cannons, of which many were bronze field pieces from Poland (Fig. 1.11). These objects gave it its popular name the 'Polish Cannon Wreck'. Ballast stones, lead ingots, boxes with tin and copper, as well as wooden beams for trading were also found and partially salvaged. The site has been partly protected in situ with polypropylene nets.[95]

BZN 3

The wreck of a mid-seventeenth-century ship was discovered in 1985 and is believed to be the remnants of the East Indiaman *De Rob* (Fig. 1.12). One salvaged bronze cannon was manufactured by Everardus Splinter in Enkhuizen for the Admiralty of Amsterdam and bears the year 1638. Dendrochronology dating revealed a date of 1640 +/- 5 for some of the wooden remains.[96]

De Rob was added to the Admiralty fleet in 1629 and fought in the Battle of Duins in 1639. The ship sank on the Texel Roads in 1640. BZN 3 was designated a national monument in 1991 and was protected in situ in 1988 with polypropylene nets and approxima-

[92] Habermehl 2000, Vos 2012 and www.maritiem-erfgoed.nl (accessed 22-1-2017).

[93] See http://www.cultuur.nl/upload/documents/adviezen/Texel-zes-scheepswrakken.pdf (accessed 29-01-2017).

[94] This was the situation in December 2015; since then another wreck has been discovered (BZN 20), but no further information about this find was known at the time of writing.

[95] See also Koeveringe et al. 2011, 49 and Vos 2012, 109–143 and e.g. Chapter 5 of this thesis.

[96] Manders 2005, Saß-Klaassen & Vernimmen 2005.

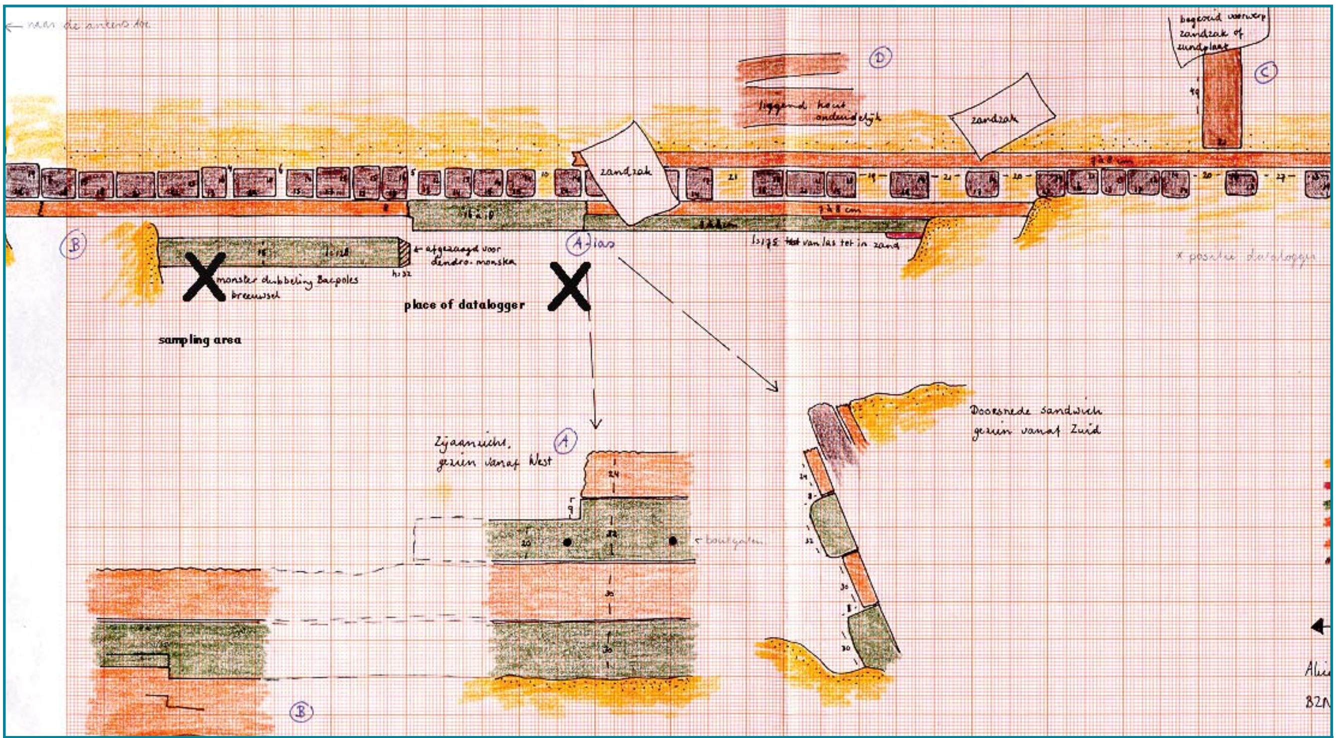


Fig. 1.12 An early site plan of the BZN 3 wreck, made before the in-situ protection of 1988. Figure: courtesy RCE.

tely 6000 sandbags, techniques that are described in Chapter 5. This protection was extended in subsequent years.[97] It was also the subject of some deterioration studies during the BACPOLES project.[98] During additional research in 2013, which followed monitoring of the protected site, new ship construction parts were discovered that turned out to be the hold of the ship, with the base of the main mast in situ, situated next to the already known cluster of anchors that would have been stored in the hold. This part of the construction has also been protected.[99]

BZN 4

This eighteenth-century merchantman with a cargo of casks filled with coffee beans (Fig. 1.13) was mistakenly identified on its discovery in 1984 as a ship that transported water from the Texel wells to the ships. It was thus called the 'Water Barrel Wreck' or 'Watervatenwrak'. The casks are made of wood from South America and the coffee beans may originate from Santa Domingo.[100] This led to the identification of BZN 4 as a West Indiaman: a ship used for trade to the West Indies (the West Coast of Africa, the Americas and the Caribbean). The wreck has been partly physically preserved in situ.[102]

BZN 8[101]

A mid-seventeenth-century merchantman that had been reinforced to be used as a warship (Fig. 1.14). A unique find of a large Hemony bronze church bell carries the date 1658. This

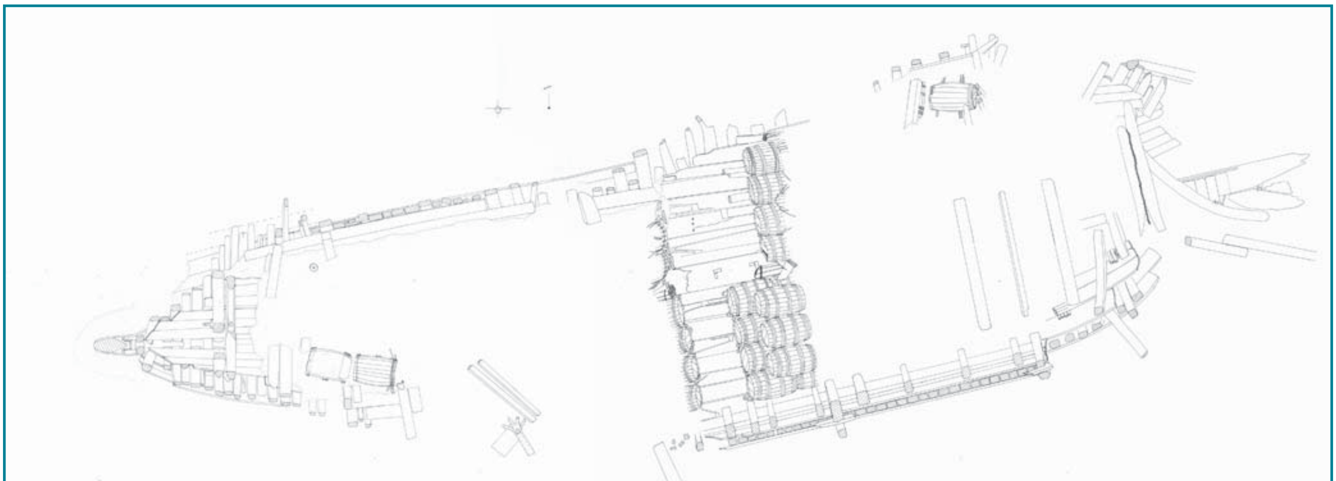


Fig. 1.13 Site plan of the BZN 4 wreck. Figure: courtesy M. Manders/RCE.

[97] Vroom 2014, Vos 2012.

[98] See Manders, 2005 (2) and Chapter 3.

[99] http://www.maritiemprogramma.nl/nieuws/MP_n_topsites_21-6-13.htm (accessed 02-04-2017).

[100] http://www.maritiemprogramma.nl/nieuws/MP_n_topsites_21-6-13.htm (accessed 02-04-2017).

[101] opsites_21-6-13.htm" http://www.maritiemprogramma.nl/nieuws/MP_n_topsites_21-6-13.htm (accessed 02-04-2017).

Fig. 1.14 Site plan of the BZN 8 wreck. Figure: courtesy M. Manders/RCE.

shipwreck is often referred to as the VOC ship, the *Lelie* (1654). This, however, cannot be correct due to a mismatch in dating between the sinking of the ship and the date on the bell. The wreck has been physically preserved in situ.[102]

BZN 9

The wreck of a seventeenth-century ship. Local divers call it the 'Two Cannon Wreck' or 'Twee Kanonnen Wrak', although many more were discovered on this site (Fig. 1.15). Parts of the wreck have been excavated; other parts are protected in situ.[103]

BZN 10

The wreck of a late seventeenth-century merchantman. It is believed to be of Northern German origin and involved in trade with the Iberian Peninsula (Fig. 1.16). It had a large cargo of Iberian jars in its hold, but also casks of anchovy and grapes. The site is protected in situ and has served as the focal point for degradation and underwater in-situ research in the Netherlands. BZN 10 was also once identified as the *Lelie*. Again, as with BZN 8, this identification was false.[104]

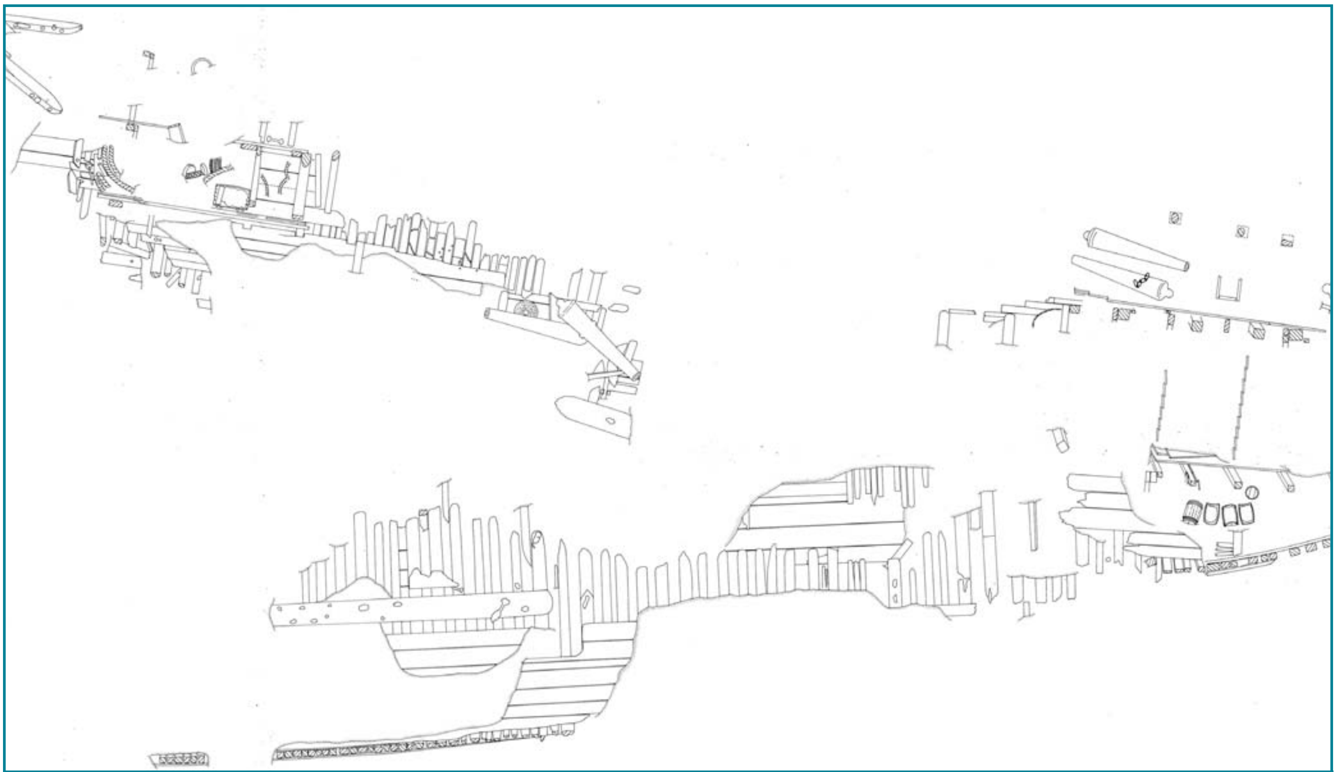


Fig. 1.15 Site plan of the BZN 9 wreck. Figure: courtesy M. Manders/RCE.

[102] http://www.maritiemprogramma.nl/nieuws/MP_n_topsites_21-6-13.htm (accessed 02-04-2017).

[103] MP_n_topsites_21-6-13.htm (accessed 02-04-2017).

[104] 03 (1), Holk 2003, Vos 2012, 244–265.

Fig. 1.16 Site plan of the BZN 10 wreck. Figure: courtesy M. Manders/RCE.

BZN 11

The wreck of a seventeenth-century ship. It is referred to as the 'Big Empty' or 'Groot Leeg' by local divers. This wreck consists of only part of the ship's construction (Fig. 1.17). No inventory, cargo or personal belongings were discovered. The wreck has deliberately not been physically protected in order to serve as a 'control' wreck for the effectiveness of in-situ protection methods.[105]

BZN 12

The wreck of another seventeenth-century ship (Fig. 1.18). Known as the 'Yellow Stone Wreck', it contains a heavy cargo of yellow 'IJssel' stones (bricks). After the initial assessment of its significance it has not been subject to further research.[106]

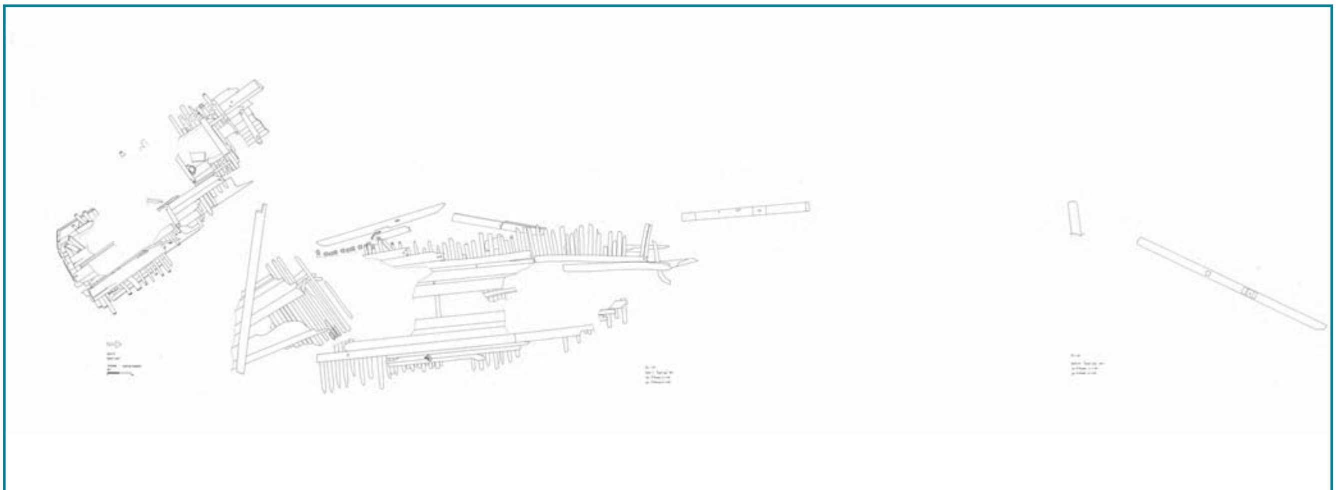


Fig. 1.17 Site plan of the BZN 11 wreck. Figure: courtesy. M. Manders/RCE.

[105] See also Vos 2012 266–279.

[106] See also Vos 2012, 280–288.

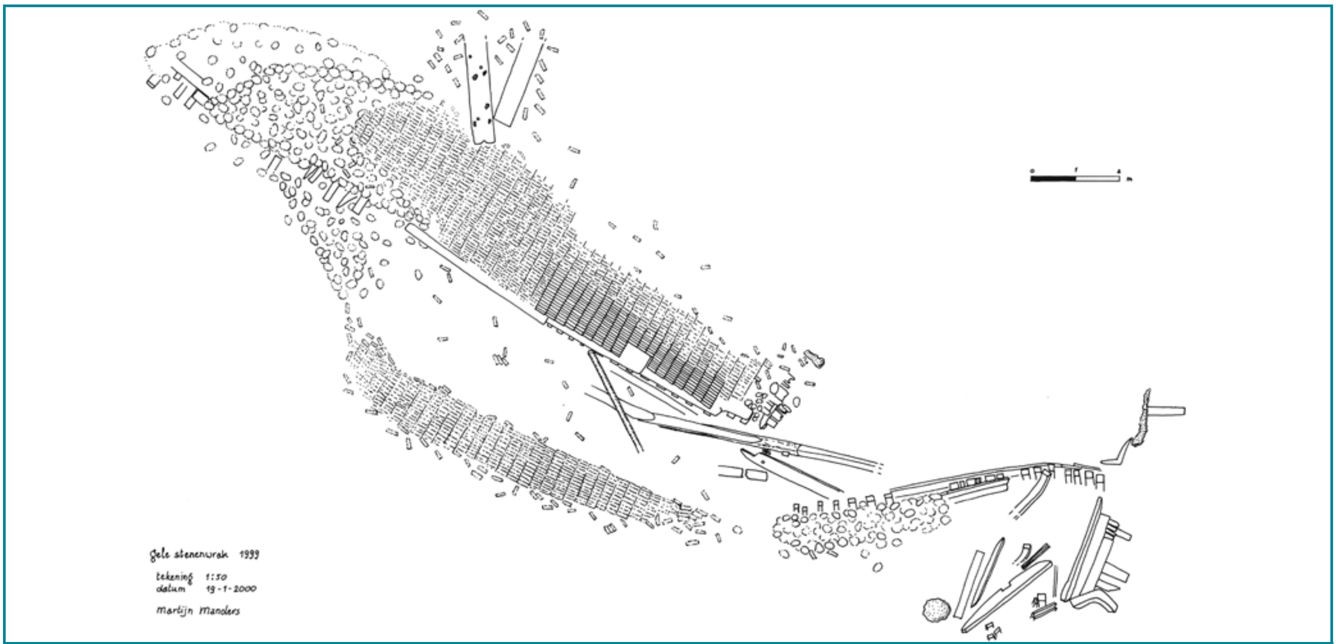


Fig. 1.18 Site plan of the BZN 12 wreck. Figure: courtesy M. Manders/RCE.

BZN 13

Shipwreck, probably of an eighteenth-century ship (Fig. 1.19). This wreck earlier had the toponym Texelstroom 13. It has a double layer of outer planking, of which one had the function to protect the ship construction against shipworm. This is an indication that the ship was used in tropical waters.[107]

BZN 14

The wreck of a seventeenth-century ship (Fig. 1.20). An enormous number of ballast stones were found on the wreck. This gave it the name of the 'Potter Wreck' by local divers. This ship also had a double layer of planking to protect it against shipworm. The aft of the ship has been excavated. Casks of fish, pepper, grain seeds, rice, cucumber and beans were discovered. This food stuff may well have been used on board. During research, pieces of coral were also found between the ballast stones. In addition to the double layer of planking, this is an indication of its use in tropical waters.[108]

BZN 15

The Burgzand Noord 15 (BZN 15) site is a shipwreck that sunk on the Dutch Texel Roads in the seventeenth century (Fig. 1.21). The site is almost 50 by 30 metres. We do not know the exact size of the original ship, as the site consists of different fragments of a shipwreck scattered across the entire area. In the south, there is a large area where ballast stones and concretions of iron from at

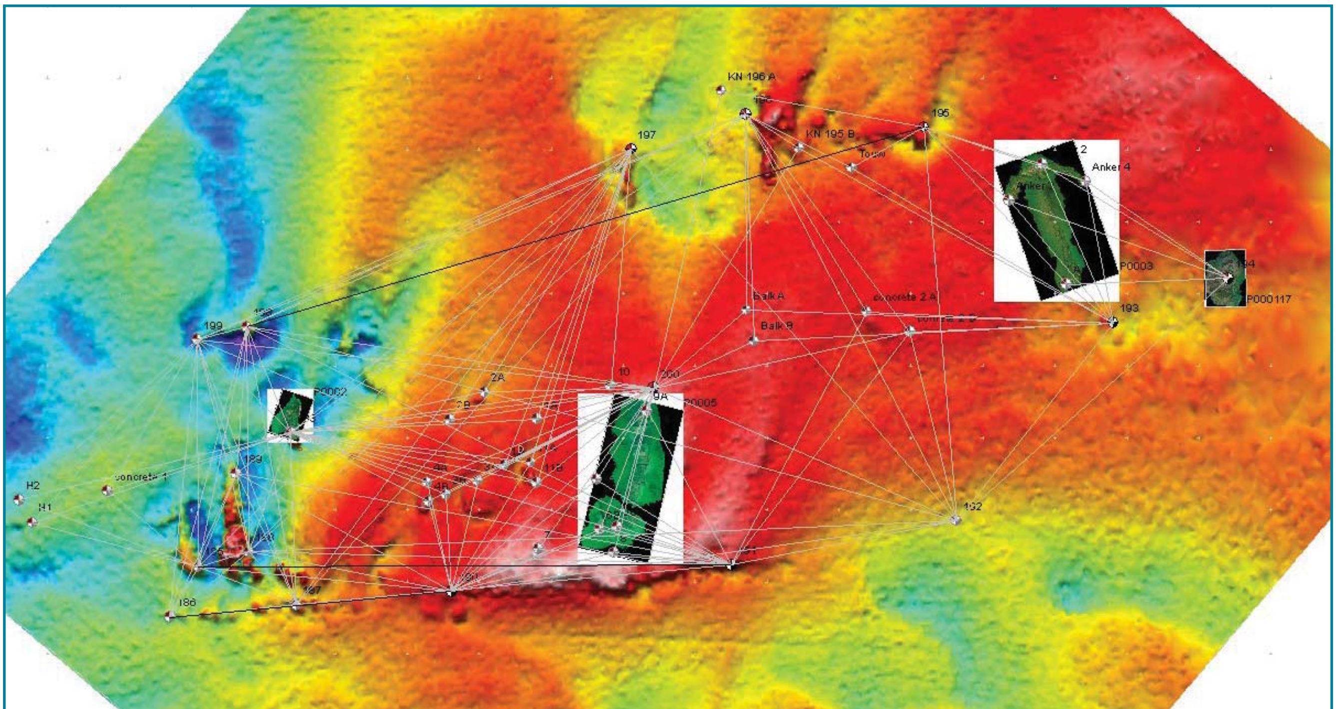


Fig. 1.22 Multibeam, site recorder data and Agisoft photogrammetry images of the BZN 17 wreck. Figure: courtesy Periplus/T.Coenen/RCE.

107 See also Vos 2012, 288–294.

108 See also Vos 2012, 294–310.

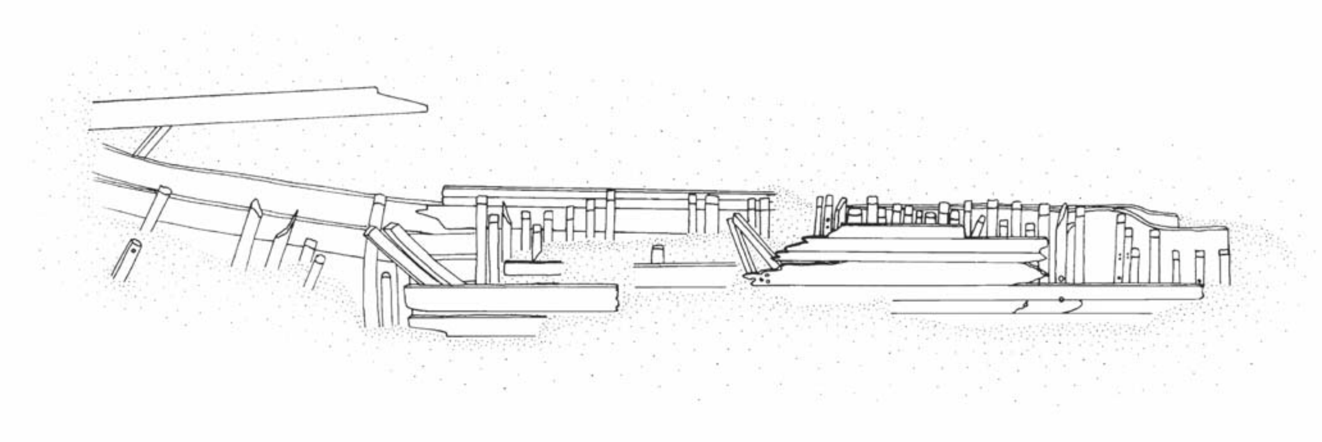


Fig. 1.19 Site plan of the BZN 13 wreck. Figure: courtesy M. Manders/RCE.

least two cannons and many iron cooking pots have been located. Hundreds of clay pipes were also found in this area. At some distance to the north, a cargo of wrought-iron staves is situated on the sea bottom. Under this, many rolls of brass were found. In these two places, there is no wood in situ. In the northern section of this site, on the edge of an old sandbank, the fragments of a shipboard were found, together with the construction of a deck. This part was deteriorating very fast. It had been slowly sliding off the bank, and most of the wood was permanently exposed to erosion and wood-boring organisms. Earlier dendrochronology dating revealed that this fragment must be from a ship that was built not long after 1641 (the youngest dating).[109] It was a shell-first carvel-built vessel carrying a cargo of half products possibly from the Baltic.

The depth of the site is 10 to 15 metres at high tide. This site was investigated and monitored during the BACPOLES project.[110]

BZN 16

Wooden wreck parts were discovered in 2002. However, these have not been seen since and may have disappeared due to the ongoing erosion in that part of the Burgzand.[111]

BZN 17

This wreck is probably a seventeenth-century ship, discovered by local divers in 2009 (Fig. 1.22). A quick survey in 2014 informed us that a fairly well-preserved shipwreck was lying upright on its keel in the sediment, preserved up to the first deck. This is quite unique in a dynamic environment such as the Wadden Sea. Locally observed deep holes indicate that some illegal excavation has taken place through the protective sand and even the clay layer. This has made the wreck especially vulnerable to mechanical, chemical and biological deterioration.[112] The local divers have salvaged extremely well-preserved clothing, possibly including a Royal British dress.[113]

BZN 18

Undated wooden shipwreck, only discovered in 2011, but erosion has exposed the wreck in a short period of time. The wood of the wreck is heavily deteriorated due to shipworm, which demonstrates that the site has been exposed on numerous occasions. In 2016, the large erosion holes had already disappeared and the site was sanding in.[114]

BZN 19

Structures of possibly yet another shipwreck were discovered during the monitoring of the Burgzand Designated area in 2014. Not much else is known at the moment.

These are the wrecks that have been discovered thus far in an area of 1200 by 600 metres.[115] BZN 17, 18 and 19 show the huge potential to discover even more wrecks in the North Burgzand area itself, or just beyond on the greater Texel Roads.

1.7 Methodology and theoretical concepts

1.7.1. Underwater archaeology, maritime archaeology and cultural heritage management

The question of whether we can manage our underwater cultural resource is broad and needs to be investigated on many levels. Using the existing archaeological heritage cycle (Fig.1.8) for guidance and the Western Wadden Sea as a test area, I will first look at what the resources encompass. To make the resources – known and unknown or potential resources – visible I will use a new method called the Historical Geomorphological Map Set (HGMS).

The resources have their value but are under threat. Only by revealing them can we mitigate against this threat. Most of the threats have already been extensively researched during the successive EU projects mentioned in Section 3.1, and the methods used to investigate and measure the human impact

[109] Vos 2012, 315

[110] See also Vos 2012, 310–320, Manders 2005 (1).

[111] See also Vos 2012, 320–324 and Brenk & Manders 2014, 48–50.

[112] See also Chapter 3.

[113] https://www.theguardian.com/world/2016/apr/21/400-year-old-dress-found-in-shipwreck-sheds-light-on-plot-to-pawn-crown-jewels (accessed 29-01-2017).

[114] Own observations by author.

[115] As much continues to occur in the area while writing, as mentioned above, the most recent date used for thesis is 1 January 2017.

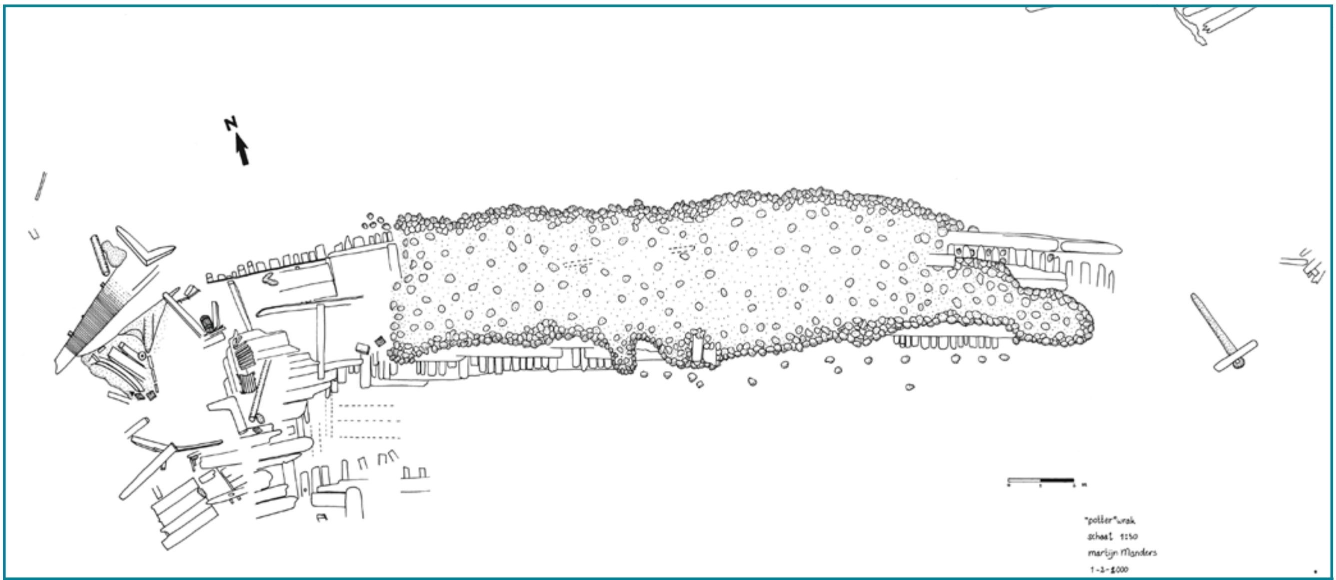


Fig. 1.20 Site plan of the BZN 14 wreck. Figure: courtesy M. Manders/RCE.

and, especially, biological, mechanical and chemical deterioration, have been developed. In the management of cultural heritage, prioritizing is of crucial importance. As a baseline for doing this, heritage managers need thorough knowledge of the exact locations of underwater heritage, the values attributed to this heritage and the factors and actors that threaten its survival and sustainable management. This all forms the basis for making a decision between preserving a site in situ or ex situ, or not taking action at all.

Ex situ preservation, which actually involves the safeguarding of the resource, is archaeologically done through excavation in one form or another. In-situ preservation entails the maintenance of a site in the place where remains have been found. This is one of the drivers in important international treaties, such as that of Valletta and the UNESCO Convention for the Protection of the Underwater Cultural Heritage. Nevertheless, while being so prominent in official management policy and formal treaties, it is important to critically consider the 'in-situ paradigm' for underwater cultural heritage management. Is it a panacea or wonder pill (Fig 1.24)? This will be investigated in the light of the threats to and potential of the maritime underwater cultural heritage resource in the study area. Before explaining and implementing this general methodology in the chapters that follow, in this section, I first discuss some key concepts that figure prominently in the field. Methodological concepts that relate to the practical issue of preservation and management of underwater archaeological resources will be introduced briefly in Section 1.7.2.

Archaeology can be described as '[t]he systematic study of past human life and culture by the recovery and examination of remaining material evidence, such as graves, buildings, tools, and pottery'[116] or as that which 'studies aspects of human life in the past through the material remains, which are often concealed by soil'.[117] Although these definitions differ, both entail the effort to reconstruct past life and behaviour through the study of material sources and resources. Archaeology can also be described as a toolbox of methods and techniques available to us for the investigation of the physical remnants or traces of humankind with the aim of gaining knowledge about our past.[118] These definitions equally suit archaeology on land and under water.

As explained in Section 1.1, underwater archaeology, as a subdiscipline of archaeology, can be described in terms of the methods and techniques we use to investigate those sites that are presently situated under water, be it shipwrecks, inundated cultural landscapes and settlements (even entire cities), or even aeroplanes. Underwater archaeology is thus defined in a technical sense as a methodological subdiscipline of archaeology.

Maritime archaeology is the set of theories, concepts, methods and techniques that we use to investigate the role of water and water systems as connectors of past societies and as a means of living, and as such as an integral part of the cultural environment of past human societies. Maritime archaeology consists of the study of shipwrecks, but also of canals, harbours, natural water systems (rivers, lakes, etc.) and other structures that relate to the diverse interactions between human societies and water.[119]

Although often complementary, underwater cultural heritage and maritime cultural heritage are not exactly the same. Underwater archaeology studies sites that happen to be under water at the time of investigation but which are, in principle, not necessarily related to the above-mentioned relationships between humans and water. The fact they are presently situated in underwater contexts may be a coincidence (e.g. due to sea level rise or the recent construction of lakes).

[116] The American Heritage Dictionary of the English Language, Fourth Edition. (2003). Accessed 29-01-2017 from http://www.thefreedictionary.com/archaeology

[117] The full original Dutch definition that I have used: 'Archeologie: bestudeert (aspecten van) menselijke samenlevingen in het verleden op grond van materiële resten (vondsten/bodemsporen), die vaak door de bodem aan het oog onttrokken zijn (bodemarchief). Kenmerkend is de methode van het oudheidkundig bodemonderzoek (opgraven)' on http://www.encyclo.nl/begrip/archeologie (accessed 29-01-2017).

[118] With the term 'toolbox' I want to make a distinction between the – in my view – incorrect association of the word 'archaeology' with the physical objects and traces in the soil. 'Archaeology' concerns the profession, the handling, the activity of investigating and reconstructing on the basis of these physical objects.

[119] See, for a more detailed definition, Chapter 2.

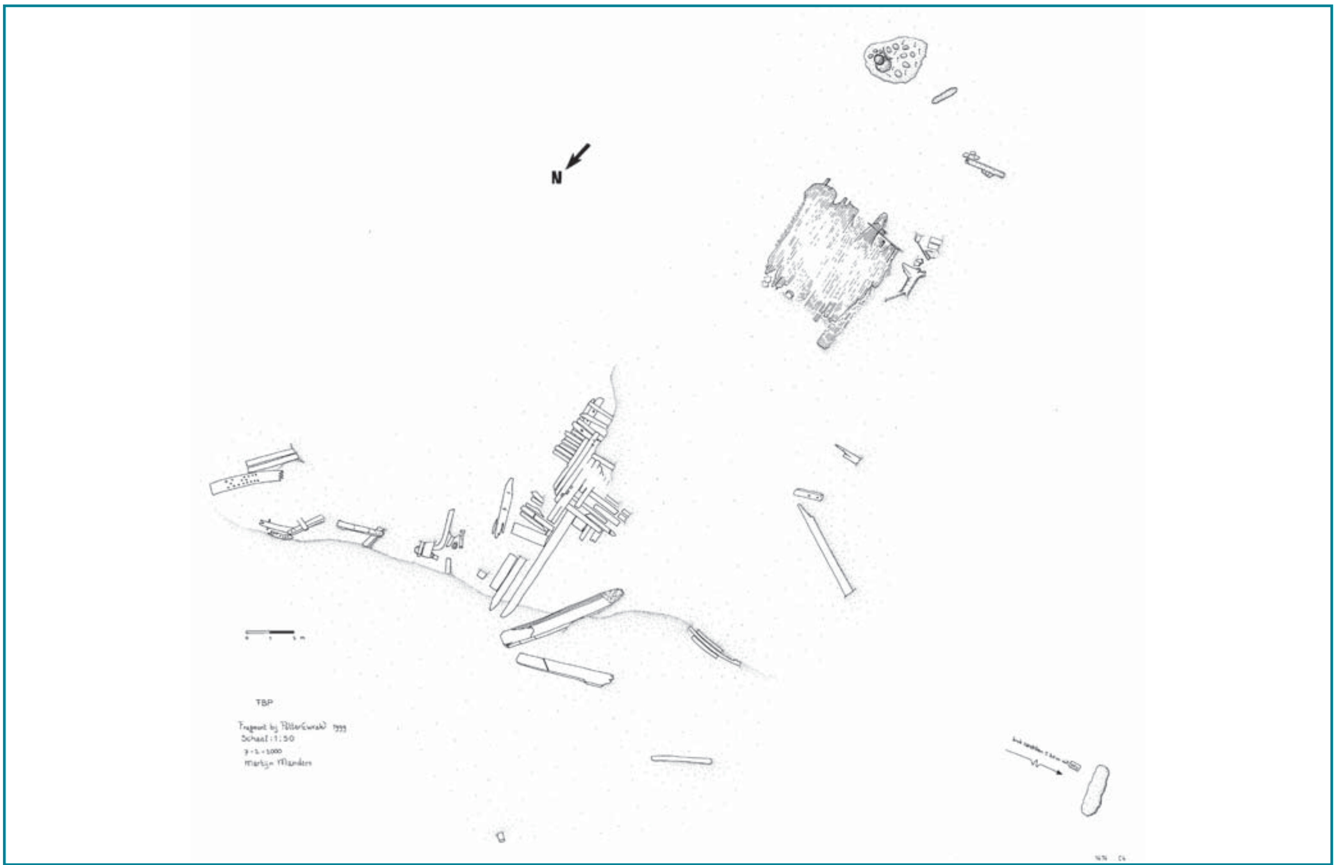


Fig. 1.21 Site plan of the BZN 15 wreck. Figure: courtesy M. Manders/RCE.

Maritime sites, on the contrary, may even be situated on land but are defined as part of the historical 'maritime cultural landscape'.[120] The maritime cultural landscape comprises the entire network of sailing routes, old as well as new, with ports and harbours along the coast, and the related constructions and remnants of human activity, under water as well as terrestrial.[121] It concerns the use of maritime space by boats and other transport mechanisms that make use of water. It comprises, therefore, not only shipwrecks, but also settlements, as well as fishing, hunting and shipping activities in the broader sense and their attendant subcultures, such as pilotage, lighthouses and seamark maintenance.[122] Moreover, it not only consists of artefacts, sites and artificial structures that relate to water as an important material resource, for an important part of the maritime cultural landscape is also intangible, cognitive or indicative. An area may be valued highly due to traditions and potential use.

Maritime cultural heritage offers us a relic and is an expression of the ways of living developed by a community in relation to water systems, which are passed on from generation to generation, including customs, practices, places, objects, artistic expressions and values. Cultural heritage often takes the form of intangible or tangible resources.[123] As explained above, this study focuses predominantly on the tangible aspect: the physical heritage of the maritime past and/or material heritage that is located under water. Tangible heritage can, however, only be interpreted properly by taking its intangible aspects into consideration as well.[124] Material objects may appear meaningless by themselves, only deriving their value, importance and meaning from the narratives, memories and associations with their historical context, and the cultural values that are currently attached to material traces in the present. Heritage is often also described as collective memory, as a social construct shaped by the political, economic and social concerns of the present.[125] The current meanings and values of ancient objects can also be shaped by recent notions of nationality, religion, ethnicity, class, wealth, gender and personal history. With such a variety of parameters that determine what heritage is, it might be better not to talk about heritage in the singular, but about heritages. For the sake of clarity, however, in this study I will talk about 'heritage', perhaps not as a plural but as a collective noun. Heritage is thus a co-creation of past and present and is therefore open to constant negotiation, revision and appropriation. Heritage is also subject to a continuous process of inclusion, exclusion and contestation.[126]

For all these reasons heritage is inherently complex.[127] This evidently makes cultural heritage management a complex challenge as well, not only from a technical but also from social, political and cultural perspectives. Although the research for this thesis initially started from evidence-based and scientific approaches, this study takes this complex nature seriously, as will become clear throughout Chapters 2 to 8.

[120] See, for example, the dried-up rivers in the Dutch landscape that contain many shipwrecks from prehistoric, Roman and medieval times.

[121] Westerdahl 1992, 6.

[122] Westerdahl 1992, 5.

[123] ICOMOS 2002

[124] Deacon 2004, 31.

[125] Peckham 2003.

[126] Ashworth et al. 2007.

[127] Graham & Howard 2008.

In dealing with the 'overlap' between underwater cultural heritage and maritime cultural heritage (Fig. 1.23), predominantly concerning shipwrecks that are situated under water, the research pays specific and systematic attention to sites in the context of their underwater environment. This relationship with the environment is essential to understanding each individual site. The relationship between each wreck and its environment can tell us something about why the ship sunk in that area, what it was doing there, why it was discovered when it was, and the reason for its current condition, not to mention possible future threats to the site and possible future accessibility. The link with the environment also adds to the overall value of the individual site. More specifically, it may also influence the value people attach to a site. Local traditions, social connections with an area and the potential or current use of a site or an area influence its historical and archaeological significance.

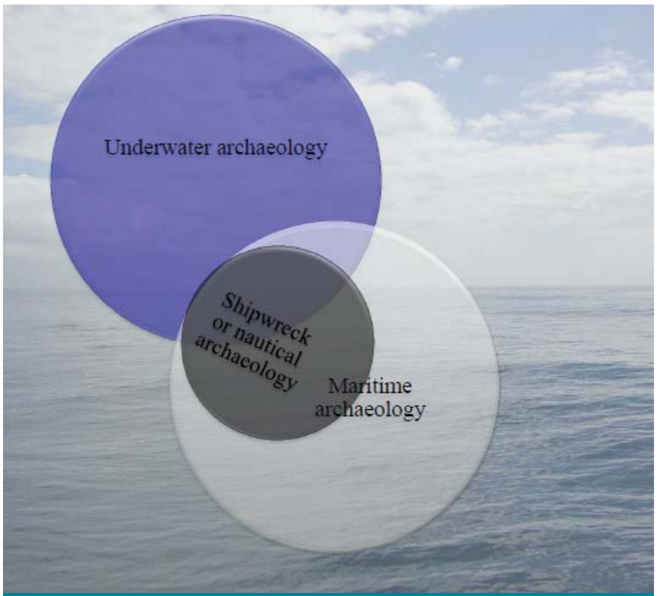


Fig. 1.23 The relationship between maritime, underwater and shipwreck archaeology. Graphic M. Manders.

Shipwrecks in themselves are essentially seen as 'time capsules' and their informative strength is the assemblage value of all the associated objects: the ship itself, its inventory, personal belongings and cargo collectively.[128] Shipwrecks are thus seen as little 'Pompeiis'. In a way, this is true for many shipwrecks, in particular those ships which sank in a singular event. Much of the material we now find on the site is related to that one event. However, post-depositional processes may have disturbed this original pattern and may also be regarded as part of the history of the site. Taking a longer term perspective on sites creates longer and more continuous stories of the object we are investigating and preserving. This poses questions that may relate to the afterlives of specific events (of which a shipwreck may have a lot to say) or to the histories of larger areas over a longer period of time. Individual shipwrecks, for example, are also part of a larger history. Every shipwreck has its own story (or multiple stories) to tell, but is, for example, also connected and part of the history of a larger area or period. They are physically and environmentally attached to a particular former or current sea, river or lake bed and, through their common past, different sites can be historically connected as well.

When we talk about sites, individual shipwrecks, we can refer to those as resources to learn about our past. The sites we know, are known resources. These known resources can be divided into the categories of archaeological remnants in situ and the sites that have already been excavated.[129] The unknown resources are those of which the location, nature, age and quality have not yet been established. The quantity and quality can only be indicated by approximation, deduced from our knowledge of the known resources. This is also the reason why these are also officially classified as 'predicted resources'. [130]

1.7.2 In-situ preservation, protection, stabilization and conservation

Throughout this thesis I will discuss in-situ preservation and in-situ protection. There are differences in the definition of these concepts.[131] While 'in-situ preservation' concerns an overarching approach to keeping the sites at the location where they have been discovered regardless of any physical or legal action taken, 'in-situ protection' concerns more active involvement in this process.[132] Protecting a site means taking action or measures to prevent further deterioration and loss. This can be done by means of artificial covering, reburial or by applying law.[133] Other terms that are often used in relation to protection are 'stabiliza-tion' or 'conservation'. These entail active involvement as well, but stabilization also implies that the focus is on the current condition: it does not necessarily entail improvements, only ensuring the situation does not deteriorate. Stabilization and conservation, therefore, mitigate against change, but do not initiate change, development or empowerment. One may consider this an interim action, merely to ensure the site does not deteriorate. However, ultimately, stabilization of a site may be all that is done, with no further action taken.[134] Conservation may be considered to be much the same as stabilization, but sug-

[128] See, for the Pompeii premise, Binford 1981.

[129] Deeben et al. 2005, 38.

[130] Deeben et al. 2005, 39. See also Chapter 4.

[131] See also Chapter 4.

[132] Although these are the definitions of preservation and protection that I use, opinions are not consistent throughout the literature. Often preservation is regarded as active involvement, although practice shows otherwise. See, for example, Ortmann 2009, 14.

[133] See also Chapter 4.

[134] Conservation and stabilization require management, involving baseline study, extensive monitoring and actions such as a follow up to maintain the quality of the site. See also Maarleveld et al. 2013.

Fig. 1.24 Is in-situ preservation a panacea or wonder-pill? Figure: courtesy M. Manders.

gests more active involvement to consolidate or improve the situation for a longer period.

For all these reasons, I will use the term 'in-situ preservation' when talking about the overall aim of leaving sites where they have been found, whether this means leaving the sites unmonitored, applying legal methods or active conservation, or stabilization of the site. The word 'protection' will be used only when actions are described. 'Conservation' will specifically be used in relation to improving the current situation and hopefully the condition of the site, while 'stabilization' will refer to a current situation that is being maintained.

1.8 Structure of the thesis

In the following chapters, the Western Wadden Sea, its cultural historical richness and all the processes, factors and actors threatening it will be dealt with separately. Chapter 2 will explore whether it is possible to gain more sound knowledge of the presence of underwater cultural heritage in the Western Wadden Sea. The chapter focuses on the richness of what has already been discovered. Through the development of a landscape approach to the archaeological heritage management of the Western Wadden Sea, and introducing the new Historical Geomorphological Map Set (HGMS), the chapter attempts to develop an understanding of the landscape and its submerged cultural heritage. The parameters that influence this landscape will be investigated and its relationship with the known and also the potential heritage will be explained. The question of how to predict the presence of still undiscovered shipwrecks in the seabed will also be answered, including how we can develop a method to create awareness of the presence of underwater cultural heritage through desk top research.

Fig. 1.25 A diver with Surface Supply Equipment (SSE) at the BZN 10 wreck. Lots of sediment is suspended in the water. Currents take and deposit the protective layer of sediment on the seabed. Photo: Paul Voorthuis, Highzone Fotografie.

The dynamics of the Western Wadden Sea pose interesting challenges for the prediction process but also act as a preserver of or aggressor towards underwater cultural heritage (Fig 1.25). Chapter 3 is dedicated to the threats to underwater cultural heritage. The known and unknown resources, particularly in the Western Wadden Sea, will be the main subject of research. The threats will be divided into mechanical, biological, chemical and human/anthropogene threats. They are, in fact, closely associated with the changes occurring on site. Hence, the more stable a site is, the better its natural protection. Chapter 3 presents an inventory of the threats while also attempting to formulate measures to manage and mitigate against these threats. The dynamics of the seabed are dealt with specifically, as these pose a big challenge for in-situ protection.

Before we start engaging in any active involvement to mitigate against change and thus the threats, we need to ask why we want to preserve sites in situ? The reason to do this may also have implications for the way we preserve and protect a site. This will be discussed in Chapter 4.

How we can preserve sites and thus mitigate against threats, and the kind of techniques that are available will be discussed in Chapter 5. Here we will look into the questions of whether in-situ management is a panacea or magic pill for cultural heritage management, and whether it is the right solution for the rich underwater cultural resources in the Western Wadden Sea.

In Chapter 6, an important and often forgotten step in underwater cultural heritage management is discussed – the issue of monitoring. Sites that are preserved and protected in situ will be investigated over a longer period of time. The chapter will explore the duration of in-situ protection, how we know a site will further deteriorate, and what kind of equipment we need to use to monitor the sites.

We could leave sites on the seabed for future generations, or without any notion of what to do with them. However, we might also make use of their richness and the beauty. Chapter 7 will be devoted to the question of the accessibility of sites and the involvement of different stakeholders. How might we bring sites to the public and the public to the sites?

In the conclusion, presented in Chapter 8, the research questions will be answered separately. The overarching questions: *'Is in-situ preservation a viable option in the management of the underwater archaeological resource?'; 'Is in-situ preservation a panacea for underwater cultural heritage management?', and, more specifically, 'Is in-situ preservation the solution for cultural heritage management in the Wadden Sea?'*, will be answered here using the data and knowledge presented in Chapters 2 to 7.

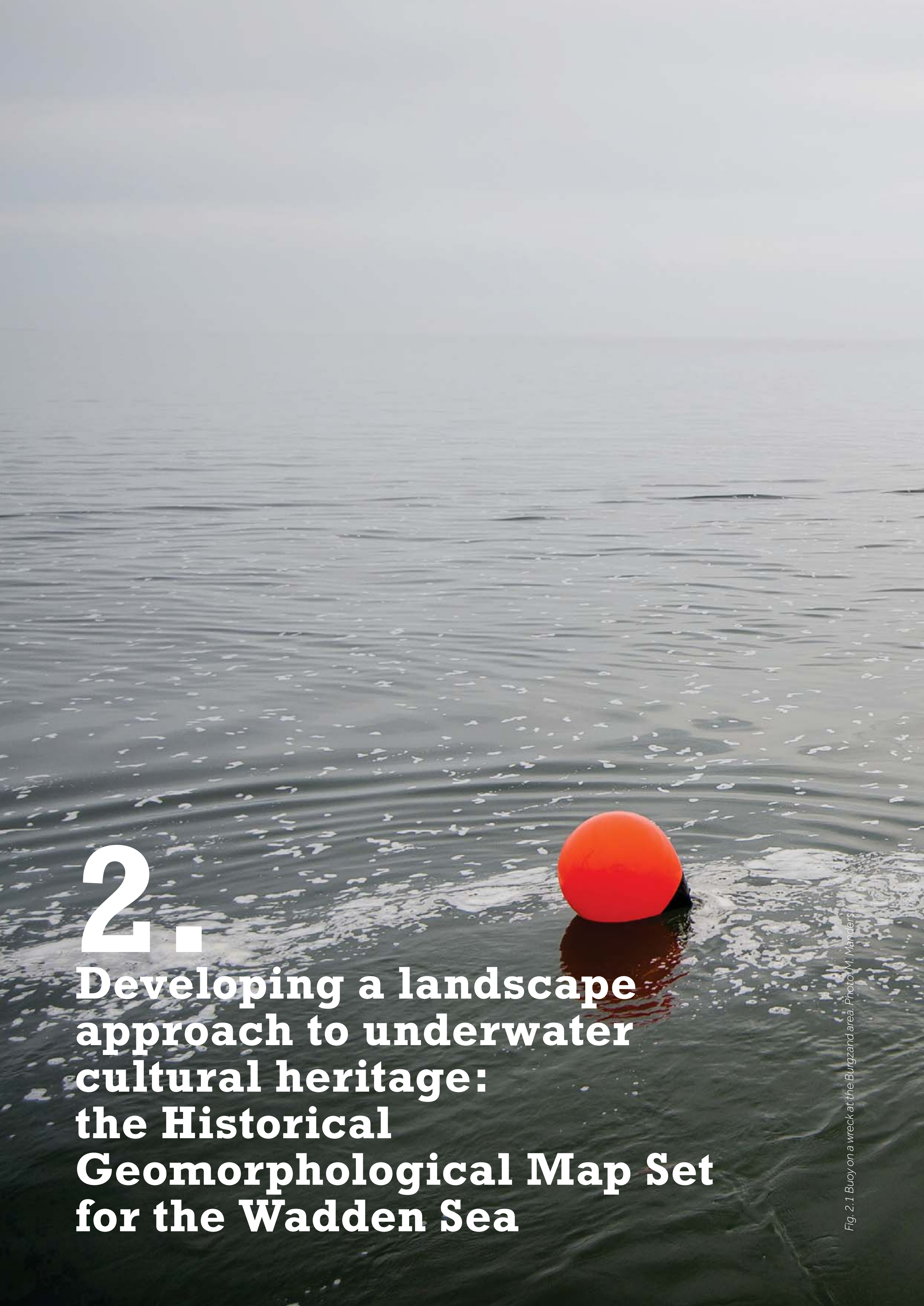


Fig. 2.1 Buoy on a wreck at the Burgzand area. Photo: M. Manders

2. Developing a landscape approach to underwater cultural heritage: the Historical Geomorphological Map Set for the Wadden Sea

2. Developing a landscape approach to underwater cultural heritage: the Historical Geomorphological Map Set for the Wadden Sea

2.1 Introduction: the necessity of a new approach

For much of its history, archaeological heritage management has been a reactive endeavour.[1] Heritage management in the Netherlands is no exception to this rule. Until the mid-1990s, recommendations on how to deal with heritage in the Netherlands were based on well-documented heritage locations, or 'known resources'.[2] Starting in 1992, these locations could be requested via the National Archaeological Database System, ARCHIS, but also via other data collections of variable reliability.[3] However, in addition to the fact that some of the data were less reliable than others (especially with regard to the exact location of sites), it quickly became clear that the known heritage sites were just a fraction of the heritage that remained hidden underground in the Netherlands. This unknown or 'potential' heritage was thought to be many times larger than the known heritage.[4]

Maritime and underwater cultural heritage are also strongly connected to the landscape. Specific landscape qualities identified by people determine the use of an area. The need and willingness to use a specific area have determined the way that it may have been altered by people to better fit the landscape to their needs. We can use such links to connect individual sites and the landscape. Through the 'reading' of recent and past landscapes, we may be able to predict where we can expect the still unknown sites to lie. This is the reason why a new tool, the Historical Geomorphological Map Set (HGMS), has been developed. The HGMS approaches underwater cultural heritage on a landscape scale. In this way, it facilitates the making of period and area-specific landscape reconstructions (palaeogeography). By reading and interpreting the landscape we can understand how people may have used it. Below, I will explain how the HGMS was developed and how it can be used.

The seabed, as mentioned above, not only consists of the cultural heritage we already know about. There is a lot of potential that has not been discovered. This potential heritage may be covered by metres of sand and clay deposited on top, or it may have completely or partially disappeared due to heavy erosion. The problem is that archaeological sites, and especially underwater archaeological sites, are not easily seen and, unfortunately, are thus not naturally taken into account when managing areas.

It is not easy to capture the known underwater cultural heritage in a single two-dimensional map. To be able to predict areas of interest we need to combine a large amount of information about the area from different time periods. By understanding the appearance and the daily use of the area in the past and present we can make some predictions about where cultural heritage might lie in the terrain.

The data for this comes from different sources, collected for many different purposes by many different people and organizations. The data is therefore not uniform for every area and every period.[5] The quality of the data also differs as to when and how it was collected and the degree of accuracy.[6] Some sets of data are also more important for one period than for another. This is because knowledge of the geological and morphological characteristics of the terrain can help determine whether prehistoric sites (previously on dry land) are present in the area or not, while knowledge of the use of the water and the adjacent coastlines and the dynamics of the Holocene sand layers are essential to the understanding of shipping and trade in the later periods. Thus, with a variety of maps we can gain an insight into

Fig. 2.2 Indicative Map of Archaeological Values (IKAW), 1997 version. Figure: courtesy RCE.

[1] See also Chapter 1 and Gould 1983, Hamersveld 2009, 109, Manders & Tilburg 2010.

[2] Deeben 2008, 7.

[3] These include WrakSys, a database system that records the locations of tens of thousands of shipwrecks uncovered through the efforts of a number of amateur archaeologists (Ruggenberg 1995).

[4] These differences are also pronounced abroad. For example, Historic England uses a chart of shipwrecks listing 53 historic Designated Wreck Sites. These only include protected shipwrecks (https://www.historicengland.org.uk/advice/planning/consents/protected-wreck-sites/, accessed 10-12-2017). Another chart compiled by a private party contains thousands of sunken ships, many of which have never been localized (http://www.shipwrecks.uk.com/info1_2.htm, accessed 29-01-2017). See also Manders 2012(2).

[5] See Chapter 1.

[6] See Chapter1, for a discussion of this, see also Wiemer 2002.

the former use of the landscape, and by hindcasting and forecasting we can make decisions on which area has what probability of containing well-preserved sites. The sites become predictable and 'visible' without us needing to go to the place itself.

The realization that the Netherlands' cultural heritage was rapidly disappearing without anyone studying or even seeing it provided the impetus for a survey of the heritage that had not yet been discovered; that is, its 'unknown resources'. In 1996, the Cultural Heritage Agency of the Netherlands[7] made its first attempt to develop a national map of expected finds: the Indicative Map of Archaeological Value (IKAW). This map was completed in 1997 (Fig. 2.2).

The IKAW was based on an analysis of the archaeological regions ('archaeo-regions')[8] defined in the digital geomorphological map,[9] the archaeological observations recorded in ARCHIS and expert knowledge on the formation of archaeological data for each archaeological region (Fig 2.3).[10] The result was a flat two-dimensional 1:50,000 map indicating zones with a high, medium or low level of expected archaeological value. The analysis conducted for each area relied almost exclusively on geological and soil survey information. In the areas where this information was lacking, in built-up areas such as cities and villages, it was not possible to provide such an indication. Areas under water were completely absent from the map, and recent disturbances in the soil were not included in the expectation valuations. This product, therefore, had several limitations, although its creators did acknowledge these limitations at the time of publication.[11]

The second version of the IKAW, which was completed in 2000, included surveys of underwater cultural-historical remains.[12] For areas under water, the map uses geological, hydrographic and geomorphological information available at the time, combined with data collected via underwater archaeological observations. Based on this analysis, the expected presence of sites is classed into one of three categories: low, medium or high. These values were determined for five maritime archaeo-regions: the IJsselmeer-Markermeer (including the polders), the Wadden Sea, the outer delta, the coastal zone and the continental plate (Fig. 2.3).[13]

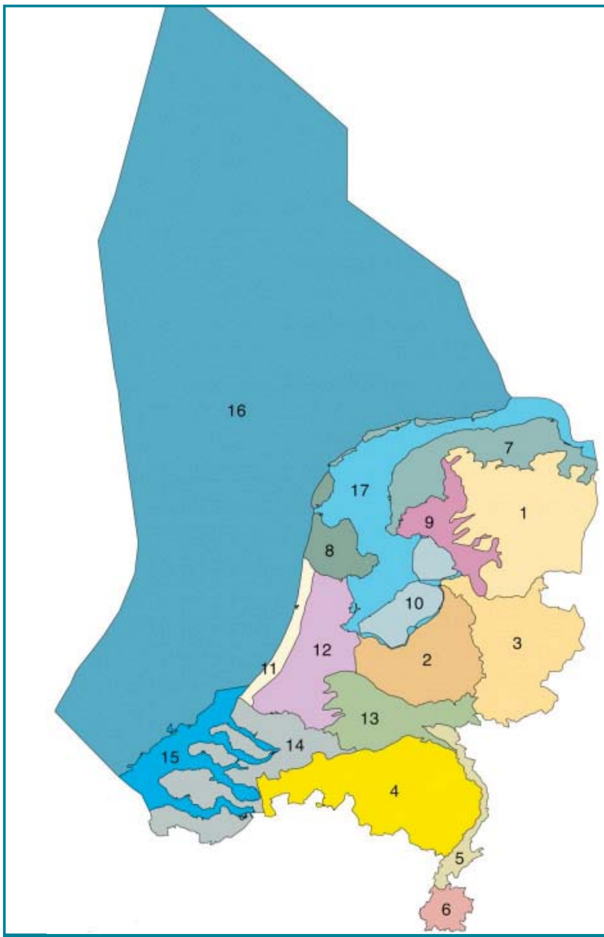


Fig. 2.3 Archaeo-regions in the Netherlands. Figure: courtesy RCE.

[7] Successor to the Netherlands Archaeological Field Survey Agency (ROB). This agency was absorbed by the Netherlands Agency for Archaeology, Cultural Landscapes and Monuments (RACM), which later became the Cultural Heritage Agency of the Netherlands (RCE). For the sake of clarity, this thesis uses the abbreviation RCE to refer to all of these organizations.

[8] An archaeo-region is an area in which there is a general relationship between the landscape and the history of habitation, as well as between the processes that form the landscape and the development of archaeological sites. It also takes into consideration the geological archive in general.

[9] De digitale geomorfologische kaart van Nederland: http://www.wageningenur.nl/nl/show/Geomorfologische-kaart.htm, (accessed 29-01-2017).

[10] Deeben 2008, 8.

[11] Deeben et al. 1997, 111–113.

[12] Lauwerier 2002, 66–72.

[13] Deeben 2008, 9, Maarleveld 1998, 55–71.

Fig. 2.4 Indicative Map of Archaeological Values (IKAW), version 2007. Figure: courtesy RCE.

The third-generation IKAW from 2007 provides more detail as to the possible location of cultural-historical remains in certain areas, such as the Province of Flevoland and the Zeeland Delta archaeo-region.[14] An integrated General Archaeological Chart has also been drawn up for the continental plate in the North Sea at a scale of 1:500,000 (Fig. 2.4).

With regard to underwater areas, the IKAWs that have been published thus far have major limitations regarding their use in a scientific or a cultural-historical management context. In the first place, the later versions of the IKAW were intended to give an indication of the expected quality of the possible finds in an area and not of actual sites themselves.[15] In this respect, these maps have not kept pace with the land maps, despite the fact that they have been integrated into a single map. Important data sets that could provide better predictions are entirely lacking.

The IKAW for the North Sea is based on the existence of a well-preserved Pleistocene strata covered by later sediments and peat. This approach can provide relatively good insight into the condition of prehistoric locations, as long as they have not been disturbed. However, it does not provide insight into the locations with the greatest likelihood of finding traces of habitation because it does not take into consideration the entire prehistoric landscape ('palaeo-landscape') covered during this period, or the interpretation of the use of the area during the period. New technological developments have recently made this a possibility. Sub-bottom profiling,[16] for example, produces a large-scale image of the prehistoric landscape with hills and valleys.[17] This knowledge helps us to predict the presence of prehistoric habitation because it can tell us something about locations suitable for former habitation and land use, and thus about the possible cultural landscape during the period.

Other data sets that are missing from the current indicative values map include disturbances in the geological profile. These are essential because they can provide insight into the potential heritage that has already been lost, and can therefore help rule out areas that do not require archaeological surveys.[18]

Soon after publication of the third-generation IKAW, it became clear that a different approach was required to generate an indicative map for sea, lake and riverbeds. The map of the North Sea was too general and, in addition to the lack of the important data sets listed above, it also did not take into consideration the dynamics of the area. As a result, the IKAW maps either had a demoralizing effect ('we can never pay for or manage so much heritage, because underwater and shipwreck archaeology is very expensive')[19] or they were used improperly and large areas were approved for use because no heritage was expected to be present.[20] Despite the fact that the map only provided an indication of the presence of cultural heritage in the ground (and, for submerged areas, only the possible condition of potential finds) and was not intended to inform immediate policy decisions, several government agencies used it for precisely that purpose.[21]

In 2012, work began on a new version of the Maritime IKAW.[22] This project initially focused on producing an Indicative Map of Archaeological Values in a few priority areas (the Western Wadden Sea, the Markermeer, the North Sea and the river delta),

[14] Deeben 2008, 9 and Peeters 2008, 31–34.

[15] In part, because it is based on the assumption that the presence of individual shipwrecks cannot be predicted, while the possibility that any shipwrecks have survived to the present can be calculated.

[16] A sub-bottom profiler uses powerful low frequency sound waves to create profiles of the upper layers of the seabed.

[17] See Fitch et al. 2007; Dix et al. 2006; Gupta et al. 2004; Gaffney et al. (eds) 2007(1), 2007 (2), 2011; Dix & Sturt 2011; Heteren et al. 2014; Ward et al. 2014.

[18] Including information about 'recent' disturbances has a mere management purpose. When attempting to interpret past use of an area this kind of information may reflect the view of the investigator and should not be taken into consideration. However, when attempting to focus on future protection and determining the archaeological value of an area at present, this information is of much importance since it can shed light on threats and the potential of a site.

[19] Alkemade et al. n.y. The website of the SIKB, in its 'handreiking Archeologie, Cultuurhistorie en Aardkundige Waarden voor waterbeheerders' 2015 ('Guide to Archaeology, Cultural History and Geological Values for Water Managers' (http://handreikingarcheologie.sikb.nl/188) still mentioned the high costs involved in underwater and shipwreck archaeology, which would certainly not stimulate involvement in the field. See, in this light, also the statement of Mr G. Poster of the Texel2010 party in the discussion report No. 4 of the Municipality of Texel, meeting of 27 October 2009, with respect to the Monuments Policy Document of Texel 2009, including the financial consequences: 'Texel2010 is tegen. We moeten af van alle extra uitgaven. We hebben niets met onderwaterarcheologie. We letten op de portemonnee.' (Texel 2010 is against. We have to rid ourselves of additional expenses. We want nothing to do with underwater archaeology. We must take care of our wallet).

[20] In the announcement of the Symposium 'Erfgoed in waterbodems 28-11-13', the organizers even mention the water beds to be exempt from the archaeological perspective. www.cultuurcompagnie.nl/clientdata/downloads/Uitnodiging-congres-over-waterbodems-28-11-2013.pdf. (this link is not accessible anymore checked 29-01-2017).

[21] See, for example, Cleveringa et al. 2012, pp. 19–20.

[22] Manders 2012 (1).

taking new insights into consideration.[23] However, it was soon decided not to produce a new generation of indicative maps but to draw up more detailed Historical Geomorphological Map Sets (HGMS) for two of the areas – the Western Wadden Sea and the Markermeer-IJmeer – and to make them available to third parties.[24] These sets of maps were intended to serve as the foundation for the further development of policy and value maps. There were several reasons for this change in the product's final form. First of all, as stated above, the development of value and policy maps requires a set of basic data and this had not yet been gathered. Thus, it was first necessary to determine which data was needed and then to collect it. Secondly, due to the decentralization of archaeological heritage management in 2007, the responsibility for managing cultural heritage was largely delegated to municipal and provincial governments.[25] Subsequently, roles shifted. Would it still be appropriate for the national government to decree which areas inside the municipal borders had high or low value when drawing up archaeological value maps? There would be several implications for municipal policy in allocating high and low values. For example, a high value could result in additional costs for preliminary surveys or consulting.[26] It would therefore be more logical, and management-wise more effective, if municipalities themselves drew up the indicative maps and subsequent policy plans.

On this basis, it was decided to focus more on the use of the right data than on the outcome of the predictive modelling. The Historical Geomorphological Map Set would provide the basic knowledge and relevant maps to serve as a sound foundation on which municipalities could base their value assessments. The basic map set would be provided in digital format and the instructions for use would be explained via sample questions. This would provide a minimum level of quality for future value and policy maps, whether they are to be drawn up by the municipality itself or by archaeological firms at the municipality's request. [27]

The pilot area for developing the HGMS was chosen to be the Western Wadden Sea, roughly bordered by the Afsluitdijk in the south, off the coast of the island of Texel in the west, the Frisian mainland in the east and stretching up to Terschelling in the north (Fig. 2.5). The Western Wadden Sea area has been inhabited,

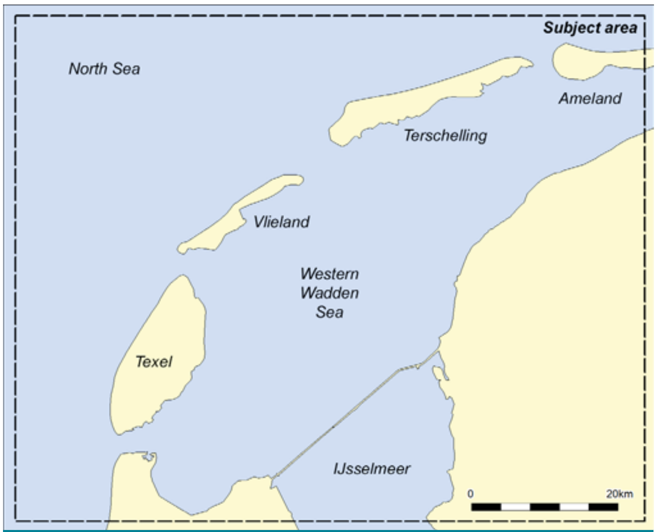


Fig. 2.5 The pilot area of the Western Wadden Sea. This is the subject area for this thesis and the development of the HGMS. Figure: courtesy Periplus Archeomare/RCE.

navigated and used intensively, but fortunately it has also been intensively monitored from an early phase, in order to provide information on shifting sand bars and shipping channels for navigational purposes.[28] The history of the area, in combination with its dynamics, the density of information available and the active local involvement in cultural heritage, were important considerations for choosing this pilot area for the development of the HGMS.[29]

2.2 The value of place and object

The decentralization of heritage management and more active local involvement may be a consequence of budget cuts by the national government, but it also reflects a wider development in which 'heritage participation' plays a larger role. This also gained more official status with the Treaty of Faro (2005).[30] Consequently, local governments and residents are increasingly taking matters into their own hands in order to improve their living environment, without waiting for the central government to take action.[31] This changes the way people value cultural heritage.

When talking about significance and value and the active involvement of different stakeholders, it is important to understand that the concept of 'value' does not have a fixed definition. Rather, cultural-historical value is determined by a group or

[23] Manders 2012 (1). The new insights into e.g. dynamics and preservation conditions in the Wadden Sea had evolved from the European cooperation projects of MoSS (Cederlund 2004) and MACHU (Oosting & Manders 2007, Manders et al. (eds) 2009 (1) and 2009 (2)).

[24] Manders et al. 2014, Houkes et al. 2014.

[25] Included in the Archaeological Heritage Management Act (WAMZ, 2007).

[26] The national government will remain active in drafting policy maps at the national level and where the national government has a direct responsibility due to national or international interests, such as the North Sea.

[27] The maps can also be used to characterize landscapes in the future in the manner currently used in England. See Dudley & Johns 2014, for example.

[28] See Chapter 6.

[29] And this was also the reason to choose the Burgzand Area as a testing site for in-situ preservation and monitoring methods. See also Chapters 1 and 3.

[30] Treaty of Faro (http://conventions.coe.int/Treaty/Commun/QueVoulezVous.asp?NT=199&CM=8&DF=1/5/2008&CL=ENG, accessed 29-01-2017). This treaty of the Council of Europe has not yet been ratified by the Netherlands. On heritage participation in the dive community, see Boelen 2009. For perception and practice of the Faro Convention in the Dutch Cultural Heritage sector, see Scharff 2013.

[31] See also Manders 2013 or the letter that was sent by 'Stichting de Noordzee' (The North Sea Foundation) to the Secretary of State Zijlstra on behalf of different stakeholder groups to protect the shipwrecks in the North Sea (21 November 2011).

society that assigns importance to an object or find, usually as a reflection of its identity. An example of this is the value assigned to the wrecks associated with the battle of the Java Sea in Indonesia, which have a different value not only to different countries – Indonesia, the Netherlands, Australia, the UK, the US and Japan – but also to different stakeholder groups, whether archaeologists or, for example, scrap metal salvers.[32] The same is true for the three British battle ships (the *Aboukir, Cressy* and *Hogue*) and the Jutland wrecks of the First World War in the North Sea.[33]

Similarly, the wrecks found in the Wadden Sea may also be valued differently, reflecting a search for a different identity. Value is created in contemporary scientific and social contexts, and may therefore also differ depending on whether it is assigned by the national government or the local municipal administration. In the context of reinforcing identity, one municipality may place a higher value on the history of its own fishery, along with the material remains related to it, while other towns or cities may consider trade to be a stronger element of their own identity. Also, it should also be kept in mind that an object or place has different values depending on the perspective of the person or group concerned and the proposed use of the object or place in the future.

The identification of what should or should not be preserved relies almost by definition on the concept of significance or value; for example, intrinsic value and the significance of change. Who has the right to determine the value of an object? Is it a specific stakeholder group such as 'archaeologists' or regional marketeers? Or perhaps 'policymakers'? Or does the value depend on the proposed 'use' of that place or object? Will we need to differentiate between the cultural significance and economic significance of an object or place? And what will we do based on that differentiation? Who will make the decision about the most 'important value', which will determine the future of the place or object? This may be a complex exercise, becoming even more challenging with the inclusion of stakeholder groups such as amateur archaeologists and even the general public in the evaluation process, due to the implementation of the Faro Convention.

To conclude, different values can be attributed to objects, sites and areas. Furthermore, place and object influence each other's value. Events that have occurred in an area have left behind material traces, which – if culturally valued – contribute to the overall value of the area, in a cultural sense but also as a living environment and as an area of economic interest. The different values given by different stakeholder groups may also influence each other.

This differentiation in the value of sites to various stakeholders is insuperable but need not be regarded as a problem as such, as long as the process of valuing the object, site or area is retraceable and solid information is used. It is for this reason that a basic set of retraceable information was collected for the HGMS as a starting point – as a kind of minimal requirement. The modular structure of the HGMS facilitates the addition of new information to the existing data set without the existing data becoming superfluous or obsolescent. The addition of data collected by different organizations, such as archaeological firms, can add diversity to the outcome of the process and therefore also add diversity to the archaeological market, which has developed as a consequence of the implementation of the Valletta Convention.

Due to the decentralization of heritage management, municipalities and provinces will now have to develop their own value maps and make their own assessments of the value of individual sites. We can expect that the added local insight and commitment will result in better management which is tailored to local needs and conditions. The role of the central government may be to supervise the process by which municipalities shift their focus to managing underwater heritage – which is still in its infancy – as well as acting as a source of expertise by answering questions, organizing workshops and meetings and developing and providing tools such as the Historic Geomorphological Map Set. Another important role is that of caretaker of the overall cultural heritage of the Netherlands, which means assessment (partly implicit and partly explicit) on the national level and serving as a fall back for the protection of those sites that will not be assessed as having high cultural heritage value from a local point of view but would be assessed as such at the national level.

2.3 The method used for the HGMS

To create a HGMS for the Wadden Sea, a project was set up as part of the Maritime Programme of the Cultural Heritage Agency of the Netherlands, executed in cooperation with the University of Leiden and Periplus/Archeomare.[34]

The project was divided into three phases:
Phase 1: Collecting all of the relevant data and editing it for comparative purposes
Phase 2: Drafting the maps and modelling the data collected in Phase 1
Phase 3: Presenting the separate data sets, including the accompanying metadata

[32] See https://www.theguardian.com/world/2016/nov/16/three-dutch-second-world-war-shipwrecks-vanish-java-sea-indonesia (accessed 29-01-2017).
[33] http://www.dailymail.co.uk/news/article-2042294/Dutch-vessels-ransack-sunken-British-warships-containing-bodies-1-500-sailors-scrap-metal.html (accessed 29-01-2017). and http://thepipeline.info/blog/2016/05/22/exclusive-named-the-salvage-company-which-looted-jutland-war-graves-as-mod-fails-to-act/ (accessed 29-01-2017).
[34] This resulted in a publication (Manders, Brenk & Kosian 2014). This chapter relies heavily on this project report.

A description of each data set was provided, explaining what the specific set could reveal about the presence of cultural heritage in the soil.

Future predictive answer models (indicative/expectation maps) can be built on the basis of a diverse range of maps, which are in turn compiled from several sets of data. The map set presented in the HGMS is the foundation – a minimum requirement – of these expectation maps. Each map is available digitally via GIS[35] and furnished with metadata concerning the drafting method, accuracy, scale and location where the original data are stored.[36] By combining various maps, we can answer questions posed by policymakers and researchers.

The HGMS for the Wadden Sea has a modular structure and consists of objective (or as objective as possible), visualized data sources, as well as maps compiled on the basis of interpretation (and therefore subjective). These maps can be divided into three categories:

1. Maps based on objective measurement data
2. Combined maps (and data sets) or results from combinations of Category 1 maps
3. Maps that illustrate the reconstructed or current use of the area

The Category 1 maps form the foundation: they are visualized data sources based on objective measurement data, which can differ in refinement and accuracy. This information is provided for each map and attached to it as metadata information. They consist of coring information and for example multibeam data. Category 2 consists of those maps combined, showing for example the amount of sediment eroded or deposited in an area. Category 3 consists for example of information derived from historical sources about trading routes.

Visualizing historical maps with GIS by digitizing them according to current projection methods involves considerable interpretation. In fact, it involves several layers of subjective interpretation: the moment of measuring depths, drawing the landscape, drafting the map, preparing it for print and, finally, converting it to the current projection and digitizing the file. Each step requires interpretation and decision-making. A depth chart of the Wadden Sea that is made up of single-beam measurements and multi-beam area measurements contains fewer layers of interpretation.[37] After such measurements are made, any irregularities (spikes) are deleted and the data are 'gridded': the measurements are compiled into a grid of standard-sized blocks with an average depth. This involves a small degree of subjectivity, but does not significantly distort the image of the sea bottom. Each map not only contains a different level of detail, but also of accuracy and subjectivity. However, each map also adds knowledge about the area and increases the likelihood of making accurate predictions, as long as the limitations inherent in each map are taken into consideration.

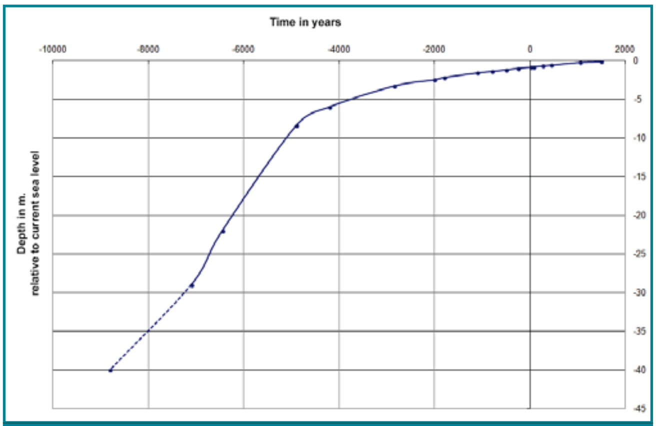


Fig. 2.6 Sea-level rise according to Kiden et al. 2008.

Initially, the HGMS used models that described the Pleistocene surface. The derived models of the location of the Pleistocene surface were based on the second version of the digital vector files used for the *Atlas of the Netherlands in the Holocene*.[38] These vector files were reconstructed from tens of thousands of core samples to act as the foundation for the palaeogeography reconstructions.[39] The location of the Pleistocene surface entailed a reconstruction of its morphology at the start of the Holocene. This reconstruction was based on the current location of the upper Pleistocene strata, empirical data on soil erosion (and preservation) in the Pleistocene surface and expert judgement. This means that the map was also partly based on interpretations and assumptions based on the current state of knowledge.

The map of the current location of upper Pleistocene deposits also includes some interpretations, extrapolations and interpolations, as it is compiled from profiles of analysed core samples. For the spaces between these samples, mathematical models of the landscape were added to produce a full landscape

[35] To this end, the MACHU GIS: http://www.machuproject.eu/machu_gis.htm (29-1-2017) was made available to provide data from the RCE, RWS and the Hydrographic Service. When the new ARCHIS 3 (Netherlands Archaeological Database) becomes available, this will be integrated as a maritime component. A full digital dataset is available at: https://easy.dans.knaw.nl/ui/datasets/id/easy-dataset:60820 (Accessed 10-12-2017)

[36] The metadata or 'data behind the data' consists (among other things) of information about the owner of the data, the place it is stored, when it was produced, by whom and the accuracy of the data.

[37] The single-beam and multibeam methods are both acoustic geophysical techniques to record the seabed surface. While a single-beam approach only uses one beam to measure the depth (as its name suggests), multibeam uses many more and basically maps larger parts of the seabed with a footprint as small as 5 by 5 cm. See more in Chapter 6.

[38] Vos et al. 2011, Vos & De Vries 2013.

[39] These cores are registered in DINO, Data en Informatie van de Nederlandse Ondergrond-loket (https://www.dinoloket.nl/, accessed 29-01-2017).

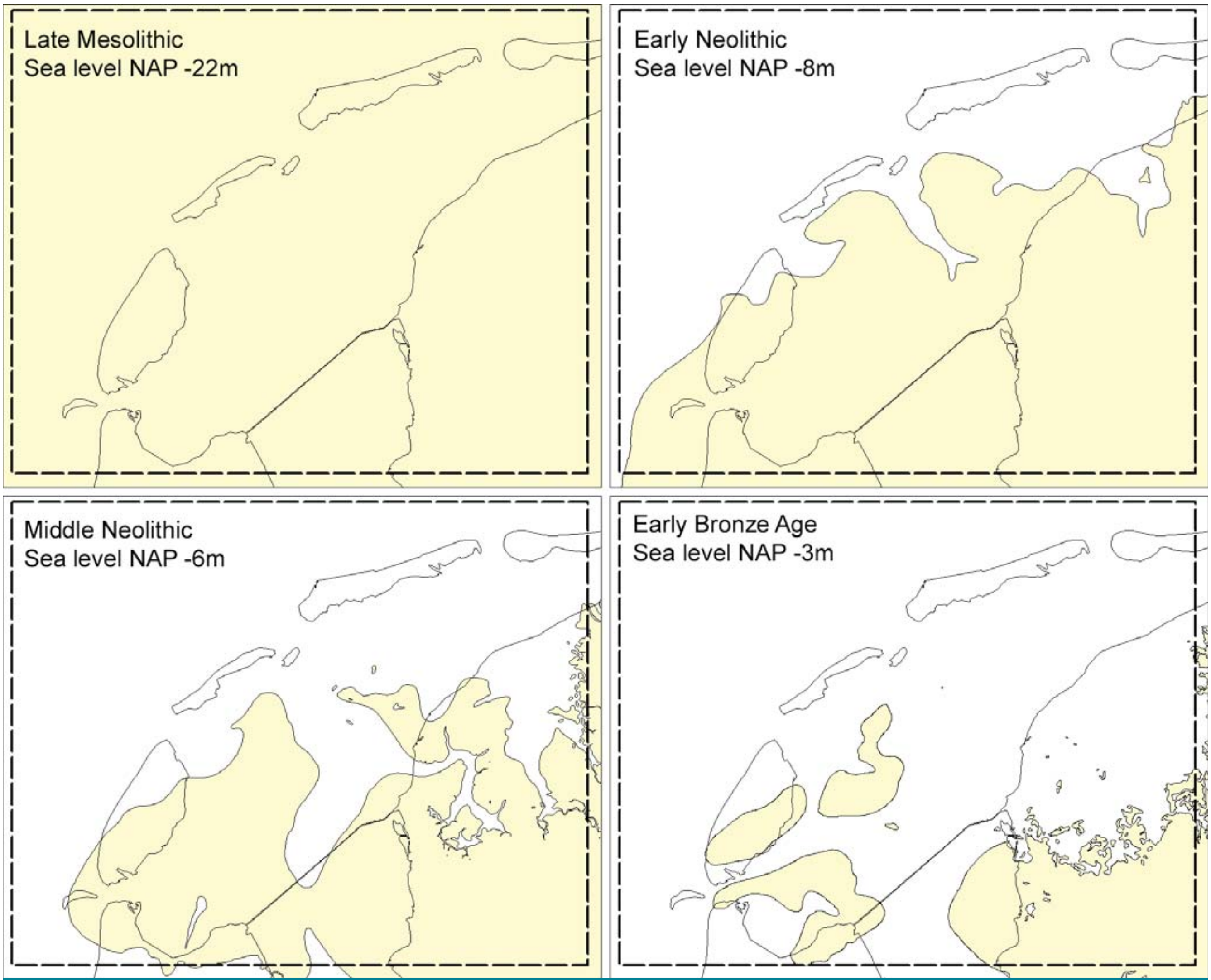


Fig. 2.7 The influence of sea-level rise in the pilot area. This is the reconstructed landscape according to Vos & De Vries (2013) with Kiden et al. (2008). Yellow is dry land, white is inundated land. Figure: courtesy Vos-De Vries/Periplus Archeomare/RCE.

reconstruction.[40] At the start of the Holocene (9000 BC) the sea level was 30 metres lower than it is today.[41] Between 9000 BC and 4200 BC (middle Neolithic) the sea level rose to NAP -6 metres. Assuming that the dry landscape in this period was not subject to dramatic changes, the model can be used to reconstruct the prehistoric and historic coastlines, and therefore indicate the high and dry areas where habitation was possible. This was done by comparing the upper Pleistocene with the sea-level rise curve (Fig. 2.6).[42]

If we wish to arrive at an expectation of the presence of prehistoric (roughly pre-Roman) sites, objects and traces, then other data is important to reconstruct the past landscape. An erosion map or a map of the current Pleistocene surface will tell us about the possible disappearance of areas in a manner similar to the map of disturbances. However, it is just as important to make an expert estimate of the human land-use system at that time using current knowledge about the prehistoric communities that used the area, combined with an interpretation of the palaeo-landscape itself.[43]

This estimation can be further divided into use of the area by hunter-gatherer societies and by early agriculturalists (starting from 5300 BC).[44] An important reason for this is the possible differences in landscape use, and therefore the distribution of sites. An interpretative map of the use of the Western Wadden Sea in prehistory has not been added to the HGMS because, as explained above, this tool has been created to allow others to make the decision about which area is more or less important to preserve. However, maps have been included that show the influence of sea-level changes over time (Fig. 2.7).[45]

Factual knowledge about the formation of the landscape and the existence of sites, combined with interpretations and the current level of knowledge about communities in this period may provide a scientifically justified expectation of finding cultural-historical values from this period.[46] Over the next few years, this perspective may be refined as better information becomes available regarding the sub-surface or sub-strata, including research into the subsequent accumulation of geological layers (including flooding, the creation of fresh water and salt water basins and the

[40] This is done through interpolation between the areas where data was available.

[41] Kiden et al. 2008.

[42] The curve used is that provided by Kiden et al. 2008.

[43] This primarily deals with the estimation of whether an area was inhabited at the time.

[44] See, for example, the role of food storage in relation to mobility (Cunningham et al. 2011) and an overview of recent theories on the life of hunter-gatherer, horticultural and agropastoral societies (Sapignoli 2014).

[45] Kiden et al. 2008.

[46] Deeben, Hallewas and Maarleveld 2002, 15–17, Maarleveld 2003.

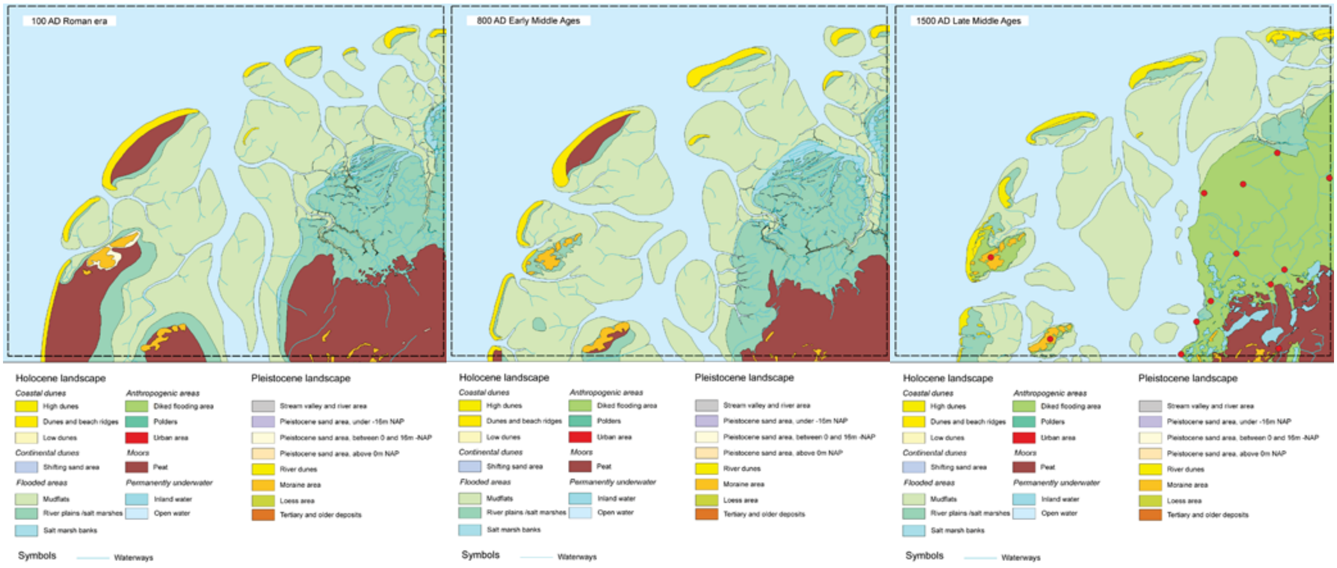


Fig. 2.8 A, B, C The reconstructed landscapes for the Roman, early and late medieval periods. RCE, based on Vos & De Vries (2013).

formation of peat bogs),[47] as well as new interpretations of the land-use practices of the various prehistoric communities based on ongoing archaeological research.[48]

An extrapolation of knowledge acquired through archaeological research on land can also be used to develop a valuation and an archaeological indication for the Western Wadden Sea area. Areas with comparable characteristics that are currently permanently under water can be allocated the same value as areas from the same period on land.[49] Since there is little historical information on the Roman to the late Middle Ages, and there are no accurate maps of those times, these periods can be analysed in roughly the same manner as the prehistoric period. Maps of the Roman era (100 AD), the early Middle Ages (800 AD) and late Middle Ages (1500 AD) were included, based on the work of Vos and De Vries (2013) (Fig. 2.8 A, B, C).[50] Maps displaying the currently known shipping routes for these periods were also added.[51] They show that the known or suspected use of the areas through the ages may help in formulating indications of the importance of certain areas during the period, and the likelihood of finding material remains from that period.[52] To make any statements about the prehistoric cultural-historical expectations, geological information is still needed.

2.3.1 Different periods, different data

As mentioned above, the HGMS has a modular structure. It is therefore also possible for future researchers to add their own data and thus make more accurate predictions, or to answer other scientific or policy questions using the various combined data sets.[53] Thus, different uses and different questions require different sets of data to be combined. This also counts for the answering of questions focusing on different periods. Not all of the data is relevant for each period.

When attempting to predict the presence of cultural heritage from a specific period, we need to identify which data it would be useful to combine and which not. A model for the prehistoric periods was created using the current data available, primarily consisting of geological maps.[54] In combination with the historic sea-level rise curve, these provide an indication of the high (often dry) and low (often wet) areas in prehistory and the condition of the surface of the Pleistocene strata (intact or eroded, and to which depth) (Fig. 2.9). The same applies to the maps for the Roman period (100 AD), the early Middle Ages (800 AD) and the late Middle Ages (1500 AD). A prediction concerning where cultural heritage can be located can be done on the basis of the existence of dry land and navigable water.[55] In the future, more

[47] See, for example, Van Zijverden's research, After the deluge, a palaeogeographical reconstruction of bronze age West-Frisia (2000–800 BC) (PhD thesis, Archaeology, Leiden) and that of Van Lanen 'Occupation patterns and land use in the Dark Age of the Lowlands'. See Van Lanen et al. 2015 (1) and 2015 (2). The amount of data available for research on land is much higher than what we have for areas under water. However, by analysing and interpreting data for land areas and from different periods in time we may also acquire more knowledge about similar areas that are now inundated.

[48] See, for example, the new theories on the life of the Neanderthal (Burke 2012).

[49] The same also applies to drained or raised areas which were used for similar purposes in specific periods, but which are now parts of the Wadden Sea that are still under water. The comparison and valuation of similar geological areas was also done in surveys of the Maasvlakte 2. There, a test excavation was performed based on the presence of a raised area in the future harbour site. Moree & Sier 2014.

[50] See, for some theory behind landscape reconstruction and its past use, Yang et al. 2014.

[51] This is largely based on the information and maps collected for De Bosatlas voor de Geschiedenis van Nederland (Beukers ed. 2011).

[52] In combination with Maritime Cultural Landscape theories that have been developed by Westerdahl (1996), we may be able to identify, for example, transit zones (locations where trade goods were moved to other means of transport, adjusting to the changing environment).

[53] Scientifically driven questions and policy-driven questions can both be answered using the HGMKS.

[54] The project uses the second version of the digital vector files used for the Atlas of the Netherlands in the Holocene (Vos 2011 & Vos & De Vries 2013).

[55] This is based on the theory that people settled on the higher and dry areas in the Dutch Delta. Although this seems to be the case, we know that in the northern provinces, when the water level was rising (around 500 BC), the people raised the land artificially to stay dry in an area that was often flooded. Indications of where navigable water lay can also be deduced from the archaeological resources by studying the types of ships that were used in specific periods and specific areas.

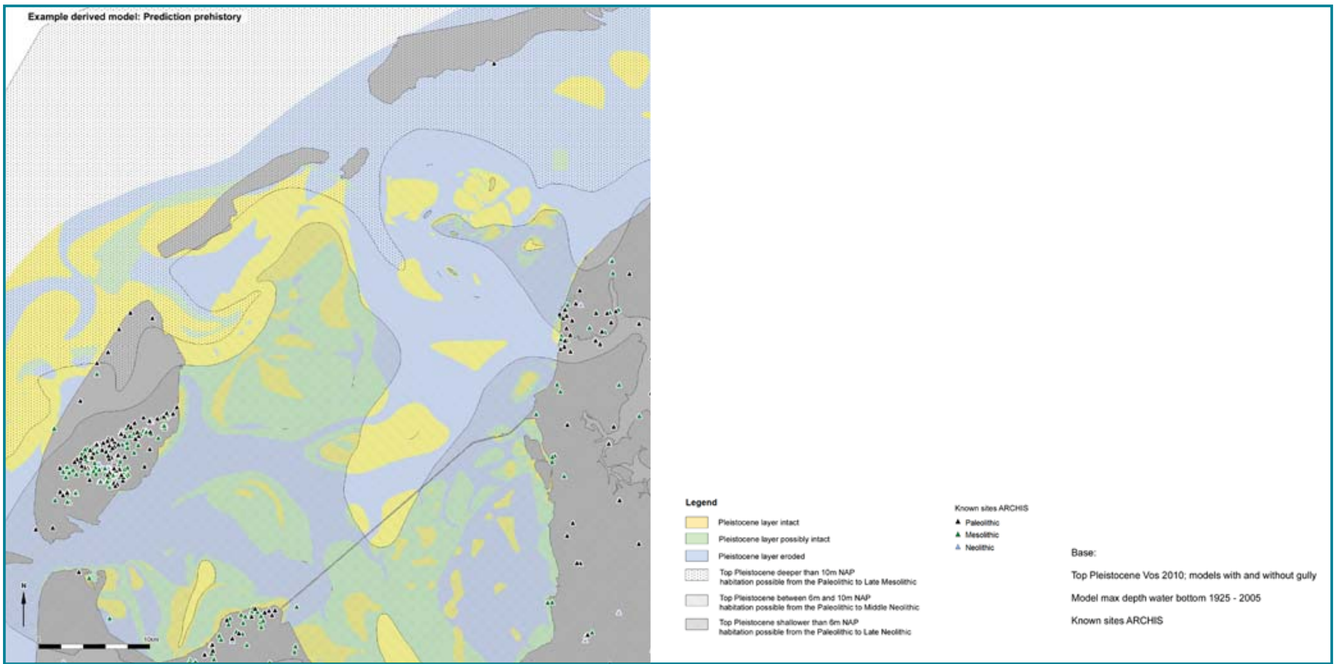


Fig. 2.9 Predictive mapping of the prehistory in the Wadden Sea (pilot area), based on the preservation of the Pleistocene layers. Figure: courtesy Periplus Archeomare/RCE.

research on the geological structure, the geomorphology and the use of the landscape (including water) will reinforce our knowledge of these periods with new, more refined, data and interpretations.[56]

For the late Holocene period (starting in the sixteenth century), a digital map set was created using historical map materials and soundings. This allows us to predict where cultural-historical objects may be located, from which period they may date and their current condition based on the natural protection provided by the soil, by examining changes in the past and creating a 'hindcast' model. This involved the use of data pertaining to changing sea currents (changes in use and an indication of hazards to navigation, sedimentation and erosion), differences in sedimentation and erosion over time (indication of hazards to navigation, loss of archaeological potential and the possible current condition of a wreck), the use of the area (for trade, fishery, other) and infrastructure works (a disturbance map of current threats and loss of archaeological potential). This data helps us to deduce the original (what was there in the beginning), extant (resources still there) and the lost resources, and the predicted or recovered resources.[57] A set of maps with known archaeological values has also been added. The known cultural-historical finds or the 'known resources' are an indication of the possible presence and condition of other sites. However, it is not always clear what is meant by 'known resources', and whether the data collections are sufficiently reliable.[58] This problem can be dealt with by keeping the various data sets with 'known values' separate,[59] and by describing the accuracy of the information for each individual set.[60]

2.3.2 Known sites

With the help of geological, geomorphological, historical data and maps and theoretical models,[61] we can acquire a reliable image of the creation of and subsequent changes to the sea floor in the Western Wadden Sea area. We can also gain insight into the possible uses of the area over time. Past cultural-historical finds can help confirm this image, as their presence in an area may be an indication of the specific use of particular areas. However, the question remains whether the discovery of shipwrecks can be predicted based on modelling an area through time, and whether, on this basis, the drafting of an indicative map of archaeological values is useful for heritage management or not. This is a topic of considerable debate in the maritime heritage management community.[62] To answer this question, it is first important to differentiate between the utility of predictions for scientific purposes and their utility for cultural heritage management.

Modelling using GIS techniques makes it possible to determine whether shipwrecks from various periods are likely or unlikely to be found in a certain area. In areas where expectations are low, it is of course still possible that sites may be found. It is a matter of deduction and spatial statistics, and the more information that is available the more accurate this process will be. The same applies to areas where expectations are high, as it is possible that nothing will ever be found in these areas. Identification of areas with high or low expectations is therefore primarily important for cultural heritage management purposes on a landscape scale. This knowledge derived from the calculation of likelihoods based on modelling can help policymakers make decisions about the best measures to be taken in relation to infrastructure projects

[56] See also, Optically Stimulating Luminescence Dating (OSL), which makes it possible to discover differentiations in the dynamic Holocene sand strata (Manders, Os & Wallinga 2009 (1) and 2009 (2)).

[57] These definitions have been derived from Deeben et al. 2006. In simplified form, see Manders 2012(2).

[58] For a discussion of this topic, see also Chapter 3.

[59] And not as one database for 'known resources'.

[60] In the metadata that should always be attached to each data layer. This is also according to the INSPIRE rules (http://inspire.ec.europa.eu/index.cfm/pageid/48, accessed 29-01-2017).

[61] For example, on the maritime cultural landscape (Westerdahl 1992 and 1998), or cognitive landscape and information (Farina et al. 2005).

[62] Frost 1964 (http://www.saudiaramcoworld.com/issue/196406/diggings.in.the.deep.htm (29-1-2017).), Muckelroy 1978, Deeben et al. 2002, Holk 2009, 111.

that may disturb the sea floor or in the selection of areas that require additional monitoring or preservation measures.

Predicting the likelihood of the presence of shipwrecks involves a close analysis of both the existing landscape and preceding palaeo-landscapes. What did the landscape look like in the past? How was it used? Has anything changed over the course of time? What influence did these changes have? Only by answering these kinds of questions can we provide an indication of the possibility of shipwrecks being located and preserved in certain areas. The distribution of underwater cultural heritage, whether prehistoric sites or wrecks from the Second World War, is not uniform, nor is it random – it follows certain patterns.[63] Moreover, since current techniques cannot provide 100 percent certainty about whether shipwrecks will be found in an area or not, it is vital that we are able to predict their possible presence in an area.[64] Ships are point locations, and although wreck formation processes may cause disturbances in the surrounding sea floor, they are notoriously difficult to find.[65] This makes it difficult to find shipwrecks over time, but it is still possible to predict the likelihood of a find in the anticipation and facilitating of the eventual discovery of a site. It is also possible to provide an indication of the likelihood of shipwrecks being located in places where ships do not normally sail, such as extremely shallow areas.

An indicative map provides a tool for making well-informed decisions on the management of heritage, in concert with economic developments. Newly developed techniques and the improvement of existing techniques are making it increasingly easier to predict and even find archaeological sites. It is even possible that we may soon be able to 'look' into the subsurface strata using geophysical prospection techniques on a large scale.[66] These may overtake the role of predictive modelling when sufficiently developed.

However, this leads to the question of how detailed the evidence-based or modelled image would or should be. To determine the value of the heritage located, we require other data about the period and the condition of the covered site.[67] These can be determined through research into landscape formation. Shipwrecks which remain completely covered are not easy to localize. It is even more difficult to appraise their value. Nevertheless, it is recommended that as much of the archive as possible is preserved in its current position (in situ). The best way to do this is to adjust plans at an early phase. This, in turn, requires a risk analysis for the area in question. Are there already sites known? Is there a high likelihood of finding heritage buried in the area? Are there other alternatives for the project? A risk analysis makes the option of adjusting plans more realistic. Although great strides have been made in working according to this method – which has also been promoted by the Valletta Convention, the Dutch Heritage Act and also the quality norms for archaeology (KNA) – plan adjustment and preservation in situ is still not the most common practice in Dutch archaeology heritage management.[68]

2.4 Sources and data

To make a risk assessment or prediction of unknown cultural heritage resources, it is necessary to work with what is already known about the area. The known resources – sites already discovered – are often a good indication that other heritage from the same period may still be present. The question in this respect is: What do we understand by 'known resources'? We might suggest that they comprise all of the archaeological sites that are known to us at a particular moment,[69] including all known physical remnants that pertain to human activity in the past. However, what does 'known' mean exactly in this context? Are these only the officially appraised sites? Or does it include other observations, such as those by non-professionals? And, if so, by whom? Do observations by fishermen, recreational divers and amateur archaeologists count as 'known resources'? In other words, is a site considered to be a known resource only when its exact location is known, or when we have a general idea of its location but still little information about its quality and value?[70]

The 'Erfgoedbalans' ('Heritage status') report[71] states that the data on the known archaeological resources in the ground should primarily be stored in the Archaeological Information System (ARCHIS[72]) and the Central Monument Archive (CMA). This implies that (according to the authors of the 'Erfgoedbalans') the known resources must be centrally registered, although the addition of the word 'primarily' may mean that this is not entirely

[63] Tilburg & Staniforth 2012, 13; Manders 2012 (2), 11.

[64] There are still no techniques available for solid identification of objects in the seabed. Sub-bottom profilers can give a reasonable idea of palaeo-landscapes, but not of small objects and certainly not over vast areas. Magnetometer research can only reveal metal objects (the differences in the earth's magnetic field). See also Dix et al. 2006 and G-Tec 2008.

[65] Smyth & Quinn 2014.

[66] At the moment, we can use sub-bottom profiling (seismic), but the level of detail is too low and the amount of data is too great to be able to easily trace shipwrecks. Magnetometers can also explore the sub-surface of the sea floor, but can only detect a large mass of metal. The images are not specific and only display the disturbances in the earth's magnetic field.

[67] The fact that the value of heritage is determined by who is appraising it will be discussed in Chapters 4, 7 and 8.

[68] Schute et al. 2013, 6.

[69] Manders 2013, 6. See also 4.6.

[70] The discussion here is about known sites. It is also important to register the absence of sites/evidence/traces in certain areas. Long-term lack of findings of any evidence of human use may turn into evidence of absence in these areas. This is just as important for the prediction of the unknown resources.

[71] Beukers (ed.) 2009, 26.

[72] ARCHIS2. A new national database (ARCHIS3) is currently under development.

the case. The same 'Erfgoedbalans' also examined maritime heritage resources in more detail[73] using ARCHIS as the sole source for this analysis. This research searched for sites based on ground use labels such as 'under water, in channels, on sandbanks and bars', 'on the beach', 'in ditch or on bank', in combination with complex types of sites such as 'ships', 'other' (a variety of complex types such as infrastructure, settlements, sanctuaries) and 'unknown'.[74] This was an attempt to make maritime heritage more accessible. The survey found a total of 2,863 underwater observations in the Netherlands, including 544 shipwrecks.[75] This number may still be exceptionally small in comparison to the total potential or unknown heritage, even with the number of sites that are known outside of the ARCHIS system, which currently consists of over 60,000 contact points (see Fig. 1.4).[76]

The Ministry of Infrastructure and Water Management (RWS) and the Hydrographic Service (Navy) also manage wreck and obstacle databases, as do several amateur archaeology and recreational diving groups. Each data set has its own limitations. The Hydrographical Service looks for obstacles and potential threats[77] and is specifically interested in where such obstacles are located. As a result, the positions are often excellent but they are not always interested in what the find represents. Additionally, the cultural-historical value of the site has a very low priority. The same can be said of the databases of the Ministry of Infrastructure and the Water Management.[78] The many, often regional, databases maintained by amateur archaeologists and other parties interested in maritime history are generally made up of data collected by other organizations and individuals. Therefore, the quality of the data in these sets varies widely, and the provenance is often difficult to trace. As the data are often simply thrown together, it is not always clear how much value should be placed on the individual data. However, the data from these databases are a welcome addition when wishing to provide an indication of the likelihood of finding cultural heritage on or in the sea floor. Individual cases must be treated with a healthy dose of scepticism.

The ARCHIS 2 system that has been used up until now by the Cultural Heritage Agency (and in fact the entire archaeological community)[79] also had its own shortcomings. First, only a very limited number of observations on and under the sea floor were included in the system (see above). Moreover, the use of land-related, complex types and the entry of data by people with little to no knowledge of underwater and/or maritime archaeology, such as fishermen and recreational divers, made it difficult to find certain observations in the system. The observations – especially the precise locations – have not always been accurately recorded.

There is also the additional problem of converting position information, as many of the observations were so old that their positions had to be converted from DECCA[80] to the more up-to-date ED50[81] and WGS84.[82] Many of these positions have also been converted to the Rijksdriehoeks Meetsysteem (RD)[83] for the ARCHIS system. This presents problems for large areas of the North Sea, since it returns negative X-values, meaning that the positions of some find locations may have changed considerably. A study of this issue has discovered deviations of up to 100 metres between the shipwreck's current position and that recorded in ARCHIS (Fig. 2.10).[84] However, ARCHIS contains the relevant archaeological information for the few shipwrecks

[73] 'Erfgoedbalans' 2009, 35.

[74] The sections on Maritime Heritage in the 'Erfgoedbalans' primarily refer to underwater cultural heritage. However, this is not always consistent. The 544 ship finds include more than 400 wrecks located in the IJsselmeer polders (see also: http://www.verganeschepen.nl/ (29-1-2017). For a proper definition of 'maritime heritage', see Wit & Sloos (2008, 55), who state that the number of observations for the complex type 'nautical' was 1,875 on 5 August 2008.

[75] Beukers (ed.) 2009, 35.

[76] A combined data set of positions in Dutch waters obtained from the databases of the Hydrographic Service, the Ministry of Infrastructure and the Environment, the Cultural Heritage Management Agency (RCE) and various amateur archaeologists managed by the RCE in Amersfoort accounts for these more than 60,000 locations.

[77] Hydrographical Service Wreck Register.

[78] SonarReg92 database, see also Hessing et al. 2013.

[79] There is an obligation to register archaeological finds in the ARCHIS2 database. https://www.rijksoverheid.nl/onderwerpen/erfgoed/inhoud/archeologie-en-opgravingen. ARCHIS 2 has recently been replaced by a new – although not completely ready – system, ARCHIS 3 (http://archeologieinnederland.nl/bronnen-en-kaarten/archis(accessed 29-01-2017).

[80] DECCA (developed by Decca Radio and Television Ltd): was a hyperbolic navigation system that worked based on medium frequency radio. The system was used for coastal navigation. http://nl.wikipedia.org/wiki/DECCA (accessed 29-1-2017).

[81] ED50. By calculating a long series of triangulation measurements that covered all of Europe (with the exception of the UK) and even parts of North Africa, ED50 was able to meet its clients' demands in a fairly short time, although it did not satisfy all of the geodetic precision and reliability requirements. ED50 locations can deviate by as much as 10 metres. MD report number: MDGAP - 2000.31. December 2000, 11. Since the block assignments for the oil and gas industry on the Netherlands' continental shelf are based on the ED50, this information is still used by the industry.

[82] WGS84 is a geocentric and earthbound system of coordinates. It was defined in 1984 by the Defense Mapping Agency (DMA), the predecessor to the current NIMA. MD report number: MDGAP - 2000.31. December 2000, 13.

[83] Rijksdriehoek Meetsysteem. This is the system maintained by the land register. The benchmark for this system is the tip of the Onze Lieve Vrouwen tower ('Lange Jan') in Amersfoort (X = 155 000, Y = 463 000).

[84] Brenk & Lil (2010). It is not always clear which projection other parties, such as fishermen, have used to record the location of shipwrecks. If ED50 was used, then the projection can occasionally be traced, but this is not possible if the location was recorded using UTM projection (Universal Transversal Mercator projection). Map projections always result in the loss of some information due to distortion of the Earth's curved surface. MD report number: MDGAP - 2000.31. December 2000, 27.

that have been entered into the system.

The first steps in linking the best databases with one another involved connecting three government databases (the Hydrographic Service's Shipwreck Register, the Ministry of Infrastructure and Water Management's SonarReg and the Cultural Heritage Agency's ARCHIS2) into a GIS environment and then issuing each object a National Contact Number (NCN).[85] This means that the location of a shipwreck on the Burgzand in the Wadden Sea that has been recorded by the Ministry of Infrastructure and Water Management or the Hydrographic Service, for example, can now be linked with the cultural-historical information collected by the RCE.[86] Since 2006, the RCE has also been developing its own maritime database and GIS. This system was developed in cooperation with the Ministry of Infrastructure and Water Management as part of the EU-sponsored MACHU project (Fig. 2.11).[87] The benefit of this system over ARCHIS 2 is that it is a GIS that is specifically geared towards collecting and presenting maritime data. Information such as the position notation has been adjusted, but specific geophysical data can be incorporated as well. Moreover, it has a worldwide coverage and is able to differentiate between various validated and invalidated data sets.[88] The MACHU system will eventually have to be integrated into the RCE's new archaeological database, ARCHIS 3.[89] This will also provide input for the Netherlands National Contact Number.

Knowledge about known heritage thus helps in making an estimate of the potential – the yet unknown –heritage in a certain area. We should realize, however, that there is a good reason why we know about these locations. The techniques for underground observation are extremely limited, so the known locations are almost, without exception, found due to them being exposed as a result of erosion.[90] Almost without exception, the known cultural-historical finds in the Western Wadden Sea are located in the zones most prone to erosion. Almost nothing has been found in the most stable zones, which are the areas with the highest potential for finding prehistoric sites. This is somewhat less the case for shipwreck sites, at least where the sea has always been relatively shallow, or with regard to larger ships, which

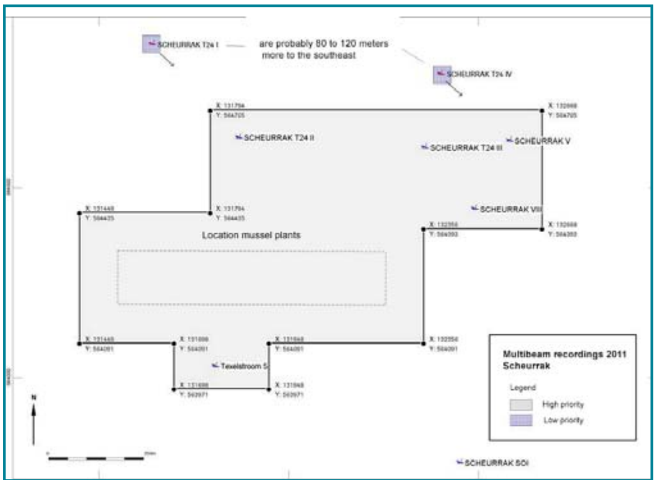


Fig. 2.10 The difference in location between positions known from the ARCHIS 2 data and the actual positions of the sites measured with multibeam sonar. Figure: courtesy Periplus Archeomare/RCE.

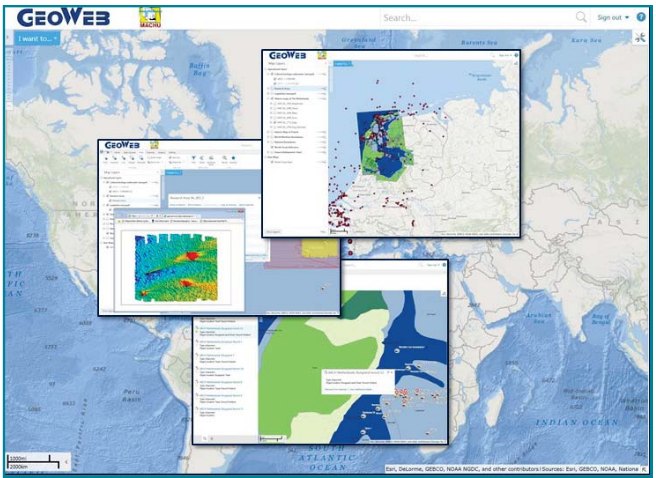


Fig. 2.11 The MACHU GIS viewer. Figure: courtesy MACHU/RCE.

[85] National Contact Number: http://www.periplus.nl/home/nl/referenties/projecten/nationaal-contactnummer-ontsluit-databases-met-wrakken-en-obstructies-onder-water (accessed 29-1-2017).

[86] However, it must be clear that the various positions in the different databases all apply to the same wreck site. This often requires considerable preparation, including surveys under water and on the surface.

[87] Managing Cultural Heritage Underwater (MACHU). Financed by the European Union Culture 2000 Programme. www.machuproject.eu (accessed 29-01-2017). Hootsen & Dijkman 2009.

[88] There are several reports and articles available about the MACHU project and the GIS. See the project reports by Oosting and Manders (eds.) 2007, Manders, Oosting and Brouwers (eds.) 2009 (1) and Manders, Oosting and Brouwers (eds.) 2009 (2).

[89] Unfortunately, this has still not been accomplished. It is now planned for some time in 2017.

[90] Brenk and Manders 2014, 26.

would usually avoid these areas. However, if any shipwrecks are located in these areas, then their quality is probably extremely high, due to them having been covered for centuries.[91]

2.5 Different databases with different numbers

Research in ARCHIS 2 in December 2013 resulted in a number of observations about the current sea bottom in the research area.[92] (based on a graphic-filter top-10 vector file); in fact, 190 wreck reports spread over 175 locations and 416 other observations spread over 109 locations (Fig. 2.12).

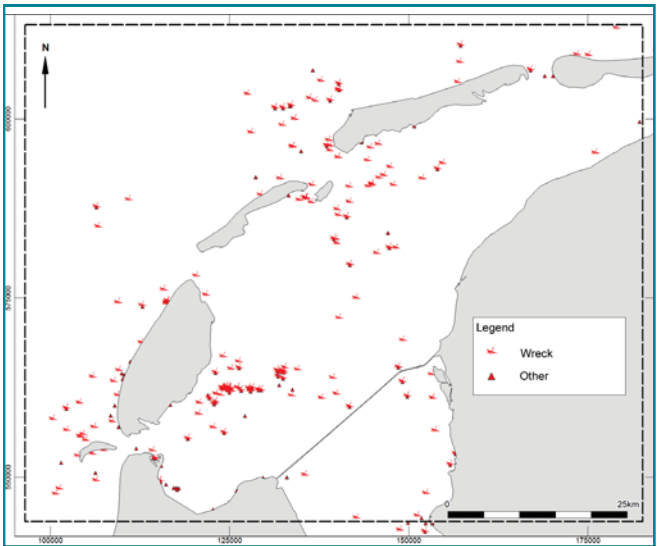


Fig. 2.12 Known locations from ARCHIS 2, the national archaeological database. Figure: courtesy Periplus Archeomare/RCE.

The Hydrographic Service maintains an overview of obstacles that may pose a hazard to navigation. This overview is published in the wreck register, HP39.[93] The register differentiates between three types of contacts: Wrecks, Obstructions and Possible Obstructions (or Foul Ground). For the same area as above, this register contains 378, 71 and 25 of these types of locations, respectively (Fig. 2.13).

Since 2009, all of the observations by the Ministry of Infrastructure and Water Management have been registered in the SonarReg92 database. Of these, 2,775 fall within the limits of the defined study area in the Western Wadden Sea. A large proportion of these (approx. 2,280) are, however, individual rocks in the Texel stone field (Fig. 2.14).[94]

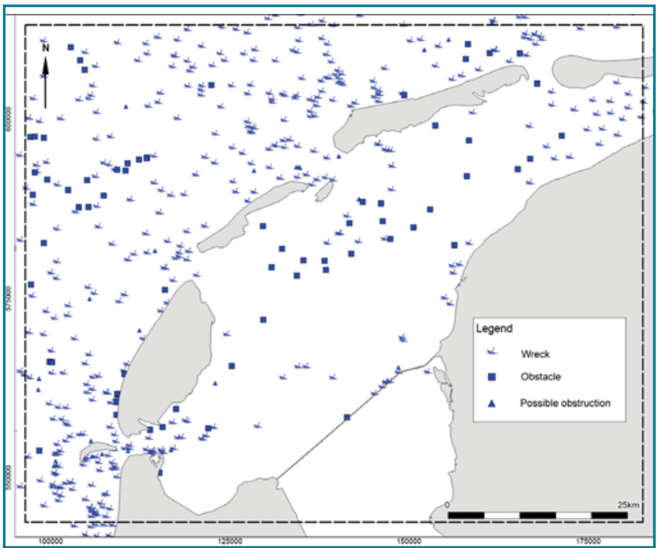


Fig. 2.13 Known locations based on the Hydrographic Service of the Navy. Figure: courtesy Periplus Archeomare/RCE/Hydrographic Service.

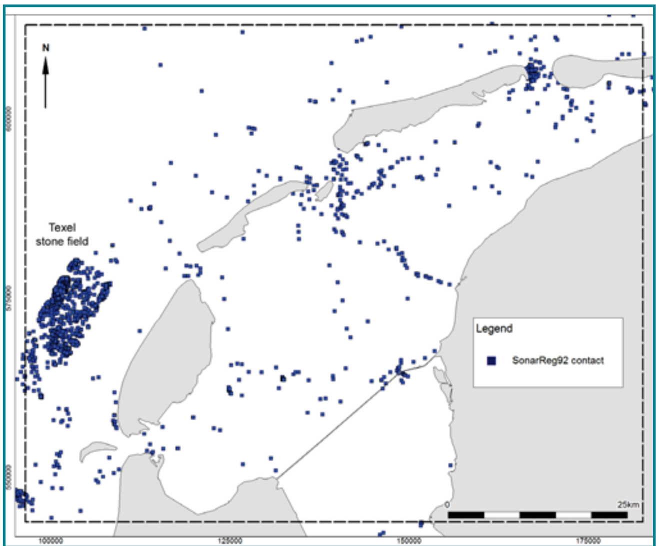


Fig. 2.14 Known locations from Rijkswaterstaat (Ministry of Infrastructure and Water Management). Note the large number of points directly west of Texel. These are from a natural formation of large boulders. Figure: courtesy Periplus Archeomare/RCE/Rijkswaterstaat.

[91] As a validation of the model, for example, in 2014, a shipwreck (Westerveld 2) was discovered on a sandbank south of Vlieland. The HGMS for the Western Wadden Sea, indicated that this area has been exceptionally stable since at least the late sixteenth century, and little to no erosion has taken place. The wreck was located next to a new channel that ran over the sandbank, disturbing the area for the first time in centuries. This information, together with the photos that the discoverer sent to us of a clinker-built boat with a naturally formed frame, resulted in a follow-up study because the boat was potentially very old. It was eventually dated to around 1500. This makes it one of the oldest vessels discovered in the Wadden Sea area. Opdebeeck & Koehler, 2014.

[92] Only objects currently under water, and no reports in former water channels or sea bottoms currently silted over.

[93] 'HP39 Wreck Register Netherlands Continental Shelf and Westerschelde', publication by the Hydrographic Service.

[94] See also Erdbrink 1950.

Based on the concept 'Simple storage – multiple use', in 2009, the three government agencies thus, took the initiative to link their databases containing information about underwater objects in the Netherlands (ARCHIS 2, the Shipwreck Register and SonarReg92). This resulted in the National Contact Number (NCN) database, a central register in which each contact is issued with a unique number. These numbers are linked to the databases at the various government agencies and are managed by a private company (Periplus) on behalf of Rijkswaterstaat, Sea and Delta.[95] Once each quarter, the numbers are updated, based on new reports from the various agencies. The NCN is accessible via a closed geoweb application managed by the Zee and Delta Infrastructure and Public Works Agency.[96] In total, 3,393 observations in the NCN fall within the limits of the study area (Fig. 2.15).

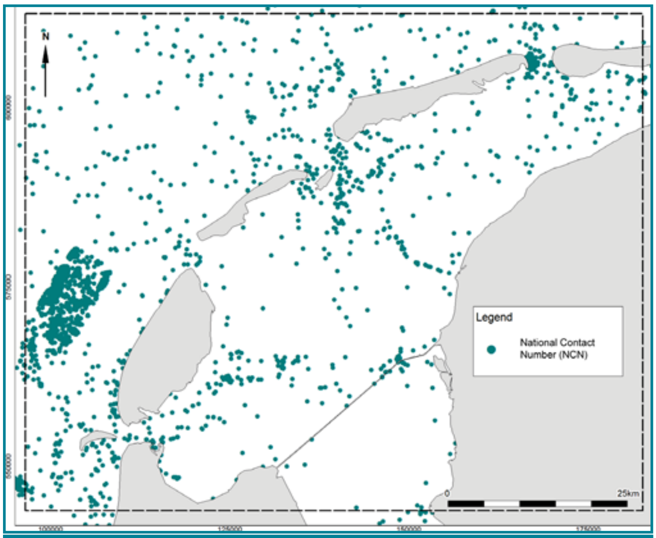


Fig. 2.15 Known locations from the National Contact Number or NCN database. Figure: courtesy Periplus Archeomare/RCE.

There are also other sources that record the locations of obstacles and shipwrecks. These are often difficult to access, or the accuracy of the data is difficult to confirm. When these data are encountered, they are reviewed to determine whether they add anything to the existing overview, after which the RCE decides whether to incorporate the data or not. In 2012, the RCE digitized an analogue register of wreck data in the North Sea and the Wadden Sea.[97] This involved two binders with 648 pages of typed text, plus three A0 format maps entitled 'Wrakkenregister Noordzee- en Waddengebied, Rijkswaterstaat Directie Friesland, Arrondissement Friesland-West'.[98] This register describes shipwreck discoveries for the period 1820–1988. The texts include descriptions of approximately 700 shipwrecks. Of these 700 wreck locations, 443 fall within the Western Wadden Sea research area (Fig. 2.16).

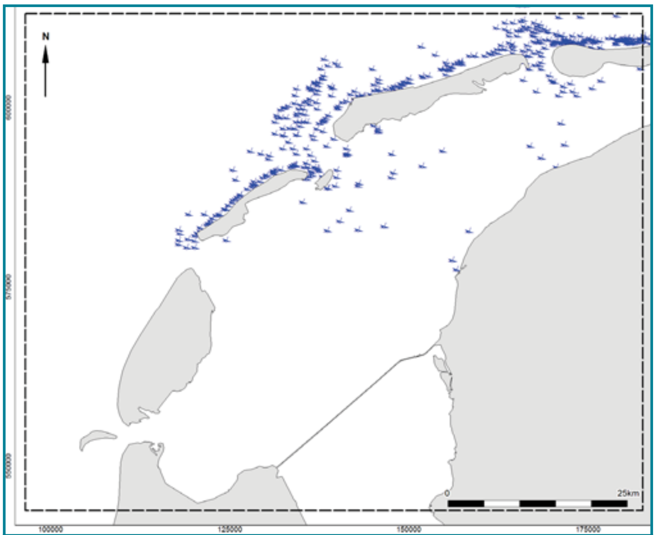


Fig. 2.16 Known locations from a regional database of Rijkswaterstaat North. Figure: courtesy Periplus Archeomare/RCE/ Rijkswaterstaat.

Recreational divers and commercial survey firms in the Netherlands also collect observations in a variety of lists and databases. These databases, which can be very large, contain unique data, as well as that accumulated by other collectors or other known private or government databases. It is therefore often impossible to differentiate between these data. Thus, the information they contain should be used with care, but may constitute unique material. These sources include the wreck files for the National Working Group for Underwater Archaeology (LWAOW),[99] Pandora (now, Wrecksite.eu),[100] GIS_RWS_DNH (Wraksys)[101] and Periplus Archeomare[102] (Fig. 2.17).

[95] The Periplus Group is a consultancy organization specialized in hydrography, geology, geophysical, maritime archaeology, GIS, data processing, data management, project management and engineering, based in the Netherlands. www.periplus.nl.
[96]https://geoweb.rijkswaterstaat.nl/GeoWeb41/?Viewer=Legger%20 Rijkswaterstaatswerken (accessed 29-01-2017).
[97] Muis & Brenk 2013.
[98] Wreck register for the North Sea and Wadden Area. Department of Public Works, Directorate Friesland, district Friesland-West.
[99] LWAOW is the avocational archaeological diving association in the Netherlands. http://www.awn-archeologie.nl/archeologie-onder-water/ (accessed 29-01-2017).
[100] Pandora.be is now known as Wrecksite.eu.
[101] The Wraksys Foundation is now managed by Hille van Dieren, Wrakkenmuseum Terschelling.
[102] Periplus Archeomare: hydrographic and maritime archaeological consulting bureau, part of the Periplus group.

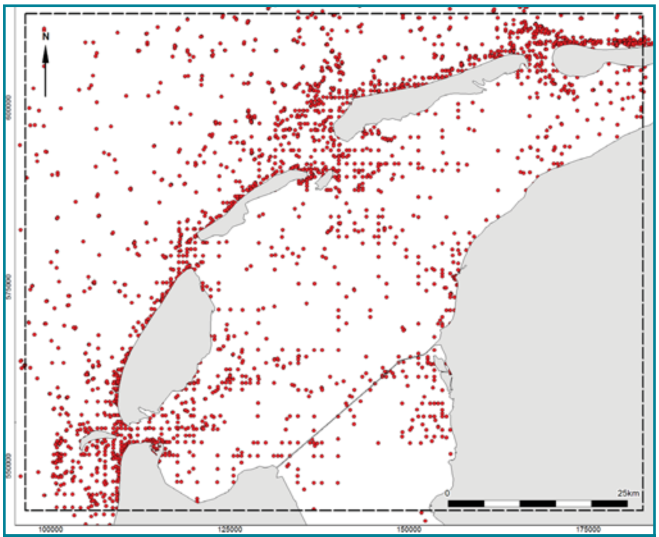


Fig. 2.17 Known locations of combined amateur archaeologists' databases. Figure: courtesy Periplus Archeomare/RCE.

In total, 6,636 observations are known for the Western Wadden Sea area. None of these observations have been verified and the overlap with the NCN has yet to be determined. Due to the number of sites, this will be an ongoing process.

It is probable that a lot of the data collected will never be shared on a large scale and therefore will not end up in a central database such as ARCHIS. There are multiple reasons for this. First, there is a long-term debate concerning public access among heritage professionals in the Netherlands, as well as other countries. Some consider that the publication of sites and their positions is a hazard to their preservation,[103] as the location will ultimately become known not only to those who have the best intentions but also those who mean to harm the resources, such as souvenir hunters and commercial salvagers. Until now, the level of law enforcement has not been sufficiently adequate to ensure protection against damage to cultural heritage.[104] Second, although promoted on a European level and followed up by some countries, others still, and by law, prohibit the publication of the positions of cultural heritage sites.[105]

Another reason for not sharing information has to do with the feeling of exclusive ownership of a site. Among several amateur archaeologist groups, there is still a sense that the sites are owned by those who discover them.[106] Sharing information does not correspond with that idea (see also Chapter 4).

2.6 Combining data in interpretive maps

The more we know about an area, the more we can understand its importance for past users and predict the unknown resources that may well be hidden under the soil surface. We can gain better insight when we correlate, combine and compare different data sets with each other and start to interpret what we see.

2.6.1 Geology and geomorphology

Composite maps can be produced by combining basic geological and geomorphological data. Identification of newly obtained data allows the assessment of the possible presence of heritage, its condition, its accessibility and any threats. This section provides a few examples based on the following basic maps, for illustrative purposes:

- » The Pleistocene land surface at the start of the Holocene (reconstruction based on the current location, minus erosion areas) (Fig 2.18B)
- » Current location of the Pleistocene upper strata (with erosion channels) (Fig 2.18A)
- » Most recent depth model (2005)

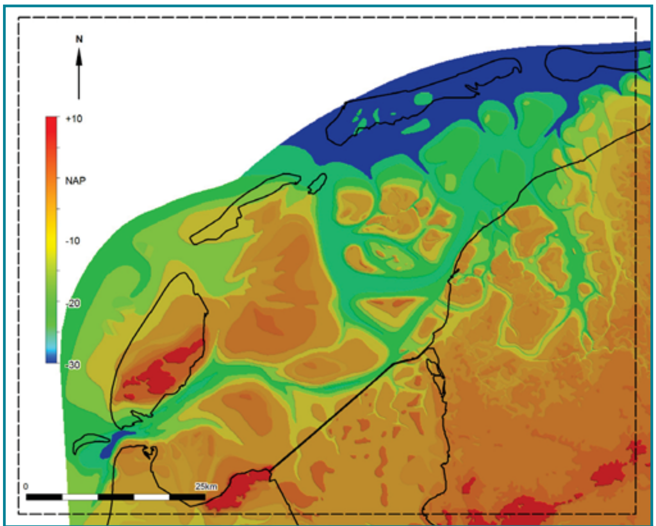
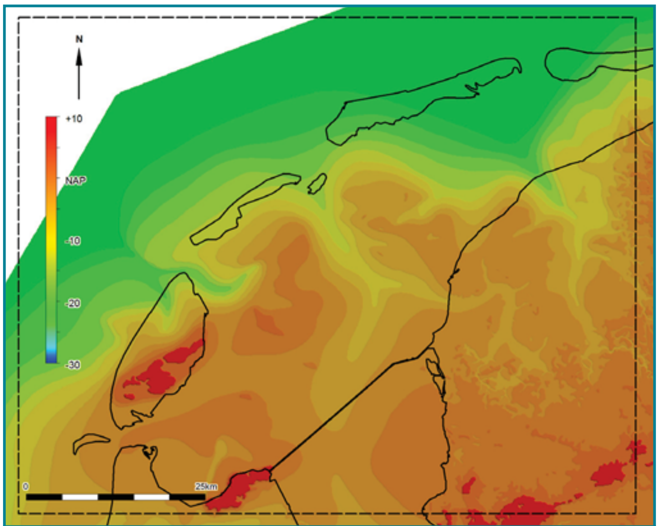


Fig. 2.18 A. The currently preserved Pleistocene layers, including the eroded areas.



B. The reconstructed Pleistocene surface, ignoring the erosion gullies. Figure: courtesy Periplus Archeomare/RCE.

[103] The MACHU Project Team 2009, 132.

[104] Erfgoedinspectie 2012, 4–5.

[105] See https://www.erfgoedinspectie.nl/toezichtvelden/archieven/inhoud/wet--en-regelgeving/overige-informatiewetgeving/openbaarheid-van-documenten-van-de-europese-unie (accessed 29-01-2017).

[106] http://www.nd.nl/artikelen/2007/mei/25/schatgraven-in-een-wereld-van-stilte (accessed 29-01-2017).

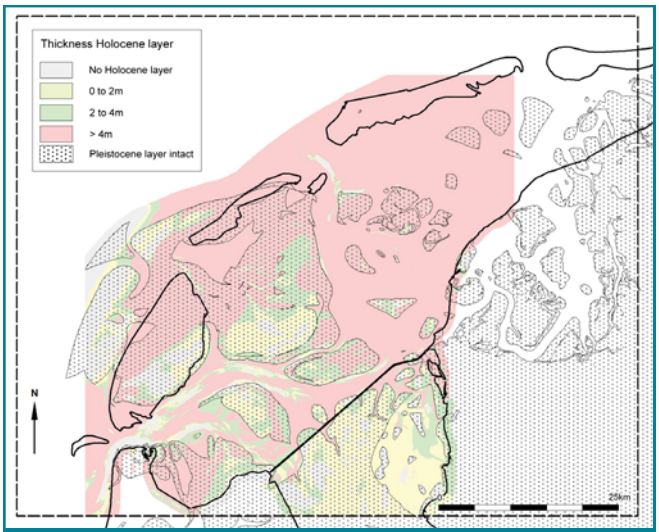


Fig. 2.19 The thickness of the Holocene layer. Figure: courtesy Periplus Archeomare/RCE.

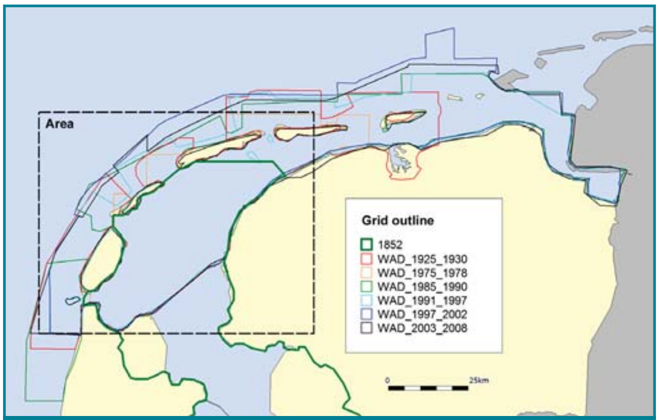


Fig. 2.20 Areas of known depth surveys. Figure: courtesy Periplus Archeomare/RCE.

Subtracting one Pleistocene model from the other creates a model that already indicates where the original Pleistocene surface may still be intact.[107] This surface also defines the maximum depth for wrecks from later periods, since the Pleistocene package is too compact for shipwrecks to sink below it (Fig. 2.18 A + B).[108]

In the early Mesolithic period (start of the Holocene), approximately 11,000 years ago, the sea level was 40 metres lower than it is today. The model for the location of the Pleistocene upper strata at the start of the Holocene, therefore, shows the dry landscape that existed at that time. The entire area, including large sections of the North Sea Basin, was above sea level and potentially suitable for habitation. As the sea level rose, more and more land became submerged. Based on the location of the upper Pleistocene strata, we can define the historical coastlines from this period (See also Fig. 2.7).

The thickness of the Holocene cover strata is determined by subtracting the current location of the sea floor (most recent depth model, 2005) from the model of the current location of the upper Pleistocene strata (Fig. 2.19). The much less compact Holocene strata is also considered to be the 'mobile layer', since it is very susceptible to erosion and sedimentation processes, at least in certain areas. It is possible that well-preserved shipwrecks could be found in this layer. Shipwrecks may become completely covered by the Holocene strata due to settling (often caused by erosion around the wreck) or sedimentation.[109] Areas with a thick layer of Holocene sand, but no shipwrecks located on the surface, may still have shipwrecks buried under the sea floor.

Changes in morphology through time can be illustrated by combining the basic information for various years since 1925. To this end, all of the basic grids since 1925 have been combined into a single model (Fig. 2.20).[110] This model consists of 20 x 20 metre grid squares, with the minimum and maximum number of values and average value for each square. Exporting the difference between the minimum and maximum value for each grid square (with a minimum of four values) results in a model that describes the thickness of the mobile layer (Fig. 2.21).

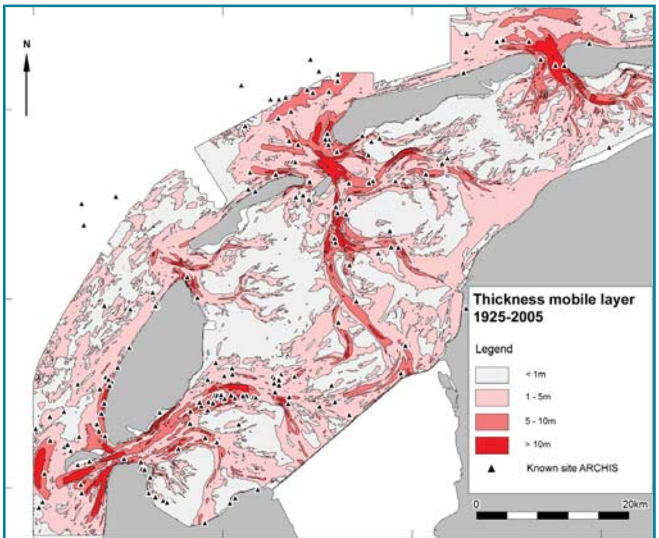


Fig. 2.21 Thickness of mobile layer, measured between 1925 and 2005. Figure: courtesy Periplus Archeomare/RCE.

[107] However, this is subject to the limitations inherent to the basic models.

[108] Manders, Os & Wallinga 2009, 46. However, due to the erosion of the Pleistocene surface, ships may sink to levels lower than the original Pleistocene upper strata.

[109] See Dix et al. 2009, 48–54.

[110] Sounding Grid Utility, QinSy.

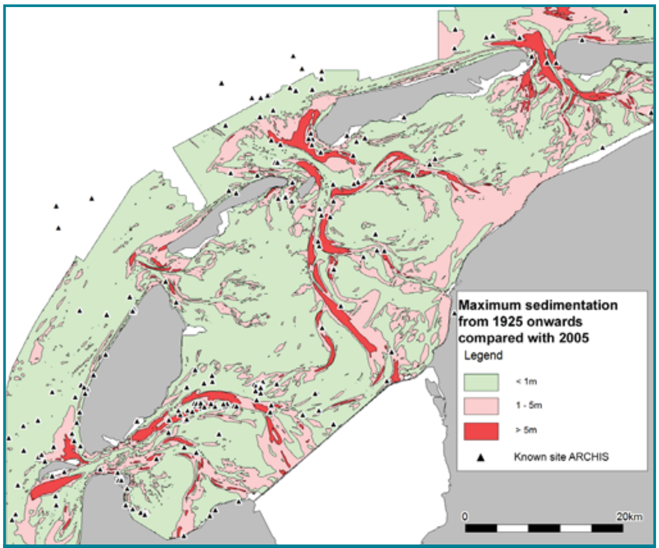


Fig. 2.22 Maximum sedimentation from 1925 onwards and in comparison with 2005. Figure: courtesy Periplus Archeomare/RCE.

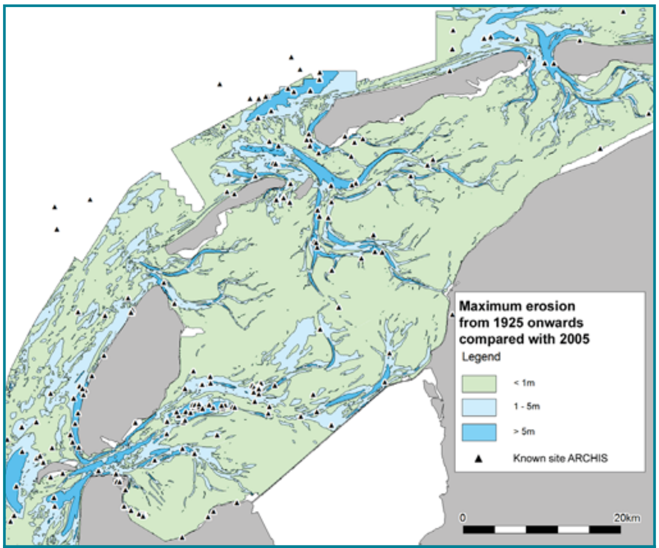


Fig. 2.23 Maximum erosion from 1925 onwards and in comparison with 2005. Figure: courtesy Periplus Archeomare/RCE.

These data sets can immediately exhibit which areas have remained stable over the 80 years between 1925 and 2005 and which areas have changed, with the model easily showing the changes over that period. Changes may include erosion, sedimentation or a combination of both. In the areas that have remained stable over the period, few archaeological observations have been recorded. However, this does not mean that no cultural heritage is present in these areas. The stable areas may simply be less travelled by ships, due to shallow waters, and, since the Holocene deposits are stable, any objects will be covered by sand and out of sight.

By comparing the shallowest value for each grid square with the most recent depth, we can create a model of the maximum degree of sedimentation (Fig. 2.22). Areas that were deeper by a metre or more in the past (between 1925 and the present (2005)) have been filled in with sediment over the past 80 years. For archaeological expectation purposes, we can determine that these areas will thus harbour no cultural-historical remains from before 1925 down to the level of the maximum depth for this period, or any such remains will be in a disturbed state. By comparing the deepest value for each grid square with the most recent depth, we can create a model that shows the maximum depth in the area (Fig. 2.23).

Areas that were shallower in the past (between 1925 and the present(2005)) have been eroded over the past 80 years. With regard to archaeological expectations, we can state that any remains in these areas will be located on the current sea floor or deeper. Almost all of the known observations in ARCHIS are plotted in these areas. They are also the areas where sites, discovered or not have disappeared over the course of time.

2.6.2 Historical data as an add-on for understanding

If we add historical data to the geological models, we can gain a better understanding of the cultural landscape during the various periods. This is because the use of the landscape largely determines where the cultural-historical remains are deposited. From a spatial and geographical perspective, historical information is often not of a uniform nature. The detail, accuracy and reliability differ from source to source, from period to period and from area to area. The information (as well as its interpretation) is also influenced by a number of factors, such as skill, utility and economic or political objectives. It is interesting to see that while beaches and harbours are often the outer limits of land maps, they are the starting point for navigational charts.[111] These, therefore, add a different dimension to our understanding of the landscape. Much of our knowledge of the sea and its uses has been recorded in historical sources, but much has not. This knowledge, often recorded in oral traditions, has been lost over time.[112]

[111] Lambert et al. 2006, 482. An integration of a land-based perspective and a sea-based perspective in studies about dynamic urban geographies could produce new ideas.

[112] Lambert et al. 2006, 483 & 486.

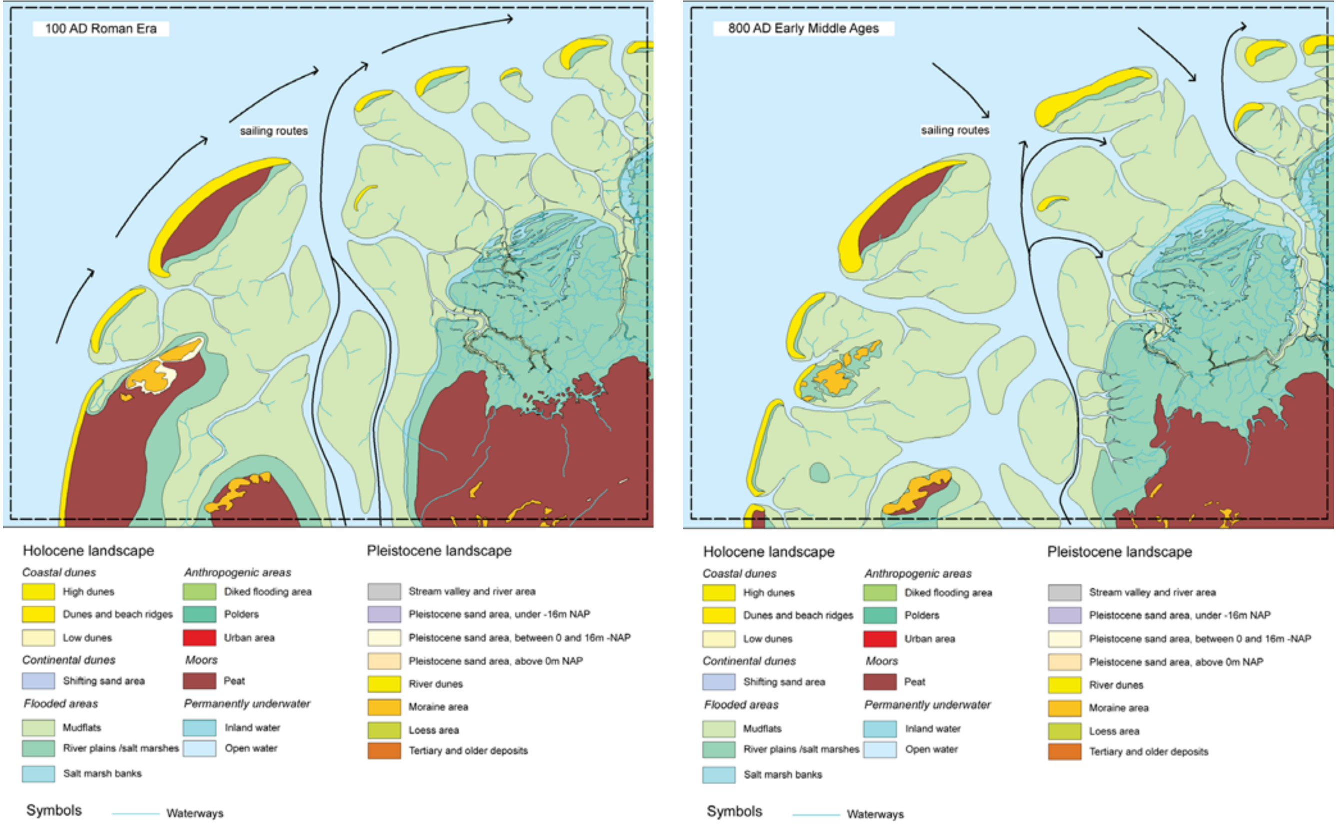


Fig. 2.24 A + B Reconstruction of the landscapes in the (A) Roman and (B) Early medieval periods (After Vos & De Vries 2013), including information on the major sailing routes. Figure: RCE.

As mentioned above, in the Netherlands, we can add historically known shipping routes from the Roman era and the early Middle Ages (Fig. 2.24 A + B). This can help clarify certain shipping lanes, but also the areas of habitation that they connected within the maritime cultural landscape. An indication of the use of the area in the modern period has been implicitly included through the digitization of historical navigational charts which also contain information about such use (Fig. 2.25A).

However, historical maps also contain much more information than data about depths and currents, such as the routes used, the harbours, beacons and anchorages.[113] This information can help us analyse the use of an area, especially when we compare the maps over the course of time. Historical information from written sources can also provide useful information, while sea battles or major storms may provide insight into the likely number of ships that have sunk in a specific area.[114]

By georeferencing historical maps and comparing them to more recent morphological maps, we can extrapolate the processes of erosion and sedimentation 'backwards' to the end of the sixteenth century. This, in turn, helps us visualize more than four

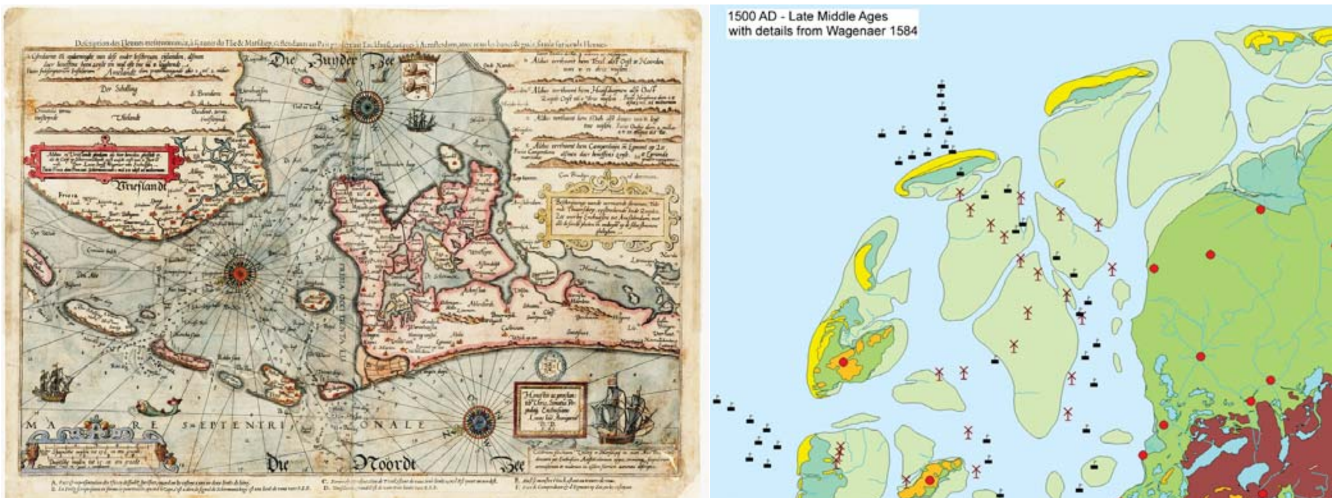


Fig. 2.25A Map of the Wadden Sea by Waghenaer from 1584. A. Original map, B. the digitalized and vectorized map. Figure: courtesy Periplus Archeomare/ RCE.

[113] http://celebrating200years.noaa.gov/new_york_charts/welcome.html#info (accessed 29-01-2017).

[114] Areas where battles have taken place may be referred to as landscapes of war. Where sea battles have taken place, we usually see no evidence on the surface of the water. However, historical knowledge ('what has happened according to a people'), knowledge of warfare and sailing ('what would be the most logical thing to do') may assist in developing a view about what may actually have happened. Based on such interpretations we can decipher the seabed and make an estimation of what material witnesses may be left under water. At the same time, any evidence found on or in the seabed may strengthen or weaken our theories and thus assist us to move closer to the truth.

[115] Westerdahl 1996.

[116] See also Wang et al. 1995

centuries of dynamics in the Wadden Sea and may provide information on the use of the area, supported by theories on the use of maritime cultural landscape, such as those developed by Westerdahl,[115] and the presence and preservation conditions of sites. The level of detail this provides is in comparison with the high-resolution morphological models, low. We therefore have to be careful to combine them into one model. They serve a purpose on a regional scale however to visualize changes that have occurred.

2.7 Geomorphological models

2.7.1 Basic geomorphological models

As stated above, the dynamics of the sea floor and the coastline is one of the Wadden Sea's defining characteristics. Since the creation of the Wadden Sea, the area has been formed by gullies that can move or change directions over time under the influence of tidal currents.[116] Insight into these geomorphological changes is absolutely vital to draw up expectation maps for the late medieval and early modern periods. The most important information for modelling morphological changes comes from depth soundings (depth measurements) of the sea floor. By comparing different soundings through time, we can gain insight into these changes. If sufficient data is available, we can also draw up predictive models for the future. As mentioned above, the current Pleistocene surface is the bottom limit for the depth in these models, since shipwrecks cannot sink into this compact layer of sand.

The depth models available for the Wadden Sea in the modern period (after 1500 AD) can be divided into three chronological stages based on the map materials available (for navigation purposes) and the accuracy and resolution of the data:

1. The period 1584–1852
2. The period 1852–1975
3. The period 1975–present

While maps dating from before 1584 are available (Jan van Scorel, c. 1550 and Christiaan Sgroten, 1573), these were not intended

Fig. 2.26 Historic (non-navigation) maps of the Wadden Sea by Jan van Scorel (c. 1552) (left) and Christiaan Sgroten (right) (Delineatio Sinus Meridionalis Maris, Vulgo De Zuyder Zee; Phrisia occidentalis, et Watterlandia, 1573).

as navigational aids and, therefore, details of water areas, such as depth soundings and shoals, are only sporadically illustrated and almost never measured (Fig. 2.26 A + B).[117]

2.7.2 The period 1584–1852

Six navigational charts from the period between the last quarter of the sixteenth century and the mid-nineteenth century were studied. These include the 1584 map by Waghenaer,[118] the 1649 map by Blaeu,[119] the 1666 map by Goos,[120] the 1773 map by Sepp,[121] the 1799 map by the British Admiralty[122] and the 1850 topographic map for the Dutch military[123] (Fig. 2.27).

Fig. 2.27 Series of historic maps by (A) Pieter Goos (1666), (B) J.C. Sepp (1777), (C) British Admiralty (1799) and the Chromo-topographic military chart of the Kingdom of the Netherlands from 1850.

[117] This does not mean that these maps cannot provide additional detail regarding the use of the landscape in this period.

[118] Lucas Janszoon Waghenaer (1533/34–1605/06). Coxswain, but became famous for this sea cartography. His Spiegel der Zeevaert from 1584 was a benchmark for future sea navigation mapping.

[119] Dr Jan (Joan) Willemsz. Blaeu (1596–1673) was a Dutch printer, publisher and cartographer. In 1649, he published (among others) the Hollandia Comitatus, which contains map material of known gullies and sandbanks in the Wadden Sea area.

[120] Pieter Goos (1616–1675) was a Dutch map maker, engraver and bookseller. The first edition of his Zee-Atlas Ofte Water-Weereld (Sea Atlas of the Water World) was published in 1666, including some navigation cartography of the Wadden Sea area: 'Pascaarte vande Zuyder-Zee, Texel, ende Vlie-stroom, als mede 't Amelander-gat'.

[121] Jan Christiaan Sepp (1739–1811) was an engraver, etcher, bookseller, author and illustrator. In 1773, he published the Nieuwe Geografische Reise- en Zak Atlas van De VII Verenigde Nederlandsche Provincien, including data from the Wadden Sea in 'De Vereenigde Nederlanden of Zeven Vrye Provinciën Gesloten in den Jaare 1579 te Utrecht in 1773'.

[122] This map, 'Dutch men of war Surrendered in the Nieueve Diep (Nieuwe Diep) to the Admirals Duncan & Mitchell. Augt. 30 1799', was probably partly produced to prepare for an Anglo-Russian invasion of Holland by the British Admiralty and partly during the invasion (according to the date). This campaign took place between 27 August and 19 November 1799, during the War of the Second Coalition, in which an expeditionary force of British and Russian troops invaded North Holland, at that time part of the Batavian Republic.

[123] Chromo-topographic military chart of the Kingdom of the Netherlands. Made by the Topographic Office of the Ministry of War in 1850.

The first known navigational chart for the Western Wadden Sea is the map entitled 'De vermaerde stroemen. 't vlie ende 't maersdiep' (The renowned currents Vlie and Marsdiep), by Lucas Janszoon Waghenaer in the Spiegel der Zeevaert, the first volume of which was published in 1584. It is assumed that Waghenaer based the charts on his own observations and measurements,[124] and they were used by sailors for many years. It is even possible that the charts were still in common use long after the most important shipping channels and sandbanks had shifted to other locations.[125]

The historical maps were made using dead reckoning. This involved drawing a coastline starting at a known point. From there, the surveyor determined the position of the coast based on the speed at which the ship was sailing, the compass course, the degree of drift and the sea currents.[126] Instruments were also available to determine latitude.[127] Longitude was much more difficult to calculate, and the methods were very unreliable. It only became possible to measure longitude accurately with the invention of the chronometer in 1762.[128] Taking this into consideration, there must have been major discrepancies between the calculated position and the actual position. This is also reflected in the maps. The map projection is also often different from that used in maps today.[129] These maps, therefore, needed to be digitally georeferenced, vectorized and,

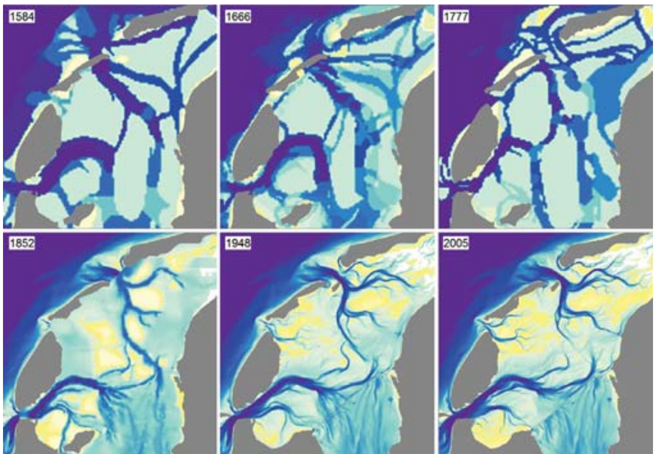


Fig. 2.28 Series of digital maps of the pilot area from 1584 (after Waghenaer), 1666 (after Goos), 1777 (after Sepp), 1852 (after Hulst Van Keulen), 1948 and 2005. Each subsequent map shows more detail due to the increasing resolution of the data. Figure: courtesy RCE/Menne Kosian.

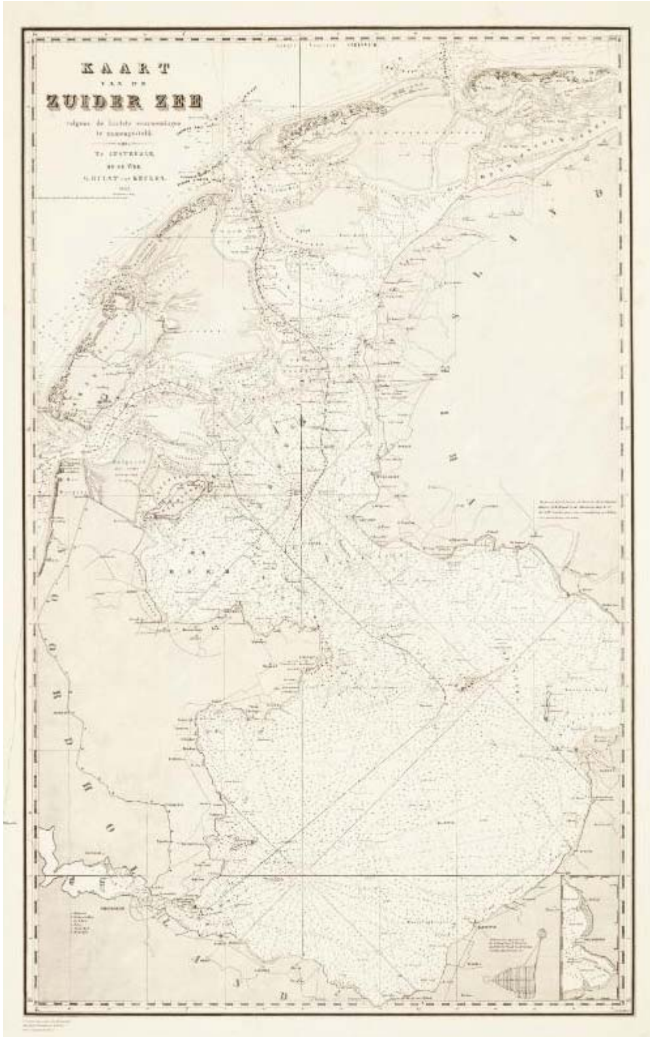


Fig. 2.29 Original map of the Zuiderzee and Waddenzee by Hulst van Keulen (1852).

where necessary, corrected for modern projections.[130]

Subsequently, similar scales and cut-outs were applied to each map. However, the maps still differ from one another in detail. For example, some contain more information than others, and several areas do not feature depth soundings. This is primarily due to the purpose for which the maps were made. They were intended as navigational aids, and ships were expected to sail along the recognized shipping channels. It was important to indicate the depths of the sailing channels and the navigational aids at sea,[131] while shoals were a threat to shipping and were to be avoided if possible. The exact depths of the sandbanks were therefore less important (Fig. 2.28).

[124] Kosian 2009, 27.

[125] Kosian 2009, 28.

[126] Kosian 2009, 26.

[127] Kosian 2009, 27.

[128] The chronometer was invented by John Harrison.

[129] The Mercator projection was in use for most of the maps after 1569. It is a cylindrical map projection which was introduced in that year by the Flemish geographer and cartographer Gerardus Mercator. It became the standard map projection for nautical purposes because it represented lines of constant course as straight segments which conserve the angles with the meridians. This is essential for navigation at sea. Therefore, it is still often in use for navigation charts. However, for many global and landmass charts, other projections are used. See also http://en.wikipedia.org/wiki/Map_projection (accessed 29-01-2017). for more information about map projections.

[130] Kosian 2013.

[131] See also Sigmond 1989, 157–158.

2.7.3 The period 1852–1975

The first detailed and reliable depth chart was the 1852 'Kaart van de Zuider Zee' (Map of the Zuyder Zee) by Hulst van Keulen.[132] The depth values are expressed in 'Amsterdam feet[133] at normal ebb tide', and were obtained through systematic manual depth soundings.[134] The map contains more than 7,000 soundings in the current Western Wadden Sea and the IJsselmeer area. Based on these measurements, depth contours were then added by hand (Fig. 2.29).

The entire original map was digitized (soundings and contour lines), and then the values were converted to the current NAP[135] in the following steps.

1. Digitization of original soundings
2. Digitization of original depth contours
3. Conversion of Amsterdam feet to metres (factor 0.2831)
4. Conversion of Normal Low Water to NAP in accordance with correction model (based on data provided by the Ministry of Infrastructure and Water Management)

The values converted to RD[136] were then applied to a grid model with 50 x 50 metre cells (Fig. 2.30).

Hand-drawn overview charts were published for the periods 1925–1930 and 1948–1951. These were then digitized in the 1980s by the Friesland Directorate for Infrastructure and Public Works. This involved drawing vertical and horizontal lines on the map, varying in distance from 90 to 250 metres. The degree of coverage for some areas may also have been examined at this time. Following this, the average value for each 250 x 250 m square was calculated. These values were then interpolated to a 20 x 20 m grid.

The soundings from before the Second World War were conducted using a manual lead, and the positions were determined using a sextant (horizontal angle measurement). It is unclear when acoustic sounding and hyperbolic positioning systems were first used, although it was probably no earlier than the late 1970s. A full-coverage system only came into use in the late 1980s and early 1990s. The original overview maps were destroyed after they were digitized. [137]

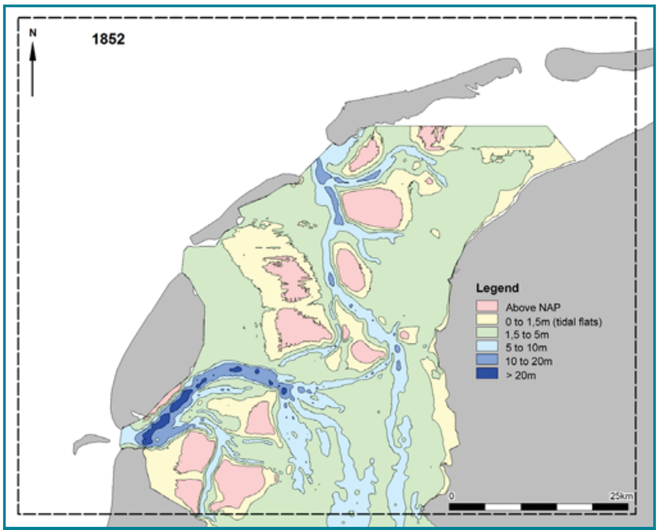


Fig. 2.30 Digitalized and vectorized map of the Zuiderzee (from Hulst van Keulen, 1852). Figure: courtesy Periplus Archeomare/RCE.

2.7.4 The period 1975–present

Starting in 1975, the depth of the Wadden Sea was systematically measured using zone soundings. The area was divided into a number of zones, with a pattern of cross-sections for each zone (Fig. 2.31). The maximum distance between the cross-sections was 200 metres. These cross-sections were measured using a single beam acoustic sounding system, which measured depth in average increments of 20 centimetres. When the data was processed and validated, spikes were removed and the values were referred to NAP. The data was then placed in a grid of 20 x 20 metre squares. The gridding method has improved significantly over the years; and since the turn of the century the preferred method has been Digipol, an interpolation technology designed by the RIKZ especially for seabeds. [138]

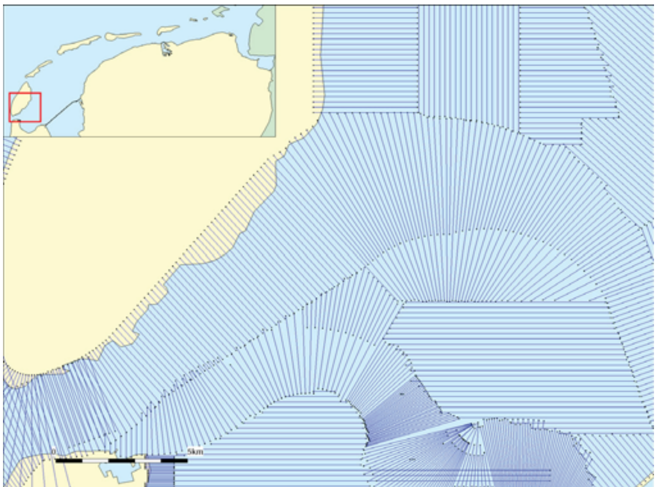


Fig. 2.31 The pattern of zone soundings in the southwestern part of the Wadden Sea near Texel and Den Helder. Figure: courtesy Periplus Archeomare/RCE.

[132] The navigation chart 'Zeekaart van de Zuiderzee en de Waddenzee (Texel - Ameland)' was published by Weduwe (widow) G. Hulst van Keulen, in 1852 in Amsterdam. Although Gerard Hulst van Keulen died in 1801, his wife must have continued the trade, as did others after her, as maps were produced throughout the nineteenth century.

[133] An Amsterdam foot is equal to 0.231 metres.

[134] Sounding was done from a ship using a sounding lead. See also Horsten et al. 1979, 316.

[135] Normaal Amsterdams Peil (Normal Amsterdam Level): reference level for water-level measurements in the Netherlands.

[136] Rijksdriehoekstelsel, coordinated conversion using RDNAPTRANS (Kadaster.nl).

[137] Source: Willem van der Hoeven, consultant for DID-DSDG.

[138] Halderen 2005, 8. RIKZ: Rijksinstituut voor Kust en Zee (National Institute for Coastal and Marine Management).

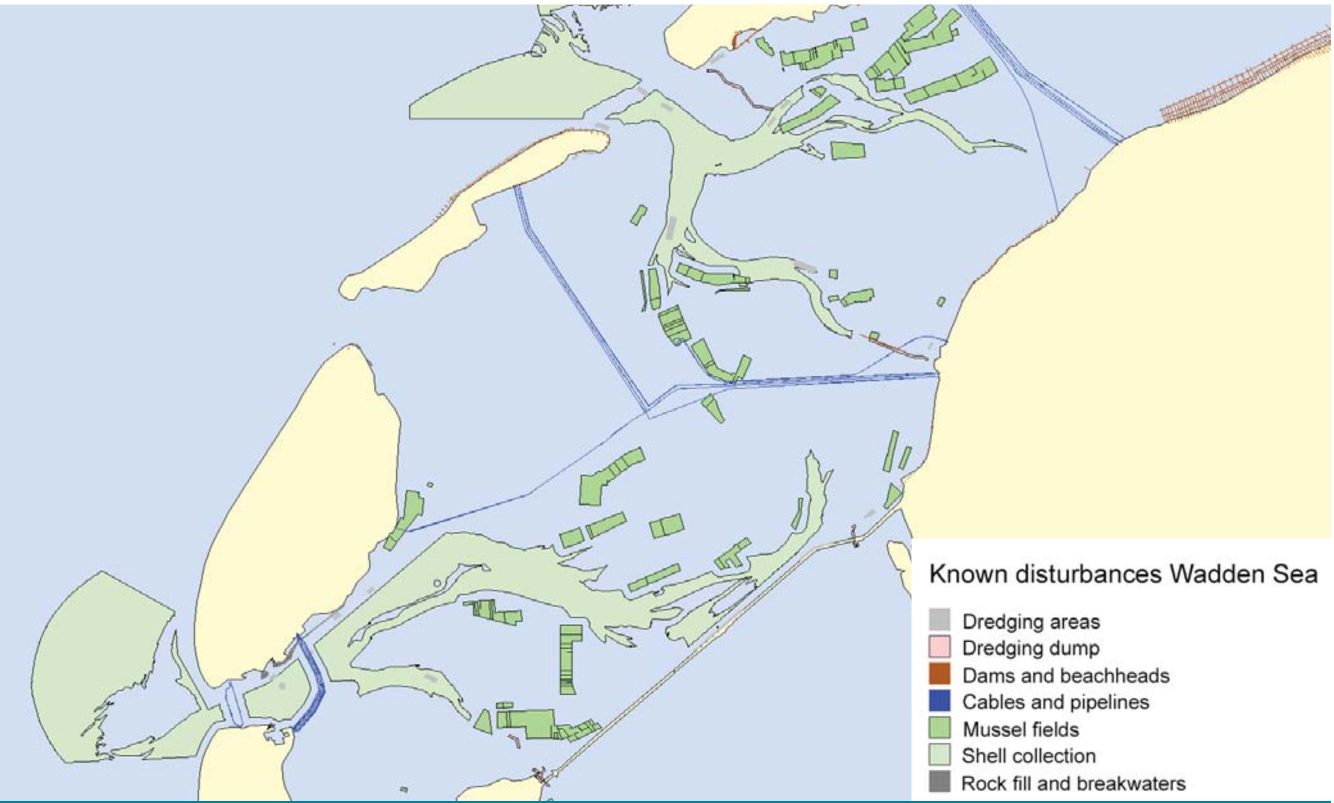


Fig. 2.32 Disturbances in the Wadden Sea pilot area. Figure: courtesy Periplus Archeomare/RCE.

2.8 Known and allocated areas for disturbances

The seabed has increasingly become a place that needs to be adapted for commercial activities, whether this is the installation of wind farms, pipelines, electric cables, the dredging of shipping lanes, sand abstraction, sea farming or the reclaiming of land for building purposes.[139] These human and other threats will be further discussed in Chapter 3.

The Ministry of Infrastructure and Water Management issues permits to keep track of which areas have been disturbed due to public works or where such disturbances are permitted. These data can be used to inventory the current disturbances of areas of interest based on geological and historical data. This is in turn valuable information for drafting policy maps for municipalities with the aim of obtaining exemptions to a certain depth, or to mark the current potential of an area.[140]

The digital map of disturbances in the HGMS shows the known disturbances of the sea floor in the pilot area, based on various sources from within the Ministry of Infrastructure and Water Management (Fig. 2.32). The disturbed areas are defined by the Ministry as polygons, in which the object information regarding sources and disturbance depth are recorded.[141]

Known sea-bottom disturbances can be divided into a number of categories.

Type	Description	Degree of disturbance
Dredging areas	Normal dredging work to keep shipping channels clear to a certain depth	In principle, only disturbance of recently accumulated sediment
Dredging dump	Dumping of dredging debris	No disturbance of the sea floor; only accumulation
Dams and beachheads	Construction of moles	Limited disturbance of sea floor only coverage
Cables and pipelines	Trenching and burying cables and pipelines	Disturbance to maximum depth of 6 m, 20 m wide
Mussel fields	Raising mussels for consumption	Disturbance of the sea floor to a depth of approx. 15 cm during harvest
Rock fill and breakwaters	Construction of reinforcing structures underwater	Limited disturbance of sea floor, only coverage
Shell collection	Shell collection through suction	Disturbance to a maximum of a few metres in depth

Table 2.1. Overview of the known disturbances in the Dutch Wadden Sea.

[139] See, for example, 'Ontwerp beleidsnota Noordzee 2016–2021' (attachment to the National Water Plan 2016–2021), for an overview of activities planned for the North Sea floor, which was published in December 2014 by the Ministries of Infrastructure and Water Management and Economic Affairs.

[140] It is also important to indicate which areas have already been disturbed, and in which areas such disturbances are permitted but where no interference has taken place. Each type of activity involves a specific degree of disturbance. See also Table 2.1.

[141] Some of the polygons were provided via the Ministry of Infrastructure and Water Management web service, and are based on the permits issued. In reality, this information should be included in the metadata xml provided along with the files, but unfortunately this is often limited or incomplete.

The HGMS provides vector files describing the various types of disturbances which cover the entire Dutch Wadden Sea area.

2.9 Refinements

Several refinements could be made to the HGMS in the future. The grid for the basic files derived from the original data for the palaeographic maps of the Netherlands is not a gradual model but a 'stepped' model with two metre intervals (Fig. 2.33). As the original information was no longer available, these large steps may pose some problems in interpretation.[142] For example, the model does not show variation between NAP -10 and -12; rather, it assigns the same variable to the entire area, then jumps two metres to the adjacent area. This may mean that the local/relative high points, where habitation may have been possible, are not shown.

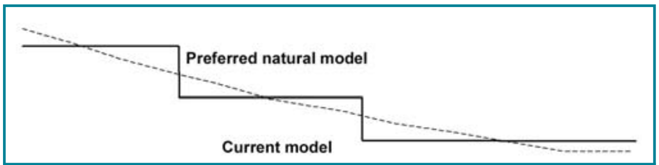


Fig. 2.33 The current maps based on the Pleistocene surface data are 'stepped models'. Ultimately, it would be better to have a more gradual model. Figure: courtesy Periplus Archeomare/RCE.

Another problem is that, in certain areas, the eroded Pleistocene surface is higher than the model for the original surface, which is, by definition, impossible. This must be due to a mistake in the original or the interpreted data.

The basic models are part of the large-scale national model, which has a relatively low resolution. The GeoTOP model would be a better alternative. In GeoTOP, the underground volume is divided into millions of 100 x 100 metre voxels (blocks) in the horizontal axis and 50 centimetres in the vertical. Parameters are then linked to each voxel. These can include geological characteristics, such as the stratigraphic unit to which the voxel belongs and the soil type (sand, peat, clay), but also physical and chemical parameters, such as the permeability to ground water. Since 2012, TNO has been working on an expansion of GeoTOP to the Wadden Sea region.[143] At the time of the analyses described above, this was not yet available.

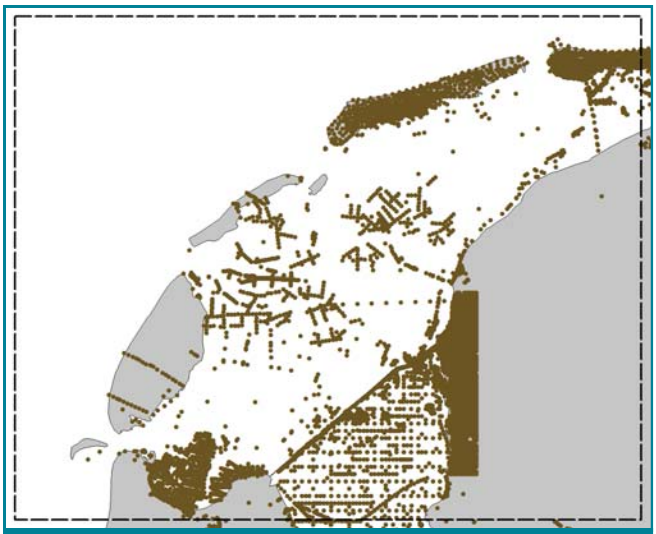


Fig. 2.34 Core density in the pilot area as registered in DINO. Figure: courtesy Periplus Archeomare/RCE/TNO.

Furthermore, it must be noted that the density of the data used for the HGMS is highly variable, with distances of up to 10 kilometres between two core samples (Fig. 2.34). This means that, in certain areas, such as the highly erosive zone of the Burgzand, the density of core samples is so low that any interpretation of whether channels are suitable for shipping must be made with the greatest of care. The map material included in the HGMS is still in the early stages, and it should be improved as new data is added over the coming years.[144] However, as municipalities and archaeological companies will use the data sets, not only will these be improved, but new local and more detailed data may also be included in the analyses, improving the overall product.[145]

Historical maps are also subject to limitations. We should keep in mind that such maps are also historical interpretations and, therefore, do not always reflect the facts and figures which may interest archaeologists and heritage managers. They are influenced by many factors, such as the quality of the surveyor and the draughtsperson, the amount of knowledge available, as well as the purpose for which the map was made.[146] Each map has its own degree of accuracy and detail. The earliest historical maps (up to 1852) are all different with regard to the density of information provided. In order to compare the maps with one another and with later depth charts, a comprehensive process of re-projection has been undertaken. This means that the resolution for these maps is very low. The first detailed and reliable depth chart is therefore the 1852 map by Hulst van Keulen.

[142] The original grid/point file from which: the Plzgeul.shp, Plzmgeul.shp, 100 nC.shp, 800 nC.shp en 1500 nC.shp. Vos & De Vries 2013.

[143] http://www.waddenacademie.nl/nl/themas/geowetenschap/instituten/geotop-in-de-waddenregio/ (accessed29-01-2017).

[144] It is recommended that the RCE should take up the task of regularly updating the basic maps of the HGMS.

[145] At the time of writing (December 2016), the municipality of Texel is working with the HGMS to produce policy maps for its seabed area.

[146] This may include navigational purposes, but also political objectives. The latter may mean that additional attention is paid to certain areas, such as borders, or names may be changed or details consciously deleted or falsified. Lambert et al. (2006, p. 487–488) argued that since gender, class and race play an important role in creating a historical geography of the sea and its landscape, they may also influence the material products, such as the map materials, as well as our image of the past.

The accuracy of the maps increases as we approach the present day. After 1975, the charts utilized a fixed cross-section pattern, so the depth charts are easier to compare to one another as the data was collected with the same method and from the same cross-sections. However, the single-beam soundings used in these charts require considerable interpolation. In smaller areas, the coverage is improved through the use of multibeam sonar.[147] This method provides a more or less accurate relief image of the sea floor. Since some sections of the pilot area are not included in the more detailed multibeam recordings, those that were recorded in these sections were not taken into consideration. They are, however, available for more detailed research in smaller areas.[148]

There are a number of studies that can be conducted to help refine the map material for the period starting from prehistory through to the late Middle Ages. For example, the GeoTOP model discussed above contains much more information than merely a description of the upper Pleistocene strata.[149] For the Western Wadden Sea, there are also descriptions of more than 5,000 core samples available (RIJP archive), which can be used to refine the models presented here. These have not yet been included because they were only recently rediscovered. [150]

Furthermore, a focused core survey has started, based on the data analysed in this study, in order to provide information for the areas where few or no core samples have yet been taken. In this regard, Optical Stimulated Luminescence (OSL) dating may provide more insight into the Holocene sand layer. Research as part of the EU-financed MACHU project has indicated that OSL dating also works for sand that has been deposited under water.[151]

The known underwater cultural heritage resources can also provide an indication of the possible presence of other objects. The known resources in the Western Wadden Sea area are fairly limited up to the late Middle Ages; however, this does not mean that nothing has been found over the past few decades. Nevertheless, important objects with very old provenance are often found at greater depths, without context, through the process of dredging or sand and gravel mining.[152] By educating the workers in this industry and making it easier to report finds, it may be possible to gain a better insight into the occurrence of prehistoric artefacts such as hand axes or frames from late medieval ships.[153]

There are also several studies under way that deal with the spatial structure and use of maritime cultural landscapes in prehistory, the Roman era and the early Middle Ages.[154] These studies will certainly result in new insights that can lead to a better understanding of the geological landscape and human use. Once we add more historical data to the geological models, we will gain a better understanding of the culture landscape during the various periods. The integration of historical geographic studies on land and those from a maritime perspective may also provide additional knowledge.

2.10 Conclusion

'In situ should be considered the first option' is a mantra constantly heard in cultural heritage management. What does it mean? More specifically, what does it mean for underwater cultural heritage objects? To answer this question, it is, firstly, important to look at what we mean by 'in situ' and, thus, the place of 'primary' deposition: the environment in which sites were created and can still be found. Objects are purposely or accidently left behind, although it is not always easy to determine the reasons behind distribution patterns. However, if we do, we will understand the area better from an archaeological and historical-geographical perspective. Landscapes are formed by the interaction of natural and human processes. Understanding these processes is the key to the biography of a place. With that information we can look further than merely those archaeological sites that are already discovered (the 'known resources') and take the step to predicting the chances of cultural heritage being found in other places and zones of the seabed. To do so, we need a lot of validated information as a basis with which to work. From this basis, we can add non-validated information, which can also yield a treasure of information, although this – often highly subjective – information should never be confused with data retrieved systematically by well-planned research projects.

[147] See also the Burgzand monitoring report (Brenk & Manders 2014).

[148] Since 2002, the wrecks in the Burgzand area have been monitored using high-resolution multibeam sonar on an annual basis. This research has led to many new insights about the behaviour of the sea floor in this area and around the wrecks in particular (Brenk & Manders 2014).

[149] The upper 50 m. The entire area is divided into cuboids of 50 m x 50 m wide and 50 cm thick.

[150] The analogue core descriptions from the archive of RWS in Harlingen (the RIJP archive) are currently being validated by Deltares and will then be added to the DINO database.

[151] Manders, Os & Wallinga 2009.

[152] A frame of a clinker-built vessel was identified at the Wreck Museum (Wrakkenmuseum) on Terschelling, which dendrochronological dating placed in the fourteenth century (after 1321 AD). It was found many years ago at a great depth (under the sand) by a sand dredger. The exact position it lay in is not known. RING 2009.

[153] A start was made with the publication of the pamphlet, 'Herkennen van archeologische vondsten uit waterbodems' ('Recognizing archaeological finds from water beds'), which was a collaboration between the RCE and RWS (Houkes & Caspers 2013).

[154] See, for example, Jansma et al. 2014 and Lanen (2015 (1) and (2)).

Seabeds are often very dynamic, especially in the Netherlands. A constant flow of natural processes that shape the seabed as well as human action that has significantly adapted the area have been ongoing for centuries. This high level dynamic was the reason why the Dutch waters were initially not included in the predictive mapping (IKAW), while later attempts did not have reliable outcomes. It was for this reason that a project to develop a more dynamic map began (4D: x, y, z and time). After initially focusing on creating an Indicative Map for the Western Wadden Sea, another direction was taken. This was not only to avoid assuming the responsibility of the municipalities, but also to focus on providing maps that offered an insight into the quality and quantity of heritage in the area.

This led to the birth of the Historical Geomorphological Map Set (HGMS). Some of the data sets necessary for establishing the HGMS were readily available, requiring no additional editing, while others required long searches and intensive editing to make them suitable for use. The project has, subsequently, been able to include data that had not been available until recently, and even to produce new data, primarily by combining different data sets. The map set can serve as a foundation for the drawing up of policy maps by municipalities and provinces. However, it can also be used to answer academic research questions.

The Historical Geomorphological Map Set consists of three groups of maps. The first group is made up of maps that were created using objective measurement data. The second is made up of combinations of maps from the first group. The third group of maps provides insight into human activity and land use in the area – including the maritime landscape – in the various historical periods. Hopefully, these maps and the accompanying acquisition of new knowledge will complement the map set that is available in the MACHU GIS, and also as a package that can be downloaded for use in internal systems. Their use will further improve our knowledge of the Western Wadden Sea area.

However, expert judgement will still be required, in addition to the data sets collected. Insight into what has happened in the past can only be gained through a combination of quantifiable data, current knowledge about a specific area and/or a specific period, logical reasoning and historical interpretation. This combination of data and specific expertise can aid in predicting the likelihood of finding heritage buried in the floor of the Western Wadden Sea. Systematic processing of the data and the clear separation of systematic (or 'objective') and incidental ('subjective') observations will help to identify the gaps in our knowledge. These gaps can then be distilled into fundamental research questions and added to national and international research agendas.

Setting priorities is an essential element in the management of underwater cultural heritage. Where can the sea floor be disturbed without damaging the historical and archaeological record? Which heritage is sufficiently important to be preserved and protected, and which is not? Where is active management necessary to preserve heritage, and where is this unnecessary due to the lack of threats? Choices will have to be made based on 'hard' numbers and 'soft' impressions. The data provided will offer the ammunition for well-founded mitigation strategies aiming to preserve our underwater cultural heritage.

To conclude, the Historical Geomorphological Map Set for the Wadden Sea is a product that is intended to help policymakers and other parties in the field of cultural heritage management. The method improves the decision-making process pertaining to the management of underwater cultural heritage. In doing so, it complements the methods used in desktop studies.[155] By giving the system a modular structure based on sound theory and method, the system can be expanded (for management and scientific reasons) and made more precise without having to replace it. Due to its structure, it does require some expert judgement, primarily when new data sets are added and when policy or value maps are produced.[156]

The Historical Geomorphological Map Set for the Wadden Sea, moreover, can also serve as a sound basis for academic research, since each data set has been validated and summarized, taking into consideration the manner in which the data were collected, when it was collected, the original purpose of the data, the reason for the collection and the processing that the data set has undergone.

By understanding the place – by being able to read the landscape from past but also from current perspectives (including management) – we can make better use of the opportunities the area offers us in terms its archaeological, historical and cultural resources. We will then also be better equipped and better prepared to mitigate against threats caused by changes.

[155] http://www.sikb.nl/doc/archeo/Protocol%204002%20Bureauonderzoek%20 4_0_definitief.pdf (accessed 29-01-2017).

[156] This also facilitates the entrepreneurship and client-orientation that are guiding principles in the current archaeological system. After all, it allows good, expert companies to distinguish themselves from the competition.

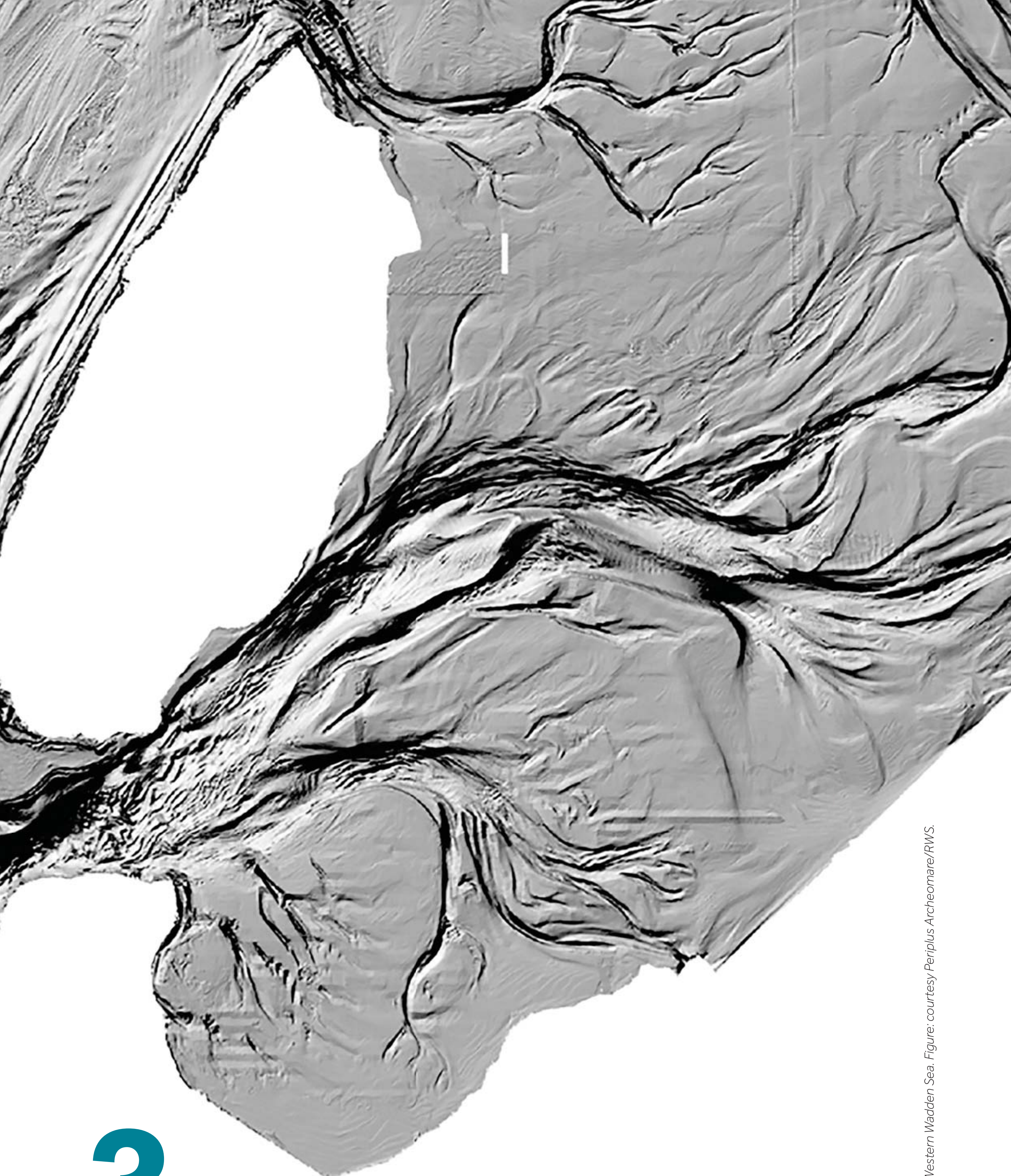


Fig. 3.1 Erosion patterns in the Western Wadden Sea. Figure: courtesy Periplus Archeomare/RWS.

3.
Threats to underwater archaeological heritage

3. Threats to underwater archaeological heritage

3.1 Introduction

The preceding chapter focused on the maritime landscape and the possible presence of cultural heritage in the Wadden Sea area. This chapter will discuss a more negative issue: the threats to underwater cultural heritage (UCH) in the area, more specifically, in the Western Wadden Sea. Threats to UCH can have different causes and can also concern different values of sites. For example, something or some process may threaten the integrity of an entire site or only the condition of a specific material. Threats are always connected to the loss of information and consequently potential knowledge. Thus, an assessment of sites in terms of threats must self-evidently have consequences for future management decisions.

Legislative protection is an important part of an overall management strategy. It defines the 'playing field' within which we must make our moves.[1] Legislation also constitutes a form of protection against cultural and industrial threats to a site, but in many cases it is not sufficient. Natural processes (mechanical, biological and chemical) may continue to occur and, therefore, a scientific understanding of the deterioration processes of sites is required to determine how best to preserve them in situ. Thus, we need to understand the environment of underwater cultural heritage and the threats, whether short or long term, that the environment poses to the present and future preservation of that heritage.

When we look into the question of what is threatening our underwater cultural heritage, we see a combination of many processes that often influence each other. In the first instance, we can mention many different threats to heritage objects under water, but what exact impact they have is not always immediately clear. What is the real cause of the threat? Is it a local – site specific – phenomenon or does it have a regional or even supra-regional effect? How long has it been a problem? What is it threatening? The integrity of the site? The condition of the materials? These questions need to be addressed prior to mitigating against them. We need to be able to refer to the effect of the threat on the future of the site.[2]

Previously, we have focused on landscapes and the relationship of individual sites to the landscape. Threats to underwater cultural heritage often have a regional character. They have implications for more than just the site with which we may be dealing. The extent of this surrounding environment is not always immediately clear, but must be considered. Changes (and thus threats) may occur on a micro-level, such as wreck parts being exposed due to illegal excavation, or chemical processes threatening a site due to contact between metals and the oxygen-rich environment, which causes corrosion. On a larger scale, however, erosion of the seabed may occur, triggering many forms of deterioration due to a changing environment. The underwater environment causes wood to deteriorate, leading to alterations in its properties. These changes occur at a cellular level due to hydrolysis, bacterial and fungal attack, and on a macroscopic level due to wood borers. This attack not only causes degradation and weight loss, but also physical damage to the archaeological material (and therefore loss of information) and loss of mechanical strength.

It is important to investigate the environmental parameters of a shipwreck site, as conditions will directly influence the state of preservation of archaeological materials. Parameters may vary within an individual site and, as a consequence, different levels of deterioration may occur on that particular site. When looking at natural deterioration processes we can make a distinction between processes within the seabed and those above the seabed sediment in open water. The factors affecting different materials in the marine environment vary depending upon whether they are exposed to seawater and oxygen or buried within sediments in an anoxic environment. In open seawater (above the seabed), mechanical and biological processes are the major causes of deterioration of wooden and organic materials. Chemical processes can also influence the corrosion of iron. This again may influence the condition of the surrounding wood.[3] Human activity can also cause serious damage. Within the seabed, the main agents of deterioration are microbial and chemical.

The various deterioration processes also interact. Microbial softening of wood may be followed by more severe abrasion due to sediment transport on the seabed in areas with strong currents. The biological weakening of timbers may also be followed by physical damage due to human impact and vice versa.

In this chapter the major causes of deterioration will be briefly described. The focus will be on the processes that have been recorded in the Western Wadden Sea. Since the early 1980s, when professional underwater archaeology in the Netherlands began, the government, through various departments, has been archaeologically involved in wreck sites in this area.[4] From the

[1] Manders 2015 (1). This defined playing field, with its boundaries formed by laws, needs to be objectively determined, with law enforcement agencies as referees. It should be recognized by all stakeholders, whether they are in favour of the preservation of underwater cultural heritage or not.

[2] Only when we know why it is important to preserve a site (its significance) and also what processes are threatening it, are we able to mitigate in the best way.

[3] We might think of iron-hulled ships, but certainly also of wooden ships and their iron fastenings, cannons and anchors.

[4] Only when we know why it is important to preserve a site (its significance) and also what processes are threatening it, are we able to mitigate in the best way.

early 2000s onwards, specific tests were performed to record the processes of degradation on the Burgzand[5] and a few specific sites within this area. Much of the information below comes from these tests and was collected during European projects: the MoSS project,[6] BACPOLES project,[7] MACHU project,[8] WreckProtect project[9] and SASMAP project.[10]

Section 3.2 deals with mechanical deterioration on the site and regional scales. Section 3.3 looks at erosion-sedimentation on individual wreck sites, while in Section 3.4 some conclusions about the seabed morphology based on the previous sections will be presented. Section 3.5 examines the biological deterioration of archaeological sites, and wooden shipwrecks in particular, while Section 3.6 considers chemical processes that pose a threat to the sites. Section 3.7 is concerned with threats from human activities in the water, both above and within the seabed, with a focus on the Western Wadden Sea.

3.2 Mechanical deterioration

Chapter 2 discussed the geomorphological changes in the study area through time, with the timelines of active change combining to offer a history of the area. However, changes also pose threats. When a wooden ship sinks, it may come to rest on or in the seabed. Subsequently, post-depositional processes form the site.[11] In many instances the marine environment is very dynamic, and physical processes around shipwreck sites, such as scour and sediment movement, are potentially the most damaging, as they can destabilize and uncover a site, leading to the rapid loss of archaeological material. At the same time, erosion that leads to the uncovering of a site may consequently result in it being discovered. On the positive side, this discovery may result in more information about the past, but on the negative side it may also result in a more rapid degradation of objects, whether the site is discovered or not. If not mechanically torn apart or washed away, the next danger will be colonization by a variety of biological organisms, chemical reactions such as corrosion, or the looting of the site.

There are several mechanisms that may lead to the deterioration of the underwater heritage. A more detailed understanding of these mechanisms is important for developing strategies for in situ preservation.

3.2.1 Currents

We can distinguish different types of currents. In seawater, currents may be caused by tidal movement, by wind or be driven by thermohaline circulation.[12] In rivers, currents are caused by gravity. Currents can influence the stability of a site and, due to their transport by currents, sand particles can have an abrasive effect on all objects protruding from the seabed. This occurs even at low current speeds; however, the faster the current, the heavier (and larger) the particles that can be displaced. Wood may have already lost its sturdiness through biological deterioration and thus may become more susceptible to the abrasive action of currents. This sanding effect not only weakens wooden structures but destroys all the details on the surface of the object, which may be vital for an understanding of the former manufacturing and use of the object.[13]

The effects of currents can be seen at different spatial scales. On a large scale, sea currents can have an enormous impact on archaeological heritage in general; that is, on both the known and unknown resources. Currents have the ability to change the seabed topography, which in turn may change the characteristics of an area and physically uncover sites. Change in the large-scale characteristics of an area may even – in extreme cases – cause discontinuity in the attachment of its inhabitants to that landscape or seascape. This may (or may not), in the long run, lead to a regional detachment in the appreciation of maritime features.[14] The physical change of the seabed topography may also lead to different behaviour in existing currents until a new equilibrium is established.[15]

The erosion of the seabed caused by currents is an enormous threat to underwater cultural heritage due to the fact that it literally exposes the resource to other deterioration processes.

[5] We might think of iron-hulled ships, but certainly also of wooden ships and their iron fastenings, cannons and anchors.

[6] MoSS: Monitoring, Safeguarding and Visualizing North-European Shipwreck Sites: Common European Underwater Cultural Heritage – Challenges for Cultural Resource Management (2002–2004). Financed through the EU Culture 2000 programme.

[7] BACPOLES: Preserving cultural heritage by preventing bacterial decay in foundation poles and archaeological sites (2002–2005). Financed through the EU 5th Framework programme.

[8] MACHU: Managing Cultural Heritage Underwater (2006–2009). Financed through the EU Culture 2000 programme.

[9] WreckProtect: Decay and protection of archaeological wooden wrecks (2009–2011). Financed through the EU 7th Framework programme.

[10] SASMAP. Development of tools and techniques to Survey, Assess, Stabilise, Monitor and Preserve underwater archaeological sites (2012–2015). Financed through the EU 7th Framework programme.

[11] Muckelroy 1978, Ward et al. 1999, Gibbs 2006.

[12] Vellinga & Wood 2008.

[13] Huisman (ed.) 2009 (1), 19.

[14] This especially counts for those who have made a transition from a sea-bordering area to an area far from the coast. When new means of living are introduced that have no connection with the use of water, this detachment is even more rapid. In some way, the cities around the former Zuiderzee, which is now closed off from the Wadden Sea, have made that change. The effect is even more visible on the east side, where the coast has been blocked by the Flevopolders. Kuinre, an early modern small Zuiderzee fishing village in the northeast is now completely disconnected from the sea.

[15] See, for example, Dongfeng 2008, or Wang et al. 2013, 163–164, Kragtwijk et al. 2004.

Fig. 3.2 The Afsluitdijk, which closed off the Ijsselmeer and the Markermeer from the Wadden Sea. Photo: RCE.

Not coincidently, most underwater sites have been discovered in highly dynamic areas in the Netherlands, such as the Wadden Sea, the coastal zones and the Delta area of Zeeland.[16] Some sites have clearly been discovered not long after being uncovered,[17] some after having been exposed for quite a while.[18]

Not only natural but also human interference may be the cause of extreme current changes. Examples include all efforts to control the water by building dikes, bridges, dredging and other ways of shaping the landscape. Ultimately, climate change – either caused by humanity or nature – may also cause new currents to flow, or flow in different directions, gain strength or disappear.[19]

The Wadden Sea is under the influence of currents caused by tidal movement. This movement causes an asymmetrical tidal current.[20] The maximum High Water (HW) is approximately +1 metre,[21] while the maximum Low Water (LW) is more or less -1 metre.[22] This means a two metre difference. This is not much compared to other areas in the world and even Europe.[23] The maximum difference in the Netherlands is approximately 4 metres.[24] The maximum current speed in the western part of the Wadden Sea is 4 knots near the entrances to the North Sea and less further inshore and on the shallow banks.[25] The higher the current speed, the more sand and the larger the particles that may be transported by the water, causing more erosion and abrasion on site.

Since 2002, the Burgzand area in the Wadden Sea has been the subject of systematic, large-scale (1200 m x 600 m) and site-specific monitoring.[26] This research area is situated 6 km from the harbour of Oudeschild. Fifteen historic shipwrecks have been located within the area.[27] The Burgzand area will be the main focus of discussion in this chapter (and in fact the thesis). It is by far the best researched and monitored underwater area in the Netherlands and all activities executed for the above-mentioned European projects have been undertaken in this area. The individual wrecks of the Burgzand area will be described in Section 3.3.

Investigations on the dynamics of the Holocene sediment layer in the Western Wadden Sea, with its core consisting of the Burgzand area through time, comparing historical navigation maps, coring and 'recent' sounding data have revealed enormous dynamics, causing shipwrecks to be covered by sediment quickly, but also eroding and exposing the sites to a range of deterioration processes (see also Chapter 2). This area of the Wadden Sea was probably subject to tidal currents long before it became a navigable inner sea in the twelfth century, especially due to a large channel running north-south that is already visible in the data on the Roman period.[28] However, the dynamics that the Western Wadden Sea is now subject to, are not so old. This is largely due to the building of the Balgzand dike in 1924 and the Afsluitdijk in 1932. Before these dikes were built, at high tide, water could flow into the Zuiderzee Basin through the Wieringen Vlaak and Friese

[16] Os & Kosian 2011, 61.

[17] The BZN 10 wreck is such an example. Here Iberian jars with baskets and large parts of the rigging, including rope, were surfacing the seabed. These objects would have deteriorated if the site had been uncovered for a long period of time.

[18] One example is the *Baron Van Pallandt van Rozendaal* (1867, toponym: Texelstroom T20), Koeveringe et al., 2011, 55.

[19] Winton et al. 2013.

[20] Astley 2016, 110–111.

[21] The predictions for Oudeschild (Texel) were + 100 cm on 28, 29 September 2015.

[22] The prediction for Oudeschild Texel was -117 cm for 23 March 2015.

[23] The world maximum is in the Bay of Fundy, Canada, with mean highest differences of 16.3 metres (http://oceanservice.noaa.gov/facts/highesttide.html, accessed 29-01-2017). The European maximum is Saint Malo in France, with a difference of around 12 metres.

[24] In Vlissingen, the difference between low and high tide can be over 4 metres.

[25] http://www.rijkswaterstaat.nl/water/waterdata_waterberichtgeving/watergegevens/ (accessed 29-01-2017). The spring flood tidal peak is a maximum of 1.3 m/s, while the ebb tides are 1.2 m/s, Astley 2016, 139.

[26] Brenk & Manders 2014. See also Chapter 2 and 6.

[27] National historic monument AMK no. 15660.

[28] See Fig. 3.7.

Fig. 3.3 Sluice gates in the Afsluitdijk. Photo courtesy RCE.

Vlaak, thus water with suspended sediment could flow deep into the Zuiderzee, depositing the smallest particles of sediment on the seabed furthest away from the North Sea inlet.[29] Now, water is pushed through the narrow influxes such as Marsdiep with greater force, but cannot flow further due to the Afsluitdijk (Fig. 3.2).[30] In the Western Wadden Sea, the tidal range also changed by 0.5 metres between 1926–1933 (8 years), probably caused by the construction of the two dikes. This tidal increase led to the destabilization and shifting of sandbanks, which is still causing the threat of exposure 90 years. In comparison, between 1933 and 2003 the tidal change was 0.1 metres.[31]

The Texelstroom gully is moving in a southerly direction and the Scheer gully is deepening and extending.[32] This change is causing shipwrecks that have been under a layer of sediment for centuries to be exposed again. This has probably also caused further erosion of the seabed in the Burgzand area, although this relationship is not indisputable.[33] A comparison with historical data and consequent monitoring since 2002 certainly reveals a deepening of the average seabed depth from 3.60 m below NAP in the 1852–1857 period to 9.59 m in the 2003–2008 period. This considerable change in seabed depth has obviously caused the severe degradation of many individual shipwrecks[34] and this process of deepening will temporarily continue.[35] However, some of the erosion may have already begun before the building of the Afsluitdijk.[36] The outlet capacities of the sluices in the dike form another threat to cultural heritage located as far as 1 km from the dike, directly north of the outlets, as a direct effect of heavy erosion of the seabed (Fig. 3.3).[37]

Another negative effect of currents on cultural heritage is that they can bring a constant flow of 'fresh' water into the area, introducing new degrading species,[38] chemicals, dissolved oxygen or, for example, more or less salinity. By definition, this has a negative effect on the stability of the environment, and stability is what is needed for in-situ preservation of archaeological sites.[39] During the research executed under the MoSS project, some parameters in open water and in the sediments were established with a data logger (Fig. 3.4).[40] The salinity recorded on the BZN 10 site – situated in the centre of the Burgzand area – fluctuated in that period between 12 and 33 PSU.[41] Although 12 PSU seems to be too low, more or less the same values were

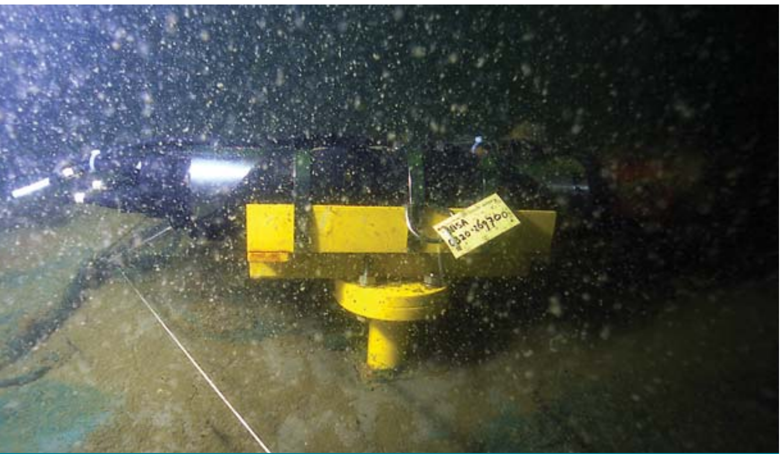


Fig. 3.4 Data logger on the BZN 10 site. Photo R. Obst/RCE.

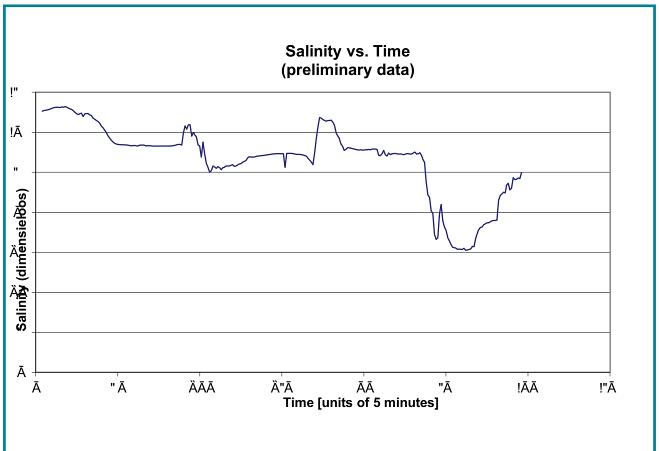


Fig. 3.5 Graphic: Salinity vs Time on the BZN 15 wreck. Figure: courtesy RCE.

[29] See, for example, Oost 1995, 77.

[30] Ibid.

[31] Astley 2016, 137–139.

[32] Brenk & Manders 2014.

[33] Changes in gully patterns have always occurred in the Wadden Sea. See, for example, the differences in the historic maps in Chapter 1. With respect to the Burgzand area, this is a much smaller but central part of the Western Wadden Sea.

[34] We may not have seen some of these wrecks before they disappeared.

[35] According to Wang et al. (2012, 42), since 1927 and until 2010, each year, 7,000,000 cubic metres of sediment has been deposited in the total Western Wadden Sea area.

[36] See Fig 3.7.

[37] The 'De Nieuwe Afsluitdijk' (-2020) project has the aim to prepare the dikes for maximum storm events occurring once every 10,000 years. This reinforcement of the dike will also be accompanied by extra capacity for the sluices (more outgoing capacity), tidal sluices to generate energy and the development of nature and tourism. What the implications will be for underwater cultural heritage is not yet clear but needs to be part of the archaeological/cultural heritage assessment.

[38] Including invasive species.

[39] Although salinity is an important parameter for the existence of the shipworm. See Section 3.5.

[40] The WaterWatch 2681 data logger was fabricated by the English manufacturer EauxSys Ltd. The data collected in the open water concerned: temperature (in Celsius), depth (in metres), salinity (in Parts per Unit, PSU), turbidity (Nephelometric Turbidity Units, NTU), dissolved oxygen (mg/L). In the sediment: Redox potential (millivolts) and acidity/basicity (pH), Gregory 2004 (3), 40.

measured at the BZN 15 site (Fig. 3.5). Recent research has revealed that salinity fluctuates in the Western Wadden Sea. It is also tending to become less saline due to climate change, combined with an increase in fresh water discharging from the rivers, to the extent that the salinity fluctuations in the water column have become stronger.[42]

The currents may also have an effect at the micro-level. Negative effects concern turbulence or eddy dynamics, which develop around objects in the seabed.[43] These local currents create scour and will wash away the protective seabed sediments, dislocate the coherence of the archaeological layers and potentially expose more of the object (Fig. 3.6).[44] Consequently, this will lead to further threats from other deterioration processes, including attack by *Teredo navalis*, fungi, bacteria and human interference, for example, by looting or fishing. These currents can therefore be responsible for loss of integrity of the site, but also loss of information about individual items.

Much research has been done on the local erosion patterns around obstacles on the seabed, such as shipwrecks, but also windfarms.[45] During the MoSS project, on-site turbidity measurements were taken at different wreck sites.[46] Turbidity refers to how clean (amounts of particles) the water is: the greater the amount of total suspended solids (TSS) in the water, the murkier it appears and the higher the measured turbidity. High turbidity may be an indication of the amount of suspended sediment in the water and thus sediment transport.[47] The data logger was deployed at five sites on the Burgzand, BZN 3, BZN 4, BZN 10, BZN 11, and BZN 15. It was also deployed more than once (seven times) on the BZN 10 site.[48] Fluctuations can be seen, as can a strong correlation between the tidal cycles and when the sediment transport is at its highest. The sediment loading within the water column increases in the last phase of the ebb tide and then drops off significantly with the flood tide, only to be repeated with the next tidal cycle.[49] The data logger showed that the Burgzand area is very dynamic, with sediment movement correlated with the tidal movement and being at its highest point in the last phase of the ebb tide.

The data logger was also equipped with a Sediment Layer Device. This was an experimental design developed by EauxSys Ltd, using an acoustic attenuation method also used for sludge density measurement.[50] The change in strength of the acoustic signal indicates the relative amounts of sediment being deposited between the transducer and the receiver. This apparatus became available for use in testing on the BZN 10 site at the end of the MoSS project. It functioned, therefore, only for a short period of time in late 2003 and was also heavily damaged after deployment. It has not been reinstalled.[51]

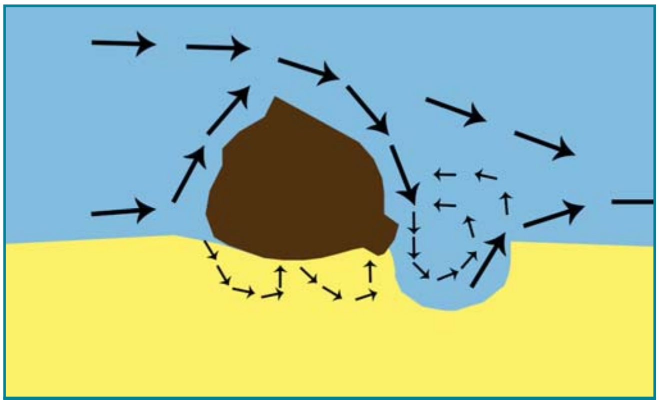


Fig. 3.6 Eddy currents cause local scouring on shipwreck sites.

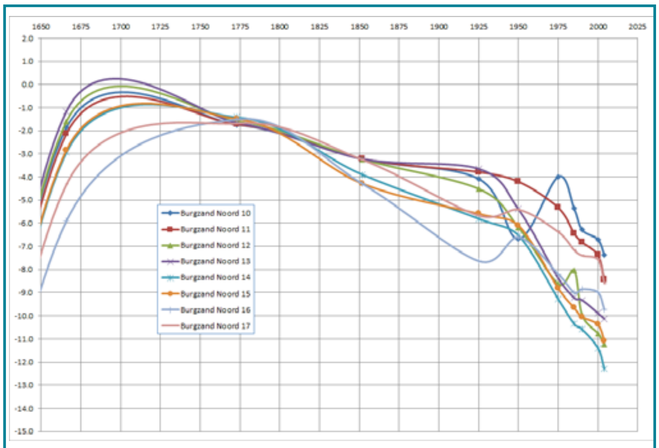


Fig. 3.7 Depth of the seabed through time on specific BZN wreck locations. Figure: courtesy Periplus Archeomare/RCE.

Regular multibeam recordings of the seabed surface around several shipwreck locations in the Burgzand area from 2002 onwards has given us much information about the processes of erosion and sedimentation round shipwrecks.[52] The comparison of older sounding data from historic maps has given us an indication of when sites have emerged from the seabed and when the open water environment must have started to threaten the sites See Fig 3.7. For the analytic results, see Section 3.3).

[41] Gregory 2004 (2), 46–47. The reason for the strong fluctuation may partly be due to fouling of the conductivity sensor; however, the profiles also indicate that another reason may be the tidal influence, bringing fresh water to the site.

[42] http://www.wadgids.nl/wadgidsenweb/index.php/waddenzee2007-2012/4-zout-gehalte.html (accessed 29-01-2017). See also Aken 2008 and Duran-Matute et al. 2014. Aken 2008 mentions a difference between 22 and 32.5 PSU. This is still significant and is caused by tidal movements and the influx of fresh water from the Rhine and especially the IJsselmeer.

[43] Quinn 2006.

[44] See also Smyth & Quinn 2014.

[45] Ibid, Whitehouse et al. 2011.

[46] Gregory 2004 (3), 38–39.

[47] Gregory 2004 (3), 39.

[48] Of which it was able to record data six times. See Table 6.1.

[49] Gregory 2004 (3), 46–47.

[50] Gregory 2004 (3), 40.

[51] An overlay between depth data and the sediment layer device that was recorded does not show a strong correlation.

[52] Manders 2009 (2).

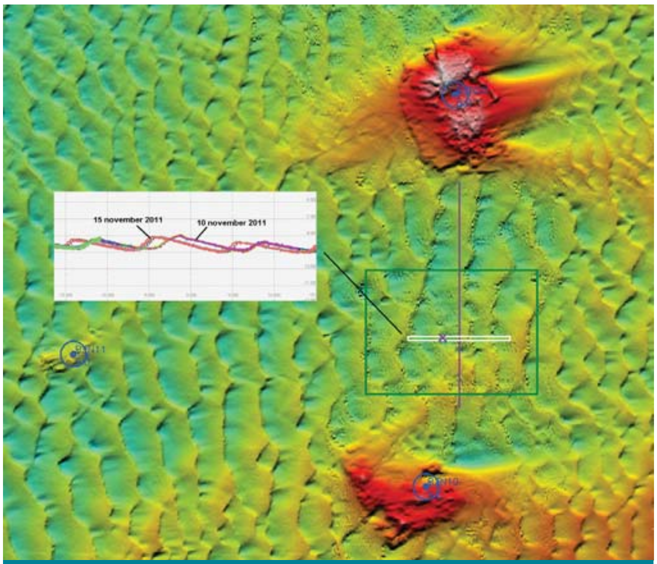


Fig. 3.8 Two multibeam recordings executed only 5 days apart (10 and 15 November 2011) revealed the movement of large sand ripples on the seabed near the BZN 3 wreck. Figure: courtesy Periplus Archeomare.

3.2.2 Swell and waves

Swell or waves, which have a certain length, may also threaten underwater sites. The energy of their motion also works downward to the extent of half the distance of the wave length.[53] A storm creates waves that compels the water onto the site and can easily stir up the seabed to a depth of 20 metres.[54] The consequences can be drastic for fragile materials such as waterlogged wood. More importantly, however, is that such a surge may expose objects in protective sediments, stir up the site and even redistribute the objects. Uncovered archaeological remains are even more vulnerable to other causes of deterioration, such as the *Teredo navalis*.

The destructive effect of seasonal storm surges has been examined at archaeological sites throughout the world.[55] The shallow Markermeer and IJsselmeer (part of the former Zuiderzee) are especially vulnerable to wave erosion.[56] However, the Wadden Sea and the coastal zones of the North Sea are also vulnerable to storm induced waves.[57] Shipwrecks are often located in shallower areas, as the dangers of running aground were much greater there. Although no specific analytical data on the effect of waves on cultural-historical sites in the Wadden Sea seabed is available, we can assume that this may be considerable.[58] Previous research has shown that the mega-ripples that run along the Dutch North Sea coast are formed by wind waves.[59] Two multibeam recordings made shortly after one another on the BZN 10 site also revealed the movement of sand waves or ripples due to wave action (Fig. 3.8). Moreover, the patterns and the sizes of these waves changed, possibly due to a storm event.[60]

3.2.3 Surf

The surf zone, up to approximately 5 metres in depth, is a high-energy zone and thus hostile to sites.[61] The effect is similar to swell or wave action. Usually, cultural heritage located in surf zones is heavily eroded. The constant waves cause protective sediment to disappear and sediment with larger grains to be more abrasive. In the Western Wadden Sea, no examples of such degradation are known of at this moment; however, the effects of strong erosion have been noted in many other parts of the world. Examples are the wreck of the *Avondster* in Sri Lanka[62] and that of a possible Dutch shipwreck found in Portuguese waters.[63]

3.2.4 Ice

Crystallization due to freezing of the seawater may have an abrasive effect on soft and deteriorated wood surfaces of archaeological objects. When the ice becomes a dense mass, the destructive effect is even more drastic.[64] In calmer waters, the ice forms thin sheets and the rafting and build-up of these ice sheets creates an irregular surface, not only above but also under water. This ice mass can reach the seabed in shallow waters and plough the sea floor. Any archaeological remains will be literally bulldozed away. Ice can also block or reroute currents which will affect the site even more.

In the Wadden Sea, during severe winters the low temperature sometimes freezes the seawater (in normal seawater of approximately 35 ppt the freezing temperature is -1.8 ˚C).[65] When the seawater begins to freeze, 'frazil' will be formed. This is the scientific name for the formation of tiny crystals only millimetres wide. In rough waters or waters with a high current velocity, the energy and turbulence mean the new ice remains a dense suspension of frazil.[66] These miniscule ice crystals have, similarly to sand particles, an abrasive effect on archaeological remains. In 1997, the average temperature measured in the Netherlands for the whole of January was -1.2 °C,[67] and ice formed on the Wadden Sea surface.[68] While the ice floes were relatively small and had no direct effect on the cultural-historical sites on the seabed, with the minimum recorded temperature of -1 °C, frazil also formed.[69] These ice crystals move up and down

[53] http://www.waterencyclopedia.com/Tw-Z/Waves.html (accessed 29-01-2017).
[54] Gregory 2004 (2), Zeiler et al. 2008, 34.
[55] Spenneman 1998.
[56] Weij 2005.
[57] Baak 2003.
[58] Multibeam recording shows different patterns of sand waves on the BZN 10 wreck, probably caused by wave action. Two multibeam recordings within 5 days on the site also revealed that their position can change quickly, Brenk & Manders 2014, 54.
[59] VLIZ 2013, 22.
[60] Brenk & Manders 2015, 2016.
[61] Manders (ed.) 2011, 15.
[62] Parthesius (ed.) 2007, 19.
[63] Sítio Arqueológico da Praia de Belinho. União de Freguesias de Belinho e Mar – Esposende. Almeida 2014.
[64] See, for example, Red Bay State of Site report, 2011, 5.
[65] In 1947 and 1963, the seasonal (winter) average of the Wadden Sea water was even -0.5 °C. Aken 2008.
[66] Wadhams n.y.
[67] https://weerverleden.nl/199701 (accessed 29-01-2017).
[68] This ice formation is not exceptional, it has occurred more often on the Wadden Sea. See also, for example, the winters of 2010 and 2012.
[69] With seawater that had a salinity of less than 35 ppm.

the seabed and may well speed up erosion of the top sandy layer and any protruding (wooden) ship elements.

3.3 An example: erosion in the Burgzand area

Due to shallowness, tidal movements, change of gullies and wave action on the Burgzand area,[70] many wrecks are subject to continuous erosion or a changing cycle of sediment erosion processes.[71] The very high level of sedimentation facilitates anaerobic conditions, and in the exposed parts of the wrecks a high concentration of destructive organisms and fouling activities have been found. The seabed is ever changing and sites are considered unstable.[72] Between 2002 and 2014, an area of 79,800 m² in the Burgzand was monitored at regular intervals of one year.[73] In this area there are four wrecks, BZN 3, 8, 10 and 11. From 2003 to 2009, the average deepening of the seabed measured in the first test area was 53 cm, which means there had been a loss of 31,849 m³ of sediment from this area.[74] The most pronounced deepening occurred between 2004 and 2005, by approximately 50 cm in just one year.

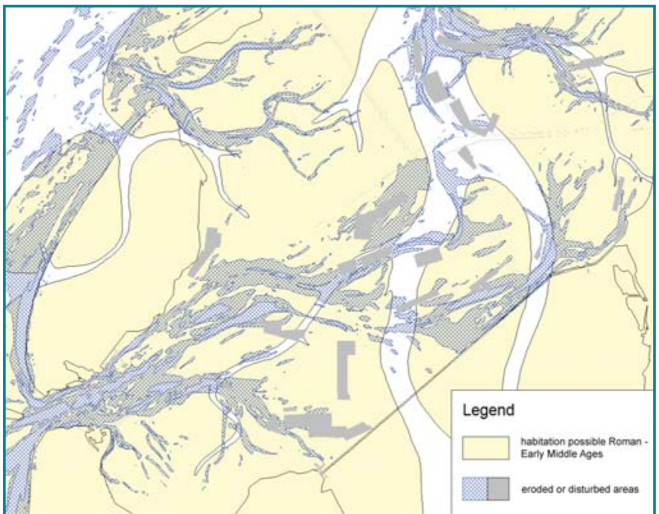


Fig. 3.9 Stable and well-preserved areas (in yellow) in the Western Wadden Sea. In blue the eroded areas. Figure: courtesy Periplus Archeomare/RCE.

In later years, the monitoring area was extended to obtain more data from more sites.[75] In this extended area, we also see the constant erosion of the seabed. Since the building of the Afsluitdijk in 1932, the area has deepened by an average of 5.1 cm per year until 2014. After correcting this number with the bottom decline (0.6 cm/y), this means annual erosion of 32.830 m³.[76]

In the case of the erosion of the Holocene seabed it is important to understand that shipwrecks do not – as previously often thought – sink into the soft sediment of the Holocene of the Wadden Sea until they reach the more compact Pleistocene layer. They may become stuck in sand layers of a much later date. This has been proven through Optical Stimulated Luminescence Dating (OSL) research, which was carried out during the MACHU project.[77] This implies that it is not sufficient to know how deep the Pleistocene layers are to ensure the good preservation of shipwrecks, as would have been suggested by the previously developed theory.[78]

Analyses of the data shows that roughly between Vogelzwin and Vaarwater naar de Cocksdorp, parts of the Lutjeswaard, Zuidoostrak and Balgzand areas remained relatively stable between 1925 and 2005.[79] The historical maps dating from 1584 to 1852 record – although in less detail – more or less the same information.[80] This means that although most areas within the Western Wadden Sea have been under the influence of ever-changing gullies and thus erosion of the Holocene and sometimes even the Pleistocene seabed, some shallow areas remained relatively stable. These places may never have been ideal for navigational purposes, but early settlements and shipwrecks that ran aground may be found here. If so, they will likely be in a relatively good state (Fig. 3.9).[81]

Cultural heritage in the eastern part of the Burgzand area and on and in Vogelzand, Scheer, Texelstroom and Scheurrak are most at risk of being exposed and degraded by erosion and subsequently other threats (Fig. 3.10).[82]

[70] With a minimum depth on the former sandbanks of just 0.5 metres and a maximum depth in the Texelstroom of 25 metres at LLW.

[71] In addition to erosion, two further processes contribute to the decrease in bed-level elevation: 1. natural gas extraction (subsiding at a rate of 3–6 mm/year); 2. large-scale geological processes (glacial rebound) also contribute to subsidence at a much lower rate of 0.2 mm/year, Astley 2016, 138. Although adding up to a larger depth, they do not seem to have as great an influence on the condition of cultural heritage on the seabed as erosion.

[72] Palma 2004 (1), 5

[73] Brenk & Manders 2014. This is the core area of the National Monument and also the area that has been monitored most.

[74] Brenk & Manders 2014.

[75] See also Chapter 6.

[76] Brenk & Manders 2014, 15.

[77] Manders et al. 2009 (1) and 2009 (2).

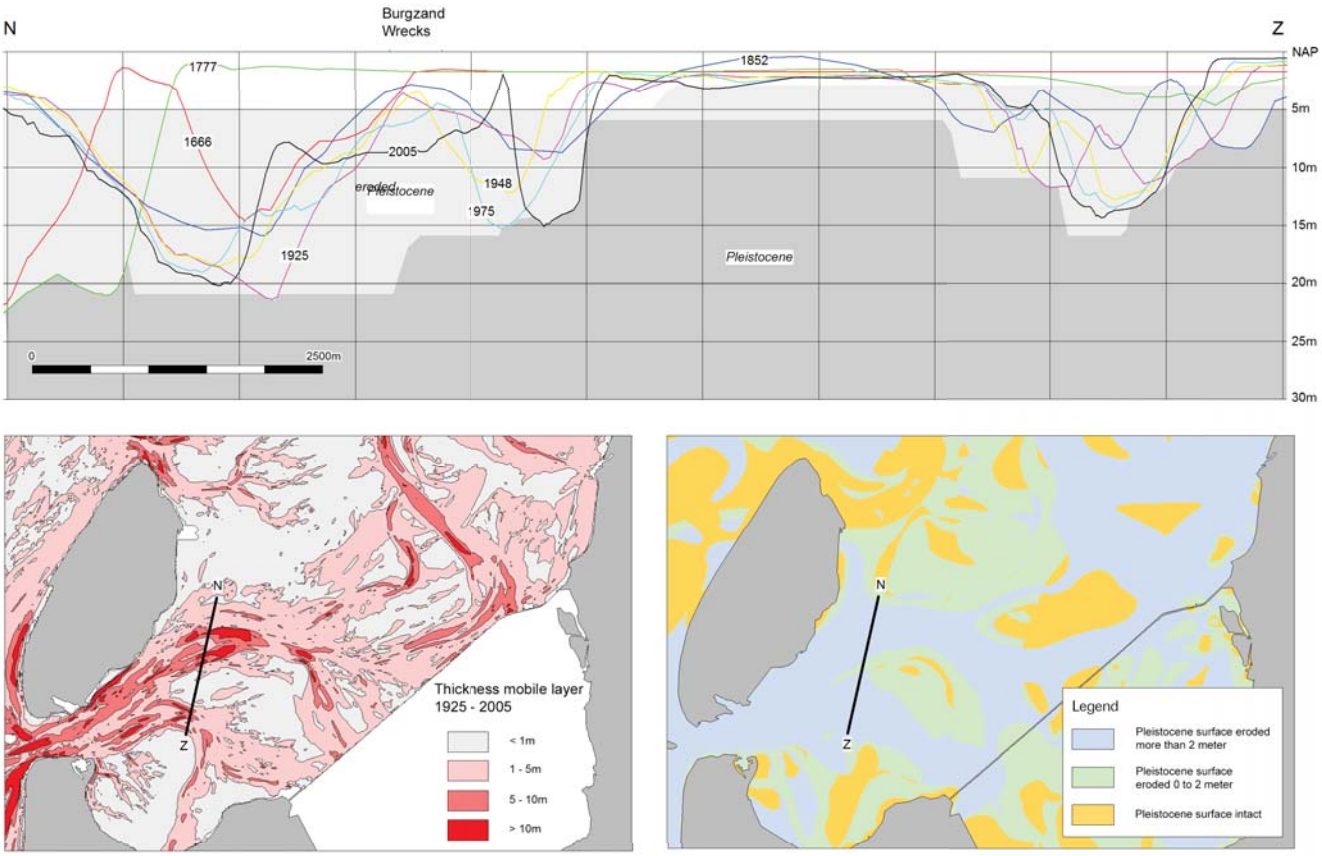
[78] Manders & Maarleveld 2006, 128.

[79] Manders et al. 2014. See also Fig.. 3.8.

[80] Manders et al. 2014, 27.

[81] See also Chapter 1.

[82] Brenk & Manders 2014, see also Brenk 2016. Analyses of the Vogelzand wrecks based on the geomorphological data not only revealed the sedimentation and erosion patterns throughout the decades, but also the erosion of the Pleistocene layer (boulder clay) after 2010, causing the area to erode to an even deeper level.



Example of a north - south profile based on digital depth models and Top Pleistocene. With the help of the supplied GIS-files, comparable profiles for the Western Wadden Sea can be generated.

Fig. 3.10 Disturbed areas due to erosion and other ground penetrating activities in the pilot area of the Western Wadden Sea. Figure: courtesy Periplus Archeomare/RCE.

Large-scale models show that the deepening or erosion of the seabed on the Burgzand is caused by the movement of the Texelstroom tidal channel towards the southeast (Fig. 3.11).[83] Therefore, the wrecks in the Burgzand area are eroding from the northwest. This process seems to have come to a halt or at least to have slowed considerably, if we look very carefully at the actual sites themselves.[84] These sites are quite stable due to the in-situ preservation that has been applied, while the ambient areas usually continue to erode.[85] However, here we can also see a decline in the speed of erosion from the northwest over recent years. This clearly shows that the erosion pattern is temporary.

In the sections below, the erosion and sedimentation patterns that have been monitored in the Burgzand area will be described for each wreck site. Physical in-situ measures on some of the wrecks have influenced the effect and patterns on site.

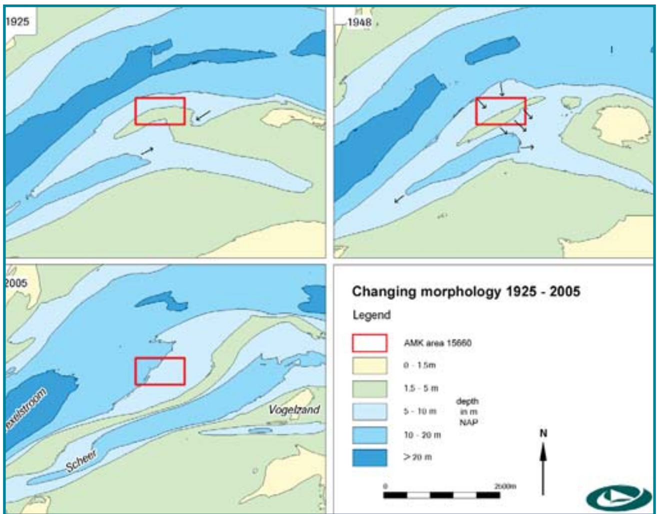


Fig. 3.11 The shifting of the Texelstroom (Texel gully) from 1925 to 2005. Figure: courtesy Periplus Archeomare/RCE.

BZN 2

The Burgzand Noord 2 (BZN 2) wreck is that of an armed seventeenth-century merchant ship loaded with scrap bronze cannons.[86] The first multibeam recordings of the site are from 2012. The recordings from 2013, 2014 and 2016 show slight sedimentation of the area. The wreck is protected – at least partly – by polypropylene nets. Divers from the Texel sports club have observed that parts of the protective nets have disappeared or been torn (Fig. 3.12), which has been repaired in 2017.

[83] Brenk & Manders 2014, 58.

[84] Brenk & Manders 2014, 58.

[85] See also Ashtley 2016.

[86] Vos 2012, 109.

BZN 3

The Burgzand Noord 3 (BZN 3) wreck is that of the East Indiaman De Rob, a VOC vessel that sank during a storm in 1640.[87] It was declared the first Dutch national underwater monument in 1991.[88] The wreck was physically protected in 1988, and this was extended in 2000, 2003 and 2013. In 2003, the site was protruding from the seabed over an area of approximately 50 metres by 50 metres. Multibeam data from 2004 to 2011 show an ongoing deepening of the surrounding area. A clear edge on the west side, from where the net protection starts, has also become visible. Some sediment had been deposited on the east side.[89] The erosion around the net continued in subsequent years, and the wreck has become largely exposed on the northwest side in particular, as well as some parts in the southern area. 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 appeared to have become separated from the main protected part. This shows that even with protection, small erosion gullies can easily form within a wreck.

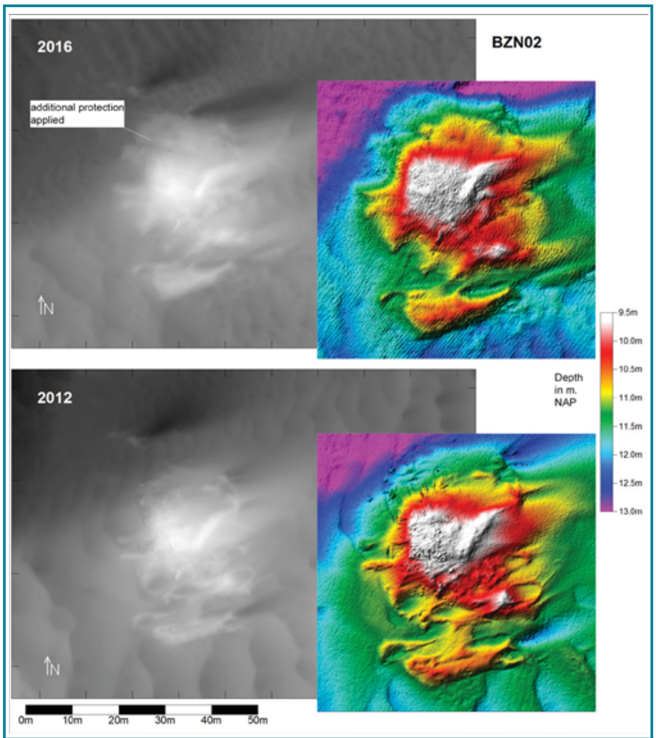


Fig. 3.12 Compilation of BZN 2 erosion-sedimentation history. Two multibeam recordings for comparison: one from 2012 and the other from 2016. Figure: courtesy Periplus Archeomare/RCE.

In 2004, the whole site seemed to have been levelled, with a great deal of sand caught in the nets. On the eastern side of the wreck mound, two to three erosion gullies started to appear, reaching a maximum depth of 2 metres in 2006.[90] Afterwards, they disappeared again and were no longer visible in 2008. 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 sides 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. In some places, small erosion pits were visible, probably due to bad connections between the strips of netting. The erosion-sedimentation erosion map produced for the period 2003–2004 clearly shows the deposition of sediment around the older protective materials from 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.[91]

The multibeam data from 2006 shows the existence of deep erosion pits on the east side of the wreck. 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 of at least 85 metres along the west side of the wreck that was visible in 2009 was probably caused by the BZN 11 wreck, which lies approximately 180 metres west of BZN 3. This shows the influence that other objects (such as other shipwrecks) can have, not only on the surrounding seabed, but also on other sites in the area.[92]

During the dives in 2013, the uncovered parts on the west side of the wreck – part of the hold – were documented and covered with polypropylene nets. The effect is clearly apparent in the multibeam data for July, immediately after the protection measures had been taken, but unfortunately the multibeam data for December of the same year shows an abnormal deepening around the anchors. This may be an indication of illegal excavation between July and December. The 2014 multibeam data shows a further deepening of the surrounding area. A comparison with historical data shows us that since 1850 the area around the wreck site has eroded by approximately 6 metres.[93] However, the protection is working. The sandbag mound that was originally used to protect the site in 1988 has remained stable throughout the entire monitoring period and the west part of the wreck has sanded in after the protective additions in 2013 (Fig. 3.13 A, B, C).[94]

[87] Vos 2012, 143.

[88] In 1991, it was registered as a National Monument under no. 361751.

[89] On the basis of the models made from the subsequent years of multibeam data.

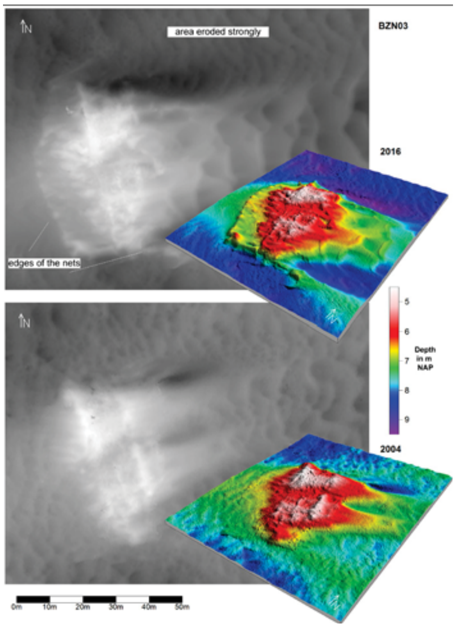
[90] Brenk & Manders, 2014, 30.

[91] Based on the subsequent multibeam recordings on site.

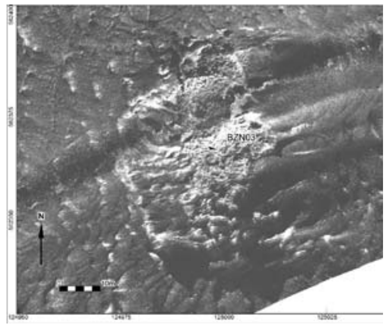
[92] Based on the multibeam recordings.

[93] Brenk & Manders 2014, 31.

[94] Brenk & Manders 2014, 30.



BZN03	Zmin	Zmed	Zmax	Zdif
2003	-11,05	-7,54	-4,53	6,5
2004	-8,92	-7,51	-4,44	4,5
2005	-10,16	-7,80	-3,78	6,4
2006	-10,82	-7,91	-4,15	6,7
2007	-10,74	-7,96	-4,50	6,2
2008	-9,41	-7,93	-4,67	4,7
2009	-9,58	-7,88	-4,64	4,9
2010	-9,32	-7,94	-4,61	4,7
2011	-9,54	-8,04	-4,63	4,9
2012	-10,18	-7,99	-4,40	5,8
2013	-9,26	-7,91	-4,59	4,7
2013	-9,47	-7,99	-4,55	4,9
2014	-9,79	-7,77	-4,55	5,2
2015	-9,89	-7,78	-4,57	5,3
2016	-14,22	-12,23	-8,76	5,5



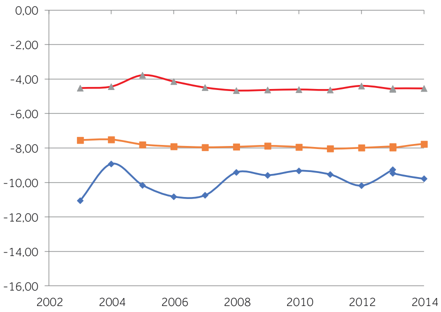
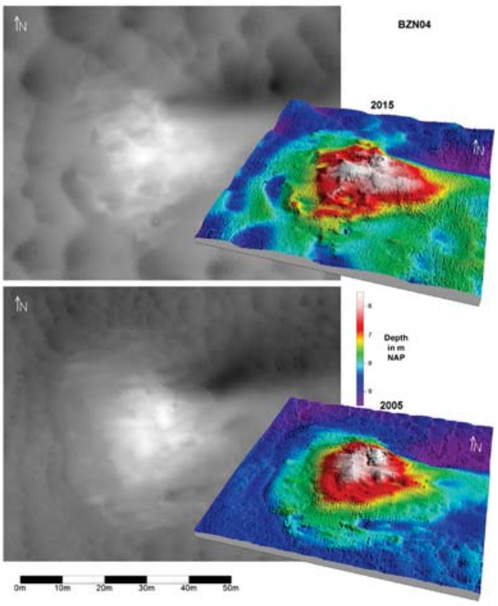


Fig. 3.13 A, B, C Compilation of BZN 3 erosion-sedimentation history. (A) Two multibeam recordings from 2004 and 2016 compared, (B) A side scan sonar image from 2016 and (C) Burial history of the site. Figures: courtesy Periplus Archeomare/RCE.

BZN 4

The Burgzand Noord 4 (BZN 4) wreck is that of a possible West Indiaman that sank in the middle of the eighteenth century. It was discovered in 1985 and after intrusive research protected in situ in 2000.[95] The site was monitored with multibeam sonar between 2005 and 2013.[96]

The morphological changes that have occurred on this site include sedimentation on the east side of the wreck after 2007 and sedimentation on the south side since 2009. Throughout the monitoring period, the wreck mound itself remained stable.[97] Since 1850, the area immediately around the site eroded by approximately 4 metres. However, in the last 10 years this process seems to have been reversed and the area has started to sedimentate (Fig. 3.14 A, B).[98]



BZN04	Zmin	Zmed	Zmax	Zdif
2003				na
2004				na
2005	-10,17	-8,50	-5,32	4,9
2006				na
2007	-10,42	-8,48	-5,09	5,3
2008	-10,37	-8,48	-5,29	5,1
2009	-10,56	-8,26	-5,20	5,4
2010	-10,03	-8,27	-5,32	4,7
2011	-10,49	-8,24	-5,24	5,3
2012	-9,80	-8,20	-5,39	4,4
2013	-9,95	-8,17	-5,14	4,8
2014	-9,83	-8,14	-5,19	4,6
2015	-10,37	-8,17	-5,22	5,1
2016	-9,61	-8,24	-5,40	4,2

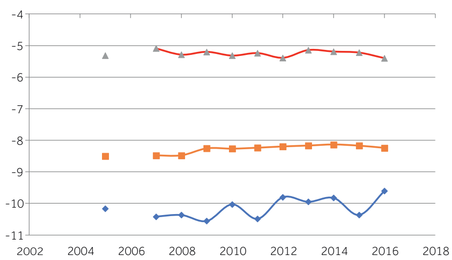


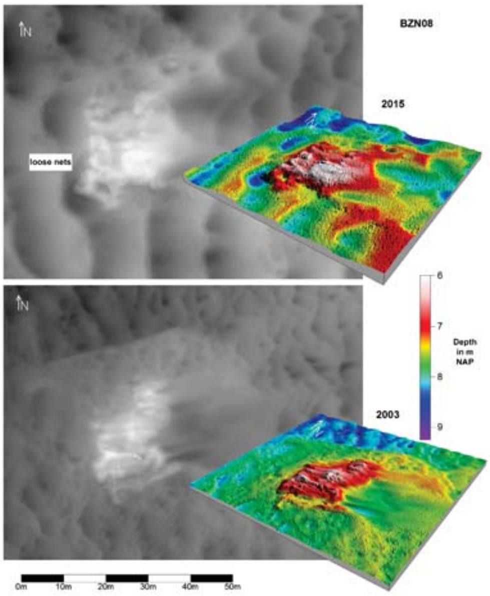
Fig. 3.14 A, B Compilation of BZN 4 erosion-sedimentation history. (A) Two multibeam recordings from 2005 and 2015 compared, (B) Burial history of the site. Figure: courtesy Periplus Archeomare/RCE.

[96] Vos 2012, 167, Kuijper & Manders 2011.

[96] Brenk & Manders 2014, 32.

[97] Brenk & Manders 2014, 32.

[98] Brenk & Manders 2014, 33.



BZN08	Zmin	Zmed	Zmax	Zdif
2003	-8,74	-7,71	-5,87	2,9
2004	-9,03	-7,83	-5,82	3,2
2005	-8,95	-8,03	-5,89	3,1
2006	-9,12	-8,02	-5,86	3,3
2007	-9,50	-8,09	-5,94	3,6
2008	-9,15	-8,09	-5,93	3,2
2009	-9,75	-8,02	-5,95	3,8
2010	-9,33	-7,99	-6,01	3,3
2011	-9,51	-7,95	-5,84	3,7
2012	-9,24	-7,92	-5,96	3,3
2013	-9,07	-7,77	-5,73	3,3
2014	-9,23	-7,69	-5,33	3,9
2015	-9,07	-7,64	-5,81	3,3
2016	-8,97	-7,79	-6,09	2,9

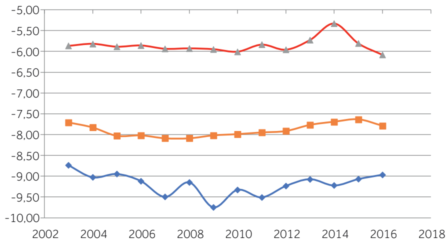


Fig. 3.15 A, B Compilation of BZN 8 erosion-sedimentation history. (A) Two multibeam recordings from 2003 and 2015 compared, (B) Burial history of the site. Figure: courtesy Periplus Archeomare/RCE.

BZN 8

Burgzand Noord 8 (BZN 8) is the wreck of a seventeenth-century armed ship. It was long thought to be the remnants of the VOC galliot De *Lelie*; however, this has turned out to be incorrect. It was discovered in 1997 and physically protected in 2003.[99] The first multibeam recording made on this site was in 2003.[100]

The wreck site is approximately 20 metres wide and 30 metres long. The maximum height differences inside and outside the wreck were 3.5 to 4 metres in 2009. At this time, on the southwest side, sharp edges had formed around the polypropylene protection nets. Before the physical protection was put in place, the stern area to the south was already the most protruding feature. Strong erosion here posed a major threat to the entire site.[101]

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 areas, some individual uncovered ship parts were being revealed and, east of the wreck mound, a large but shallow erosion pit approximately 4 by 8 metres was becoming visible in the middle of the wreck. East of the wreck mound, in the north and south regions, more sand had been deposited and two large sand ridges had formed. Especially in 2006, a lot of sand seems to have been deposited on the wreck site. On the west side, the edges of the protection nets were covered with sand. In 2008, the erosion pit in the east had deepened, and this continued in 2009. Inside the wreck, the mound was levelling out due to sediment build up.[102]

From 1850 until around 1950, the wreck area eroded by approximately 3 metres, after which sedimentation took over. However, from 1980 onwards, the area started to erode again, by another 4 metres. Since 2003, when the protection measures were put in place, the wreck mound has hardly changed, while the surrounding area has further eroded (Fig. 3.15 A, B).[103]

BZN 9

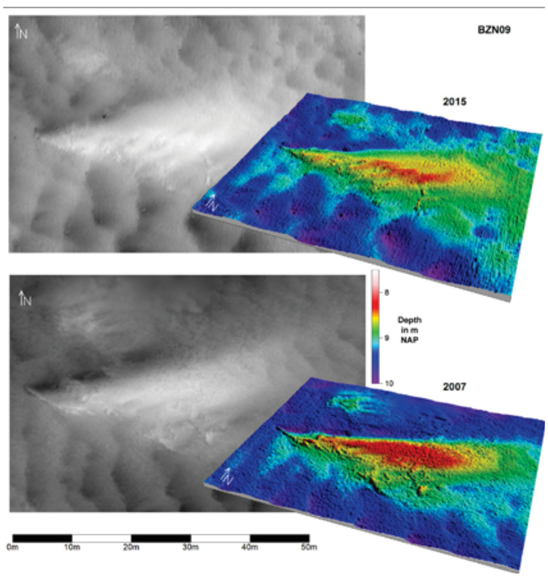
The Burgzand Noord 9 (BZN 9), a seventeenth-century armed merchantman, was recorded for the first time in 2007. The wreck was found in the 1990s and investigated in 1998.[104] The sediment layer in the wreck area eroded approximately 5 metres between 1850 and around 1985. Subsequently, the area has remained fairly stable, but from 1995 on the area began to erode yet again, by another 1.5 metres.[105] Over the last couple of years, sedimentation and erosion seem to be fluctuating irregularly, with some net sedimentation in recent years, but more pronounced individual wreck parts visible on site (Fig. 3.16 A, B).[106]

BZN 10

The Burgzand Noord 10 (BZN 10) wreck is that of a seventeenth-century trader.[107] It was discovered in the 1990s and physically protected in 2000, which was extended in 2001 to 800 m² and in 2003 to 2000 m².[108] Subsequently, the protection has been maintained, and in 2013 and 2014 a for the Netherlands new method of in-situ preservation using artificial seagrass was trialled.[109]

Multibeam recordings of the BZN 10 wreck since 2002 are available for this research (Fig. 3.17). The first recording was produced for the MoSS project and focused only on this wreck site.[110] The physical protective nets are clearly visible in the image. The site was still relatively flat, but some archaeological features were already protruding, including one 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.

[99] Vos 2012, 193.
[100] Brenk & Manders 2014, 34.
[101] Vos 2012, 198.
[102] Based on the subsequent multibeam data on the site.
[103] Brenk & Manders 2014, 35.
[104] Vos 2012, 219.
[105] Brenk & Manders 2014, 37.
[106] Brenk & Manders 2014, 36–37.
[107] See also Vos 2012, 245–264 or Holk 2003, 8–11 and Manders 2003 (1), 6–7.
[108] Brenk & Manders 2014, 38.
[109] See Coenen et al. 2013, Gregory & Manders (eds) 2016.
[110] Brenk 2003, 21, 22.



BZN09	Zmin	Zmed	Zmax	Zdif
2003				na
2004				na
2005				na
2006				na
2007	-10,03	-9,32	-8,11	1,9
2008	-10,04	-9,31	-8,00	2,0
2009	-10,17	-9,21	-7,99	2,2
2010	-10,13	-9,29	-8,27	1,9
2011	-10,20	-9,31	-7,42	2,8
2012	-10,06	-9,37	-8,19	1,9
2013	-10,27	-9,30	-8,23	2,0
2014	-10,1	-9,1	-8,2	1,9
2015	-10,18	-9,16	-8,28	1,9
2016	-10,00	-9,34	-8,31	1,7

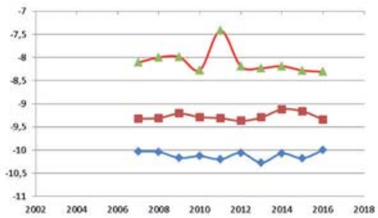


Fig. 3.16 A, B Compilation of BZN 9 erosion-sedimentation history. (A) Two multibeam recordings from 2007 and 2015 compared, (B) Burial history of the site. Figure: courtesy Periplus Archeomare/RCE.

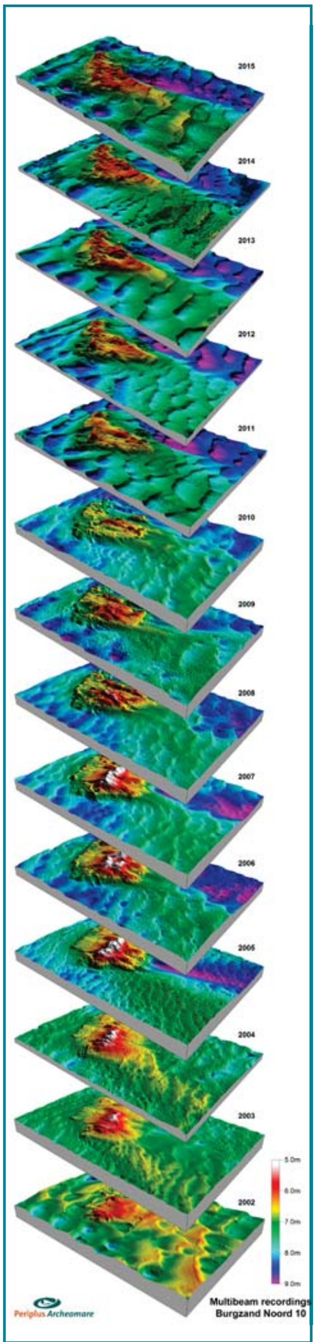
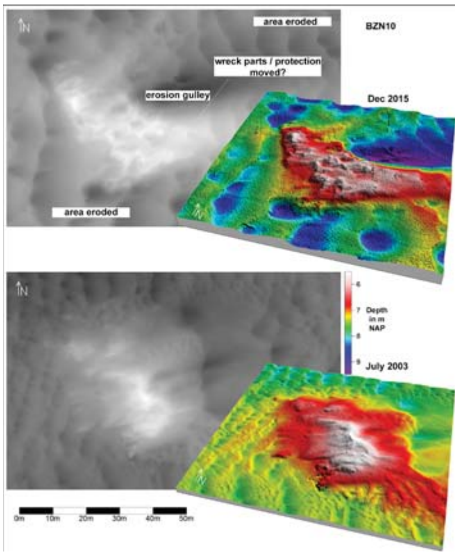


Fig. 3.17 The multibeam monitoring is possibly the longest measured sequence on a wreck site: from 2002 to 2016. Figure: courtesy Periplus Archeomare/RCE.

In 2003, after the extension of the covering, the site was 30 metres wide, with strips of netting extending another 10 metres on the east side. The length of the site was 40 metres. More sediment had settled on the wreck, covering all the archaeological material. From the west side to the middle of the wreck mound, we measured 20 metres, while 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. Even more sediment had been caught in the wreck and the sand ridge in the southeast had extended. 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 on 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 again been filled with sand. 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. Moreover, in the area around the wreck site, the seabed had deepened further and by 2007 the situation had worsened. On the north-northeast side, a strong erosion gully 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 is situated 180 metres to the west of BZN 10.

The proximity of this 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. If we take into account the fact that the physically protected part of the site has gained more sediment over that same period, the deepening has been much greater in the surrounding seabed. The most severe erosion took place in 2004–2005, with the average deepening approximately 34 cm. 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. It is striking, however, that 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 that the nets had reached their maximum extension and sand



BZN10nw	Zmin	Zmed	Zmax	Zdif
2002	-8,98	-7,02	-5,52	3,5
2003	-8,44	-7,28	-5	3,4
2004	-9,05	-7,31	-4,39	4,7
2005	-9,34	-7,7	-3,92	5,4
2006	-9,45	-7,81	-4,42	5,0
2007	-9,82	-7,92	-4,41	5,4
2008	-9,04	-7,95	-5,11	3,9
2009	-9,5	-7,89	-5,31	4,2
2010	-9,1	-7,9	-5,53	3,6
2011	-9,57	-7,88	-5,42	4,2
2012	-9,28	-7,91	-5,50	3,8
2013,5	-9,35	-7,88	-5,45	3,9
2013,9	-9,29	-7,79	-5,41	3,9
2014	-9,05	-7,68	-5,48	3,6
2015	-10,00	-7,65	-5,40	4,6
2016	-9,61	-7,64	-5,47	4,1

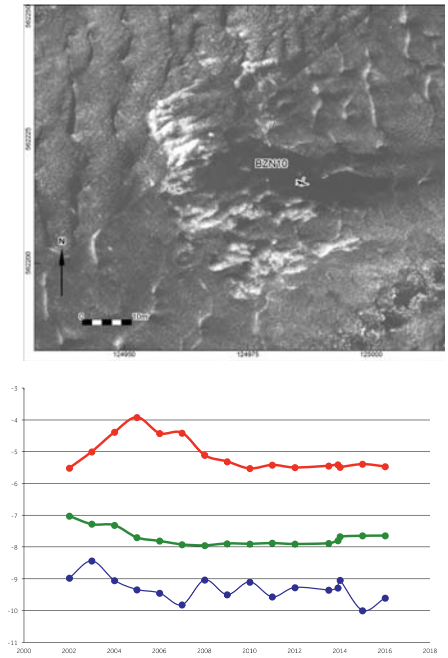


Fig. 3.18 A, B, C Compilation of BZN 10 erosion-sedimentation history. (A) Two multibeam recordings from 2003 and 2015 compared, (B) A side scan sonar image of the BZN 10 wreck site from 2016, (C) Burial history of the wreck site. Figure: courtesy Periplus Archeomare/RCE.

started to flow out from under the protective nets in some areas. From 2010 onwards, gullies started to form on top of the protective nets.[111]

In 2013, the wreck was used as a test location for the European SASMAP project, 'Development of tools and techniques to Survey, Assess, Stabilise, Monitor and Preserve underwater archaeological sites'.[112] As the name suggests, this project was developing all sort of tools for archaeological heritage management under water. Part of this is the development and trial of artificial seagrass as a method to preserve shipwrecks. On the southwest side of the wreck, four mats were initially installed in 2013. They were not only designed to function as protection for what lies underneath them, but also to protect the polypropylene net edges, which are vulnerable to underscouring, and for additional sand catching. In the first instance, this has worked remarkably well.[113] Sand has been deposited in between the fronds of the mats as well as immediately before and after, thereby protecting the edges of the nets. The fronds also slow down the current but do not form a hard edge. Therefore, sedimentation proceeds more gradually.[114] On this basis, in 2014, another four mats were installed in the mid-east section, on the edge of an impression that had formed due to erosion.[115] In 2015, it was observed that the sandbags holding the artificial seagrass mats down on the site had been underscoured. However, it may in the future be possible to fix this by installing the mats using a different technique.

The wreck was recorded twice by multibeam in 2013, immediately after the installation of the first four artificial seagrass mats in July that year and again in December. This gives us a unique opportunity to compare the seabed morphology and effectiveness of the mats over a short period of time. The seabed morphology in July 2013 showed a pattern of small sand ripples, while in December this has changed into large (mega) ripples. This may be a seasonal phenomenon (due to wave action (?), see also 3.2.2), but no specific research has yet been done.[116]

The wreck area eroded by approximately 4 metres between 1850 and 1950, after which it started to sediment again, until approximately 1980, when erosion again took over. The in-situ protection in 2003 had an effect on the average sand deposits, but in 2005 erosion continued once again. The sediment layer in the BZN 10 area has vertically eroded by 77 cm since 2002. Since 2008, it remains more or less stable, with a slight increase in sedimentation in recent years. Natural changes to the seabed (changing of the course of the Texelstroom) may have a strong influence on the continuous sedimentation on the south side of the wreck and the forming of an erosion gully in the north part (Fig. 3.18 A, B, C).[117]

BZN 11

The Burgzand Noord 11 (BZN 11) wreck was probably a seventeenth-century merchant vessel. It was discovered in 1997 and researched in 2002 and 2007.[118] After 2002, it was decided that this site should be left unprotected, as a reference or benchmark for the other wrecks in the area.

In 2003, the site consisted of a large wreck section, 25 metres long by 8 metres wide, surrounded by loose wreck parts. There was a strong erosion gully 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, which was at least 50 metres long, was forming to the east. From 2004, the deep erosion gully levelled

[111] Brenk & Manders 2012, 2013 and 2014. Erosion and sedimentation patterns are distilled from the subsequent multibeam data collected on site.

[112] See, for example, www.sasmap.eu (accessed 29-01-2017).

[113] Brenk & Manders 2014, 39, Coenen et al. 2013.

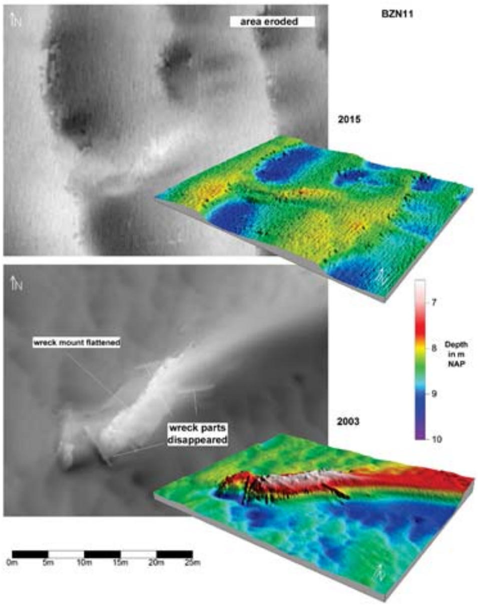
[114] Gregory & Manders (eds) 2016.

[115] Gregory & Manders (eds) 2016.

[116] Brenk & Manders 2014, 39.

[117] Brenk & Manders 2014, 41.

[118] See also Vos 2012, 267–278.



BZN11	Zmin	Zmed	Zmax	Zdif
2003	-9,58	-8,39	-6,16	3,4
2004	-9,48	-8,44	-6,25	3,2
2005	-9,56	-8,49	-6,01	3,6
2006	-10,46	-8,62	-6,12	4,3
2007	-9,84	-8,76	-6,70	3,1
2008	-9,83	-8,84	-7,20	2,6
2009	-9,81	-8,66	-7,26	2,5
2010	-9,38	-8,71	-7,61	1,8
2011	-9,50	-8,69	-7,70	1,8
2012	-9,36	-8,66	-7,65	1,7
2013	-9,34	-8,61	-7,72	1,6
2014	-10,06	-8,60	-7,71	2,4
2015	-9,45	-8,53	-7,77	1,7
2016	-9,02	-8,40	-7,80	1,2

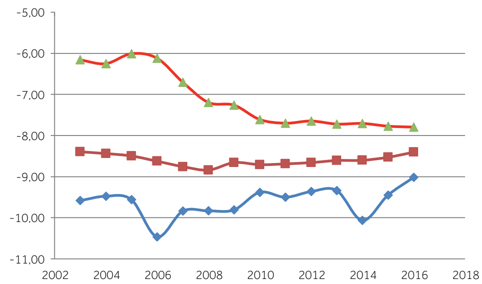


Fig. 3.19 A, B Compilation of BZN 11 erosion-sedimentation history. (A) Two multibeam recordings from 2003 and 2015 compared, (B) Burial history of the wreck site. Figure: courtesy Periplus Archeomare/RCE.

out. This was still the case in 2006, but in the southwest some strong erosion pits seemed to be undermining the ship construction. In 2008, and 2009, the site was still as large as in 2004, but the seabed around it had flattened out further.

In general, the wreck appears 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. In 2013, these loose parts and the wreck mound had almost completely disappeared. The whole area had flattened out, and most of the objects above the seabed (causing eddy currents) had disappeared.[119]

The historical and more recent data show that from 1852 onwards the wreck would have eroded gradually, and since its discovery in 1997 this process of erosion accelerated, deepening the site by 6 metres in total (Fig. 3.19 A, B).[120]

BZN 12

The Burgzand Noord 12 (BZN 12) wreck, a seventeenth-century merchantman with a heavy cargo of bricks,[121] was recorded with multibeam for the first time in October 2012. After three years of monitoring (December 2013, 2014 and 2015), little difference in seabed morphology could be seen (Fig. 3.20).[122]

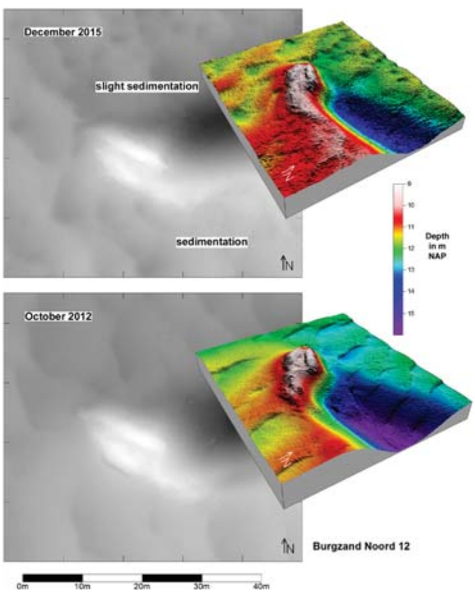


Fig. 3.20 A, B Compilation of the BZN 12 erosion-sedimentation history. (A) Two multibeam recordings from 2012 and 2015 compared, (B) Burial history of the wreck site. Figure: courtesy Periplus Archeomare/RCE.

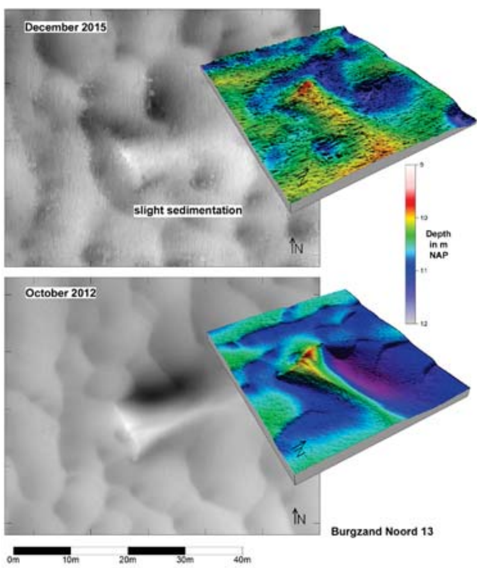


Fig. 3.21 Compilation of the BZN 13 erosion-sedimentation history. Two multibeam recordings from 2012 and 2015 compared. Figure: courtesy Periplus Archeomare/RCE.

[119] Brenk & Manders 2014, 42.

[120] Brenk & Manders 2014, 43.

[121] Vos 2012, 281–287.

[122] Brenk & Manders 2014, 44.

BZN 13

The Burgzand Noord 13 (BZN 13) wreck, a seventeenth-century shipwreck (board) was recorded for the first time in 2012. The multibeam recording from December 2013 showed that the gully to the north of the site had sanded in. This process had continued in 2014 and the area was flattening out. The resolution of 2015 was lower than the other multibeam recordings, but seemed to show the same flattening out of the surrounding area (Fig. 3.21). [123]

BZN 14

The Burgzand Noord 14 (BZN 14) wreck, a seventeenth-century armed merchantman, was recorded in 2012 for the first time.[124] The recordings from December 2013, October 2014 and December 2015 show that the northern part of the area around the wreck site had deepened considerably (Fig. 3.22).[125]

BZN 15

The Burgzand Noord 15 (BZN 15) wreck site was first assessed in 1999. It consisted of partly disarticulated ship parts and cargo. The most protruding element was a cargo of iron rods. The wreck was dated to the seventeenth century,[126] and was recorded with multibeam for the first time in October 2012. A comparison with the recordings in 2013 and 2014 revealed various long objects (one even as long as 4 metres) to the south of the earlier recorded iron rods. The area itself is deepening, which is also apparent in the recording from 2015 (although the resolution of this recording is considerably lower than those made previously) (Fig. 3.23).[127]

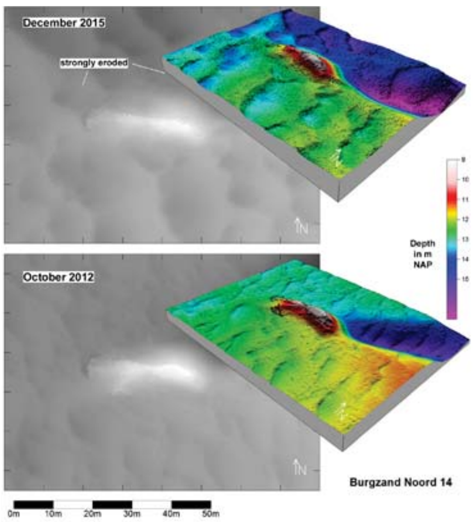


Fig. 3.22 Compilation of the BZN 14 erosion-sedimentation history. Two multibeam recordings from 2012 and 2015 compared. Figure: courtesy Periplus Archeomare/RCE.

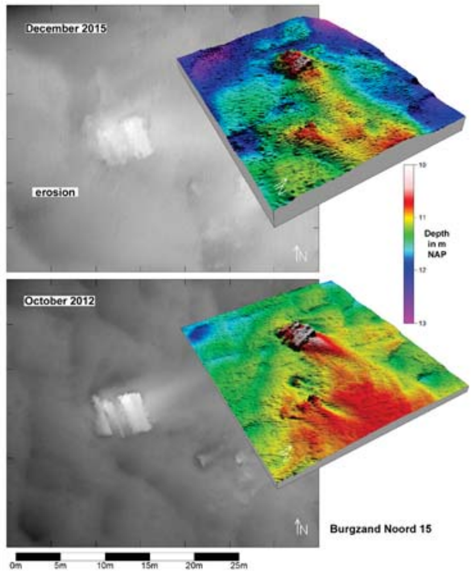


Fig. 3.23 Compilation of the BZN 15 erosion-sedimentation history. Two multibeam recordings from 2012 and 2015 compared. Figure: courtesy Periplus Archeomare/RCE.

BZN 16

The first multibeam recording of the Burgzand Noord 16 (BZN 16) wreck (a seventeenth/eighteenth-century shipwreck) area was made in 2011. Wooden wreck parts were reported by government archaeologists in 2002. In the 2011 recording, however, no evidence of any shipwreck was found in a radius of 50 metres from the reported location. This may be because the location was not accurately recorded or the wreck parts had eroded and washed away. The latter is a plausible explanation as the area had deepened by 2 metres since the first report of a wreck (Fig. 3.24).[128]

BZN 17

The Burgzand Noord 17 (BZN 17) wreck was discovered in 2009 and was recorded with multibeam for the first time in 2011. The wreck parts cover an area of 25 by 15 metres. Between 2011 and

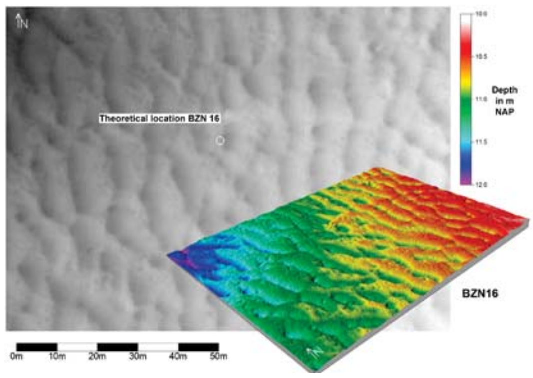


Fig. 3.24 One multibeam from 2015 of the BZN 16. The wreck is not visible. Figure: courtesy Periplus Archeomare/RCE.

[123] Brenk & Manders 2014, 45.

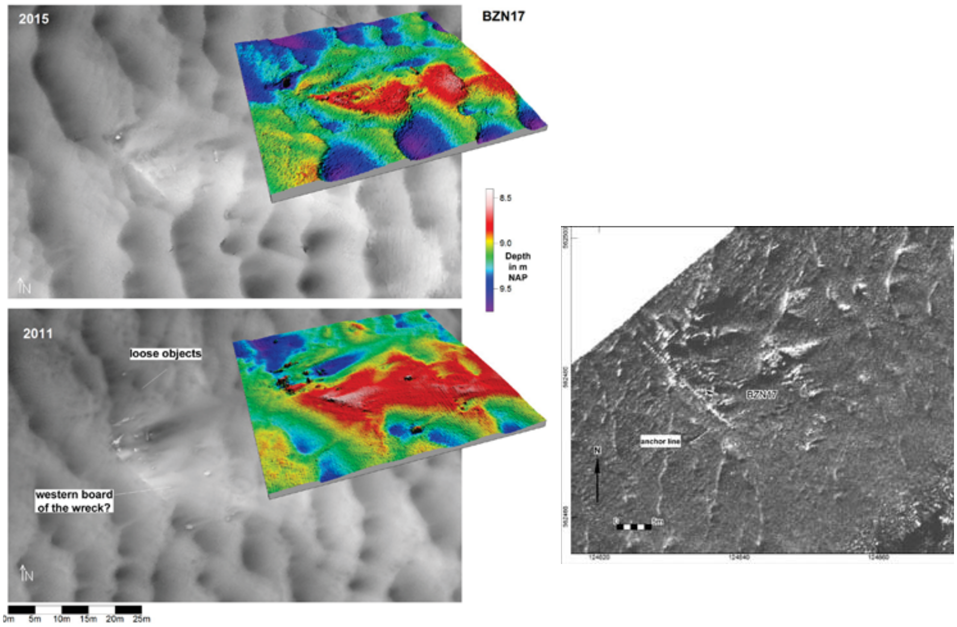
[124] Vos 2012, 295–309.

[125] Brenk & Manders 2014, 46.

[126] Vos 2012, 311–319.

[127] Brenk & Manders 2014, 47.

[128] Brenk & Manders 2014, 48, 49.



BZN17	Zmin	Zmed	Zmax	Zdif
2011	-9,91	-9,20	-8,26	1,7
2012	-9,91	-9,26	-8,42	1,5
2013,5	-10,13	-9,26	-8,45	1,7
2013,9	-10,14	-9,27	-8,36	1,8
2014	-10,06	-9,26	-8,38	1,7
2015	-10,18	-9,30	-8,45	1,7
BZN19	Zmin	Zmed	Zmax	Zdif
2014				
2015	-9,82	-8,96	-8,20	1,61
BZN20	Zmin	Zmed	Zmax	Zdif

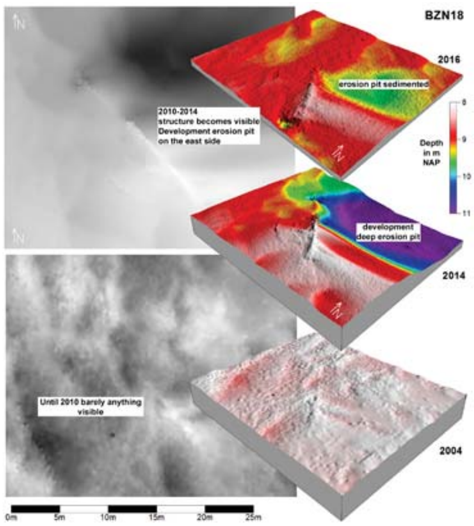
Fig. 3.25 A, B, C Compilation of the BZN 17 erosion-sedimentation history. (A) Two multibeam recordings from 2011 and 2015 compared, (B) A side scan sonar image from 2016, (C) Burial history of the site. Figure: courtesy Periplus Archeomare/RCE.

2012, almost no changes were visible. In 2013, a structure of more than 5 metres long had become visible on the south side of the wreck. During a quick survey in 2014, done by the RCE, this turned out to be a board of a ship. It also became immediately obvious that heavy airlifting had occurred on the site, assumed to have been done by local diving groups. This site disturbance is clearly visible in the multibeam sonar data of 2014. Large holes have appeared in the centre of the wreck site.[129] A further investigation was carried out in 2015 to look into the possibilities of physically protecting the site [130] and this was done in 2016 (Fig. 3.25 A, B, C).

BZN 18

Analyses of the multibeam sonar from 2009 revealed a new shipwreck (BZN 18) 40 metres from the BZN 3 wreck. Prior to this, no clear structures had been visible. Dive research in 2013 revealed it to be a wreck approximately 25 metres long. Not much else is known about the site, except that it had already been severely attacked by *Teredo navalis*. Since 1850, the area has deepened by approximately 6 metres. It is striking that shortly after the appearance of the wreck at the seabed surface in 2009, a deep erosion pit quickly developed to the east side. In 2013, the pit reached its maximum depth of 3 metres. Subsequently, the scour pit was filled and completely levelled out in 2015.

During a dive survey in 2013, the height difference between the wreck and the east side was already more than 2 metres.[131] This, however, had disappeared in 2015, when the area around the wreck flattened out (Fig. 3.26 A, B).[132]



BZN18	Zmin	Zmed	Zmax	Zdif
2003				
2004	-8,66	-8,14	-7,74	0,9
2005				
2006	-9,29	-8,39	-7,72	1,6
2007	-8,96	-8,51	-7,78	1,2
2008	-9,08	-8,66	-7,80	1,3
2009	-10,36	-8,76	-7,78	2,6
2010	-10,54	-8,77	-7,78	2,8
2011	-11,54	-9,05	-7,82	3,7
2012	-12,05	-9,11	-7,84	4,2
2013,5	-12,21	-9,20	-7,75	4,5
2013,9	-11,43	-9,04	-7,83	3,6
2014	-12,06	-9,56	-7,80	4,3
2015	-10,01	-8,97	-8,11	1,9
2016	-9,79	-9,01	-8,26	1,5

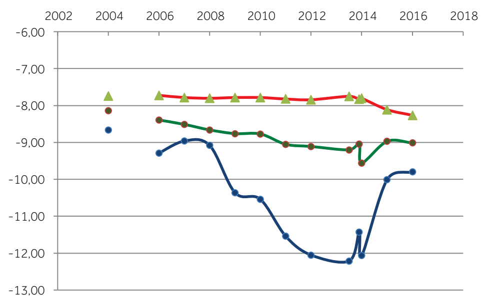


Fig. 3.26 A, B Compilation of the BZN 18 erosion-sedimentation history. (A) Three multibeam recordings from 2004, 2014 and 2016 compared. This comparison shows us how dynamic a site can be over a short period of time. (B) Burial history of the site. Figure: courtesy Periplus Archeomare/RCE.

[129] Brenk & Manders 2014, 50.

[130] Opdebeeck 2015.

[131] Report on BZN 18 dive action by the author. Internal reporting RCE.

[132] Analyses based on the multibeam animation made of the BZN 18 wreck from the period 2004–2015.

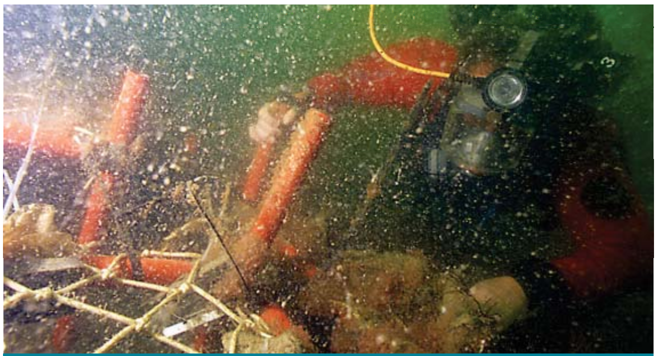


Fig. 3.27 A frame at the BZN 10 site used during the MoSS project to fix the wood samples for measurements in the water column (aerobic samples). Photo: R. Obst/RCE/MoSS project.

3.4 Some conclusions about the seabed morphology

The Western Wadden Sea is a dynamic area, and this constitutes a major threat to the in-situ preservation of the wreck sites described above, as well as a potential threat to other, as yet unknown sites. The mobile Holocene layer is changing in thickness regularly, consequently covering and exposing shipwrecks. On a larger scale, we see that the currents and wave actions have an influence on the morphology of the seabed. Gullies, tidal channels and former sandbanks change place and course, opening up new areas which threaten the cultural heritage. These areas are the Burgzand, Vogelzand, Scheer, Texelstroom and Scheurrak.

There are also more stable areas: roughly the area between Vogelzwin and Vaarwater naar de Cocksdorp, and parts of the Lutjeswaard, Zuidoostrak and Balgzand. Historical research has shown these to be generally stable for a long time. Research on sedimentation and erosion in the greater Western Wadden Sea has shown that sedimentation is the general trend in the area. However, mainly due to the building of the Afsluitdijk in 1932, there is no stability as yet, and it may take another century before the entire area is stable once again.[133]

The dynamics of sedimentation and erosion due to currents and waves at the site level of some of the wrecks in the Burgzand area have also been investigated, finding that, each year, the morphology around the monitored shipwrecks changes. The obstruction of the wreck itself causes local eddy currents that can cause scour and erosion pits in and around the site. The in-situ stabilization methods have worked to create a more stable environment. The tendency, however, is that the Texelstroom is moving southwards over the Burgzand area, which in some places will cause strong erosion patterns. Nevertheless, due to its continuous movement, some wreck sites in the northern part of the area are again in the process of sedimentation.

3.5 Biological threats

3.5.1 Introduction

Archaeological sites are not only subject to mechanical deterioration, there is also a biological threat, with wood being especially vulnerable to attack. The effects of biological attack can vary. While specialized fungi and bacteria are able to degrade wood for example, usually by relatively slow biochemical processes, bivalves and crustaceans effectively fragment wood, thereby contributing to a much faster degradation process.

Biological attack of organic materials by wood borers, fungi and most bacteria is primarily dependent on the presence of oxygen. We can therefore make a distinction between the processes that occur above the seabed and those within the seabed. Within the seabed, the amount of oxygen is usually extremely low or even non-existent. However, sea organisms can also be the cause of seabed disturbance due to bioturbation and, therefore, introduce oxygen into deeper areas of the seabed.[134] Elements of a site directly exposed to the seawater, or a thicker layer of the sediment, may become aerobic and therefore subject to severe biological and chemical deterioration.

In the light of this basic knowledge about biological deterioration of archaeological wood under water, a series of European projects were designed, in which tests were conducted and the type and speed of biodeterioration were measured.[135] This also resulted in the development of ways to monitor sites.[136]

Between 2001 and 2004, the BZN 10 wreck was the test and sample site for the Culture 2000 MoSS project.[137] At this protected wreck site, artificial woodblocks and a data logger to measure the environmental conditions were installed above the seabed to investigate degradation in aerobic conditions, and also in the seabed (actually on site) to investigate degradation in anaerobic conditions.[138] In a large frame, 150 woodblocks (20 x 7 x 2.5 cm) of fresh oak (*Quercus sp.*) and pine (*Pinus sylvestrus*) and archaeological wood (also oak: *Quercus sp.*) were exposed above the seabed (Fig. 3.27).[139] Some of these blocks were physically protected with Terram geotextile (of different grades: 500, 1000, 2000 and 4000) and others were not (see for more on this Chapter 5).[140] Sets of blocks were collected after 3 months and 12 months, respectively.[141]

[133] Some of the changes in erosion and sedimentation patterns have also been caused by the Balgzand dike, which was built in 1924. See also Brenk & Manders 2014, 10.

[134] See, for example, Volkenborn et al. 2007.

[135] See, for example, the results of the MoSS, BACPOLES, MACHU, WreckProtect and SASMAP projects.

[136] See also Chapter 6.

[137] See also Section 3.1.

[138] Water-Watch System 2681 – subsea logger from EauxSys (UK) Ltd. In open water, it measured temperature, depth, dissolved oxygen and conductivity (which can be converted into salinity). Turbidity and sediment movements were also trialled. In the sediment, pH and redox potential were measured, Gregory 2004 (1).

[139] Pine and oak were the main wood types used in European shipbuilding in the sixteenth and seventeenth centuries. The archaeological wood from the *Mary Rose* shipwreck (1545, Portsmouth) was provided by the *Mary Rose* Archaeological Services, a partner in the MoSS project.

[140] The higher the grade, the more dense and less flexible the geotextile.

[141] At the start of the project, wood samples were placed above the seabed for 3, 12, 24, 36 and 48 months. However, due to time restriction within the project, only the samples for 3 and 12 months were collected.

Fig. 3.28 PVC pipes at the BZN 10 site with wood samples to measure the decay in the sediment (anaerobic samples). Photo: R. Obst/RCE/MoSS project.

Fig. 3.30 Anemones growing in abundance on the BZN 11 wreck site. Photo: RCE/M. Manders.

The blocks that were used to investigate the anaerobic environment were placed in the burial mound of the BZN 10 on the west side of the wreck, close to the frame for the aerobic samples. In total, 280 small blocks (5 x 2 cm, 5 x 3 cm) of fresh oak and pine were buried in open PVC tubes in the sediment (Fig. 3.28). They were collected at the same time-intervals as the aerobic woodblocks. A control material, Shirley Textile, was also placed in the sediment (Fig. 3.29).[142] This fabric consists of 96% cellulose, which enables us to investigate the extent of attack caused by cellulose degrading bacteria and fungi.

Bacterial decay of submerged wood was also the special focus between 2002 to 2005 in the European 7th Framework financed BACPOLES project. In addition to house foundation poles and other kinds of archaeological sites, two submerged wrecks in the Wadden Sea were also chosen as test and sample sites: the BZN 3 and BZN 15.

The outcomes of these two projects form the basis of the information on biological deterioration of sites assembled in this chapter.

3.5.2 Above the seabed

There is a lack of natural hard substrate habitats in the oceans of the world, including Dutch waters. Therefore, when a ship sinks to the seabed, various marine invertebrates will colonize it relatively quickly, and there is strong competition among species for space.

Fig. 3.29 Shirley textile samples to measure the deterioration of cellulose in the anaerobic environment. Photo: MoSS project.

Fig. 3.31 An Iberian jar, part of the cargo of the BZN 10 ship, with a woven basket that deteriorated due to the currents and the crabs. Photo: RCE.

Above the sediment, the environment is often oxygen rich.[143] Exposed parts of a wreck are thus subject to a variety of biological deterioration processes.

Bacteria and fungi produce extracellular enzymes which destroy the material on which they grow, while crustaceans and molluscs bore into wood, which they ingest and may subsequently utilize. Additionally, there are fouling organisms, such as algae, moss animals,[144] *Tunicata, Actiniaria,* or sea anemones, barnacles and *Mollusca*, which use the wood and also other natural and human-made materials as a substrate on which to grow. Within the BACPOLES and MoSS projects, visual observations of abundant growth of sea anemones on unstable, heavily deteriorated wooden wrecks were made. This causes the break up of ship elements, due to the greater resistance of the structure to the currents (Fig. 3.30).[145] Bioturbation by shells, lugworms and crabs has also been observed. The latter even 'attack' exposed archaeological objects (Fig. 3.31). Their effects have not been scientifically measured.

By far the most damaging of these organisms are the marine wood borers, which may cause damage to exposed shipwrecks and loss of archaeological information in an extremely short period of time. After the marine borers, the next agents of deterioration to consider are fungi and bacteria. These micro-organisms have a relatively minor part to play in the total breakdown of wood in seawater but their activity will affect its long-term preservation.

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[142] Palma 2004, 7.

[143] Murray et al. 2005.

[144] A sedentary colonial aquatic sea animal, either encrusting rocks, seaweed or other surfaces, or forming stalked fronds. Also Polyzoa or Bryozoa.

[145] For example, the control samples taken within the MoSS project at the 12 and even 3 month intervals were thoroughly covered in barnacles, bivalves and algae.

Fig. 3.32 Teredo navalis or shipworm. Photo: courtesy National Museum Denmark.

3.5.3 Within the seabed

Usually, only the first few millimetres of the sediment is oxygenated. Bioturbation by invertebrates, wave action or other cultural and natural processes may extend this oxygenated zone downwards.[147] The depth of the sediment does affect the amount of micro-organisms present. However, bacteria, unlike the marine borers and fungi, can survive in environments with very low oxygen concentrations, even in anaerobic or anoxic conditions.[148] Relatively high numbers of aerobic bacteria and fungi occur in the first few centimetres of most marine sediments, but numbers are rapidly reduced in deeper sediment layers.

3.5.4 Different environments, different degradation processes

Different environments, dominated by the absence or presence of oxygen for example, trigger the biological deterioration of material on site due to the presence of different animals. Below, the most damaging species will be discussed.

Wood-boring bivalves

Wood-boring bivalves, generally called shipworms, belong to the families *Teredinidae* and *Pholadidae* (Fig. 3.32). Together they constitute the suborder *Pholadina* of the *Eulamelli* branch of the order *Myoida*.[149] Shipworms are potentially the most rapid decomposers of wood structures under water. Moreover, when released into the water column they can travel long distances in a relatively short period in search of wood.[150]

Shipworm larvae settle onto submerged wood and undergo a metamorphosis, becoming tiny juveniles that mature while living inside the wood.[151] The entrance hole where the larvae first settle is small and only slightly enlarges during the life span of a shipworm. The organisms filter feed and obtain oxygen by pumping water in and out through their siphons. These tube-like organs are the only part of the animal that is visible outside the wood. The siphons normally extend out of the entrance holes but will be quickly retracted if disturbed. As long as a shipworm can position its siphons in an oxygenated environment, it can bore deep into a wreck lying in sediment. Shipworms need oxygen-rich water in their burrows for respiration to survive. Nevertheless, they can seal their burrows for several weeks if the surrounding conditions become unfavourable.

The major factors influencing colonization by marine borers, including shipworms, are temperature, salinity, depth and the dissolved oxygen content of the water.[152] Adult species of the *Teredo navalis* are tolerant of waters with a minimum temperature as low as -1.4 ˚C and as high as 30 ˚C. They are, however, most active between 15 ˚C and 25 ˚C. They start spawning at 11 ˚C and the larvae are active between 7.5 ˚C and 30 ˚C. Metamorphosis of the larvae is possible above 12 ˚C. This means that for the reproduction and development of a healthy population, 11 ˚C is the minimum for at least some period of time each year. Larvae need 1 ˚C more to develop into adult *Teredo*, at least also for some period of time each year. This is certainly the case for the Wadden Sea.

In addition, normal boring activities of adults occur in salinities from 7 to 9 PSU.[153] Salinity less than 4–6 PSU are lethal. Reproduction is possible above 8–9 PSU. Adults remain active between 7–45 PSU and larvae from 6–31 PSU, while 5 PSU or lower is lethal to the larvae.[154] Active shipworm has been detected from 0 to almost 30 metres.[155] Although probably a very important parameter, not much work has been done on the oxygen tolerance of the shipworm. However, the minimum tolerance levels are estimated to be less than 1 mg oxygen per litre within 24 hours for larvae and 1 month for adults.[156] A healthy condition consists of an oxygen level of more than 4 mg/litre (Fig. 3.33).[157]

Currents are important in relation to the animal's capacity to

[146] They may be responsible for making the wood soft by destroying the inner cell structures. This again makes the wood vulnerable to mechanical deterioration.

[147] Helmholtz Centre for Ocean Research Kiel (GEOMAR) 2014.

[148] For example, sulphur-reducing bacteria. See, for example, Muyzer & Stams 2008.

[149] Turner 1966.

[150] Manders (ed.) 2011, 14, 19.

[151] See also Nair & Saraswathy 1971.

[152] WreckProtect guideline, Manders (ed.) 2011. Sometimes other figures are mentioned: For temperature: *Teredo navalis* individuals can survive in water temperatures as high as 30 °C, although growth may cease above 25 °C. Minimum reproductive temperature is reported as approximately 11–15 °C. The species has recently been reported in the Weser Estuary, northern Germany, where winter water temperatures of 0.7 °C were recorded (http://www.sms.si.edu/irlspec/Teredo_navalis.htm, accessed 27-01-2017).
Salinity: the NEMESIS database provides a salinity range of 5–45 ppt for the *Teredo navalis*. A lethal low salinity limit of 5 ppt has been suggested for larval individuals.
Oxygen: *Teredo navalis* can survive extended periods of anoxia (up to 6 weeks) by suspending feeding activities and remaining sealed in burrows, metabolizing stored glycogen reserves for energy. NEMESIS (http://invasions.si.edu/nemesis/CH-ECO.jsp?Species_name=Teredo + navalis, accessed 29-01-2017).

[153] Manders (ed.) 2011.

[154] Manders (ed.) 2011, 19.

[155] http://eol.org/pages/439957/details#habitat (accessed 29-01-2017).

[156] The adults can retract into their burrows.

[157] Manders (ed.) 2011, 19.

Top layer, classification for *larvae*			
Class	**1**	**2**	**3**
Temperature (°C)	< 7 lethal	7 – 12 survival	> 12 development possible
Salinity (PSU)	< 5 lethal	5 – 8 survival	> 8 metamorphosis possible
Oxygen (mg O2/l)	< 1 lethal 24 hr	1 – 4 effect on physiology	> 4 healthy condition
Currents (m/s)	0.1 (<120km/2wks)	0.1-0.2 (120-240 km/2wks)	> 0.2 (>240 km/2wks)
Bottom layer, classification for *adults*			
Class	**1**	**2**	**3**
Temperature (°C)	< - 2 lethal	2 – 11 survival	> 11 reproduction possible
Salinity (PSU)	< 4 lethal	4 – 8 survival	> 8 reproduction possible
Oxygen (mg O2/l)	< 1 lethal 4 wks	1 - 4 effect on physiology	> 4 healthy condition

Fig. 3.33 Table with parameters for adult and larvae of the Teredo navalis to survive. Figure: courtesy WreckProtect Project.

Fig. 3.34 Wood from the BZN 18 site completely eaten and crumbled due to Teredo attack. Photo: Paul Voorthuis, Highzone Fotografie.

travel. Adults can spread in driftwood. Larvae are free-swimmers and can do so for between 2 to 4 weeks, after which they must find wood substrate to colonize.[158]

In *Teredinidae*, the nearly hemispherical shells cover only the anterior part of the animal, and a thin calcareous layer deposited on the walls of the burrows protects the rest of the worm-like body. Species in this family also have two associated calcified structures at the posterior end called the pallets. These are used to close the small hole connecting the burrow to the external environment.[159]

The average length of an individual *Teredo navalis* is approximately 20 cm,[160] while those in tropical waters may reach 50 cm.[161] Shipworm individuals typically live for 1–3 years. After settling, they bore into the wood and seldom along the wood surface. The mollusc digs approximately 1 cm wide burrows up to 0.6–1 m long.[162] It avoids joints and knots and turns around when it reaches the end of the timber. The wood on the outside looks almost intact except for the entrance holes. The damage is therefore not always easy to detect by eye, especially under water.

Despite extensive internal damage, a wreck that has been attacked by shipworm of the family *Teredinidae* may remain intact for a long time after infestation because the burrows of these shipworms are lined with calcium. This supporting structure helps to hold the piece of wood together, although the material strength is severely reduced. Such infested wood is very fragile and may easily break upon impact with other objects such as fishing nets, divers, anchor lines or moving debris on the seabed (Fig. 3.34).

The infestation and consequently devastating effect of the shipworm on submerged wooden structures has been a problem in the Netherlands for a long time. Early severe infestations are historically recorded in 1730–1733, 1770, 1827 and 1858–1859.[163] The 1730s infestation may have been the most disastrous, causing great concern among the Dutch. The attack also destroyed most dikes, embankments and sluice gates. Before 1730, there is no mention of such a plague; however, the shipworm was known as early as the 1720s, when it is already mentioned in texts.[164]

The major threat posed by this creature concerns the fact that the Netherlands heavily depends on its sea defence measures (Fig. 3.35). The causes of the attack in 1730, 1731 and 1732 thus had to be found. At the time, 82 men were sentenced to death for alleged homosexuality, which had supposedly caused the attack by the shipworm.[165] In addition, the *Teredo* led to the first

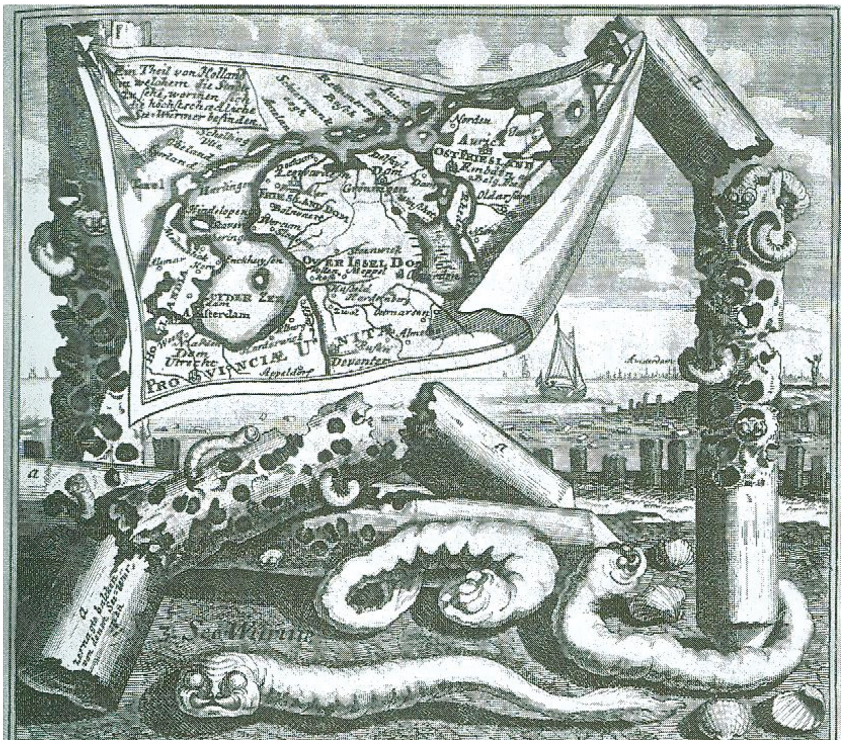

Fig. 3.35 Historical print of the devastating shipworm attack on quays and dikes in the Netherlands in 1733.

[158] Manders (ed.) 2011, 14, Toth et al. 2015, 2–5.
[159] Palma & Santhakumaran 2014, 15.
[160] http://eol.org/pages/439957/details#habitat (accessed 29-01-2017). According to Palma and Santhakumaran, their length can range from 15 to 180 cm (2014, 22).
[161] Sordyl et al. 1998.
[162] http://www.sms.si.edu/irlspec/Teredo_navalis.htm (accessed 29-01-2017), Lane 1959, Turner 1966, ITIS 2007.
[163] Manders & De Bruyn 2011, 82.
[164] Bruyn 2010.
[165] Bruyn 2010.

Fig. 3.37 The OVM 14 is a well-preserved shipwreck with high upright construction in the Oostvoornsemeer (Oostvoorne lake). Photo: courtesy Kuyvenhoven.

Heritage act in the Netherlands in 1734, due to the fact that dolmen (*hunebedden*) were being removed and used to defend the coast in the north of the Netherlands, rather than the wooden defences that were being attacked by shipworm.[166]

Shipworm has also posed an enormous threat to wooden ships in the past. During his fourth voyage in 1502, Columbus experienced the devastating effect they could have on the hulls of ships. Near Panama, two of his ships, the Gallega and Vizcaina, were lost due to shipworm damage.[167] The VOC also repeatedly mentions attacks on their ships in tropical waters.[168] Although it is also often thought that the *Teredo* is an invasive species, pre-Christian era Greek and Roman sources and fossil finds in the UK and Belgium suggest the organism was present in Europe as early as the Eocene.[169] The significant problems arising after 1730 in the Netherlands may have been due to more favourable conditions for the reproduction and survival of shipworm, thus causing an explosion of the population.

Shipworm has caused problems with wooden structures – including shipwrecks – in many parts of the world. As seen above, this is no different for the Netherlands and the Wadden Sea.

Until recently, the Baltic Sea was free of *Teredo navalis*. This is one of the major reasons why the Baltic Sea contains so many extremely well-preserved shipwrecks. However, over the past few years *Teredo navalis* and its destructive effect on wooden shipwrecks and harbour installations have been recorded in Denmark and Germany, ranging from the entrance to the Baltic Sea to the German state of Mecklenburg-Vorpommern.[170] This is probably due to the introduction of more saline seawater from the North Sea into the Baltic Sea and possibly also due to an increase in water temperature due to climate change.[171] Research in the WreckProtect project revealed that although there is a real threat in the southern part of the Baltic Sea, large areas to the north will not be infested in the near future (Fig. 3.36).[172]
In the 1960s, the Oostvoornsemeer (a lake) in the Netherlands was formed by closing off the Brielse Maas from the sea. Subsequently, it was used for sand extraction for the extension of the Rotterdam harbour. In the process, the lake was deepened by 20 to 45 metres. During these dredging activities, several historical shipwrecks emerged from the seabed.[173] These, however, remained in a very good condition due to the fact that the original salt water area had desalinized. This has made the Oostvoornsemeer unique and a popular dive spot (Fig. 3.37).[174]

Fig. 3.36 A pamphlet showing the threat of shipworm in the Baltic was produced in the EU WreckProtect project. Figure: courtesy WreckProtect project.

166 Bruyn 2010, Willems 1999, 9.

167 See, for example, http://archive.archaeology.org/0607/reviews/columbus.html (accessed 27-01-2017).

168 See, for example, Duivenvoorde 2008, 330–355.

169 See also Borges et al. 2014, Palma & Santhakumaran 214, 5.

170 Gjelstrup Björdahl & Gregory (eds) 2011.

171 http://www.eucc-d.de/tl_files/eucc/Global%20Change%20and%20Baltic%20Coastal%20Zones/Chapter%204%20Stoermer.pdf (accessed 29-01-2017).

172 Manders (ed.) 2011, 39.

173 Brenk & Muis 2014.

174 https://www.duikersgids.nl/actueel/oostvoornse-meer-wordt-mogelijk-onderwatermuseum (accessed 29-01-2017), Berkers 2015.

Fig. 3.38 A. A piece of wood from one of the Oostvoornsemeer wrecks which has been attacked by shipworm. Photo: Paul Voorthuis, Highzone Fotografie, B. A small shipworm removed from a piece of wood from one of the Oostvoornsemeer wrecks. Photo: Paul Voorthuis, Highzone Fotografie, C. X-ray of wood from one of the Oostvoornsemeer wrecks that is completely infested by shipworm. Photo: P. Paalvast/RCE.

In 2008, it was decided to reverse this desalinization process to improve the water quality and to make the area a unique brackish water lake.[175] This meant salinizing the lake again. The advice of the RCE was to keep the salinity lower than 8 ppt. Unfortunately – probably due to a miscommunication – the salinity was finally set to a Chloride level of 8 ppt. This, however, results in a salinity level of 14 ppt, way above the minimum levels.[176] Subsequently, archaeological research executed in 2012 revealed an attack by shipworm.[177] This was the start of intensive research to investigate the presence of shipworm, its spread and influence on the shipwrecks in this area.[178]

In July 2014, wood samples taken from 7 sites indicated that 6 had been attacked by the shipworm *Teredo navalis* (Fig. 3.38).[179] Only at the deepest site, at 35 to 40 metres and 8 °C, were no living *Teredo* found. Investigation of the environment showed that here temperature and depth seem to be the limiting factors. Although the maximum depth at which *Teredo* has been found to date is a little below 30 metres, there is as yet no hard evidence to suggest why it should not be present at greater depths. The site, therefore, still has to be monitored for colonization by shipworm.

Shipworm is thus probably the most damaging sea organism on wooden shipwrecks and other submerged wooden structures. One *Teredo navalis* can eat away a 20 cm piece of wood in one year.[180] Wood samples investigated in the MoSS project removed from the water after 3 months already showed the early stages of infestation by wood borers identified as *Teredo navalis*. This was much worse in unprotected woodblocks after 12 months, which had been heavily attacked.[181] Pine samples placed on site for 12 months showed different levels of attack, while the oak samples were generally less attacked.[182] The difference in oak and pine is interesting if we think of the sacrificial layer of pine wood planks that shipbuilders used to add to ships that were going to the tropics. Was the choice only based on the price of the wood or were they well aware of the fact that pine is more susceptible to attack? The continuous damage in the past, but also today, is enormous and the costs of repair or replacement of harbour structures are high.[183]

Crustaceans

In contrast to shipworms that penetrate the wood, wood-eating crustaceans mainly gnaw and burrow on the surface. The species causing the most problems are members of the genera *Limnoria, Sphaeroma* and Chelura.[184] These crustaceans are collectively called 'gribbles' (Fig. 3.39). In areas with very little tidal movement, wood attacked by gribbles often develops an hourglass-shaped appearance because the predominant attacks occur close to the mean seawater level. However, gribbles also degrade wood in deeper waters.[185] In the family *Limnoriidae*, cellulose is degraded during passage through the gut. Members of the family *Sphaeromatidae*, which does not ingest wood, break down the wood mechanically and also cause enormous damage.

The effect of Limnoria lignorum is generally less destructive than that of *Teredo navalis*, but over an extended period of time, wood strength can be compromised and important archaeological information may be lost, especially because it attacks the surface

Fig. 3.39 Gribble. Photo: courtesy National Museum of Denmark.

[175] Ruiter 2012.

[176] Coenen & Houkes 2014.

[177] There was recent attack, with live *Teredo navalis* found in almost all the wrecks that were sampled, except for OVM 12 (see below). An old Teredo attack was also identified. A significant attack may also have occurred between the closure of the first Brielse dam in the 1950s and the dam that closed off the Oostvoornsemeer from the sea. Before that time, fresh river water may have had an influence on the relatively well-preserved state of many of the wrecks.

[178] Coenen & Houkes 2014.

[179] Paalvast 2014.

[180] Appelqvist 2011, 62.

[181] Palma 2004 (2), 24–25.

[182] This depends on the different geotextiles that were used to protect the control samples.

[183] Elam 2009, 4 & 7.

[184] Appelqvist 2011, 57.

[185] http://www.cabi.org/isc/datasheet/109146 (accessed 29-01-2017).

of the wood. Gribble requires an aerobic and saline environment[186] with and attack was observed on aerobic wood samples in the Wadden Sea.[187]

Micro-organisms

Specialized fungi and bacteria degrade wood in all types of aquatic environments. The fungi belong mainly to the group of *Ascomycetes* and *Fungi imperfecti*, and form what is known as soft-rot decay.[188] Using filamentous growth, hyphae penetrate into the wood structure and utilize the wood components (cellulose, hemicelluloses and lignin) in enzymatic processes.[189] Soft-rot decay results in a loss of cell-wall material in the outermost surface layer of the wood, as the fungi are dependent on access to higher levels of dissolved oxygen from the water. For most marine fungi, levels of less than 0.30 ml/litre (approximately 0.5mg/litre) have been reported to prevent their growth.[190] Wood from sluice doors is, for example, often subject to fungi attack due to the high levels of oxygen often present.[191] Wood that is water-saturated, but where there is still ample oxygen supplied, is often mainly degraded by soft-rot fungi.[192] It is then present in the outer layers of the wood. Other fungi such as white-rot and brown-rot are also extremely destructive to wood.[193] However, they are only active in wood that is partly dried out (20–80%) and in an even more oxygen-rich environment than soft rot.[194]

Observations have been made of sample wood (oak and pine) being infected by marine fungi as quickly as 3 months – after being placed on the BZN 10 wreck in the Wadden Sea.[195] Moreover, all of the samples of archaeological wood from the BZN 3 and BZN 15 wrecks were colonized by fungi.[196]

Bacteria degrade waterlogged wood more slowly than fungi. However, in low-oxygen to near anaerobic conditions, only bacterial degradation can be found.[197] Two types of bacteria have been recognized as the main wood degraders, namely erosion and tunnelling bacteria.[198] Although wood degradation by erosion bacteria was reported in the 1980s,[199] little was known about their taxonomy and growth because for a long time they had not been successfully isolated or cultivated in pure cultures.[200] Some studies were done in the BACPOLES project.[201] Tunnelling bacteria are active in seawater conditions[202] but require higher concentrations of oxygen for activity. They can especially be found in the outer layers of non-buried wood, whereas erosion bacteria are able to degrade wood under near anaerobic conditions, including interior parts of the wood. For archaeological wood, information on the behaviour of erosion bacteria and on the damage they may do to archaeological wood in situ is of prime importance for the management and protection of archaeological sites, since they may often be the only degraders left in the environment.

A strong smell of hydrogen sulphide was the first indication that bacterial decay had occurred in wood from the wrecks in the Wadden Sea. This odour was noticed, for example, when the Terram geotextile and the sediment were removed from the woodblocks (pine and oak) sampled from the BZN 10 wreck.[203] The smell was also noticed from the wood samples dug up from the anaerobic sediment on that same site and from samples taken in the BACPOLES project from wrecks BZN 3 and 15.[204] The wood

186 http://www.marinespecies.org/aphia.php?p=taxdetails&id=118917 (accessed 29-01-2017).

187 Unprotected pinewood sample taken from the seabed (aerobic) after 12 months. Palma 2004 (2), 25.

188 Björdal et al. 1999, 63, See also Huisman et al. 2008, 34.

189 Daniel & Nilsson 1998.

190 Gregory 2004 (1), 4.

191 Bijen 2003, 153.

192 Grosser 1985.

193 Grosser 1985.

194 Huisman et al. 2008, 34.

195 Palma 2004 (2), 25. Even wood samples that were protected with Terram geotextile of the highest grades (4000) showed evidence of attack.

196 Klaassen (ed.) 2005, 80–81.

197 Blanchette 2000; Björdal et al. 1999.

198 Gelbrich et al. 2008, 24.

199 Holt and Jones 1983; Daniel and Nilsson 1986.

200 Nilsson et al. 2008, 17.

201 The majority of bacteria cannot be cultured and identified using standard methods. This is a major limitation in the development of preventive treatments. This is the reason why the BACPOLES project undertook trials attempting to identify bacteria without an initial bias of culturing. This was done by using a relatively new molecular technique: 16S rDNA, with which we were able to identify a highly variable level of bacterial diversity within each group of sample sites. Only 15% of the marine samples showed similarity. This preliminary research must be continued in the future. Landy et al. 2008, 106–116.

202 Venkatasamy et al. 1990, Nilsson & Singh 2004.

203 Palma 2004 (2), 24, 25. For Terram Geotextile, see Chapter 5.

204 Palma 2004 (2), 25; Klaassen et al. 2005. Wood samples from the BZN 3 wreck were taken from a part of the ship's board that has never physically been covered with protection material, but had been covered with a 30 to 100 cm thick layer of sediment for many centuries.
The sediment consists of pure sea sand, which is alkaline, has a very low carbon content, no nitrogen, is low in phosphorus, low in base cations, low in sulphur and with medium levels of iron.
The surrounding water is alkaline, contains no dissolved organic carbon, is low in nitrogen, low in nitrate, contains no ammonium, a medium amount of phosphate, and is high in base cations, high in sulphate and high in iron. The water has a high conductivity, which is not so strange, due to its salinity (See Klaassen et al. 2005).
The BZN 15 wreck lies at a depth of 10 to 15 metres at high tide. Only two wood samples were taken from the wreck: an oak plank of 20 to 30cm and a pine plank of 30 to 40 cm below the surface. The planks were cut into several smaller samples for analyses. Here, the sediment is comparable to the BZN 3 wreck: pure sea sand, alkaline, very low in carbon content, no nitrogen, low in phosphorus, low in base cations, low in sulphur and with medium levels of iron. The surrounding water is alkaline, with no dissolved organic carbon, low in nitrogen, low in nitrate, no ammonium, low in phosphate, high in base cations, high in sulphate and low in iron. Naturally, the seawater here has a high conductivity as well (Klaassen et al. 2005).

proved to be very soft and spongy in some areas. The presence of erosion bacteria attack was confirmed by microscopic research.[205] The woodblocks that were buried in the sediment of the BZN 10 shipwreck showed a distinctive degradation pattern from bacteria in oak and pine samples after 12 months on site. This bacterial degradation had also been detected in the Shirley Textile (cotton) samples that were removed after 3 months on site.[206]

Of the archaeological wood from BZN 3, sampled in the BACPOLES project, four pine samples were fully degraded by bacteria. Half of the total number of samples were severely degraded while, in the other half, a gradient from moderate to weak was visible. Active erosion bacteria were detected in two of the four samples. The two archaeological planks from the BZN 15 site, also sampled in the BACPOLES project were also fully and severely degraded by bacteria. Active erosion bacteria were detected in both.[207]

Both the pine and oak samples were degraded. This degradation was already visible on samples left on site for 3 months. The samples were all infested by erosion bacteria, with non-degraded tissue in the wood being rare. Sapwood, if present, was always severely degraded. It also seems that the dimension of the timber is negatively correlated with the degree of degradation, and[208] this seems to have more influence than the age of the wood. The oak shipwreck (archaeological) timber from the BZN 3 and 15 sites only consisted of sawn heartwood, but in all pieces a gradient in the degree of degradation was still found (severe to moderate). In a comparison with terrestrial sites in the BACPOLES project, with fresh water soil conditions, the sawn timber from the wreck sites showed relatively less degradation, despite their also relatively small dimensions.[209] A comparison of samples from the BZN 10 wreck with other wrecks that were investigated in the same way during the MoSS project – the Vrouw *Maria* and *Darsser Cog* (in brackish to almost fresh water conditions) – also showed less degradation for the Burgzand wreck (saline).[210] This decrease in the extent of bacterial degradation of wood may be caused by the toxic effects of high concentrations of hydrogen sulphide produced by sulphate-reducing bacteria present in organic-rich marine sediments. [211]

Apparently, these factors affect the speed of degradation to such an extent that the effect of age (and therefore the exposure time) is minimal. Temperature also seems to be important, the higher it is, the more degradation, because it affects the growth of micro-organisms.

It remains difficult, however, to pinpoint the environmental conditions which optimize the decay of wood by erosion bacteria. They are active in virtually all waterlogged environments. Moreover, the low redox values encountered at these sites are typical for iron Fe-reducing and sometimes for sulphate-reducing environments that are essentially without oxygen. Until now, it was not known whether erosion bacteria have a requirement for oxygen that would be needed for lignin modification.[212] However, the results indicate that erosion bacteria may be active in essentially oxygen-free environments,[213] and therefore have to be considered anaerobes. It would seem that erosion bacteria have developed a method for lignin modification that works under anoxic conditions.

In addition, water flux may also be crucial for the spread of erosion bacteria.[214] This means that the orientation and placement of the structural ship element or object may affect the severity of degradation by erosion bacteria.[215] This is an interesting hypothesis and, although laboratory tests have been executed in the BACPOLES project, this still needs extensive research with actual field sampling before it can be confirmed.[216]

If we take a look at the pH conditions of the sites, we see that they generally need to be slightly more alkaline for bacteria (pH 7 to 8) than for fungi. However, there are exceptions. Sulphur oxidizers can even be active and grow in an acid environment with a pH of less than 2.[217]

Degradation by erosion bacteria, causing mass loss and associated increased water content, makes the wood extremely sensitive to abrasion, scouring, warping, cracking and even disintegration during drying out. If archaeological wood needs to be excavated, it has to be thoroughly protected during and after an excavation to prevent such damage. Excavation and recovery of large degraded wooden objects is difficult because of a massive loss of strength and, although large objects therefore need ample support before they can be lifted, it must be recognized that the supporting material may deform the wood surface locally.

Although bacterial degradation can be severe, it usually does not

[205] Nilsson & Björdahl 2008, 6–7, Palma 2004 (2), 23.

[206] Palma 2004 (2), 23–27, Wyeth 2004, 29–32.

[207] Klaassen et al. 2005, 80–81.

[208] Huisman et al. 2008, 42.

[209] Huisman et al. 2008, 42.

[210] See, for example, the results of the Tensile Testing of buried cotton samples in the MoSS project (Wyeth 2004, 29).

[211] Huisman et al. 2008, 42.

[212] Blanchette 2000.

[213] i.e. (O2) < 10-6 M.

[214] Klaassen 2008, 61–68.

[215] Suggested in Klaassen (ed.) 2005, 90.

[216] Klaassen 2008, 61–68.

[217] Rawlings 2005 (http://www.microbialcellfactories.com/content/4/1/13, accessed 29-01-2017).

cause as severe damage to the archaeological wood as fungal or *Teredo* degradation. While the latter can destroy features and sources of archaeological information, bacteria usually only damage the inner cell structure. Nonetheless, bacteriological degradation may sometimes be the only direct threat to a shipwreck, especially in areas with a lack of oxygen.[218]

3.5.5 Some conclusions on the biological threats

Biological deterioration of wooden shipwrecks is a continuous process. In aerobic environments, more species are active, while in less aerobic and even anaerobic or anoxic environments, erosion bacteria may still be active. However, the speed of deterioration varies. While deterioration by *Teredo navalis* is extremely violent and rapid, erosion bacteria work at a much slower pace. Biological attack can be accelerated by mechanical attack, such as erosion of the seabed. Water flux and the amount of organic matter in the sediment also have an influence on the deterioration of wood.

3.6 Chemical threats

As on land, several processes may occur that chemically threaten archaeological sites. On a large scale, climate change may cause pH in water to change,[219a] changes of current may cause different sediments or types of water to mingle and start reactions, while activities on the site may cause oxygen to react with archaeologically valuable material. Different materials and elements may react with each other. Changes in the environment due to climate change, excavation, bioturbation or more common natural changes in the seabed trigger new reactions that cause a change in the equilibrium, which is often found to a varying extent on historic sites.

Chemical processes can affect the integrity of archaeological objects. One of the most common processes is the corrosion of iron and other metals. In marine environments, this occurs in oxygen-rich environments as well as under anaerobic reducing conditions. When oxygen is present, iron corrodes to form iron hydroxides. Under reducing conditions, the typical corrosion products are iron mono-sulphides. Iron corrosion products can precipitate in the structure of organic materials – including wood – that are in contact with or in close proximity to the corroding iron. Iron mono-sulphides and di-sulphides such as pyrite are also formed under reducing conditions in sea floor sediments and can precipitate. Iron mono-sulphides and di-sulphides may be oxidized in the presence of oxygen. This can occur when shipwrecks that were buried under reducing conditions within seabed sediment are exposed to oxygenated water. However, this is also a common occurrence once the organic materials are recovered from a site. These oxidation reactions produce sulphuric acid and a range of intermediate iron-sulphur species. The strong acidification that results, causes a range of degradation reactions in wood, bone and metals [119b]. The above-mentioned processes have been identified on several ships, ship fragments and artefacts recovered from the seabed, such as the *Vasa*, a warship in Sweden, the *Mary Rose* in England, the *Batavia* in Western Australia, the BZN 3 and 15 wrecks and the *Ventjager wreck* and *Roompot* wreck in the Netherlands.

During the study of degradation patterns, wood from the BZN 3 and 15 sites appeared to contain substantial amounts of pyrite (FeS_2). The chemical wood analyses that are available confirm that high concentrations of iron (Fe: 1.1–2.3 %) and sulphur (S: 0.8–2.4 %) occur in the wood from BZN 15.[220] Pyrite is formed in reducing environments, where ample reducible iron, sulphate and organic matter are available. The organic matter is used by bacteria to reduce iron to form Fe2+ and sulphate to form bisulfide (HS-), which subsequently react to form sulphides. The presence of pyrite minerals has been observed under the microscope in many wood samples, but the amount of such minerals formed would be dependent on the supply of sulphate and iron. In fresh water, little sulphate is available, so pyrite will be scarce, whereas, in seawater, sulphate is present in much larger amounts. Iron may be available in the sediment and in wood in proximity to iron objects (e.g. nails, bolts, cannons and anchors), but will be in shorter supply elsewhere inside the wood.[221]

Pyrite may cause degradation in addition to bacterial activity if burial conditions change. It is unstable in oxygenated environments and releases sulphuric acid when it comes into contact with oxygen.[222]
The acid produced by this process is detrimental to the wood because of localized low pH (lower than 3) that causes hydrolysis of cellulose. Several ships that have been recovered from the sea floor – including the Vasa, the *Mary Rose* and the *Batavia* – have suffered severe damage as a result of such processes.[223] There are some indications that wood from the marine shipwrecks in this study may also have become subject to the same damage under oxygenated conditions. Tell-tale orange-brown iron oxide precipitates were observed[224] during microbial culturing of wood samples from the BZN 3 wreck.[225] The presence of pyrite was

[218] This is not only the case for wooden shipwrecks, as iron hulls may also be under threat by degrading bacteria such as the Halomas titanicae, a species of bacteria named after the ship it is eating away, the HMS Titanic. http://www.dailymail.co.uk/sciencetech/article-1336542/Halomonas-titanicae-New-rust-eating-bacteria-destroying-wreck-Titanic.html (accessed 10-03-2017).

[219a] Dunkley 2015, 220.

[219b] Klaassen 2005.

[220] Klaassen 2005.

[221] Huisman 2009 (1).

[222] According to: $4\,FeS_2 + 15\,O_2 + 10\,H_2O \rightarrow 4\,FeOOH + 8\,SO_4^{2-} + 16\,H^+$, see also Huisman 2009 (1) and 2009 (2).

[223] MacLeod & Kenna 1990; Sandström et al. 2002, 2003 & 2005; Fors 2005, Hamer 2002.

[224] Nilsson pers. comm.

[225] Björdal & Nilsson 2008.

also shown separately in one of these samples.[226] Finally, the presence of holes made by shipworm in the wood of BZN 15 is evidence that it had been in an aerobic environment some time before sampling, and therefore under direct threat of damage by pyrite oxidation.[227]

3.6.1 Some conclusions on the chemical threats

Different materials and elements may cause chemical reactions when they are combined. This also occurs in and on the seabed. Changes in the environment trigger new reactions that cause a change in the equilibrium that is often found to a varying extent on historic sites.

The most well-known chemical deterioration process is that of corrosion. This is also active in the Wadden Sea, especially with iron in high-oxygen and saline areas. This is the case for objects surfacing the seabed. In low-oxygen conditions, for example in the sediment, the process of corrosion is much less, but may exist, especially under the influence of biological attack by bacteria. This form of corrosion may cause significant problems when wood is salvaged and needs to be conserved. The results of this process have been noted in large conservation projects such as that of the *Vasa* and the *Mary Rose*.

3.7 Human threats

Human threats to underwater cultural heritage (UCH) may be considerable. Human activity can either affect underwater cultural heritage directly or indirectly. An obvious and much debated problem is treasure hunting.[228] This is a direct threat to underwater cultural heritage, as are other forms of commercial salvaging and even opportunistic souvenir hunting by recreational divers. However, while such activities are a severe threat regarding perceptions and opinions of underwater cultural heritage and its preservation in situ, they probably only pose a small direct threat to UCH in general, especially when compared to the multiple other human-induced threats. Other human interventions may very well have much larger effects, sometimes direct, sometimes indirect. One only need consider the debates on the effects of trawling on underwater cultural heritage.[229]

It will be impossible to discuss all forms of human activity that directly or indirectly, immediately or eventually threaten our underwater cultural heritage. Below, I will discuss some examples in relation to the Western Wadden Sea area:

1. Looting, commercial salvaging and souvenir hunting
2. Fishing
3. Dredging and development works
4. Archaeology
5. Perception of significance

3.7.1 Looting, commercial salvaging and souvenir hunting

The primary aim of commercial salvaging is to make money and not to learn more about the past. It is as simple as it is logical, otherwise it would not be commercial salvaging. This fundamental difference leads to – among other issues – different selection criteria and different working methods and techniques, aiming to make profits for a few and not for the benefit of all.[230] Treasure hunting has the aim to – as the name suggests – find valuable treasure. It is usually triggered by the assumed economic value of the archaeological finds. In relation to shipwrecks, these treasures are often associated with precious metals and stones. This hunt for objects of economic value usually leads to commercial salvaging, which has often attracted much attention from the media and thereby sent a different message to the public than that preferred by cultural heritage managers.[231]

However, it is not always easy to make an immediate distinction between treasure hunting, looting and souvenir hunting. They represent a sliding scale. An obvious and clear example of large-scale commercial salvaging on a historic shipwreck in the Netherlands is the HMS *Lutine* (1799).[232] The various activities concerning the salvage of wreck materials have a 200 year history, beginning right after the disaster. This case, therefore, is interesting in the sense that, over the years, salvaging on a site changes from the removal of contemporary objects to compensate the owners of the ship, or for reuse, to commercial salvaging related to cultural heritage and that which aims to salvage a wreck's scrap or economic value.

The salvage of still useful materials has a long tradition. In the Wadden Sea, examples of contemporary salvaging have been archaeologically identified on the Scheurrak SO1 wreck (end of the sixteenth century)[233] and the *Buytensorgh* (1753)[234] (Fig. 3.40). Important archaeological finds, such as the Vasa (1628),

[226] Fors 2005.

[227] Huisman 2005, 199.

[228] Grenier et al. 2006, x–xii. The UNESCO Convention for the Protection of the Underwater Cultural Heritage (Paris, 2001), for example, is still very much focused on the fight against treasure hunting.

[229] Evans, Firth & Staniforth 2009, Tolson & Gerth 2009 and Kingsley 2009.

[230] http://www.bloombergview.com/articles/2014-05-07/treasure-hunting-is-the-world-s-worst-investment (accessed 29-01-2017).

[231] There are many examples of this. See, for example, http://www.dailymail.co.uk/news/article-3101245/Treasure-hunters-believe-gold-stolen-Confederates-Civil-War-worth-2million-Lake-Michigan-shipwreck.html (accessed 29-01-2017).

[232] Hendriksma 2013, Strick 1986, Huiskes & Weerdt (eds) 1999, Molen 1970.

[233] The only part of the portside of the ship that has survived was investigated, removed and conserved. It shows clear axe marks on the frames. The portside was that part of the ship still surfacing the low water mark and must have been cut away to provide access to the ship. Manders 2003 (2), 326.

[234] Braven et al. 2003, 53.

Fig. 3.40 The only surviving piece of the portside of the Scheurrak SO1 wreck. This piece was cut out of the structure, most probably immediately after sinking at the end of the sixteenth century.

were salvaged for cannons immediately after sinking.[235] The HMS *Lutine* had a cargo of gold on board for the Hamburg stock exchange when it sank between Terschelling and Vlieland in 1799,[236] and since then mystery has surrounded the wreckage and its cargo. The first official salvage attempt occurred as early as January 1800,[237] and unofficially, there may have been many more attempts. There are stories of fishermen who attempted to find the gold from the *Lutine*,[238] and there are some indications that these attempts may have been successful one night in October 1799, but this cannot be confirmed.[239] In recent years, research has been conducted on site to gain an understanding of what really happened during that night in October 1799.[240] New plans are being developed.[241]

Commercial salvaging is directed towards making money. The shipwrecks are a resource, a mine exploited to make that money (Fig. 3.41). However, historical and archaeological research may play a role in the process of commercial salvaging, by locating the site of investigation, or by confirming or enhancing stories about a site and in so doing raising the market value of the objects concerned. People are usually more prone to pay higher prices for objects with a context or story. Therefore contextualizing a site may be well important in the commercial exploitation of a site. Although money can be made through the commercial salvaging of shipwrecks, this revenue model is – especially with respect to cultural heritage sites – very doubtful and often fails.[241]

The most significant problem with commercial salvaging may not be the direct disturbance of any particular archaeological site, but how it affects the way people look at – especially – shipwrecks, with a focus on commercial value, which may eventually have an effect on the public perception of the entire underwater resource. This may be much more problematic than any one site being destroyed. Working on wrecks, telling their stories and removing great artefacts does appeal to the general public. However, the real context of the artefacts is often forgotten and the story lacks any scientific basis, with the information or knowledge gained minimal and/or untrustworthy.[243]

Some sites are salvaged purely for their material value. The difference from the above is that here – for the actors involved – the story of the ship is never important and sometimes it is found to be better to remain silent about where the material comes from. Dutch examples of scrap metal salvaging are the *Kerwood* (1919) and the three British warships, the HMS *Aboukir*, HMS *Cressy* and HMS *Hogue* (1914).[244] In the Wadden Sea, bricks,

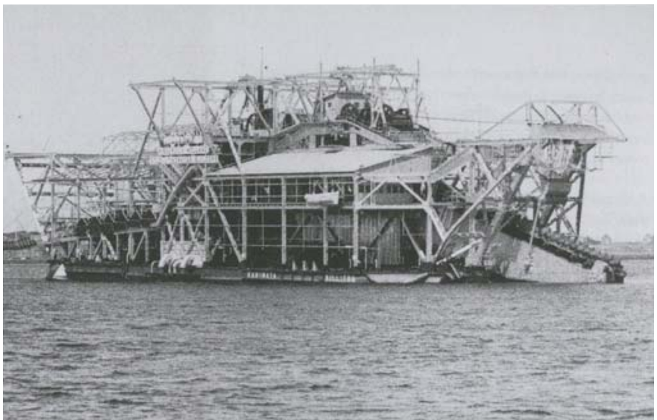

Fig. 3.41 The Karimata, a large tin mill that was used for dredging the Lutine (1799) site in the hope of finding gold bars. Although one bar was found, the mill failed overall, destroying large parts of the still surviving structure of the wreck. Photo: courtesy D. Bruin.

[235] Cederlund 2006, 68–108.

[236] The amount of gold that was on board is unknown and has been debated since the sinking of the ship. See also, Hendriksma 2013, 142ff.

[237] Dieren 1999, 98–99.

[238] See, for example, Hendriksma 2013, 155–156.

[239] See, for example, Strick 1986, but also Hendriksma 2013, 200, Dieren 1999, 95–122.

[240] Duijf & Maarleveld 1999, 123–132.

[241] New project proposals have been delivered to RWS and the RCE to obtain permits for excavation at the supposed wreck site of the HMS Lutine.

[242] http://www.bloombergview.com/articles/2014-05-07/treasure-hunting-is-the-world-s-worst-investment (accessed 29-01-2017).

[243] The information is often untrustworthy because there are different incentives. Money making is the biggest driver, not curiosity. Time is money and the story is a selling point. Objects may illustrate what we already know or they may be deliberately or even unintentionally connected to a wreck because the story has to be enhanced or a shipwreck needs to be identified.

[244] The Kerwood sank in 1919 after it hit a mine. Its copper and lead value and the profits made by salvaging them marked the founding of the salvaging company, Friendship BV, from Terschelling. (http://wrakkenmuseum.nl/kerwood, accessed 29-01-2017). The HMS Aboukir, HMS Cressy and HMS Hogue sank in 1914 after being torpedoed by a German submarine. More than 1400 lost their lives. The wrecks have been salvaged for scrap metal (http://www.worldwar1.co.uk/cressy.htm, accessed 29-01-2017).

leather and tropical hardwood are also known to have been salvaged on a smaller scale, all for reuse.[245]

It can be safely assumed that objects have been removed from all shipwrecks discovered in the Wadden Sea. It is not always bad intentions that initiated such activity. Some of the wrecks are perceived to have been 'saved' from being washed away by currents, after having been exposed by the ongoing erosion of the seabed.[246] Other objects have been dug out, with severe damage to the site as a consequence. Some of these objects find their way to auction houses or websites; others will end up in someone's garage or on their mantelpiece.[247] The looting or souvenir hunting can be so extreme that entire sites are plundered, or at least damaged in such a way that their value can be compromised to a large extent.[248] Objects taken from wreck sites are often removed without considering the context. The loss of context means an object also loses much of its value.[249]

Taking objects from wrecks is not merely something done for financial reasons or to have a souvenir to remember the past. It also concerns the issue of ownership of a site or may at least be an expression of or deliberate evidence that a diver has been there. This territoriality can occur on a private or group level.[250] This intrinsic claim of ownership has a long tradition along the Dutch Wadden Sea coast[251] and may explain the hesitance of people from the Dutch Wadden Islands to report their finds or involve the national government in shipwreck management in the Wadden Sea.[252] Undermining the in-situ protection of shipwrecks such as the BZN 3 may thus be seen as a local response to activities undertaken by the central authorities; in other words, a warning not to interfere with their history and past, which is claimed to be the exclusive right of the inhabitants themselves.[253]

Before the 2007 Monuments Law was implemented,[254] much heritage management was indeed organized centrally. Today, municipalities are at the forefront of organizing the management of their cultural heritage. This means that there is a logical basis for this behaviour. Cultural heritage management can be decentralized and municipalities can prioritize what they protect

[245] See, for example, http://www.leerbewerken-texel.nl/nl-300jaaroudleer.html (accessed 29-01-2017).

[246] See, for example, the attempts of the Municipality of Texel to grant permission to the amateur archaeologists of the island to salvage objects from sites if they believe these will be lost or destroyed due to natural erosion. For this reason, in November 2015, a pilot was started by signing a cooperation agreement between the Municipality of Texel, the Cultural Heritage Agency of the Netherlands, the Ministry of Education, Culture and Science, the Province of North Holland and the sports divers of Dive Team Texel. More about this pilot project can be found on http://maritiem-nieuws.nl/69229/pilot-voor-behoud-archeologisch-erfgoed-texelse-zeebodem-2/ (accessed 29-01-2017) or http://archeologieinnederland.nl/nieuws/pilot-van-start-voor-behoud-archeologisch-erfgoed-texelse-zeebodem (accessed 29-01-2017).

[247] In principle, good developments consists of the establishment of private museums and participation in public museums. For example, the establishment of the Wrakkenmuseum on Terschelling and the Kaap Skil Museum van Jutters en Zeelui on Texel. See, for example, Kleij 1991.

[248] One such example is the wreck of the Kursk, a trader from DFDS that sank in 1912 on its way from Antwerp to St Petersburg with a cargo of Baccarat Crystal and a national gift from the French to the Russians to commemorate the battle of Borodino (1812). See, for some studies on the effect of avocational diving on shipwrecks in the Baltic Sea, also Olsson 2009 and Hansson 2009.

[249] There is even evidence of providing false context to objects. Some sites in the Wadden Sea have been named incorrectly and all of the objects taken from the site have been related by the local community to that particular historical ship. See, for example, the incorrectly identified VOC ship De Lelie (BZN 8 and 10) and the 'Orangewoudt'; see the movie Vergaan Oranjewoudt in 1757 bij Texel by Enting Films 2014). Sometimes, after many years, objects from different wrecks are mixed up.

[250] Vero Copner Wynne-Edwards suggested that territoriality operates in order to control population size. Julian Edney, a psychologist from Arizona State University, described Wynne-Edwards's hypothesis in this way:
'(T)erritoriality is a link between social behaviour (competition and dominance) and population control in many animals. Communities regulate their own numbers by the use of "conventionalized" competition, usually among males, for territory and the accompanying rights to food and (sometimes) mates. The winners are dominant animals and acquire social status, but since they are a fraction of the population, only a few community members get access to space, scarce resources, and females, thus limiting the size of the next generation. The next generation is also guaranteed food, because winners of territory spread themselves thinly over the terrain. Thus the habitat's food sources are not exploited beyond regenerative capacity, and a reasonable supply is ensured for the future'. Taken from: https://blogs.scientificamerican.com/thoughtful-animal/defending-your-territory-is-peeing-on-the-wall-just-for-the-dogs/ (accessed 29-03-2017). For an example of this behaviour, see: http://visserijnieuws.punt.nl/content/2006/06/dode-bij-ongeval-met-kotter (accessed 29-01-2017).

[251] See, for example, Molen 1978, 106-137.

[252] This has been observed several times, with the most recent example being the discovery of the BZN 17 wreck and the objects that have been removed from it. The fear that the central government is not doing enough to research and preserve the sites – and the question of whether in-situ protection is useful – led to a meeting with the mayor of Texel on 24 February 2015.

[253] One subject of research in the Maritime Programme of the RCE includes understanding the perceptions of avocational divers and municipalities regarding the national government and the RCE. In the light of the decentralization of heritage management to a local level, it is important to evaluate the current positions and roles of the different stakeholders.

[254] This is the Monuments Law of 1988, with the implementation of the Treaty of Valletta (Wet op de Archeologische Monumentenzorg 2007) (http://www.omgevingindepraktijk.nl/sites/default/files/bestanden/Erfgoed/RV-1a-Monumentenwet%201988.pdf, accessed 29-01-2017). Since July 2016, a new Heritage act has been in place (http://wetten.overheid.nl/BWBR0037521/2016-07-01, accessed 4-1-2017).

and what not.[255] Nevertheless, people are still required to report their finds[256] and intrusive activities are prohibited without an excavation permit.[257] Until the new Heritage act was implemented in July 2016, it proved very difficult to effectively enforce the law. One of the main issues was that those appealing to the law have to prove that intrusive activities have occurred on a shipwreck. The seabed is very dynamic and although excavating objects without a permit was made illegal it was not prohibited to remove finds from the seabed surface. Illegal excavation could only be proven if it was visually observed.[258] This has changed in the new Heritage act, which came into force on 1 July 2016.[259] It is now sufficient to prove that the sites are being disturbed. The removal of objects from a site is also considered to be an act of disturbance, as is cutting the protection nets. Will this simple change of wording in the new law be sufficient to preserve and protect? This will have to be proved in the coming years. Not being able to enforce the Heritage act forms a major threat to the cultural heritage on the seabed, which we have seen in the past.[260]

3.7.2 Farming and fishing

Tension may arise between the use of the sea for farming and fishing and cultural heritage. The Wadden Sea has long been used as a source of food. Fish and shells are important resources. In earlier times, until the early twentieth century, seagrass (*Zostera marina* and *noltii*) grew in large fields on the seabed and was harvested for mattresses and dikes.[261] This seagrass disappeared in the Dutch Wadden Sea[262] due to disease[263] and the closing of the Afsluitdijk in 1932. Today, replanting of the species is being tested.[264] In addition to its attractiveness for sea life and water clarity, seagrass may also make the seabed less susceptible to erosion, just as the artificial seagrass on the BZN 10 site does at the moment.[265]

The most important commercial shells in the Wadden Sea are the common cockle (*Cerastoderma edule*) and the mussel (*Mytilus edulis*). The mechanical fishery of common cockle in the Wadden Sea area has been fiercely debated, resulting in this form of fishery being prohibited in 2005.[266] The method of fishing was very intrusive on the top layer of the seabed and although its negative effect on the population of cockles was disputed, the method had a negative effect on the cultural heritage in the seabed. [267]

The Wadden Sea is also an important area for mussels. Of all the mussels traded at the Dutch fish auction centres, 50% come from the Wadden Sea.[268] In addition, an enormous number of mussel seeds are harvested, caught and bred. The mussel fields stabilize the seabed and form a kind of natural protection against erosion of the seabed.[269] However, harvesting the mussels and mussel seeds from the seabed is harmful to the upper layer.[270] Again, this may also threaten those wrecks that are surfacing the seabed. Mussel seed capture installations (MZI) have now been designed to catch seed mussels from the water. This should be less intrusive than fishing for them from the seabed. However, MZIs may have other negative effects on the wrecks or other cultural heritage that might possibly be present in the seabed.

There are at least two ways to construct MZIs. There are floating models that are secured in place with anchors or concrete blocks on the seabed, and fixed MZIs, which are attached to poles that are driven into the seabed. The latter is most intrusive and poses a real threat to cultural heritage in the sediment.[271] For a few years, the floating version was preferred by the Cultural Heritage Agency of the Netherlands (RCE), which gave approval to operate in such a way. Unfortunately, however, in the dynamic Wadden Sea, the anchors proved not to be strong enough, and in 2014, the mussel seed farmers decided to use the fixed method (Fig. 3.42).[272] In addition to the intrusive driving of the poles into the seabed, the question of whether the fixed method also has a negative effect on erosion-sedimentation patterns on the seabed is still the subject of research. Monitoring of the areas

[255] With the new Heritage act that came into force in 2016, the roles of municipalities have become even greater.

[256] There was, unfortunately, no date attached to the report. Article 53, Monuments Law 1988 and Article 5.10 in the Heritage act of 2016. See also, http://archeologiein-nederland.nl/omgaan-met-archeologie/vondsten-melden (accessed 4-1-2017).

[257] Article 45-48 Monuments Law 1988.

[258] See, for example, the case of the Kursk, mentioned above.

[259] https://cultureelerfgoed.nl/dossiers/erfgoedwet (accessed 29-01-2017).

[260] See, for example, the problems with law enforcement on the three English warships in the North Sea: http://www.dailymail.co.uk/news/article-2042294/Dutch-vessels-ransack-sunken-British-warships-containing-bodies-1-500-sailors-scrap-metal.html (accessed 04-02-2017). A discussion on the 'Duikforum' clearly shows that law enforcement on underwater sites will be extremely difficult and will need to include a change in mentality by many wreck divers as well: https://www.duikforum.nl/forum/duiken/wrakduiken/47931-regels-voor-wrakduikers-die-souveniers-van-wrakken-meenemen (accessed 08-04-2017).

[261] Bos & Katwijk 2005, 9.

[262] Except for a small population near the Eems. Bos & Katwijk 2005, 18, 21.

[263] Bos & Katwijk 9.

[264] See Bos & Katwijk 2005, Heide et al. 2006.

[265] For artificial seagrass on BZN 10, see Section 3.3.

[266] https://www.sp.nl/opinie/krista-van-velzen/2003/verbied-mechanische-kokkel-visserij (accessed 29-01-2017).

[267] http://www.trouw.nl/tr/nl/4492/Nederland/article/detail/1362959/2007/03/06/Geen-negatief-effect-mechanische-kokkelvisserij.dhtml (accessed 29-01-2017).

[268] http://www.waddenzee.nl/Mosselvisserij.1913.0.html (accessed 2-7-2015)

[269] This may also have a positive effect on the growth of natural seagrass in the Wadden Sea.

[270] Bos & Katwijk 2005, 9(http://www.waddenacademie.nl/fileadmin/inhoud/pdf/02_taken/kennisagendarapporten/2011-02_Clear_as_Mud_webversie.pdf, accessed 29-01-2017).

[271] Waldus et al. 2009, 5.

[272] This has not been approved by the RCE. At the time of writing, the discussion between the RCE and the Ministry of I&M is ongoing.

Fig. 3.42 The Burgzand area with mussel seed installations (MZIs) in the background. Photo: M. Manders.

with multibeam sonar before the installation and after the poles have been taken out of the sediment do not show significant changes in the seabed surface.[273] Another risk related to the use of MZIs that should be further investigated is growth in the amount of organic carbon (C) on the seabed after installation of large MZIs.[274] This may cause more bacteriological attacks on the wooden shipwreck structures in the sediment.

A possible synergy between underwater cultural heritage and mussel cultivation has been proposed, with the idea of using in-situ preserved shipwrecks as places to install these MZIs.[275]

In the Western Wadden Sea, several types of fishing occur. Most forms of fishery are prohibited on the tidal flats,[276] but in other areas, which are often subject to seabed erosion and which include wrecks that are surfacing the seabed, trawling for shrimp or flatfish continues.[277] The trawling nets disturb the seabed directly and may become entangled in the wooden constructions

Fig. 3.43 Sumwing trawling gear. Photo: Paul Voorthuis, Highzone Fotografie.

of wrecks, with consequent damage to these sites.[278] In-situ protection by covering a site with polypropylene nets mitigates against threats by trawling, as they transform the site into a sloping artificial reef which the nets pass over (see Chapter 5.2.3). New bottom-trawling methods have also decreased the impact of such nets on the seabed (Fig. 3.43).[279] On a worldwide scale, deep sea trawling is considered to be one of the most damaging human activities with respect to underwater cultural heritage.[280]

3.7.3 Dredging and development works

It is clear that although the Western Wadden Sea is part of a UNESCO World Heritage site, the system is under considerable pressure from human use and exploitation. This also has an impact on sediment dynamics. These anthropogenic pressures and influences include many different activities, such as the above-mentioned salvaging, farming and fishing (Fig. 3.44 A B C). There is also still considerable dredging occurring to maintain the waterways.[281] These areas, however, are usually already disturbed to a certain depth and as long as those maximum depths and areas are recognized, there seems to be not much risk of additional disturbance to existing cultural heritage sites. However, harbours must be accessible to ships whose sizes are ever-increasing. This increases the pressure to dredge deeper channels, with consequences for hidden cultural heritage resources. Moreover, the introduction of larger ships may lead to the disturbance of the seabed and the introduction of more oxygen into the water locally, due to propeller movement.

As we know, the closure of the former Zuiderzee by the Afsluitdijk in 1932 and also the Lauwerszee in 1968, changed the dynamics of the Wadden Sea; for example, the tidal amplitude and fine sediment dynamics were affected. The system is still finding a new equilibrium, with substantial morphological changes as a result.[282] A similar kind of effect has occurred due to the fixing of

[273] Brenk & Van Lil 2016.

[274] Kamermans et al. 2008, 5.

[275] KustMail 2007, 8.

[276] Among which, some of the most stable places, see http://www.rli.nl/publicaties/2007/advies/natuurlijk-vissen-op-de-waddenzee (accessed 29-01-2017).

[277] See https://zoek.officielebekendmakingen.nl/kst-26431-94.html (accessed 29-01-2017).

[278] In the early 2000s, the fish auction (*visafslag*) in Wieringen notified the RCE that a frame of an old shipwreck with a label from the AAO (Afdeling Archeologie Onderwater, the department of underwater archaeology of the Ministry of WVC, the predecessor of the RCE) was brought in by one of the trawlers. It turned out to be from the BZN 10 site.

[279] http://www.sumwing.nl/ (accessed 29-01-2017).

[280] Evans et al. 2009, Kingsley 2012.

[281] Arcadis 2011.

[282] See also Wang et al. 2012.

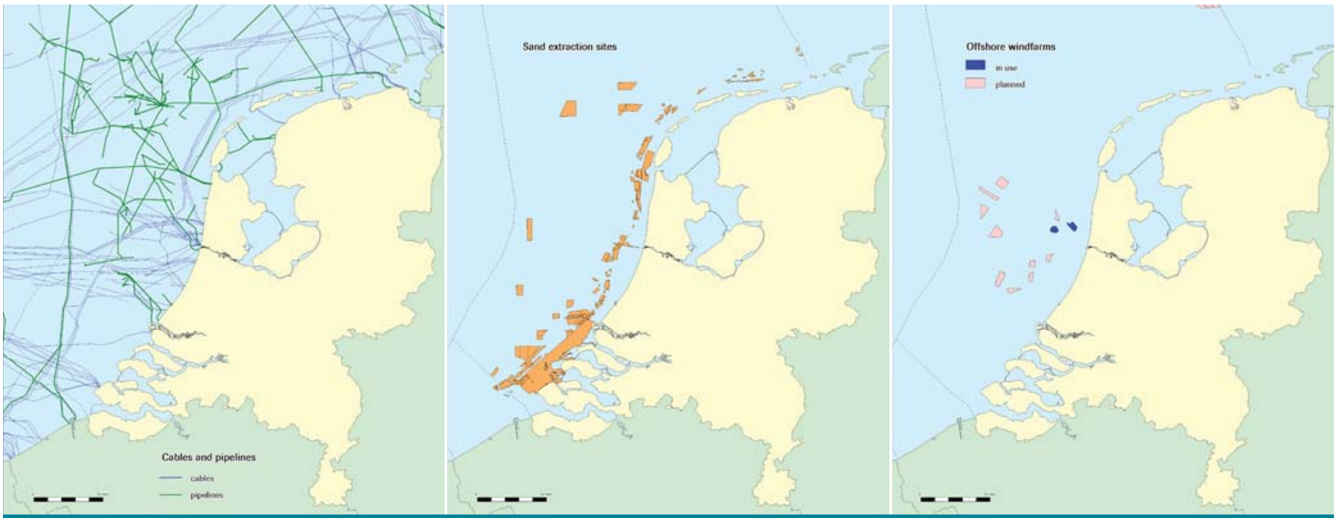

Fig. 3.44 Several kinds of human threat to the seabed: A. Cables and pipelines, B. Sand extraction sites, C. Offshore windfarms. Figures: courtesy Periplus Archeomare/RCE.

the island coastlines using dikes, which do not allow the coastlines to move and form naturally. In addition, gas and salt extraction from deep layers underneath the Wadden Sea basin are causing subsidence and increased demand for sediment.[283]

3.7.4 Archaeology

Archaeologists may also pose a threat to the underwater cultural heritage, especially when research is executed incorrectly, which may result in the immediate physical deterioration of the site. A direct and obvious effect is the careless movement of divers in and around a wreck. This may result in damage to or the uncovering of artefacts, but also the breaking off of structural elements of the shipwreck. The chances of something such as this occurring are particularly great when such elements are also weakened due to biological, other mechanical or chemical deterioration. However, the uncovering of a site for investigation may also be the cause of further erosion, due to the changing of local eddy currents and the scouring of, or attack by, degrading animals such as shipworm. The effects can also be negative in the longer term. Firstly, oxygen will be introduced to elements that were previously covered and bioturbation may have an effect on those layers that have been sufficiently covered before. Secondly, poor re-burial of the site with sediment may result in the deterioration of areas that have been stable for centuries.[284]

Another large threat that archaeologists may pose is excavating without any prior plan or research question. Requirements for responsible intrusive research have been listed in the ICOMOS charter on the protection and management of the Underwater Cultural Heritage (Sofia 1996) and the UNESCO Convention on the Protection of the Underwater Cultural Heritage (Paris 2001). Without clear and well-founded research questions, we will not know if the excavation of a particular site is of value, and the project will certainly lack direction.[285] Archaeology would be reduced to *Lustgrabung*, keeping us busy, without learning from this material source.[286]

3.7.5 Perceptions threatening underwater cultural heritage

As the name suggests, underwater cultural heritage lies hidden under water. Out of sight may be out of mind.[287] The Wadden Sea is not a popular sports diving place. Low visibility under water, tidal flow and better alternatives nearby (e.g. the North Sea) are three important reasons why this is the case.[288] At present, it still remains difficult to visualize underwater shipwrecks and make them accessible to the non-diving public (See Chapter 7).[289] Visual contact, therefore, almost exclusively remains possible by a site visit. This also directly reflects on the way local governments take up their responsibility for underwater cultural heritage management. At present, very few municipalities have included their underwater territory in heritage policy maps.[290] This may pose a threat, since this heritage may not be taken into account in development planning.

Decentralization of cultural heritage management has the advantage that municipalities become more aware of their responsibilities for managing the whole spectrum of cultural heritage, including the underwater element, but the high costs may become an issue. Archaeological management, in general, is seen as a high financial risk, where the cost factor is of more importance than the knowledge that can be gained.[291] In addition, although positive in the sense of more awareness and involve-

[283] Duren et al. 2011, 8.

[284] This process of degradation was noted at the shipwreck site of the *Ranger* in Port Royal (Jamaica) during the UNESCO foundation course on underwater cultural heritage, which was held in 2012 (http://www.unesco.org/new/en/culture/themes/underwater-cultural-heritage/education/capacity-building/, accessed 29-01-2017), and on the OVM 8 shipwreck in Lake Oostvoorne in the Netherlands in 2014.

[285] Questions need to be answered using specific methods.

[286] *Lustgrabung* is the German word for undertaking an excavation without any focus, in the hope of finding something special.

[287] Gregory 2009, Kingsley 2012.

[288] Meulen et al. 2012.

[289] Although big steps are being taken using new technologies for mapping the seabed (see also Chapter 2), including 3D photography (Skarlatos et al. 2012) and even 3D printing (http://www.aima-underwater.org.au/uploads/52708/ufiles/AIMA_Newsletters/NLv32n4y13.pdf, accessed 29-01-2017).

[290] According to the Erfgoed Monitor (Heritage Monitor) 2013, 27% of the municipalities have declared they have included underwater cultural heritage in their heritage policy maps (http://cultureelerfgoed.nl/publicaties/erfgoedmonitor. Accessed 29-01-2017). Unselective testing by the Maritime Programme of the RCE, however, revealed that this percentage may be a bit high.

[291] See http://www.binnenlandsbestuur.nl/ruimte-en-milieu/achtergrond/achtergrond/bodemschat-is-kostenpost.9462527.lynkx (accessed 29-01-2017).

ment, decentralization also means more power to local stakeholders with different views on how to treat cultural heritage.[292] This requires a different role for state services and their archaeologists. They will need to change their role from being the decision-makers to becoming providers of guidance in the process of significance assessment and selection of sites.[293]

One important aspect to overcome is the biased view on in-situ preservation. While official institutes, backed up by official laws and policies 'preach' in-situ preservation as the first option, the public wants to see and feel its past.[294] Although there is something to say for both points of view, and both can also coexist, government budgets and activities are not always in line with responsible in-situ preservation policy.[295] For industrial parties, contractors, entrepreneurs and many municipalities, archaeology has therefore primarily become an expense issue and restrictor of development.[296]

3.7.6 Some conclusions on human threats

The human or anthropogenic threat is potentially great. Some of the threats are direct and obvious, and their impact can easily be understood and measured. However, human activities and interventions may also affect underwater cultural heritage many years, decades or even centuries after the fact. The Wadden Sea is one of the most diked seas in the world. In addition to the building of the Afsluitdijk, this general use of dikes has led to a change in erosion-sedimentation patterns and thus the mechanical deterioration of underwater cultural heritage over a long period of time. Salvaging, farming, fishing and dredging have all had a direct effect by disturbing the seabed, as well as an effect over the long run, by causing a change in scour or erosion patterns around shipwrecks and other features. Even archaeologists may cause unintended damage due to improper handling or due to no or poor treatment of the site after exploration. Unfortunately, due to the delay in effects, it is often difficult to hold the original disturber accountable (financially or otherwise) for the degradation of underwater cultural heritage. Finally, the lack of interest in underwater cultural heritage may also lead to neglect of the resource.

3.8 General conclusions on threats

There are many processes that threaten underwater cultural heritage. Any change in the environment is generally not good, as underwater cultural heritage thrives better under stable conditions. Cultural heritage managers study 'change over time' and attempt to avoid or mitigate against it. The threats can generally be divided into mechanical, biological, chemical and human grounds of deterioration. All these processes are interlinked and may enhance individual effects. Erosion, especially, is a big threat in the Wadden Sea. This process is a catalyst for biological and human activities on site. The greatest biological threat is shipworm (*Teredo navalis*). In effect, it can destroy wood that surfaces the seabed within one year. If the site becomes anaerobic, only erosion bacteria remain active. This is an ongoing but slow process of deterioration. Treasure and souvenir hunting pose obvious threats to underwater cultural heritage; however, the use of the seabed for farming and fishing may well pose the biggest threat.

It is important to better understand the different processes of deterioration, both on site and on a larger scale, in order to find ways to mitigate against threats using the best in-situ preservation methods. Some threats may be easily identified because they have a direct and obvious effect. However, some may result in the gradual damage to the underwater cultural heritage over decades or even hundreds of years. These effects have to be taken into consideration when protecting a site in situ. One example is climate change but, on a smaller scale, there may be numerous effects of a newly built bridge, a wind farm, a dike or sand extraction on current patterns and gullies on the seabed, which may result in the erosion of newly exposed sites.

It is impossible to hold the builders of the Afsluitdijk (1932) responsible for the damage this construction causes to historic shipwrecks in the Wadden Sea, even if this is at least partly true. However, on the basis of a more sound understanding of the processes and their long-term effects, heritage management decisions may be better made. People's perceptions are also important when aiming to better preserve underwater cultural heritage. One enormous disadvantage for underwater cultural heritage is the fact that it is generally not visible, or barely so, especially in the Wadden Sea. It is not always easy to see the advantages of having such a rich resource that can tell us about our past within one's territorial boundaries.

While the implementation of the Treaty of Valletta has led to a growth in archaeological activities, the system leans heavily (if not completely) on the 'disturber pays' principle. Determining who is responsible for destroying an underwater archaeological site is not always simple, while the damage may also be due to effects continuing for decades or even centuries. Those responsible for overall management do not have the financial resources to pay for activities to preserve in situ or ex situ: all in all this means we face a complex situation of a heritage under threat. However, it

[292] Manders 2015 (2).

[293] Manders 2015 (2).

[294] Willems 2012, 4–5.

[295] At present, there is no permanent budget available for in-situ protection and monitoring by the Cultural Heritage Agency of the Netherlands.

[296] http://www.binnenlandsbestuur.nl/ruimte-en-milieu/achtergrond/achtergrond/bodemschat-is-kostenpost.9462527.lynkx (accessed 29-01-2017).

may be worthwhile to make the effort to continue to embrace the principle of in-situ preservation as an important part of underwater cultural heritage management (See also Fig 1.8). It will not be easy, but as I will argue in the coming chapters, there are many reasons to at least try.

4. Why preserve underwater heritage in situ?

Fig. 4.1 Monument label on the BZN 3 site.

4. Why preserve underwater heritage in situ?

4.1 Introduction

As described above, the underwater cultural heritage is constantly under threat. Some areas with strong currents and tidal movements, for example, may be more hostile to underwater cultural heritage than others. As we have seen in the previous chapters, the Wadden Sea is a hostile area. Seabed erosion, abrasion, biological attack by shipworm, fungi and bacteria, and on top of all this, the multiple threats caused by humans, all occur in this area. However, it is possible to take action to mitigate these threats, as part of a responsible management strategy. In recent years, it has become increasingly common practice to manage the underwater cultural resource in a more holistic manner; for example, to treat the resource as a whole, with a view to the future, and in a proactive way, keeping in mind the different values that a site may have to various actors.

Excavations are carried out according to both national and international standards in many countries in the world,[1] with the intention to not spoil this finite resource or allow it to disappear without proper data collection. Archaeological excavation is a method of ex-situ preservation of data. The knowledge about wrecks in the Wadden Sea and in the context of the Wadden Sea – considered as both an important natural environment and cultural context – has increased considerably due to research ranging from sampling to full-scale excavation, and even integral landscape approaches dealing with multiple sites at the same time. In addition, sites that have not been excavated are protected and managed in situ.[2] The basic reason for this is often universal and applicable to terrestrial as well as underwater sites. The desire to protect underwater heritage exists: sites are preserved in often extremely good conditions, but are still under threat (Chapter 1, 2 and 3). Some sites are representative of specific elements of Dutch history, and although perhaps not directly visible to the community at large, are highly visible to specific stakeholder groups, such as the sports divers that do dive the Wadden Sea (and are often strong voiced), to be enjoyed as recreational objects (see Chapter 7).

Current international standards state that in-situ preservation is the first option to be considered when managing a site.[3] However, what is the reason for this? Why not consider excavation first and foremost?

Before we attempt to answer this question from a cultural heritage management perspective, we must ask ourselves what 'in-situ preservation' of underwater heritage sites means. Is it – as is often said – 'brushing sites under the carpet (of sand)'? Or does it serve a higher goal? And also: Can we really physically protect underwater sites from identified threats?

This chapter starts by outlining a general idea of what in-situ preservation and protection mean. This will be followed by an answer to the question of why we should undertake the in-situ preservation of our underwater cultural heritage sites, while also considering the reasons why this might not be preferable.

4.2 What is an in-situ site and what is part of it?

In archaeology, 'in situ' means 'the original place of deposition'.[4] However, there are no defined rules about how 'original' this deposition should be. Is it the first deposition, or a deposition (with subsequent related processes) of a later date? As Schiffer (1985) asked: Is it a primary, secondary or de facto refuse?[5] A 'primary refuse' may, for example, have led to reuse or redepositioning. After deposition, post-depositional processes (de facto refuse) alter the place and the objects in it. It is extremely rare to find an archaeological site which a community suddenly ceased to inhabit[6] at one point in time, and impossible to find one that has not been altered through post-depositional processes.[7] This is no different for underwater sites, as we have seen in previous chapters. While following the definition of 'in situ' as the 'original place of deposition' may give us some headaches in determining whether originality is primary, secondary or de facto, in this thesis, 'in situ' will simply be defined as the place where we discover the cultural material in or on the seabed.

Another issue concerns what 'belongs' to the site and what we want to preserve or restore. Are we selectively attempting to preserve the original status of sites at the time of deposition (which is basically impossible)? Or are we attempting to preserve the current situation, including the post-depositional processes,

[1] In the Netherlands, archaeological research must be executed according to the Dutch Quality Standards for Archaeology (KNA, Kwaliteits Norm Archeologie: Willems & Brandt 2004). International reference to the Annex of the UNESCO Convention on the Protection of Underwater Cultural Heritage (Paris, 2001). The Annex is a 'Code of Good Practice'.

[2] While doing research for this thesis, I noticed that the archaeological dictionaries *Archeologische termen en technieken*, Champion et al. 1981 and the MacMillan *Dictionary of Archaeology*, Whitehouse 1983, do not even mention the concept and definition of in-situ preservation.

[3] The ICOMOS Charter on the Protection and Management of Underwater Cultural Heritage (Sofia, 1996). Convention on the Protection of the Underwater Cultural Heritage (Paris, 2001); European Convention on the Protection of the Archaeological Heritage (Valletta, 1992).

[4] See, for example: http://www.unesco.org/new/en/culture/themes/underwater-cultural-heritage/protection/in situ-protection/ (accessed 2-7-2015)

[5] Schiffer 1985, Binford 1981, 203.

[6] Binford 1981, 196.

[7] These post-depositional processes may be very strong or very weak, but a site and the material of which it consists will, for example, always be subject to degradation processes. As Binford puts it: 'The archaeological record is the disorganized arrangement of matter regularly generated after the point of time' ... 'The archaeological record is ravaged by time and needs to be treated as such rather than as a preserved past', Binford 1981, 196.

hence the 'full' story of the site? This decision may remain part of the process of assessment by an expert (expert judgement) as there is no straightforward answer. Changes have occurred and 'gaps' concerning what has happened in the past also appear. The above issues, which have become known in the archaeological literature as the 'Pompeii premise' debate, have been extensively discussed by two archaeologists in particular – Michael Schiffer and Lewis Binford.

The Pompeii premise debate reflects on the way archaeologists formerly treated their finds as if they were moments frozen in time, similar to the ancient city of Pompeii, which in 79 AD was covered with hot volcanic ash leaving the site 'frozen' in an instant. The premise has two basic assumptions: first, that items found by archaeologists have been placed there by the last historical actor of the living system under study, and second, that these items mirror the activities that took place in the area in which they are now found.

We must keep in mind that the discussion of the Pompeii premise was provoked by the archaeological analyses of terrestrial and continuous habitation sites and was not systematically related to shipwrecks located under water. Binford stated that the 'Pompeii premise is important only if one adopts a strict inductive approach to the archaeological record, expecting to uncover archaeological facts with self-evident meaning for the past'[8] and 'Pompeii is only ideal for one interested in events, specific behaviours and event-centred "history"'.[9] This is, however, largely what research on individual shipwrecks quite often concerns. Shipwrecks, and their 'primary refuse', are matters of a specific event (the sinking of the ship as a singular event), considered to be due to specific behaviour (erroneous navigation or a battle at sea) and are thus seen as part of an event-centred history. Of course, we can think of many exceptions; a ship or shipwreck may have been reused, for example, as a ship barrier and been subject to post-depositional processes. Nevertheless, at first sight, Pompeii-like sites may appear more often under water than on land.[10]

However, Binford is also right in stating that we 'must understand the archaeological record in the state in which it is available to us'[11] and that '[t]he challenge is how to use the "distorted" stuff',[12] because –although shipwrecks often represent the materialization of a 'unique event' – processes of deposition always change the original situation. The ability to reconstruct the past depends on how we interpret what has remained through time, distorted by all sorts of human and natural processes known as 'N-Transforms' (natural transformations) and 'C-Transforms' (cultural transformations), as defined by Schiffer.[13]

When we look once more at the influential definitions of 'archaeology', they all entail reference to an effort to reconstruct past life and behaviour through material relics or resources.[14] Essential to this is a thorough understanding of post-depositional processes that have occurred on a site, as they are also part of the site's history and may be caused by natural processes or human activity.[15] A concern for the effects of natural or human-induced changes to and interventions in the landscape on individual sites is reflected in the current change of perceptions in underwater archaeology, which does not focus on singular sites, but on archaeological landscapes and their development and value through time.[16] A landscape approach, however, entails the issue of where a site begins and ends and thus also whether it is acceptable to preserve sites completely or only partly. How often

[8] Binford 1981, 198.

[9] Binford 1981, 205.

[10] See also the examples in Chapter 1.

[11] Binford 1981, 205.

[12] Binford 1981, 205.

[13] Schiffer 1973, 25–29.

[14] See Chapter 2.

[15] Binford (1981) and Schiffer (1985) both talk about cultural formation processes (C-transforms) and non-cultural formation processes (N-transforms). A wreckage may cause sedimentation or erosion in new places, which may have led to different use of the environment in the past, such as the opening of new waterways, dredging for a new harbour or reclaiming land. Also, the salvage history of a shipwreck may be an important part of the site's history. See, for example, the salvage history of the Lutine (1799), lying between Vlieland and Terschelling in the Netherlands, Strick 1986, Huiskes & De Weerdt (eds) 1999 and Hendriksma 2013.

[16] There are many examples of combined strategies to investigate archaeological sites in the wider context of cultural landscapes that demonstrate their added value. Natural and cultural developments, as well as intangible issues such as ideology and geopolitical strategies, have an influence on land or seascapes of war and can be much better researched in a wider context rather than being addressed site by site (see, for example: laarse-rob-van-der--carr-gilly---landscapes-of-war-trauma-and-occupation-painful-heritage-and-memory.pdf (accessed 20-6-2014)). A specific example is Scapa Flow on the Orkney Islands. This natural anchor site had been recommended as a Royal Naval Anchorage in the early nineteenth century. On the outbreak of the First World War, it became the home for the Grand Fleet and coastal defence batteries were built, as well as other defences at the entrance to prevent enemy ships or submarines entering the waters of Scapa Flow. As part of the Armistice agreement, Germany had to surrender most of its fleet. However, the 74 ships interned at Scapa Flow in November 1918 were scuttled by their captains on 21 June 1919. Of the 52 ships that went down, 7 remain. In the Second World War, the Home Fleet of the British Navy returned to Scapa Flow, but due to poor defences the HMS *Royal Oak* was sunk by the German U-47 on 14 October 1939. This triggered the strengthening of defences on land, as well as in the water with the Churchill Barriers. Anti-aircraft guns were installed on shore as well as on the ships that protected the anchorage from air attack, making it safer. Some of the war's major naval actions commenced from Scapa Flow, and the area is now a significant maritime cultural landscape with sites on land as well as under water. Although the individual sites date back to the two world wars, they can be interlinked with each other through the history of the place. The sites are material witnesses of ideological and geopolitical strategies and activities. See also: http://www.scapaflowwrecks.com/ (accessed 20-6-2014).

is a wreck site considered to consist of only the visual constructural elements of the former ship and not the surrounding seabed, even when cultural materials are scattered around, or when the former ship appears to be part of a barrier or related to the historic filling of an area?[17] Here we encounter a complex issue. Ultimately, worldwide, large areas and whole regions are linked by ships, sea routes and maritime cultural landscapes.[18] The boundaries, therefore, must and will be determined by many factors, such as geological elements, and historical and administrative boundaries and the questions raised in research.[19]

Questions such as 'What should be preserved and protected and what not?' and 'What is worth preserving?' are difficult to answer from more encompassing geographical and temporal perspectives. 'Are we focusing on the well-preserved heritage of a specific period or are we interested in the long sequence of use, with its subsequent changes and landscape transformations – a layered heritage?' This question arises, for example, when we think of protecting the Burgzand area as a whole. Is it because of its significance as a roadstead in general; that is, of understanding a past cultural system? Or perhaps we are only concerned about the Dutch Golden Age? Or are we interested in the area as a whole and over the long term, with its uses by communities from prehistory to modern times? In other words, what belongs to the narratives we want to investigate and/or keep and what not?

These questions form the basis of significance assessments, which determine selection and deselection. Such assessments should be an important tool in overall heritage management, for which many government institutes are responsible.[20] Although selections happen (for example to become a national monument), in practice not many underwater sites have been explicitly deselected. Primarily, this is because few underwater sites have undergone the extensive research required for such an archaeological significance assessment. Implicitly, sites are often not further investigated by the cultural heritage officers responsible due to the expected low archaeo-logical value. Thus, there might be a lot to gain by making these implicit choices more explicit. The practice of deselecting is thus more common in terrestrial archaeology,[21] and means that no further protection or action is undertaken by the authorities. However, this may offer opportunities for others to become involved in archaeological research on site. What these others (other than archaeologists and cultural heritage managers) would like to do with a site depends on the value they attach to the site or the area.[22]

What archaeologists, cultural heritage managers or other stakeholders involved would like to investigate, preserve or use in another way, ultimately depends on which value prevails for the specific stakeholder group.[23] It is not a given, but determined by those who wish to 'use' it. This also implies that one site may have various values, promoted by different stakeholders.

4.3 Different views on in-situ preservation

Between different stakeholders, and certainly also among cultural heritage managers and archaeologists, the terms 'in-situ protection', 'preservation' and 'conservation' have been – and are – often used in an interchangeable but narrow way. It is not always easy to understand the difference (See also Chapter 1.7.2). The reason for the initial widespread acceptance of the Valletta Treaty in Europe by archaeologists and politicians may lie in the fact that for many stakeholders the words may have been the same, but the meaning they gave them and intentions they had may have been different. When in-situ preservation – as well as protection and conservation – is interpreted as 'brushing sites under the carpet' and 'out of sight is out of mind', or more diplomatically, 'leaving sites where they are' without any further action, it becomes clear that this may be considered the 'cheaper' option, and of interest to those who are liable to pay.

Conversely, associating in-situ preservation with responsible management, less destruction of the resources than before, and more job opportunities financed outside the public system, this seems not only to be the more responsible form of management and a more sustainable use of resources, but also to offer more security for jobs into the future. For academic archaeologists, however, in-situ management may seem like the shutting down of opportunities to learn about the past by undertaking intrusive research on site.

[17] One example is the ship barrier in Greiffswald (Belasus 2009, 93-98).

[18] We can look far beyond administrative borders and see the world being connected. Ships were the essential connectors in the grain trade from Western Europe and the Baltic, connecting countries such as the Netherlands, Denmark and Poland directly. A larger network of European trade, expanding this – for the Netherlands, 'mother trade' – further with the 'doorgaende vaart' to France, Portugal and the Mediterranean.

[19] From a Dutch perspective, we can also think of research topics such as the Atlantic world and the Dutch http://www.culturalheritageconnections.org/wiki/The_Atlantic_World_and_the_Dutch_1500-2000_(AWAD) (accessed 20-6-2014). However, another, much older, and good example is the world heritage site 'Prehistoric Pile dwellings around the Alps: http://whc.unesco.org/en/list/1363 (accessed 20-6-2014). Connecting those sites, geographically very distant, requires new approaches, using multidisciplinarity in research, as well as in visualization.

[20] In the Netherlands, it is not only the Ministry of Education, Culture and Science (OCW) that is involved in the management of the underwater cultural heritage. For example, the Ministries of Infrastructure and Environment (I&M), Economic Affairs (EZ) and Defence (Defensie) are also involved.

[21] See, for example, http://archeologieinnederland.nl/vrijwilligers-de-archeologie (accessed 16-1-2016).

[22] See also Chapter 7.

[23] For more about values, see Chapter 2.

The various interpretations have led to a misunderstanding between important stakeholders, who actually need to cooperate in order to make the widespread policy of in-situ management a success. Today, more than twenty five years after the signing of the treaty and a decade after its implementation in the Dutch Heritage Act, for many of the stakeholder groups – from academic archaeologists to developers and even the general public – the policy of in-situ preservation still often has a negative connotation. Much of this negativism may be addressed by clarifying the different points of view and incentives people have, but also by ensuring everybody speaks the same language, using the same definitions when talking about preservation, conservation and protection, and also, for example, issues such as site stabilization.

An important starting point for all stakeholders involved is the question: Why do we want to preserve sites in situ? While answered from a cultural heritage management perspective below, the answer to this question may be – as indicated above – very different depending on the stakeholder. However, in addressing this question I hope to reach the core of the reason for being involved, as well as the basis of possible conflicts. The choice of in-situ preservation may be based on different cultural heritage values, which include scientific values, but also aesthetic values, enjoyment or commemoration. At the same time, the economic dimension – i.e. economic development through planned construction in, or use of, the area and the possible profits for heritage management – should not be overlooked. There is a need to strike a balance between these values. The Quality Standards for Dutch Archaeology (KNA) includes a check list that aims to obtain a balanced assessment of the 'archaeological value, quality and aesthetic value (whether it is visible and worth seeing)'. Nevertheless, the person using the checklist makes a difference; usually this is an archaeologist, which means there is a natural biase towards science.

Whether to preserve in situ or not is a management decision based on the balancing of different values regarded as important by the stakeholders involved.[24] It should be based on a site – and preferably also area – significance assessment, which determines the different values of the site and preferably also the landscape in which the site is situated. However, as indicated above, values are subjective. Therefore, it is important to consider who is determining this value and who has the right to do so. We also have to keep in mind that the level on which one operates may make a difference to how sites are assessed. For example, a site which is not rated of high cultural heritage value at a national level may be so at the regional level and vice versa.

In-situ protection should also be based on the assessment of threats and should consist of mitigation against these threats. It is important, in doing so, to take note of the perspectives of the different stakeholders regarding the physical protection of an archaeological site.[25] Differences may arise in relation to how long in-situ protection should be applied. Should it be long term or short term, for example? For some stakeholders, in-situ preservation and protection may even be synonymous with not having to deal physically with these sites at all; or, stated more positively, entailing considerably lower costs than opting for excavation. To paraphrase Willems (2012), the in-situ dogma is led by bureaucratization and commercialization. Money, time and responsibility seem to be the driving factors.

Since the signing of the Valletta Treaty, many countries in Europe have been frenetically holding to in-situ policy. In addition, due to the drafting of the UNESCO Convention for the Protection of the Underwater Cultural Heritage (Paris, 2001), and its signing and ratification by many countries, this policy has been given a firm basis in the management of archaeological – including underwater – heritage. It has gone so far that the doctrine of 'in situ is the first option to consider' has, for many, become 'the preferred option'. However, there is a massive difference between these two phrases. While the latter fits perfectly in the minds of those for whom in-situ preservation has become a goal in itself, how can we say that in situ is the preferred option in any general sense, without considering the individual situation of each site? Should such assessment not be part of the mitigation process or prior to that? Considering in-situ preservation (and active in-situ protection) to be *the first option* is thus different from it being *the preferred option*. This is the starting point from which we should all at least begin, and after thoughtful consideration and for the right reasons, we might depart in various directions.

Policies may not always be formulated or supported for obvious reasons. In-situ protection may well be regarded as the cheap option. In addition to the question of whether this is true, we are also risking forgetting why we choose preservation. It is not our sole aim to protect cultural-historical sites simply because we do not have the money (or do not want to spend the money) to investigate them. We also want to learn from the past, and on the basis of our curiosity, preserve for later generations what we have learned. Ultimately, archaeologists want to learn from the past and pass this knowledge on to society, so others may also understand their past, present and future. Curiosity is thus an important asset to have for an archaeologist. However, it will not be satisfied by in-situ preservation or in-situ conservation of sites alone. Intrusive research may be necessary for this. Those seeking enjoyment – the incentive for sports diving communities – may profit from in-situ policy and management as well. However, this will depend on the way we protect sites and present

[24] Usually, even broader than a solely archaeological management or cultural heritage management decision.

[25] For the physical protection methods, see Chapter 5.

them in situ. Therefore, although this stakeholder group might in the first instance be reluctant to support in-situ preservation and protection, it may easily become the biggest supporter depending on the way it is executed.

Another issue for divers generally is that diving is still a relatively exclusive activity and access to wrecks is therefore also exclusive. Taking objects from this environment reduces this exclusive access enormously, and also deprives the site of its exciting and mysterious environment, which adds to the enjoyment. Only when salvage is combined with archaeological research and post-archaeological processing will the benefits of excavation become clear. This takes time, and while it may enhance the enjoyment factor for larger groups of museum visitors, who will be able to see the physical remnants of the past, it will not enhance the experience of those who want to visit the sites under water.

4.4 Defining common-sense arguments for in-situ preservation

The reasons for preservation depend on the value we attach to the sites as a society, with different perspectives of different stakeholder groups and even individuals. However, from a purely archaeological and cultural point of view, there are many well-founded reasons for wanting to preserve shipwrecks in situ.

First and foremost, for archaeologists, the intrinsic value of a particular site should primarily determine the response to the question of why it should be protected and not another. The archaeological value of an individual site is not easy to determine, quantify or qualify. However, there are methods in place in the Netherlands in the form of the Quality Standards for Dutch Archaeology (KNA) and specifically the 'KNA 3.2 Waterbodems', which has been specifically developed for underwater archaeology.[26]

There are also other reasons for the in-situ preservation of culturally significant sites. In the past few years, the issue of in-situ preservation has been widely debated in the field of archaeology.[27] This debate has, however, led to some confusion within and outside the archaeological community. An often cited reason for in-situ protection is that we should preserve some material for future generations.[28] This notion alone has little or no value, and has the capacity to fuel critics who believe that in-situ preservation is equivalent to out-of-sight and therefore out-of-mind. It is impossible to predict and therefore to decide what values future generations will hold, because we cannot know what they will consider to be their heritage. It may be better to preserve the past for ourselves – based on what we consider important to preserve for the short and long-term future and on what we want to tell future generations (starting with our children) about us and our past. In the first instance, this may sound like a minor rewording of the same idea, but there is a crucial difference: we will decide for ourselves what to give; we will decide from our own perspective what is important or not and will not dictate it to others (the future generation).

Several other reasons for preserving shipwrecks in situ, both from a philosophical and from a practical point of view, are mentioned below.[29]

4.4.1 For future enjoyment and research

It is commonly held that we must not only aim to preserve a representative part of the maritime past for scientific research, but also for future enjoyment and research. We should, however, keep in mind that the selection of what to preserve is our choice, as part of contemporary society, with our own understanding and set of values. Thus, we are passing on what we think is worth keeping for future generations. Moreover, it is only possible to make a selection of what to preserve because the number of submerged sites of potential archaeological interest is immense.[30] Before we make such a decision, therefore, it is important to know the extent of the archaeological resource. We also have to investigate the likely meaning (significance) of the individual sites for maritime archaeology and for the reconstruction of our past. This can be achieved by assessing each site individually and the archaeological resource in general.

In the past, in-situ preservation was carried out with the intention of leaving archaeological sites for future generations or even for eternity.[31] Today, we know that protection in situ can slow the process of degradation but it is impossible to completely stop the deterioration of sites.[32] If we want it to be effective, in-situ preservation often means active involvement (and thus becomes protection), with the awareness that all efforts are temporary.[33] It is, therefore, important to have some idea about how long certain kinds of measures can protect an underwater site. The protective measures should be selected based on their capacity to minimize deterioration of a site but also allow access

[26] 'KNA 3.2 Waterbodems' www.SIKB.nl (accessed 9-1-2016). The 'KNA Waterbodems' was recently incorporated, along with the quality standards for land archaeology, into a BRL 4000 (accessed 19-1-2017).

[27] See, for example, Willems 2012, Staniforth & Shefi 2010.

[28] See, for example, Spennemann 2011 or Ortmann 2009, 2.

[29] Most of these reasons were first published in Manders 2004 (1).

[30] UNESCO estimates that there are 3,000,000 undiscovered shipwrecks around the world. Promotion folder, the UNESCO Convention on the Protection of the Underwater Cultural Heritage, n.y, 4.

[31] Acknowledging this makes it easier to understand that no future activities, including maintenance and monitoring, were planned. 'Eternity' meant leaving the sites as they were found, and with no plans for the future.

[32] See Chapter 3 .

[33] This is also the case for shipwrecks and objects which have been raised, conserved and preserved ex situ.

Fig. 4.2 Diving on wrecks may just be for the fun of it. Sports divers on the shore of the Oostvoornsemeer. Photo: M. Manders.

to the site in the future for archaeological purposes, for other scientific research and sometimes even for the sake of their enjoyment. It is not only important to save a cross-section of maritime history (the Stepping Stones, see amongst others 4.6) for future research (when we might have a different view on our past and different questions to ask); the choices must also be acceptable to the general public.[34]

The aspect of enjoyment (in addition to research) should not solely be focused on future generations. In fact, making sure that the current generation has the opportunity to enjoy its heritage, including underwater cultural heritage, is extremely important. Through this, understanding or awareness can be created, which again is essential for the effective protection and management of the underwater cultural resource (Fig. 4.2).[35]

4.4.2 Showing responsibility and commitment

Most countries today have well-developed legislation and regulatory systems to protect cultural heritage, in Europe often based on the Valletta Convention. Maritime and underwater archaeological heritage is often included in this legislation or, if not, separate laws have been made. This shows the commitment of countries, assuming responsibility for preserving their own and also a common maritime past.[36] The protection of archaeological sites under water in legal and physical ways is a logical method to manage these sites responsibly.

Some international regulations concerning the protection of underwater maritime heritage go even further by stating that in-situ preservation should be considered as the first option. These include the European Convention on the Protection of the Archaeological Heritage of 1992 (in short Valletta Convention or Treaty of Valletta),[37] the UNESCO Convention on the Protection of the Underwater Cultural Heritage of 2001[38] and the ICOMOS Charter on the Protection and Management of Underwater Cultural Heritage of 1996.[39] In the Netherlands, underwater

[34] Although we (society) cannot foresee exactly what future generations will want to know, we can select those sites that we think are interesting and that we want the next generations to take note of. Therefore, there has to be acceptance from the general public.

[35] This issue is discussed further in Chapter 7.

[36] For example, through the protection of sites that have a shared past. See, for example, the protection of the Sofia Albertina in the Netherlands (Overmeer 2012) and the foreign Dutch shipwrecks programme of the RCE http://archeologieinnederland.nl/internationaal-beheer (accessed 3-7-2015)

[37] European Convention on the Protection of the Archaeological Heritage (Malta Convention/Valletta Treaty): http://conventions.coe.int/treaty/en/treaties/html/143.htm (accessed 3-7-2015).

[38] UNESCO Convention on the Protection of the Underwater Cultural Heritage, Paris 2001: unesdoc.unesco.org/images/0012/001260/126065e.pdf

[39] ICOMOS Charter on the Protection and Management of the Underwater Cultural Heritage, Sofia 1996; http://www.international.icomos.org/charters/underwater_e.htm

cultural heritage is protected by the Heritage Act of 2016.[40] Not protecting underwater cultural heritage would undermine cultural heritage management generally, especially in the Netherlands, where protection concerns terrestrial and underwater sites combined. [41] Selection procedures, laws and defined responsibilities are all in place for archaeological heritage as a whole and should thus be executed similarly in all environments.

4.4.3 An enormous number of sites

The number of submerged sites discovered, notably shipwrecks, is steadily increasing and there are insufficient resources to assess them all. In addition, many countries have shifted their priorities explicitly or implicitly by not only regarding centuries old shipwrecks as part of their heritage, but also wrecks from eras such as the First and Second World Wars, and even more recent times.[42] Combined with an increased interest in submerged prehistoric sites on the seabed,[43] this has resulted in the steep growth in the number of submerged sites recorded in official databases. For example, in the Netherlands, the official archaeological database, ARCHIS, consists of approximately 1,500 archaeologically validated sites under water.[44] The number of new sites being discovered and reported is approximately 50 to 100 per year.[45] This is comparable with other countries with well-developed underwater cultural heritage management systems in place. In Australia, for example, there are over 7,000 registered historic shipwreck sites.[46] Every year, 100 to 200 new sites are reported. In Denmark, there are almost 1,000 designated shipwreck sites and over 1,500 submerged settlement sites.[47] This is probably just a fraction of what still remains to be discovered or even what lies on the seabed, has been detected, but is still unassessed. An effort to combine as many existing databases with underwater positions as possible has led to the creation of a database managed by the RCE consisting of approximately 60,000 contact points, representing all the locations registered in different databases from different sources.[48] Most of these sites have not been archaeologically assessed and their value to underwater cultural heritage remains unknown. These numbers simply illustrate the richness of our underwater cultural heritage. However, in many countries, unfortunately, these sites remain a forgotten cultural resource in heritage management.[49]

Today, diving is not such an unusual hobby. Equipment that provides visibility even in the murkiest water is readily available, as well as equipment that can penetrate into the seabed.[50] This has caused a dramatic increase in the number of archaeologically interesting underwater sites being registered. These more advanced survey methods make it possible for many to explore the underwater world at a reasonable cost. This increased accessibility to our maritime past has created an immense problem. To keep pace with the number of sites reported every year, thousands of archaeologists from the maritime archaeological community would be needed to investigate them all.[51] Even if thousands of archaeologists worldwide were available, this would only create new problems. When archaeologists do work in the field, they also create huge amounts of work for themselves in the form of post-processing and conservation work. In the

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[40] This used to be the Monuments Act (Monumentenwet) 1988. Followed by the 'Wet op de Archeologische MonumentenZorg' (WAMZ, 2007) which had this law as a basis but also included the Valletta Treaty. On 1 July 2016, the new Erfgoedwet (Heritage Act) came into force. This new law will have a major influence on the effectiveness of law enforcement in UCH management. In the Monuments Act, it was still important to prove somebody had been illegally digging under water. It was, therefore, almost impossible to catch someone in the act of doing so. The new law also declares the moving and removal of objects from an archaeological site to be illegal. This is much easier to prove. It does, however, also have downsides, for example, the criminalization of souvenir hunters (http://cultureelerfgoed.nl/sites/default/files/publications/heritage-act-2016.pdf, accessed 19-12017). See also Chapters 3 and 7.

[41] See also Chapter 1.

[42] As an example, the Netherlands has even dropped the minimum age of 50 years for cultural heritage sites.

[43] See, for example, the extensive research executed on the harbour extension of Rotterdam (Maasvlakte 2): http://www.rotterdam.nl/Clusters/Stadsbeheer/Images%202015/BOOR/PDF/BR566_Maasvlakte2_ENGLISH.pdf (accessed 15-12-2015) or the extensive work of, for example, Gaffney et al. 2007.

[44] In ARCHIS 2, 63,555 National Monuments are registered, 1,454 of them are archaeological monuments (checked on 9-6-2015). Although many more sites are included in the database, it proved to be impossible to select 'maritime' or 'underwater'. The 1,500 is a rough estimation. The fact that they cannot be selected shows the bias against these fields of cultural heritage and archaeology, but hopefully this will be resolved with the new ARCHIS 3.

[45] See also Chapter 1.

[46] Australian National Shipwreck Database: http//www.aima.iinet.net.au.

[47] Every country has its own set of selection criteria that define which sites are archaeologically or historically important. The registration of sites also differ. Attempts to similarly assess sites have been undertaken in the EU Culture 2000 project, MACHU (Managing Cultural Heritage Underwater), September 2006 to September 2009. See also: www.machuproject.eu.

[48] See also Chapter 1.

[49] The Dutch example of approximately 1,500 sites registered in the national cultural heritage database, while a database of 60,000 contacts exists, is not abnormal. In this light, it is also interesting to note that the Third National Cultural Heritage Census in China in 2009 mentioned that it had 70 ancient shipwrecks in its ocean territory, while the National Conservation Center for Underwater Cultural Heritage estimated that in the Southern China Sea alone there are 2,000 or more shipwrecks. Even this estimate might be on the low side. Source www.whatsonxiamen.com/news19118.html (accessed on 02-04-2017).

[50] For around $US 2,000 one can buy a Hummingbird side scan sonar. See Kaeser & Litts 2013.

[51] Some countries have taken up this lack of capacity in a very serious way. China has, since 1989, educated 90 underwater archaeologists and will in 2014 educate another 30. www.whatsonxiamen.com/news191118.html (accessed on 24-7-2014). Indonesia is also forming an army of underwater archaeologists at an incredible speed, Sudaryadi et al. 2012.

early 1990s, the archaeological community in the Netherlands was forced to keep its archaeologists indoors in order to process all the material and data gathered. We are still dealing with the post-processing of archaeological finds and data that remain.[52] Hence, in-situ preservation is a way to keep sites 'in storage', against an expected reasonable cost.[53]

4.4.4 Underwater archaeology is expensive

We have to acknowledge that an underwater excavation can be very expensive in comparison to terrestrial archaeology (see Chapter 5),[54] and the same can be said when comparing in-situ preservation of underwater sites with those on land. Although diving is no longer as exclusive as it used to be, all underwater interventions are still relatively expensive. It is necessary to use special equipment, and to be able to work accurately requires many hours under water. Moreover, there is only a limited amount of time that a diver can stay under water each dive, and therefore an underwater project requires more time and more people to do the same work in comparison with archaeological projects on land. In some countries, underwater archaeologists need special training and licences[55] and are exposed to the challenges posed by weather. This usually makes an underwater excavation far more expensive than a regular excavation on land. With respect to tax payers money (as the government is often involved) or other private sources of money (NGOs or Malta-related contractors), we have to be very selective with respect to which sites will be excavated. Before any such undertaking, the logistics, planning, execution and associated expenditures for an excavation must be thoroughly investigated and accounted for. In most countries, the excavation of a shipwreck involves heavy investment in resources, both in terms of staff time and finances. Post-excavation analysis, conservation and subsequent curation also need to be taken into consideration.[56]

For governments, as suggested above, the priority has been to preserve sites in situ, partly due to the imputed high costs of the alternative; that is, excavation, but also to avoid deselection of sites.[57] However, while this in-situ approach may essentially be less 'expensive' than excavation, in the long run it may not be a cheap option either. Costs for responsible in-situ management may include monitoring and maintenance of the site, for example.[58]

4.4.5 A time gap

Another reason to apply in-situ preservation, including mitigatory protection methods, is the fact that there is often a major time gap between discovery and a planned excavation.[59] This means that many sites that have been located and are awaiting investigation may require protection in the interim in order to maintain the quality of the archaeological information. Decisions about how to manage a single site must be made in relation to other sites.[60] Thus, we aim to develop objective criteria on which to base our decisions regarding whether a site can or should be protected in situ. While this takes time, a lack of capacity and financial resources, and the necessity of political commitment, heavily influence these decisions.

The following activities or elements, which sometimes demand considerable time, must be carried out or established before excavation can start:

- First, a non-intrusive assessment, where possible
- A project design
- Advance funding for the whole project
- A timetable
- Research objectives: where details of the methodology and techniques to be employed are defined in the project design
- A competent, suitable and qualified investigating team must be established
- Any political or legal issues must be resolved, including ownership of a wreck[61]

It is essential to establish the research objectives of an excavation. Once an object or site has been excavated it will never be the same. In this sense, excavation is destructive and therefore requires strict regulation.
It is, of course, impossible to obtain all information encapsulated in a site. There may be hundreds of potential questions, for

[52] Erfgoedinspectie 2010. See also http://www.nwo.nl/onderzoek-en-resultaten/programmas/odyssee/achtergrond (Accessed 3-7-2015)
[53] See Chapter 5 for cost indications in-situ conservation.
[54] Kelly & Thomas 2012, 83.
[55] Certification for scientific divers is not the same across the world. Even in Europe there are big differences, see, for example, the European Diver Certificate, NL: Duikarbeid A + B, UK: HSE.
[56] See, for example, the Annex to the UNESCO Convention for the Protection of the Underwater Cultural Heritage (Paris, 2001), the Dutch Quality Standards for Archaeology. KNA 3.2 (BRL 4000), Hamilton 1997 or Viduka 2012.
[57] http://archeologieonline.nl/nieuws/kosten-archeologisch-onderzoek-rijzen-de-pan-uit. On in-situ preservation being cheaper see, Willems 2012. Gemeente Oldambt. Raadsvergadering d.d. 17 November 2010, Raadsvoorstel Nota Archeologie en Beleidskaart Archeologie, punt 3.2 of Beleidsnota archeologie gemeente Nieuwegein. Van vondst naar verhaal, Raadsnummer Versie 2.1 concept Date 01 June 2012, 32.
[58] See also Chapter 5.
[59] The Scheurrak SO1 wreck was discovered in 1986. In 1989, excavation started but was only finished in 1997. Large parts of the construction are still lying in the seabed of the Wadden Sea. The *Mary Rose* was discovered in 1971 and raised in 1982. Excavation lasted from 1979 to 1982, while the conservation and restoration of objects and the hull is still ongoing.
[60] See also, for example, Chapter 5.
[61] Maarleveld et al. (eds) 2013, 64.

example, when the cargo or the construction of a ship are studied. By excavating the cargo alone and attempting to answer a few questions, you remove the source, which consequently will limit the number of questions that can be addressed in the future. It is, therefore, important to have experience in the field of research (expert judgement) and to be acquainted with current and past research and research agenda(s) before starting an excavation. On this basis, the most important questions can be determined. In the Netherlands, there is such an archaeological research agenda.[62] Although primarily set up for use in terrestrial archaeology, the underwater and maritime components have now been integrated into the new version, rather than setting up a specific underwater or maritime research agenda.[63]

4.4.6 Difficulties of conservation

Another reason to promote in-situ preservation of shipwrecks is to keep them in safe underwater storage in their 'natural' environment until new and better conservation methods are developed. For example, traditional polyethylene glycol (PEG) conservation treatment has recently been questioned because of problems with increased sulphur and iron concentration, which have been identified in timbers of various wrecks, including the Vasa in Sweden and the *Mary Rose* in the United Kingdom. The conservation of iron wrecks or large iron objects has always been a major issue.[64]

4.4.7 Current experience and enjoyment

Information from archaeological excavations will eventually flow into the education system, and museums will be filled with objects produced by such an approach. All of this is valuable, but what is the role of the public and its experience of the past?[65] Museums make an enormous effort to give the public such an experience.[66] However, this is different from the experiences and the enjoyment we have while diving on a real wreck site (See also Chapter 7). Shipwrecks that are preserved in situ may well be used as places to gain this experience and enjoyment. The current Heritage Act (and the past Monuments Act) in the Netherlands provides the basis for such enjoyment by stipulating that divers can dive on any site they wish, but excavation, moving and removal are prohibited. Sites that are fully protected in situ and thus covered, may not offer much excitement, while other wrecks that do not need physical protection probably will. This may be an important selection criterion for in-situ preservation in the future.

4.4.8 Different values of preservation

Shipwrecks have many different values. They are looked at from different angles and by different people, and are thus also significant for a number of reasons and for a number of different stakeholders. A site may be under threat not only from the perspective of underwater archaeologists, but also from that of ecologists, sports divers and even fishermen. Quite a few of the identified threats to shipwrecks in the Wadden Sea have a negative effects for a number of stakeholders. Shipwrecks contain vital information about our past, that is true, but they are also important for biodiversity and are great places for diving.[67]

There are mitigation strategies for all these threats; obvious and more creative ones. They range from in-situ protection methods to keep the soil environment waterlogged and oxygen free (See also Chapter 5), to the setting up of cooperation agreements between different users (stakeholders). The mitigation strategies must thus be adapted and accepted by a larger group of stakeholders than archaeologists or cultural heritage managers alone. Managing a wreck or the underwater resource in general becomes a task that is not only focused on the cultural value but also on a careful consideration of various values and the creation of support. This has become especially important in the light of the national policy in the Netherlands regarding decentralization, as a result of which, even more people are becoming directly involved and different values have to be balanced and protected.[68]

4.5 Arguments against in-situ preservation

Although there are many reasons to preserve our underwater cultural heritage in situ there are also reasons not to. Obviously, if a site is not considered to be of high archaeological value, there is no reason to protect it for that particular reason. Moreover, sites may be sacrificed in the process of mitigating the effect of works on the broader environment, or other values of a certain location or site will prevail and the archaeological information will be sacrificed. There are, however, other downsides to this concept of in-situ preservation that are related specifically to cultural heritage management issues.

[62] The 'Nationale Onderzoeksagenda Archeologie 1.0' (NOaA) is currently under revision and will have a different structure when finished. For the current NOaA, see: http://archeologieinnederland.nl/bronnen-en-kaarten/nationale-onderzoeksagenda-archeologie-10. For the new NOaA, see: http://www.cultureelerfgoed.nl/dossiers/verbeteracties-archeologie/kenniskaart-deelproject-1-nieuwe-nationale-onderzoeksagenda

[63] It has taken many years to incorporate these maritime and underwater archaeological topics. In an earlier stage, the aim was to develop a separate agenda; however, new insights have resulted in the conviction that the basic questions about our past can be answered through the archaeological investigation of the material past on land as well as underwater, terrestrial as well as maritime.

[64] This is partly due to the lack of knowledge concerning how to preserve large amounts of metals in situ, but also due to the fact that large iron wrecks are – due to the material they are built with and the fact that they have relatively recently sunk – often still well intact and largely protruding from the seabed. See for more info also Chapter 2 and 6.

[65] Shanks 1992.

[66] See Chapter 7.

[67] http://cultureelerfgoed.nl/nieuws/bescherming-scheepswrakken-biedt-kansen-voor-biobouwers (accessed 19-01-2017).

[68] For more on this, see Chapter 2.

4.5.1 No inclusion in regional identity building

Through archaeological excavations we can learn more about our past. This understanding helps us to build our current identity.[69] Deciding not to excavate means limiting the amount of information we can extract from a site and thus of gaining information which would potentially rebuild, reshape or reinforce our identity. A cultural assessment is the next best thing, ignoring the site the worst. Out-of-sight may mean out-of-mind and this may entail less information with which to build collective memory. In addition, learning less about the past may mean that the social role of archaeology – and, in fact, cultural heritage management in general – will be diminished, not to mention the negative economic impact, because 'in-situ management' will still be costly but nothing will be gained in terms of knowledge.

4.5.2 No methodological development or capacity building

Excavation under water is based on the same premises as on land. However, the methodology is often different, and even within various underwater environments (fresh and salt water, currents, low or high visibility, etc.), different methods and techniques are often required. Without practice, it is difficult to develop new methodologies and techniques and to improve the quality of the profession. Moreover, without sufficient numbers of accessible underwater archaeological excavations there will be a lack of practice in the profession and a hold on new capacity.

This is a realistic threat. Archaeological excavations, especially under water have decreased in number over the years under the influence of new legislation, policy and the fear of high costs. This is a process that can be seen in the Netherlands. In combination with very strict diving law, this has resulted in a halt to the active participation by amateur archaeologists and international or other archaeologists who do not have the appropriate diving licenses, restricting activities to professionally licenced underwater archaeologists.[70] While an exception has been negotiated for students,[71] they are not permitted to participate in excavation techniques that use airlifts and water dredges, which are considered to require heavy equipment. Therefore, it has become difficult to exchange knowledge with experts on site and there is no build up of expertise in excavation by students (See also Chapter 1).

4.5.3 Ongoing degradation

Although we can mitigate against the negative effects of natural and anthropological interventions with in-situ protection and conservation, we must realize that the process of degradation continues. We may be able to slow down the degradation process and even counter some threats, but others will continue (at a slow rate). For example, if we remove oxygen from a site, most biological attack will cease, but erosion bacteria are still able to survive in anoxic environments.[72]

4.5.4 The long-term financial consequences

It is often said that in-situ preservation is a cheaper option than excavation. This may be true for the initial stage; however, when considering long-term management, this may be somewhat different. This, of course, depends on how the concepts of responsible heritage and in-situ management are understood in practice. In-situ preservation often requires active involvement (protection), at least in terms of monitoring and the mitigation of negative effects on site, such as repair and maintenance. Why, other than for budgetary reasons, would we proclaim preservation and protection as a policy otherwise? It seems logical that when a site has been determined to be of archaeological value it will – with the prevailing in-situ policy –be preserved in situ and measures will be taken to ensure its value is determined over time. This involvement in the management of in-situ preserved sites requires long-term budgets to ensure continuity. These budgets will need to grow as more sites are preserved and protected in situ.[73]

4.5.5 Is the in-situ dogma 'threatening archaeology'?

In-situ preservation is a tool of management; one step in a larger process (See Fig 1.8). It comes after considerate evaluation and should be balanced with other steps in management. This includes excavation, or using the site to gain knowledge. It is for this particular reason that traditional archaeologists see a global in-situ policy – often considered to be a dogma – as a threat to the development of underwater archaeology in itself,[74] and there is a lot to say for this. There is a natural tension between the two: in-situ preservation often means a non-disturbance approach, considering the site as a resource for the future, but not now. A site may trigger curiosity, but cannot satisfy it. This may be partly due to the predominant all-or-nothing approach; either excavate or do-not-touch and leave in situ. However, should we be so rigid in this choice? Both are important steps in cultural heritage management.

If we decide to preserve in situ for the purpose of investigating them at a later date, can we find a middle ground? We could start by officially including partial excavation as a form of archaeological heritage management. These excavations could be used (carefully) to answer a few obviously significant questions, while

[69] See, for example, Jones 1997.

[70] See, for example: http://www.werkenonderoverdruk.nl/ (accessed 3-7-2015).

[71] This has also been implemented in the dive law 'working under excess pressure', Articles 6.31 and 6.8. See also Vroom 2017.

[72] See Chapter 3.

[73] See Chapter 5.

[74] http://www.unesco.org/new/en/culture/themes/underwater-cultural-heritage/unesco-manual-for-activities-directed-at-underwater-cultural-heritage/unesco-manual/general-principles/in situ-preservation-as-first-option/ (accessed 15-12-2015).

the rest of the site is either preserved in situ or deselected altogether. This seems to be more in line with the essence of archaeology, which is guided by a curiosity to learn about the past.

It is still difficult to express this option – of only doing partial excavation and preserving the other part in situ or deselecting – explicitly. Implicitly, it has been done often enough. Sometimes the choice may have been triggered by a lack of money (in the long term), sometimes there was a desire to continue but the political support was lacking, or there was a shift in priorities.[75]

There are some visible changes of approach in cultural heritage management: from the almost blind sense of urgency not to excavate to a more pragmatic approach to how best to excavate within the context of cultural heritage management.[76] Moreover, boundaries are being explored and some rules and regulations are being re-evaluated.[77] For example, does cultural heritage management benefit from the exclusive involvement of highly educated professionals, or should it be more open? Fortunately, there already seems to be wider involvement of professionals other than archaeological stakeholders.[78] At least this shows a wider interest and commitment. More people are becoming involved in the study of the past. However, could they also be more involved in the preservation of this past in situ? This depends on the approach. Basically, people want to learn, people are curious. Increasing involvement may also be a good response to critics who claim that in-situ policy brushes sites under the carpet. Proof of a neglect of sites in situ, it is argued, can be found in the fact that in the Netherlands, for example, active in-situ preservation activities and the essential monitoring and follow up are not budgeted.[79] This means that in practice they do not form part of the task or daily undertaking of cultural heritage management. This lack of management results in well-known sites falling apart under the eyes of those stakeholders who should be partners in the management exercise, but who can see that the government is failing in its responsibilities.[80]

If in-situ preservation is taken seriously, would it not be more logical to have a sufficient permanent budget available, allowing effective actions to preserve, protect and conserve sites to be taken? Fortunately, in 2013, a small first step was taken by making funds available for national archaeological monuments.[81] The next step will be to have sufficient regular budgets available, to make the selection procedures for national monuments easier and quicker and to include sites that do not have national monument status when allocating budgets.

4.6 In-situ preservation in numbers

So how much are we preserving in situ? With the Valletta Treaty signed in 1992 and implemented in Dutch law in 2007, it is of interest to take a look at what has actually happened in overall archaeological heritage management in the Netherlands. The *RIGO Rapport*, written in 2012 to evaluate the effectiveness of the implementation of the Valletta Treaty for archaeological heritage management in the Netherlands, states that there are no quantitative analyses of in-situ preservation numbers.[82] This is rather reprehensible, considering that in-situ preservation is, according to this convention, 'the first option to consider'. How can we consider it, if we do not have any data to support action?

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[75] The Scheurrak SO1 wreck (sixteenth century) has been excavated. However, the wreck itself, including a large concretion with cannons and objects, was left on site (Manders 2003 (2)). The *Aanloop Molengat* wreck (seventeenth century) has also been excavated, but the construction, including its heavy cargo was partly left on site (Maarleveld & Overmeer 2012). Both sites were not fully excavated for different reasons: lack of resources (budget and qualified personnel) and the urge to move on (change in attitude towards archaeology, see also Chapter 1).

[76] See, for example, the reburying of artefacts after excavation in Veth et al. 2014 and Bergstrand & Nyström Godfrey (eds) 2007.

[77] See also: http://nl.magazine.maritiemprogramma.nl/emagazine-mp05-nl/#!/pilot-van-start-voor-behoud-archeologisch-erfgoed-texelse-zeebodem (accessed 29-03-2017).

[78] Activities for excavation: see HMS London (1665), Thames mouth: www.dailymail.co.uk/news/article-2633884. Also, each year the Province of Flevoland, the Municipality of Lelystad, the Museum Nieuwland, the University of Groningen and the RCE organize a field school in which one of the known wrecks in the Flevopolders is investigated, often intrusively. These field schools are used in the first instance to train students in archaeology, but amateur archaeologists have also regularly been involved. (http://oud.cultureelerfgoed.nl/archeologie/maritieme-archeologie/onderzoek/afgerond-onderzoek/international-fieldschool-for-maritim).

[79] Caspers et al. 2011, 7.

[80] Some examples of this are the *Stirling Castle* (1679–1703) on the Goodwin Sands, UK, which was once praised as one of the best preserved wrecks in the UK and which is now rapidly deteriorating. The shipwrecks on the Burgzand are also rapidly deteriorating, at least those that have not been actively conserved in situ. Some sports divers think that the government is not doing enough to prevent this. At least, they do not appreciate current in-situ policy (see, for example, Eelman 2002). The mid-sixteenth-century Ritthem wreck in Zeeland, the Netherlands, is rapidly deteriorating and suffering from underscouring (Vos 2009). However, nothing is being done, due to the fact that the threat comes from natural sources, the province and municipality do not have the knowledge or money to do 'something', and the central government agencies, the RCE (because cultural heritage management is decentralized) and RWS (because natural processes are deteriorating) will not assume responsibility. Amateur and contract archaeologists have also noted degradation of shipwrecks in the Oostvoornsemeer by shipworm. Although different administration levels are working together to find a solution, the process of negotiation between governmental (municipalities, province, Water board and RCE) and other stakeholders is moving slowly; too slow for divers who can see the situation is getting worse almost by the day.

[81] The BRIM funds, http://cultureelerfgoed.nl/dossiers/subsidies/instandhoudings-subsidie and http://cultureelerfgoed.nl/sites/default/files/publications/beukers_archeologische_rijksmonumenten_informatie_voor_eigenaren_beheerders_en_gebruikers.pdf (accessed 18-10-2015).

[82] Keers et al. 2011. This is the case 20 years after signing the Valletta Treaty and 5 years after its implementation in Dutch law.

In its evaluation, the RIGO report did not take underwater cultural heritage into account when evaluating the effect of the Valletta Treaty on Dutch cultural heritage management. This shows the lack of interest in and understanding of this topic within the wider archaeological community, despite the fact that underwater sites are included in the national databases and institutes that were involved in the questionnaires which formed the bases of the report are officially also responsible for this part of the cultural heritage.

Although no overall quantitative analyses were available in the RIGO report, some data regarding in-situ preservation can be found. Unfortunately, most – if not all – of the analysis is based on assumptions and not real measured data. The RIGO report itself states that approximately 20% of all sites that are considered to be worth preserving are in fact preserved in situ (see for more below).[83] This, in itself, does not suggest that the first consideration to preserve in situ – as stated in the Valletta Treaty – is being fully met, because it clearly suggests that four out of five sites have not been preserved in situ.

This, being the practice is particularly interesting if we take into consideration Goudswaard (2006) who, in relation to the terrestrial Betuweroute project, stated that in-situ preservation would be 80% cheaper than excavating.[84] This is also an interesting figure and might be convincing enough for those who have to fund such projects, but what does it mean? Would it be 80% cheaper simply because it entails avoiding the areas altogether during the building process, and thereby does not entail excavation and preservation ex situ either? Does it include long-term monitoring?

It is an interesting fact that while the Valletta Treaty stipulates that the disturber pays for direct disturbance, long-term management is not stipulated. Therefore, it is ultimately not the problem of the disturber if a site is merely left in situ, insofar as the responsibility for any long-term action is not theirs and will not lead to them incur costs.

These comparisons of the cost of leaving sites in situ or excavating and preserving ex situ do not, therefore, offer any real figures and the issue is not well regulated by the implementation of the Valletta Treaty in the Netherlands. It is more interesting to see that even without this cost incentive (of disturbers having to take responsibility for sites when left in situ) the vast majority of sites are not being preserved in situ.

Preceding and anticipating the evaluation report by RIGO, RAAP[85] – a Dutch archaeological company – started its own internal research to answer the question of how many of the sites that are regarded as worth protecting, have indeed been protected, excavated or left alone.[86] Its conclusion was that of all the sites RAAP had identified and reported on,[87] for every ten that were considered to be worth preserving, the advice to do so had been given for seven and ultimately four had been preserved.[88] As we saw above, in their evaluation, RIGO came up with an estimate of 20% for the whole of the Netherlands. The Raad van Cultuur (Council of Culture) considered that this figure was not well founded and demanded through the State Secretary that research be carried out to determine the real figure.[89] Through the RCE, this research assignment was given to RAAP, due to the research it had already carried out, and it was asked to provide quantitative analyses concerning the number of sites that are being preserved in situ.[90]

Based on 6,000 research reports that were evaluated for the period between 2007 and 2011, of all archaeological sites, 31.9% were being preserved in situ. Thus, one in three sites are actually being preserved in situ. Although neglected in the RIGO report, RAAP had included 'maritime' in their research, but due to a lack of good (ready) data no quantitative analyses had been done.[91] This presents the danger of becoming a vicious circle, in the sense that due to a lack of interest or sense of difficulty, there is a lack of activity, which results in a lack of data. It is, therefore, a positive sign that RAAP had made the effort to look into the data for maritime cultural heritage and reported this omission.[92] It is now of urgency to collect this data on underwater cultural heritage. We require data on the amount of known and unknown heritage; data on the sites that are considered to be of high archaeological value and thus in need of protection; the threats; the effect of in-situ mitigation strategies; and the costs involved in in-situ preservation of underwater sites.

An important part of in-situ preservation is protection by law. In addition to the fact that in the Netherlands all 'archaeological' sites are protected by a blanket law, regardless of whether these sites have been found or not,[93] those that are registered as

[83] Keers et al. 2011.

[84] Goudswaard 2006.

[85] Schute et al. 2011.

[86] RAAP-rapport 2525, 2011.

[87] In total, 1,979 RAAP research reports were issued between the 1 September 2007 and 1 May 2011.

[88] To be precise, 38.2%.

[89] Tweede Kamer, vergaderjaar 2011-2012, 33 053, no. 3.

[90] Schute et al. 2013.

[91] Schute et al., 2013, 75, note 52.

[92] It is, however, important to mention that the definition of 'maritime' and 'underwater' are not the same. Maritime cultural heritage refers to all the heritage concerned with the relationship between human societies and water, regardless of whether this is under water or on land (harbours, jetties, shipwrecks), while underwater cultural heritage refers to what is lying still fully or partly under water. This may also concern the relationship between human societies and water, such as bridges and shipwrecks, but they might also be inundated prehistoric sites.

[93] Otte 2009, 116.

national monuments may be protected by additional laws.[94] In 2015 there were 63,555 National Monuments in the Netherlands, of which 1,454 are 'archaeological' sites, and only six were lying under water.[95] This number of underwater sites is thus very low (0.0001% of the total National Monuments and 0.004% of the national archaeological monuments), perhaps preposterous if we keep in mind that they not only encompass shipwrecks, but also sunken bridges and villages, and that two-thirds of the Netherlands (including the EEZ) is water.[96] The Netherlands has been shaped by the relationship of its people to the water and can therefore be called a maritime nation.[97]

Why are there not more maritime and underwater national archaeological monuments? Is it because they are not considered to be of national importance? Is it because the sites do not need protection? Is it because the process of registration is too complicated and time consuming? Or is there merely a lack of interest? Although the latter would be a logical explanation, it would be the most devastating and negatively charged. It would suggest, first of all, that there is no universal, objective way to evaluate an archaeological site (on land or under water) such that it leads to a certain kind of protection or not. Moreover, it would also suggest, as a consequence, that sites are being designated significant based on an arbitrary and possible personal interest.

The amount of national underwater cultural heritage recognized, even considering the maritime monuments that are not lying under water, is certainly not sufficient to consider these to be the 'stepping stones' in Dutch maritime history.[98] If this was a reason to designate more sites – and this is legitimate – then there would be nothing against assigning more underwater sites to the list. A top 50 or 100 would be possible and offer a tool for telling the maritime history of the Netherlands to its own people and also abroad as an export product. It would even be preferable.[99] This would be equivalent to 0.034% to 0.069% of the current total number of national archaeological monuments.

At present, seven wrecks have been physically protected on the Burgzand in the Western Wadden Sea.[100] In addition, three other sites – a Roman quay in the Maas in Cuijk,[101] a seventeenth-century shipwreck in Lake Oostvoorne[102] and a fifteenth-century shipwreck in the IJsselmeer[103] – have been physically protected. This demonstrates that the focus on archaeological research ánd management in the Netherlands has been, on the Western Wadden Sea.

4.7 Conclusion

In situ means 'original place of deposition'. This definition is not straightforward and may lead to discussion about what 'original' means and what belongs to a site. In relation to shipwrecks, it is often more clear what belongs to the site and what not: a disaster occurred and the ship sank with everything it had on board. Everything on the ship at that specific moment and connected to the event thus belongs to the site. Post-depositional processes may also form part of the site, at least insofar as they may disturb the view we have of the past. This, however, needs to be acknowledged to begin with, and the distinction of what is contemporary and what is not should be made. What we consider to belong to the site in situ determines what we preserve and why.

There are several overarching reasons why we preserve sites in situ: it may be for future research and enjoyment, showing that we are serious about our responsibility and have a commitment; there is an enormous number of underwater sites and many more are being discovered annually which makes it impossible to deal with them straight away; underwater research is expensive and there is usually a time gap between the discovery and investigation of a site and in the meantime it needs to be taken care of; and there may be conservation difficulties that force us to maintain a site in an environment that ensures it remains in relatively good condition for many years, rather than changing the environment by removing it, with all the conservation problems that arise as a result. We may also decide to keep a site preserved in situ for other reasons, such as the wish and the need to experience and enjoy a site underwater now, or perhaps another value that has been attached to the site by another stakeholder.

[94] See also: https://cultureelerfgoed.nl/onderwerpen/advies/archeologische-rijksmonumenten (accessed 29-03-2017).

[95] ARCHIS 2 and Erfgoed Monitor RCE (Heritage Monitor RCE). Accessed 2-7-2015. It turned out to be difficult to select maritime and underwater sites from the databases since there are no specific tabs to select these sites in the overall database. One site, the *Aanloop Molengat* wreck site, was still in the process of being declared a National Monument when these calculations were made. However, whether we are talking about 6 or 7 sites does not make a big difference. Of those 7 there are 5 shipwrecks and two Roman Bridges. Another site, Valkenisse is a half-submerged site of a village. 11 shipwrecks in the polders (now dry land) are National Monuments.

[96] The whole North Sea seabed is an inundated prehistoric landscape with still undiscovered camps and other human traces. See Gaffney et al. 2007.

[97] Nevertheless, 7.3% of GDP comes from maritime businesses and 440,000 people (5% of Dutch employees work directly in this industry). http://www.maritiemland.nl/news/maritiem-bedrijfsleven-nauw-betrokken-bij-opstellen-maritieme-strategie-3/

[98] Manders 2015(2). A quick search through the National Monuments list shows 22 sites (out of 1,454 archaeological sites) that can be regarded as 'maritime', Houkes 2015.

[99] See Beerepoot (2012) on this subject.

[100] This is one national monument.

[101] Manders 2006 (3).

[102] Kleij 1993.

[103] http://www.flevolanderfgoed.nl/home/erfgoed/oostelijk-flevoland-2/scheepswrakken-2/wrak-1460.html (accessed 29-03-2017).

There are also reasons not to opt for in-situ preservation. One obvious reason is that the site has no or very low archaeological value. However, there are also more fundamental reasons: if left in situ, it may not be included in regional or national identity; there will be no methodological development and capacity building; the sites will continue to deteriorate; and there will still be long-term financial consequences.

Optimistically, we can say that on land – that is with respect to the 'terrestrial' cultural heritage – approximately 30% of all archaeological sites that have been discovered, assessed and proposed to be preserved in situ, will be preserved in situ. For underwater sites, we still have no numbers, but here a distinction will have to be made between sites being left under water and those being actively protected. The percentage of the former may be high, the latter very low.

At present, nine archaeological sites have been physically protected under water, six are lying in the Western Wadden Sea. This shows the current focus, not only of archaeological research but also management, on the Western Wadden Sea. Only six underwater archaeological sites are national monuments, which is equivalent to 0.0001% of the total Dutch National Monuments and 0.004% of national archaeological monuments.

Once we know why we want to protect an underwater site, we can start to think of how to do so. The way we protect a site has implications for how we will use it, now and in the near future. This decision should reflect why we – as a society – wish to preserve the sites and thus what values prevail in relation to that site. The different views on in-situ preservation reveal the need to talk among stakeholder groups, even before actively working together in underwater cultural heritage management, with the aim of creating a more balanced in-situ policy.

5. How do we physically protect underwater heritage sites in situ?

Fig. 5.1 Artificial seagrass mat lowered down to the BZN 10 site. Photo: Paul Voorthuis, Highzone Fotografie.

5. How do we physically protect underwater heritage sites in situ?[1]

5.1 Introduction

After gaining an understanding of the deterioration processes occurring on site, as well as the execution of a baseline study on the condition of a site and the formulation of reasons for protection (including what values prevail), measures to mitigate degradation can be taken. These measures are always a compromise between (1) the archaeological or other value of the site, (2) the reasons we want to preserve it, (3) the expected effects of the mitigation strategy, (4) the time span over which it has to be effective, (5) the effect on the local environment and (6) the resources required. When we talk about in-situ preservation, we usually mean sites that are protected in their original position and context, preserving and protecting their current condition and archaeological integrity as long as possible or needed. However, it is obvious that techniques used for reburial of underwater sites post excavation should also be included in an evaluation of the different methods that are and can be used for in-situ protection.

Ongoing monitoring of a wreck site is a critical component of the overall conservation management plan and one way to investigate the effectiveness of the in-situ conservation measures taken. This should be taken into consideration before deploying any in-situ protection methods. Unfortunately, it is often the case that when shipwrecks are protected in situ, little, if any, subsequent monitoring to determine the effectiveness of such techniques is undertaken. A holistic approach to the study of the environment pre- and post-burial is necessary to gain a full understanding of the changes occurring in the local reburial environment. This information allows accurate assessment of the success, or otherwise, of the mitigation strategy in relation to the long-term preservation of the wreck site.[2]

In-situ conservation of underwater sites has increased considerably since the 1990s.[3] The first serious attempts were already made in the 1980s, also in the Western Wadden Sea.[4] The techniques used have ranged from the relatively simple depositing of extra layers of sediment and/or sandbagging a site, to more complicated techniques that promote the natural accumulation of sediment on a site and the construction of artificial mounds in several layers.[5] These techniques will be described below. I will first discuss the three different ways of physically protecting sites in situ in Section 5.2, followed by a discussion of reburial in Section 5.3. Then, in Section 5.4, the protection of a single object or site in comparison to the landscape approach will be discussed, followed by the complex issue of protecting well-preserved sites in Section 5.5, how to choose the best method (Section 5.6), and the costs involved (Section 5.7). Why and when excavation is still an option in underwater cultural heritage management will be explained in Section 5.8. This will be followed by a discussion on avoiding a dualism between in situ protection and excavation and the need for the latter in archaeological heritage management in Section 5.9. The chapter will finish with some concluding remarks (Section 5.10).

5.2 Three ways to preserve sites in situ

Generally speaking, there are three different ways to physically protect underwater sites in situ.

1. A barrier can be placed between the object and the major or other threats.
2. Sacrificial material can help to preserve a site over a longer period of time.
3. A site can be covered.[6]

The chemical protection of cultural heritage sites has also been trialled and microbiological methods of protecting wrecks against bacterial degradation have also been discussed. These will, however, not be taken into account here, as they do not seem to be viable options.[7] In addition, after excavation, sites may also be reburied in order to preserve the archaeological materials. In this process, the same methods, techniques and materials are used.

5.2.1 Barrier methods

Although sediment can serve as a barrier, in this section the barrier methods discussed only concern human-made material that is used to obstruct the main confirmed threats to specific

[1] Parts of the research below have already been published in Manders, Gregory & Richards 2008 and Manders (ed.) 2011.

[2] For monitoring, see Chapter 6.

[3] Oxley 1998 (1), 1998 (2).

[4] The first physical in-situ protection in the Netherlands was executed in 1988 on the BZN 3 wreck in the Wadden Sea, Maarleveld 1988.

[5] The County Museum of Bohuslän, Sweden, protected the wreck of the seventeenth-century Danish warship Stora Sophia in 2002. A mound was created over the site consisting of gravel covered with EPDM rubber carpet and small stone blocks.

[6] There is little data to indicate how long sites can be preserved in situ and what the effects are regarding their integrity, the condition of the materials that are being protected or even the protective materials themselves. Much of this depends on different parameters and thus are site specific. However, within the SASMAP project (www.sasmap.eu, accessed 30-01-2017). an investigation of the quality of the protective materials used is being conducted. New, as well as old material from different in-situ protected sites is being examined. See also Gregory, Shashoua & Eriksen (eds) 2013, 47.

[7] Chemicals were used in the 1970s to protect underwater sites. One example is the use of Tributyltin Oxide on the Rapid wreck in Australia (Ortmann 2009). The BACPOLES project discussed whether the introduction of bacteriophages (viruses) could stop bacteriological decay. However, in addition to the fact that the introduction of phages is not be something that would be met with much enthusiasm by cultural heritage managers, it would also be a temporary, short-term solution, as bacteriophages live on bacteria and if this food source decreases, the phages will also die. Also, it has been proven to be difficult to identify and isolate wood-degrading bacteria. It is, however, important to know which bacteria are present, as specific bacteria require specific phages, see Mårdh 2005 & BACPOLES team 2005, 206.

Fig. 5.2 Biofouling on a data logger placed on the BZN 10 site in different periods: A. Grown over by red weed, B. Covered with acorn barnacles. Photos: M. Manders.

material or the site in general. Geotextiles can serve as a barrier method and will be further discussed below.[8] Other materials include plastic film, such as PVC barrier materials. Flexible barrier materials which are placed around pilings may also have potential applications for archaeological timbers that protrude too far from the seabed to be covered with sediment. These have not been used for the protection of underwater cultural heritage sites until recently. However, they could be of use by creating a physical, and possibly an oxygen-free, barrier around the objects to be protected. PVC barrier materials have been trialled in Denmark.[9] The main aim of such methods is protection against shipworm larvae. This barrier does not allow the larvae to attach to the wood surface. Furthermore, any living shipworm in the timber will not be able to respire due to the lack of oxygen. There are several proprietary manufacturers of these materials. One of the major manufacturers is Pile-Gard and the flexibility of the material they produce would appear to allow it to be moulded to timbers.[10]

A possible barrier method that is still to be trialled is the use of long ropes placed around wood. According to Paalvast (2014), who undertook some initial testing, these ropes become overgrown with sea life that uses up all the oxygen under the rope. This would make colonization of the wood unattractive to *Teredo navalis*.[11] Indeed, this may be a cost-effective solution for the protection of pilings in water; whether this will be practical for the protection of underwater cultural heritage sites remains to be seen. Interesting observations of biofouling were also made on the surface of geotextile bags used in the MoSS project and sandbags investigated during the SASMAP project. Evidence of barnacles, algae, bivalves and other marine organisms was recorded. Sometimes the surfaces were completely overgrown.[12] It has been suggested that the growth of barnacles, which can be extremely abundant in the Western Wadden Sea, provides a 'screen' against wood borer attack, in the eventuality that infestation has not already occurred.[13] However, due to the low intensity of sampling within the MoSS project, which made this suggestion (once after 3 and once after 12 months), this could not be confirmed. In addition, observations made on the biofouling of the data logger that was in place during the MoSS project suggests that this coverage may be seasonal and thus may only have a temporary preventive effect (Fig. 5.2 A + B).[14]

There are also other methods in use that serve as a barrier to protect underwater cultural heritage. In Croatia, cages have been constructed around Roman shipwrecks to prevent them from being looted by divers (Fig. 5.3).[15] Here, looting is considered to be the main threat to the sites, which consist – at least visually – of only tumuli of amphoras and ballast stones.[16] Obviously, these cages do not prevent biological deterioration. The first cage was installed in 1990. Newly designed cages have been placed on site since. Monitoring of the separate sites is done by local dive schools, which have also been permitted to give guided tours around the wreck, even within the cage.[17] In 2000, two Phoenician shipwrecks off the coast of Cartagena were given the same kind of protection against looting. When closed, the site is completely invisible to possible visitors, while the cages in Croatia are made

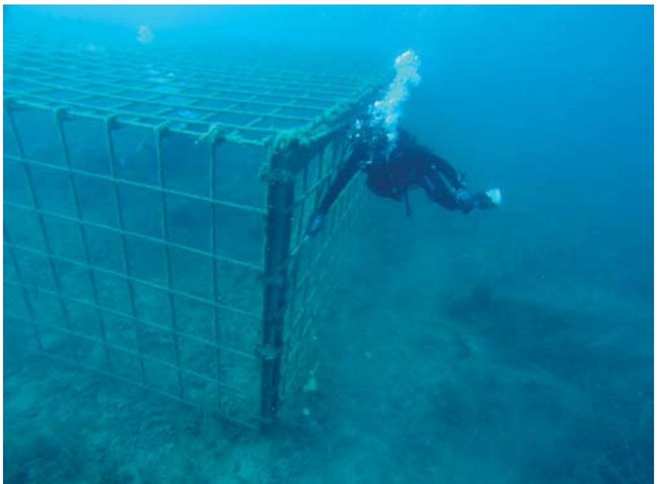

Fig. 5.3 Roman shipwrecks mainly consisting of amphora tumuli are being protected with cages. Photo: L. Bekic.

[8] See, for example, the use of geotextiles on the Zakynthos shipwreck in Greece (Pournou et al. 1999).

[9] Manders (ed.), 2011, 35, Fig. 30.

[10] http://www.barrierimp.com (accessed18-10-2015)

[11] http://www.nrc.nl/handelsblad/2014/04/14/paalworm-is-blij-met-warm-te-1367295 (accessed 30-01-2017).

[12] Palma 2004 (2), 23 and Coenen et al. 2013, 47.

[13] Palma 2004 (2), 23.

[14] Gregory 2004 (3), 42, Vroom & Koppen 2003, 12–14.

[15] Bekić & Miholjek (eds) 2009.

[16] Pešić 2011.

[17] Bekić & Miholjek (eds) 2009.

Fig. 5.4 Pinewood doubling or sheeting was used on Dutch ships that went to the tropics to protect the hull against attack by shipworm. Here, the lower part of the stern of the Buitenzorg, a VOC ship that went down in the Wadden Sea in 1760. Photo: M. Manders.

with bars so that the sites may be viewed from a distance but not touched.[18]

5.2.2 Sacrificial in-situ protection

Some materials degrade more readily and rapidly than others. With this in mind, sites can be protected by introducing sacrificial new material that will be attacked instead of the original archaeological material.

Two examples are the use of sacrificial metals and wood. In the 17th and 18th century, Dutch wooden ship hulls were often protected against shipworm (*Teredo navalis*) by adding a sacrificial layer of thin pinewood over the oak hull (Fig. 5.4). This 'doubling' seems to have been an effective way of preserving the most valuable ship hull on trips to the tropics. The pinewood layer was used in combination with tar and hair mats between the hull and the doubling, as well as thousands of iron nails that were used to fix the thin planks onto the ship's hull. These nails, with large heads, would rust in saline waters and form a protective corrosive layer offering additional protection to the hull.[19]

This idea of using sacrificial wood to protect other wood might also be used when protecting an archaeological site. However, practicalities may be an issue. Observations on shipwrecks have clearly shown that the shipworm likes to drill through oak as well as pinewood. It does, however, seem to have some preferences.[20] The reason why a shipworm drills through wood is to create a living space in which it can also protect itself against fluctuations in, for example, salinity, by closing off the tube that it has created.[21] It does not eat the wood. Therefore, the preference of the animal should lie in easy access and minimal effort to drill through the wood structure. Since *Teredo navalis* seems to have no problems in drilling through hard oak wood, it remains to be seen whether less resistant wood would be a solution that would distract the shipworm from the archaeological wood over a long period of time.[22]

Not being able to withstand the attack of *Teredo* for a very long time may have been the reason why, in the seventeenth century, (at least) some Dutch ships that were to be in the tropics for a very long time were protected with another layer of oak planks in addition to the sacrificial pinewood. The solution was not only sought in the type of wood, but also in the number of layers that could be 'eaten' away.[23] One downside to adding easily accessible sacrificial wood might be that it has a negative effect on archaeological sites in situ, insofar as it may make it easier for the site to be colonized.

Iron ship hulls are often protected with sacrificial anodes of inferior metal such as zinc, magnesium or aluminium. In passive cathodic protection, these blocks of metal are attached to the metal object that is to be protected. The naturally occurring electrochemical potentials of different metals are used to provide protection. Corrosion will take place on the anodes rather

[18] Negueruela 2000.

[19] For doubling, see also Duivenvoorde 2008, 174. It was also fascinating to find a pole, probably used in a quay or harbour structure, in Zeeland, the southwestern province of the Netherlands, in 2004. This pole was protected against Teredo in exactly the same way as the hull of wooden ships. See Akker et al. 2007, 97.

[20] In the wrecks in the Wadden Sea, oak as well as pinewood is attacked. Research with sacrificial woodblocks, however, showed that the shipworm has a preference for pinewood. See also Chapter 3 and Paalvast 2014, 74.

[21] Appelqvist 2011, 59.

[22] See also Palma 2004 (2), 25.

[23] A double layer of full oak planking has been archaeologically observed on different Dutch wrecks, such as the Mauritius wreck (see e.g. L'Hour et al. 1990) and historically described, for example, on the *Eendracht* from the Schouten and Lemaire expedition between 1614 and 1616. See Spruit & Manders 2007.

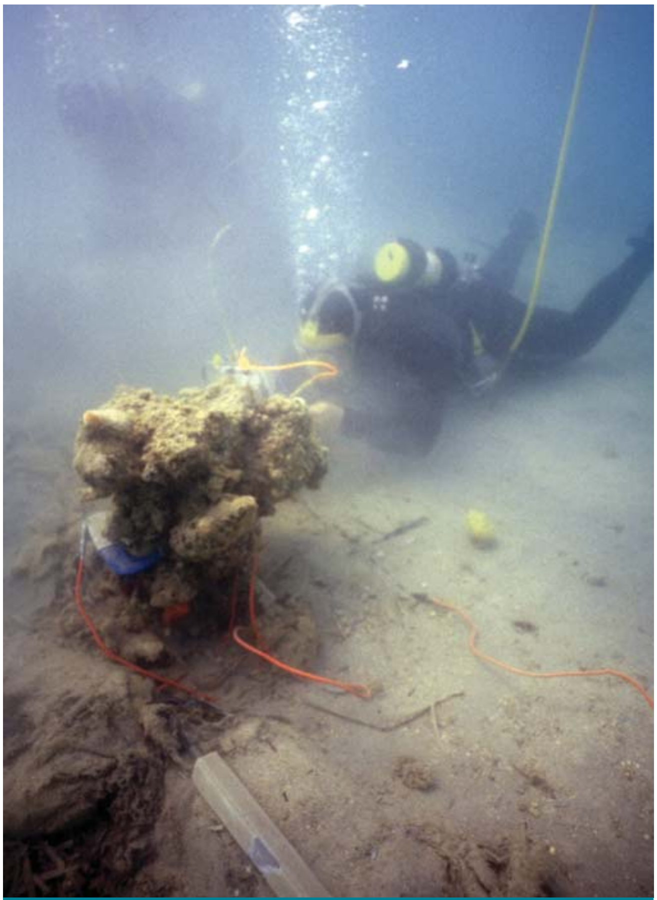

Fig. 5.5 Cathodic protection of an anchor at the James Matthews site in Australia. Photo: Maritime Museum of Western Australia.

than the higher quality metal object. This method is in use for the protection of pipelines, oil rigs and, for example, ship hulls, and has also been and is still applied on cultural heritage sites. For example, several iron cannons lying on the seabed have been preserved in situ in this way.[24] Other ship elements have also been preserved, such as the windlass, chain and deck knees on the *James Matthews*[25] and the engine of the Xantho,[26] both in Australia (Fig. 5.5). A free flow seawater environment is ideal for the use of sacrificial anodes. Its use in the sediment is more problematic because a current flow is needed, as well as regular monitoring.

In addition to sacrificial (or galvanic) anode cathodic protection, impressed current cathodic protection also exists. This requires an external power source with inert anodes.[27] At present, in the Netherlands and the Western Wadden Sea no cathodic protection methods have been applied on cultural heritage sites under water. The protection would allow metal parts of shipwrecks to have a longer lifetime in the water. This may be important for scientific reasons, to ensure sufficient time to organize proper ex-situ conservation or to allow for visitors (sports divers) to view the objects in situ.[28] Some of the wrecks in the Burgzand area have exposed iron objects that could be protected in this way.[29]

5.2.3 Covering a site

Covering sites with sediment or other materials works by limiting the access of oxygen. The presence of oxygen can be the cause of severe corrosion or biological attack from bacteria, fungi or shipworm. In environments where sediment erosion is not prevalent, a covering of just a few centimetres is sufficient to prevent the diffusion of oxygen and thus the growth of shipworm, one of the most vicious degraders in salt water.[30]

Covering with loose sediment

The simplest way of protecting or stabilizing a site in situ is to dump either clay or sand on it. Whether this is effective or not depends on the dynamics and whether other measures are taken to keep the added sediment on the site. However, even in still water, the dumping of sediment has to be done carefully and with much thought. When dumping fine sand from the water surface, it may disperse and not all end up on site.[31] The deeper a site is, the bigger the problem to ensure the sediment ends up where it should. Moreover, in relation to particle size, the finer the grain, the better it is for creating an anaerobic environment, but the more difficult it becomes to deposit it on the right spot. Open areas may then not have sufficient protection. In addition, even in water that is usually stable, shallow sites are especially vulnerable to wind erosion and ice disturbing the seabed. Marine traffic such as sailing boats (with their leeboards) can also form a threat by cutting through the top sediment layer, while motor boats may push away sediment from the seabed, especially in places where they must manoeuvre.[32]

Another aspect to keep in mind is that when lose sediment is dumped on a site, it may mingle with the original stratigraphic layers and obscure observations of where the historical layers begin and end. This can be mitigated by adding an artificial layer – for example geotextile – between the original sediment on site and the material deposited on it.[33] To make a clear distinction

[24] MacLeod 1995, https://www.environment.gov.au/heritage/places/national/sirius(accessed 30-01-2017). On the 1790 shipwreck of HMS *Sirius*, see Bartuli et al. 2008.

[25] Heldtberg, MacLeod & Richards 2004, McCarty 1998. For more information, see also Steyne & MacLeod 2011

[26] Edwards & Cooper, 2013, McCarthy 1998.

[27] https://www.corrosion.nl/iccp-cathodic-protection/ (accessed 30-01-2017).

[28] See, for example, the cannon (carronade) from the HMS *Sirius* (http://www.museum.wa.gov.au/maritime-archaeology-db/bibliography/conservation-carronade-wrecksite-hms-sirius-1790-norfolk-island, accessed 30-01-2017).

[29] The iron anchors at the BZN 3 site and an exposed cannon on the BZN 10 site, for example. Before taking such actions, research to establish the current condition of these objects should first be conducted.

[30] See Chapter 3.

[31] For example, the *Day Dawn* wreck in 1982 (Moran 1997, p 129), *William Salthouse* (Harvey 1996, Hosty 1988).

[32] The fifteenth-century Hoornse Hop 1 wreck and nearby the foundered eighteenth-century Hoornse Hop 2 (Bartels 2011) are both lying near the entrance to the harbour of Hoorn and at a depth of only 3.5 metres. Multibeam sonar revealed that both wrecks are under threat of being hit by the swords and long keels of pleasure yachts. Also, the Roman site (Quay, Cuijk 6000 area) at Cuijk is constantly under threat of being hit by large river boats or of the silt being blown away by ship propeller action, Manders 2006 (3), and Manders & Brouwers 2016.

[33] This has, for example, been done on the Cuijk 6000 site, see Section 4.6.

Fig. 5.6 A logboat supported with sandbags during a training course in in-situ protection for the WreckProtect project in 2011. Photo: M. Manders.

Fig. 5.7 Six thousand sandbags were used to protect the BZN 3 wreck in 1988. Photo: RCE.

between the original sediment on site and the deposited sediment, one can also choose a completely different sand (not present in the local environment). In this case, it is important to know the origin of the sand, as unwanted materials such as iron and too much organic material may have negative effects on the site due to unwanted biological and chemical processes and bioturbation.[34]

Sandbags

Sandbagging has often been used in the past, as the unit costs are low and they effectively act as a barrier against looting, erosion and shipworm by creating an anoxic environment in which the shipworm larvae cannot settle (Fig. 5.6).

There are some aspects to keep in mind when installing sand-bags on site. Deployment is often expensive and time consuming in terms of person hours required and the difficulty of moving sandbags around under water.

Sandbags are also often overfilled. This not only makes them more difficult to deploy, but by filling them too much they create an obstruction on the seabed which, if currents are present on the site, can cause scour around the edges of the sandbagged areas. This undermines them and can expose new areas of the wreck. As a rule of thumb, the sandbag should only be a third to a half filled. Fine-grained sand with a low organic content is best. When keeping to these rules it is possible to 'mould' the sand-bags around structures and keep as low a profile as possible.[35] Moreover, it is extremely important that synthetic sandbags are used, as any made of natural material will be microbially degraded very rapidly, probably within a few months.[36]

Sandbags have been used in many cases. However, as with many of the protective measures deployed, there is a lack of systematic assessment or long-term monitoring of the efficacy of in-situ stabilization. They may be seen as a temporary stabilization method, although it should be noted that the BZN 3 wreck site was sandbagged in 1988 and the mound still serves as firm protection (Fig. 5.7). The quality of the fabric of the sandbags was also investigated in the SASMAP project. Although slightly degraded, after almost 26 years in the water they are still in remarkably good condition.[37] Unfortunately, the bags also create a huge barrier to monitoring the quality of the wood inside the mound. In brief, sandbagging is most effective for small areas where currents threaten to remove archaeological material.[38]

Geotextiles

Geotextiles are finely woven or non-woven synthetic fabrics and have been used for all sorts of purposes, including coastal engineering aiming to prevent coastal erosion.[39] They are commonly used in marine archaeology to cover areas or trenches at the end of an excavation season.[40] Laying a geotex-tile cover over an area and then backfilling enables the cultural layers that have been excavated to be relatively easily relocated in the following season. They have also been used as physical barriers to protect against shipworm on archaeological sites. Research carried out on the site known as the Zakynthos Wreck[41] has shown that a specific grade of geotextile, Terram 4000,[42] was effective at preventing the larvae of shipworm settling on the wood. Similarly, in the EU MoSS project, work with geotextiles showed the same results, as has research on the wrecks of the HMS Colossus[43] and the Swash Channel Wreck.[44] The flexibility of the fabrics makes them ideal to mould around timbers which are standing upright on the seabed. However, the higher the number of Terram geotextiles, the more dense and the less easy (less flexible) they are to use.

Moreover, the material can be extremely buoyant and, as a standard roll is 4 metres wide, weights need to be added to lower the material onto the seabed. If large areas are to be covered, the geotextile can be prepared by inserting eyelets, allowing several parts to be easily joined using cable ties. Unrolling geotextile is

[34] See also Kroes et al. 2013 and Chapter 3.

[35] Gregory & Manders 2011, 112.

[36] See, for example, the use of hessian bags at the Swash Channel wreck, Palma 2009.

[37] Gregory et al. 2013.

[38] Oxley 1998 (1), 1998 (2), Richards et al. 2009, Steyne 2009, Soulsby 1997.

[39] Terram Geosynthetics product folder, England April 1999, TC/E 001.

[40] See, for example, http://www.thetoc.gr/eng/culture-arts/article/zakynthos-spanish-shipwreck-excavations-end-for-season (accessed 30-01-2017).

[41] Pournou et al. 2001.

[42] Producers of geotextile include Terram: www.terram.com (accessed 30-01-2017). and Propex: http://propexglobal.com/ (accessed 30-01-2017).

[43] Camidge 2009.

[44] Palma 2009.

Fig. 5.8 A + B Geotextile rolled out over a wreck site during the UNESCO Advanced Course on In-situ Preservation in Thailand. Photos: M. Manders.

often easier if there are two divers. They should ensure that any current is behind them, which will also facilitate unrolling of the geotextile. At the same time, the divers can use sandbags to weigh down the geotextile as it is being rolled out and prevent it floating. This job can also be divided between the two divers: one rolling out the geotextile and the other placing the sandbags, as was done on test sites in Tudse Hage (for the WreckProtect project) and in Rayong, Thailand (for the UNESCO Advanced Course on In-situ Preservation) (Fig. 5.8 A + B).[45]

As seen within the MoSS project, Terram geotextile in the form of bags may also filter sand out of the water when, for example, wrapped around an object. The amount of sand caught is related to the thickness and density of the geotextile. The project study found that the lower the grade, the more sediment trapped, even though the bags were floating approximately one metre from the seabed. After twelve months on site, samples were completely covered by sediment within the geotextile bags.[46] Moreover, evidence of barnacles, algae, bivalves and other marine organisms was recorded on the surface of the geotextile bags. This shows that the geotextile may be used as a component to create an artificial reef underwater that can be naturally overgrown.[47]

Geotextile has been found to work well against attack by *Teredo navalis* or shipworm. The level of attack decreased with the thickness of the geotextile grades used. The grades of 2000 and 4000 were free of attack. While the lower grades of textile (500 and 1000) however, could not prevent attack by *Teredo navalis*, the attack was less severe. It can be concluded that the lower grades slow down attack, perhaps in combination with the sediment that they catch, and the higher grades of Terram prevent attack.[48]

Covering with the help of sediment transport

Although sites are often protected against biological deterioration due to elements such as wood borers, underwater archaeological sites are also threatened by sediment transport. However, this sediment transport can also be used to the advantage of protection on site. While sand may cause erosion and abrasion, if sand suspended in water can be trapped in one way or another and kept on site it may be used to cover it and create an oxygen-free environment.

Artificial seagrass

One method which is used in the offshore industry for stabilizing pipelines and cables involves the use of artificial seagrass. There are several proprietary products on the market, all of which function on the same principle (Fig. 5.9).[49] When deployed, one should ensure that there is sediment transport on the site. This can be easily noted by looking at bed forms, that is, sand ripples on the seabed. During tests, it was observed that aligning the long edge of the mat with artificial seagrass perpendicular to the direction of any current allowed the maximum amount of sediment to be trapped.[50]

The easiest way to install the mats is by ensuring the current is behind the diver, which facilitates the rolling out of the mat. After installation it is beneficial to regularly 'rustle' the fronds to make sure they are not filled with seaweed or other detritus. Moreover, when sediment settles between the fronds, this movement of sand also has a cleaning function.

The mats can be quite expensive, especially in relation to the budgets available for archaeological projects. Within some projects, they were produced manually; however, this is labour intensive.[51]

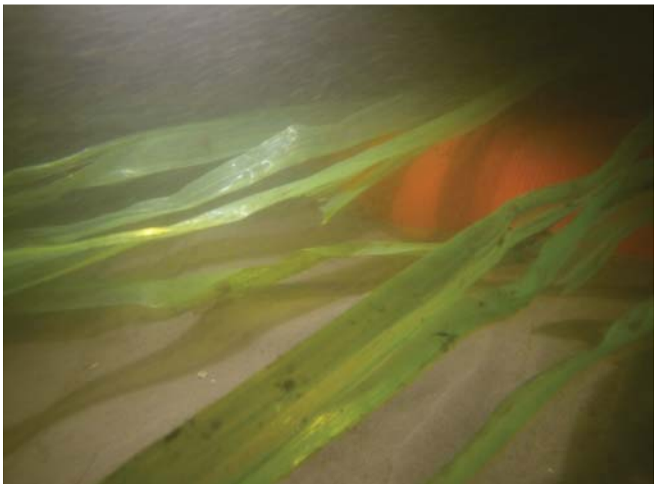

Fig. 5.9 Artificial seagrass, as installed on the BZN 10 wreck. The fronds are lying almost flat on the seabed due to the current. Photo: M. Manders.

[45] Field school in-situ preservation, WreckProtect project in 2011, Roskilde Denmark. http://www.unescobkk.org/culture/uch/capacity-building/courses/advanced/in situ-preservation/ (accessed 16-3-2017).

[46] Palma 2004 (2), 23.

[47] For more about plans to create artificial reefs on shipwrecks see: https://erfgoedstem.nl/bescherming-scheepswrakken-en-kansen-biobouwers-wadden-zee/ (accessed 08-04-2017).

[48] Palma 2004 (2), 23.

[49] Producers of artificial seagrass: Seabed Scour Control Systems (http://www.sscsystems.com, accessed 30-01-2017), Cegrass Control Systems Cebo UK Ltd.

[50] Gregory & Manders 2016, 65–73.

[51] http://www.unescobkk.org/culture/uch/capacity-building/courses/advanced/in situ-preservation/ (accessed 30-01-2017).

Fig. 5.10 Detail of the artificial seagrass mats with hoisting frame and gravel-filled tubes as weights on the edges. Photo: Paul Voorthuis, Highzone Fotografie.

The mats need to be fastened to the seabed. This can be done by anchors (as are used by Seabed Scour Systems, (SSCS) the producer of the tested seagrass mats). These penetrate 80 to 100 cm into the seabed and could damage underlying cultural heritage.[52] They can also be weighted down with heavy material such sandbags. SSCS has now developed a system where each mat is weighted down with gravel-filled tubes on each side (Fig. 5.10). These mats were tested during the EU-funded SASMAP project.[53] The prepared mats can be installed on the seabed in a couple of minutes with the help of a specially developed hoisting frame that picks up and releases the mats. This, however, requires a large ship and crane for installation.[54]

In strong currents, the seagrass fronds can actually lie flat and are ineffectual at collecting sediment. Tests with different sizes of fronds have revealed that in areas with strong currents, shorter fronds are more effective, due to the fact that they remain upright more easily than longer fronds.[55] However, according to the tests, the Wadden Sea turned out to be extremely hostile and not favorite to use the mats and especially the fixing system. The latter seriously has to be reconsidered.

Although the artificial seagrass mats filter the suspended sediment out of the water, the collected sediment can easily be scoured out as well. However, due to the fact that the fronds will stand upright again as a result, the process of capturing the sand may start all over again. This process might work well especially when there is no barnacle growth on the fronds.

Artificial seagrass mats can be best used to protect sites with low height differences (e.g. not much of the ship's construction protruding from the seabed) and low to modest current speed. At present, it is also being tested as a soft barrier on the edges of debris netting protection, designed to avoid scour on the netting.[56]

Notable examples where artificial sea grasses have been used or trialled are on the wrecks of the *William Salthouse* (Australia),[57] the *James Matthews* (Australia),[58] the Hårbølle Wreck (Denmark)[59] and a test site in Thailand[60] (Fig. 5.11). For the SASMAP project, tests were undertaken at the BZN 10 wreck (the Netherlands), Tudse Hage (Denmark) and Baiae, Naples (Italy).[61]

Obviously, another form of in-situ protection could be the reintroduction of natural seagrass in areas where this has disappeared. This, however, involves mitigation measures that address why the natural seagrass disappeared in the first place; for example, it may be necessary to improve the water quality. The introduction of seagrass has been attempted at various sites, often with disappointing results.[62] There are also plans for other areas that include cultural heritage.[63] Encouraging,

Fig. 5.11 Artificial seagrass as used under water during the UNESCO Advanced Course on In-situ Preservation in Thailand. Photo: M. Manders.

[52] Coenen et al. 2013, 38.

[53] www.sasmap.eu (accessed 30-01-2017).

[54] Coenen et al. 2013.

[55] Ibid.

[56] This test is being undertaken at the BZN 10 site as part of the SASMAP project.

[57] Steyne, 2009.

[58] Richards et al. 2009.

[59] Gregory, 2008.

[60] http://www.unescobkk.org/culture/uch/capacity-building/courses/advanced/in situ-preservation/ (accessed 30-01-2017).

[61] Coenen et al. 2013.

[62] See, for example, Fonseca et al. 1998, 43 and also the introduction of turtle grass in Biscayne National Park: Skowronek et al. 1987, 317.

Fig. 5.12 A. Preparing polypropylene nets weighted down with sandbags to be used on the Avondster wreck site (1659) in Sri Lanka, B. The nets installed on the wreck. Photos: courtesy Avondster Project.

however, is that through natural dispersion, seagrass is slowly starting to recolonize the Dutch part of the Wadden Sea.[64]

Debris netting/shade cloth

Debris netting is net-like material which is used when carrying out construction work on buildings in order to prevent any building debris falling on passers-by.[65] Shade cloth is quite similar but used to protect plants against the full strength of the sun (Fig. 5.12 A + B).[66] The archaeological use of debris netting was first developed in the Netherlands and was further developed in the EU MoSS project.[67] The debris netting functions in a similar way to the artificial seagrass. The idea is that the net is loosely fastened over the structure to be protected, so that it floats in the water (Fig. 5.13). As with the artificial seagrass, the method is dependent on there being currents and sediment transport in the water. If there is sediment transport and the sediment is sufficiently fine to pass through the mesh, the sediments will be slowed due to friction, come out of suspension and subsequently become trapped under the net, creating a burial mound under water.

With the use of shade cloth/debris nets one should ensure that there is sediment transport on the site and have an idea of what kinds of sediment are being transported in terms of particle size. Debris netting which has a mesh size large enough for the sediment to pass through should always be chosen. One type of net where there is a recognized good compromise between strength and mesh size is known as the 'Windbreak net' of 230 gm-2, mesh size 5 x 2 mm.

Most debris nets are supplied in 50 metre rolls which are 2-3 metres wide. The net is extremely buoyant and therefore should be weighted when installed under water, for example by wrapping it around a metal rod. Eyelets on the edges of the net should be inserted – but are usually already made in the factory – both to enable fixing of the net into the seabed and joining nets together. When joining the nets together, there should be an overlap between the two. In this way, potential gaps between the nets

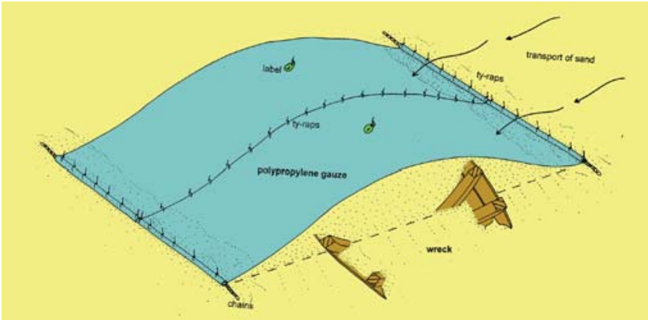

Fig. 5.13 The method of using polypropylene nets on shipwrecks. The sand transported by the current will pass through the tiny holes in the net and settle on the wreck. Drawing: M. Manders.

when they tighten due to the sediment build up can be avoided. Where possible, the long edge of the net should be aligned perpendicular to the direction of any current in order to trap the maximum amount of sediment. Installation on site is facilitated by ensuring that any current is behind the diver when positioning the net, allowing easier roll out of the net and also avoiding entanglement. The net must not be stretched tight on the seabed but should be loose. For example, when covering a length of 5 metres, at least a few metres of net more (>2mtr) should be rolled out so that there is enough loose material to float in the water column.

The net can be fixed to the seabed either with long pegs which penetrate the seabed or heavy material such as anchor chain or sandbags (Fig. 5.14).[68] Small fishing buoys, designed to give the net buoyancy when fixed on the seabed, have been trialled as a method of keeping the net off the seabed (Fig. 5.15).[69] After initial installation, monitoring of the net is very important. Shortly after installation, the net should be checked and shaken to remove any sediment which is lying on top and attach further buoys if necessary for more buoyancy. The net is vulnerable to tearing, particularly where it is held down or anchored with pins and where two mats are joined together. It is important to check this as well because tears may quickly undo everything that has been achieved.

[63] For the Wadden Sea see: http://klimaatbuffers.nl/g-wadden-seagrass-restoration (accessed 30-01-2017).

[64] https://www.waddenvereniging.nl/onswerk/zeegrasherstel (accessed 16-03-2017).

[65] Some producers of debris nets are: UK: Coastal nets: http://www.coastalnets.co.uk/industrial_main.htm (accessed 30-01-2017).
US: Several: http://www.macraesbluebook.com/search/product_company_list.cfm?prod_code=5182050 (accessed 30-01-2017). South Korea: Tasco Ltd: http://www.alibaba.com/product-free/102525712/Scaffolding_Net.html (accessed 30-01-2017).

[66] See, for example, http://www.shadeclothstore.com/depts/shadeclothapplications.html (accessed 30-01-2017) and Manders 2006(2).

[67] Vos 2012, 89–105, Manders 2004 (2), 6–8.

[68] In the Wadden Sea, old (anchor or fishing) chains have been used to weigh down the nets. On the *Avondster* site in Sri Lanka, sandbags were rolled into the sides of the nets and fixed with cable ties to weigh the nets down, Manders 2006 (2) and Manders & Weerasinghe, 2007.

[69] See Manders (ed.) 2011, 32–33.

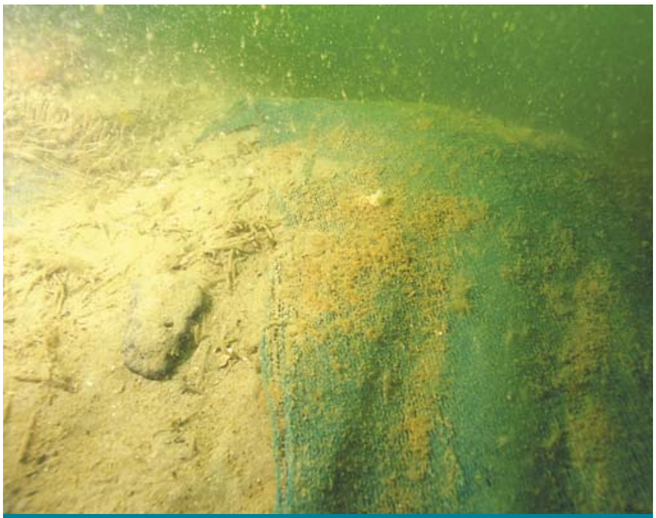

Fig. 5.14 The BZN 10 wreck covered with polypropylene scaffolding nets. photo: courtesy R. Obst.

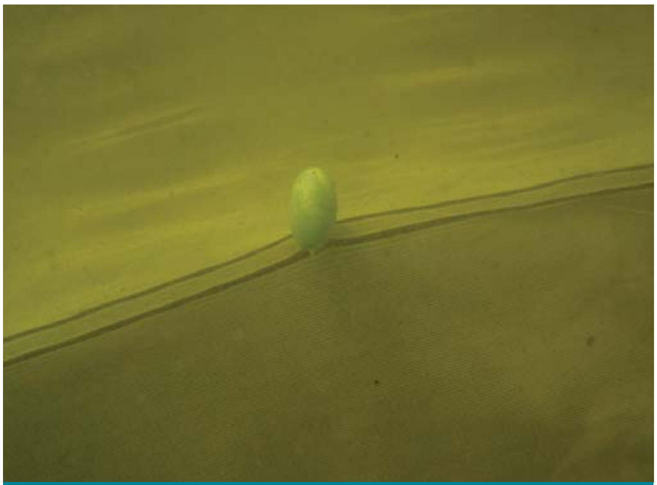

Fig. 5.15 Polypropylene scaffolding net installed on the BZN 3 wreck, with small buoys to keep the net afloat until sand has settled. Photo: M. Manders.

Parts of the wreck that protrude from the seabed may initially damage the nets which are loosely placed on the site. To avoid this, one can cover these parts with sandbags or add sediment with a water pump before or just after installing the nets.[70]

The method has been used successfully on several sites, notably the wrecks of the Burgzand Noord, that is, BZN 2, 3, 4, 8, 9, 10 and 17 in the Netherlands,[71] the *Avondster* in Sri Lanka[72] and the Darsser cog in Germany,[73] a test site in Thailand,[74] and it was successfully trialled around the wreck of the Hårbølle site in Denmark[75] (Fig. 5.16). However, trials of the netting on the HMS Colossus[76] and the Swash Channel wreck[77] were not deemed successful. It is most likely that this was due to the incorrect use of the materials on site. This again emphasizes the need to understand the way in-situ stabilization methods work and that they will not necessarily be effective on every site.

Fig. 5.16: Nets with small buoys used for the protection of a test site during the UNESCO Advanced Course on In-situ Preservation in Thailand. Photo: courtesy UNESCO.

Damage to shipwreck sites in the Netherlands are frequently caused by the often violent natural conditions, fishing or sports divers. Although the initial protection by debris nets seems to be very effective in this area and under these conditions, long-term management requires more than this solution. Currently, the RCE and the 'Programma naar een Rijke Waddenzee' (Programme for a Rich Wadden Sea)[78] are in the process of developing a method to stabilize wreck mounds after sand has been caught by the nets, by promoting the colonization of bio-builders such as mussels and oysters on site.[79]

5.3 Reburial underwater

Shipworm cannot survive for long periods in the absence of dissolved oxygen and it is a fact that wood, when buried in the seabed, will only be susceptible to slow microbial degradation caused by bacteria, due to the lack of oxygen in marine sediments.[80] Thus, covering or reburying wood is one way of preventing further attack by shipworm, the main degrader in a salt water environment. Covering or reburial has been achieved by several methods, as has already been explained in Section 5.2, but may also include natural or intentional backfilling of timbers after excavation, sediment dumping or deflection of sediment to cover a site in situ. Furthermore, artefacts have been reburied after raising and documenting. Reburial can thus be a management solution.

5.3.1 Backfilling after excavation

A shipwreck site is rarely completely excavated during the course of a single excavation period (See also Chapter 4).[81] Alternately, a site may not be completely excavated if the whole hull is not to be removed. Thus, between excavation periods, sites are often either purposely re-covered with sediment or left to be naturally covered by sediment. This covering is essential to protect the archaeological information against erosion and especially if the

[70] Additional sediment was pumped under the debris nets with a water dredge on the *Avondster* wreck in Sri Lanka and also on the extensions of debris netting on the BZN 3 wreck that were laid on site in 2013.

[71] Manders 2004 (1), 2004 (2), 2004 (3), Manders 2006 (1), Vos 2012.

[72] Manders et al. 2004, Manders, 2006 (2).

[73] Jöns 2004.

[74] http://www.unescobkk.org/culture/uch/capacity-building/courses/advanced/in situ-preservation (accessed 30-01-2017).

[75] Gregory, Ringgaard & Dencker 2008.

[76] Camidge 2009.

[77] Palma 2009.

[78] https://rijkewaddenzee.nl/het-programma/ (accessed 28-01-2017).

[79] https://maritiem-erfgoed.nl/inhoud/bescherming-scheepswrakken-biedt-kansen-voor-biobouwers (accessed 28-01-2017).

[80] See also Chapter 3.

[81] In practice, shipwrecks will often not be completely excavated at all.

area is known to be affected by shipworm. The summer months, when most excavations take place, are a prime breeding time for shipworm; thus, it is extremely important that sites are not left uncovered. However, for backfilling to be successful, it should be determined that these sediments will not be removed due to natural sediment transport.

5.3.2 Reburial and redepositioning

A frequently used word in the context of in-situ preservation is 'reburial'. Before discussing the ways to do this, we should ask ourselves what the word actually means in an underwater archaeological context. The word can be used for different situations. A site may be in need of reburial because it has been uncovered by natural or direct/indirect human activity. This is the case for a vast majority of the sites that are currently being conserved in situ, since most sites were found because they surfaced the seabed.[82] Moreover, if sites are fully covered, there is usually no need for active in-situ protection and reburial. This kind of reburial of cultural-historical material that is under threat fits perfectly with the aims and definitions of in-situ preservation and management.[83]

Sometimes, however, reburial is used for mitigation after excavation. This may be part of the overall management plan; a way of taking care of a site. Reburial may then mean, for example, temporary protection, covering exposed timbers between excavation seasons,[84] but also semi-permanent reburial after the termination of an excavation or even relocation of a site that has not undergone any excavation.[85] These kinds of reburial may not fully coincide with the definition of in-situ preservation as previously laid out in this thesis.[86]

Reburial of excavated sites may take place precisely on the spot where the objects were found, in an attempt to preserve the integrity and/or spirit of the place and at least a part of its context, if not all. However, reburial can also take place in the area at large. Similar natural conditions may then be taken into account, but by moving the objects, the integrity of the separate elements of the site will then be lost.[87]

Reburial has also become a means of mitigation against the high costs of excavation due to the conservation of materials that is often required afterwards. With the reburial of timbers and other finds, this can be avoided. There is something to say for this, not to mention the over-full museums and archaeological depots.[88]

There are also situations in which it is thinkable that there is no time to raise funds for conservation, subsequent long-term storage and/or display of all the finds, including the hull structure.[89] This may be the case, for example, when, due to sub-sea development, it may be necessary to completely excavate a site and recover artefacts as part of a rescue programme. We must ask ourselves whether we should always excavate whole sites and conserve all of the objects under any circumstances. Not all objects can be put on display and sometimes it is better to preserve objects in the natural environment rather than remove them and conserve ex situ. This however also relies on the questions asked when planning an excavation. Thus, hull remains and even artefacts can also be redeposited in the appropriate environment (whether nearby or further away from the original site) to facilitate their long-term storage. Hence, the final meaning of the term 'reburial'.

One of the first attempts at controlled reburial of archaeological remains under water was carried out in the 1980s. From 1980 to 1984, Parks Canada excavated the remains of the Basque whaler *San Juan* in Red Bay, Labrador.[90] Following the excavation, raising and documentation of the wreck, the timbers were reburied to protect them against biological, chemical and especially physical deterioration due to ice flows. What made this early project different from other reburial attempts at the time was that monitoring of the reburied timbers and the surrounding reburial environment was planned from the outset. Sandbags and the ballast from the ship were used to construct an underwater

[82] It remains difficult to find sites that are fully covered by silt.

[83] See Chapter 4.

[84] See, for example, the protection measures taken during the Zakynthos excavations in Greece, Pournou 1999.

[85] This is often triggered by money issues (cost of space, conservation, etc.).

[86] See Chapter 4. For different approaches to reburial, see the examples of the *Fredericus* site in Sweden (RAAR Project), the Clarence shipwreck in Australia (http://www.ahspp.org.au/), and the reburial of the Greifswald shipwreck http://www.suedkurier.de/skplus/skthemen/leben-und-wissen/Wrackfunde-auf-dem-Grund-der-Ostsee;art1003203, 5793696 (accessed 30-01-2017), Val 7 near Amsterdam, the Netherlands (Waldus 2010) and Lake Constance. See the UNESCO Convention on the Protection of the Underwater Cultural Heritage: Annex Rules concerning activities directed at underwater cultural heritage, II. Project design. See also KNA Waterbodems 3.2 at http://www.sikb.nl/doc/KNAwaterbodems32/000.%20Voorblad%20KNA%20Waterbodems%20versie%203.2%20definitief.pdf (accessed 30-01-2017).

[87] The Cultural Heritage Agency of the Netherlands (RCE) has a reburial location in the Dutch Flevopolders near the village of Nijkerk.

[88] See, for example, Rappard 2014, 6.

[89] In addition to the high cost of the conservation of shipwrecks, for archaeological depots, it would also be difficult to deal with the depositioning of these large objects. This is the reason why the Dutch Minister has ordered the establishment of a national maritime depot. However, capacity and space would be easily and quickly filled if all investigated shipwrecks were to be removed from the silt, conserved and depositioned in this depot in Lelystad. Although assessed and some partly excavated, at present, no shipwreck from the Western Wadden Sea has been removed and depositioned. A stern part from the *Buytensorgh* (VOC returnship, wrecked 1770) and a part of the portside of the Scheurrak SO1 ship (sixteenth-century grain trader) are the only ship structures in the national depot in Lelystad. Larger parts of the Scheurrak SO1 are 'stored' in the wet depot (below groundwater level) near Nijkerk.

[90] Stewart, Murdock & Wadell 1995.

cofferdam, where the timbers were placed in several layers, each separated by a layer of sand. Modern wood blocks were placed alongside each layer for subsequent removal and analysis. The burial mound was then covered with a heavy-duty plastic tarpaulin anchored by concrete-filled rubber tyres.

A similar project recently began in Sweden, which set out to validate the efficacy of reburial of archaeological materials in the marine environment. The 'Reburial and Analysis of Archaeological Remains' project focuses on the reburial of artefacts from the wreck of the *Fredericus* (1719) in the Swedish island port of Marstrand.[91] Archaeological investigations were initiated in the harbour because of the need to reinforce the quay. Two major investigations were undertaken. One was an excavation of the wreck of the frigate *Fredericus*, sunk in a battle between Sweden and Denmark, and the other was an investigation of an area alongside the quay, which revealed cultural remains dating back to the seventeenth century. These two excavations yielded approximately 10,000 artefacts. Full conservation treatment of all of the excavated artefacts was considered both impractical and unnecessary from an archaeological perspective, and it was decided that 85–90% of the finds would be reburied after proper archaeological documentation.

Among other materials (a shipwreck rarely consists of just wood), modern wood samples were left exposed to seawater and reburied at various depths down to 50 cm. Results after three years of reburial showed that the samples left exposed to seawater were rapidly and heavily degraded by wood borers, while those covered by sediments were only microbially degraded.[92] The results reflect those on the Red Bay wreck and other experiments on the reburial of wood, all of which suggest that even a thin covering of sediment is significant enough to limit the amount of oxygen in the sediment to a degree that does not allow the shipworm to survive.[93]

Reburial can be done using existing sediment transport over a site. One or a combination of the previously described methods to catch sediment can be applied. Reburial of the site can also be done using geotextiles, plastic geomembranes or the dumping of coarser grained material (gravel) to ensure the sediment is not removed.[94]

Local sediment from surrounding areas is often used for reburial and is generally characterized by its suitability. However, the porosity and organic content of any sediment should be assessed, at least before applying. Sediment should ideally be fine-grained sands, which are less porous and naturally contain less organic material than larger particle sized sediment. This leads to lower rates of mineralization when the dominant process is sulphate reduction, which is typical of marine sediments (See Chapter 3). This contrasts with the higher rates of mineralization in more porous sediment with higher organic contents.

The optimal depth of burial depends on the nature of the sediment to be used. However, as mentioned above, even a thin covering of sediment will limit the oxygen content sufficiently to prevent the survival of wood borers. Reburying artefacts in one layer, as well as providing a detailed site plan, makes it easier to return to the site if objects or ship structures need to be accessed for research or monitoring. The materials used in the reburial, including labels and containers, should be durable.

In addition to the above-mentioned Red Bay and Marstrand projects, the Clarence project should also be mentioned.[95] This project aimed specifically at reburial and finding cheaper ways to conduct archaeological research on shipwrecks.

Another reburial has been executed at a ship barrier consisting of 20 historical shipwrecks in the Bay of Greifswald. The barrier was found with aerial photography (Fig. 5.17 A + B). It was created in 1715 when the Swedish navy ballasted the ships, sinking them in alignment in water that was 3 to 4 metres deep. Together, they formed a 980 metre defensive barrier which prevented enemy fleets from entering the bay. As one of the wrecks (9 x 3 metres) needed to be removed to allow the Nord Stream pipeline to be

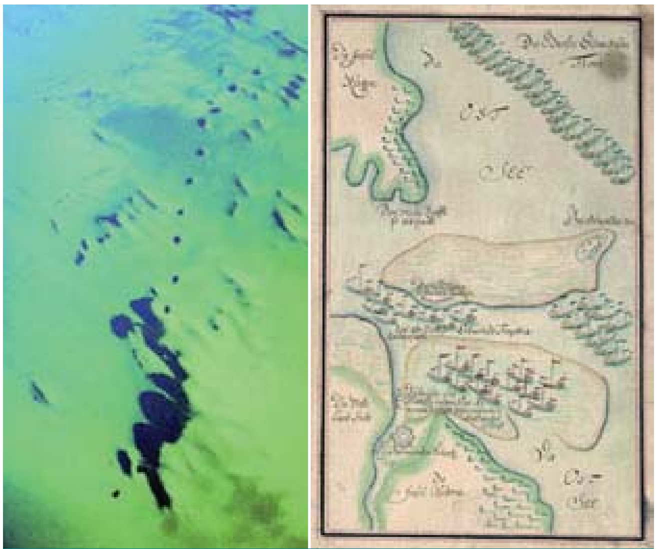

Fig. 5.17 A + B The Greifswald ship barrier. The dots on the aerial photo are the wrecks. Photo: courtesy MACHU project.

[91] Bergstrand & Godfrey (eds) 2007.

[92] Gjelstrup Björdahl & Nilsson 2007.

[93] Waddell 1994.

[94] This was done between excavation seasons in the *Mary Rose* project, Staniforth & Stefi 2010, 1547.

[95] See also an earlier paper on the possible use of the reburial of ship timbers in Gregory 1999, and http://www.ahspp.org.au/ (accessed 30-01-2017).

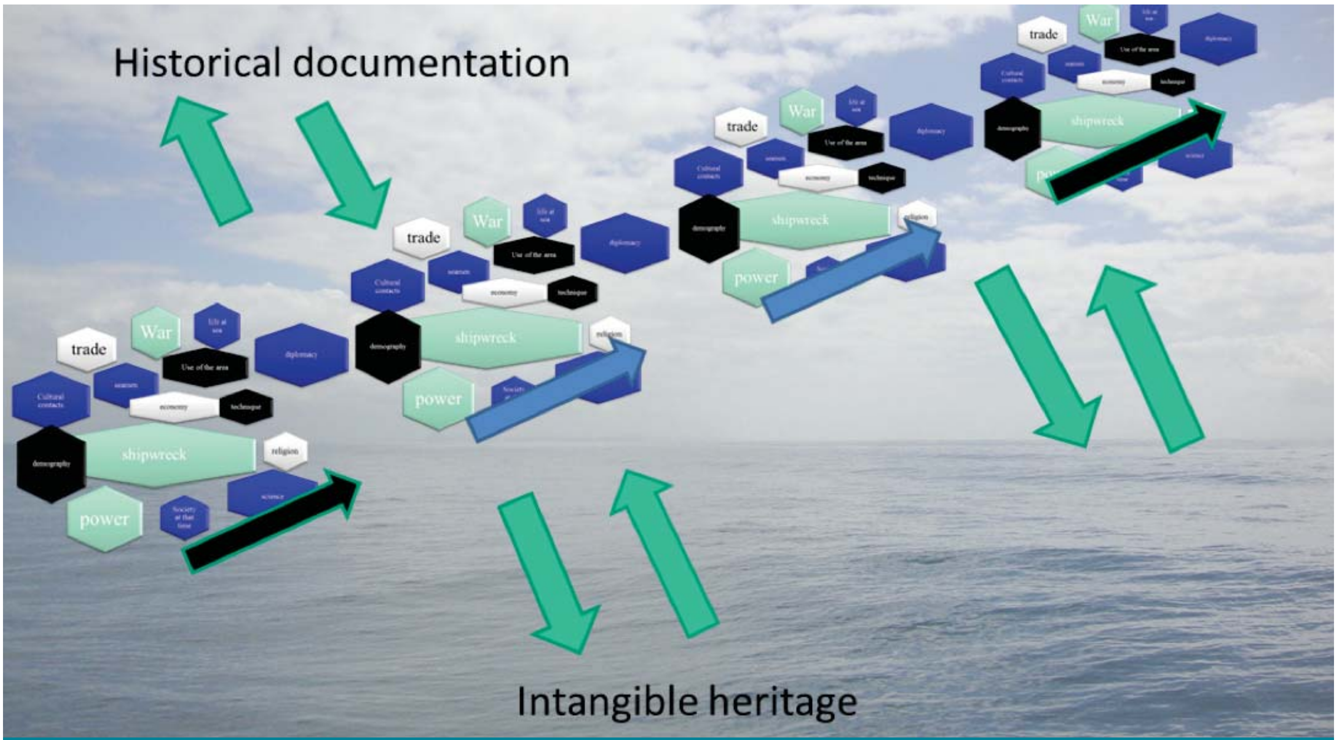

Fig. 5.18 Each single shipwreck may tell multiple stories about the past. Together, they tell the history of a people or a country. Figure: courtesy M. Manders.

laid,[96] the whole wreck was lifted out of the way and reburied a couple of hundred metres away.[97]

A wreck near the island of Reichenau in Lake Constance, Germany, was also reburied in a certain sense.[98] This fourteenth-century shipwreck was lying in such shallow water that the archaeologists in charge decided to temporarily remove it from the lakebed, investigate it, deepen the hollow in which it was found and put the wreck back into it. It was then further protected with geotextile and sandbags.[99]

In the Netherlands, there is a central reburial area. This is the field depot of the Cultural Heritage Agency of the Netherlands established in the 1980s, which has been used since then for the reburial of excavated material from shipwrecks in the polder, but also from excavated underwater sites. Wood is deposited under the groundwater table.[100] Unfortunately, no research has been done to monitor the effects.

The reburial of shipwrecks and artefacts is different from the relocation of wrecks, usually undertaken for other reasons. Some shipwrecks, such as VAL7 in the Netherlands[101] and the Gresham Ship[102] in the UK, have been relocated to another area to be enjoyed by sports divers, but without further protection.

5.4 The 'single' object vs landscape approach

Shipwrecks have been the primary focus of underwater archaeological research for a very long time. This has not only resulted in an object-focused approach but also in a narrow view regarding those wrecks as time capsules, nothing less but certainly nothing more.[103] This perspective on shipwrecks as enclosed stand-alone objects has had an influence on the management of the underwater cultural heritage. First of all, the focus has been on the ship and the event of its wrecking. This also concerns the connection and integrity of the objects belonging to the ship, all relating to a certain event at a certain time. Less emphasis has been placed on the development of the place, the site or local marine environment. Post-depositional processes are often not taken into account in research and even less from the perspective of adding information about the history of the place.[104] Moreover, not much emphasis has been put on shipwrecks in a wider context, as part of the maritime or broader cultural landscape. Sites are, therefore, still mainly individually assessed, in an ad-hoc approach, often not taking into account the significance they have for the surrounding area and vice versa.[105]

[96] Lüth & Staude 2009.

[97] Mierlo & Brenk 2010.

[98] http://www.focus.de/panorama/vermischtes/bodensee-600-jahre-altes-schiffswrack-vor-insel-reichenau-entdeckt-_aid_451385.html (accessed 28-01-2017).

[99] Mainberger 2007.

[100] http://www2.rgzm.de/navis/Musea/Nisa/cnis021.htm (accessed 28-01-2017).

[101] See Waldus 2010.

[102] The ship's oak timbers are now part of an 'underwater museum' in Stoney Cove, Leicestershire, which is explored by the site's 30,000 trainee divers each year. See more at: http://www.ancient-origins.net/news-general/thames-shipwreck-identified-cherabin-english-pirate-ship-pillaged-queen-001982#sthash.adkiCQjJ.dpuf (accessed 30-01-2017).

[103] See also discussion on the Pompeii premise, Chapter 4.

[104] Research on post-depositional processes on shipwreck sites is certainly not new. Muckelroy (1978) has written about them, and, for example, Ward et al. 1999 followed on from this. However, it is still not common practice to include this topic in research on shipwrecks.

[105] One example that illustrates this view is the excavation and reburial of a shipwreck near the Island of Reichenau in Lake Constance, Germany, that has been described previously. This sixteenth-century wreck, although clearly connected with the World Heritage island of Reichenau, was partly exposed in shallow waters and therefore under threat. It was decided to excavate the wreck parts (the ship as a construction) and then rebury the site by deepening the lake bed and 'sink' the site deeper into the soil, protecting it afterwards with sandbags. http://www.uwarc.de/reichenau.php (accessed 30-01-2017), and Mainberger et al. 2011. See also the example of the shipwreck of Greifswald.

Although this is a very focused approach, it has not contributed to the recognition that shipwrecks are connected to societies and cultures on shore and thus that they have significance for local communities (Fig. 5.18).[106]

This has also led to shipwrecks being regarded as accidental finds, intrinsically concluding that there has been no connection between the wreck and the location in which it was wrecked.[107] This perception will continue until we break the vicious circle. As long as geological, geomorphological and other environmental research is not common practice in shipwreck research, there will be no notion of the connection of the site to its historical environment, and thus this will not be taken into account.

This alone is already objectionable, but shipwrecks being regarded as enclosed stand-alone sites also makes it apparently easier to remove them from the environment, with which – in this view – they have nothing to do and nothing in common.[108] This removal may even occur prior to any archaeological research.[109] It is not unusual that objects from underwater cultural heritage sites are salvaged from a sea or riverbed in order to investigate them out of context, and the suggestion to do so has even been made by professional archaeologists.[110]

As a consequence, it is not surprising that the underwater cultural heritage is still often neglected in the process of developing policies and planning.[111] More emphasis should be given to connecting sites through a shared history in time and space.[112] There is no better way to link larger areas (e.g. for a World Heritage listing) than the maritime connection.[113]

5.5 The in-situ protection of well-preserved shipwrecks

Time and again, we are thrilled by the discovery of yet another well-preserved shipwreck. The discussion about what should be regarded as a well-preserved shipwreck was taken up in the MoSS project.[114] Within this European project, it became clear that 'well preserved' had a different meaning in the Netherlands than in the Baltic Sea Area, where three partner countries of the project 'met' (Sweden, Finland and Germany). While in the Netherlands one criterion was that it had to be possible to fully reconstruct a shipwreck from the archaeologically investigated remains, in the Baltic, a 'well-preserved' shipwreck was one that was usually still standing upright on the seabed, sometimes even with the masts upright (Fig. 5.19).[115] The condition of these ships (which can barely be called 'wrecks') is an indication of the stable conditions of the environment they are in. As long as nothing

Fig. 5.19 The Ghost Wreck, a seventeenth-century (possibly Dutch) flute ship in Swedish waters. The ship is extremely well preserved, standing with its masts still upright. Photo: Ghostwreck Project.

[106] Or even land-based archaeologists.

[107] See also Chapter 1.

[108] 'Een schip vergaat twee maal': a ship wrecks twice. Eelman 2002.

[109] Examples are abundant, see, for example, Cederlund 2004.

[110] On several occasions, excavation of the Roman Quay in Cuijk (the Netherlands) has been suggested by removing the 'archaeological layer' with a water dredge onto a sieve, after which the individual objects could be further processed. A new project proposal for the shipwreck of the Lutine (1799) suggested more or less the same thing, arguing that it not be referred to as an excavation but merely a salvage operation, because the site would be too disturbed to be of archaeological value anyway. Internal communication with RCE, RWS and the proposed project leaders, 2014.

[111] Houkes n.y.

[112] See also the remarks on the history of an area through time and place.

[113] Until now, this has not been taken up explicitly as a subject for World Heritage nomination; however, there are quite a few nominated sites that implicitly focus on this connection, such as the Viking sites in northern Europe and the fortresses on the European Caribbean islands. Many World Heritage sites have an essential maritime cultural component also extending into the adjacent waters. However, the underwater cultural heritage sites – although strongly connected – have not been included in the World Heritage Site Management Plan. Examples are Qal'at al Bahrain, the ancient harbour and capital of Dilmun, Old Havana and its fortifications, the old town of Galle and its fortification, and the Micronesian stone heritage, as discussed in 'Celebrating the Genius of Navigators', Ceremonial Centres of the Early Micronesian States: Nan Madol and Lelu.

[114] Manders & Lüth 2004, 65, 68.

[115] It remains difficult to define what 'well preserved' means. The same discussion occurred during the MoSS project and was focused on the monitoring, visualizing and safeguarding of well-preserved shipwreck finds. The shipwrecks investigated included the *Vrouw Maria* (1771), a ship wrecked off the Finnish coast that still has its mast standing upright, the Eric Nordevall (1856), a paddle-steamer in Lake Vattern, Sweden, in excellent condition and the BZN 10 wreck (seventeenth century), although mainly submerged in the seabed, it is a complete portside of a ship, including its cargo, which can be fully reconstructed. See the publications of the MoSS project at http://moss.nba.fi/ (accessed 30-01-2017).

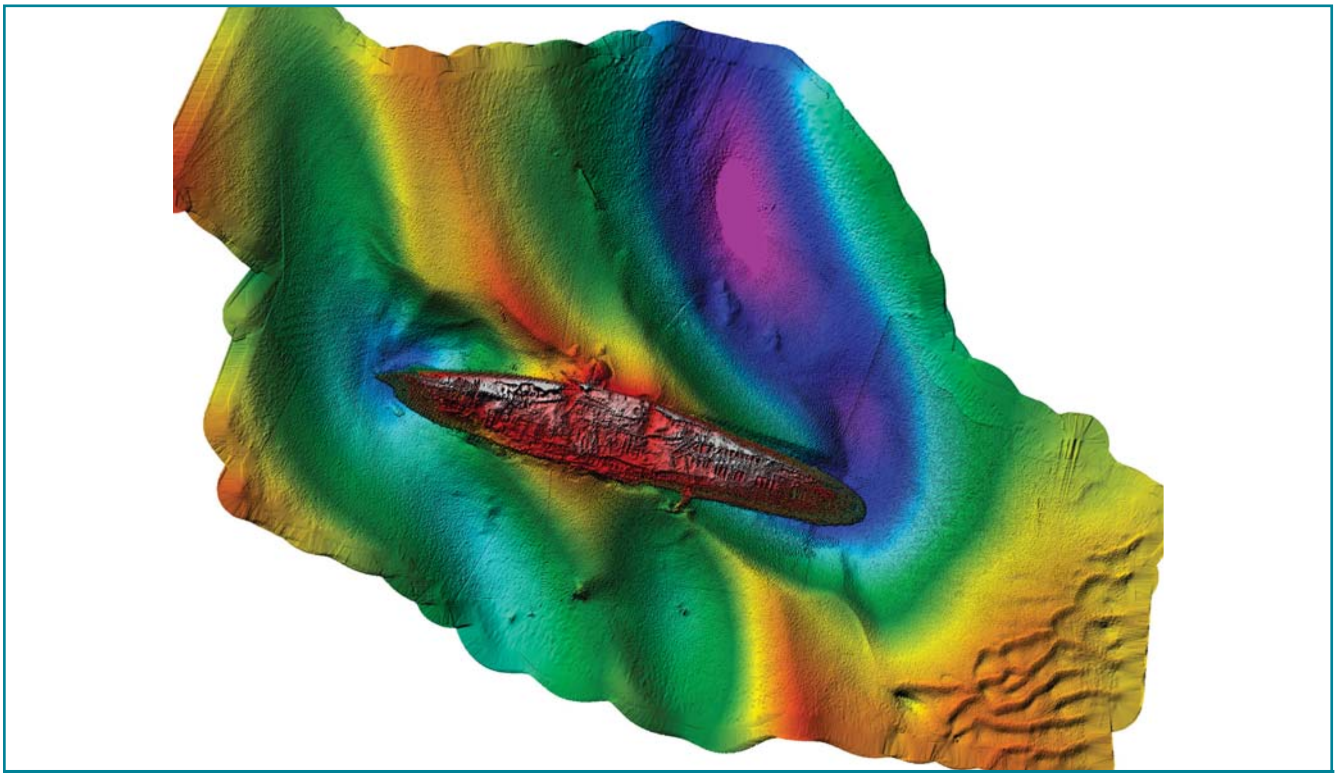

Fig. 5.20 Multibeam recording of HNLMS Koningin Emma der Nederlanden (Queen Emma, scuttled 1943). Figure: Periplus Archeomare.

changes, these ships may sit there for a few hundred years more before they fall apart. In practice, in-situ preservation consists of monitoring possible changes, and not much more. However, what if the situation changes? What if human interventions have greater effects? What if climatic and water conditions change? What if invasive species start to attack these sites? Can we then protect the ships against this and keep them preserved in situ? This is something that has concerned scientists for quite some time. The Baltic Sea is known for having excellent conditions – low salinity, cold and stable water on the seabed, slow currents – in which to preserve wooden ships, with other locations being the Black Sea in the southeast of Europe, and the Great Lakes between the US and Canada.[116]

With respect to iron and steel wrecks, just like wooden shipwrecks, preservation depends on the existence or lack of oxygen. The best preservation areas would be deep, still water. Many iron and steel wrecks are not yet 100 years old. For many countries, this remains a reason not to protect them.[117] However, time may in fact be the only reason why these wrecks have not yet collapsed.[118] At present, there is still a lack of understanding about how iron and steel wrecks can be well preserved in situ. Experiments with sacrificial anodes have been undertaken.[119] In Australia, a specific seminar was devoted to iron, steel and steamship archaeology.[120] In 2015, for the first time, a project proposal (ReWarShip) to manage and preserve iron and steel wrecks (WW1 and WW2 wrecks) within the scope of a programme financed by the European Union was submitted.[121] Unfortunately, this project was not funded.

Whether wood, iron or steel, well-preserved shipwrecks protrude from the seabed for metres, or basically lie on top of it (Fig. 5.20). This makes them vulnerable to mechanical attack by natural erosion, looting or fishing activities, but also to biological threats, especially if new invasive species are introduced.[122] Climate change may provide a helping hand to such processes by changing the environmental conditions.[123]

If this occurs, it will be important to determine how we make choices about what to preserve and where. Is the aim to preserve the whole wood structure? The structural integrity of the ship (wreck)? Then the best solution may be to raise and conserve it, or to raise it and subsequently place it in a stable environment.[124]

Considering these difficulties of preserving sites in situ, it is important to ask ourselves the following questions:

» Does the site have to be preserved in situ?
» Might we lose part of the structure, e.g. the upright masts? If yes, then we might be able to lower the height of the construction and cover the site.
» Should the site remain in situ and, if so, does it need to be visible? And in what way?

[116] Black Sea: http://oceanexplorer.noaa.gov/explorations/07blacksea/background/plan/media/sinop.html (accessed 30-01-2017), Great Lakes, Cain 1983.

[117] For the Netherlands, it used to be 50 years minimum, but this is no longer the case. Today, protection under the Heritage Act is only based on the significance of the site. The UNESCO Convention has a minimum of 100 years old.

[118] http://www.dailymail.co.uk/sciencetech/article-1346446/Titanic-wreck-completely-destroyed-20-years-new-rust-eating-bacteria.html (accessed 30-01-2017). or http://www.advanceddivermagazine.com/articles/lusitania/lusitania.html (accessed 30-01-2017).

[119] See also Section 5.2.

[120] McCarthy (ed.) 2010.

[121] The project ReWarShip was proposed in summer 2015 for the Horizon 2020 call, but unfortunately was rejected.

[122] Gjelstrup Björdahl & Gregory 2011, 3–7.

[123] Duren et al. 2011, 8.

[124] To compare with the action taken for reburial. However, here it would be better to call this 'repositioning' rather than 'reburial', since no covering will take place.

In the latter case, sacrificial elements might work for a while. The site can then be investigated in situ, data collected, samples of construction can be taken here and there, depending on the questions we have. However, it should be accepted that the physical quality of the site will deteriorate and might even disappear over time. Knowing the rapid rate of deterioration caused by shipworm, a change in the environment could be disastrous.[125] These situations require immediate handling. However, the budgets that are needed to 'safeguard' a well-preserved shipwreck and the process required to obtain permission to undertake ex-situ protection, unfortunately usually taking a great deal of time to negotiate, often years.

Management plans to act when extreme changes occur are usually not in place. However, this might be the best and most practical solution for these types of sites. This could be incorporated into risk assessment practices. Areas that seem to be extremely stable, may not immediately require action, but the consequences of any change may be dramatic. Areas such as the Goodwin Sands in the UK, the Southern Delta of Zeeland and the Western Wadden Sea in the Netherlands experience frequent changes in the seabed with devastating effect on present underwater cultural heritage. Even here, well-preserved shipwrecks can be discovered, especially when the situation changes drastically. It is then necessary to act quickly and preparations that anticipate potential changes may be the only way to move forward. Starting to develop mitigation strategies only after changes occur may be a strategy of too little, too late.[126]

5.6 Choosing the method of in-situ preservation

5.6.1 Introduction

If an initial assessment of the environment of a site reveals that there are serious natural or other threats, strategies should be implemented to mitigate against them. It is at this stage that an overall evaluation should be made of whether it is desirable and feasible, both practically and economically, to leave the site in situ. As mention above, in-situ preservation and protection are options in cultural heritage management. Depending on the nature of the environment and the historical and archaeological significance of a site, excavation, followed by conservation or redeposition in a more benign environment, may be the only option to ensure that at least the information is preserved.

For wooden wrecks, significant threats include the possibility of further physical deterioration and biological deterioration caused by bacteria, fungi or wood-boring organisms. The bacterial decay is continuous even in environments with very little or no oxygen present.[127] Although we can still learn, it has become clear by now that in low oxygen or anoxic conditions the deterioration rate will be very low and of no comparison to the rapid and high level impact of deterioration by wood borers such as shipworm.[128] To mitigate these deterioration processes, sites are often covered using the different methods mentioned above (Section 5.2). In the right circumstances, this can both alleviate scour and prevent the activity of wood-boring organisms.[129]

Most in-situ protection techniques are developed specifically for use at one particular site or in a specific environment, thus they are tailor-made and therefore not always easy to compare. However, the techniques used may often be partially applied to other situations. Below are two tables that present an overview of the factors on the basis of which an appropriate method can be chosen.

1. Table 5.1 outlines the effectiveness of different methods for different types of environments.
2. Table 5.2 shows how different methods of in-situ preservation mitigate against specific threats.

For example, geotextiles may be used in different ways: as a layer placed between the sediment and the archaeological objects, or as a barrier method, wrapping objects or a structure. These different uses mean it may be effective in different scenarios. The rubber sheeting method that was used on the Stora Sofia in Sweden represents various methods that cover a site, but which do not actively capture sand. These kinds of methods should be used in combination with, for example, additional sand deposits.

[125] See, for example, the devastating effect of the *Teredo navalis* on the wrecks in the Oostvoornsemeer. http://www.maritiemprogramma.nl/magazine/MP03/MP03_05.1.htm (accessed 30-01-2017).

[126] On the Goodwin Sands, the *Stirling Castle* (wrecked 1703), and in the Southern Delta, the *Roompot* (wrecked 1853). Both are wrecks that have begun protruding from the seabed due to sand shifts. They belonged to the best preserved sites in northwestern Europe, but have been deteriorating rapidly over the last couple of years. Another wreck that is well preserved, with the boards still standing at least 3 metres is the OVM 14. This wreck, which lies at 30 metres depth in the Oostvoornsemeer, is now under threat of being destroyed by the *Teredo navalis*, which has been reintroduced into the lake due to the salinization of the water.

[127] See Chapter 3.

[128] See, for example, the natural conditions around the well-preserved shipwrecks in the Baltic Sea such as the Ghost Wreck or those in the Black Sea.

[129] See Chapter 3 on mitigation against multiple threats.

5.6.2 A Western Wadden Sea example: the Burgzand Noord 10 site

The BZN 10 site consists of a sandy seabed, some flat areas and undulating seabed with salt water and strong tidal currents. It also lies completely submerged in 9 metres of water. It has primarily been protected physically with polypropylene debris nets. These nets score + to ++ on all parameters and, in practice, the polypropylene nets work excellently. The artificial seagrass that was installed in 2013 and 2014 should also be suitable for the environment, except for the height differences on site.

Conditions	**Type of method**							
	Sandbags	Debris nets	Geotextiles	Added sand layer	Added stone layer	Cages	Rubber sheeting[12]	Artificial seagrass
Sandy seabed	+	++	++	++	(+)[8]	(+)[10]	+	++
Rocky seabed	++	-	++ (as barrier method)	+	++	+	-	-
Pebbles	++	-	++ (as barrier method)	+	++	+	-	-
Clay	+	+	+	+	(+)[8]	(+)[10]	+	+
Silt	+	++	+	+	(+)[8]	(+)[10]	+	+
Tidal movements	+	++	+	-	++	(+)[10]	+	++
Currents	+	++	+	-	++	(+)[10]	+	++
Still water	+	-	+	+	+	+	+	-
Wave action	++	(+)[2]	+	-	++	(+)[10]	+	+
Brackish water	++	++	++	+	++	+	+	+
Fresh water	++	++	++	+	++	+	+	+[11]
Salt water	++	++	++	+	++	+	+	++
Shallow water (0-10 m)	++	++	++	(+)[5]	++	+	+	++
Partly submerged	+	-	+ (not as barrier method)	+	+	-	0	-
Temporarily submerged	+	(+)[3]	+ (not as barrier method)	(+)[6]	+	-	0	–
Depth range 10-50 m	(+)[1]	++	++	+	+	+	+	+
Deep water (below 50 m)	(+)[1]	(+)[4]	+	(+)[7]	+	0	+	0
Flat seabed	++	++	+	+	+	+	+	+
Undulating seabed	++	+	+	+	+	-	0	+
Object slightly protruding from seabed	+	++	+	+	+	+	0	+
Object strongly protruding from seabed	-	-	+ as barrier method	-	-	++	-	-
Ice forming (icebergs)	+	0	0	0	(+)[9]	0	0	-

Table 5.1. The effectiveness of different methods for different types of environments.

(Legend: + to our knowledge the method works in this type of environment; ++ the method works excellently; - the particular in-situ method has a negative effect on the site for this environment; 0 neutral, it has no specific effect)

Specific elements in an environment were isolated to create this table. In practice, an area always consists of several of the parameters mentioned. Sometimes only one of these parameters prevails, sometimes a combination of several. The indications are based on the circumstances in which the different methods have been used and reports on the effects.

1 It may be difficult to put all the sandbags in the right place at great depth.

2 Before all the sand has been caught by the nets this kind of protection is vulnerable to damage.

3 This will only work when the nets have had time to catch sufficient sand particles when submerged.

4 This method will be difficult to install at greater depths, and sediment transport is still needed.

5 As long as these shallow waters are calm. However, in shallow waters the effects of storms are usually great.

6 'Temporarily submerged' means there is water movement, the less intensive this is, the better.

7 It may be difficult to deposit the sand in the right place.

8 Stone coverage on soft soil is usually unstable.

9 Stones may offer some protection; however, icebergs often have enough force to push the blocks away.

10 Cages protrude from the seabed and are thus vulnerable to all sorts of things becoming entangled in them. If used, a good foundation should be created, especially in soft sediments.

11 Polypropylene nets and seagrass need tidal movements to be really effective. These do not exist in fresh water.

12 We consider rubber sheeting not to provide a specific in-situ preservation method on its own. It does keep sediment on the site but will actively promote sedimentation on it. The sheeting on its own does not make the environment anaerobic.

Mitigating	Sandbags	Debris nets	Geotextiles	Added sand layer	Added stone layer	Cages	Rubber sheeting	Artificial seagrass
Abrasion	++	++	++	+	++	-	++	+
Site erosion	++	++	++	-	++	-	++	++
Area erosion	-	+	+	+	-	-	+	+
Shipworm	+	++	++	+	+	-	+	+
Gribble	+	++	++	+	+	-	+	+
Fungi	+	++	++	+	+	-	+	+
Bacteria	0	0	0	0	0	-	0	0
Looting	+	0	0	-	++	+	0	0
Fishing	+	+	+	+	+	-	+	0

Table 5.2. Various physical protection methods and the way they mitigate against specific deterioration processes.

(Legend: + to our knowledge the method works in this typical environment; ++ the method works excellently; - the particular in-situ method has a negative effect on the site for this environment; 0 neutral, it has no specific effect)

This table reveals that cages are effective against looting, but not against any other deterioration factors. They may even have a more negative effect, especially when there are currents around the site (see also Table 5.1). However, this is also the only method of physical in-situ protection that helps to raise awareness, unlike all the other covering methods (out of sight, out of mind). We also see that none of the methods have much effect on the levels of bacterial deterioration. Some erosion bacteria can continue to degrade the wood in near-anaerobic conditions. We should keep in mind, however, that these processes are slow.

5.7 The costs of in-situ preservation

Within the framework of the overall evaluation and decision-making process with respect to preserving in situ or not, a cost-benefit analysis should also be undertaken. This starts by providing an indication of the costs of the protection measures that may be taken. When defining the costs of in-situ preservation of a shipwreck there are many parameters to keep in mind. Some of them are very obvious, while others are not, as they may have a delayed and/or indirect effect on the site. The development of laws to protect sites, the organization of law enforcement, and the setting up of a registration system all have to be taken into account. Furthermore, costs may vary from country to country and over time. It is important to know if certain circumstances already exist for other reasons, for example are being dealt with by other institutions. Calculating the long-term economic effects of in-situ preservation may be very difficult, but they can be estimated. The first step always includes an estimation and calculation of the different effects of in-situ protection. A general model that might be used by cultural heritage managers or other stakeholders to calculate general costs and select sites is, however, difficult to present. Each site has its own individual characteristics and parameters and, therefore, costs may vary enormously, depending on the physical in-situ protection methods that need to be applied. However, an overview of the parameters that one needs to think of can be presented here.

Some important parameters to include in cost calculations for in-situ protection are:

- The environment in which a shipwreck lies (depth, visibility, current, stability)
- The law in the particular country (dive with professional divers, ship under class, etc.)
- The condition of the wreck
- The method of protection
- The cost of materials
- The monitoring strategy that will be chosen
- The standard of living in the country (which influences the prices of materials, rentals, salaries)

Many of the above parameters are more or less connected to each other. The frequency of monitoring visits depends, for example, on the stability of the environment, the quality of the wreck and the method of protection that has been chosen. At the same time, the method of protection depends on the environment, the type and the significance of the site.

Salaries, costs of ship rental, work-related policies and legal frameworks vary across the world. Their implications for the cost of in-situ management can be huge.[130] Within the WreckProtect project, financial data on in-situ protection projects was collected from different parts of Europe.[131] It became clear that the personnel costs for professional divers and maritime archaeologists were the major expenses for each project, followed by costs for the rental of diving vessels and the equipment necessary for diving. The material costs of the protection measures were usually the cheapest.[132] This may be different in other countries where salaries are much lower and equipment and materials more difficult to acquire. In any case, we should keep in mind that only a relatively small number of wrecks have been preserved in

[130] One can think of the need to sail under class (for insurances) and the consequent costs for renting a ship, but also the differences in dive regulations.

[131] Gjelstrub Björdal & Gregory (eds) 2011, 127–130 and Manders (ed.) 2011, 42–47.

[132] In China, the costs for renting a ship during the excavation of the Nan'ao No.1 shipwreck was 80,000 Yuan ($12,310) per day (www.whatsonxiamen.com/news19118.html accessed 30-01-2017).

Expenditure		Specific costs (€)	Total Cost (€)
Travel, food and lodging			7,000
Personnel			30,000
	Professional diver/day	650	
	Maritime archaeologist/day	900	
Ship (excluding outward/return journey)			17,500
Equipment (diving gear, containers, compressor, etc.)			14,000
Material for protection (cable ties, scaffolding nets, labels, etc.)			1,500
	Scaffolding nets (roll of 3 x 50 m)	120	
Table 5.3: The cost for in situ protection of the BZN 10 site.			**70,000**

situ, in different environments and mitigating against different threats. This is reflected in the methods and techniques chosen and also the costs of protection.

The Stora Sofia in Sweden has been preserved in situ against the oxygen-rich environment, the dynamic seabed and attack by shipworm by covering the site with gravel and rubber matting.[133] The work on this 40 metre long wreck took 10 days and cost 71,000 euros. This is very much in line with the costs for the protection of the BZN 10 wreck in 2009, also approximately 40 metres long, using debris netting. Although work was done on site prior to this and also afterwards,[134] the protection measures took 10 days with a total cost of approximately 70,000 euros (See Table 5.3). The reasons for protecting the site were also similar: it was a shipwreck that had partly emerged from the seabed in a dynamic environment, with abrasion and the *Teredo navalis* as the main degraders.

In comparison, smaller wreck sites seem to be more expensive to preserve per metre in length. The Zakynthos Wreck in Greece, for example, is only 15 metres long. Its protection of geotextile, sandbags and gravel required 35,000 euros, while the protection of the 8 metre long Hårbølle Wreck in Denmark cost 46,000 euros.[135] However, interestingly, if we take the GDP of Greece and Denmark into consideration and the length of the wrecks as well, then suddenly the costs of these two wrecks are very much comparable.[136] Fieldwork in both cases took 7 days.

5.7.1 A breakdown of costs: the Burgzand Noord 10 example

As noted above, the in-situ protection of the BZN 10 wreck executed in 2009 in the Dutch Western Wadden Sea cost roughly €70,000. The site was first protected in situ in 2001. Geophysical monitoring of the area in 2009, however, revealed strong erosion and damage around the already physically protected site. The Cultural Heritage Agency of the Netherlands thus decided to act by repairing and extending the physical protection of the BZN 10 wreck. A diving team was appointed to protect the wreck from erosion due to the tidal currents. The method applied to the site was the same as before: debris netting (scaffolding nets), aimed to accumulate and cover the remains with sediments. The team was made up of 4 professional divers and 1 maritime archaeologist. The work was done in 2 weeks (10 diving days) and in that period a protected layer of debris netting was re-installed over the whole site. The largest expenditures were the personnel costs, ship and diving equipment.

The list above clearly shows the differences in expenditure between personnel (42%), boat rental (25%), dive materials (20%), travel, food and lodging costs (10%) and material costs (no more than 3% of the total cost).

Artificial seagrass was also tested on the BZN 10 site in 2013 and 2014.[137] The methodology of placing mats of 2.5 x 5 metres prepared with artificial seagrass fronds was developed for the offshore industry, initially for the protection of underwater pipelines. With a large frame, mat after mat can be installed on the seabed by just one diver. This considerably lowers the personnel costs. The mats themselves are, however, still very expensive, costing approximately 80 times more than polypropylene nets.[138] These huge initial costs make them too expensive for most archaeological projects to use at the moment.[139]

5.8 To excavate or not, that is the question

Whether to excavate and ultimately raise a historical shipwreck or not, is a topic that generates long discussions, and the decision is often dependent on many parameters. The reality is that in addition to intrinsic values, economics and budgets are also important factors. Working professionally, for example according to the Annex of the UNESCO Convention, demands the planning and full financing of the project in advance.[140] Careful analysis of

[133] See Chapter 3.

[134] See Chapter 3.

[135] Manders (ed.) 2011, 42.

[136] I made some calculations as an exercise using the 2013 GDP of Greece (USD 241,796 million) and Denmark (USD 330,014 million) as a figure for the cost of living and therefore salaries, rentals and materials. http://www.clge.eu/documents/events/168/14_09_26_CLGE_Fees_2015_v1.0.pdf (accessed 31-10-2017).

[137] Coenen et al. 2013

[138] Debris net are approximately €0.80 per square metre, while commercially made seagrass fronds cost €64 per square metre.

[139] For example, protection of 2000 m² (40 x 50 metres) would cost €1600 with debris nets, but €128,000 with artificial seagrass mats.

[140] UNESCO Convention for the Protection of the Underwater Cultural Heritage (Paris, 2001). See Annex, Rules 9, 10, 17, 18 & 19.

Fig. 5.21 The Vasa, the Swedish warship that sank in 1628 immediately after its launch, is also an example of a well-preserved ship in Baltic waters. Photo: Karolina Kristensson, the Swedish National Maritime Museums.

the economic consequences of excavation and subsequent raising of the wreck or certain parts is important. What will be done with the parts after removal? Will they be preserved? Restored? Or will they be reburied or even destroyed? The calculation of the costs of an excavation and subsequent treatment is not yet standard procedure but generally the costs will be known or estimated to some extent. However, the real costs of in-situ preservation are often less known and also not formally considered before making a decision. Funding needed for conservation and especially restoration of these kinds of large objects often depend on public participation.[141]

More often than being physically protected, sites are left in place unmonitored and without any mitigation measures taken. The consequence is that many wrecks are subject to continuous degradation until they disappear. The process is often invisible as it takes place in the sea, out of the public eye.[142] This is the cheapest option of all, as any mitigation measures cost money. The costs of in-situ protection can only be roughly compared to those associated with the physical raising of a shipwreck, its full conservation and display to the public in a suitable museum setting. There are some difficulties in determining the true costs of such activities as only a few wrecks worldwide have been protected in situ, and only a few large size wrecks have been excavated, raised, conserved and exhibited.[143]

However, we have indications that there is a great difference between the initial costs of in-situ preservation, ongoing in-situ protection itself and the costs of the raising and ex-situ conservation of a wreck. Nevertheless, again there are also huge differences depending on the site. The physical protection of a wreck with polypropylene nets in the Western Wadden Sea costs about 70,000 euros (as we have seen in Table 5.3), while an excavation will cost millions. In-situ preservation also means regular monitoring and maintenance (the frequency is dependent on such factors as the type of protection, activities in the area, climate and environment). Each monitoring visit costs at least 3,000 euros (see Chapter 6). While this may add up in the long run, excavation and conservation, storage or display of artefacts and maintenance of a collection throughout the years will also incur ongoing costs.

With respect to in-situ protection, it is always important to have a management plan to keep track of activities and changes on site. Active in-situ protection implicitly means that a site has been valued highly and is 'worth' preservation. Therefore, it should be taken care of: monitoring will always be required afterwards.[144] Measures to mitigate against threats will also have to be taken.[145] Physical protection or site stabilization may have to be deployed.[146] In-situ preservation, in general, and protection in particular, not only maintain the site in the environment that has preserved it for many years – thus, if not changed, in favourable conditions – it also keeps it connected to the environment, the landscape it belongs to.[147]

If we take this into consideration, this also means that management should be executed on a larger scale, exceeding the site (e.g. wreck) alone. In-situ preservation should, therefore, not just concern the management of a single site, but take an area approach to preserving sites in their context. This may concern a multiple number of sites, or a chain of sites that are geographically or historically related. Keeping this in mind, the costs of in-situ preservation add up. To be able to accredit values to sites, one needs to have knowledge, which can only be gained through research. Therefore, although in-situ preservation may be considered the first option, it does not absolve us from doing research.

[141] See, for example, the public financial support for the *Mary Rose* in the UK (http://www.maryrose.org/why-we-need-your-support/, accessed 16-10-2015), but also the conservation of the Zwammerdam ships in the Netherlands (Leidse Courant, 7 October 1985, 8 (http://leiden.courant.nu/issue/LLC/1985-10-07/edition/0/page/8?query=Romeins%20Castellum&sort=relevance, accessed 30-01-2017).

[142] See also Chapter 7.

[143] See, for example, the *Mary Rose* in the UK and the Vasa in Sweden as examples of large ships that have been excavated, conserved and exhibited. A much smaller example is the Bremen cog in Germany.

[144] See Chapter 6.

[145] See Chapter 3.

[146] See Chapter 5.

[147] See Chapter 5.

Fig. 5.22 A. The Bremen Cog at the German Maritime Museum in Bremerhaven, Germany, and B. One of the Skudelev ships in the Vikingshipmuseum in Roskilde, Denmark. Photos: M. Manders.

Fig. 5.23 The IJssel cog (fifteenth century) found in the river Ijssel in Kampen, the Netherlands. Photo: M. Manders.

5.8.1 Costs of ex-situ preservation

Only a few shipwrecks in the world have been raised from a sea, river or lakebed and subsequently conserved and put on display. The warships Vasa in Sweden and the *Mary Rose* are probably the best known examples (Fig. 5.21). In northern Europe, there is also the Bremen Cog and the Viking ships from Roskilde (Fig. 5.22 A + B). In early 2016, a medieval cog was raised from the IJssel river, it will be conserved, restored and put on display in the municipality of Kampen (Fig. 5.23).[148] In the Mediterranean, well-known examples are the Kyrenia, Yassi Ada I and Serçe Limani in Turkey, the Ma'agan Mikael in Israel, and the Grado and Gela in Italy.[149] Outside Europe, we can think, for example, of the stern section of the *Batavia* in Australia (Fig. 5.24) and the Nanhai 1 wreck in China.[150] This small number of shipwrecks exhibited to the public today, indicate the high costs involved and the long-term commitment to such a process. This commitment often absorbs all capacity within an institute, which may lead to a monological approach within a country, focusing on one site. This may create problems for the overall management of the underwater cultural heritage in a country.

When attempting to estimate the costs of raising a wreck, we must rely on the facts and figures related to previous projects and the costs of subsequent steps in the ongoing process. As most of these projects have been extremely large and the finances never fully secured, they were executed over several decades, using many different sources of funding and also the voluntary aid of many people.[151] The decision to raise the Vasa in 1961, for example, was not determined by economic factors, but rather driven by enthusiasm and patriotism.[152] The Viking ships in Roskilde fjord were a similar case, excavated in 1962, as was the *Mary Rose* in 1980.[153] The decisions we make today may be no different; however, the long-term financial implications will often need to be known before taking the step to raise the wreck. Risk assessments are a very important part of this exercise. Looking at the cases of the *Mary Rose* and the Vasa, it is apparent that the

[148] This is the idea at the moment. Research on the quality of the wood and the additional information acquired from excavation should reveal if this is plausible.

[149] Swiny & Katzev 1973, Bass & Van Doorninck 1982, 71, Bass et al. 2004. http://mushecht.haifa.ac.il/archeology/maagan_ship_eng.aspx (accessed 30-01-2017), Davidde 2004.

[150] http://www.environment.gov.au/heritage/places/national/batavia (accessed 30-01-2017), http://www.unesco.org/new/en/culture/themes/underwater-cultural-heritage/about-the-heritage/underwater-museums/the-guangdong-maritime-silk-road-museum-nanhai-no-1-museum/ (accessed 30-01-2017).

[151] See also, for example, the *Mary Rose*. Whether this is in compliance with Rule 17 of the Annex of the UNESCO Convention of 2001 is doubtful, but would probably not have been undertaken if they had to do so in advance.

[152] See, for example, https://www.abc.se/~pa/publ/vasasalv.htm (accessed 30-01-2017).

[153] For the Viking ships in Roskilde, see Olsen & Crumlin-Pedersen 1990. For the *Mary Rose*, see, for example, Marsden 2003.

[154] The Vasa Museum had 1.2 million visitors in 2014 (http://www.vasamuseet.se/en/Press/Vasa-in-brief/Who-visits-Vasa/), see also http://www.thelocal.se/20150916/swedens-vasa-sails-into-worlds-top-museums-list (accessed 30-01-2017). For the *Mary Rose*, the visitor numbers were at 250,000, 18 weeks after re-opening in May 2013 (http://www.maryrose.org/250000-visitors/, accessed 30-01-2017)

Fig. 5.24 The Batavia (1629), which sank off the West Australian coast and is now exhibited in the Shipwreck Gallery of the Western Maritime Museum in Australia. Photo: M. Manders.

decisions – based on the heart and the passion to conserve out of national pride – has ultimately paid off, with around one million of visitors to both museums every year.[154] The Vasa museum is today the number one tourist attraction in Sweden, and of great economic importance for the city and the museum itself.[155] However, for other shipwrecks, the situation may not be as positive. The fact is that the daily costs of storage, maintenance and display might severely strain the budget of a smaller museum.

Not all negative or positive effects can be sufficiently anticipated when deciding whether to excavate, conserve and display a wreck. Indirect positive effects might for example also include the creation of awareness, identity building and capacity building in underwater cultural heritage, as well as in underwater archaeology and conservation. It is also difficult to quantify the effect of gaining knowledge. We can only estimate the economic effect of a country or city becoming known for some reason and thus triggering tourist traffic.[156] Promotion and pride related to the raising of a ship should be part of the strategy of promoting an area for example. All these factors have a long-term effect and cannot always be easily identified and related directly to investment in excavating, raising and conservation of a specific wreck.

The whole process of ex-situ conservation, restoration and exhibition thus encompasses many parameters. Firstly, there is the underwater work before the decision is even made to raise a wreck. Secondly, the wreck and its content needs to be investigated and a decision about whether to raise the wreck completely, excavate first and/or only remove parts must be made. Thirdly, it is also important to determine the condition of a wreck (its structural condition and the condition of the wood and metal elements itself), as this can help us determine what kind of support is required and what kind of conservation strategy is demanded. This may require extensive sampling and laboratory research. The depth of the find layers in the wreck will also help to determine the weight of the wreck and also how many objects may have to be raised and conserved. The question connected to this is whether these objects will be conserved, reburied or destroyed after they have been removed.

Determining the reasons for removal will help to identify the essential elements of the wreck site. This, in turn, will help keep costs down and focus on what is of real importance. Scientific questions (often related to why a wreck will be raised) have to be addressed for the same reason: What do we really need to know and what would be nice to know? Physical circumstances are of course important when raising and investigating a ship (visibility, currents, depth, temperature). They will, for example, determine

[154] The Vasa Museum had 1.2 million visitors in 2014 (http://www.vasamuseet.se/en/Press/Vasa-in-brief/Who-visits-Vasa/), see also http://www.thelocal.se/20150916/swedens-vasa-sails-into-worlds-top-museums-list (accessed 30-01-2017). For the *Mary Rose*, the visitor numbers were at 250,000, 18 weeks after re-opening in May 2013 (http://www.maryrose.org/250000-visitors/, accessed 30-01-2017)

[155] http://www.visitstockholm.com/en/See--do/Attractions/the-vasa-museum/ (accessed 30-01-2017).

[156] For a discussion of the economic impact of cultural buildings, see Llop & Arauzo-Carod 2008.

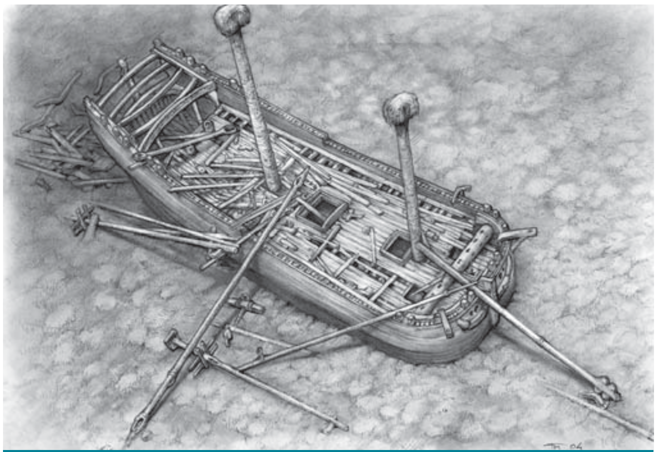

Fig. 5.25 Drawing of the Vrouw Maria, a Dutch ship that sank in 1771 in Finnish waters. Figure: courtesy National Board of Antiquities, Finland.

your time underwater, your 'perception grid' (how much you can know before you start removal). The same can be said in relation to other issues related to diving, such as policies and laws.

Archaeologists can research, document and register every part of the ship on land or under water. Working on land is often quicker, safer and provides more detail (larger perception grid). All these decisions also have to be made. Conservators start by cleaning and storing the wood in water tanks. After cleaning and documenting, the conservation treatment can start. This may be done by impregnation with polyethylene glycol (PEG), but other methods are also used. This process could take from two to ten years, depending on the physical state of the wood, the method used and the process of drying, either by freeze-drying or controlled drying.[157] After treatment, the wooden parts are again cleaned and the restoration process starts. This is the moment that parts of the construction, if necessary, are put together and the wreck is remodelled with attention to the aesthetic elements: it is prepared for exhibition. Special support construction for the timber and climatic control of humidity in the building is a requirement.

Wrecks can be conserved for storage or display. In the latter case, conservation must be followed by the restoration process. The work connected to the display of a wreck creates an enormous difference in costs. For example, the exhibition of a wreck often requires a large building and all sorts of display facilities and other direct costs for restoration (cleaning, putting the pieces back together, creating structural support, etc.).

The costs of conservation and restoration are also partly related to the amount of wood that needs to be treated. This can vary enormously.[158] The size and condition of the hull are thus important. It has proven difficult to obtain complete figures for the cost of the full conservation of a large ship.[159] A significant part of the financial figures for the sites compared in the WreckProtect project were estimated afterwards and paid for over many years, through many different private and public sources and in different countries. However, ultimately we can obtain a good impression of the costs involved in the full conservation of a historic shipwreck.[160]

As there have been discussions recently on raising the Ghost Wreck found near Gotland in the Swedish Economic Zone, the *Vrouw Maria* in Finnish waters and the medieval cog in the IJssel river in the Netherlands, these figures could have great significance in the discussion of strategies for the management of these finds (Fig. 5.25).[161] When considering such a large project, involving the excavation, conservation and display of a shipwreck, it is important to develop a business model that includes social (soft) parameters regarding awareness-raising and promotion (of pride and identity, as this is often the reason for undertaking such an endeavour), before the decision to undertake such a project is made.

The *Mary Rose*, which is approximately the same size as the BZN 10 wreck, has cost about 77 million euro to conserve and put on display, while the in-situ protection of the BZN 10 wreck on the Burgzand in 2009 cost around 0.07 million euro.[162] While the BZN 10 will be kept in its 'original' context,[163] and in some cases this even provides better temporary protection against degradation than the raising of a wreck, it may not fulfil the wishes of a larger group of stakeholders who would like greater enjoyment of it. The 'power' of enjoyment is discussed in Chapter 7.

It is important to understand that the costs of in-situ protection, as is shown above in relation to the BZN 10, concern only one step in the entire in-situ protection strategy, as laid out in the

[157] For methods of conservation, see, for example: http://nautarch.tamu.edu/CRL/conservationmanual/ (accessed 30-01-2017).

[158] Newport ship (found on land) consisted of 700 cubic metres, while the Roskilde 2 side consisted of only 1.6 cubic metres.

[159] Gjelstrup Björdahl & Gregory (eds) 2011, 127.

[160] Manders (ed.) 2011, 45.

[161] The raising of the *Vrouw Maria* and the Ghost Wreck remains in the realm of ideas, see Alvik et al. 2014, http://www.bureausla.nl/batavialand-lelystad/ (accessed 30-01-2017). The IJssel cog was excavated in 2015 and raised in February 2016. The wreck will – if it is as complete as expected and the condition of the wood is good enough – be conserved afterwards. For more information, see http://www.kamper-kogge.nl/wrak_ijssel_kogge_kampen/download/20140913_Presentatie-Kampen-AO.pdf (accessed 30-01-2017). http://www.livescience.com/53744-photos-medieval-dutch-shipwreck.html (accessed 28-1-2017).

[162] Manders (ed.) 2011, 43. In 2009, at the ARC-Nautica Conference in Dubrovnic, Croatia, Christopher Dobbs of the *Mary Rose* Trust outlined the total costs related to the *Mary Rose*. He was able to divide them into following categories:
£2.8 million (€3.9 million) for the raising of the ship
£6.1 million (€8.5 million) for management to date
£4.2 million (€5.8 million) for impregnation/conservation of the hull (estimation)
Thus, a total of £13 million (about €18 million) for raising and conservation. Much of the underwater excavation work was done on a voluntary basis, and was not included. This work was estimated at 11.5 person months in active diving time, which can be roughly estimated to cost £8 million (€11 million). Future costs for an adequate building for display are estimated at £35 million (about €48 million) not including all services. If we summarize the costs and include diving and building, the estimated total cost is about €77 million. This is excluding the new building for the *Mary Rose* that opened its doors in 2013. The €70,000 for the BZN 10 wreck does not include the costs of other protection measures and monitoring.

[163] See also Chapter 3.

management plan for the site (Fig. 5.26).[164] For some wrecks, a single protective action may be sufficient, alongside regular monitoring and repairs. However, for the BZN 10 wreck, several such actions were needed and will be needed in the future.[165] Long-term commitment will thus increase the overall cost of in-situ preservation. At the same time, this can also be argued in the case of the *Mary Rose* and other cases of ex-situ preservation.[166] One important difference, however, is that these wrecks can be easily seen and will provide income for a larger group of people, while shipwrecks protected in situ often remain out of sight and, if accessible, then only to a small number of people. A small income stream may be generated by accommodating specialized programmes for sports divers, etc. (see Chapter 7).[167] The success of these activities, however, also relies on other parameters, such as accessibility of the area and the site, visibility under water and local dive operators.

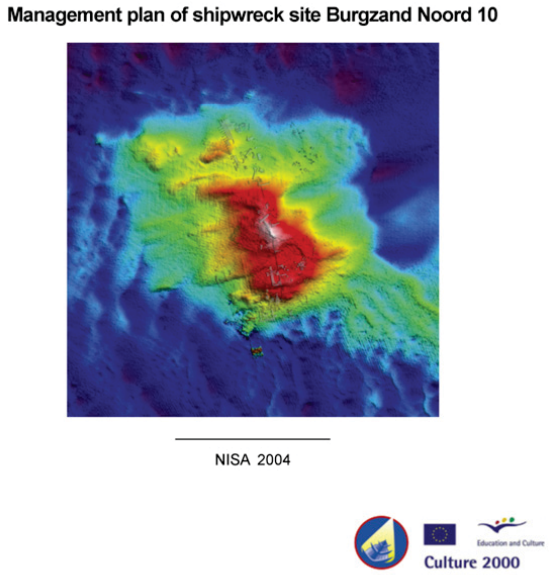

Fig. 5.26 Management plan for the BZN 10 wreck. Figure: RCE.

5.9 Avoiding the dualism: excavation is an option

Although most legal and policy frameworks emphasize that protection of the underwater cultural heritage in situ should be seen as a first option (and priority), excavation is still an option.[168] Excavations may be expensive – as we have seen – but they also serve an important purpose. One significant aspect of archaeology includes investigating material culture in order to learn from the past. Ultimately, this is what archaeologists want and what they are trained for.[169] Investigation may result in partial or complete excavations. After on-site recording, objects are retrieved for later archaeological analyses, conservation, storage and display. The same principles theoretically apply to underwater archaeology. However, underwater archaeologists are subjected to many practical difficulties in the aquatic environment which require specific personnel and technical equipment.

When a new underwater site is located, priorities have to be set. As we have seen above, the costs associated with the retrieval of a shipwreck are huge and, therefore, stakeholders who are responsible for the protection and management of cultural heritage must make decisions on the best approach to a specific object or site.

There are at least six obvious alternatives for managers of cultural heritage to consider, including excavation:

1. A wreck can be preserved for future generations in situ
2. A wreck can be preserved in situ temporarily until planned excavation
3. A wreck can be excavated, raised and conserved
4. A wreck can be excavated and reburied
5. A wreck can be excavated and the physical material destroyed afterwards
6. A wreck can be left under water without intervention[170]

The decision about what to do often depends on the funding available for the project, but there are many ways to make good and acceptable decisions. Most important is that the project is managed and discussed in a cross-disciplinary context involving multiple stakeholders such as archaeologists, conservators, divers, engineers, geophysicists and cultural heritage managers.

Internationally, the Annex (or code of good practice) of the UNESCO Convention for the Protection of the Underwater Cultural Heritage (Paris, 2001) stipulates all the steps that should be considered when dealing with intrusive research.[171] In the

[164] http://www.machuproject.eu/documenten/mp_bzn-10.pdf (accessed 30-01-2017).
[165] See Chapter 3.
[166] See also Catsambis et al. 2011, 1045.
[167] See, for example, the arrangements made with local dive shops in Croatia: http://icua.hr/en/underwatersitesandmuseums (accessed 30-01-2017).
[168] See, for example, the international agreements of: the UNESCO Convention for the Protection of the Underwater Cultural Heritage (Paris, 2001), and the Valletta Treaty (Valletta, 1996).
[169] See also the discussion on archaeology vs cultural heritage management in Chapter 2.
[170] Either selected as being worth protecting or deselected and not taken into consideration.
[171] Annex of the UNESCO Convention for the Protection of the Underwater Cultural Heritage. http://www.unesco.org/new/en/culture/themes/underwater-cultural-heritage/2001-convention/ (accessed 30-01-2017), or at the ICUCH Home page: http://icuch.icomos.org/ (accessed 30- 01- 2017). Code of Good Practice for the Management of the Underwater Cultural Heritage in the Baltic Sea Region (COPUCH): http://www.nba.fi/en/File/701/copuch-ohjeistus.pdf (accessed 30-01-2017).
European Convention on the Protection of the Archaeological Heritage (Revised). Valetta, 16.I.1992: http://conventions.coe.int/treaty/en/treaties/html/143.htm (accessed 21-11-2010).
ICOMOS Charter on the Protection and Management of Underwater Cultural Heritage of 1996: http://www.icomos.org/charters/underwater_e.pdf. (accessed 30-01-2017).

Netherlands, the Quality Standards for Dutch Archaeology do the same.[172]

There are thus several reasons to choose in-situ protection or excavation. In-situ preservation, protection, conservation and stabilization are – as is excavation – tools for the management of our enormously rich cultural heritage. It is important to look for a balance between the different measures that can be taken. Excavation is part of the archaeology toolbox, while in-situ preservation, conservation or site stabilization are not.[173] These are tools of cultural heritage management. Thus, there is an essential difference between the two. While archaeology strives to reconstruct what has happened by studying the material witnesses of this past, cultural heritage management is the profession that deals with the management of these material witnesses in the present. In-situ preservation is one of the tools of cultural heritage management and essential when dealing with this extreme abundance of heritage in a responsible way.

5.10 Conclusions on methods used for in-situ preservation and future directions

In the last two decades, the predominant focus in underwater archaeology has been on in-situ preservation and the development of appropriate policies and legislation to politically galvanize these trends. However, in-situ preservation is not as straightforward as it seems, posing many significant questions for those considering this option. For example, what are the major degradation factors affecting a shipwreck site and what techniques can be suitably employed to halt or at least decrease the rate of deterioration? It should be clear that in-situ preservation often requires active involvement, using different – often tailor-made – conservation and protection methods.

In the last 20 years, many experiments using different protection techniques have been undertaken in as many different environments. Some of these protected sites have been little monitored, while almost no pre- nor post-reburial monitoring has been undertaken, which makes evaluation of this particular technique extremely difficult and almost impossible. Some general rules, however, can be drawn up based on the many projects executed, including those in the Western Wadden Sea.

Firstly, mitigation must focus on the most degrading factors. If possible, different threats should be prevented or inhibited using one method. Secondly, in addition to mitigation against the most significant physical-mechanical, biological, chemical and human threats, it is also very important to determine why the site should be preserved and what value(s) we think should prevail, because a site will be preserved in a different way depending on whether it needs to be protected for future research or so it can be enjoyed by sports divers. The protection of underwater archaeological sites will always be, in part, individually customized to accommodate the unique qualities of each site.

The in-situ preservation or reburial of archaeological remains should be envisaged as a tool that may be utilized in an overall management strategy and not as a means to an end in itself. At present, in-situ management strategies are often reactive, that is, a site is discovered because it has been exposed and then a decision about how the site will be managed must be made. Therefore, in the coming years, the search for techniques that can discover sites before they are exposed and begin to deteriorate will be the challenge. If successful, we will be able to better protect archaeologically valuable sites before active deterioration occurs. In addition, by being able to look into the seabed, the site may be better connected to the surrounding area with its former contemporary seabed surfaces. Its value – being truly in situ and still part of the historical seabed layers – can be established without excavation.

An issue that must be discussed among scholars is the possibility of the in-situ preservation of intact sunken ships. These vessels can hardly be considered 'wrecks', since they stand almost completely upright on the seabed. This issue is more relevant in some parts of the world. For example, the Baltic, the Arctic, the Black Sea and the Great Lakes are known to have such well-preserved sites. They are in very stable environments with near anoxic conditions. Due to climate change, these vessels may be threatened by new degradation factors and burial may not be a logistically viable option. Well-preserved shipwreck sites may also be found in other areas. Dynamic areas such as the Goodwin Sands in the UK, the Southern Delta and the Wadden Sea in the Netherlands may have led to wooden shipwrecks being rapidly buried by natural processes. Examples include the *Stirling Castle* (1703) on the Goodwin Sands and the *Roompot* (1853) in the Southern Delta of Zeeland in the Netherlands. The *Stirling Castle* has been well preserved for almost two centuries, but is now under major threat due to natural erosion on site, while the *Roompot* has managed to stay covered by sediment for about 150 years. The same kinds of well-preserved shipwrecks may be found in the Western Wadden Sea at those places where the seabed has been stable for a long period of time. In fact, this potential has already been proven by the discovery of the seventeenth-century BZN 17 wreck, which is preserved up to its first deck.[174]

[172] http://www.sikb.nl/richtlijnen_detail.aspx?id=12861 (accessed 30-01-2017).

[173] This view is not supported by all archaeologists. See, for example, Schute et al. 2011, 22. A parallel can be seen in the commonly used expression that '... the archaeology in the ground has to be preserved'. This is, in my view, a misreading of definitions, since objects and traces (and when assessed, cultural heritage) can be found in the ground and archaeology is the methodology used to investigate this.

[174] https://maritiemprogramma.wordpress.com/2015/08/31/laatste-blog-bevindingen-burgzand-noord-17/ (accessed 30-01-2017).

Even if well-preserved ships remain in reasonably stable environments, the question of what to do with them still remains. At great depths (e.g. the Ghost Wreck, the *Titanic*), in remote places (e.g. the Arctic) and covered in sediment, it is not likely they will be easily enjoyed by sports divers, and should this be the case, it would pose an immediate threat to the sites. The main threat to well-preserved sites in stable environments may well be the slow but continuous bacterial degradation. Even metal shipwrecks face such threats.[175] Ex-situ preservation in the form of removal and conservation is extremely expensive, but the different options have to be considered and a management plan, including a decision-support system, should be in place.[176] The reasons for protecting a site in situ or not, should be clear to archaeologists, conservators, scientists, policymakers and the general public. This means that universal criteria should be developed and adopted by the maritime archaeological community.

If we look at the cost of in-situ preservation it is evident that, especially in Europe, personnel costs are the highest, while the in-situ protection materials (not produced in Europe) are often the cheapest. When we consider preservation in situ, there are a few other key issues that need to be addressed, some before we take the decision to do so, some during and some afterwards.

A discussion may arise on the difference between reburial and in-situ protection. In a way, most in-situ protection techniques will result in the reburying of a site. Most of the sites that have been discovered are uncovered due to erosion processes. After excavation seasons, sites have to be protected and reburial often takes place. Entire wrecks or various objects may also be removed and reburied at a different location from where they were found. Here, there is a difference between the two, since in-situ protection entails the preservation of the site itself, the original place of deposition.

This brings us to the issue of shipwrecks as sites versus archaeological landscapes that include shipwrecks. Shipwrecks are connected to the location in which they are found, in one way or another. They are connected to the landscape and combined with it they form the history of the place. If we consider shipwrecks as accidental finds, then there is no connection whatsoever to the place and only the wrecks themselves are the focus of concern, orphaned from their surroundings.

Although well-functioning techniques have been developed for underwater in-situ protection, there is still a major problem with how to deal with well-preserved shipwrecks that are surfacing the seabed for several metres. Ships standing with their masts still upright can be found in some places in the world, but usually not in the Wadden Sea due to its more violent conditions. However, even here, large well-preserved constructions might be found. The fact that there are such examples in the comparable Southern Zeeland Delta and the Goodwin Sands suggest this could well be the case. It may not happen that often, but when it does the mitigation activities should be focused on the fact that these sites are unique and thus that a unique response is required, such as the decision to raise the wreck.

The choice of whether to preserve in situ or not, will not only depend on the comparison of the direct costs of in-situ preservation and excavation. There are other issues and costs involved as well. They may, for example, concern the costs of avoiding the site (see Valletta Treaty), or the possible dangers a wreck creates by leaving it on the seabed. However, there is also the question of what we might gain by exhibition. Here, is it apparent that excavation will remain an option. Thus, in-situ preservation and excavation are both tools of cultural heritage management.

It is important to constantly ask: Why do we want to preserve sites in situ? Moreover, it is also important to identify who wants to do so. We have to acknowledge that there are different views about what in-situ preservation entails. These views may change from stakeholder to stakeholder, because definitions have not been set in stone and different actors will have their own ideal system. This may range from a cheap method to deal with cultural heritage, to the need to have a decision-support system with management plans in place to responsibly manage our underwater cultural heritage. The reasons behind a decision to undertake in-situ preservation may therefore not be exactly the same for each stakeholder or for each site. We need, therefore, to determine what these reasons are and start discussions with different stakeholders before implementing any in-situ protection methods. If we do not, we may end up with a heritage that is too expensive to maintain or that is managed against the wishes of other stakeholders. Ultimately, this may mean losing them as shareholders of this heritage.

[175] See, for example, http://www.dailymail.co.uk/sciencetech/article-1346446/Titanic-wreck-completely-destroyed-20-years-new-rust-eating-bacteria.html (accessed 30-01-2017).

[176] See Pater & Manders 2009.

6. Monitoring the effects of in situ preservation

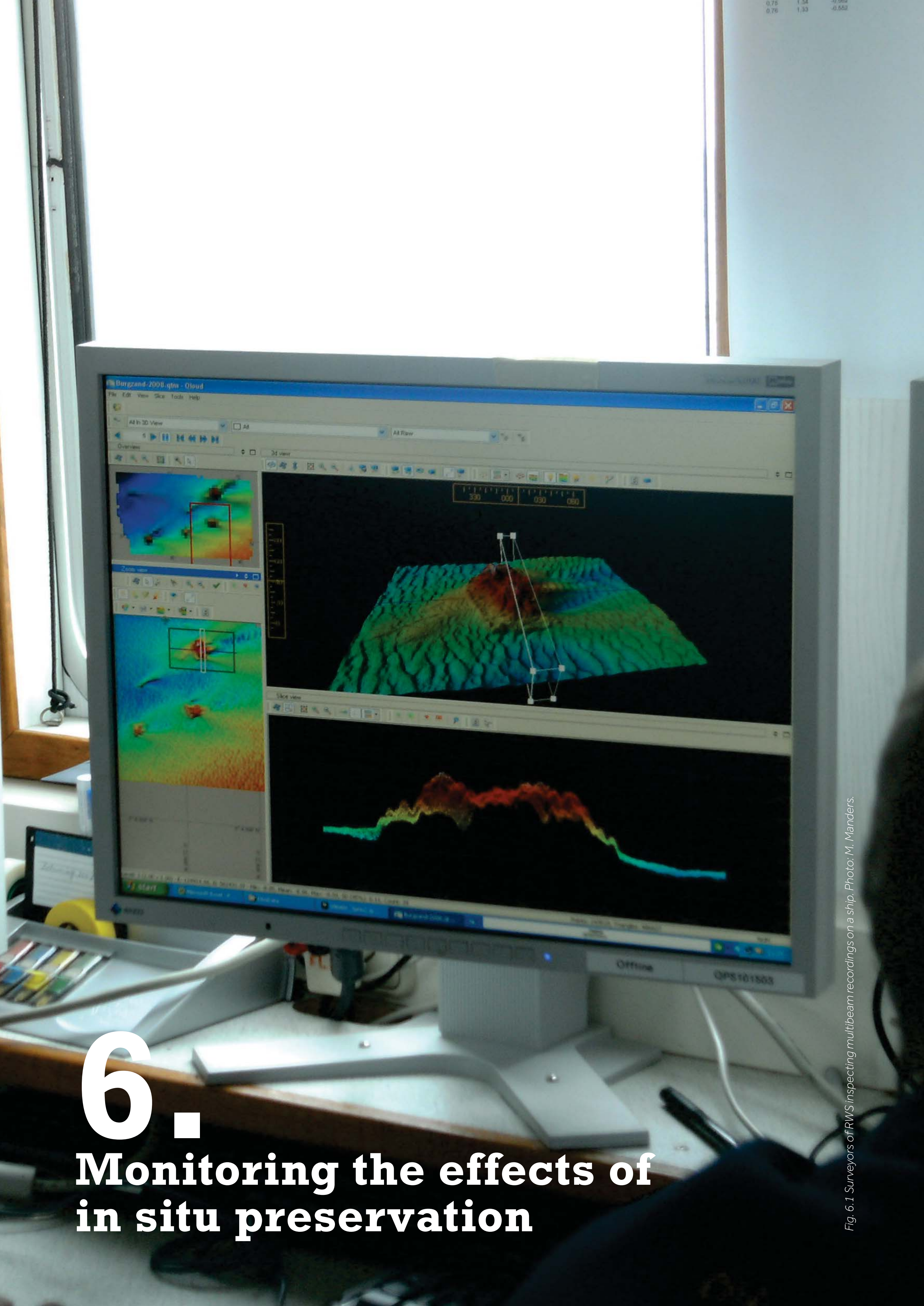

Fig. 6.1 Surveyors of RWS inspecting multibeam recordings on a ship. Photo: M. Manders.

6. Monitoring the effects of in situ preservation

6.1 Introduction

Installing in situ protection is not the final activity and thus also not the final investment in underwater archaeological sites. In situ protection requires continuous monitoring because long-term stability is often not guaranteed in non-homogenous environments.[1] Single events such as storms or heavy currents may leave a wreck totally or partly unprotected overnight.[2] More gradual, insidious and delayed processes also have effects on these sites, which often remain unseen. Therefore, a management programme or plan aiming to monitor the stability of the protective layer and the erosion of the site is necessary.[3]

Monitoring entails observation. It concerns observing changes at an archaeological site over a certain (often predefined) span of time. As stated previously, in situ preservation without a monitoring programme is indeed similar to brushing sites under the carpet. It would be a sign of pure neglect. Unfortunately, this is still what often happens.

However, what if we do agree to monitor the sites that we preserve in situ? What are the key parameters we should measure when monitoring the condition of a site and the changes occurring in the present or in the future? The way we monitor depends on the budget and staff available, the number and quality of the sites that have to be monitored, the nature of the threats, the aim of sustainable in situ preservation (always a combination of scientific and societal/cultural goals) and the level of detail required. Another important issue to consider is the environmental context: sites in active, 'hostile' environments need, for example, to be monitored more often than those in stable environments.

The information that needs to be collected to assess the current and possible future state of an archaeological site includes:

1. Its present archaeological value or significance (as established in an evaluation)
2. Its size
3. The relationship between the site and its environment
4. Its current condition
5. Roughly which materials are present
6. An overview of past, present and future threats

Technically, underwater archaeological sites can be monitored in different ways and performed using various options, such as divers, through the use of remotely operated vehicles (ROVs) or data loggers (Fig. 6.2). From the water surface, geophysical methods or coring can be used, or a combination of these methods.[4] By using a combination of methods, different elements of a site can be investigated: the site in its broader context, its natural environment and the condition of the wreck and the materials of which it consists. Many of these methods have been tested in underwater cultural heritage management in the Netherlands for a number of years. The Burgzand area has often been used as a testing site.

Monitoring is an essential part of underwater cultural heritage management and also crucial for the in situ preservation aspect of management. In situ preservation should not cease after initial measures have been taken and the site has been stabilized. The physical condition of a site will never improve; it can only become worse. Thus, it is essential to identify and mitigate against the threats and to slow down the degradation processes as much as we can. Determining these threats must be done by an assessment on the site level. This was addressed in Chapter 3. The use of physical protection methods are a way to mitigate against these threats. These, however, cannot guarantee the same protection under all conditions. This was explained in Chapters 4 and 5.

Monitoring is necessary to ensure continued stability, or at least to know whether any changes have occurred compared to the initial assessment stage. It has to be kept in mind that many sites

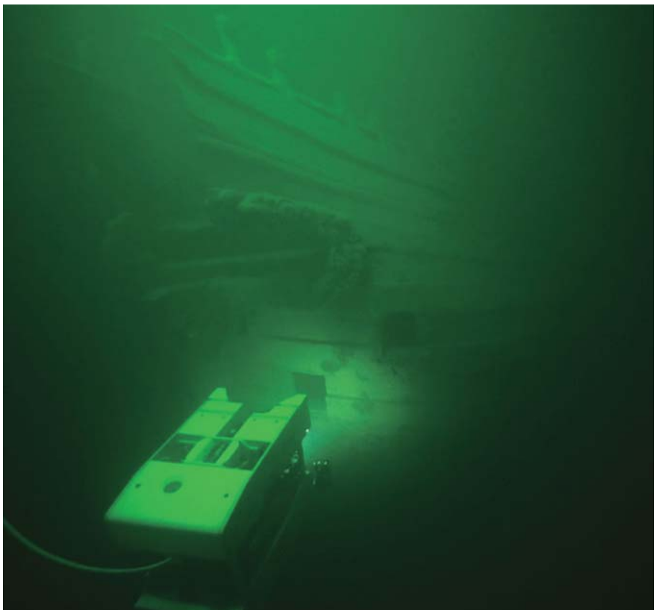

Fig. 6.2 A remotely operated vehicle inspecting a shipwreck. (the Ghost ship in Sweden). Photo courtesy Ghost ship project.

[1] As we have seen with the previous example of the BZN 10, when monitoring activity in 2009 resulted in the repair of the protection layer that was laid in previous years.

[2] For an onshore example, see http://www.livescience.com/24816-hurricane-sandy-exposes-shipwreck.html (accessed 30-01-2017). for underwater see, for example: http://www.dailymail.co.uk/news/article-2500038/Mysterious-remains-boat-seen-time-fierce-storms-shift-sand-castle.html (accessed 30-01-2017).

[3] See also Chapter 3.

[4] Some experience of monitoring has been gained in European collaborations, including the Culture 2000 MoSS project and BACPOLES, under the EU 5th Framework Programme.

are discovered because the environment has changed.[5] This often also means an immediate threat. Sites that are continuously protected by sediment are predominantly in a stable environment. These sites, however, are often still undiscovered. Those we do discover are often partially or completely uncovered and immediately under threat (except those found in specific areas like the Baltic, see Chapter 5.5). Being exposed, visible and thus in a more oxygen-rich environment means the site is vulnerable to mechanical-physical, biological, chemical and human or anthropogenic deterioration. This is certainly the case in the Wadden Sea, as was shown in Chapter 3.

After discovery, immediate information is required about the situation. This is baseline data with which we can compare data gathered later to determine any changes. Although monitoring is often focused on the physical status of the wreck, it is obviously also important to know what the site consists of and consider its cultural and historical value.[6] Why is a specific site so important and what will we lose if the site deteriorates? This should be part of the initial significance assessment, which needs to be executed prior to in situ protection. By determining the value of the place, we know what we need to protect; we know what may affect it and how we should mitigate through in situ protection.

The overall management of a site in situ thus consists of: a cultural heritage significance assessment of the site (including its relationship to the area); an assessment of the threats; a decision about the prevailing values; determination of in situ preservation methods; and the ongoing monitoring of change, including, if needed, a mitigation strategy when changes are observed.

Monitoring results should provide input to an ongoing monitoring programme for an individual site. All monitoring programmes should provide input to an overall programme for an entire state or country with a longer term focus. Although the development of the Management Plans in the MoSS project and the Geographical Information System (GIS) in the MACHU project were preparatory steps towards the implementation of such a national monitoring programme and decision support system in the Netherlands, it has still not been implemented fully due to the lack of capacity, the vast number of sites, the reliance on various registration systems and the lack of a sense of urgency.[7]

6.2 Managing change

Monitoring is an important aspect of management. It provides the data on the basis of which we can measure and note any changes. However, an effective monitoring programme will also look at the specific qualities of a site: its cultural significance and its condition. Cultural significance is related to the condition of the site. The physical quality has a direct link with the integrity of the site and the information it holds. Therefore, changes may result in loss of significance.

The causes of change, the processes occurring and the physical variability in an area are all part of the process of change. Understanding of how changes arise and what the implications are or will be in terms of altering or affecting the intrinsic value of a site may help to make decisions on its future. Is the change beneficial (e.g. more sedimentation or stability), neutral or adverse (e.g. more erosion)? Is it permanent or temporary? Are the effects direct, indirect, synergistic or cumulative? The risk of changes will be better predicted if the broader area is considered, rather than only the defined limits of one single site. The change in sedimentation – erosion patterns within a larger area, for example – can have a future effect on an individual site. At an even greater macro level, climate change can have a major influence on erosion-sedimentation patterns.[8]

The value or significance of a site may change not only due to physical events but also due to changes in perceptions of what is important or not. Prevailing values may shift. We might think here of the change in significance of First World War shipwrecks to people globally.[9] We need to define the significance of such changes in relation to what we want to protect.

6.3 Types of change

There are different kinds of change that should be considered when monitoring underwater archaeological sites. The following definitions have been taken from Manders et al. (2012).[10] The dynamics of change can be seen as being beneficial, neutral or adverse, as well as permanent or temporary (long, medium or short term) in nature. The latter may also concern whether changes are reversible or irreversible.

[5] See Chapter 1.

[6] See below.

[7] Manders & Luth 2004, Hootsen & Dijkman 2009. We are still waiting for ARCHIS 3 to be fully available (15-1-2017) and made compatible with the maritime GIS developed within the MACHU project.

[8] Kaslegard 2011, 28–31.

[9] One example is the value of the three warships *Aboukir, Cressy* and *Hogue* that were sunk by a German submarine in the North Sea in 1914. In 1953, the British government issued a salvaging contract to a German company for the three wrecks, in which approximately 1,400 people died. Now, 100 years after the sinking of the ships, they have become cultural heritage and are also regarded as war graves. For more about the three British warships and the efforts to protect them against looting and illegal salvaging see, for example, http://gingerliberal.blogspot.nl/2012/02/at-6.html (accessed 31-01-2017). and also https://hansard.digiminster.com/Commons/2015-09-07/debates/1509089000123/ProtectionOfTheWrecksOfHMSCressyHMS*Hogue*AndHMSAboukir (accessed 31-01-2017).

[10] Manders et al. 2012.

Activities, processes and physical alterations to the environment can all give rise to a range of ways in which new effects can occur. This is the process of change. These effects may be direct, indirect, synergistic (i.e. how different factors interact to create a different kind of change) or cumulative. Moreover, the outcome of change can be considered in terms of what intrinsic values are altered, which outcomes may affect physical materials, settings, surroundings and perceptual, cultural and socioeconomic issues (education, amenity and economic aspects).

Thus, the significance of change cannot be determined without understanding both the intrinsic values[11] and the types of change which may occur, including uncertainties that may exist, such as:

- The magnitude of change. This is best thought of in terms of how far the intrinsic values of heritage may be altered and in particular how this would enhance or diminish the value of the site. This will include how much both physical and perceptual aspects will be altered by the various ways that changes arise. There is also a distinction to be made between how much change will happen, where it starts and where it will or could end up (see limits of acceptable change). As an example, one can think of the effect that erosion on the seabed will have on the cultural significance of an underwater archaeological site: how much will change once the erosion has occurred?
- Risk and opportunity prediction. This is normally considered in terms of weighing up the seriousness of a hazard against the likelihood of it occurring. A similar concept can be applied to change in cultural heritage, where either the intrinsic values of a place or asset are not fully understood, or the magnitude of change cannot easily be predicted. The change may be either beneficial or adverse; thus, the uncertainty may be expressed either as a risk or an opportunity. One example of this is the prediction of how likely it is that the erosion of the seabed will occur.
- Uncertainty and predictability. The two are related, as uncertainty is a simple acknowledgement that not everything is known to a level that is desirable. Predictability reflects a more quantitative approach to defining levels of uncertainty, usually based on the sampling parameters of studies undertaken to characterize the nature of the heritage asset (e.g. by non-intrusive survey or physical evaluation) and/or the scale of changes likely to occur. In the case of underwater cultural heritage, these might, for example, include a prediction of increased levels of damage to a shipwreck as a result of increased visits by recreational divers.
- Significance of effects. This concerns a balance between the importance of the cultural heritage in question (an individual site or area) and how much it will be changed for better or worse. If the site changes, how important is this? Would it effect its significance? Thresholds of significance are highly variable but can be related to how far the effects of change support and enhance, or are contrary to, specific cultural heritage objectives, policies or standards. This also encompasses external developments that may concern a variety of international, national, regional and local conventions, treaties, laws, policies, plans and programmes, codes of practice, design briefs, research designs, etc., which help to define standards against which significance can be judged.
- Sustainability of change. This concerns weighing up the balance between the social, economic and environmental needs of society, which extends beyond the limits of how significance is measured in relation to heritage or environmental assessments. The way in which cultural heritage significance is judged may change when these values are weighed against other non-heritage environmental, social or economic needs. As an example: the building of a dam may be necessary for the safety of the people. It will, however, cause erosion of the seabed. Do the negative effects outweigh the benefits or vice versa?
- Limits of acceptable change. There are various ways of looking at this, but often policies and legislation will indicate that significant change (as determined on the basis of considerations such as those outlined above) goes beyond a threshold of what is acceptable. In the public realm, this may be defined by legislation and policy, but for some situations, ethics, professional standards or technical considerations may define the limits of acceptable change. Public and legal opinion may also set the boundaries of what is acceptable and what is not.
- Regulation and management. This is a highly relevant topic related to significance, both because regulatory bodies do much to define standards (e.g. significant criteria) and because they will often help define what is or is not acceptable. By doing so, they ensure the application of measures to avoid, reduce, offset or reverse negative effects, and promote beneficial ones.
- Indicators and monitoring. These are further essential aspects when considering the significance of change, because the actual changes that occur as the result of implementation very often differ from what was expected. This is especially true in archaeology, where unexpected new discoveries are often made that alter the parameters under which the original assessment was made. Monitoring is, therefore, not only a means of checking whether initial assessments were right, but also for determining whether modifying actions are required to account for new conditions. Indicators can be a useful way to collect data of critical interest that enable us to construct a broader picture of what is going on at a site. Monitoring in its fullest sense also means collating information in such a way that it can aid us to make better judgements of significance in the first place.

[11] See also Chapter 2.

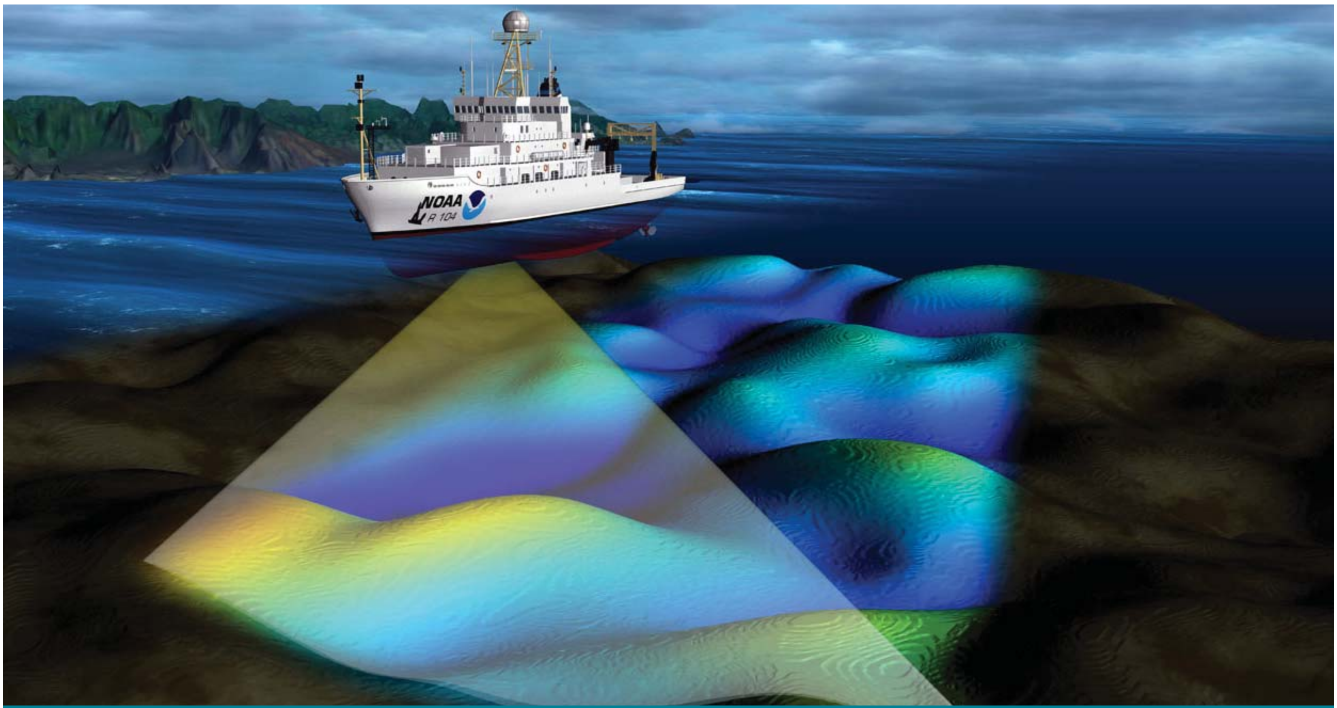

Fig. 6.3 Recording with multibeam. Courtesy NOAA, United States.

As has been illustrated, significance in relation to change can mean a range of things. When it is assessed, several different values must be taken into account and weighed against each other. As a result, it is crucial that when making an assessment of significance or monitoring change, we do so in a structured and consistent manner, related to the original baseline data,[12] and that we make decisions about what we consider to be the most important aspects of a site to protect.

6.4 Measuring the extent of deterioration

6.4.1 Baseline data

Monitoring starts by relating the current situation to previous circumstances. Collecting baseline data is therefore the starting point. This is the information collected at a site ideally as soon as possible after discovery but preferably after or during the cultural heritage significance assessment and at least prior to any mitigation measures. These mitigation measures should, after all, work against further decay, deterioration or loss of value and their effectiveness should be measured.

After mitigation, data on the same variables should be collected and a timeline for further monitoring developed. This timeline is an indication of how often a site needs to be monitored in the future. This may also change over time for a number of reasons. For example, new information might indicate that severe changes are currently occurring or will do so in the near future and the site has to be examined more often. The reverse is also possible: a site may become more stable and less monitoring required. Setting up a timeline for monitoring is not hard science as such, but influenced by observations from subsequent monitoring and can, according to this, be intensified or not. Baseline data consists of the assessment of the site, including its significance assessment (important for determining what to preserve and protect in situ), and a physical condition report, which should be repeated during monitoring.

Although important to establish baseline data for each site individually, there is often data available about the environment that can serve as universal values. If the on-site data deviate from these more or less standard values, then there is a good chance that actions will have to be taken to mitigate against these changes.

Since the early 2000s, several EU funded projects have partly focused on carrying out baseline studies and subsequent monitoring of underwater cultural heritage sites.[13] Some results related to the monitoring of sites in the Wadden Sea will be presented below.

6.4.2 Monitoring

Many processes may cause degradation, while individual processes also influence each other.[14] It is therefore important to determine which process is ‘triggered’ by what set of circumstances and how severe the destruction associated with that particular degradation process will be.

There are many different methods used to monitor sedimentation and/or erosion of the surrounding seabed, ranging from simple underwater visual inspection to the installation of measurement equipment on site. These, however, only measure the changes on a small scale and in specific locations. Repetitive monitoring can tell us, at the least, something about the process of sedimentation or erosion on the local scale. The European project, Monitoring of Shipwreck Sites (MoSS, 2001–2004), trialled an acoustic system to measure sediment changes on the local scale.[15] Although it was not very successful, due to the fact that it was tested for only a short period of time and the equipment broke down in the highly dynamic environment of the Wadden Sea, the short series of data showed that this kind of method could be used.

[12] See subsection 6.4.1.

[13] See Section 3.1.

[14] See Chapter 3.

[15] See Chapter 2.

In recent years, major developments in marine geophysical techniques have led to the implementation of multibeam sonar in underwater cultural heritage management (Fig. 6.3).

Multibeam recording provides information about what can be detected on the seabed, and due to its exact depth measurements it can also be used to monitor changes in the seabed across much larger areas than can locally applicable equipment. Its resolution depends on depth, with the highest possible footprint being one measurement per 5 x 5 cm. Its vertical accuracy is up to 2 cm.[16] This even makes the installation of measurement equipment – which, as seen above, is work intensive and vulnerable to defects – obsolete in many cases, except when continuous data is required.

Unfortunately, at present, there is still no system that can provide us with a view of material buried in the seabed and which could also be applied over large areas. However, a few systems are currently being developed which are based on sub-bottom profilers. The results are promising, but more research is required before they can be used effectively.[17] As soon as these systems are operational on a large scale, we will be able to use them to detect sites that are still in their protective burial environment and, if necessary, stabilize such sites before they become exposed. In this manner, sites that are still buried and unexcavated can also be integrated into the overall management programme of a specific area or underwater cultural heritage as a whole.

6.4.3 Measurement of various physicochemical parameters

Measurement of various physicochemical parameters in the sediment and surrounding water can provide more insight into the stability of the shipwreck environment and the ongoing mechanical, chemical and biological processes occurring on the site. These parameters include the redox potential, pH, dissolved oxygen levels and sulphide concentrations.

Redox measurements indicate the oxidizing/reducing nature of the local environment. They can give us insight into whether the seabed has a good protective consistency that will remain low in oxygen or rapidly become so. Measurements of pH can tell us how acid the water or the sediment are. Acid environments preserve different materials than alkaline environments, and organisms also behave differently.[18] By measuring dissolved oxygen in water or sediment we can investigate whether corrosion, for example, can take place or organisms that require oxygen can survive. Sulphide concentrations in the sediment are an indication of sulphur reducing bacteria in the sediment.[19]

Some parameters are easy to measure and may remain stable over a longer period of time. Others are more difficult to investigate in situ and fluctuate more often in value. The accurate measurement of dissolved oxygen content in sediments in situ, for example, is difficult because it is easily corrupted by oxygen from the water column. Attempts have been made to minimize this unreliability by measuring these various parameters in situ using electrodes attached to data loggers deployed on a site. In the MoSS project, a data logger was developed and trialled to measure the redox potential and pH of the sediment, and the salinity, dissolved oxygen content, depth, turbidity and temperature of the surrounding water.[2] (Fig. 6.4)

A similar system was also used to measure redox potential and pH in the Marstrand reburial project, while a new type of underwater data logger was developed and tested in the SASMAP project. The parameters for this open water system were: conductivity (to measure salinity), temperature, depth and an acoustic Doppler current profiler. Also, a diver-based data logging system was developed that can measure sediment profiles up to a depth of 50 cm. The parameters for this equipment are dissolved oxygen, pH, redox and sulphide.[22] Tests showed that dissolved oxygen probing is reliable with this system.[22]

Fig. 6.4 Diver with data logger on the BZN 10 wreck. Photo: R. Obst.

[16] Ernstsen 2006.

[17] Plets et al. 2009, IMAGO 2002, 20–25, http://sasmap.eu/progress/2013/wp2/ (accessed 21-10-2015).

[18] See, for example, http://www.fondriest.com/environmental-measurements/parameters/water-quality/ph/ (accessed 21-10-2015).

[19] Mudryk et al. 2000.

[20] Gregory 2004 (1), 8.

[21] EauxSys Ltd. Reburial and Analysis of Archaeological Remains: RAAR, within the SASMAP project, Unisense developed the open water data logger as well as the diver-based data logging system, Gregory et al. 2013.

[22] See http://sasmap.eu/progress/2013/wp3/#c50076 (accessed 30-01-2017).

Deterioration can also be assessed and measured by taking samples from the original shipwreck and/or by placing modern test materials on the wreck site. X-ray photography of submerged modern wood blocks can show the presence of degradative wood borers such as *Teredo navalis*, while microscopic analysis can show the types of bacteria and fungi causing deterioration (Fig. 6.5).[23] In this manner, it is possible to use these results as a 'proxy' indicator of the environment and its specific threats. General parameters can thus be established for specific environments. More importantly, we can study the ongoing processes of deterioration in the area and thereby assess future threats to a site.

Initiatives are now being undertaken to develop techniques to qualify the severity of attack and the state of preservation of wood in situ. Presently, most of the analytical techniques used to measure the extent of degradation of waterlogged wood are laboratory based and require samples recovered from a site. The density of waterlogged wood is a good parameter for assessing the state of preservation,[24] as density will decrease as more of the wood cell wall is degraded by microorganisms. Research investigating the density of waterlogged wood in marine environments in situ by means of relative conductivity is currently being undertaken at the National Museum of Denmark. The principle is that as the wood cell is degraded it becomes more porous and is filled with surrounding seawater, which has a higher conductivity than the undegraded wood. Good calibration curves for the density of wood as a function of relative conductivity have been established in the laboratory and equipment is currently being developed to enable these measurements to be done under water in situ. Using such methods, it should be easier to assess the state of preservation of wood without recourse to sampling, thus gaining insight into the rate of deterioration without damaging the wood.[25] In this way, we can gather information without essentially compromising the integrity of the site. This information can help us to design the best in situ preservation method, with wood quality measurements comparable with baseline data over time. Knowing the state of preservation enables conservators to choose the optimal conservation process in those cases where it may be decided to raise materials.

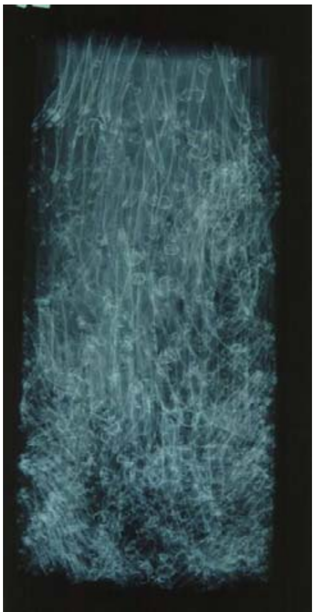

Fig. 6.5 X-ray of a pine block from the aerobic samples on the BZN 10 wreck. Note the severity of attack after one year on the site. Photo: courtesy MoSS project.

6.5 Monitoring in open water, on and in the seabed

6.5.1 Introduction

To monitor sites and determine the changes that are happening, it is necessary to measure and observe changes in the open water environment as well as on and in the seabed. These are basically three different environments with their own characteristics. This also means that the method and techniques for assembling the information may be different, as well as the information gathered. The data acquired may be used to make comparisons with future or past values: as baseline data or monitoring data.

6.5.2 The open water

Data for monitoring the possible effects of the open water environment, above the seabed, can be acquired in the following ways:

1. Technical devices such as data loggers and probes
2. By obtaining this information from large oceanographic institutes that undertake measurements for other purposes
3. Placing sacrificial objects in the water and measuring their deterioration rate over time
4. Taking water samples and post-recovery analyses

As we have seen above, a data logger has been used several times on archaeological shipwreck sites in the Western Wadden Sea to obtain environmental data. For example, during the MoSS project and the BACPOLES project, such data loggers were installed,[26] measuring pH and redox in the sediment and conductivity, salinity, dissolved oxygen (amount and percentage), turbidity, depth and temperature in the water.

It is, however, also possible to obtain data for specific areas from governmental institutions that monitor standard water quality parameters.[27] In situations that appear to be relatively stable, it is

[23] See Chapter 3.

[24] See, for example, Palma 2004 (2), 11.

[25] Gregory et al. 2013.

[26] Water samples were taken just above the seabed of the BZN 3 and BZN 15 sites. The environmental conditions of water and soil were measured with a WaterWatch 2681 data logger (manufactured by EauxSys Ltd, UK). This device measured salinity, dissolved oxygen, turbidity, depth and temperature of the water while employing two probes to determine pH and redox in the sediment. Experience with the data logger, which was still in an experimental phase, was gained in the EU funded MoSS project on the BZN 10 site.

[27] For example, Stanev et al. 2011.

not always necessary to collect continuous or even repetitive data. New sites, however, should have environmental parameters included in the initial baseline studies. Data can be obtained specifically through data loggers and sampling, but may also be extrapolated from already known data.[28]

To investigate the open water environment, water samples can also be taken. This was done for the BZN 3 and 15 sites during the BACPOLES project. Water surrounding the wrecks was found to be alkaline, with no dissolved organic carbon, low in nitrogen, low in nitrate, without immonium, low in phosphate, high in base cations,[29] high in sulphate, low in iron and high in conductivity (due to the salt).[30] Analyses of the water sampled close to the wooden wreck parts also showed extremely high Na, K, Cl- and SO42-, Ca and Mg levels.[31]

The data logger gave the following values:

	BZN 3	BZN 10	BZN 10	BZN 11	BZN 4	BZN 15
Temp (Celsius)	18, 9-21, 53	14, 48-18, 21	16, 97-19, 41	16, 97-18, 73	15, 98-17, 03	19, 79-20, 34
Turbidity (FTU)	10-58	0-7827	0-9546	8-60	8-118	6-1002
Depth (m)	5, 27-7, 16	7, 02-8, 28	6, 16-8, 22	8, 43-10, 35	8, 32-10, 32	8, 73-10, 7
Diss.Ox-1 (% saturation)	73, 9-94, 6	27, 7-145, 6	54, 3-110, 1	121, 0-163, 1	118, 6-163, 7	66, 4-81, 2
Conductivity (mSiemens/cm)	41, 66-47, 78	X	X	X	X	22, 74-45, 63
pH	6, 54-8, 39	X	X	7, 7-8, 24	7, 25-8, 76	7, 71-8, 42
Redox (mVolt)	227- -9	36- -482	X	116- -156	318- -177	134- -33
Salinity	29, 89-34, 89	X	8, 81-38, 28	X	X	15, 26-33, 2
Diss.Ox-2 (ml/L)	5, 5-8, 34	2, 7-20, 67	4, 34-12, 18	11, 46-15, 62	11, 47-15, 77	5, 11-6, 53
Date	27–28 Aug 2002	12/6/02–11/7/02	12/7/02–25/7/02	18/6/02–19/6/02	16/6/02–17/6/02	13/8/02–14/8/02

Table 6.1 Data logger values per BZN site.

The datalogger at times gave some extreme readings (See table 6.1, the measured low salinity at BZN 10), which on hindside cannot be double checked. Some conclusions can be made though. As we can see, many of the parameters for BZN 3 and 15 are comparable, as are those for the BZN 10 site that was monitored during the MoSS project. This is logical, as the sites are all close to each other and the measurements were taken more or less in the same period (summer 2002). In different seasons, however, there can be differences in parameters. For the BZN 10 wreck, for example, the temperature ranged between a reasonably stable 17 °C in July 2002 to as low as 1 °C on 17 December that same year.[32] We can assume that these data are representative of the water surrounding all the wreck sites on the Burgzand and thus can serve as baseline data for most of the wrecks in the area.

6.5.3 On the seabed

Information from the seabed surface – on the seabed – can be measured in several ways:

1. Visually, by divers or ROV
2. With marine geophysics such as single beam, multibeam, side scan sonar
3. Traditional sounding (sounding lead)
4. Laser, aerial photography and satellite

The visual inspection of a site can be achieved by sending down divers or by using Remote Operating Vehicles (ROVs) with a camera mounted. Visual inspection can tell us about the pure physical conditions of a site. This can be done when parts of a wreck are exposed. Divers can also identify whether a site is being attacked by wood borers or if the integrity of the site has

[28] Either through oceanographic institutes or from earlier activities on nearby shipwrecks.

[29] Cations are ions or groups of ions having a positive charge and characteristically moving towards the negative electrode in electrolysis. Base cations are defined as the most prevalent, exchangeable and weak acid cations in the soil.

[30] Gelbrich et al. 2005, 80–81. The samples were taken in August 2002.

[31] Huisman et al. 2008, 37.

[32] Most measurements with the EaxSys WaterWatch data logger were taken on the BZN 10. See also Chapter 3. Coldest temperature measured on site with a Suunto computer was -1 °C.

been compromised.[33] One limitation to the use of divers and ROVs is the fact that it is more difficult to obtain a good insight into the location and thus an overview of the site.

6.5.4 Marine geophysics to monitor sediment change

This creation of an overview is not a problem when using bathymetric systems such as multibeam, side scan and single beam sonar. These techniques were developed to create maps of the seafloor. Some equipment can even give us a rough insight into what is happening in the seabed, such as sub-bottom profilers and magnetometers. These have been highly specialized equipment for a long time and expensive to deploy. Today, they are not only becoming more accurate, but have also dropped considerably in price. They have thus become available to many people, professionals as well as avocational groups.

Obviously, many government institutions have access to marine geophysical technical devices that can be used to monitor the effects of sediment transport over a wreck site. In the Netherlands, the RCE works with the Rijkswaterstaat (RWS, Directorate-General for Public Works and Water Management, part of the Ministry of Infrastructure and Water Management) to obtain multibeam data and also with commercial survey companies such as Periplus and DEEP.[34] Repeated surveys carried out at different times using multibeam can be digitally subtracted from each other in order to map where there are areas of sedimentation and/or erosion of sediment. This was trialled in the Burgzand area, with the longest repetitive monitoring survey on the BZN 10 wreck.[35]

Single beam can also be used for the monitoring of larger landscapes in particular. It – as the name suggests – records the depth of the seabed using a single sound beam rather than multiple (as in the multibeam). It has been used, for example, to map the overall Western Wadden Sea seabed.[36]

Although it does not record actual depth, side scan sonar can also be used to monitor changes at protected submerged cultural heritage sites and in their environment. This equipment, which can scan large areas of the seabed in a relatively short time, has become very cheap in the last couple of years and its use is now widespread.[37]

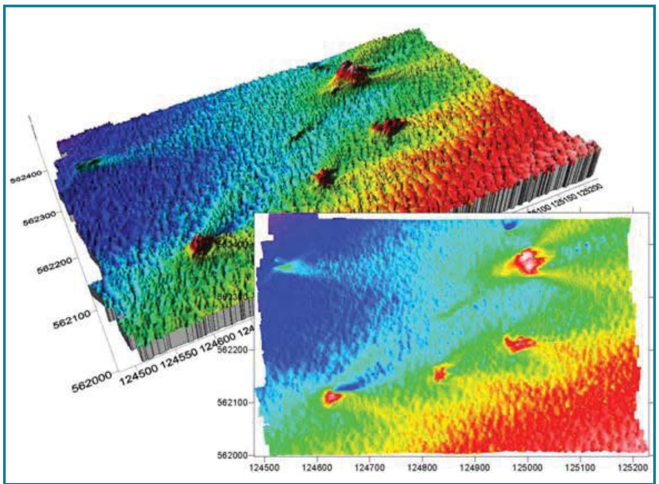

Fig. 6.6 Multibeam consists of real depth measurements, and is thus three dimensional. It can therefore be looked at from different angles. Figure: courtesy Periplus Archeomare/RCE.

Multibeam recording as a way to monitor shipwreck sites[38]
If we had to mention one type of equipment that is of enormous help in the monitoring of sites on the seabed, then it would have to be the multibeam echo sounder, which is an instrument used in hydrography to plot the seabed. The multibeam sends multiple sound pulses to the seabed in a narrow path under a ship, accurately measuring depth. Usually, the higher the frequency, the better the accuracy.[39] At present, in ideal conditions, some systems can produce images as good as the side scan sonar, but including actual depths.[40]

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 in one single track as a side scan sonar, 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 such as sedimentation or erosion processes. It is, therefore, a cost-effective method for monitoring archaeological sites – including their environment – under water.[41]

Multibeam data can also be processed in such a way as to create a three-dimensional image. 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 in which visualization is becoming increasingly important, these kinds of images can also be very useful in communicating with a broader audience (Fig. 6.6).

Multibeam can also be a highly effective tool for regular or specific monitoring. One example of specific monitoring is an investigation of the possible looting of a site near the Dutch town of Hoorn. The Cultural Heritage Agency had been informed by local divers that looters were active at an eighteenth-century

[33] It is not, however, always easy to detect living Teredo in wood.

[34] See, for example, Brenk & Manders 2015.

[35] See Chapter 3.

[36] See Chapter 1.

[37] See, for example, http://www.fws.gov/panamacity/resources/An%20Illustrated%20Guide%20to%20Low-Cost%20Sonar%20Habitat%20Mapping%20v1.1.pdf (accessed 31-01-2017).

[38] This chapter has to a great extent been published in the MACHU Final Report, Manders 2009, 59–68.

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

[40] 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.

[41] See also the final report of the Rasse project by Bates et al. (2007) and the article by Mayer et al. (2009) for their conclusions on the use of multibeam for underwater cultural heritage management.

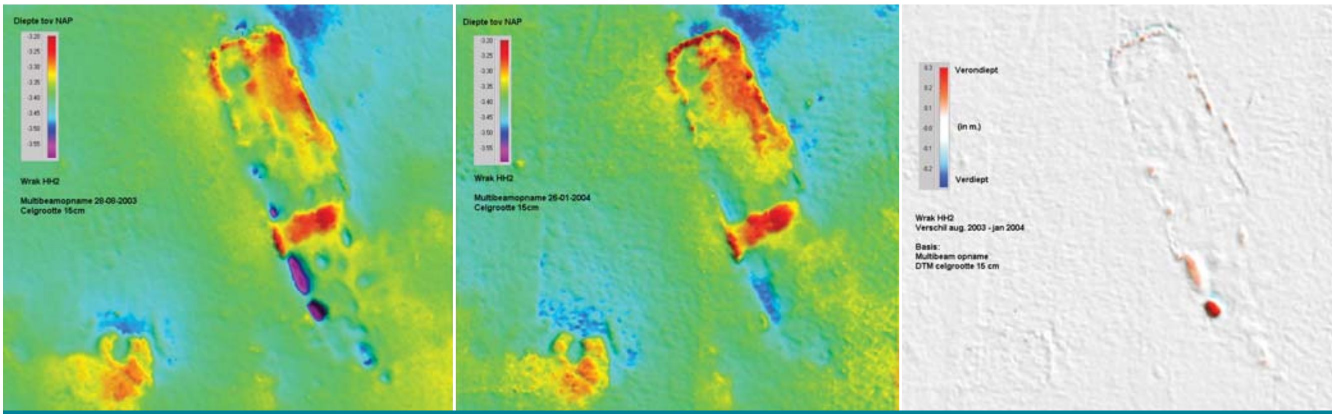

Fig. 6.7 A, B, C Two different multibeam recordings (A + B) made on the Hoornse Hop 2 wreck near Hoorn in the Netherlands to investigate possible illegal excavation on the site. Picture C is the result of a comparison. The results revealed that there had been more sanding in, and this was not consistent with supposed illegal excavation. Figures: RWS-IJsselmeer.

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 passed on revealed that the site had not been touched for a while (Fig. 6.7 A, B, C).

At the Banjaard area in Zeeland, old wreck positions have been reanalysed on the basis of new multibeam recordings. The nineteenth-century 'Spot by 11' wreck, for example, was found to be approximately 100 metres south of its original position.[42]

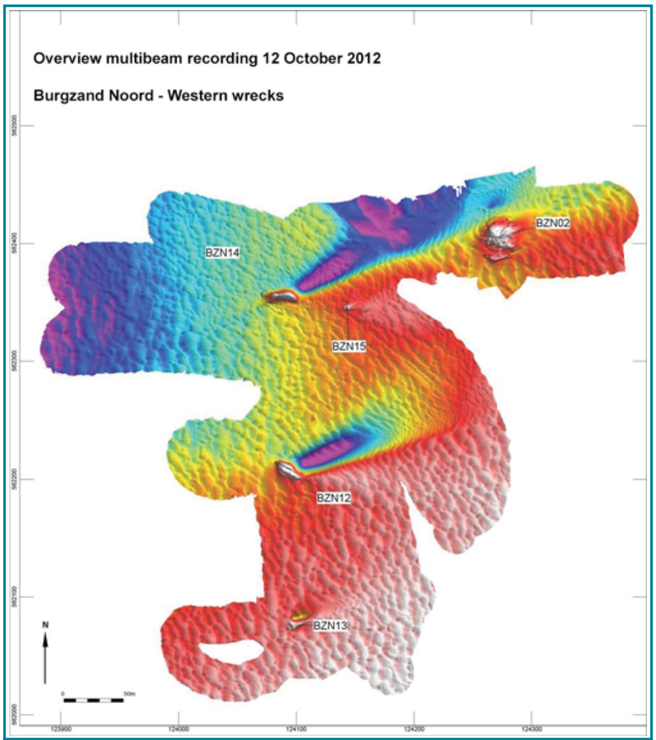

Fig. 6.8 Multibeam on a regional scale. Figure: Periplus Archeomare.

The multiple depth measurements taken with multibeam can also be used as input for erosion-sedimentation models on a regional as well as on a larger scale, such as that produced by Southampton University (UK) for the southern North Sea basin and the Burgzand area at large (Fig. 6.8).[43]

A coring plan for Optically Stimulated Luminescence (OSL) dating 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 (Fig. 6.9).[44]

Another use for multibeam is in archaeological assessments and excavations. Its accurate positioning, depth measurements and the overview it provides offer an accurate basis for site plans. This not only saves valuable time, but also often proves to be more accurate than measurements done by hand.[45]

The multibeam echo sounder is used by many organizations whose remit includes managing the waters and seabeds of Europe. In the Netherlands, they include the RWS and the

Fig. 6.9 Using multibeam recording on the BZN 10 wreck to plan OSL dating. Photo: Paul Voorthuis, Highzone Fotografie.

[42] The site location was registered incorrectly in ARCHIS. Its position was corrected after multibeam recording of the site in 2008, Konsberg EM 3002D.

[43] See Dix et al. 2009 (1).

[44] See Manders et al. 2009 (1), 2009 (2).

[45] 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 underwater excavation, executed by a private archaeological company in 2006: the excavation of the ship De Jonge Jacob (1858). See Waldus (ed.) 2009 (http://www.rtvoost.nl/tv/uitzending.aspx?uid=335462&_ga=1.146288626.730270569.1452855246, accessed 30-01-2017).

Ministry of Defence's Hydrographic Service.[46] Data they collect for other purposes can – in many cases – be used for archaeological monitoring.[47] Harvesting of information from third parties makes monitoring even more cost effective.[48]

Multibeam monitoring on the Burgzand, Texel

With this in mind, the Burgzand area was extensively monitored using multibeam echo sounder. In 2002 and 2004, the system used was a Reson Seabat 8101, while in 2003 and from 2005 onwards the equipment used was a Reson Seabat 8125, a top-of-the-range system.[49] The latter 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, at 40 pulses every second. The 8101 has a lower resolution, using only 101 beams.

From 2002 onwards, the monitoring was performed in collaboration with the RWS, the main management agency for waterways in the Netherlands.[50] The first recordings (2002 to 2005) were made for the EU MoSS project (Monitoring of Shipwreck Sites) and were later taken over by the MACHU project.[51] After the MACHU project in 2009, the monitoring continued until the present day (Fig. 6.10).[52] This long series of continuous data offers a detailed insight into what is happening on the seabed in this area. The multibeam recordings are made each year, usually around October-November. Specific events, such as storms, have not been taken into account, although it is known that these can have a strong and sudden impact on the seabed and the shipwrecks in and on it.[53] The focus has been on long-term effects on the sites, and this also means more flexibility when it comes to the availability of the surveyors and their equipment.

To begin with, four archaeological shipwrecks (BZN 3, 8, 10 and 11), which lie in an area of 200 x 250 metres – the heart of the Burgzand area and the former Texel Roads – were monitored with multibeam.[54] While BZN 3, 8 and 10 were physically protected in situ, BZN 11 was not and this wreck served as a benchmark.[55]

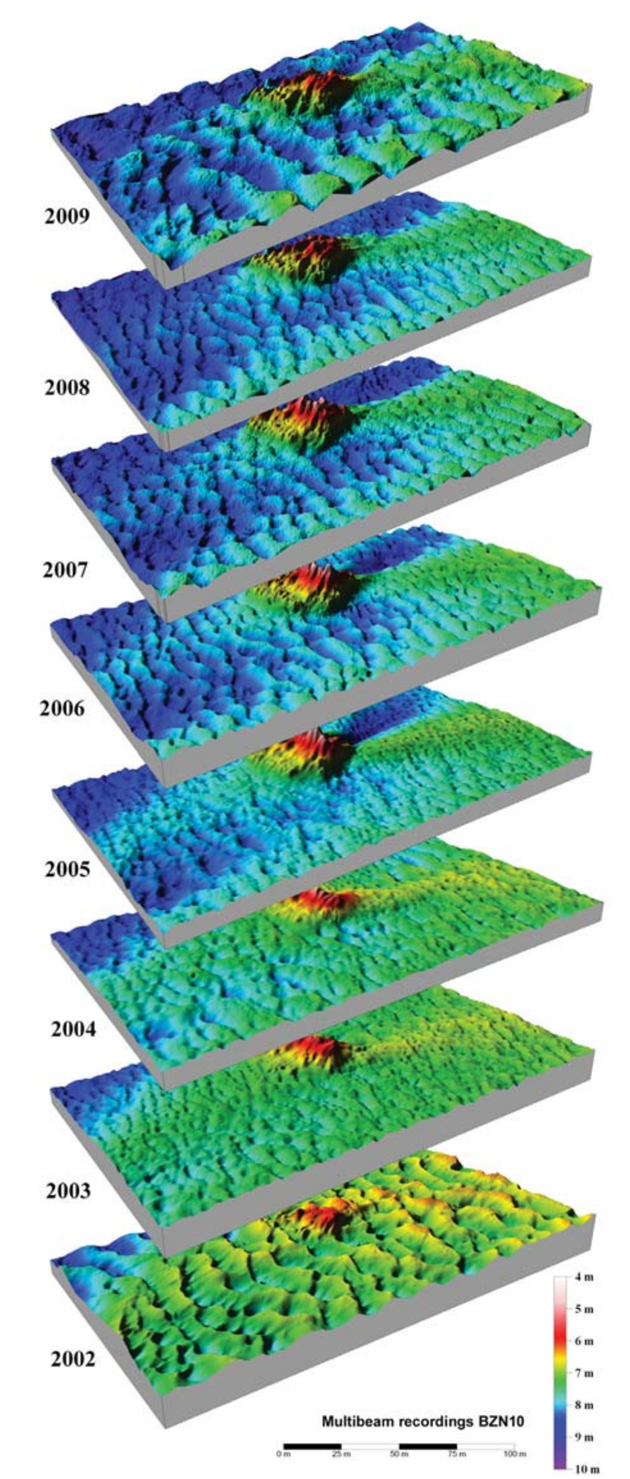

Fig. 6.10 Monitoring by using annual multibeam recordings and comparing them with each other. Figure: Periplus Archeomare/RCE.

[46] As a comparison, in Belgium, the Flanders Marine Institute (VLIZ), which coordinates scientific research in the North Sea, and Flemish Hydrography, serve as centres of expertise for this kind of work. See also Demerre 2009.

[47] When multibeam is used for the monitoring of shipping lanes, the main focus is to detect any obstacles, such as protruding shipwrecks or a 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. However, by analysing the data originally recorded, this more detailed information may be obtained without having to go back to the site. 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.

[48] See also Chapter 5.

[49] Talbot 2005.

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

[51] See also Brenk 2003.

[52] This is arranged within the covenant with Rijkswaterstaat and is believed to be the longest shipwreck monitoring of this kind in the world.

[53] Extreme examples of the effect of storms and hurricanes on the seabed and shipwrecks are known. See, for example, Gonzalez 2015.

[54] See also Chapter 3.

[55] See Chapter 3.

As quickly as the wrecks can be uncovered by the highly dynamic environment, they can quickly be covered again with a protective layer of Holocene sand.[56] This process is continuous.

6.5.5 In the seabed

Data for monitoring the effect of the sediment on the physical quality of the site can be acquired in the following ways:

- Probes and data loggers[57]
- Sacrificial objects
- Sampling

Nearly all of the biogeochemical processes in young sediments (e.g. the dynamic Holocene sand layers in the Wadden Sea) are directly or indirectly connected with the degradation of organic matter.[58] Organic matter in the seawater and the seabed may be produced by algae and other organisms in open water, which subsequently sink to the seabed and become incorporated into the sediment. There may also be remains of plant material, such as seagrass or seaweed, or shipwreck material deposited within the sediment.[59] The utilization of organic matter by organisms within sediments involves oxidation reduction (redox) reactions.[60]

Usually, only the first few millimetres of the seabed sediment are oxygenated. Through bioturbation by invertebrates and advection, this oxygen zone may, however, extend downwards. A few centimetres under the oxygenated zone, nitrate serves as the oxidizing agent, followed by manganese and iron oxides deeper in the sediment. Below this, sulphate is the principal oxidizing agent, and sulphate reduction is often the dominant process in shallow marine sediments due to the high concentrations of sulphate in seawater.[61]

The seabed in the Western Wadden Sea consists mainly of sand. Small and large blocks of peat are a reminder of the time that the Wadden Sea was still a swampy area.[62] Often, as part of the many post-depositional processes, a layer of fine clay settles between the construction parts of a shipwreck. During sampling on the BZN 15 site, little lumps of this clay were observed, while on other sites with more intact wreck structures this clay can be found as continuous layers covering archaeological material.[63] These observations tell us something about the wrecking process and the dynamics of the seabed. A continuous layer of fine clay usually means that everything that is below it is in relatively good condition, while lumps and blocks of peat tell us something about the dynamics of erosion in the area.[64]

In terms of monitoring within sediments, the dissolved oxygen content, concentrations of various chemical species, porosity and the organic content of the sediment can all yield information about the ongoing biogeochemical processes in the sediment and the rate of deterioration of organic matter. A monitoring programme can use data logging devices or analysis of pore water taken from core samples. The following parameters may be assessed to obtain an idea of the nature of the buried environment:

- Dissolved oxygen content
- Redox potential, through measurements or the presence of monosulfides
- Sulphate/sulphide and also total sulphur content
- Organic content of sediment
- Porosity of sediment
- Water flow[65]

These parameters will give a good indication of whether the environment is oxic or anoxic and which dominant process are taking place in the sediment.

A characterization of the soil of the Wadden Sea seabed can be provided through analyses of samples taken during the BACPOLES project on the BZN 3 and BZN 15 sites in 2002. The soil on both these sites consisted of pure sea sand, it was alkaline, very low in carbon content, no nitrogen was present, it was low in phosphorus, low in base cations, low in sulphur and medium in iron. We can assume this will also be similar to the top layer of the seabed on the Burgzand and in the Western Wadden Sea in general.

When removing the top layer on the wreck sites in the Burgzand area of the Western Wadden Sea, it can be noted that the sand is usually black. This was also noticed during sampling on the BZN 3 and 15 wrecks.[66] This black colour is indicative of reducing conditions, as it is caused by the presence of Fe (II) minerals. In contrast, Fe (III) minerals would give the soil a more yellow-brown or orange-brown colour. In anoxic sediments influenced by a marine environment and with organic matter and iron, there is usually a high concentration of sulphur (S) present. In such

[56] See also Chapter 3.

[57] Sub-bottom profilers may also be available for in-sediment monitoring. However, at present, no clear information is available on the possibility of identifying different qualities of wood through the sub-bottom profiling signals (Plets et al. 2008).

[58] Rullkötter 2000.

[59] See also Chapter 3.

[60] Schulz 2000.

[61] Kasten & Jørgensen 2000.

[62] See also Chapter 1.

[63] Observations made by the author during assessments and excavations in the Western Wadden Sea area, such as on the Scheurrak SO1 wreck and also BZN 10 wreck. See also Manders 2005 (1).

[64] Of course, as long as the lumps of clay do not have a direct human origin, for example, excavation.

[65] Klaassen (ed.) 2005.

[66] Huisman et al. 2008, 36.

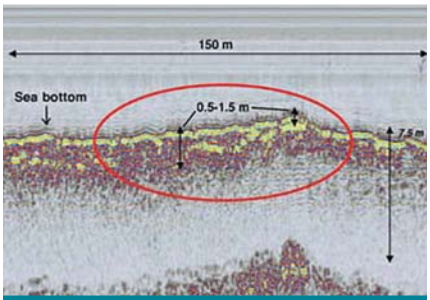

Fig. 6.11 Sub-bottom profiler recording of the BZN 3 wreck. Figure: Deltares/RCE/MACHU project.

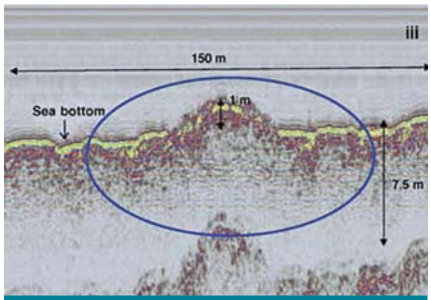

Fig. 6.12 Sub-bottom profiler recording of the BZN 10 wreck. Figure: Deltares/RCE/MACHU project.

environments, ample pyrite (FeS_2) can form in the soil mass. The BZN 3 and 15 sites had very low sulphur contents, which can be explained by the very sandy, organic-poor sediment in which pyrite usually does not form. Phosphorus (P) is also quite low in the minero genic sediments. However, the sites showed high concentrations of Ca, which is logical in relation to the presence of calcite in the sand.

The Fe contents were highly variable. This probably reflects variations in redox conditions that cause local dissolution and precipitation of Fe minerals, especially Fe (hydr)oxides. The pH was neutral to basic, which conforms to the more or less uniform hydrogen carbonate (HCO3--) concentrations that were detected. A depth profile of redox potential confirmed that reducing conditions had been reached at BZN 3 and 15.[67] Measurements with the same data logger at the BZN 10 site revealed that redox values dropped from an aerobic +36 mV to an anaerobic -460 mV within 12 days, after which it stabilized.[68] The pH of the sediment was constantly around 8 on the BZN 10 site during measurement with the data logger.

It is not easy to monitor conditions within the seabed without physically removing the sediment or physically penetrating the soil with sensors. However, to investigate the position of an archaeological site within the seabed and to monitor the effectiveness of physical in situ protection methods added to the site, sub-bottom profiling can be considered.[69] This technique was, for example, in use for the monitoring of the BZN 3 wreck (protected with sandbags and debris netting) and the BZN 10 wreck site (protected with debris netting alone) in 2009. Within the MACHU project, a seismic chirp sub-bottom profiler was used in combination with a side scan sonar. The primary reason for this research was to investigate the use of this technique in monitoring, and especially to see whether the combination of the two systems could detect disturbances in sedimentation processes on the seabed. A second reason was to map the thickness of the sand layers that had settled on the wreck site after the physical protection measures were taken.

The work was performed by Deltares using a side scan sonar CM2 system from C-MAX, with a frequency of 325 kHz, a resolution of 0.1 metres and a search path of 100 metres.[70] The sub-bottom profiler was an SB-0512i system from Edgetech. This seismic chirp system can easily distinguish different sediment layers and objects (in particular large objects) in the first 15 metres of the seabed.

Different frequencies were used in the Wadden Sea, between 0.5 and 7.2 kHz. A measurement was taken every 0.75 metres.[71]

Unfortunately, due to the presence of sport divers while recording, it proved impossible to investigate the whole area. Only a few measurements were taken at the BZN 3 and BZN 10 wrecks but some interesting conclusions can be drawn from the data collected, which will be discussed briefly here.

- First, the BZN 3 site is clearly visible on the side scan as well as in the chirp data (Fig. 6.11). The chirp profile shows us a sedimentation layer of approximately 0.5 metres 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 added in 2009, had managed to hold another half a metre of sand. On the flanks of the mound, as much as 1.5 metres of sediment had been caught with this protection technique. This is the area where no sandbags had previously been deposited (in 1988).

- Second, the chirp data from the BZN 10 site show relatively sharp flanks with low reflections in some places (Fig. 6.12). This means that there was less sediment under the polypropylene nets and that the nets were more or less hanging loose. Measurements with the sub-bottom profiler showed a sediment layer at least 1 metre thick on top of the wreck.

This research, although not extensively executed, with only two profiles, demonstrates the use of seismic chirp data in monitoring physically protected wreck sites. The data allow us to monitor the amount of sediment caught in the polypropylene nets.

New research using 3D seismic data will, in the near future, allow us to monitor the sedimentation rate over a whole site.[72] Tests with a new 3D system on the BZN 10 site in 2014 for the SASMAP project were unfortunately not very successful due to the roughness of the sea surface at the time of recording (Fig. 6.13). However, the Innomar 3D parametric sub-bottom profiling system tested did give good results on other sites.[73]

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[67] Huisman et al. 2008, 39.

[68] Measured between 11/6/2002 and 11/7/2002.

[69] Manders 2009 (1).

[70] Paap & de Kleine 2009.

[71] Two measurements per second at a sailing speed of 3 knots (1.5 m/s). The side scan and seismic chirp data were processed using Petrel (3D modelling software) to visualize the results in 3D, Paap & De Kleine 2009.

[72] Early attempts to use 3D seismic on archaeological sites in the UK are described by Bull et al. (2005). In the Netherlands, the first attempts were made in the IMAGO project, Brenk, Romein & Missiaen 2003.

[73] Al-Hamdani et al. 2013, Gregory & Manders (eds) 2016.

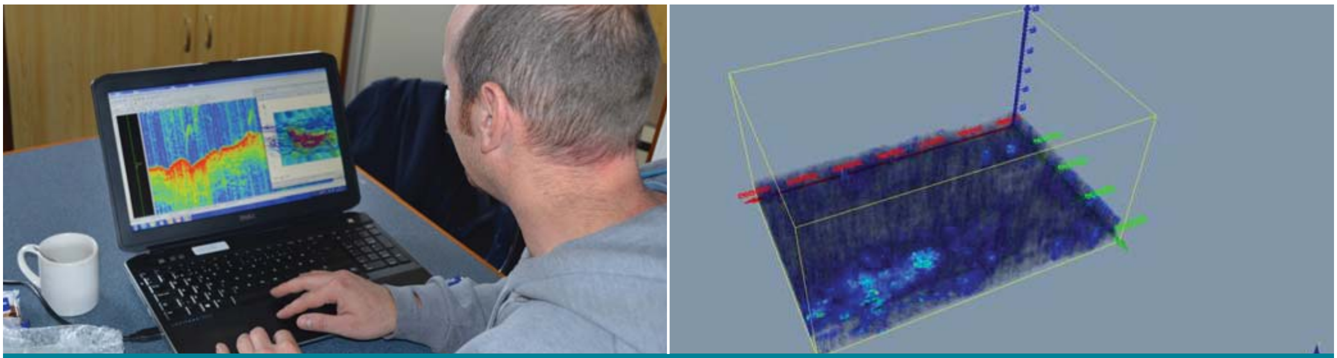

Fig. 6.13 3D sub-bottom profiling from the BZN 10 wreck. Figure: INNOMAR/RCE/SASMAP project.

6.6 Optical dating: potentially a valuable tool for underwater cultural heritage management[74]

Coring can be used to investigate what is in the seabed. It can be used to search for a site, to interpret, for example, sediment layers or areas with archaeological finds, or to investigate environmental parameters within an area. However, for the interpretation and monitoring of a site, another kind of analysis can be added to the toolbox. As we have seen, knowledge about sediment dynamics is of great importance for the management of shipwrecks on the seabed. On the one hand, transport of sediment will allow for rapid burial of the wreck. On the other hand, sediments transported by currents can be highly erosive, which can eventually lead to the complete destruction of a wreck site.[75] In order to understand more about the sediment dynamics in and around a shipwreck, a study was conducted in the MACHU project using OSL dating, grain-size analysis and anthropogenic metal analysis. This integrated research was designed to provide greater understanding of the history of post-depositional processes at particular sites. The effectiveness of in situ preservation using polypropylene netting could also be investigated in this way.

6.6.1 Optical dating, grain-size distribution and anthropogenic metals

For the first time ever,[76] an underwater shipwreck (the BZN 10) was investigated and its surrounding sediments successfully dated using the OSL method (Fig. 6.14). Optical dating is used to determine the time of deposition and burial of sandy deposits. The method determines the last exposure to light of sand or silt-sized minerals.[77] It may thus give some valuable information about the stability of a site over time as well as the effectiveness of in situ protection methods.

OSL dating has been applied regularly on sediments from land sites.[78] However, application of the same method to sediments in the Wadden Sea is not straightforward. Light exposure of the grains prior to deposition and burial may be too limited (due to filtering of sunlight through the water) to completely reset the OSL signal (i.e. to set the OSL clock to zero). Any remaining OSL signal will result in a positive age offset, with the OSL age on such deposits overestimating 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 to be reset) and attempt 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. A prerequisite for optical dating to be successful is that the most light-sensitive part of the OSL signal should be erased to negligible levels for at least part of the grains at the time of deposition. Given the highly dynamic environment of the Wadden Sea, it was expected that this prerequisite would be met.

The study not only applied OSL dating but also looked at grain-size distribution and anthropogenic metals to investigate the sedimentation process and the provenance of the deposits.[79] By studying grain-size distribution, it is possible to determine whether sedimentation is continuous or occurred during specific events, as well as whether sediment has been transported through waves (fining upward sequences) or is deposited from the water column during periods of low energy. In addition to grain-size analyses, anthropogenic trace metals and stable lead isotopes can be used.

Fig. 6.14 Executing coring with the Ackermann core on the BZN 10 site. Photo: Paul Voorthuis, Highzone Fotografie.

[74] This section is a summary of Manders et al. 2009 (1) and Manders et al. 2009 (2).

[75] See Chapter 1.

[76] As far as is known by the researchers.

[77] See, for more about OSL, Chapter 2.

[78] See, for example, Bluszcz 2005.

[79] Manders et al. 2009 (2).

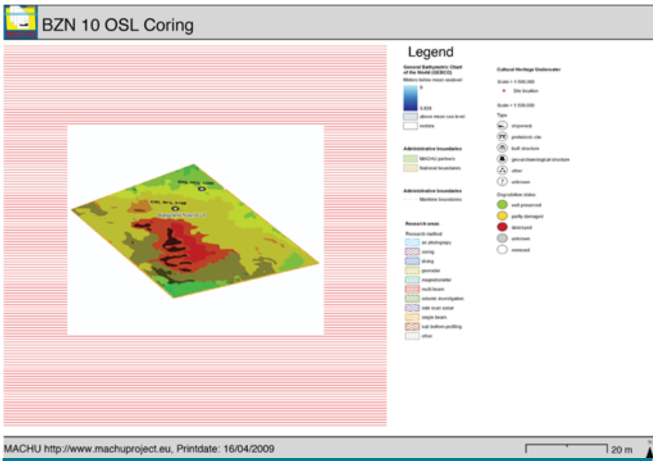

Fig. 6.15 Position of the two Ackermann cores on the BZN 10 wreck site. Figure: RCE/MACHU project.

Fig. 6.16 The Ackermann core. Photo: Paul Voorthuis, Highzone Fotografie.

Stable lead isotopes allow the creation of a fingerprint of anthropogenic lead. From 1950 to 1983, lead was added as an anti-knock agent in petrol. This lead originated from Broken Hill, Australia, having a very different lead isotopic ration compared with European industrial lead and natural lead. By studying metal profiles in the sediment, the onset of the industrial revolution, the introduction and use of the anti-knock agent and the last 25 years could be dated.[80] In addition, if the metal profiles and stable lead isotopes could be used to identify sedimentation events, this would provide useful information, such as rate and frequency of burial or erosion events of shipwrecks in dynamic sandy environments in shallow (less than 30 metres) continental seas.

By measuring major elements, as well as carbon and sulphur content in the sediment, the occurrence of sulphate reduction could also be established.[81] Sulphate reduction can cause sulphidization of metal (iron) objects in shipwrecks, such as nails. It will also hamper the exhibition and conservation of the ship after removal because of oxidation of the previously formed sulphides. These will produce sulphuric acid, causing all kinds of problems.[82] Erosion events may also be marked by changes in grain size and heavy mineral concentrations that may be indicated by trace elements such as rare earth elements (REE), zirconium (Zr) and titanium (Ti). Major element concentrations, and carbon and sulphur content reflect lithological changes (such as calcium carbonate and clay content) and can therefore add to our understanding of the sedimentation history.

The optical dating, grain-size analysis and chemical pollution studies were applied to the sediment taken from two cores (no. 9108 and no. 9208). The specific aims of this study on the BZN 10 wreck were:

- To investigate the application of OSL dating in relation 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. By accurately dating sand, in theory, the age of a wreck can be narrowed down, making identification easier. In addition, transport of 'bleached' sand after the sinking of the ship could give an indication as to when and how fast the ship was buried. If younger sand is found in or below a shipwreck, it is likely that the wreck moved after sinking and that the environment is highly dynamic. This would imply the threat of the ship being repeatedly exposed. This information may be important for the significance assessment of the site, and for determining whether to preserve in situ or ex situ (through excavation).
- To test, underneath the wreck, the hypothesis that shipwrecks sink into the Holocene sediment of the Wadden Sea, which appears to be less consolidated than the hard Pleistocene subsurface.[83]
- To use drilling in the wreck to find in situ shipwreck-related debris and sediment layers. In this way, it may be possible to establish whether a site contains relatively undisturbed sediment layers that may contain artefacts from the wreck site.
- To investigate, above the wreck, 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. Seven shipwrecks in the Wadden Sea have been physically protected in situ with polypropylene nets. These nets could be used as independent age markers and thus serve as a control for the OSL dating.

6.6.2 Fieldwork and sample selection

The two core samples were taken from the site by the Geonaut, operated by BAM-De Ruiter Boringen en Bemaling BV.[84] These were drilled 8.75 metres (9108) and 5.95 metres (9208) respectively into the seabed. One of these Ackermann cores was intended to go through the wreck (no. 9108) and one just next to it (no. 9208). The aim was to go through the whole Holocene layer and one or two metres into the Pleistocene sediments below.[85] It was hoped that the core through the wreck site (no. 9108) would

[80] Walraven et al. 1996.

[81] See also Chapter 3.

[82] See also Chapter 3.

[83] See also Chapter 1.

[84] On 27 November 2007.

[85] For more information about the sampling, see MACHU Report 2: Manders et al. 2009 (1).

strike timbers from the ship structure. This could then be used as a reference point for dating the sediment (Fig. 6.15).

Ackermann cores consist of RVS tubes 350 mm long and 66 mm wide (Fig. 6.16). No light can penetrate to the undisturbed samples, which together make up one continuous sample. The core taken near the wreck (9208) was almost 6 metres long and consisted of 17 separate samples. The core inside the wreck was almost 9 metres long and consisted of 25 samples. Unfortunately, the latter core did not hit the ship structure, but probably passed between two parts of the wreck, as parts of the protective nets were present in the samples.

6.6.3 Analyses

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. After discussion between the Netherlands Centre for Luminescence Dating (NCL) and the Dutch Cultural Heritage Agency, ten samples were selected for full analysis.

For both cores, the samples from the upper metre below the seabed were not reliable for dating.[86] However, the age of these sediments is very likely to be 100 years or less. At the location of the BZN 10 (9108), the results from underlying sediments (1.5–3.5 metres below the seabed) indicated an age of around 300 years; these age estimates are likely to be valid. Hence, optical dating suggests these sediments are of a similar age to the BZN 10 wreck, which has been dated to the second half of the seventeenth century.[87] The optical age obtained from a sample from the other core (9208) at a similar depth (1.6 metres below the seabed) gave a much older age (~700 years). The samples from more than 4 metres below the seabed at the wreck position (9108) indicated ages between ~600 and 800 years, with the results on the oldest sample likely to be unreliable. It was concluded that the core did not penetrate the entire Holocene sedimentary body and that Holocene sediments were present below the wreck. This was an important conclusion, since it addressed one of the aims of the study, which was to investigate the theory that wrecks in the Wadden Sea sink through the soft Holocene sediment to finally rest on the harder Pleistocene layer.[88] The answer was no, or at least not always (Fig. 6.17).

6.6.4 Grain sizes

Prior to the coring, the BZN 10 wreck had been covered with a polypropylene debris net in 2000, 2001 and 2003.[89] In core 9108, the net from 2000 or 2001 was found at a depth of 40 cm.[90]

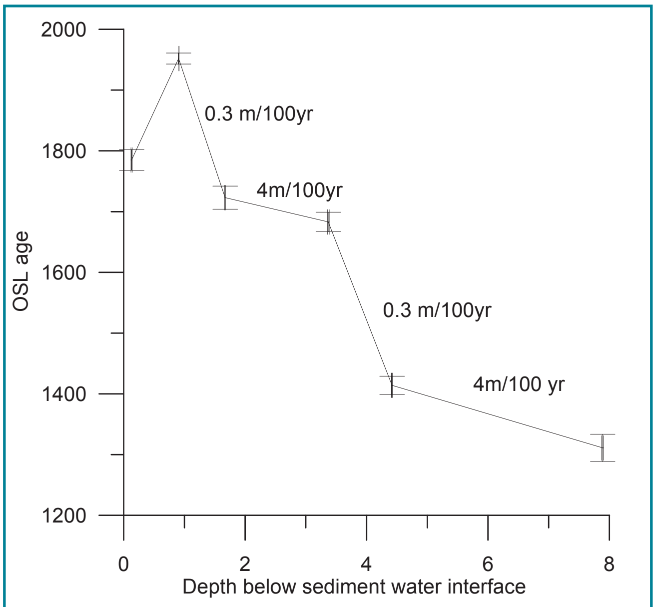

Fig. 6.17 Depth vs age plot for core 9108. The plot shows two periods of rapid deposition (1300–1400 and 1650–1700). In the intervals between and after these periods, sedimentation rates were much lower and might even be erosional. Figure: RCE/MACHU project.

Distinct regions of similar grain-size distributions could be recognized in both cores. In core 9108, in addition to the clay lenses occurring 4 metres below the surface, clay lenses were also found in the interval from 3–4 metres below the seabed surface. The pattern of median grain sizes and distribution between approximately 4 metres below the surface in core 9108 seemed to correspond with the level below approximately 1.5 metres in core 9208. This again corresponded with the measurement data from both cores. The 9108 core was taken at a water depth of -5.66 metres, while 9208 was taken at -7.97 metres, a difference of 2.31 metres.

The deposition of the upper 3 metres of core 9108 was possibly related to the sinking of the ship (post-depositional processes). This would have caused lower water velocity and the deposition of sand, which buried the wreck. The grain-size distribution of this sand did 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 debris net (upper metre in core 9108), was characterized by a similar grain-size distribution to the rest of the core. However, the carbonate (shell) content seemed to be somewhat higher. The higher carbonate content at the top of core 9108 coincided with a heavy mineral-rich layer. This suggests that

[86] Manders et al. 2009 (2), 43.

[87] See Chapter 3.

[88] See Chapters 1 and 3.

[89] After the coring, more in situ protection was carried out on site.

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

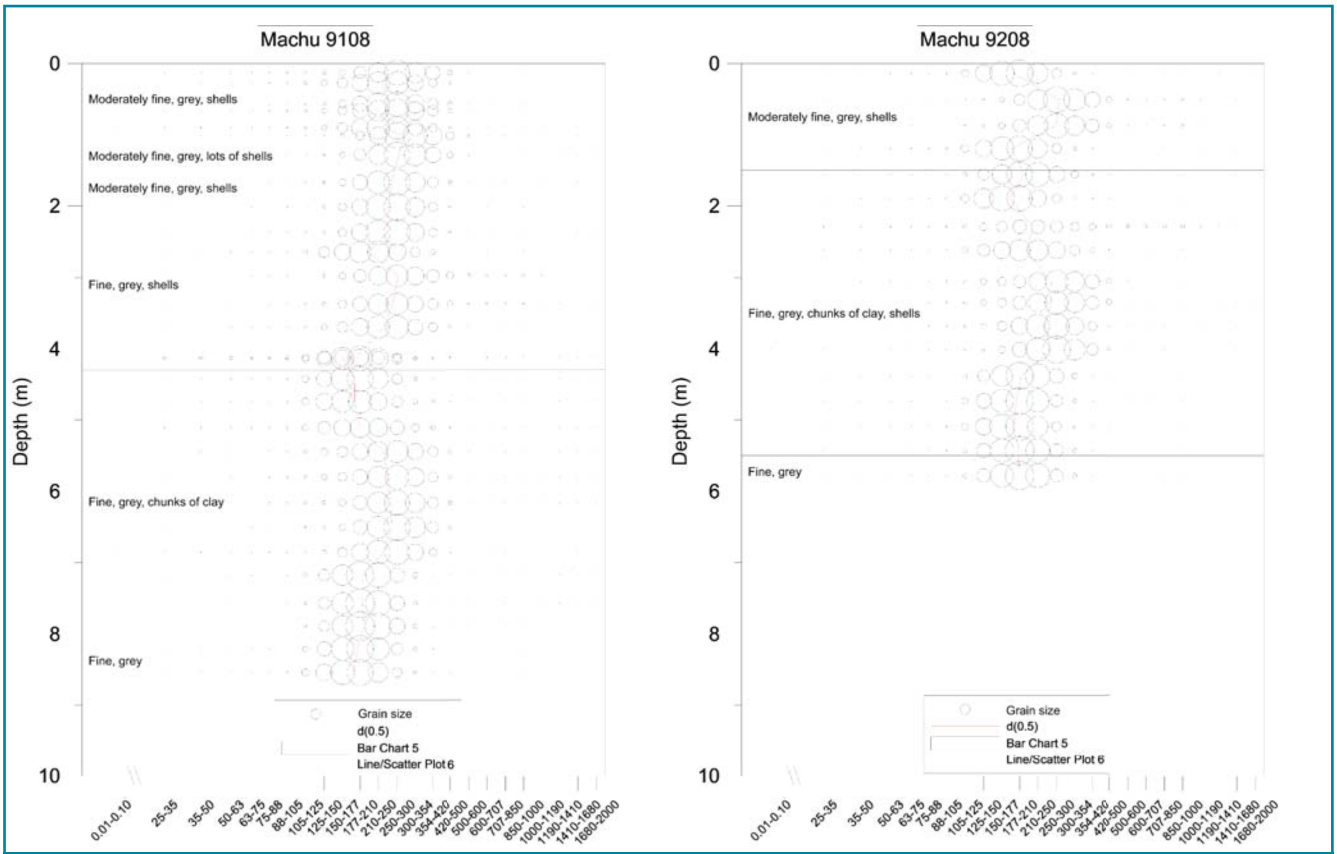

Fig. 6.18 Grain-size distribution for both cores (9108 and 9208). Figure: RCE/MACHU project.

high carbonate content correlates with a more dynamic environment (Fig. 6.18).

6.6.5 Geochemical patterns

The observed changes in grain-size distributions were also reflected in the geochemical patterns. At the top of core 9108, the clay mineral content was somewhat higher, also reflected in the finer grain size. At the top of core 9208, there was an increase in the d50 of the sand fraction, recorded as a decrease in the aluminium (Al) content. The high iron content at the top of core 9108 was accompanied by an increase in titanium (Ti), lanthanides (Ln),[91] chromium (Cr), uranium (U) and thorium (Th). This indicates an increase in heavy minerals such as ilmenite ($FeTiO_3$), magnetite ($Fe^{3+}_2Fe^{2+}O_4$), zircon (ZrSiO4) and chromite (FeCr2O4) 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 protection 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 were therefore indicative of erosion events.

Anthropogenic metals generally showed almost no trends from the top to the bottom of the cores. The content of these metals were, however, very low and fell in the natural range for these elements, suggesting that all the sediment was of local unpolluted origin. Anthropogenic metals are transported as very fine particles, often associated with organic matter, which only settle under very low energy conditions. Only during events in which the mixing of sand and clay occurs in the water column, such as heavy storms, may such particles be trapped in the sediment.

Lead isotopic ratios in core 9108 showed some very high radiogenic values (between 1.22 and 1.35), especially at the top. These values indicate the presence of the parent isotopes U and Th.[92] The high values for the 206Pb/207Pb ratio coincide with high values for REE, Cr, Fe, Zr and Ti,[93] which indicate the presence of heavy minerals such as chromite (FeCr2O4), ilmenite (FeTiO3) and zircon (ZrSiO4), and phosphate minerals such as monazite ((Ce, La)PO4) and xenotime (YPO4). Sands containing percent-level values of these minerals are known to occur on the Wadden Islands.[94] These minerals, especially the phosphates, are also 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.[95] 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 the period after 1850 was not present; nor were any petrol-derived 206Pb/207Pb ratios observed, indicating that the fine fraction of the sediment was certainly pre-1950 (Fig. 6.19 A, B, C, D).

6.6.6 Summarizing the results

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, and specifically in the Wadden Sea. However, it

[91] Often also collectively known as rare earth elements (REE).

[92] U = Uranium, Th = Thorun.

[93] Pb = lead, Cr = Chromium, Fe = Iron, Zr = Zirkonium, Ti = Titanium.

[94] Meijer et al. 1996 (1), 1996 (2).

[95] Al = Aluminium.

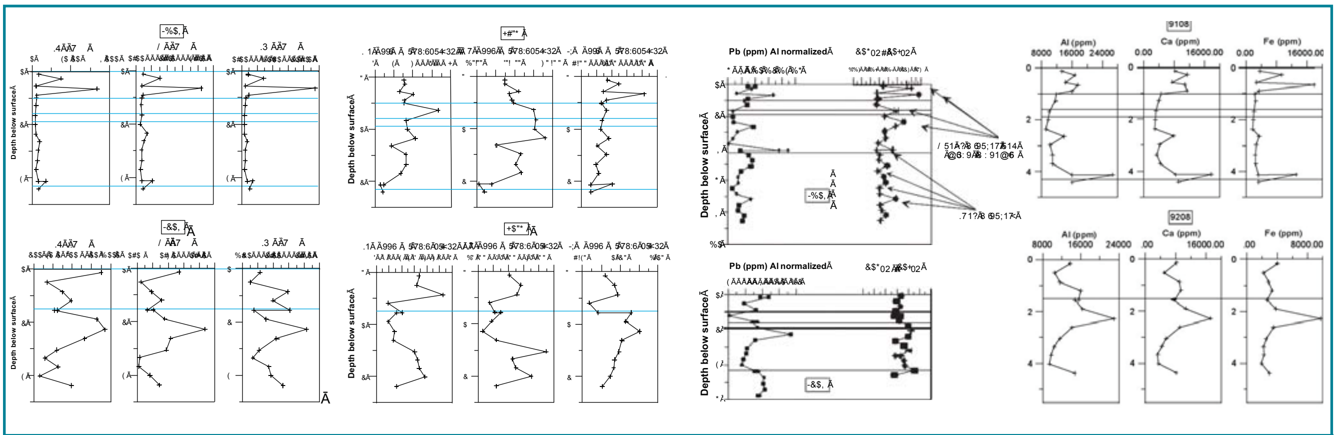

Fig. 6.19 (A) Major element variations for both cores, (B) Indicator elements for heavy minerals in both cores, (C) Al normalized Pb and 206Pb/207Pb versus depth, (D) Al normalized metal profiles in both cores. Figures: RCE/MACHU project.

should be noted that there may be 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 offer any useful results, full analyses were successful.[96]

The OSL dates show that neither of the two cores reached the Pleistocene sediment.[97] This means that the wreck parts are lying in and on Holocene sediments and not directly on top of the Pleistocene layer. The sediment – particularly that in the wreck – was 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. On this basis, we can conclude that it is also possible to find wrecks at a greater depth under the seabed surface. The sites deeper in the sediment may be older, since the OSL dating tells us that at 4 to 8 metres, the sediment was last uncovered in the fourteenth and fifteenth centuries. Historical 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.[98] Remnants of these old sandbanks may still exist at greater depths. These relics of the ancient maritime landscape may not have been uncovered by changing current patterns for centuries, and are therefore likely to contain wrecks of high archaeological value.[99] There is definitely such potential in 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.[100]

Core 9108, which was taken in the middle of the site location, gives a sediment dating of 1723 +/-38 years (between 1685 and 1761), 1.575 metres under the seabed. At 3.325 metres, the sediment is dated to 1683 +/-32 (between 1651 and 1715). These dates coincide with the age of the wreck. Below that level, at 4.375 metres, the age increases, dating to 1414 +/-30 (between 1384 and 1444). Although we have to be careful not to jump to conclusions on the basis of only a few dating samples, 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. This consists of fine sand with shells.[101] According to the OSL dates, the 2 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 was already confirmed by the archaeological assessment performed in 1999,

[96] Manders et al. 2009 (1), 42.

[97] Wallinga et al. 2009.

[98] Oost 1995, Kosian 2009.

[99] Examples of relatively intact shallow areas in the Western Wadden Sea have also been identified. See Chapter 2.

[100] 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 fourteenth century (after 1321). *RING* Internal Report number: 2009023, 2009.

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

when parts of well-preserved cargo, inventory and ship were surfacing the seabed. However, we also now know that at some locations on the site almost 2 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.[102] The OSL dates from just outside the wreck mound (core 9208) show a considerable increase in age at a relatively low depth (at 1.575 metres, dating to 1313 +/-33 = 1280–1346). Eventually, with more coring, the extent of the archaeological site might be determined with OSL.

The two cores show a striking similarity between the pattern in median grain sizes and distribution of the layer 4 metres below the surface in the wreck and the layer 1.5 metres below the surface outside the wreck. The water 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 the conclusion can be drawn that a considerable amount of the top sediment outside the wreck has been disturbed over time and affected by heavy erosion. These dynamics can be confirmed at least for the last few years by the analyses of the multibeam echo sounding sequence taken at this site.[103]

It can be concluded that OSL can add to the understanding of site formation processes and can also help to determine the quality of the archaeological resource without using excavation.

The question here, however, is whether OSL is useful for monitoring the in situ protection methods used on the BZN wrecks. Although the results from this research – consisting of only two cores – are too limited to draw many conclusions, some preliminary conclusions can be made. In theory, the amount of deposition under the nets should be measurable by the cores. However, in the study, while the age of the sedimentation could be determined as recent, it was not possible to distinguish recent age differences in sufficient detail to establish sedimentation rates and events over a few years. Nevertheless, a comparison between sedimentation layers in and outside the wreck showed 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-rich and heavy mineral-rich deposits were found, suggesting that although protection with debris nets works, there is still movement of sand, and dynamic sedimentary conditions prevail.

While this shows the effectiveness of in situ preservation with polypropylene nets in the Wadden Sea, it also reveals that the sediment steady state remains fragile and can easily become unbalanced. This result supports the argument for the use of multibeam echo sounder surveys to regularly to monitor these dynamics.[104] If monitoring reveals a sharp decline in the protection of the wreck, action should be taken to reapply in situ protection or, if important archaeological values are lost, to launch an excavation of the wreck or part of it.

OSL is potentially a valuable tool for monitoring. If the most recent sand particles can be dated, it can be used to evaluate build-up of sediment prior to and after protection measures have been installed on site. The method can also provide valuable information on whether a site has been eroded and/or if sand has been deposited over the longer period after wreckage. This information can help to determine the archaeological significance of a site and also give an indication of the preservation condition at the location. However, this study also showed the importance of combining OSL research with grain-size analyses and data on anthropogenic trace metals and stable lead isotopes.

6.7 Wood analyses for baseline data and monitoring

Most shipwrecks from the Burgzand area are from the seventeenth century and thus made of wood. Wood can be monitored visually in situ or it can be sampled. Visually, wood can be inspected for growths, integrity of the construction, and also previous or present attack by shipworm or gribble, for example.[105] The presence and activity of wood deteriorating organisms on exposed timbers under water is not always easy to monitor directly. However, it can be monitored in other ways, such as taking samples from the original construction or by the placement of sacrificial blocks of modern wood around a site and recording the presence or absence of organisms.[106] If they are present, it is highly likely that any newly exposed timbers will also be colonized. If so, steps to mitigate their effects can be taken. The temperature, dissolved oxygen and salinity of the water will have an effect on the growth of the main degraders, the wood-boring organisms.[107] These environmental parameters can – as we have seen – be measured using data loggers.

We can identify wood degraders and possibly develop mitigation strategies against them, perhaps by altering the environmental parameters. If we cannot find suitable mitigation strategies, we should reconsider the decision to maintain the site in situ. However, even if we decide to conserve or even study the wreck ex situ, it is important to have some information about the condition of the wood first. Is it strong enough to be raised?

[102] 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.

[103] See Chapter 3.

[104] See also Manders 2009 (2).

[105] See Chapter 3.

[106] See also Chapter 3.

[107] See Chapter 3.

Fig. 6.20 (A) Pilodyn, (B) Pilodyn as used under water. Photos: courtesy National Museum of Denmark.

What kind of conservation strategy is needed to preserve the site?

In terms of assessing wood deterioration, a simple metal probe made of a thin rod can be pressed into the wood. When the wood is badly degraded, there will be little resistance. Alternatively, a more elaborate, yet similar method, can be used, known as the Pilodyn (Fig. 6.20 A + B).[108]

The more degraded the wood, the further the pin will penetrate. Within the EU SASMAP project, an even more accurate instrument to measure the density of wood (the WP4UW) was developed, which could be used under water (Fig. 6.21).[109] Wood density in general is a good parameter for determining levels of degradation. Micro-organisms operate on a cellular level and as they remove cell wall material, this is replaced by water. As a result, the more degraded the wood, the lower its density.[110]

Density can also be assessed using cores taken in situ with an increment borer, but with wood that has been degraded by Teredo it is best to take larger samples, as the holes the shipworm makes may influence the measurements. This is the reason why in the MoSS and BACPOLES projects parts of the ship construction were sawn off and removed from the water to be investigated in the laboratory. In comparison to only investigating the density and subsequent water content of the wood, a more accurate method for the examination of the condition of the timber is microscopic analyses of samples, which will reveal the state and degree of degradation and the specific cause.[111]

Fig. 6.21 The WP4UW equipment to measure the condition of wood under water. Photo: courtesy National Museum of Denmark/SASMAP project.

When sampling archaeological wood from a site, it is important to not only pay attention to the specific find conditions, such as depth within the sediment, type of sediment and location, but also the type of wood and the former function of the object that is sampled. The latter is important because this may tell us something about the former (contemporary) exposure to degradation that the wood was subjected to. Different types of wood may be subjected to different forms of attack and at different rates.

On the BZN 15 site, one oak plank lying 20–30 cm below the surface was sampled, while a pine plank lying 30–40 cm below the surface was also sampled (Fig. 6.22). Both planks had been covered with sand for some time, but the oak plank had probably been in contact with the open water a few times. The oak plank was part of the outer planking of the ship, while the pine plank was part of the doubling (sacrificial planking), possibly to protect the ship against attack by *Teredo navalis*.[112] While the ship was in use, the outer double planking of pine would have been in

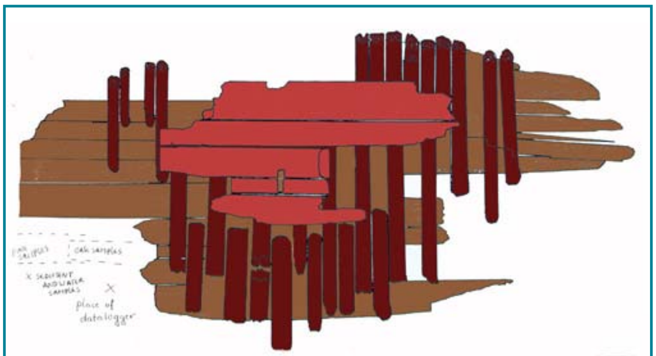

Fig. 6.22 The location of the sampled wood at the BZN 15 wreck site. Figure: M. Manders/BACPOLES Project.

[108] Gregory et al. 2007.

[109] Gregory & Manders 2016, 61.

[110] See Chapter 3.

[111] Klaassen (ed.) 2005.

[112] See also Chapter 3.

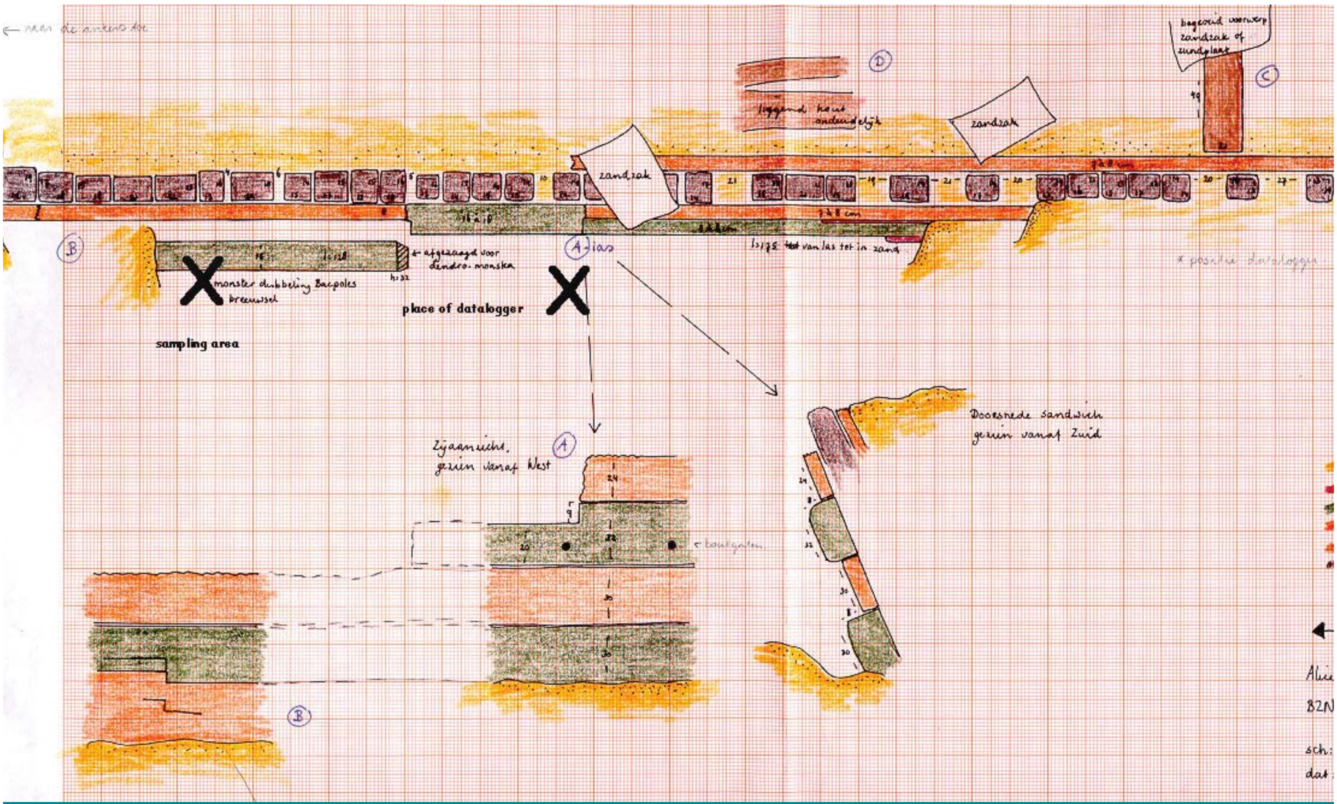

Fig. 6.23 The location of the sampled wood at the BZN 3 wreck site. Figure: M. Manders/BACPOLES Project.

constant contact with the open water. The oak planking may have been protected by the pine layer. After wreckage, the ship was most probably lying on its side with the pine planking now below the oak planking.[113]
On the BZN 3 wreck, two wood samples were taken from a thick oak plank which turned out to be a wale (Fig. 6.23).[114] The wood was covered with 30 cm to a maximum of 110 cm of sediment.[115] This wale would have been on the outside of the ship. However, its position would have meant it was mainly above the water.

The analyses of the samples revealed degradation of the cell walls by erosion bacteria for both of the wrecks investigated on the Burgzand, the BZN 3 and 15, and both wood species, oak and pine.[116] The same was true for active wood degrading bacteria.[117] The intensity of the degradation, however, varied.

All samples were degraded by erosion bacteria; non-degraded tissue in the wood was rare. Sapwood, if present, was always severely degraded. One result derived from the research in the BACPOLES project was that the original dimensions of the timber are negatively correlated with the degree of degradation but not the exposure time.[118] At all of the sites – on (wet) land as well as underwater sites – sampled within the BACPOLES project, thicker oak piles were severely degraded on the outside, while in deeper layers the degree of degradation was less and sometimes even absent. The thinner sawn oak timbers were severely degraded. The oak shipwreck timber from the marine sites only consisted of sawn heartwood, but in all cases, wood degradation was still found (severe to moderate). Furthermore, the pine from BZN 15 was severely degraded. However, compared to the other sites in the overall project, the marine samples were still less degraded than those surrounded by fresh water.[119]

The relatively smaller degree of bacterial decay at the marine sites could indicate that marine seafloor conditions are less favourable to erosion bacteria than fresh water soil conditions. This was also observed in the samples that were taken on the BZN 10 site during the MoSS project, compared to the Darsser cog and the *Vrouw Maria* in more brackish to fresh water environments.[120] Apparently, the factors mentioned above (size and salinity) affect the speed of degradation to such an extent that the effect of age (and therefore the exposure time) is minimal.[121]

In relation to in situ protection of archaeological wood, it has also been suggested that water flow through wood may be an important factor that determines the degree of degradation by erosion bacteria.[122] It is possible that only minor changes in the hydrology of a site may have major effects on the level of degradation – positively or negatively. This seems not to be of great concern to the underwater sites. However, it should be kept in mind that the protection installed also minimizes the water flow around the wreck as much as possible.

In the samples investigated from the submerged marine sites of BZN 3 and 15, wood colonizing fungi was present throughout,

113 Manders 2005 (1).
114 Manders 2005 (2).
115 Manders 2005 (2).
116 Gelbrich et al. 2005, 81.
117 Gelbrich et al. 2005, 81.
118 Klaassen (ed.) 2005.
119 See also Chapter 3.
120 See also Chapter 3.
121 See also Björdal et al. 1999.
122 Huisman & Klaassen 2005, Klaassen 2005 and Klaassen 2008.

but no traces of the severely degrading soft rot was found.[123] However, two other shipwrecks from Almere in the Flevopolders in the Netherlands (reclaimed land), also sampled within the BACPOLES project, did have soft rot. It is unclear whether this was already present while the ships were still in use or whether the wood was affected when the polder was reclaimed. It is well known that soft rot occurs in ships even when they are still in use.[124] If present, fungi in wood removed from the seabed may become active again when it comes into contact with oxygen, thus destroying the wood rapidly.[125]

A study of degradation patterns confirmed that the wood from the BZN 3, BZN 15 and also the two wrecks in the Flevopolders contained substantial amounts of pyrite (FeS_2).[126] This can cause severe degradation of the wood.[127]

6.8 Structuring the monitoring of a site

As we have seen, there are many methods, tools or instruments that can help us to determine the condition of a site, either as part of a baseline study or subsequent monitoring. All of these aid management of changes in the environment, the wreck or even the material the site consists of. They are, however, of no value if we do not work systematically. Above all, monitoring concerns the systematic follow up and comparison of observations and measurements. New developments in technology, such as the introduction of multibeam sonar, can help us to detail our observation grid, but the comparison of results also relies on data collected previously. With coring, OSL, seismic research and research using historical maps, we can go back in time to reconstruct developments. A baseline study, however, needs to be more thorough and systematically executed, not only on one, but on all sites. A protocol with premises and operational principles to standardize the process for this is indispensable.

The same can be said concerning subsequent regular monitoring on site. Although many sites have been assessed over the years in the Netherlands, and the Wadden Sea in particular, baseline data has only been systematically collected during EU projects and thus not taken up as an inclusive task during the cultural heritage significance assessments.[128] A management plan that was developed within the MoSS project could serve as a standard for these baseline studies, in combination with the actual significance assessment and subsequent monitoring.[129]

MONITORING PROTOCOL FOR UNDERWATER SITES (as executed in the Netherlands)
ADMINISTRATIVE
DATE: date of monitoring
TIME: time of monitoring
PLACE: place of monitoring: Name of area, toponym of site, geographical position
TRANSPORT: way of transport: name of ship executing the work
DIVERS: names of divers executing monitoring
DIVE MINUTES: total time spent underwater

WHEATER CIRCUMSTANCES
TEMPERATURE: outside temperature
WIND: wind on location and direction
CLOUDS: yes or no
RAIN: yes or no

DIVE CIRCUMSTANCES
TEMPERATURE WATER: temperature of the water on surface and on the seabed
VISABILITY: visibility under water
CURRENT: details on velocity and direction
TIDAL MOVEMENTS: yes or no and at what stage
DEPTH: depth of working, of shipwreck

SONAR
DATE: when executed
NUMBER: following number
DETAILS: what kind of sonar, technical details (like resolution), coverage of the area

DEGRADATION PROCESSES
PH WATER: parameter pH
TEMPERATURE WATER: parameter temperature in Celsius
SEDIMENT MOVEMENTS: description
GROWTH ON WRECK: organic growth of organisms, yes or no and what kind
TEREDO NAVALIS: yes or no, life or death and how much
OTHER BORING SPECIES: gribble, etc.
BACTERIOLOGICAL DEGRADATION: Any present and how observed?
SPEED/FORCE OF CURRENT: parameter velocity in m/s
SALINITY: parameter salinity in ppm and how measured
WATERTRANSPORT: parameter turbidity: amount of sediment dissolved in water.
FYSICAL DEGRADATION BY HUMAN SOCIETY: looting? Fishing? Etc.
GENERAL QUALITY OF WOOD: Visual observations
DIFFERENCES IN WEB: differences in new and old measurements. Initially for triangulation measurements of the site, Web-it was used. Nowadays other systems like Site Recorder are more often used.[1]
GENERAL QUALITY OF THE WRECK: in comparison to earlier monitoring.

NEW ARCHAEOLOGICAL INFORMATION:
FINDS: which finds have been taken from the wreck and what are the results.
SAMPLES: which samples have been taken from the wreck and what are the results.
PROTECTION: what has been done in order to protect further degradation.
FUTURE PROTECTION: What has to be done in order to protect further degradation.
DOCUMENTATION: yes or no, how and where to find the information.
WRITTEN BY:

Fig. 6.24 A monitoring plan, as developed for monitoring actions at the Cultural Heritage Agency of the Netherlands (RCE). Figure: M. Manders.

Although implemented for the management of Dutch shipwrecks outside of the Netherlands, it has not, however, been standardized for the management of underwater archaeological sites in the Netherlands itself.[130]

A brief monitoring guideline was developed and applied within the MoSS and the BACPOLES projects.[131] The parameters on which to collect data were based on the deterioration of wood in the marine environment, but most of the guideline is straightforward and contains important points to consider for general monitoring.

Monitoring protocols have been developed for terrestrial sites in the Netherlands as well.[132] However, there is still no widely accepted protocol on how to monitor underwater archaeological sites, either nationally or internationally. There are also no rules about what constitutes best practice in monitoring. We are actually still seeking acknowledgement of the fact that monitoring is an important part of cultural heritage management. The guideline, presented above (Fig. 6.24), was developed within subsequent European projects and used for the wrecks on the Burgzand.[133] Efforts are being made to include the monitoring of underwater sites as well. At the time of writing, there is discus-

[123] For soft rot attack, oxygen is needed. See also Daniel & Nilsson 1998.
[124] See, for example, Sylvester 1976, Tromp 1835.
[125] For more on bacterial, fungi and Teredo deterioration, see Chapter 3. See also http://inspectapedia.com/mold/Activity_of_Mold.php (accessed 31-01-2017).
[126] Klaassen (ed.) 2005.
[127] See Chapter 3.
[128] Baseline data for degradation research was collected on the above-mentioned MoSS, BACPOLES, MACHU, WreckProtect and SASMAP projects.
[129] See Manders 2004 (3) and Manders 2012 (3).
[130] It is not a requirement to use the Management Plan for sites within Dutch territory. The manner of reporting is laid out in the Dutch Archaeology Quality Standard (KNA: www.sikb.nl). For management of Dutch-owned shipwrecks overseas (WIC, VOC, Admiralty and Navy ships), the Maritime Programme of the RCE uses the Management Plans http://www.maritiemprogramma.nl/magazine/print/MP_eng_01_print_version_utrecht.pdf (accessed 31-01-2017).
[131] See Section 3.1.
[132] Smit et al. 2006, Os et al. 2012.
[133] These were the MoSS, BACPOLES and MACHU projects. See also Chapter 3.

sion about whether this should be an overarching protocol for both terrestrial and underwater sites or whether these protocols should be distinct.

As the environmental parameters and threats differ so much, the question of whether an effort should be made to standardize the archaeological monitoring protocol for both land and water or whether they should be kept separate must be considered. The way a site needs to be monitored depends on the forms of mitigation against significant and potentially large threats, but also on how we have protected the site (what kind of method and against what kind of threat) and the reason why – in the first place – a site has been protected. All the above may differ for underwater and terrestrial sites.

Not many countries have a monitoring programme in place. English Heritage contracts a diving unit to monitor all the designated wreck sites.[134] Although most countries – including the Netherlands – have a budget for underwater cultural heritage management, no structural funds have been allocated for active in situ protection or monitoring.[135] This seems, in fact, to be contradictory to the primary aim to preserve 'archaeological' sites in situ. By explicitly selecting sites to be preserved in situ, governments are implicitly suggesting that it is worth doing so. The consequences of these decisions, however, are clearly not being considered if there are no budgets for protection and monitoring.

A large problem for in situ preservation, conservation and monitoring may lie in the perception of it. Systematically following the process of protection and monitoring will show that in situ preservation is not such a cheap option after all. This is especially the case if increasing numbers of sites are to be preserved and physically protected in situ. Only by acknowledging this can solutions be found to control budgets. Cooperation between stakeholders might be one of these solutions, but strong selection and deselection procedures are also required.[136]

The introduction of new techniques in monitoring will not only make the data collected better and the observation grids finer, they may also be more cost effective.[137] When we look specifically at the costs of monitoring, the introduction of the multibeam echo sounder is a huge cost saver, due to the fact that divers are not required. Agreements with survey companies and between ministries can make the process of recording even more effective and, thus, also cheaper.[138] Multibeam data is collected for all sorts of reasons but can also be used in cultural heritage management.

In the Netherlands, including the Western Wadden Sea, baseline studies have mainly been conducted within large-scale European projects. The character of such projects is experimentation and finding the best solutions. This, by definition, makes the research relatively expensive. However, integrated, good-quality baseline studies can be executed in a more cost-effective way. Information about environmental parameters can be obtained from other oceanographic institutes, from large-scale preliminary studies, such as the Historical Geomorphological Map Sets, as described in Chapter 2, or from former baseline studies carried out in proximity. It is, therefore, not always necessary to include data loggers, or the introduction of and research on sacrificial or sampling in general. All these require a lot of labour and large (long-term) budgets.

Basic environmental information can allow us to identify the greatest threats to cultural heritage, on the basis of which a risk inventory can be made and efforts to mitigate against these threats can be undertaken. Dunkley (2008) describes the same kind of procedure for the above-mentioned designated wreck sites.[139] This kind of system, including a risk decision tree, could be developed and implemented for the wrecks in the Wadden Sea and for underwater archaeological management in the Netherlands overall.

This all depends on the threats that are dominant, the environment, budgets and the significance of the site when choosing the methodology and techniques for monitoring the site.[140] A

[134] The English Dive Contract is currently with Wessex Archaeology.

[135] However, for a few years, money from the BRIM fund has been made available for monitoring of national monument sites, including archaeological sites.

[136] With cooperation, costs may be shared, strong and clear selection may not only keep the number of sites down, but also may avoid the suggestion that archaeologists always want to preserve everything. Lennon & Foley 2006, 34.

[137] See, for example, the huge benefits of Computer Cision Photogrammetry: https://maritiemprogramma.wordpress.com/tag/computer-vision-photogrammetry/ (accessed 31-01-2017).

[138] MP: The Maritime Programme of the RCE has made agreements with survey companies to make such recordings of pinpointed wrecks for a fixed price. This price is much lower than usual multibeam recording assignments due to the fact that the companies can decide themselves when to record the wreck and, therefore, can schedule the work during low season and when passing the site on their way to or from other jobs.

[139] Dunkley 2008.

[140] See also Chapter 3.

rough estimation of costs for different monitoring actions is listed below.

Monitoring BZN 10, 2009[141]	
METHOD	**COST/DAY in €**
Monitoring by diving	6,200
Ship rental with sonar/multibeam (no personnel costs included)	3,000
Ship rental with ROV facilities (no personnel costs included)	15,000-20,000[142]

Table 6.2. Costs of monitoring BZN 10.

UCH management comprises all the steps needed to preserve or investigate underwater archaeological sites 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. Here, in particular, lies a threat: the 'maintenance' of UCH involves a lot of time, people and money. This is the 'downside' of extensive inventories and a preference for preserving sites in situ. The more sites we know about, the more sites will be marked as being of national or even international importance. The more sites that are preserved in situ, the more time and money will 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.

6.9 Conclusion

If in situ preservation is taken seriously, then preserving and protecting sites in situ means taking full responsibility for them. Applying protection methods should lead to longer and better preservation. Having taken the measures on site, this needs to be followed by monitoring of the effects. Has there been any change? Is the protection doing its job? Is further action needed? The monitoring of sites can be standardized with forms or protocols. Some parameters should be measured on all sites to allow comparison. Other parameters, however, may only have to be investigated once and can be used for a larger area.

The introduction of new techniques has led to more accurate data collection and the opportunity to answer new scientific questions in archaeology and cultural heritage management. The multibeam echo sounder provides a tool for better monitoring of the seabed, 3D sub-bottom profiling gives us a better understanding of what is happening in the seabed, and OSL, grain size and anthropogenic metal analyses can be used to investigate the history of sedimentation and accretion on site. Due to specific and detailed research undertaken in various European projects, data has been collected with data loggers and laboratory research on archaeological material has been undertaken, which can be regarded as baseline data for all the wrecks in the Western Wadden Sea area.

Taking the responsibility to monitor the sites that have been preserved in situ is not yet common practice. There are no budgets to do so. As more sites are selected for in situ preservation – the basis of our current archaeological system – this will eventually lead to more sites needing to be taken care of and hence higher costs for management. This will also be repetitive and thus the costs cumulative.

Monitoring is executed over a longer period of time, keeping in mind the circumstances, the natural conditions of the site, the reason why a site was chosen for in situ protection, the method of protection and a time frame for future actions. With the decentralization of cultural heritage management, provinces and municipalities in particular have become directly responsible for the management of underwater cultural heritage. In relation to the Western Wadden Sea area investigated here, the Municipality of Texel will have to take up responsibility for the largest area, but others will also need to introduce the management of this often invisible cultural heritage resource into their policy.

The national government will also have to take up its role in the management of the proclaimed National Monuments. At the moment, there are only seven underwater sites.[143] This is not a particularly representative collection of our maritime past. The in situ preservation, protection and monitoring of 50 to 100 sites (from the 60,000 locations we have in our databases) would form a workable core to establish these 'stepping stones'.[144] However, it is still unclear who will pay the bill for their management, which consists of a significance assessment, preservation and protection, ongoing monitoring and maintenance. But if we go this direction we should also start thinking about how to use these as national icons and archaeological windows to a common past.

[141] Information from RCE, the Netherlands, see also Manders (ed.) 2011.

[142] The costs of ROVs have dropped dramatically in recent years. However, cheap instruments, such as the RB Micro-50 (approx. €2,000) http://www.cheaprov.com/, accessed 30-1-2017), or the ROV-in-a-Box Project Kit (approx. €250) http://www.nventivity.com/roviab.html, accessed 31-01-2017) are not suitable for the Wadden Sea environment.

[143] At the end of 2016, the *Aanloop Molengat* wreck was made the seventh National Heritage Site under water. http://www.monumentaal.com/scheepswrak-aanloop-molengat-eerste-rijksmonument-noordzee/ (accessed 31-01-2017).

[144] Manders 2015 (2).

7. Making underwater cultural heritage accessible to the public

Fig. 7.1 Diver on a shipwreck in the Oostvoornsemeer. Photo: Cor Kuyvenhoven.

7. Making underwater cultural heritage accessible to the public

7.1 Introduction

While there are many reasons to aim for preservation in situ, there may be also downsides to this.[0] As some threats may not be easily mitigated, which may compromise the significance of the site in the long run, costs for preservation may rise to unmanageable heights while little new knowledge about our past is collected. This may result in the decision to excavate a site. In addition, the use of certain protection methods may mean that the richness of underwater cultural resources becomes less visible to the general public. This may not encourage their interest or desire to engage. Is there a way to avoid this? Is it possible to preserve in situ and still address the public interest? Awareness raising and stimulating public engagement is important in the protection and management of the underwater cultural heritage. Athough there may be many ways to organize this through different channels I would like to mainly focus in this chapter on the role museums can play in this.[1]

It has to be noted that not all wrecks undergo physical protection. As we have seen, some natural environments – such as in the Baltic Sea – are very stable and large-scale physical protection seems unnecessary.[2] Some other environments, such as the highly dynamic, shallow Wadden Sea in the Netherlands and the Goodwin Sands in the UK, can be both protective of and hostile to underwater archaeological sites due to the dynamics of the environment.[3] In these areas, much effort has to be made to physically stabilize a site.

However, it is always a matter of balancing the costs, the effects of protective measures, and the importance of the site. Cultural heritage sites are assessed on their archaeological, historical or aesthetic value.[4] The prioritizing of sites may be pragmatic: not all sites can be actively protected and managed, simply because of insufficient money, time and human resources. When a wreck site does not seem worth protecting – physically or legally – a choice must be made to excavate it or leave it unattended.[5]

The prioritization of sites is to a certain extent always subjective. Therefore, a measure of intersubjectivity may be ensured through the establishment of a decision-support system using management plans, monitoring protocols and research agendas.[6] In this way, decisions can always be tracked and the process monitored.

Sometimes it is not possible to protect a site appropriately over a long period due to a lack of scientific or technical knowledge. Large twentieth-century iron shipwrecks are an example of this. What can be done to protect a 150 metre long iron hull protruding at least 10 metres from the seabed in a highly dynamic area?[7]

Furthermore, since sites have different values it is possible that those left untouched from a heritage management point of view may still be of interest to other stakeholders. Sports divers may like the aesthetics of a site and perhaps even the educational

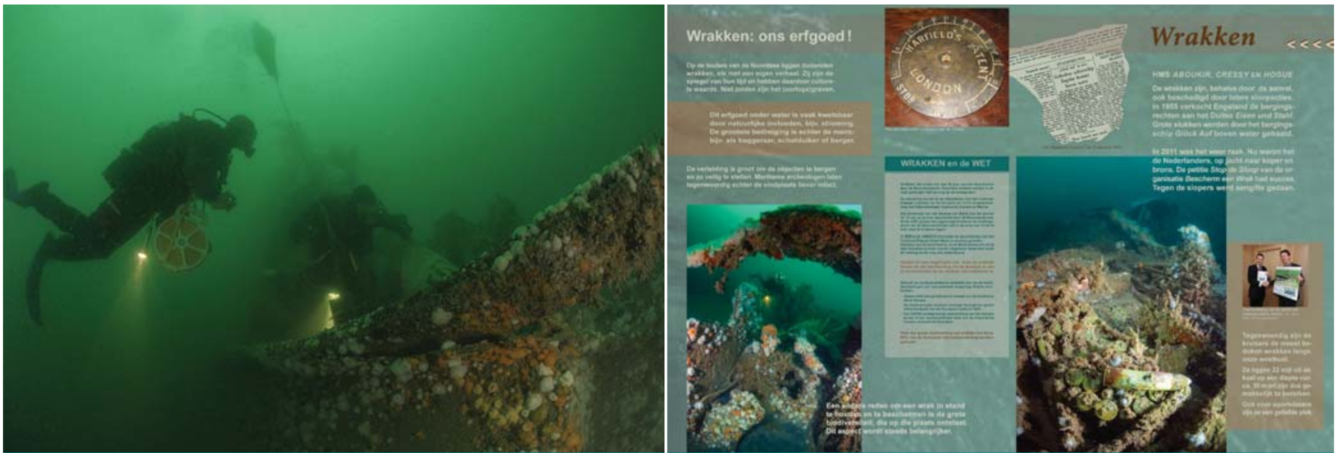

Fig. 7.2 (A) Diving on the three WW1 British cruisers, the Aboukir, Cressy and Hogue in the North Sea. Photo: Cor Kuyvenhoven, (B) The three wrecks are also hotspots for biodiversity and, due to their popularity for sports diving, there is a lot of public involvement in their protection against looting and demolition for scrap metal. Figure: Foundation Duik de Noordzee Schoon.

[0] See Chapter 4.

[1] The media can be an important partner for awareness raising as well .

[2] See Chapter 3 and 5.5.

[3] See Chapter 1 on the dynamics of the Wadden Sea.

[4] Manders, Tilburg & Staniforth 2012.

[5] This should be one of the choices within a selection procedure. The selection procedure may be positive (something must be preserved in situ or ex situ) or negative (the area or site is released from further investigation). See also Dutch Quality Standards at www.sikb.nl (accessed 31-01-2017).

[6] Pater & Manders 2009. In the Dutch Quality Standards, a score can be added to determine the significance of a site. This could be used as a decision-support system. However, due to the fact that assessments are made by many different institutes and individuals, it may be difficult to come up with a solid comparable scoring system.

[7] See, for example, Chapter 5 on the use of anodes, and for a discussion of the preservation of well-preserved shipwrecks.

Fig. 7.3 The Vasa Museum is the most visited museum in the whole of Scandinavia. Photo: Anneli Karlsson, the Swedish National Maritime Museums.

value. The worth of a site may also lie in its memorial value. The choice can be made to allow these other values to prevail and take measures accordingly. Thus, a wreck site may not be covered but kept visible for visiting divers (Fig. 7.2 A + B). There may be all sorts of ways to reach out to other stakeholders while leaving wrecks in situ. Leaving sites uncared for and deselecting them from a cultural heritage perspective is a passive approach. Actively, we can mitigate and attempt to find middle ground: protecting parts of a wreck or specific historical and archaeological values, while keeping in mind the other (often non-scientific) values that stakeholders associate with the wreck site.

Participation in the process of underwater cultural heritage management by other stakeholders, such as sports divers, municipalities and other governmental agencies, may also be a way forward that balances the different values, and creates awareness and acceptance of in situ policy.[8] This may eventually lead to the opening up of underwater sites for other groups, joint cooperation between different stakeholders to preserve sites in situ and the development of underwater museums or heritage trails.

In this chapter, we will discuss the relationship between museums and underwater cultural heritage, especially those sites that are preserved in situ. Section 7.2 introduces the museums and sites and the role of awareness-raising in the field of cultural heritage management. In Section 7.3, the various ways of bringing people to an archaeological site will be discussed, while in Section 7.4 several ways to bring in situ preserved sites to the public will be presented and discussed.

7.2 Museums and sites preserved in situ

In general, the preference for keeping archaeological sites on the seabed instead of excavating has consequences for the way traditional museums deal with underwater archaeological resources. Museums are key to informing and raising awareness among the general public. Their importance is related not only to the richness and exceptional conditions in which they present our underwater cultural heritage, but more specifically to the stories behind and beyond the objects. Examples of this range from a dress found in the BZN 17 wreck to entire Dutch warships that are rapidly disappearing in the Java Sea. Here we are dealing with completely different sites: one is a seventeenth-century wooden ship filled with exceptionally well-preserved items, while the other consists of three steel wrecks that have almost completely disappeared from the seabed.[9] To tell their stories and to bring them to life for the public, archaeologists traditionally depend extensively on museums. This relationship benefits both sides: creating awareness is the best way to ensure the protection of underwater cultural heritage, while the people reached may also become regular museum visitors.

Museums such as the *Mary Rose* in Portsmouth (UK) and the Vasa in Stockholm (Sweden) have been highly successful in spreading awareness among the public.[10] The Vasa is, with at least 750,000 visitors annually, the most visited museum in Scandinavia (Fig. 7.3).[11] These museums are, however, built on material and information gathered during excavations. The archaeological excavations have provided context to the objects, and the ships and their contents are preserved ex situ.

How can we accomplish this when the objects in question remain under water and are difficult to access? The answer lies in bringing either the visitor physically to the site or the site virtually to the visitor: in other words, taking the museum out of the building.

[8] See also Manders 2015 (1) & Manders (2).

[9] https://www.theguardian.com/world/2016/apr/21/400-year-old-dress-found-in-shipwreck-sheds-light-on-plot-to-pawn-crown-jewels (accessed 19-03-2017), and https://www.maritime-heritage.com/content/first-results-dutch-indonesian-investigation-java-sea-released (accessed 19-03-2017).

[10] The Tudor ship, the *Mary Rose*, sank in the Solent near Portsmouth in 1545, was excavated in the early 1980s, and then removed from the seabed in 1982. Sixty million spectators worldwide watched this event on television. Since then, the vessel has moved to the Naval Dockyards in Portsmouth, where 4 million people have visited the ship's hull (presently undergoing conservation) and its artefacts, which are on display in the adjoining museum. See http://www.maryrose.org (accessed 31-01-2017). The Swedish flagship Vasa sank near Stockholm on its maiden voyage in 1628 and was brought to the surface in 1961. In 1962, a temporary museum was constructed for the ship and its artefacts. A permanent museum was inaugurated in 1992. See http://www.vasamuseet.se (accessed 31-01-2017).

[11] The UNESCO Convention on the Protection of the Underwater Cultural Heritage (Information Kit on the Promotion of the Convention), Paris, 8. In 2013, the museum had over 1,000,000 visitors (http://www.vasamuseet.se/en/Press/Vasa-in-brief/Who-visits-Vasa/ accessed 15-5-2014).

[12] The NOB (Nederlandse Onderwatersport Bond) is the Netherlands' largest sports diving community, with 20,000 members. It is estimated that there are approximately 1.2 million (± 15 percent) sports divers active in the United States. See http://www.undercurrent.org (accessed 31-01-2017).

Fig. 7.4 Amateur archaeologists of LWAOW preparing for a dive on one of the wrecks in the Oostvoornsemeer. Photo: M. Manders.

7.3 Bringing visitors to the site

The first thing that comes to mind when thinking about bringing visitors to a site is that this may involve diving – and indeed, a large part of the visiting public comes from the diving community. However, the amateur diving community is not merely a large group; it is also an important stakeholder in the management and protection of underwater cultural heritage.[12] In many countries, they comprise the primary source for new discoveries and function as the 'eyes and ears' of professional archaeologists and policymakers in underwater cultural heritage.[13] It is, therefore, important to enlist them as allies in site management: turning them from stakeholders into shareholders. In fact, in many countries, including the Netherlands, underwater archaeology began as a result of amateur divers' interest in marine history. One such worldwide operational maritime archaeology community, comprising both amateur and professional archaeologists, is the Nautical Archaeological Society (NAS), but there are many other local, national and even international groups of amateur divers operating, such as Deguwa (Germany), and LWAOW and STIMON (both from the Netherlands) (Fig. 7.4).[14]

Restrictions in access to underwater sites, as a result of either legal or physical protection, form a serious threat to the involvement of this group. Therefore, denying access to one site could be compensated by enhancing accessibility to other sites and areas. This notion is growing, as is the number of new initiatives to create greater access to underwater archaeological sites.[15] For example, in the last few decades, underwater parks, heritage trails, site and area specific activities, and underwater museums have been created.[16]

An underwater park is an area with some sort of legal status and protection. This may be created (and is often the case) because of the outstanding natural values, but it may also include or even exclusively be established for, cultural heritage protection. Underwater parks and reserves have been in use for quite some time, with new additions being considered in many parts of the world. Examples involving cultural heritage values include the Baltic Blue Parks, Caesarea in Israel, Wardang Island in South Australia, the Florida Keys National Marine Sanctuary and Emerald Bay State Underwater Park, California, in the US. There has also been an increase in individual sites being opened to the public.[17]

Underwater heritage trails are discovery routes encouraging the exploration of areas with outstanding heritage.[18] The development of underwater heritage trails and the creation of access to individual sites is potentially a multi-million dollar business, particularly considering the number of active sports divers in the world and the impact that the protection of natural and cultural resources may have on national tourism. This has not yet been explored to its full extent.[19]

[13] In 2015, the RCE initiated research on the activities, role and perceptions of sports divers and amateur archaeologists in relation to cultural heritage management. This resulted in a publication (Bouman 2015), a symposium (http://nl.magazine.maritiemprogramma.nl/eMagazine-MP05-NL/#!/inzet-van-vrijwilligers-in-de-onderwaterarcheologiehttp://nl.magazine.maritiemprogramma.nl/eMagazine-MP05-NL/#!/inzet-van-vrijwilligers-in-de-onderwaterarcheologie, accessed 31-01-2017), and initiatives such as the pilot for cooperation within the framework of the law (http://nl.magazine.maritiemprogramma.nl/eMagazine-MP05-NL/#!/pilot-van-start-voor-behoud-archeologisch-erfgoed-texelse-zeebodem, accessed 31-01-2017).

[14] For the NAS, see: https://www.nauticalarchaeologysociety.org/ (accessed 31-01-2017). DEGUWA stands for Deutsche Gesellschaft zur Förderung der Unterwasserarchäologie e.V. The two Dutch amateur archaeologist groups are Stichting Maritiem Onderzoek (STIMON) and Landelijke Werkgroep Archeologie Onderwater (LWAOW).

[15] See, for example, the initiatives to develop an underwater park in the Oostvoornsemeer (see: http://www.cultureelerfgoed.nl/nieuws/archeologen-duiken-in-het-oostvoornse-meer, accessed 31-01-2017). and the immersion of VAL 7 at another location to be used as a diving spot for sports divers (http://m.iamsterdam.com/explore_locations/view/277 (accessed 16-12-2015), see also http://www.machuproject.eu/WIS-viewer.htm for more on the VAL 7 site (accessed 31-01-2017).

[16] See, for example, the special edition of the UNESCO Courier on Submerged Memory, from 2009 (http://unesdoc.unesco.org/images/0018/001865/186515e.pdf, (accessed 31-01-2017), Lomdahl n.y. and the latest efforts in Kenya: http://www.nation.co.ke/news/Kenya-to-build-regions-first-undersea-museum/-/1056/2998052/-/4lcql7/-/index.html (accessed 31-01-2017).

[17] Individual sites made effectively accessible to the public as underwater museums include the eighteenth-century French flagship Océan in Portugal, the eighteenth-century Swedish warship Kronprins Gustav Adolf in Finland and the Baiheliang in China. See also http://www.unesco.org/new/en/culture/themes/underwater-cultural-heritage/about-the-heritage/underwater-museums (accessed 31-01-2017). Some other sites that have been opened to the public are the Portuguese warship Santo Antonio (1697) in Fort Jesus, Kenya, Underwater Museum, the Blue Parks in the Baltic Sea, the Underwater Shipwreck Discovery Trail, developed by the Victoria Archaeological Survey in Australia and the Fathom Five National Marine Park in Canada.

[18] A heritage trail is a defined route which points to significant heritage aspects that a community wishes to highlight and present to locals and visitors (http://www.heritage.tas.gov.au/media/pdf/trails.pdf, accessed 31-01-2017).

[19] One initiative in the field of dive tourism in relation to cultural heritage is the seaway trail, which enables diving around the Great Lakes of the United States. See http://www.seawaytrail.com (accessed 31-01-2017).

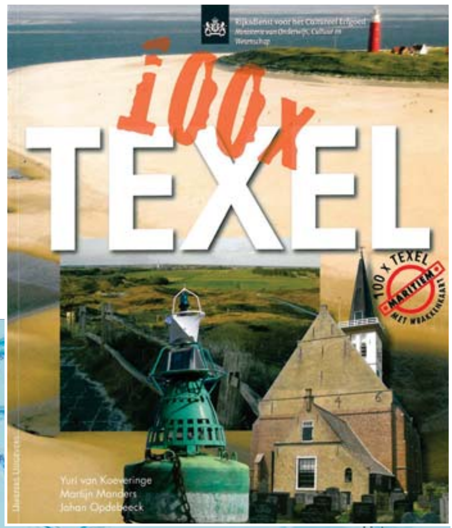

Fig. 7.5 The shipwrecks in the Western Wadden Sea are also interesting objects that could be presented to a larger public in book form accompanied by a map that can be taken along when biking on the island or sailing on the Burgzand. Figure: courtesy Uniepers Uitgevers/RCE.

Underwater trails or site visits can be educational and perhaps they also should be. Visitors should have the feeling they have got something out of the experience: perhaps not by collecting the objects, but at least from hearing the stories. The desire for such experiences can be supported. Individual sites may function as specific windows to the past. Often underwater site visits are focused on the site itself and not the larger area or the moment in time it was active. This differs from heritage trails, with such maritime trails on shore often telling a larger story.[20] The individual sites open to the public may not be those that are the most archaeologically valuable in the area, as these may be physically covered and closed to the public. Therefore, the publicly accessible sites may, by default, become the places about which stories are recounted, stories of particular ships within the wider context and the physically tangible evidence of the past. In other words, perhaps in some cases it may be more enjoyable and more of an experience to be able to touch the past than to only be able to look or read about it.

The initiatives to visualize underwater areas, such as the development of the Historical Geomorphological Map Set for the Wadden Sea, may provide a good basis for associating individual sites with the larger geographical area and to visualize this for a larger stakeholder group.[21] A trail can thus also be set up in a larger area. It may even comprise underwater and terrestrial sites. We might think of a trail of the Dutch Golden Era in the Wadden Sea, for example. The visibility is not exceptionally good in the Wadden Sea, but this can be compensated for well-preserved wrecks with an interesting story and all recognized stepping stones in this significant period of Dutch maritime history. The trail might focus on attracting experienced divers from across the world with an interest in maritime history. It could thus be marketed as a challenge.[22] Out of the water, the experience could continue on land, with a maritime trail on the island of Texel (Fig. 7.5).[23]

[20] See, for example, the maritime trails on the Cayman Islands (Leshikar – Denton, 2006) or the maritime promotion of South Africa on the web (http://www.southafrica.net/za/nl/articles/entry/article-southafrica.net-shipwrecks-off-south-africas-coast, accessed 31-01-2017).

[21] See Chapter 7.

[22] This enthusiasm was felt by a group of experienced divers from the Nautical Archaeological Society in the UK when, in 2007, they visited an in situ preserved wreck – the BZN 10 in the Wadden Sea.

[23] See, for example, Koeveringe et al. 2011.

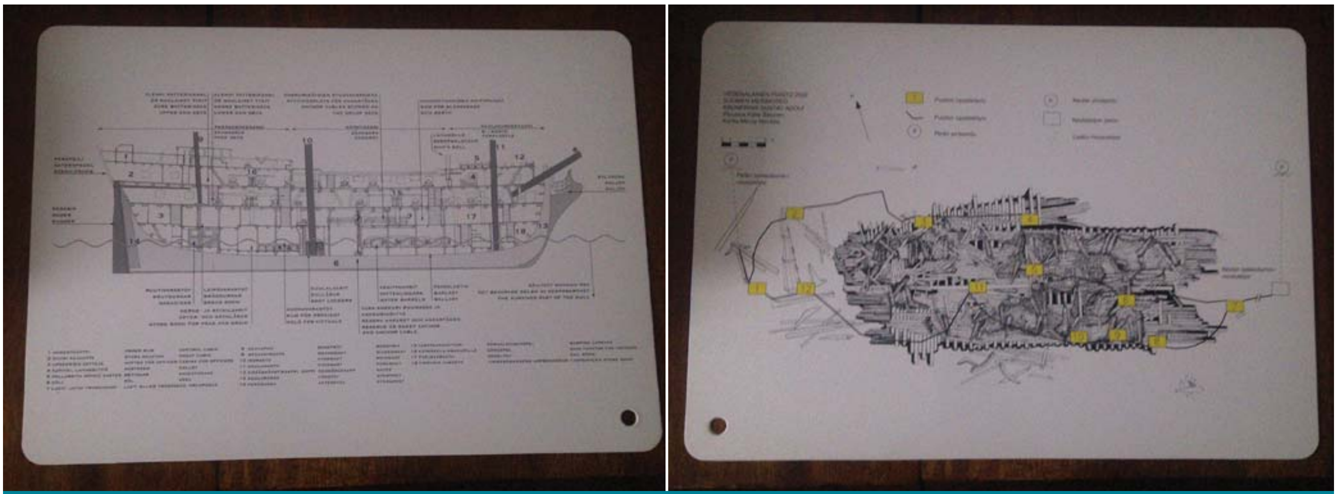

Fig. 7.6 A water resistant site map to bring to the site of the wreck of the Kronprins Gustav Adolf (1788) in Finland. . Site map, courtesy National Board of Antiquities, Finland. Photo: M. Manders.

Diving is an experience; diving around a shipwreck still lying where the disaster happened is a multi-level experience. It is interesting to consider all the possibilities these educational trails can offer. With the development of new visual and aural techniques and aids, trails can be vividly brought to life. For example, diving-helmet mounted displays are now being developed with visual projections on the interior of the glass.[24] The potential for underwater heritage is remarkable: imagine being able to witness historical reconstructions or the excavations virtually in progress while the actual shipwreck lies before you on the seabed.[25] This may be especially important in areas with poorer visibility, such as the Western Wadden Sea. Tests with underwater Wi-Fi and internet[26] are challenging us to explore even wilder dreams, such as diving with live feeds, putting your information on Facebook, provoking discussion while still on site, or asking others to identify objects or offer suggestions about what to do. A site plan and the position of the diver, even in bad visibility can also be obtained.[27] Although fully functioning underwater internet is not yet available, new developments with iPads and mobile phones that can be taken underwater[28] equipped with image recognition and augmented reality that are connected to beacons are already coming very close.[29]

Until development of such multimedia techniques has advanced sufficiently for large-scale use, we will continue to make information for divers available on the regular internet and in books, and on information columns on the seabed, plastic signage panels or water-resistant booklets (Fig. 7.6).[30]

Non-divers can also participate by visiting shallow sites in clear water while snorkelling, or taking guided tours in glass-bottom boats.[31] This, however, is not really an option in the Western Wadden Sea due to poor visibility and the depth of the wrecks. However, the public can still learn about underwater cultural heritage while sailing in the area or travelling near the coast, for example by using GPS route plans and mobile phone apps which can supply information on nearby shipwrecks or other underwater archaeological sites in the vicinity.[32] This method of transmitting information is already in use for land sites and can easily be deployed for sites under water.[33] As suggested above, maritime

[24] This technique was first employed for fighter pilots. Projection inside dive helmets is used by the Dutch navy to project side scan sonar pictures (high-frequency sound wave pictures from the seabed) to help the diver find his or her way in low-to-zero visibility water. The same technology is also used in 3D video gaming with the use of glasses. See, for example, http://www.geek.com/chips/f-35-helmet-uses-retinal-projection-to-give-pilots-a-gods-eye-view-1616488/ (accessed 31-01-2017). and http://www.soundmetrics.com/Industries-Served/Military/Search-Recovery (accessed 31-01-2017).

[25] This is currently being tested by the NHL University of Applied Sciences in Leeuwarden in cooperation with the RCE for an exhibition of the seventeenth-century shipwreck *de Melkmeid* in IJsland. A 3D image of the wreck underwater has been created, in which visitors may move around. In addition, augmented reality images of what it should look like may be laid over the 3D animation. The tests are still in their early stages.

[26] See, for example, http://www.ibtimes.com/deep-sea-internet-researchers-successfully-test-underwater-wi-fi-network-lake-erie-1429310 (accessed 31-01-2017).

[27] http://www.buffalo.edu/news/releases/2013/10/030.html (accessed 31-01-2017). or http://www.ece.neu.edu/wineslab/papers/Yifan_WUWNet2013.pdf (accessed 31-01-2017).

[28] http://www.myultraproof.com/underwater-use/ (accessed 31-01-2017).

[29] See, for example, http://www.reefid.org/ (accessed 17-12-2015) and https://itunes.apple.com/mw/app/red-sea-reef/id954730175?mt=8 (accessed 31-01-2017).

[30] See, for example, the signage being produced for the *Gustav Adolf* wreck in Finland.

[31] An example of this can be seen on: http://www.visitgeorgianbay.com/lighthouse-marine.cfm?action=1&things_to_doid=3&category=6 (accessed 31-01-2017).

[32] For the Western Wadden Sea, the basic work (data collection and writing of background information) for such applications has already been done. See, for example, Koeveringe et al. 2011.

[33] GPS positioning for archaeological sites is available for cities such as Split and Nice (among many others). There is a GPS heritage trail in the Archaeology Park of Malange in Belgium. See also http://www.archeopass.be (accessed on 31-01-2017). Archaeological sites can already be marked on route with TomTom (https://mydrive.tomtom.com/en_gb/, accessed 31-01-2017), but may easily be added on water navigation maps, including some background information on the sites for visiting tourists, whether in a boat on the surface or under water.

trails can also be set out on land, overlooking the sea, with information about the wrecks on panels, maps or booklets.[34]

7.4 Bringing the site to the people

Traditionally, maritime heritage has been brought to the public through artefacts recovered from the seabed and displayed in museums. Ideally, these artefacts have been recovered by archaeologists, but many museums also have artefacts in their collections retrieved through commercial salvage, dredging or souvenir hunting.[35] In these instances, the objects themselves have to tell their story out of context. Occasionally, an entire ship and its contents are displayed together, as is the case for the Vasa.[36]

In China, a further step has been taken, with an entire unexcavated ship brought into a museum setting to enable the public to experience the excitement of archaeological research and underwater excavation for themselves.[37] The new Guangdong Maritime Silk Road Museum in Yangjiang, Guangdong Province – also called the Crystal Palace – has been constructed with an enormous basin, 64 metres long, 40 metres wide and 23 metres high, for the Nan Hai 1 wreck – a 30 metre long shipwreck from the Song Dynasty (960–1279) discovered in 1987. It was raised from the seabed in December 2007 to form the centrepiece of the new museum. It is expected that within 10 years up to 80,000 objects will be excavated from the wreck and presented in the museum.[38]

The growing importance of the non-diving public to underwater cultural heritage is underlined in Alexandria, Egypt, where a museum consisting of an area above water and another underwater area with a controlled environment and better visibility is planned be constructed.[39] Artefacts that have already been removed from the seabed for research will be placed in this area and thus ensure public access. In a sense, this could be regarded as the 'Disneyfication' of underwater cultural heritage, but it does at least enable the public to experience for themselves the mystery of the underwater environment while at the same time providing funds for the management of the site.[40]

In certain cases, however, sites lack artefacts or are inaccessible due to their environment. An excavation may not have taken place at the site and it may instead be covered for protection. How can the public interest be addressed in these instances? From the point of view of a traditional museum, this might seem difficult. Museums are used to amassing objects for the purposes of display. However, in the years to come, how many shipwrecks will be excavated and how many will be preserved in situ? Due to enormous pressure for access to the seabed for aggregate extraction and offshore construction work, some archaeological sites will have to be removed by excavation.[41] When this occurs, according to the 2001 UNESCO Convention, the excavations will have to be performed according to rules of good practice.[42] These guarantee the proper treatment of artefacts and the gathering of good-quality information, ready for museum display.[43] It should also be remembered that many museums have already assembled considerable collections of archaeological material from underwater sites over extended periods of time.[44]

These artefacts may constitute a more than sufficient resource to form the basis of exhibitions and illustrate the stories that museums wish to recount. If not, there is also the possibility of borrowing artefacts from museums or central archaeological depots. These finds are often not owned by museums, but instead belong to the State, as is the case in the Netherlands.[45] In some countries, the artefacts, data and documents from archaeological research in central archaeological depots are linked to government-run museum bodies that encourage display. Important, however, is that the single or small collections

[34] See, for example, the publication *100 x Texel Maritiem* (Koeveringe et al. 2011), which also includes an all-weather map with maritime sites on land as well as under water.

[35] See, for example, the collection of Chinese porcelain from the Geldermalsen Wreck (1752) at the Groninger Museum (http://collectie.groningermuseum.nl/brief.aspx, accessed 31-01-2017).

[36] See note 1021.

[37] The wreck was raised in one block with its surrounding sediment www.whatsonxiamen.com/news19118.html (accessed on 31-01-2017).

[38] www.whatsonxiamen.com/news19118.html (accessed on 31-01-2017).

[39] http://www.dailymail.co.uk/travel/travel_news/article-3305205/Underwater-world-Incredible-98million-museum-Alexandria-planned-beneath-SEA-allowing-tourists-view-sunken-Egyptian-relics-ancient-cities.html (accessed 31-01-2017).

[40] The same kind of idea has been implemented at the Guaranguao Reef Cannons Preserve in the Dominican Republic. For more information, see http://www.unesco.org/culture/en/underwater (accessed 31-01-2017).

[41] Many European countries have ratified the Valletta Treaty (European Convention on the Protection of the Archaeological Heritage 1992). This European agreement ensures that cultural heritage is taken into account in infrastructural works under water and on land. See conventions.coe.int/Treaty/en/Treaties/Html/143.htm (accessed 31-01-2017).

[42] Which are described in the Annex of the UNESCO Convention for the Protection of the Underwater Cultural Heritage (Paris, 2001).

[43] Rule 24 of the Annex mentions the conservation of archaeological remains.

[44] The Swedish Maritime Museum alone has collected 60,000 objects, ranging from complete ships (and shipwrecks) to small objects, in just over 100 years (http://www.sjohistoriska.se/en/Collections/Objects/, accessed 31-01-2017). Het Scheepvaartmuseum (Maritime Museum in Amsterdam) has approximately 300,000 objects, according to http://www.bankgiroloterij.nl/goede-doelen/het-scheepvaart-museum.htm accessed 31-01-2017) and the national maritime depot in Lelystad has 35,000 objects (https://www.flickr.com/photos/98015679@N04/sets/72157634579575313/, accessed 31-01-2017).

[45] Dutch Monuments Act 1988, paragraph 6, Art. 51.

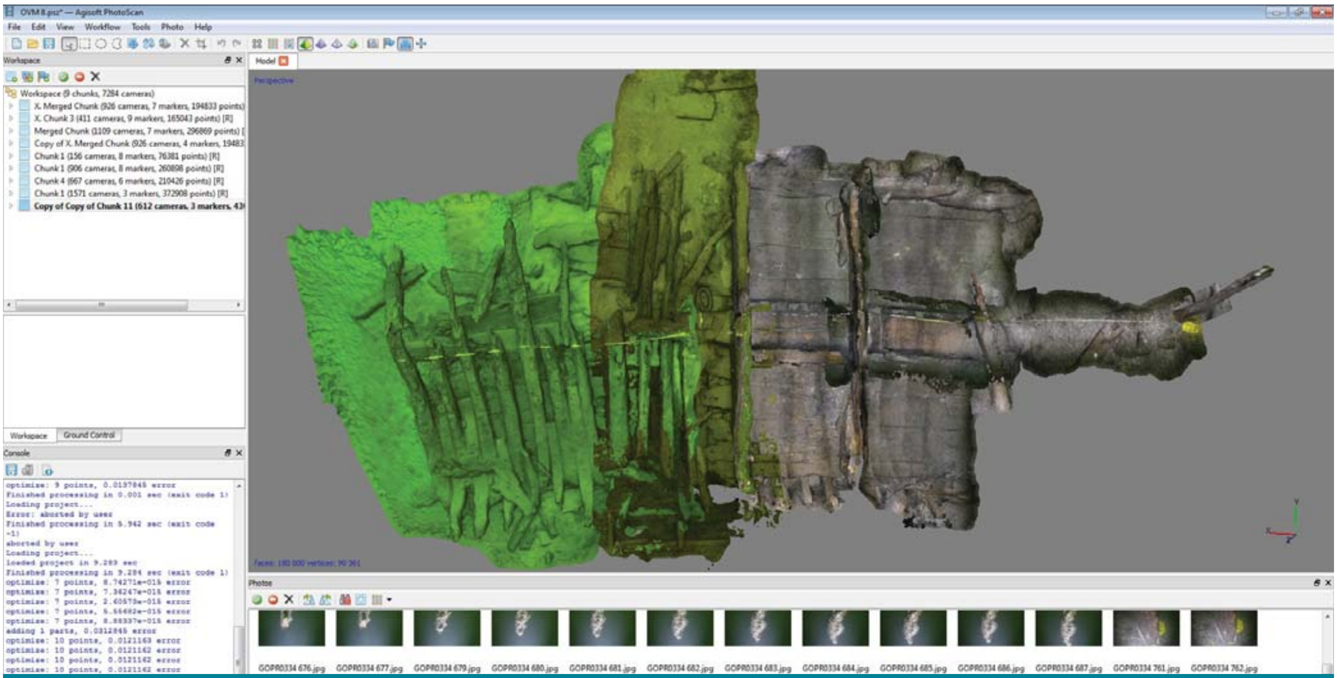

Fig. 7.7 3D photogrammetry with Agisoft. Not only interesting for scientific use, but also to bring the site closer to people who do not dive. Figure: RCE.

of objects are connected to a site or other salvaged objects, in order to create context and to form at least a virtual collection.

With new techniques and the urge to digitalize and present everything in 'open source', this is becoming a realistic option.[46] Elaborating more on the reconnecting of information and objects from one site, new digital recording methods have great advantages. As an example, 3D photogrammetry has evolved into a great tool for archaeological and cultural heritage management research, but may also prove to be extremely useful in virtually reconnecting objects already removed from a site with each other and the site itself, and to targeting those who cannot gain access to the site (Fig. 7.7).[47]

Today, the development of interactive digital supports has opened a whole new range of possibilities for transmitting information to the public. Alongside traditional displays of artefacts, it is now possible to recreate the feel of specific environments, bringing objects and sites into the building. Holographic displays and 3D projections offer tantalizing impressions,[48] even odours can be added, vividly recreating the atmosphere of specific sites (Fig. 7.8).[49] The photographic aids to digitalize shipwrecks in 3D and subsequent printing of the site in 3D also offer new opportunities. Sites can now be recorded and printed in precise scale models, to be used for exhibition and educational purposes.[50] The same can be done for individual objects.[51] Some sites have a live webcam connection to a museum or a website. Developments are rapidly taking place in this respect as well.[52]

The advent of the World Wide Web has introduced many new ways of raising awareness. Beyond the museum building, the web has become one of the information exchange forums most frequently used by scientists and others related to the field of underwater archaeology. Crowdfunding platforms even open up possibilities to become more intensely involved in archaeological projects, even professional ones, through the financial commitment.[53] The growing number of links and websites, however, often remain inaccessible to the general public. The information exchanged is often not traceable and, if so, frequently presented in a highly academic way. Sites that do consist of approachable information do not reach a broader audience, due to search

[46] See, for example, all the efforts to create digital access to cultural heritage and cultural heritage data through Europeana (http://www.europeana.eu/, accessed 31-01-2017).

[47] See, for example, the blog of the 3D recording in the Oostvoornsemeer of 10 June 2015 at https://maritiemprogramma.wordpress.com/page/3/ (accessed 31-01-2017).

[48] For an exhibition about the Hoorn, a Dutch ship lost in Patagonia, Argentina, a transparent 'floating' 3D projection lent the entire display an almost mystical atmosphere. See also http://www.zoektochtnaardehoorn.nl (accessed 31-01-2017). Fascinating and publicly appealing animation can also be made by projecting text, film and animated images near or even on archaeological objects in an exhibition, which has been done for the exhibition of one of the Mongol grenades discovered on the Takashima wreck site, and which is exhibited at the Kyushu National Museum. The NHL University of Applied Sciences has developed a 3D virtual ship from the seventeenth century (Pinas) and is now working on a 3D model of the Melkmeid shipwreck in IJsland that can be overlain with augmented reality of how the ship must have looked before it sank: https://maritiemprogramma.wordpress.com/category/pinas-project/ (accessed 28-01-2017).

[49] For the exhibition 'Emmers vol verhalen' (Buckets full of stories), odours were added to create a maritime atmosphere. See www.machuproject.eu. Manders, A. 2009.

[50] 3D photogrammetry (Agisoft) as an aid to map underwater wrecks can now be connected to 3D printing and thus physical objects can be created from sites that are left under water: http://3dprint.com/103762/shipwrecks-photogrammetry/ (accessed 31-01-2017).

[51] See, for example, https://3dprintingindustry.com/?s=archaeology&lang=en (accessed 31-01-2017).

[52] A webcam is present on the *Amsterdam* wreck site at Hastings in England. See: http://nl.webcams.travel/webcam/1260441126 (accessed 31-01-2017). and http://voc.axiscam.net/view/index.shtml (accessed 1-16-2016), when checked the camera was inactive.

[53] See, for example, the http://cultureelerfgoed.nl/nieuws/crowdfunding-platform-maritiem-programma-van-start (accessed 310-1-2017).

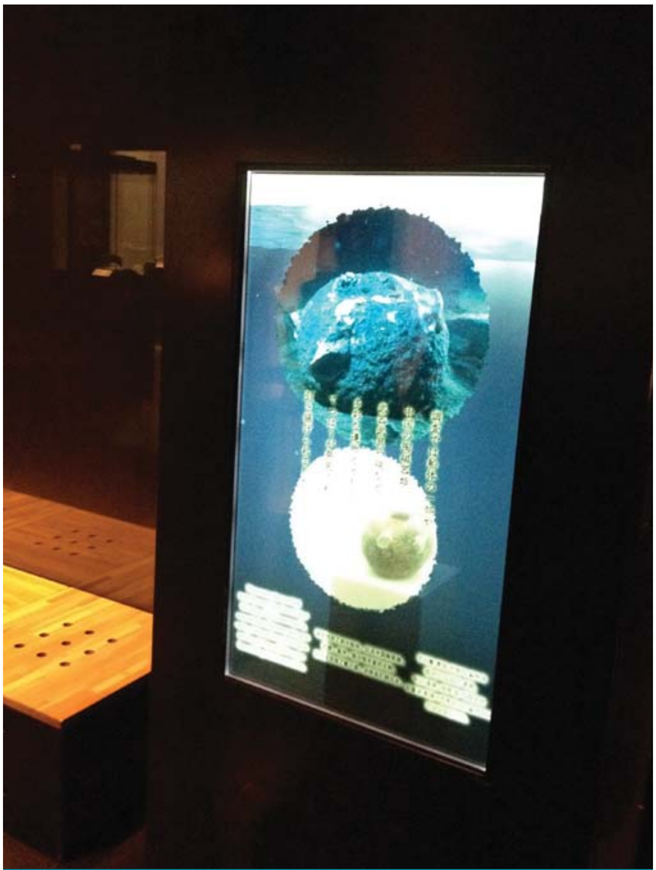

Fig. 7.8 A thirteenth-century grenade in a display case with various animated images projected on the glass screen. Kyushu National Museum, Japan. Photo: M. Manders.

engine prioritization of websites according to visitor numbers.[54] With average visitor numbers amounting to between a few hundred and a couple of thousand, it is difficult for most of the potentially interesting websites, Facebook pages and digital underwater museums to reach and address new visitors in large numbers.[55] This situation can be reversed through the contracting of specialized companies, but funding is not always available.[56] One possible way of breaking this vicious circle is for the organizations involved to join initiatives on centralized archaeological pages.[57] Another interesting possibility that is worth exploring concerns linking up with larger, commercial internet sites that can sponsor site exposure and thereby increase traffic.

The information exchanged need not only come from excavated sites. Basic information gained through inventories and non-intrusive significance assessments can be of great use in creating presentations for the wider public. Connecting the information about different sites with information about the area they are in, the history of the place and general historical facts will put the individual sites in perspective and also add to the tangibility of our common past and the creation of identity.[58] This connection of underwater sites (including the individual objects) can be limited to regional areas such as the Burgzand or even the Western Wadden Sea, but also may extend across borders, exploring the relationship between sites, the environment, trading routes and markets.[59]

[54] MACHU, which links websites from seven different European countries, receives approximately 1,000 visitors per month.

[55] Some research was done for the Maritime Programme of the RCE. As a programme, it only ran for a specific period of time (2012–2016). In that period – being part of a governmental organization – it changed its internet address four times (as part of www.machuproject.eu (accessed 31-01-2017), as part of www.cultureelerfgoed.nl (accessed 31-01-2017), with a specialized website www.maritiemprogramma.nl (accessed 31-01-2017). and as a 'dossier' on the RCE website www.archeologieinnederland.nl (accessed 31-01-2017). It was, therefore, not possible to collect any useful data on the website visitors themselves. On the Facebook page, the number of visitors changed for each message that was published, ranging between 120 and over 3000. This is more than usually would be reached through conventional (hard copy) publications, but remains limited. As a comparison, an interview of the author on a national television programme, 'De Wereld Leert Door' (http://tvblik.nl/de-wereld-leert-door/martijn-manders, accessed 31-01-2017), reached over 500,000 people during its original broadcast.

[56] For example, PPC (Pay Per Click) Search engines such as Miva (http://www.miva.com, accessed 31-01-2017).

[57] Two examples are archeologie.startpagina.nl (the Netherlands) and archeologie.start.be/(Belgium). A similar initiative is in the making in the Netherlands for maritime organizations involved in history and archaeology, including museums, in the maritime platform.

[58] Manders 2015 (1).

[59] See, for example, the Maritime Silk Road (http://www.chinaheritagequarterly.org/articles.php?searchterm=001_maritimesilk.inc&issue=001, accessed 31-01-2017).

Fig. 7.9 Kinetic 3D experiences diving around the Vrouw Maria (1771), a Dutch ship lying in Finnish waters. The Maritime Museum of Finland in Kottka. Photo: courtesy Maritime Museum Finland/NBA.

7.5 Conclusion

Although in situ preservation of underwater archaeological sites is considered to be the first option for many widely accepted reasons, it may create difficulties in raising awareness of the existence and richness of underwater cultural heritage. However, the difficulties it poses to traditional methods of exhibition and communication also challenge us to find new innovative ways forward. Museums housed inside buildings must review the stories they want to tell. They should determine whether these stories can be told with existing collections of artefacts. They need to invest in new ways and techniques to provide new and varied experiences; for example, in possible links from the museum building to sites on the seabed (Fig. 7.9).

Museums need not be housed in buildings. In some cases, sites themselves have become underwater museums (Fig. 7.10). Although often less accessible than a museum building, these are highly successful in addressing one major stakeholder in the protection of underwater cultural heritage: the sports diver. With the introduction of new visualization techniques, the challenge is to deploy these in the underwater cultural heritage field, both for research purposes and for the benefit of the general public.

Reaching large numbers of people previously not involved and increasing general awareness remains a challenge. This is not due to the subject, but is largely a problem of resources and utilizing the right channels of information. With the ratification of the UNESCO Convention on the Protection of the Underwater Cultural Heritage by the Netherlands soon to occur, and an increased interest in the ratification of the Faro Convention as well, this issue needs to be made a priority to ensure that awareness of the richness of our underwater cultural resource continues to grow. It is important to understand, however, that awareness and acceptance of the in situ policy needs to be created not only through a top-down or deductive approach, but also from the bottom up, or through an inductive approach, which not only addresses other stakeholders but works with them to establish cooperation and encourage our joint responsibility.[60]

Fig. 7.10: A simple way to impart information about underwater cultural heritage found in an area is to place information boards on the shore. This was an idea suggested for the Oostvoornsemeer (Lake Oostvoorne), but could also be used in Texel. Figure: T. Coenen/RCE.

[60] Manders & Underwood 2012.

8.
Conclusion

8. Conclusion

8.1 Summary

Through the example of the Western Wadden Sea area, this thesis aimed to demonstrate some of the dilemmas that are confronting underwater cultural heritage management. These concern the abundance of underwater cultural heritage (as shown in Chapters 1 and 2), the complexity of gaining insight into underwater resources (Chapter 2), the various threats these resources are subject to (Chapter 3) and, in relation to this, the possibilities there are to mitigate against these threats (Chapters 5, 6 and 7). The latter is specifically focused on the possibilities and impossibilities associated with applying in situ preservation to an underwater site.

Each year many sites of high archaeological significance are found on and in the seabeds of the world. This also regularly occurs in the Western Wadden Sea area. The potential of these new sites is high. Usually when they are found, they are already at risk. Once exposed they are under threat from biological, mechanical, human and even chemical deterioration. The different deterioration processes affect each other. Erosion of the seabed exposes the wreck site. This causes abrasion on the wood, the introduction of oxygen and easier accessibility for humans and animals. Bioturbation causes direct disturbance of the find layers but also more oxygen in the ground, which stimulates bio-activity.

There are several ways to mitigate against these threats. We can, for example, excavate (and thus preserve ex situ), but then we need to have a sufficient budget, sufficient capacity, appropriate facilities and sound scientific input, among other things, as well as robust research questions and high-quality research methodologies to ensure the optimal safeguarding of materials, data and information, as we have seen in Chapter 5 (Section 5.8). We can also aim for in situ preservation over the long run or as a temporary measure. The reasons to do so were laid out in Chapter 4. However, and although often thought to the contrary, choosing this option does not relieve us from any further responsibility or action.

While in situ preservation concerns the overall aim of maintaining sites where they are found, in situ protection concerns a more active role, making sure these sites remain preserved in place. This involves physical protection of archaeological sites, as well as monitoring and maintenance. This was explained in Chapters 5 and 6. Protection is the preferred way of dealing with sites in the Western Wadden Sea area because of the dynamics of the area.

Physical in situ protection may be a solution that keeps the sites protected on the seabed. However, this protection requires a clear purpose and goal. We need to understand why we are protecting the site. For example, if we wish to preserve the intrinsic significance of the site, what needs to be protected and against what kind of threats? What is the significance of any change in circumstances? Through practical experiments over the years, different methods have been developed, but there is a need to continue developing new protection methods in order to find the best solutions for each site; each with its own circumstances. The best way to develop new techniques and ideas is to work in a multidisciplinary way with researchers, engineers, conservators, marine archaeologists and other practitioners working, for example, in the field of maritime engineering and construction. An excellent example of this is the project that has been initiated in the Wadden Sea by the Cultural Heritage Agency of the Netherlands (RCE) and the Programma Rijke Waddenzee (Rich Wadden Sea Programme) to not only physically protect the most valuable wrecks, but also to use them as artificial reefs in order to promote biodiversity.

A multidisciplinary approach can thus be ensured through cooperation between different stakeholders protecting different values. Sites may then be protected for their cultural heritage value as well as for biodiversity reasons and/or for the recreational enjoyment of divers. The protection of underwater cultural heritage is therefore not just something for individuals to strive for, involving only a single stakeholder group. Sometimes it is not even one governmental body alone that is involved, but concerns a number of cooperating stakeholders and alliances between governments at different levels. The protection should be balanced against different issues such as cultural and economic benefit or public engagement. This balancing act is the core of cultural heritage management.

For the cultural heritage manager it is important to make choices between what will and will not be managed at the level he or she is involved in. One important choice to make is whether a site needs in situ protection, can be 'deselected' or if an excavation is needed. This decision should be based on reliable data and with an acknowledgement that 'gone is gone'. One needs to realize that underwater excavations are expensive and must be done according to specific national and international procedures, such as those stipulated in the UNESCO Convention for the Protection of the Underwater Cultural Heritage (Paris, 2001), the ICOMOS Charter for the Protection and Management of the Underwater Cultural Heritage (Sofia 1996) or the Dutch Quality Standards (KNA). Conversely, in situ preservation also requires taking responsibility over a longer period of time, involving intensive and high-quality research and monitoring. The heritage or site manager should also be aware of different values attributed to the site and the importance of balancing the wishes and needs of different stakeholders in order to create a well-supported in situ preservation system in close collaboration with multiple shareholders. He or she then becomes a broker, balancing the different needs and wishes necessary to preserve a site for future generations, the nation, region or location and the wishes of other – often multiple – stakeholders. Structural budgets are needed to create and to sustain such a well-supported in situ preservation system.

For many years, since the signing of the Valletta Treaty in 1992, in situ preservation has been generally thought of as a panacea in cultural heritage management in general. This has resulted in a somewhat one-sided aim and approach to our heritage: the aim to protect over a long period of time for future generations and future research. In other words, for later, later and later. This has frequently led to a situation in which out of sight was out of mind. The development of underwater cultural heritage management was explained in Chapter 1. The lack of ability to bring sites and their inclusive information about the past to the people for enjoyment or research has often alienated people from the resource. This has been rather disadvantageous to the emancipation of in situ protection as part of underwater cultural heritage management. It is true that in situ preservation and management have an accepted place on the political level. Law has also provided tools for protection and law enforcement (although not sufficient). However, unfortunately, generally no structural financial means are available for in situ protection and monitoring to support this policy in the Netherlands and many other countries in the world. This illustrates the difference in perceptions between stakeholders about what we expect in situ preservation to be or what it should be. It is either considered a cheaper option in management or the best way to keep sites available for future research and enjoyment. In relation to the former, no regular financial investments are deemed necessary and responsibility often stops immediately after the decision to leave a site in situ, while for the latter, active involvement – and thus management – is often needed to keep the site and the potential information it contains available for later study.

Luckily, a change in attitude is slowly becoming apparent. However, the current circumstances may not be conducive. Telling the real story about the costs of in situ protection, that there is a need for follow up, or that it is not a solution for eternity, may frighten investors and primary public bodies, especially in times of economic and financial deficit or crisis. However, this only means it is even more important to be fair about needs and to reserve budgets for the longer term. With pressure from different stakeholder groups (sometimes appreciating sites for different reasons), public bodies will confront the problem that needs to be resolved. This may entail becoming actively involved in preservation in situ, or pointing out to others their responsibility, or even taking the decision to excavate and thus preserve knowledge and objects ex situ. Selectively, sites or areas may also be proclaimed National Monuments as part of a series of stepping stones illustrating the national maritime history of the Netherlands. This will increase the need for the national government to take up its responsibility for the management of these sites. The stepping stones may then be a tool for all of us, young and old, and from all parts of society, to tell and explain to others the maritime history of the Netherlands. The stories may then be brought to the public through museums or by bringing people to the physical sites, or by using new technologies, as described in Chapter 7.

8.2 Answering the research questions

In the following, I will systematically summarize the possible answers to the research questions developed at the start of this research and formulated in Chapter 1 of this thesis.

If possible, how can we gain insight into the presence of underwater cultural heritage and of maritime underwater heritage, in particular, in the Western Wadden Sea?

To a certain extent we can. Water itself, unfortunately, prevents most people in society from engaging with underwater cultural heritage when it is preserved in situ. However, technological developments are giving us increasing numbers of technical tools help us to create better knowledge and insight. As we saw in Chapter 2, we are now able to develop a reliable overview of the known underwater cultural heritage in an area. There are, however, different levels of what we can consider 'known' and 'reliable'. An analysis of the many databases – from governmental organizations such as the RCE, the Ministry of Infrastructure and Water Management (Rijkswaterstaat) and the Hydrographic Service of the Navy, to the databases of several amateur archaeological associations – that was used to gain insight into the locations known on the Dutch seabeds, showed that there are different levels of accuracy in relation to positioning, as well as archaeological and historical information. Sometimes we will only have a position, while at other times there is a full assessment report. Expert judgements to assess the quality of the information forms a good basis for management. The information from the Hydrographic Service and the Ministry of Infrastructure and Water Management may be just as important for management as the information from archaeologists and sports divers. While the first two usually have precise and correct positions in their databases, most objects are referred to as 'obstacles' and there may not be much archaeological information available. In relation to the databases of the RCE, but also those of amateur archaeologists, positions may not be always accurate due to the use of inferior techniques and the transformation of these positions into different projection systems. This ultimately leads to the loss of accuracy in relation to each individual site but also – and more seriously – to a devaluation of the whole database, to the extent that the accurate location of each site is not known.

The underwater cultural heritage, however, not only consists of what we know, there is still so much we do not know. Often the sites are hidden under the seabed surface. Techniques are becoming available, such as the 3D sub-bottom profilers that are currently being tested at different sites in Europe, with which we can create accurate images of what lies in the sediment, especially over large areas. However, at the moment the chances of finding something like a shipwreck in the seabed are still minimal as the perception grid of this equipment is relatively small.

Gaining an insight into the unknown resources is thus far from being a straightforward exercise. We can predict or model the unknown resources to some extent. We can divide areas into places where there is a likelihood of finding sites, or where we will certainly not find them and where they are very likely to be present. Whether we can regard all of the 'positive' predictions as cultural heritage is another question. This depends on what society thinks is worth preserving and what we want to use it for. This may, for example, be for future research, commemoration or enjoyment. Although touched upon here, it has not been the aim of this thesis to answer this latter question.

Objects may be purposely or accidently left behind. It is not always easy to identify the reasons. However, each site can provide us with information about the locational characteristics of the area in which it is positioned. Landscapes are formed by interactions of natural and human processes. Understanding these processes is an important key to the biography of a place. With that understanding, we may be able to look further than just those archaeological or other sites that have been discovered already (known resources). We can predict the chances of cultural heritage still existing in specific areas or places (predicted but yet unknown resources). From this basis of validated information we can add non-validated information, such as historical sources, historic maps or sightings by others, which can yield a treasure of information as well, although this is often subjective and should never be confused with objective data from systematic research.

The Western Wadden Sea in the Netherlands is a very dynamic region, heavily influenced by tidal effects, erosion and sedimentation processes. A constant flow of these natural processes has shaped the seabed, while human activities have adapted the area for their own use. This has been going on for centuries. If we want to manage the underwater cultural heritage effectively under these dynamic conditions, we need to set priorities. It is essential to create an overview of the area's palaeo-geographical and environmental development to be able to make decisions about where to actively protect sites, where sites can remain on the seabed without much interference or where there will most probably not be any valuable sites present. Choices will have to be made due to the potential richness of the resources and the threats present or predicted. These choices will have to be based on both 'hard' facts and figures (e.g. the amount of sediment disappearing where sites have been discovered) and 'soft' impressions (where sites and future threats are predicted). The combined information will provide the ammunition for well-grounded mitigation strategies that preserve our underwater cultural heritage more effectively.

By understanding the place and its geological and cultural genesis and development – being able to read the landscape from past but also from current perspectives, as has been described in Chapter 2 – we can focus on its current and future use; for example, for enjoyment, as is outlined in Chapter 7.

To gain better insight into the known and the unknown (predicted) heritage resources a system of comparable maps from primary and secondary sources, and with a combination of quantitative and qualitative information, was developed. With the Historical Geomorphological Map Set (HGMS; Chapter 2), it is possible to gain an understanding of the biography of the landscape from geological, morphological and historical perspectives. In this way, the Western Wadden Sea might be described as an area where the known resources can be divided into different groups, with different levels of accuracy about their location and the level of information assessed.

From the cultural heritage resource database (ARCHIS 2), for example, 190 wrecks and 416 other observations over 109 locations are known to lie in the limited study area of the Western Wadden Sea. The combined official governmental agency databases, managed through the National Contact Number (NCN) system, contained (on the same date, December 2013), in total, 3,393 observations within the limits of the study area. This differs significantly from the number of sites in ARCHIS 2, but can be explained by the fact that ARCHIS contains cultural-historical weighted sites while the databases from the Hydrographic Service and the Ministry of Infrastructure and Water Management include 'obstacles' in general, as mentioned above. The latter databases, for example, also include the Texel Stone Field, with approximately 2,280 natural erratic stones of glacial (Saalian) origin, which makes a huge difference.

If we compare ARCHIS with the total of 6,636 observations from other unverified sources, mainly consisting of amateur archaeology databases that are known for the Western Wadden Sea area, we see another discrepancy in numbers. None of the observations from these sources, however, have been verified, and the overlap with the NCN system has yet to be determined. This number of observations does, however, show the potential of the area.

If we look at the unknown or predicted resources, we see more of this potential. Roughly between Vogelzwin and Vaarwater naar de Cocksdorp, as well as parts of Lutjeswaard and Zuidoostrak and parts of the Balgzand area were all geologically and morphologically relatively stable in the period between 1925 and 2005. The historic maps dating from 1584 to 1852 show – although in less detail – more or less the same information. This means that although most areas within the Western Wadden Sea have been influenced by ever-changing gullies and thus there has been erosion of the Holocene and sometimes even the Pleistocene seabed, some shallow areas have remained relatively stable. These places may have never been ideal for navigational purposes, but early settlements and ships that may have run-aground may still be found there. If so, they will likely be in a comparably good state.

Cultural heritage in the eastern part of the Burgzand area and on/in Vogelzand, Scheer, Texelstroom and Scheurrak are most at risk of being uncovered and degraded by erosion and subsequently exposed to other threats. In these areas, we find most wreck sites. Sometimes, if recently uncovered, they are in a remarkably good state of preservation, such as BZN 10 and especially BZN 17. Sometimes, however, they are already heavily degraded due to having been exposed for too long before discovery or because they have been exposed multiple times, with a loss of a great deal of information of archaeological value.

If possible, how can we develop an approach to co-create this knowledge by means of desktop research that can serve as a basis for heritage management?

As demonstrated in Chapter 2, this is currently being done through the combination of maps in the Historical Geomorphological Map Set (HGMS). This process is combining 'hard' (quantitative and science-based) as well as 'soft' (qualitative and interpretative) information. For example, it includes the known resources, the geological make up in the area, sedimentation versus erosion processes, and mechanical, chemical and anthropogenic threats, but also historical maps. The information they provide on former uses of the area have proved to be an asset in gaining a thorough understanding of the history and development of the area.

Thus, the HGMS will help us to predict where sites are likely to be located. The power of the tool lies in the combination of different sources of information and the metadata that it also contains. Making data sets available, combining them for interpretation, but also keeping them physically separate, is exactly the right thing to do, as we have seen above. There is a lot of data available that may not be compared on a one-to-one basis. Not all the data has the same detail or the same level of accuracy. Simply putting them altogether would mean that the overall dataset would be 'corrupted' to some extent, its quality no better than the lowest quality data set included.

Although the HGMS consists of a set of basic information – providing maps that give an overview of the quality and quantity of archaeological heritage in the area – it is also a flexible data set. This means that new information can be added to the model without changing the original data sets. In combination with a geographical information system (GIS), it is very easy to add new data layers and to visually combine and correlate different data sets and information. Metadata added to the different data sets will provide the user with all the information about the source, the owner, and also the accuracy of the data.

Being able to add other data sets provides variability in the analyses. While the basic set of data provides the essential information that is needed for the analyses of the known and the unknown/predicted resources in the area, newly added information may provide a more accurate view, a more dense observation grid or a different and new focus for research. This may, for example, be the case when local databases of finds are added, or newly discovered and digitalized maps, recent analyses of cores, or sand layers dated with OSL are included (see also Chapter 6). By combining or comparing the maps with this new data, our knowledge of the archaeology and heritage of the Western Wadden Sea area and the way to deal with it will be improved. However, expert judgement will always be needed in addition to the objective data. Insights into what has happened in the past can only be created through a combination of quantifiable data, current (personal) knowledge about a specific area and/or a specific period and deductive reasoning. This can aid in predicting the likelihood of finding sites buried in the seabed of the Western Wadden Sea. By systematically processing the data and by clearly separating objective and subjective observations, we may also better identify the gaps in our present knowledge. These gaps can then be distilled into fundamental research questions and added to national and international research agendas.

The HGMS may serve several purposes: as a foundation for the drawing up of policy maps by municipalities and provinces, for example, or as an aid to answer academic questions. The HGMS for the Wadden Sea can serve as a sound basis for academic research, since each data set has been validated and summarized taking into consideration the manner in which the data was collected, when it was collected, the original purpose of the data, the reason for the collection and the processing that the data set has undergone. It is also suitable to an academic approach because of the modulated set up, which makes it easy to combine, add one's own insights and thus to differentiate potentially without limit.

The HGMS consists of three groups of maps. The first consists of maps that were created using objective measurement data. The second consists of combinations of maps from the first group. The third group provides insight into use by humans, reconstructed for the various periods.

The HGMS for the Wadden Sea can also be of great use to policymakers and other parties in the field of cultural heritage management. The main idea behind the method developed is to improve the decision-making process pertaining to the management of underwater cultural heritage. In doing so, it complements the methods used in desktop studies. The modular structure of the HGMS will thus provide opportunities for archaeological organizations to differentiate in their methods of approaching the same questions. This is not only important for a free market, but also for other stakeholders, because in this way, data from different, non-academic sources and from different groups with different aims can be added to answer questions in society and not only those concerned with scientific values.

Shipwrecks are often found by accident. How can the chances of finding them be better predicted?
Prediction is possible to a certain extent. Indeed, shipwrecks are often found by accident, for example during construction work, dredging, fishing or by sports divers. On the basis of the information we can obtain by combining the maps available in the HGMS, we can, however, also predict the likelihood of finding shipwrecks in a certain area. This was discussed in detail in Chapter 2. Although this is not an exact science, it is possible to point out areas in which there is little likelihood of finding shipwrecks (e.g. the areas dredged or eroded down to the Pleistocene) and those in which the likelihood is great (e.g. being located on an important trading route and with little erosion over a long period of time).

Being able to predict the chances of finding shipwrecks is enormously important because this would also mean that the management of unknown resources are taken into consideration in advance, rather than having to deal with unexpected finds when work is already underway. Nevertheless, shipwrecks generally need to be surfacing the seabed before they become evident, as it is still difficult to look into the seabed. Techniques and methods such as 3D sub-bottom profiling are improving drastically and are very promising, but thus far they are not accurate enough for large-scale searches in the sediment.

We need, however, to start acknowledging that it is possible to differentiate areas where the chances of finding wrecks are more or less likely. This was not the case with earlier predictive mappings of the Wadden Sea. The first predictive mapping excluded all areas of water in the Netherlands, as if there was nothing there (see the earlier versions of the IKAW, the Indicative Map of Archaeological Values). In later versions, water covered areas were taken into account to predict the presence of prehistoric settlements on the seabed, but there was no concern about the possible presence and, therefore, also richness of the underwater maritime past. The HGMS, in contrast, will be a tool that can be used for the predictive modelling of shipwrecks as well.

Nevertheless, potential and known underwater heritage is still not being taken into account when municipalities draw up their heritage policy. In the past, neglect of underwater cultural heritage, even by government agencies that should know, has resulted in other agencies, archaeological companies and contracting companies taking this part of the cultural heritage less seriously: 'out of sight is out of mind'. This was illustrated in Chapter 3.

Moreover, desk-based research and pre-disturbance surveys have often not taken place before seabed disturbance occurred. The combination of disinterest, a lack of incentive to understand and search for sites, a lack of will from governmental organizations, of the false assumption that ships may have sunk anywhere and thus can be found anywhere (i.e. are randomly distributed over an area), the specific nature of the – often hostile – environment (sedimentation-erosion, bad visibility, etc.) and possibly simple ignorance, of not knowing where to start, has led to the fact that when underwater sites are discovered it is usually by accident. This in turn can pose immediate dilemmas, for example, when a site is discovered during a construction project that is already under way.

As shown with the HGMS, we can predict the chances of finding shipwrecks in an area. Our 'observation grid' may for now not be as detailed as for sites on land, but the overview it gives us must be accepted and acknowledged. We now have the capacity to make an informed judgement about the likelihood of finding something or not. We can divide a region, in our case the Wadden Sea, into areas with low, medium and high probability of the presence of shipwrecks or other sites. This is important for the overall management of resources. The historical use and the natural condition of an area may increase or diminish the chance of finding a wreck. An area between two important trading cities, for example, will increase the chances. By reconstructing the former maritime cultural landscape, with its harbours, known transportation routes, connected river systems, transition points and its dynamics though time, including the risk areas for transportation, it is possible to differentiate and make significant predictions. Therefore, although often found by accident, shipwrecks do not have to be accidental finds.

How is it possible to preserve 'unknown resources' in situ?
We can take precautionary measures to protect an area with a high probability of finding archaeological sites, whether they are shipwrecks, prehistoric or other sites. This can, for example, be done through law and specific policies. This option was explained in Chapters 4 and 5. We may, however, want to make these sites 'visible' and thus turn them into sites we know more about. Although this seems to be the best solution in relation to the development of management strategies, it is not as straightforward as it sounds.

Big steps have been made in the development of equipment to detect sites on the seabed. Side scan sonar and multibeam sonar are incomparable to the previous generations of equipment in terms of resolution and accuracy. However, the technology required to detect sites in the seabed is still not sufficiently advanced. While the equipment can usually indicate general disturbances or indications, it remains generally difficult to confirm these or obtain more detailed information. What we might discover in the seabed, therefore, remains an educated guess based on the combining of all the information we can gather (such as that provided by the HGMS, Chapter 2).

By officially acknowledging that this process of predicting sites in certain areas is of value and including it in the assessment of an area prior to any development, or recognizing it as a valuable asset in local management policies, unknown resources can be preserved in situ. For example, areas with high predictive values may be avoided in development activities, additional regular measurements may be carried out to monitor changes in the area (see Chapter 6) and activities to mitigate against possible changes can be supported and promoted. At the same time, we should acknowledge that this protection strategy concerns the protection and preservation of potential (the educated guess); the downside of this is that we may use our efforts for an area that looked promising, but eventually may not contain that what we thought it would be. Many areas in which there is a high probability of finding shipwrecks and undisturbed prehistoric layers are those that are not much affected by erosion processes (Chapters 2 and 3). Therefore, the effort to protect may only require the application and recognition of law, ensuring that no human activity such as trawling, dredging or drilling leads to seabed disturbance.

What is threatening the shipwrecks in the Western Wadden Sea?

The Western Wadden Sea is home to many deterioration processes. In Chapter 3, we divided them into four categories: mechanical, biological, chemical and anthropogenic.

Mechanical deterioration

The Western Wadden Sea is a dynamic area. The Holocene layer regularly changes in thickness, alternately covering and exposing shipwrecks. On a larger scale, it is apparent that currents and wave actions have an influence on the morphology of the seabed. Gullies, tidal channels and sandbanks change place and course, opening up new areas, in which cultural heritage comes under threat. These areas are the Burgzand, Vogelzand, Scheer, Texelstroom and Scheurrak.

As we have seen, there are also more stable areas: roughly the area between Vogelzwin and Vaarwater naar de Cocksdorp, parts of Lutjeswaard and Zuidoostrak and parts of Balgzand. Historical research has demonstrated that these areas have generally been stable for a long time. Research on sedimentation and erosion patterns in the Wadden Sea has shown that sedimentation rather than erosion is generally occurring in the area. However, mainly due to the building of the Afsluitdijk in 1932, there is not yet stability in the Western Wadden Sea area, and it may take another century before this occurs.

In this study, the dynamics of sedimentation and erosion, the effects of currents and waves on site level, were investigated on some of the wrecks in the Burgzand area. It was found that each year the morphology around the monitored shipwrecks changed. The obstruction of currents by the wreck itself causes local eddy currents that can cause scour and erosion pits in and around the site. The general tendency in the region is that the Texelstroom is moving southwards over the Burgzand area, which in some places will cause strong erosion patterns. However, due to its continuous move from north to south, erosion in the northern part of the area is already slowing down and there are also signs of sedimentation. The erosion and sedimentation patterns are thus temporary and mitigation is possible. However, during periods of strong erosion it is (extremely) difficult to protect the sites.

Biological deterioration

Biological deterioration on wooden shipwrecks is a continuous process. In aerobic environments, species such as the shipworm, which can cause rapid deterioration, are active, while in less aerobic and even anaerobic or anoxic environments deterioration is ongoing and bacteria can be active. The speed of deterioration, however, changes. In the Western Wadden Sea, deterioration caused by *Teredo navalis* is extremely violent and rapid, while fungi work at a much slower pace and erosion bacteria at an even slower pace. Biological attack can be accelerated by mechanical attack such as erosion of the seabed. Water flux and the amount of organic matter in the soil also have an influence on the speed of deterioration of wood.

Chemical deterioration

The chemical deterioration process most often found in the Wadden Sea is that of corrosion. This process is especially active with iron in high oxygen and saline areas. All objects surfacing the seabed are subject to this process. In low oxygen conditions, for example within the sediment, this process of corrosion is much less rapid, but may exist, especially under the influence of biological attack by bacteria. This form of corrosion may cause major problems when wood is salvaged and it will need to be conserved. The results of this process have been noted in large conservation projects such as that of the Vasa and the *Mary Rose* but were also observed in wood on the BZN 3 wreck. Climate change will probably cause the sea waters to become more acid. This will create all sorts of reactions in the sediment and on the seabed, of which we have no full overview as yet.

Anthropogenic threat

The human or anthropogenic threats are divers. Some of the threats are direct and obvious, such as in the case of looting, trawling and dredging. Their impact can easily be understood and measured. However, human activities and interventions may also affect underwater cultural heritage with a delay of many years, decades or even centuries, or in a slow continuous process that can only be measured over such long periods. For example, the Wadden Sea is one of the most diked seas in the world. This, including the building of the Afsluitdijk, has led to a change in sedimentation-erosion patterns and thus mechanical deterioration of underwater cultural heritage over a long period of time. Salvaging, treasure hunting, farming, fishing and dredging have also all had a direct effect by disturbing the seabed, as well as an effect over the long run, by causing change in scour or erosion patterns around, for example, shipwrecks. Even archaeologists may cause unintended damage through improper handling or through a lack of, or bad, treatment of a site after investigation.

Unfortunately, due to the delay in effects, it is often difficult to hold the original disturber financially or otherwise accountable for the degradation of underwater cultural heritage. One final threat to underwater cultural heritage that should be mentioned is the lack of interest in this resource, which can lead to its neglect.

Management of threats

There are thus many processes that threaten underwater cultural heritage. A stable area is the most likely place for an archaeological site to survive. Changes in the environment are generally not good for underwater cultural heritage. Cultural heritage managers thus study change and attempt to avoid or mitigate against it. All these processes of change are interlinked and may intensify individual effects.

Erosion, in particular, is a big threat in the Wadden Sea. This process is a catalyst for biological and human activities on site. The moving sediment, however, may be used to the benefit of protection as well. By catching suspended sand particles with nets it is possible to rebury a site. Some threats may thus be easy to identify and mitigate against because they have a direct and obvious effect. However, some may result in damage to underwater cultural heritage over decades or even hundreds of years. These effects are often not taken into consideration when protecting a site in situ, and it may also be very difficult to do so; for example, climate change must be addressed at a different level.

However, on a smaller scale, it is relatively easy to model the potential long-term effects of a newly built bridge, a wind farm, a dike or sand extraction on current patterns and gullies on the seabed, which may result in the erosion of newly exposed sites. The effects of human behaviour should be investigated by monitoring sites over a sufficient period of time. This was discussed in Chapter 6, where it was argued that such monitoring should be agreed upon project by project, while implementing lessons from past monitoring programmes. Works that have already been executed that clearly show effects on the seabed should also be monitored over a long period of time. This monitoring activity should not be done in order to find someone to blame, but to learn for the future. Politically and legally, it is impossible to still hold the builders of the Afsluitdijk (1932) responsible for the damage done to historic shipwrecks in the Wadden Sea, even if this is – at least partly – true.

Stakeholder perceptions of change and management should also be taken into consideration. One enormous disadvantage for underwater cultural heritage is the fact that it is not, or is barely, visible, especially in the Wadden Sea. In Chapter 7, I made an effort to deal with this issue. It is not always easy to see the advantages of having such a rich resource of the past within one's territorial boundaries. The implementation of the Valletta Treaty led to a growth in archaeological activities. However, we should ask what has come of it?

The system leans heavily (if not completely) on the 'disturber pays' principle. However, as discussed above, it is not always clear who disturbed or destroyed an underwater archaeological site. The damage done may occur over decades or centuries and no one can be held responsible, at least not financially. Those responsible for overall management do not always have the financial resources to pay for activities to preserve in situ or ex situ. However, if we understand deterioration processes and the long-term effects, we may be able to make better decisions when executing large-scale projects (similar to the building of the Afsluitdijk) in the future, or to take measures to mitigate against long-term deterioration processes. Moreover, if this knowledge is taken into account and the principle implemented during the disturbance activities, the initial disturber could be required to allocate funds towards future mitigation measures, rather than attempting to solve the problem afterwards with only limited government money. The costs of mitigation strategies and even long-term monitoring could also – and would have to – be taken into account by the disturber when deciding on the execution of a project.

Deterioration processes are abundant in the Western Wadden Sea (Chapter 3). It is a hostile place for submerged cultural heritage on the one hand, but when protected well (by either nature or society), it is also an area with excellent preservation conditions. The variety of threats and the use value of the wrecks also create various options for finding solutions. There are mitigation strategies for all of the threats. Some are quite obvious, others need to be more creative. They range from in situ protection methods to keeping the soil environment waterlogged and oxygen-free and sometimes even low in organic material. In Chapter 5, these methods were described.

However, it is important stakeholders start sharing responsibility for the shipwrecks. Agreements between different users (stakeholders) can be made on the use, research and enjoyment of the different wreck sites. Which site will be open to the public? Which one will we wrap in protective material to keep it in store for future research? Which site might be a perfect 'hard substrate' in the Wadden Sea? In Chapter 7, some solutions were laid out. Not all sites are heavily under threat. Some remain in relatively stable areas, in which we may find well-preserved and very old shipwrecks. The discovery of the Westerveld 2 wreck near Vlieland from around 1500 clearly shows the potential, but also the need to take action after discovery occurs.[1]

[1] Although having been protected for many centuries in a relatively safe and stable environment, a sudden change of currents in the area uncovered the Westerveld 2 site and subsequently destroyed the 500-year-old wreck. Efforts to save the wreck in situ by RCE and RWS had little effect. The lack of clarity about who was responsible and who would pay for emergency excavation – the national government or the municipality of Vlieland – resulted in the loss of the wreck without further action being taken.

In relation to the overall management of our resources, it is also important to realize that quite a few of the threats to shipwrecks in the Wadden Sea that have been identified will have negative effects for stakeholders other than archaeologists. Shipwrecks contain information about our past, but may also be important for biodiversity. Shipwrecks are also great places to dive. At the same time, shipwrecks may be destroyed by fishing nets and fishing nets destroyed or lost on shipwrecks. This mutual sense of threat is important to acknowledge, especially when looking for solutions for long-term management, as it will broaden the acceptance of ways to mitigate against the threats.

Is in situ preservation a panacea for underwater cultural heritage management in general? What are the alternatives?

In the last two decades, the predominant focus in underwater archaeology has been on in situ preservation and the development of appropriate policies and legislation to politically galvanize these trends (see Chapter 4). However, in situ preservation is not as straightforward as it seems, posing many significant questions for those considering this option. For example, what are the major degradation factors affecting a shipwreck site and what techniques can be suitably employed to halt or at least decrease the rate of deterioration (Chapter 3)? It should be clear that in situ preservation often requires active involvement, using different, often tailor-made, conservation and protection methods (Chapters 5 and 6).

In situ preservation is not a panacea for underwater cultural heritage management. Leaving sites on the seabed, with further, often costly, activities to be undertaken, is one option out of several. Excavation is always another option. Sometimes it is not feasible to leave a wreck on the seabed due to the heavy and rapid deterioration processes or construction work that has to be done. Even if we leave wrecks on the seabed, deterioration is continuous. The choice to leave a wreck in situ depends on what we want to do with it. Is it for enjoyment, commemoration, the spirit of the place, science? A shipwreck may have many values. A combination of these values may even be preserved, since there is no 'magic pill' in heritage management. Underwater cultural heritage management comprises many different steps and decisions to be made, involving many different and sometimes incommensurable values. From this perspective, in situ preservation is not always the right solution.

The management of underwater cultural heritage not only requires the expertise of archaeologists. Chemists, geologists, hydrographers and, of course, cultural heritage managers, planners and nature conservationists (or developers) are also important. In situ management requires many stakeholders to work together. Cultural heritage managers should be able to balance the needs and wishes of these different stakeholders. They are, moreover, not alone. Often parallel issues require management in one and the same area, at a different pace and starting and ending at different times. This may also result in management plans on different issues running in parallel – on heritage, safety, ecology, water management or tourism, for example – a recipe for future friction or even major clashes.

What is important in management is that we create a long-term view of what we would like to achieve. Underwater cultural heritage management concerns management and care over a long period of time. It is important to know what we want to get out of all this management and protection of the underwater cultural heritage; what we intend to learn from it, or how we want to enjoy the sites. To best do this, somebody has to take the lead and responsibility for a site. Very often this is shared. The owner of the land/water resource has a say, the administrator, the municipality and the sometimes also the national government. In the Wadden Sea, this may mean that in one and the same area, activities may be carried out and control may be claimed by the Ministry of Education, Culture and Science, the Ministry of Infrastructure and Water Management, the Ministry of Economic Affairs, the Province of North Holland and the Municipality of Texel. Thus, it can become quite difficult to determine who is doing what, or responsible for what, and to subsequently agree where the money should come from to pay for all the different activities. It is thus important to resolve all these issues and create a responsible management plan for an area, including underwater cultural heritage, a plan that includes a budget for long-term management (Chapters 5 and 6).

In relation to sites that have not yet been discovered, management is even more difficult. We can attempt to manage them as part of our overall resources. This may, however, mean even stronger means of persuasion are needed if we are to convince people to pay for something they cannot see. A maritime landscape approach would be a possibility in this case, combining the protection of natural and cultural values in a restricted area and creating favourable situations for this.

In situ management requires more than merely leaving wrecks in the place they were found. In situ protection, monitoring and maintenance are also part of this, as explained in Chapters 5 and 6. A budget is required to execute such work. If we want to give high priority to in situ preservation, we should have the funds to do so. As we saw in this thesis, adding a protective layer to a wreck in the Wadden Sea costs around €70,000 (e.g. the BZN 10), each monitoring action adds at least another €3,000 (for multibeam) and approximately €6,000 per day for diving (BZN 10). However, the excavation of sites easily costs millions of euros. This remains an option. Developing a national research agenda that includes important questions on these issues that we think should be answered makes it perfectly acceptable to invest in excavation as well. Archaeological sites are certainly locations to learn about our past.

Is in situ preservation the solution for cultural heritage management in the Western Wadden Sea? What are the alternatives?
In situ preservation with the use of in situ protection methods has proven to be effective in the Western Wadden Sea. The methods that have been developed – and that are described in Chapter 5 – and the structural monitoring of these protected sites – described in Chapter 6 – have proven this. For 30 years physical methods have been applied, ranging from sandbags and polypropylene nets to artificial seagrass. The oldest protected wreck, the BZN 3, is still well protected after all these decades, while the physical protection placed on other wrecks in the Burgzand is still functioning. We can clearly see their effect if we compare the results with the BZN 11 wreck, a site that has not been protected and that has now almost completely disappeared.

It is good to see that protection has made a difference, even under demanding circumstances. The constant tidal changes create a situation of cyclic erosion and sedimentation, which is also periodically fierce or moderate. This may mean that a site comes under threat for a while, but subsequently is naturally well protected under a thick layer of sediment. We need to be prepared for these changes and can do so by examining previous processes of erosion and sedimentation (hindcast), predicting the future processes (forecast) and the effect they may have on known and unknown archaeological sites in the seabed. We also need to be able to predict how long a threat to a site may last. This is very specific to each location because it also includes the reasons why we choose preservation (Chapter 4). The technical data on the basis of which we make such decision can be extracted from the information gathered and compared in a system such as the HGMS (Chapter 2).

In order to be effective, in situ preservation should be part of an overall management plan for the Western Wadden Sea. Such a plan should at least be implemented by the different Wadden Sea municipalities and the two provinces of North Holland and Friesland, and possibly included in the management of the Wadden Sea as a World Heritage Monument. The time is ripe to include the outstanding cultural values of the Wadden Sea into its management strategy, and eventually add the maritime cultural heritage, recognizing its outstanding value and making the Wadden Sea a combined natural and cultural World Heritage site. Whatever happens, a permanent budget to preserve cultural sites in situ should be provided and soon. There will be a permanent responsibility that needs to be taken up. Synergy between natural heritage protection, cultural heritage protection, economic activities and tourism, for example, as part of the overall management of the area, should be part of the solution.

Ideally, a local interdisciplinary team of heritage managers and underwater archaeologists for the (Western) Wadden Sea area should be established. Sharing the responsibility in this way would not be that much of a financial burden and will have a lot of positive outcomes. It will create more local involvement because it will become a combined regional responsibility. This will most probably also result in quicker response times when sites are discovered, and activities will be executed in closer proximity to local stakeholders and therefore be more visible to them. There may then be more flexibility in relation to potential activities in municipal cultural heritage management, science (even in collaboration with the Wadden Academy) and activities within the framework of the Valletta Treaty. The relationship between society and the waters of the Wadden Sea, as a means of transport and a resource of high-quality food still forms the essence of the Wadden Sea today. In other words, it is largely created and cultivated by society and its needs, and is therefore to be highly regarded in all its cultural value.

Regarding the techniques for physical protection of sites in situ as laid out in Chapter 5, over the last 20 years, many experiments have been undertaken in as many different environments across the world. Some of these locations have been little monitored since. Moreover, in instances of reburial there was no pre-reburial surveying or post-reburial monitoring, which makes an evaluation of the different techniques extremely difficult, if not impossible. Some general rules, however, can be deduced from the many projects executed, including those in the Western Wadden Sea.

First of all, mitigation must focus on the factors that cause the most degradation (Chapters 3, 4, 5 and 6). If possible, different threats should be overcome or ameliorated using one method. In addition to the mitigation of the most significant physical-mechanical, biological, chemical and human threats, it is also very important to think of why the site needs to be preserved. What value prevails? As we have seen, a site will be preserved in one way if it needs to be protected for future research, or in another way if it is to be enjoyed by sports divers. The protection of underwater archaeological sites will always be, in part, individually customized to accommodate the unique qualities of each site.

Shared responsibility is the key for in situ management. It will be the task of the heritage manager to balance the different values assigned to a wreck, and the various wishes and needs of the different stakeholders. These heritage managers may very well be government employees at the national, provincial or municipal level. However, cultural heritage concerns what a society as a whole wants to preserve and not only what heritage managers employed by government think is important. The source community must have a say in what happens. Moreover, those who might want to disturb a site for one reason or another must also be part of the conversation if they are to make an informed decision on whether to disturb or to avoid. Archaeologists and cultural heritage officers should consider roles such as offering guidance, explaining and describing the site, or as brokers, connecting different ideas about the significance and the uses of cultural heritage in the public domain.

Convincing others will become increasingly important. In situ management entails a difficult balance of the different needs and wishes of different stakeholders. This is important because without the support of several stakeholder groups there will not be a basis for in situ management. Awareness-raising is thus very important. Sites need to be explained and become physically and virtually accessible. This means that we not only require in situ management, but that there needs to be room for ex situ preservation as well. This might entail the removal of artefacts through excavation or, for example, 3D visualizations. Underwater sites should be opened to the public through underwater museums and dive trails; reconstructions of what is left on the seabed should also be made, examples of which were given in Chapter 7. Only by opening up this often very invisible but highly significant cultural heritage will support grow: we need to bring the sites to the people and the people to the sites.

Reaching large groups of new people in order to increase awareness remains a challenge, but one that must be faced. This is not due to the nature of the subject – as in fact most people find underwater cultural heritage and underwater archaeology interesting and exciting – the problem is largely one of resources and awareness, utilizing the right channels of information. With the ratification of the UNESCO Convention on the Protection of the Underwater Cultural Heritage by the Netherlands soon to take place and an increased interest in the ratification of the Faro Convention as well, this issue needs to be made a priority to ensure that awareness of the richness of our underwater cultural resource continues to grow and to ensure its management is a shared responsibility.

Here also, the Western Wadden Sea could play a leading role. We already have a good idea of the richness of the material cultural past that is present on and in the seabed. This is due to the efforts of the national government over years in this area, as is reflected in this thesis. The underwater sites largely represent a story of the area we know and which also has its material witnesses onshore. The entire Wadden Sea area in fact represents the influence human beings have had – and still have – on nature. This active engagement and influence of culture and nature – however logical and very much visible in the area – has not yet led to the inclusion of outstanding cultural heritage values in the UNESCO world heritage nomination of the Wadden Sea, as we have seen above. Fortunately, the views are changing and it would not be surprising if in a few years this is set right. The area can serve as an example of the perfect balance between the two.

The appreciation of the different values of underwater cultural heritage may play an important role in this as well. Shipwrecks may form hotspots of biodiversity on the seabed. More fish may mean a thriving sustainable fishing industry, not only in the Wadden Sea itself but also in the adjacent North Sea. The Wadden Sea has been a central place for trade, a food resource and a way of life for many centuries. This past is visible in traditions and stories, but also through the only objective resource – the material witnesses of the past – archaeological sites in and on the seabed. They are undeniably part of the area; their presence should be acknowledged and managed in situ and ex situ.

8.3 Final word

To conclude this thesis, I would like to return to my initial research question:

How can we manage the underwater cultural resource?

The underwater cultural resource can be managed only by looking at it from a high level, inclusively rather than on a case by case basis, proactively rather than reactively. What we know about it – the sites that have been detected – is probably only a fraction of what is present in the area. The value of each site can be measured on different levels and by different stakeholders, and quite rightly so. Cultural heritage concerns what we as a society want to preserve for the future. Sites need, therefore, to be connected to that society, and all the individual sites connected to each other through the society protecting them.

Managing underwater cultural heritage can be and often is structured, ranging from desktop research and surveys to in situ protection and excavation. All of these different steps are important in the process of management and need to be balanced. If there are no inventories or surveys, there will be no overview; if there are no assessments, there will be no clear knowledge and no well-founded decisions about what to keep and what not; if there is no in situ protection, there will be a loss of many sites before any decision is made about what to do with them; if there is no excavation, there will be no or only little building of knowledge. This knowledge is, in turn, the basis of decisions to preserve, deselect or excavate.

An important question to ask ourselves is: Who is responsible for making decisions within this process? This is not an easy question to answer, however, the more inclusive the process, the more sustainable these decisions will be, even if the decision-making process itself may become more difficult. We are all in it for something. The view of an archaeologist may differ from that of a politician. However, as long as the discussion about what needs to occur is fair and open, the decision will have results that last.

The question: 'What's in it for me or us?', should be asked. Solutions can be sought. A shipwreck can be preserved in situ while promoting biodiversity and creating an enthusiastic diving community around the wreck site. New technologies are making new forms of interaction between archaeologists and non-archaeologists possible, and also between divers and non-divers, between sites and museum visitors. This is the way forward because, in the end, awareness-raising, respect and understanding are the key to ensuring the future of our underwater cultural heritage and its management, also in the Western Wadden Sea.

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I may have to start by asking 'Where should I start?' ...

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But now it is done. It took a very long time, too long. Let's get on with our lives, there are still so many paths to travel ...
Life is too short.

Literature

Literature

Adams, J. ; Holk, A.F.L. van ; Maarleveld, Th. J. , 1990, *'Archaeological survey : Grootschalige locatie voor berging van baggerspecie uit het benedenrivierengebied*', Rotterdam.

Aken,Hendrik M. van, 2008, Variability of the salinity in the western Wadden Sea on tidal to centennial time scales, *Journal of Sea Research* 04, 59, 121-132.

Akker, J. van den, M. Manders, W. van der Wens & A. Zandstra (eds), 2007, *Bundel maritieme vindplaatsen* 1, Amersfoort RACM en LWAOW.

Al-Hamdani, Zyad, Maria Geraga, George Pantopoulos, George Papatheodorou and Jens Wunderlich, 2013, WP2 Development of Tools for Surveying and Monitoring Coastal and Underwater Archaeological Sites, in: David Gregory, Yvonne Shashoua and Anne Marie Eriksen, *SASMAP Progress report* 2012-2013, 12-17.

Alkemade, Monika, Wilfried hessing & Kees Kaptein, n.y., *Verder met Malta. Handreiking voor de gemeentelijke archeologische monumentenzorg (AMZ*), Vereniging Nederlandse Gemeenten, Den Haag.

Alvik, Riikka, Vesa Hautsalo, Ulla Klemelä, Aki Leinonen, Hannu Matikka, Sallamaria Tikkanen & Eeva Vakkari, 2014, *The Vrouw Maria Underwater project 2009–2012 final report* National Board of Antiquities Helsinki.

Appelqvist, C., 2011, Wood degraders in the Baltic Sea. In: C. Gjelstrup Björdal and D. Gregory (eds), *WreckProtect. Decay and protection of archaeological wooden shipwrecks* , pp. 57-64.Oxford: Archaeopress

Arcadis, 2011,, *Nadere effectenanalyse Natura 2000 gebieden Waddenzee en Noordzeekustzone beheerplankader voor baggeren*, Apeldoorn

Ashworth, G.J., Graham, B.J. and Tunbridge J.E., 2007, *Pluralising Pasts: Heritage, Identity and Place in Multicultural Societies*, London.

Astley 2016 Studying the site formation processes of shipwrecks through the use of multibeam bathymetry time-series, Phd Southampton University, UK

Baak, M.A.X. van, 2003, Storm-erosion effects on safety of sea dikes by probabilistic coastal morphologic modelling, , *XXX IAHR Congress AUTh*, Thessaloniki, Greece.

Baarse, Gerrit, BB&C, 2014, Natural solutions to cope with accelerated sea level rise in the Wadden Sea region. *Towards an integrated long term adaptation strategy framework. Knowledge for Climate report number* KfC 132/2014.

BACPOLES whole team, 2005, Chapter 8. Conclusions, In: Rene Klaassen (ed) Preserving cultural heritage by preventing bacterial decay of wood in foundation poles and archaeological sites. *BACPOLES, final report* EVK4-CT-2001 – 00043, Wageningen

Bartels, M. H., 2011, *Gezonken als een baksteen. De tjalk van Karsten Hoytes 1752. Archeologisch en cultuurhistorisch onderzoek naar een gezonken vrachtvaarder in het Hoornse Hop*. Hoorn.

Bartuli, Cecilia, Roberto Petriaggi, Barbara Davidde, Emanuela Palmisano, Gaetano Lino, 2008, *In situ conservation by cathodic protection of cast iron findings in marine environment, 9th International Conference on NDT of Art, Jerusalem Israel*, 25-30 May 2008. On http://www.ndt.net/article/art2008/papers/093Bartuli.pdf.

Bass, G.F.& Frederick H. van Doorninck, Jr, 1982, *Yassi Ada I. A Seventh Century Byzantine Shipwreck*, College Station: Texas A&M University Press.

Bass, George F. and Frederick H. van Doorninck, Jr., 1971, A fourth-century shipwreck at Yassi Ada, *American Journal of Archaeology*, Vol. 75, No. 1. Jan., 27-37

Bass, George F., Sheila Matthews, J. Richard Steffy and Frederick H. van Doorninck Jr., 2004, Serçe Limani. *An Eleventh-Century Shipwreck Vol. 1, The Ship and Its Anchorage, Crew, and Passengers*, Texas A&M University Press.

Bates, Dr. Richard, Martin Dean, Mark Lawrence, Philip Robertson, Fernando Tempera, Sarah Laird, 2007, Innovative approaches to Rapid Archaeological Site Surveying and Evaluation (RASSE). Final Report for English Heritage Project number 3837.

Bekić, Luka & Igor Miholjek (eds), 2009, Exploring Underwater Heritage in Croatia. A Handbook, Zadar.

Belasus, Mike, 2009, Russian gas and a Swedish Ship Barrier of 1715, in: Manders, Martijn, Rob Oosting & Will Brouwers (eds), *MACHU Final Report* 3, Amersfoort, 93-100

Beerepoot, Matthijs, 2012, Identiteitsvorming door de canon. Over het debat rond de identiteitsvormende nevenfunctie van de historische canon van Nederland en de effecten van dit debat op het gebruik van de canon, *scriptie Universiteit Utrecht*.

Bekić, L., Miholjek, L. (eds., 2009,) *Exploring Underwater Heritage in Croatia - A Handbook*. Zadar.

Bergstrand T. & Nyström Godfrey I. (eds), 2007, Reburial and analyses of archaeological remains. Studies on the effect of reburial on archaeological materials performed in Marstrand, Sweden 2002-2005. The RAAR Project. *Kulturhistoriska dokumentationer nr 20*. Bohusläns Museums förlag, Uddevalla.

Berkers, Rob, 2015, *Toeristisch-recreatieve impuls Oostvoornse Meer. Visiedeel - 21/01/2015* - Gemeente Westvoorne.

Beukers, E (ed), 2009, *Erfgoedbalans 2009. Archeologie, monumenten en cultuurlandschap in Nederland*, Rijksdienst voor het cultureel Erfgoed, amersfoort

Beukers, E (ed.), 2011, *De Bosatlas voor de Geschiedenis van Nederland*, Groningen, Noordhoff.

Bijen, Jan, 2003, *Durability of engineering structures. Design, repair and maintenance*. Woodhead Publishing Ltd Cambridge England.

Binford, Lewis R., 1981, Behavioral Archaeology and the "Pompeii Premise". *Journal of Anthropological Research*, Vol. 37, No. 3 (Autumn, 1981), pp. 195-208

Björdal, C.G., Nilsson, T., Daniel, G., 1999, Microbial decay of waterlogged archaeological wood found in Sweden. Applicable to archaeology and conservation. International Biodeterioration & Biodegradation 43, 63 - 71

Björdal, C. G., Nilsson, T., 2008, Reburial of shipwrecks in marine sediments. A long term study on wood degradation. Journal of Archaeological Science 35, 862-872.

Blanchette, R.A., 2000, A review of microbial deterioration found in archaeological wood from different environments. *International Biodeterioration & Biodegradation* 46, 189- 204

Bluszcz, A., 2005, OSL Dating in Archaeology, In: E. Marian Scott, Andrey Yu. Alekseev, Ganna Zaitseva (eds), Impact of the Environment on Human Migration in Eurasia *Volume 42 of the series NATO Science Series: IV: Earth and Environmental Sciences*, 137-149

Boelen, Barbera, 2009, Een erfgoedcommunity voor de onderwaterarcheologie, *bachelors scriptie aan de Reinwardt Academie*, Amersfoort

Bonke, Hans, 2002, Texel en de VOC, In: Vibeke Roeper en Ineke Vonk-Uitgeest (eds) *Schepen op de rede. Texelaars in de Oost. Maritiem en Jutters Museum/Stichting VOC 2002* Texel, 17-41.

Borges, Luísa M.S., Lucas M Merckelbach, Íris Sampaio and Simon M Cragg, 2014, Diversity, environmental requirements, and biogeography of bivalve wood-borers (Teredinidae) in European coastal waters, *Frontiers in Zoology*, 11:13 doi:10.1186/1742-9994-11-13

Bos, A.J.J., Wallinga, J., Johns, C., Abellon, R.D., Brouwer, J.C., Schaart D.R. and Murray A.S., 2006, Accurate calibration of a laboratory beta particle dose rate for dating purposes.
Radiation Measurements 41, 1020-1025.

Bouman, David, 2015, *Eindrapportage van het onderzoek 'Duiken op wrakken. Vrijwilligers in de onderwater Archeologie*, . Maritime Research & Consultancy (MR&C) RDR 2015 157 MR&C

Brand, F.P., P.G.M. Diebels, H. Maurits, W.F.J. Mörzer Bruyns & W. Weber (eds.), 1987, *Plundering, of verrijking van de scheepvaartgeschiedenis? Cahier 1 Voordrachten en discussie, gehouden tijdens een door de Sectie Scheepvaart- en Maritieme Musea van de Nederlandse Museumvereniging georganiseerd symposium op 17 september 1986 in het Rijksmuseum 'Nederlands Scheepvaart Museum' te Amsterdam*, Amsterdam.

Braven, A.den, S. Broekman, M. Huisman,, W. Kemme, M. Mostert, & R. van 't Veer, 2003, *De Buytensorgh: Onderzoek, restauratie, presentatie van een 18e eeuws VOC schip. Unpublished report. Amsterdams Archeologisch Centrum*. University of Amsterdam.

Brenk, Seger van den, 2003, Innovative research at the BZN 10 wreck site. *MoSS Newsletter* 4, 21-23.

Brenk, Seger van den, 2016, ARCHIS waarnemingen waterbodem. Systematische opnamen en monitoring. 5.8 Waarneming 47688 (Vogelzand IV) *Rapport 16A023-01*, Amsterdam

Brenk, S. van den & R. van Lil, 2010, , Monitoring Mosselzaadinvanginstallatie. Gebied Scheurrak, Waddenzee, *Periplus Archeomare Rapport* 10_A003, Amsterdam

Brenk, S. van den & R. van Lil, 2016, Monitoring Mosselzaadinvanginstallaties Burgzand Waddenzee, *Periplus Archeomare rapport* nr 15 A033-01, Amsterdam

Brenk, S. van den & M. R. Manders, 2014, Monitoring Scheepswrakken Burgzand Noord Periode 1998-2013*, Periplus Archeomare/RCE Rapport* 13-A031, Amsterdam

Brenk, S. van den & M. R. Manders, 2015, Monitoring Scheepswrakken Burgzand Noord Periode 1998-2014, *Periplus Archeomare/RCE Rapport* 15A002, Amsterdam

Brenk, van den, S. en Manders, M.R, 2016, Monitoring scheepswrakken Burgzand Noord, periode 1998-2015. Periplus Archeomare/RCE rapport 15A030, Amsterdam

Brenk, S. & Muis, L.A., 2014, Hoge resolutie multibeamopnamen en Fysische metingen Oostvoornsemeer, conceptrapport*, Periplus Archeomare rapport* nr 14A010-01, Amsterdam

Brenk, Seger van den, Remco Romijn & Tine Missiaen, 2003, IMAGO Rapport Prijsvraag en onderzoek Waddenzee. *Eindrapport IMAGO, RDIJ Rapport nr*. 2003-13c, Lelystad.

Brouwers, W., E. Jansma & M. Manders, 2013: Romeinse scheepsresten in Nederland, *ARCHEObrief* 17(4), 13-27

Brouwers, W., E. Jansma & M. Manders, 2015: Middeleeuwse scheepsresten in Nederland: de Vroege Middeleeuwen (500-1050). *ArcheoBrief* 19(3), 6-24

Bruyn, Vincent de, 2010, De paalworm; een historisch literatuuronderzoek naar de paalwormen die de schepen en kaden bedreigden, en de manieren waarop men het houtwerk probeerde te beschermen, *stageverslag & Paper in opdracht van de Particuliere Hogeschool Saxion Next en de Rijksdienst voor het Cultureel Erfgoed*, Deventer/Amersfoort

Bull, J., M. Gutowski, J. Dix, T. Henstock, P. Hogarth, P. White, T. Leighton, 2005, Design of a 3D Chirp sub-bottom imaging system. *Marine Geophysical Researches* 26, 157-169

Burke, Ariane, 2012, Spatial abilities, cognition and the pattern of Neanderthal and modern human dispersals, *Quaternary International,* Volume 247, 9 January, 230–235

Cain, Emily, 1983, *Ghost Ships: Hamilton and Scourge Historical Treasures from the War of 1812,* The Hamilton and Scourge Foundation

Camidge, K., 2009, "HMS Colossus, An experimental Site Stabilization", Conservation and *Management of Archaeological Sites*, vol. 11, no. 2, pp. 161-188.

Caspers, Sabrine, Wim Knol & Henk Kars, 2011, *Richtlijnen voor maatwerk, Onderzoeksrapport project Archeologievriendelijk bouwen & fysiek behoud*, Amsterdam.

Catsambis, Alexis, Ben Ford & Donny L. Hamilton, 2011, *The Oxford Handbook to Maritime Archaeology*, Oxford University Press.

Cederlund, Carl Olof, 2004, The Safeguarding of the paddle steamer E. Nordevall, *MoSS Newsletter* 3/2004. p. 13-15.

Cederlund, Carl Olof, 2006, *Vasa I, The Archaeology of a Swedish Warship of 1628*, Statens maritima museer, Stockholm.

Champion, Sara, E. van Ginkel & A.B. Döbken, 1981*, Archeologische termen en technieken. Alfabetische gids*, Amerongen.

Cleveringa, J. , F. van Vliet, J.H. Bergsma, R.J. Jonkvorst, 2012, Zandwinning op de Zeeuwse banken. Onderzoek naar effecten op ecologische en aardkundige waarden en kostenaspecten, *Rapport Bureau Waardenburg* bv (nr. 11-180), opdrachtgever Rijkswaterstaat Dienst Noordzee.

Coenen, Thijs, Martijn Manders, Barbara Davidde, David Gregory, Yvonne Shashoua, Brian Smith and Jørgen Dencker, 2013, WP. In situ stabilization of underwater archaeological sites, in: David Gregory, Yvonne Shashoua and Anne Marie Eriksen, *SASMAP Progress Report* 2012-2013, 34-51

Coenen, Thijs & Marie-Catherine Houkes, 2014, *Het Oostvoornse Meer onderzocht*
Voorlopige resultaten ten behoeve van Visie OVM, Versie 2.0 17 december.

CPSL, 2010, The role of spatial planning and sediment in coastal risk management. Wadden Sea Ecosystem No. 28. Common Wadden Sea Secretariat, Trilateral Working Group on Coastal Protection and Sea Level Rise (CPSL), *CPSL Third Report*, Wilhelmshaven, Germany.

Cunningham, A.C., M.A.J.Bakker, S. van Heteren, B. van der Valk, A.J.F. van der Spek, D.R. Schaart, J. Wallinga, 2011, Extracting storm-surge data from coastal dunes for improved assessment of flood risk. *Geology* 39, 1063-1066

Daalder, R. E. van Eyck van Heslinga, J.Th. Lindblad, P. Rogaar & P. Schonewille (eds.), 1998, *Goud uit graan. Nederland en het Oostzeegebied 1600-1850*, Amsterdam

Daniel, Geoffrey & Thomas Nilsson, 1998, Developments in the study of soft rot and bacterial decay, In: Alan Bruce et al (eds), *Forest Products Biotechnology*, 37-63.

Davidde, B.,2004, Methods and strategies for the conservation and museum display in situ of underwater cultural heritage. *Archaeologia Maritima Mediterranea*, vol. 1, 136-150

Deacon, H., 2004, 'Intangible Heritage in Conservation Management Planning:
The Case of Robben Island', *International Journal of Heritage Studies* 10, 309–19.

Deeben, J., D.P. Hallewas, J. Kolen & R. Wiemer, 1997, Beyond the Chrystal Ball. Predictive Modelling as a Tool in archaeological Heritage Management and Occupation History, in: W.J.H. Willems, H. Kars & D.P. Hallewas (eds), *Archaeological Heritage Management in the Netherlands. Fifty Years State Service for Archaeological Investigations*, Assen/Amersfoort, 76-118.

Deeben, J., D.P. Hallewas & Th.J. Maarleveld, 2002, Predictive modelling in Archaeological Heritage Management of the Netherlands: the Indicative Map of Archaeological Values (2nd Generation), *Berichten van de Rijksdienst voor het Oudheidkundig Bodemonderzoek* 45, 9-56.

Deeben, J., B. Groenewoudt, D. Halewas, C. van Rooijen & P. Zoetbrood, 2005, Op zoek naar de archeologische voorraad, in: M.H. van den Driesch & W.J.H. Willems (red.): *Innovatie in de Nederlandse archeologie. Liber amicorum voor Roel W. Brandt*, Gouda, 37- 54

Deeben, J.H.C, B.J. Groenewoudt, D.P. Hallewas, C.A.M. van Rooijen & P.A.M. Zoetbrood, 2006, In Search of the Archaeological Resource, in: R.M. Van Heeringen & R.C.G.M. Lauwerier (red.), *Berichten van de Rijksdienst voor het Oudheidkundig Bodemonderzoek*, Volume 46, 113-127.

Deeben, Jos, 2008, Inleiding op de derde generatie van de Indicatieve Kaart van Archeologische Waarden, In: J.H.C. Deeben (ed.): De Indicatieve Kaart van Archeologische Waarden, derde generatie. *Rapportage Archeologische Monumentenzorg* 155, Amersfoort.

Demerre, Ine, 2009, Cooperation with non-archaeological scientific institutes, organisations and individuals, in: Manders, Martijn, Rob Oosting & Will Brouwers (eds.), *MACHU report* No.2, 30-32.

Dienst der Hydrografie, n.y., *HP39 Wrakkenregister Nederlands Continentaal Plat en Westerschelde.*

Dieren, Hille van, 1999, 200 jaar jacht naar goud en zilver, in: Huiskes, Bert & Gerald de Weerdt (eds), *De Lutine 1799-1999. De raadselachtige ondergang van een schip vol goud*, Bussum.

Hootsen, H. and W. Dijkman. 2009. 'Building a Geographical Information System in MACHU ,in: M. Manders, R. Oosting and W. Brouwers (eds), *Machu Final Report* 3. Amersfoort: Managing Cultural Heritage Underwater, 15-30.

Dix, J.K., A. Bastos, R.M.K. Plets, J.M. Bull, and T.J. Henstock, 2006, High resolution sonar for the archaeological investigation of marine aggregate deposits. *English Heritage Aggregate Levy Sustainability Fund Project 3364 Final Report*, www.ads.adhs.ac.uk, 92.

Dix, Justin, Pierre Cazenave, David Lambkin, Tim Rangecroft, Chris Pater & Ian Oxley, 2009, (1): Sedimentation-Erosion Modelling as a tool for Underwater Cultural Heritage Management, in: Manders, Martijn, Rob Oosting & Will Brouwers, *MACHU Final Report*, Nr.3, 48- 54.

Dix, J. & Sturt, F., 2011, *The Relic Palaeo-landscapes of the Thames Estuary. MALSF*, Southampton.

Dongfeng Xie, Shu Gao & Ya Ping Wang, 2008, Morphodynamic modelling of open-sea tidal channels eroded into a sandy seabed, with reference to the channel systems on the China coast, *Geo-Mar Lett*, 28, 255–263

Dudley, Peter & Charles Johns, 2014, Historical Seascape Characterisation South West Peninsula, Section 1 Implementing the Method,. *Historic Environment Projects Cornwall Council. Final Report* 28-1-2014

Duijf, Ane Jan & Thijs Maarleveld, 1999, Archeologisch onderzoek naar het vergaan van de Lutine, in: Huiskes, Bert & Gerald de Weerdt (eds), *De Lutine 1799-1999. De raadselachtige ondergang van een schip vol goud*, Bussum.

Duivenvoorde, Wendy van, 2008, The Batavia shipwreck: an archaeological study of an early seventeenth-century Dutch East Indiaman, *Dissertation Texas A&M University*.

Dunkley, Mark, 2008, *Hazardous, Bracklesham Bay, West Sussex, Conservation Statement & Management Pla*n, EH.

Dunckley, Mark, 2015, 'Climate is what we expect, weather is what we get'. Managing the potential effects of oceanic climate change on underwater cultural heritage, in: Willems, Willem & Henk van schaik, *Water & Heritage. Material conceptual and spiritual connections,* Side Stone Press, 217-231

Duran-Matute, M., T. Gerkema, G. J. de Boer, J. J. Nauw, and U. Gräwe, 2014, Residual circulation and freshwater transport in the Dutch Wadden Sea: a numerical modelling study. *Ocean Science*, 10, 611–632.

Duren, Luca van, Han Winterwerp, Bram van Prooijen, Herman Ridderinkhof & Albert Oost, 2011, Clear as Mud: understanding fine sediment dynamics in the Wadden Sea – Action Plan, October

Edwards, Kevin & Darren Cooper, 2013, Digitizing 'Xantho': Notes on a project to digitally record an assemblage of complex engine components from a 19th-century steamship [online]. *AIMA Bulletin*, Vol. 37, Nov, 42-47

Eelkema, M., Z.B. Wang and M.J.F. Stive,2012), Impact of back-barrier dams on the development of the ebb-tidal delta of the Eastern Scheldt. *Journal of Coastal Research*, 28 (6), 1591-1605.

Eelman, C.J., 1986, Zoeken en vinden, in: *knob, Verantwoord onder water*, Amsterdam, 3-9.

Eelman, H., 2002, Een schip vergaat twee maal. Onderwaterarcheologie op de Rede van Texel, in: V. Roeper & I Vonk-Uitgeest (eds): *Texel en de VOC: schepen op de Rede, Texelaars in de Oost, Texel,* 136-146

Elam, Michael L., 2009, Pacific Northwest Aquatic Invasive Species Profile
Great Naval Shipworm Teredo navalis, *Fish* 423 [accessed on 21-1-2016 at: http://depts.washington.edu/oldenlab/wordpress/wp-content/uploads/2013/03/Teredo-navalis_Elam.pdf]

Elias, E.P.L., A.J.F. Van der Spek, Z.B. Wang & J. de Ronde, 2012, Morphodynamic development and sediment budget of the Dutch Wadden Sea over the last century. *Netherlands Journal of Geosciences – Geologie en Mijnbouw*, 91.3, 293 - 310.

English Heritage, 2005, *English Heritage Strategy 2005-2010 'Making the Past Part of Our Future'*, [online] available at: https://historicengland.org.uk/images-books/publications/eh-strategy-2005-2010/ [Accessed 29-1-2016]

Erdbrink, D.P., 1950, Stenenvelden in de Noordzee, *Publicatie van de Nederlandse Geologische Vereniging,* vol 2, nr. 8, 44-49.

Erfgoedinspectie, April 2010, Zoek! E*en zoektocht naar de rapporten van opgravingen 2003-2006*, 9.

Erfgoedinspectie, 2012, *Grenzen overschreden? Onderzoek naar onrechtmatig handelen op de gebieden van archeologie en archieven*, Erfgoedinspectie Den Haag.

Ernstsen, Verner B., Riko Noormets, Dierk Hebbeln, Alex Bartholomä, Burg W. Flemming, 2006, Precision of high-resolution multibeam echo sounding coupled with high-accuracy positioning in a shallow water coastal environment, *Geo-Marine Letters*, September 2006, Volume 26, Issue 3, 141-149.

Evans, A.M., A. Firth & M. Staniforth, 2009, Old and New Threats to Submerged Cultural Landscapes: Fishing, Farming and Energy Development, *Conservation and Management of Archaeological Sites* 11.1: 44–54

Farina, Almo, Jan Bogaert, Ileana Schipani, 2005, Cognitive landscape and information: new perspectives to investigate the ecological complexity, *BioSystems* 79 (2005) 235–240.

Fitch, Simon, Vince Gaffney and Ken Thomson, 2007, *In Sight of Doggerland: From speculative survey to landscape exploration*: http://intarch.ac.uk Last updated: Wed May 23 2007

Fonseca, Mark S., W. Judson Kenworthy, and Gordon W. Thayer, 1998, Guidelines for the Conservation and restoration of Seagrasses in the United States and adjacent waters, *Science for solutions, NOAA's coastal ocean program, Decision Analysis Series* No. 12, NOAA.

Fontijn, David, 2017, Erfgoedkrentenwegers, in: Mark Geels & Tim van Opijnen: *Nederland in Ideeën. Waar verzet jij je tegen? 101 wetenschappers, ondernemers en kunstenaars geven antwoord op de vraag van Anton Corbijn*, 203-206.

Fors, Y., 2005, *Sulfur speciation and distribution in the Vasa's wood, Licentiate thess, Department of Structural chemistry*, Stockholm University

Frost, Honor, 1964, Diggings in The Deep, *Saudi Aramco World*, Volume 15, Number 6, 28-32 [accessed through: http://www.saudiaramcoworld.com/issue/196406/diggings.in.the.deep.htm, 7-9-2014].

Gaffney, Vincent, Kenneth Thomson and Simon Fitch (eds) 2007 (1), *Mapping Doggerland. The Mesolithic Landscapes of the Southern North Sea. A project funded by the Aggregates Levy Sustainability Fund and administered by English Heritage.*

Gaffney, V., K. Thomson & S. Fitch (eds), 2007 (2), *Mapping Doggerland: The Mesolithic Land surfaces of the Southern North Sea. Archaeopress* (Oxford).

Gaffney, V., S. Fitch, E. Ramsey & E. Kitchen, 2011, West Coast Paleolandscapes
Survey (Main Project). English Heritage and Welsh Assembly Government.
Available at http://www.cambria.org.uk/lostlandscapes/WCPStechnical.pdf [accessed 14 January 2014]

Gelbrich, Jana, 2008, *Bacterial wood degradation – A study of chemical changes and growth conditions obacteria, Dissertation,* Universität Göttingen, Göttingen.

Gelbrich , Jana, Hans Huisman, Ev Kretchmar, Rene Klaassen, Herman Keijer, Norbert Lamersdorf, 2005, Chapter 3. Sample Sites, In: Rene Klaassen (ed) , Preserving cultural heritage by preventing bacterial decay of wood in foundation poles and archaeological sites. *BACPOLES, final report EVK4-CT-2001 – 00043.*

Gelbrich, Jana, Carsten Mai & Holger Militz, 2008, Chemical changes in wood degraded by bacteria, *International Biodeterioration and Biodegradation* 61, 24-32

Gibbs, M., 2006, Cultural Site Formation Processes in Maritime Archaeology: Disaster Response, Salvage and Muckelroy 30 Years on. *The International Journal of Nautical Archaeology* 35 (1): 4-19.

Gjelstrup Björdahl, Charlotte & Thomas Nilsson, 2007, Appendix 4. Reburial experiment in the harbour of Marstrand. Degradation of wood.Bergstrand, Thomas & Inger Nyström Godfrey, *Reburial and analyses of archaeological remains. Studies on the effect of reburial on archaeological materials performed in Marstrand, Sweden 2002-2005. The RAAR project.*

Gjelstrup Björdahl, Charlotte & David Gregory (eds),2011, *WreckProtect. Decay and protection of archaeological wooden shipwrecks,* Oxford.

Gjelstrup Björdahl, Charlotte & David Gregory, 2011, 1. Introduction, in: Gjelstrup Björdahl, Charlotte & David Gregory (eds*), WreckProtect. Decay and protection of archaeological wooden shipwrecks*, 3-7.

Gonzalez, Jesus Vincente, 2015, The ghost wreck off Siboney Beach, *Culture & Development* 13 , 62-68.

Goudswaard, B., 2000, The Late Roman Bridge at Cuijk, *Proceedings of the National Service for Archaeological Heritage in the Netherlands,* ROB Volume 44

Goudswaard, B., 2006, Archeologie in de Betuweroute: Malta in de maak: archeologisch management tijdens het Betuwerouteproject. *Rapportage Archeologische Monumentenzorg* 101. NS/ROB, Utrecht/Amersfoort

Gould, Richard A. (red), 1983, *Shipwreck anthropology*, University of New Mexico Press, Albuquerque.

Graham, Brian J., Peter Howard, 2008 , Heritage and Identity. Introduction, In: Brian J. Graham, Peter Howard (Eds*): The Ashgate Research Companion to Heritage and Identity*, Ashgate Publishing, Ltd, 1-15.

Green, E.L., (ed.), 1984, *Ethics and Values in Archaeology*, New York.

Gregory, D.J., 1999, Re-burial of timbers in the marine environment as a means of their long-term storage: experimental studies in Lynæs Sands, Denmark, *TheInternationalJournalofNauticalArchaeology,* 27:4, 343 - 358.

Gregory, David, 2004 (1), Data loggers, *MoSSNewsletter* 2/2004, 8-9

Gregory, David 2004 (2), Degradation of Wooden Shipwrecks: Threats, *MoSSNewsletter* 2,Monitoring,4-5

Gregory, D., 2004 (3), Monitoring wooden shipwrecks: monitoring the Burgzand Noord 10 and Darss Cog using the WauxSys data logger. In: Cederlund, C.O. (ed.), *FinalReport[oftheMOSSproject]*, The National board of antigquities Helsinki, Finland, pp. 38 – 48

Gregory, David, 2009, Out of Sight but Not Out of Mind, in: Richards, Vicki & Jennifer McKinnon, Public,*InSituConservationofCultural Heritage:Public,ProfessionalsandPreservation*, Flinders University Program in Maritime Archaeology, 1-17.

Gregory, D., P. Jensen, H. Matthiesen & K. Strætkvern, 2007, The correlation between bulk density and shock resistance of waterlogged archaeological wood using the Pilodyn. Studies in Conservation, 52, 289-298.

Gregory, D., R. Ringgaard & J. Dencker, 2008, From a grain of sand a mountain appears. Sediment transport and entrapment to facilitate the in situ stabilisation of exposed wreck sites. Maritime Newsletter from Denmark, Syddansk Universitet. 23, 15-23.

Gregory, D. & M. Manders (eds), 2016, Best practices for locating, surveying, assessing, monitoring and preserving underwater archaeological sites, SASMAP Guideline Manual 2

Gregory, David, Yvonne Shashoa & Anne Marie Eriksen (eds), 2013, SASMAP Collaborative Research Project. Development of tools and techniques to Survey, Assess, Stabilise, Monitor And Preserve underwater archaeological sites, *Progress2012-2013*, SASMAP consortium, Copenhagen.

Grenier, Robert, David Nutley & Ian Cochran (eds), 2006, *HeritageatRisk–SpecialEdition-UnderwaterCulturalHeritageatRisk,*Icomos, Paris.

Grosser, D., 1985, *Pflanzliche und tiersche Bau- und WerkholzSchädlinge*.DRW-Verlag,Leinfelden-Echterdingen.

Gupta, S., J. Collier, A. Palmer-Felgate, J. Dickinson, K. Bushe & S. Humber, 2004, Submerged Palaeo-Arun River: *Reconstructionof PrehistoricLandsurfacesandEvaluationofArchaeologicalResourcePotential.IntergratedProjects1and2*. Imperial College (London).

Habermehl, Nico, 2000, *ScheepswrakkenindeWaddenzee(1500–1900*),Lelystad.

Halderen, Lidia van, 2005, Vergelijking tussen de interpolatiemethodes DIGIPOL, SURFIS en KRIGING. *StageverslagRijkswaterstaat MinisterievanVerkeerenWaterstaat,* Rapportnummer AGI-2005-GPMP-015, 20 juni.

Hamer, Mick, 2002, Ships wrecked, *NewScientist,* 5 October, 38-40

Hamersveld, Ineke van (Red.), 2009, *CulturalPolicyintheNetherlands*, edition 2009, The Hague/Amsterdam.

Hamilton, Donny L., 1997, Basic Methods of Conserving Underwater Archaeological Material Culture

Hansen, H., 1986 (1), voc-wrakken wachten niet op archeologen, *deVolkskrant* 26-5-86.

Hansen, H., 1986 (2) Dieper duiken in wrak Amsterdam, *deVolkskrant* 23-6-86.

Hansen, H., 1986 (3), Scheepswrak bij Texel wordt stukje bij beetje blootgelegd,*deVolkskrant*1-8-86.

Hansen, H., 1986 (4), Zeeuwse oudheden onder water bedreigd, *deVolkskrant* 23-8-86.

Hansson, Jim, 2009, How does scuba diving affect our wrecks? In: in: Manders, Martijn, Rob Oosting & Will Brouwers (eds*),MACHU FinalReport* 3, Amersfoort, 90-94.

Harvey, P., 1996, A review of stabilisation works on the wreck of the William Salthouse in Port Phillip Bay. *BulletinoftheAustralasian InstituteforMaritimeArchaeology*, 20(2), 1-8.

Heide, T. van der, M.M. Van Katwijk & G.W. Geerling, 2006, *EenverkennningvandegroeimogelijkhedenvanondergedokenGrootzeegras (Zosteramarina)indeNederlandseWaddenzee,* Rijkswaterstaat (RWS)/Rijksinstituut voor Kust en Zee (RIKZ).

Heldtberg, M., I.D. MacLeod & V.L. Richards, 2004, Corrosion and cathodic protection of iron in seawater: a case study of the James Matthews (1841), *ProceedingsofMetal2004,NationalMuseumofAustraliaCanberra* ACT 4-8 October, 75-87.

Hendriksma, Martin, 2013, *Lutine.Despannendsegoudjachtooit*,Breda.

Hessing, W.A.M., K. Klerks, W.J. Weerheijm, 2013, VESTIGIA Archeologie & Cultuurhistorie, rapport V984 definitieve versie 2.0, d.d. 17 januari 2013. *ToelichtingbijdeArcheologischeBeleidskaartvandeGemeenteTexel,* Geactualiseerde versie 2013.

Heteren, S. van, J.A.C. Meekes, M.A.J. Bakker, V. Gaffney, S. Fitch, B.R. Gearey & B.F.Paap, B.F., 2014, Reconstructing North Sea palaeolandscapes from 3D and highdensity
2D seismic data: an overview. *NetherlandsJournalofGeosciences*,31-42

Holk, André van, 2003, The interpretation of the artefactual remains from the wreck site BZN 10,*MoSSNewsletter* 4, 8-12.

Holk, André van, 2009, Scheepswrak gedetecteerd met geofysische technieken, Paleo-Aktueel 20, 111.

Holmes, R.L., 1983, Computer-assisted quality-control in tree-ring dating and measurement. Tree-Ring Bulletin 43, 69 - 78

Holt, D.M., & E.B. Jones, 1983, Bacterial degradation of lignified wood cell walls in anaerobic aquatic habitats.*ApplEnvironMicrobiol*. 46(3), 722-727

Hootsen, Herman & Wim Dijkman, 2009, Building a Geographic Information System in MACHU, *MachuFinalReport* Nr.3, Amersfoort, 16-31.

Horsten, Theo, Johan Hos & H. Klein, 1979,*EncyclopedievandeZeilvaart* (Dutch edition of the Nautical Terms Under Sail publication (1978, London), Bussum

Hosty, K., 1988, Bagging the William Salthouse: site stabilization work on the William Salthouse. *BulletinoftheAustralasianInstitute for Maritime Archaeology*, 12(2), 1988, 13-16.

Houkes, M.C., n.y., *Erfgoed,waterbodemsenhetbestemmingsplan*, Rijksdienst voor het Cultureel Erfgoed, Amersfoort.

Houkes, M.C., S. van den Brenk, R. van Lil, M. Manders, 2014, *HetMarkermeerenIJmeerinbeeld,Deontwikkelingvaneenhistorisch geomorfologischekaartensetvoordewaterbodem* , Rijksdienst voor het Cultureel Erfgoed, Amersfoort

Houkes, M.C. & S. Caspers, 2013, *Herkennenvanarcheologischevondstenuitwaterbodems*, Rijksdienst voor het Cultureel Erfgoed, Amersfoort.

Huiskes, Bert & Gerald de Weerdt (eds), 1999, *DeLutine1799-1999.Deraadselachtigeondergangvaneenschipvolgoud*, Bussum.

Huisman, D.J., 2005, Chapter 7. Erosion bacteria and sulphur, in: Klaassen, Rene, *BACPOLESFinalReportEVK4-CT-2001-00043*, Wageningen, 198-202

Huisman, D.J., R.K.W.M. Klaassen , 2005, Variations in wood degradation in in three roman oak ships from the Netherlands. In: Hoffmann, P., S. Straetkvern, J.A. Spriggs, D. Gregory (eds.), *Proceedingsofthe9thICOM-WOAMconference* , Copenhagen, 2004, ICOM-WOAM, Bremerhaven, pp. 145 - 169

Huisman, D.J., M.R. Manders, E. Kretschmar, R.K.W.M. Klaassen & N. Lamersdorf, 2008, Burial conditions and wood degradation on archaeologicalsitesintheNetherlands.*InternationalBiodeteriorationandBiodegradation*61,33-44.

Huisman, D.J., 2009 (1), Iron In: D.J. Huisman,*Degradationofarchaeologicalremains* , SdU, Den Haag.

Huisman, D.J., 2009 (2), Where does it all start? The origin of reduced sulfur species in archaeological wood, In: K. Straetkvern & D.J. Huisman, 2009, Proceedings of the 10th ICOM Group on Wet Organic Archaeological Materials Conference, Amsterdam 2007, *NederlandseArcheologischeRapporten(NAR)*37, RACM, Amersfoort, 577 - 588
ICOMOS, 2002, International Cultural Tourism Charter.*PrinciplesAndGuidelinesForManagingTourismAtPlacesOfCulturalAnd Heritage Significance*. ICOMOS International Cultural Tourism Committee.

IMAGO, 2002, Rapport Informatiestrategie.*RDIJrapport* nr. 2002-5, Lelystad.

IT IS, 2007, *IntegratedTaxonomicInformationSystem* (http://www.itis.gov/), [accessed 18-1-2016]

Jacobs, Els M., 1996, Hoofdstuk III. De grootste multinational van de zeventiende eeuw. In: Drechsel, Willem (ed): *VarennaardeOost. In het kielzog van de Oost-Indiëvaarders*, Rijswijk, 31-47.

Jansma, E., K. Haneca & M. Kosian, 2014, A dendrochronological reassessment of three Roman boats from Utrecht (the Netherlands). *JournalofArchaeologicalScience* 50, 584-596.

Jessurun, J., 1991, Scheepsarcheologie en monumentenzorg, in: R. Reinders & R. Oosting (eds.), Scheepsarcheologie: prioriteiten en lopendonderzoek.*InleidingengehoudentijdensdeGlavimanssymposia1986en1988*, Lelystad (Flevobericht, 322), 19-21.

Jones, Siân, 1997, *Thearchaeologyofethnicity:constructingidentitiesinthepastandpresent,*Routledge London & New York.

Jöns, Hauke, 2004, Safeguarding the Darsser Cog, *MoSSNewsletter* 3, 8-11.

Jörg, C.J.A., 1986: *TheGeldermalsen.HistoryandPorcelain*,Groningen.

Kaeser, Adam J. & Thom L. Litts, 2013, *Anillustratedguidetolow-cost,sidescansonarhabitatmapping.* Version 1.0 April..

Kamermans, Pauline, Marnix Poelman, Erik Meesters, Ilse De Mesel, Cor Smit & Sophie Brasseur, 2008, Onderzoek naar Duurzame Schelpdiervisserij(PRODUS)*Eindrapportdeelproject1cAlternatievemosselzaadwinningmetMosselZaadInvangsystemen:variatiein zaadinvang en effecten van MZI's op het ecosysteem,* Rapport C075/08.

Kaslegard, Anne S., 2011, *ClimateChangeandCulturalHeritageintheNordicCountries*, Nordic Council of Ministers, Copenhagen.

Kasten, Sabine & Bo Barker Jørgensen, 2000, Sulfate Reduction in Marine Sediments, in: Schulz, Horst D. and Zabel, Matthias (eds), *MarineGeochemistry*, Springer Berlin Heidelberg, 263-281

Keers, Geurt, Hans van der Reijden & Hans van Rossum, 2011, *Conceptrapport.Ruimtevoorarcheologie.Themaveldrapportages evaluatieWamz*.

Kelly, Robert L. & David Hurst Thomas, 2012, *Archaeology*,6thEdition,WadsworthPublishing.

Kiden, P., B. Makaske & O. van de Plassche, 2008, Waarom verschillende zeespiegelreconstructies voor Nederland? *Grondbooren hamer*62.

Kingsley, Sean A., 2009, Deep-Sea Fishing Impacts on the Shipwrecks of the English Channel & Western Approaches, *OddyseyPapers*4.

Kingsley, Sean A., 2012, *Out of Sight, Out of Mind? Fishing & Shipwrecked Heritage*, Wreck Watch Int., London UK.

Klaassen, R.,(ed.), 2005, Preserving cultural heritage by preventing bacterial decay of wood in foundation poles and archaeological sites.*BACPOLES, final report EVK4-CT-2001 – 00043*.

Klaassen, Rene, 2005, Chapter 6. Water flow experiment, in: Klaassen,R.,(ed.), Preserving cultural heritage by preventing bacterial decayofwoodinfoundationpolesandarchaeologicalsites. *BACPOLES, final report EVK4-CT-2001 – 00043*, 184-198.

Klaassen, Rene´ K.W.M., 2008, Water flow through wooden foundation piles: A preliminary study, *International Biodeterioration & Biodegradation* 61,2008 61–68

Kleij, Piet, 1991, *OnderwaterarcheologierondTexel:eenschatkameronderdezeespiegel*. Stichting Texels Museum.

Kleij, P., 1993, Oostvoornsemeer Zuidoever: een Straatvaarder voor Rotterdam,in: Reinder Reinders & André van Holk (eds), *Scheepslading.InleidingengehoudentijdenshetzesdeGlavimanssymposionRotterdam*,april1992,44-56

Knaw, 1985, *Rapportvandecommissienormenonderzoekscheepswrakken*, Amsterdam.

Knob, 1986, *Verantwoordonderwater*, Amsterdam.

Koeveringe, Yuri van, Martijn Manders & Johan Opdebeeck, 2011, *100xTexelMaritiem*, Uniepers Hoorn.

Kosian, Menne, 2009, Historic Maritime Maps in GIS. Gising dead-reckoning, in: Manders, Martijn, Rob Oosting, Will Brouwers (eds.*), MACHUreport* 2, January, 26-28.

Kosian, Menne, 2013, Het vergelijken van historische zeekaarten in GIS, *Geo-Info* 2013-6, 4-9.

Kragtwijk, N.G., T.J. Zitman, M.J.F. Stiveb & Z.B. Wang, 2004, Morphological response of tidal basins to human interventions, *Coastal Engineering*. 51, 207–221

Kroes, R.A.C., M.R. Manders & I.A. Schute, 2013, Scheepswrak Hindeloopen 3, Gemeente Nijefurd; archeologisch vooronderzoek: een inventariserend veldonderzoek onder water, waarderende fase, *RAAP-Rapport* 2703 (Herziene versie).

Kuijper, Wim & Martijn Manders, 2009 (2011), Coffee, cacao and sugar cane in a shipwreck at the bottom of the Waddenzee,the Netherlands, in: Corrie Bakels & Hans Kamermans (eds), *AnalectaPraehistoricaLeidensia* 41, Leiden University, 73-87

KustMail, 2007, year 6, nr. 5 October

Lambert, David, Luciana Martins, Miles Ogborn, 2006, Currents, Visions and Voyages: Historical Geographies of the Sea, *Journalof HistoricalGeography* 32, 479 – 493

Landy, Eleanor T., Julian I. Mitchell, Sarah Hotchkiss, Rod A. Eaton, 2008, Bacterial diversity associated with archaeological waterlogged wood: Ribosomal RNA clone libraries and denaturing gradient gel electrophoresis (DGGE*),InternationalBiodeteriorationand Biodegradation*61, 106-116

Lane, C.E.,1959, Some aspects of the general biology of Teredo. pp. 137-144 in: Ray D.L. (Ed.) *MarineBoringandFoulingOrganisms*. UniversityofWashingtonPress,Seatle.

Lanen, R.J. van, M. Kosian, B. Groenewoudt, M. Spek & E. Jansma, 2015 (1): Best travel options: modelling Roman and early-medieval routes in the Netherlands using a multi-proxy approach. *JournalofArchaeologicalScience:Reports* 3,144-159.

Lanen, R.J. van, M. Kosian, B. Groenewoudt & E. Jansma, 2015 (2), Finding a way - modelling landscape prerequisites for Roman and early-medieval routes in the Netherlands. *Geoarchaeology*. Doi:10.1002/gea.21510.

Lauwerier, R.C.G.M., & R.M. Lotte (eds.), 2002, *Archeologiebalans*2002, Amersfoort.

Leeuwen, S.J. van, M.-J. Bogaardt & F.G. Wortelboer, 2008, Noordzee en Waddenzee: natuur en beleid Achtergronddocument bij de Natuurbalans,*PBLRapport* 500402013/2008

Lennon, John & Malcolm Foley, 2006, *Darktourism.Theattractionofdeathanddisaster* , Thomson Learning.

L'Hour, M., L. Long & E. Rieth, 1990, The wreck of an "experimental" ship of the "Oost-Indische Companie": the Mauritius (1609) , *The international journal of nautical archaeology and underwater exploration*, ISSN 0305-7445, vol. 19, 63-73

Lipe, W.D., 1974: A Conservation Model for American Archaeology, *TheKiva*39,213-243.

Llop, Maria & Josep M. Arauzo Carod, 2008, Economic Impact Of A New Museum On The Local Economy: "The Gaudí Centre", Document de treball n° -9.

Lomdahl, Andrea, n.y.,*UnderwaterShipwreckDiscoveryTrail,developedbytheVictoriaArchaeologicalSurvey* .

Lüth, Friedrich & Kathrin Staude, 2009, The Greifswald ship barrier. Management of Change, in: Manders, Martijn, Rob Oosting & Will Brouwers (eds), *Machureport* Nr.2, January, 32-34.

Maarleveld, Th.J., 1982, 1981. *EenjaararcheologieinNederlandsewateren*,Rijswijk.

Maarleveld, Th.J., 1983, 1982. *EentweedejaararcheologieinNederlandsewateren*,Rijswijk.

Maarleveld, Th.J., 1984, 1983. *DerdejaararcheologieinNederlandsewateren*,Rijswijk.

Maarleveld, TH.J., 1988, Texel - Burgzand III : een scheepswrak met bewapening, in : W.A. van Es.H. Sarfatij en P.J. Woltering; *ArcheologieinNederland.Derijkdomvanhetbodemarchief.*Amsterdam, Amersfoort, 189-191

Maarleveld, Th.J., 1993 (1), Aanloop Molengat of lading als aanleiding, in: R. Reinders & A. van Holk (eds.), *Scheepsladingen*,Groningen, 32-44.

Maarleveld, Th.J., 1993 (2), Between Frugality and Eclecticism. Some Thoughts on the Management of an Archaeological Cornucopia, *TheBulletinoftheAustralianInstituteforMaritimeArchaeology* 17/2, 31-36.

Maarleveld, Th.J., 1995, Environmental Factors in Underwater Cultural Heritage Management. A Refl ection on the Dutch Situation, in: O. Olsen, J. Skamby Madsen & F. Rieck (eds.),*Shipshape*. Essays for Ole Crumlin-Pedersen, Roskilde, 313-328.

Maarleveld, Th.J., 1998,*ArchaeologicalheritagemanagementinDutchwaters:exploratorystudies*,Lelystad.

Maarleveld, Thijs J., 2003, Predictive assessment as a tool in Dutch maritime heritage management, *BulletinoftheAustralasian InstituteforMaritimeArchaeology* 27, 121-134.

Maarleveld, Thijs & Alice Overmeer, 2012, Aanloop Molengat. Maritime archaeology and intermediate trade during the Thirty Years' War, *JournalofArchaeologyintheLowCountries* 4-1 (October 2012), 95-150.

Maarleveld, Th.J., U. Guérin & B. Egger (eds.), 2013, *ManualforActivitiesdirectedatUnderwaterCulturalHeritage.AguideontheRules annexedtotheUNESCO2001ConventionontheProtectionoftheUnderwaterCulturalHeritage.* Paris, UNESCO.

MacLeod, I.D. & C. Kenna, 1990, Degradation of archaeological timbers by pyrite: oxidation of iron and sulphur species In: Hoffmann, P.(ed.),*Proceedingsofthe4thICOMgrouponWetOrganicArchaeologicalMaterial,*Bremerhaven. pp. 133 - 142

Mainberger, Martin, 2007, *Ein historisches Schiffswrack vor Niederzell, Insel Reichenau.*http://www.bodensee-ufer.de/Reichenau-MM-Marz07.pdf

Mainberger, M, B. Dieckmann, D. Bibby & M. Steffen, 2011, *Entscheidung für Option 5: Ein Schiffswrack vor der Insel Reichenau wird tiefergelegt. Archäologische Ausgrabungen in Baden-Württemberg*, 305 – 309

Manders, Angela, 2009, MACHU – An outreach initiative. Buckets full of stories, lost below the surface and found again, in: Manders, Martijn,RobOosting&WillBrouwers,*MachuReport*Nr. 2, Amersfoort

Manders, Martijn, 2003 (1), 'Preliminary results of the investigation into the ship construction of the BZN 10 wreck', *MoSSNewsletter* 4, 6-8.

Manders, Martijn R.,2003 (2), The mysteries of a Baltic trader, In: Beltrame, Carlo (ed): Boats, ships and shipyards. *Proceedingsofthe ninthISBSA*,. 320-328

Manders, Martijn, 2004 (1) 'Why do we safeguard shipwrecks?', *MoSSNewsletter* 3,4-6.

Manders, Martijn, 2004 (2), 'The Safeguarding of BZN 10', *MoSSNewsletter* , 3, 6-8.

Manders, Martijn, 2004 (3), Safeguarding a site: the Master-Management Plan, MoSS Newsletter 3/2004, 16-20

Manders, M.R. & F. Lüth, 2004, Safeguarding, In: Cederlund, C.O. (ed.), *MoSSprojectFinalReport*,TheNationalboardofantiquities Helsinki, Finland, 63 - 70

Manders, M.R., W.M. Chandraratne, A.M.A. Dayananda, R. Muthucumarana, K.B.C. Weerasena, K.D.P. Weerasingha, 2004, 'The physical protection of a 17th century VOC shipwreck in Sri Lanka', *CurrentScience*, 86, 9, 2004, 101-107

Manders, Martijn, 2005 (1), Site 12. Burgzand Noord 15 (BZN 15) wreck, Wadden Sea, The Netherlands, in: Klaassen, Rene (ed): *BACPOLESFinalreport.* Eight appendices belonging to the final report, Wageningen, 45-55.

Manders, Martijn, 2005 (2), Site 13. Burgzand Noord 3 (BZN 3) wreck, Wadden Sea, The Netherlands, in: Klaassen, Rene (ed): *BACPOLESFinalreport*. Eight appendices belonging to the final report, Wageningen, 55-64.

Manders, Martijn, 2006 (3), Fysieke beschermingsmaatregelen onderwater van palengebied 6000 in Cuijk *BRAM13*, RACM.

Manders, M.R. & Th.J. Maarleveld, 2006, Managing the Maritime Heritage under Water.Thechoicesweface.*BerichtenvandeRijksdienstvoorhetBodemkundig Onderzoek*46, 127-141

Manders, M.R., 2006(1), The in situ protection of a 17th century trading vessel in the Netherlands, in: Robert Grenier, David Nutley & Ian Cochran (eds); *HeritageatRisk–SpecialEdition-UnderwaterCulturalHeritageatRis*k, 70-72.

Manders, M.R., 2006 (2), The in situ protection of a Dutch colonial vessel in Sri Lankan Waters, in: Robert Grenier, David Nutley & Ian Cochran (eds); Heritage at Risk –Special Edition- Underwater Cultural Heritage at Risk , 58 – 60.

Manders, Martijn & Palitha Weerasinghe, 10. Protecting the Avondster. In: Parthesius (ed.): Excavation Report of the VOC ship Avondster, *CentreforInternationalHeritageActivities,SpecialPublication*No.1, 2007, 157-171.

Manders, Martijn, David Gregory & Vicki Richards, 2008, The in situ preservation of archaeological sites underwater: an evaluation of some techniques, in: Eric May, Mark Jones, Julian Mitchel (eds): *HeritageMicrobiologyandScience.Microbes,MonumentsandMaritime Materials,* The Royal Society of Chemistry, 179-204

Manders, Martijn 2009 (1), Chirp and Sonar, In: Manders, Martijn, Will Brouwers & Rob Oosting (eds.), *FinalMACHUReport* Nr. 3, 71

Manders, Martijn, 2009 (2), Multibeam recording as a way to monitor shipwreck sites, in: Manders,Martijn, Will Brouwers, Rob Oosting (eds.),*FinalMACHUReport,* November 2009, 59-68.

Manders, Martijn, Rob Oosting & Will Brouwers (eds) 2009 (1), *MACHUreport* Nr. 2, Amersfoort.

Manders, Martijn, Rob Oosting & Will Brouwers (eds) 2009 (2), *MACHU final report* Nr. 3, Amersfoort.

Manders, Martijn, Bertil van Os, Jakob Wallinga, 2009 (1), Investigating sediment dynamics in and around shipwrecks. Combining optical dating, grain size analyses and chemical proxies. In: Manders, Martijn , Rob Oosting, Will Brouwers (eds), *MACHUreport*Nr.2, 40-43.

Manders, Martijn, Bertil van Os & Jakob Wallinga, 2009(2), Optical dating: potentially a valuable tool for underwater cultural heritage management. In: Manders, Martijn, Will Brouwers & Rob Oosting (eds.), *FinalMACHUReport*, 2009, 40-48.

Manders, M. & B. van Tilburg, 2010, Een visie voor het maritieme erfgoed, Amersfoort.

Manders, Martijn (ed), 2011, *Guidelinesforprotectionofsubmergedwoodenculturalheritage* , WreckProtect, Amersfoort.

Manders, Martijn & Vincent de Bruyn, 2011, 8.2. Shipworm: an old story of trouble, In: Gjelstrup Björdahl, Charlotte & David Gregory (eds),*WreckProtect.Decayandprotectionofarchaeologicalwoodenshipwrecks* , Oxford, 82-88

Manders, Martijn , 2012 (1) , *UitvoeringsprogrammaMaritiemProgramma2012-2015,internalreportRCE*, amersfoort.

Manders, Martijn R., 2012 (2), Unit 4. Underwater Archaeological Resources, In: Manders, Martijn R. & Christopher J. Underwood (eds), *TrainingManualfortheUNESCOFoundationCourseontheProtectionandManagementofUnderwaterCulturalHeritageinAsiaandt he Pacific,* UNESCO Bangkok.

Manders, Martijn R., 2012 (3), Appendix E. Management Plan, In: Manders, Martijn R. & Christopher J. Underwood (eds), *TrainingManual for the UNESCO Foundation Course on the Protection and Management of Underwater Cultural Heritage in Asia and the Pacific,* UNESCO Bangkok.

Manders, Martijn R., Hans K. Van Tilburg & Mark Staniforth, 2012, Unit 6 Significance Assessment, in: Martijn R. Manders & Christopher J. Underwood, *TrainingManualfortheUNESCOCourseontheProtectionandManagementofUnderwaterCulturalHeritageinAsiaand the Pacific,* UNESCO, Bangkok.

Manders, Martijn R. & Christopher J. Underwood, 2012, Unit 17, Public Archaeology, Raising Awareness and Public Participation Projects in Underwater and Maritime Archaeology, in: Martijn R. Manders & Christopher J. Underwood,*TrainingManualfortheUNESCO Course on the Protection and Management of Underwater Cultural Heritage in Asia and the Pacific,* UNESCO Bangkok.

Manders, Martijn, 2013, Ons erfgoed? Mijn erfgoed? In: Mark Geels & Tim van Oppijnen (eds), *NederlandinIdeeën.101denkersover inzichteneninnovatiesdieonslandverander(d)en,* Amsterdam.

Manders, M, S. van den Brenk & M. Kosian ,2014, *DegelaagdegeschiedenisvandeWestelijkeWaddenzee.HistorischGeo-Morfologische KaartensetvandeWaddenzee,* Rijksdienst voor het Cultureel Erfgoed, Amersfoort, 2014

Manders, Martijn & Wim Kuijper, 2015, Shipwrecks in Dutch Waters with Botanical Cargo or Victuals in: Bakels, Corrie & Hans Kamermans (eds.). *AnalectaPraehistoricaLeidensia* 45. Leiden, Leiden University Press, 141-173.

Manders, Martijn, 2015 (1), The invisible treasures of the past, in: Monique H. van den Dries, Sjoerd van der Linden & Amy Strecker, *Fernweh.Crossingbordersandconnectingpeopleinarchaeologicalheritagemanagement.Essaysinhonourofprof.WillemJ.H.Willems*, Leiden.

Manders, Martijn, 2015 (2), My Heritage, Your Heritage, Our Heritage? The Growing Awareness of Local Communities and Consequent Bottom up approaches in Maritime Cultural Heritage Management, in: Maurizio Di Stefano (ed) ICOMOS 18th General Assembly. *HeritageandLandscapeasHumanValuesConferenceProceedings,451-454.*

Manders, M. & Gregory, D. (eds), 2016, Guidelines to the process of underwater archaeological research, *SASMAPGuidelineManual*1. Amersfoort: SASMAP project.

Manders, M.R. & W.F.G.J. Brouwers (eds), 2016, Gebied 6000. Duikonderzoek naar de Romeinse loskade bij Cuijk, *Rapportage ArcheologischeMonumentenzorg229*, amersfoort

Marsden, Peter,2003, *Sealedbytime.ThelossandrecoveryoftheMaryRose*,MaryRoseTrust.

Mårdh, Sven, 2005, Bacteriophages production, in: Rene Klaassen (ed), Preserving cultural heritage by preventing bacterial decay of woodinfoundationpolesandarchaeologicalsites.*BACPOLES, finalreportEVK4-CT-2001* – 00043, Wageningen,177-184

Mayer, Larry A., Brian Calder, James S. Schmidt & Chris Malzone, 2009, *ProvidingtheThirdDimension:High-ResolutionMultibeamSonar asaToolforArchaeologicalInvestigation–AnExamplefromtheD-DayBeachesofNormandy* . Downloaded from http://www.thsoa.org/hy03/2_1.pdf on the 25th of September.

McCarthy, M., 1998, S.S. Xantho: the pre-disturbance, assessment, excavation and management of an iron shipwreck off the Western Australia, *InternationalJournalofNauticalArchaeology,*17.4,339-347.

McCarthy, M. (ed) *Iron,steelandsteamshiparchaeology*, AIMA, Fremantle, 2010.

McKee, Alexander, 1982, *HowwefoundtheMaryRose*,London

McLeod, Ian Donald, 1995, Technical Communication. In situ corrosion studies on the Duart Point Wreck, 1994, *IJNA*(1995)24.1: 53-59

MinisterievanVerkeerenWaterstaat,Directoraat-GeneraalRijkswaterstaat,
Meetkundige Dienst, 2000, *"Coördinaattransformatiesenkaartprojecties"*,3e herziene uitgave, MD-rapportnummer: MDGAP - 2000.31. December 2000.

Meijer, F., 1986, Met archeologie onder water is het nog behelpen, *HetParool* 5-4-1986.

Meulen, Gerwin van der, Dorien Blikman & John Pertijs, 2012, Inventarisatie watersportsector Noord-Holland, *DECISIO*,3januari

Mierlo, B.E.J.M. van & S. van den Brenk, 2010, Greifswalder Bodden. Shipwreck relocation, Periplus Archeomare Report 10_A014 *Nord Streamdocumentnr*. G-PE-LG-REP-500-WRECKREL-03.

MinisterievanLandbouw,NatuurenVoedselkwaliteit,n.y.,*BeleidMosselzaadinvanginstallaties(MZI's)periode2010t/m2013*

Molen, S. J. Van der, 1970, The lutine Treasure.*The150-yearsearchforgoldinthewreckofthefrigateLutine*, Adlard Coles, London, U.K

Molen, S. J. Van der, 1978, *O,welkeenontzettendewaterplas!VergetenepistelsoverdeWaddenzee,* P.N. Van Kampen & Zn, Baarn

Moran, V., 1997, Sea Scour Control Systems – some considerations for use. *BulletinoftheAustralasianInstituteforMaritime Archaeology*,21(1&2),133-134.

Moree, J.M. & M.M. Sier (eds), 2014, Twintig meter diep! Mesolithicum in de Yangtzehaven-Maasvlakte te Rotterdam, *BOORrapporten* 523, Rotterdam

Morel, J.-M.A.W., & R. Oosting (eds.), 1994, *nisajaarboek1,Jaarverslag1994*,Lelystad

Morel, J.-M.A.W., & R. Oosting (eds.), 1995, *nisaJaarboek2,Jaarverslag1995*,Lelystad.

Muckelroy, Keith, 1978, *Maritime* Archaeology, Cambridge.

Mudryk, Zbigniew Jan, Beata Podgórska, Anetta Ameryk & Jerzy Bolałek, 2000, The occurrence and activity of sulphate-reducing bacteria in the bottom sediments of the Gulf of Gdańsk, *OCEANOLOGIA*, 42 (1), 105–117

Murray, James W., Keith Stewart, Steven Kassakian, Marta Krynytzky & Doug DiJulio, 2005, Oxic, Suboxic and Anoxic Conditions in the Black Sea, In: A. Gilbert, V. Yanko-Hombach and N. Panin (eds.): *Climatechangeandcoastlinemigrationasfactorsinhumanadaptationto thecircum-ponticregion:Frompasttoforecast.,* Kluwer.

Muyzer, Gerard & Alfons J. M. Stams, 2008, The ecology and biotechnology of sulphate-reducing bacteria, *NatureReviewsMicrobiology* 6,441-454

Nair, N. B. & M. Saraswathy, 1971, "The biology of wood-boring teredinid molluscs." *Advancesinmarinebiology* 9: 335-509.

Negueruela, Iván, 2000, Managing the maritime heritage: the National Maritime Archaeological Museum and National Centre for Underwater Research, Cartagena, Spain
IJNA, Volume 29, Issue 2, pages 179–198

Nilsson, T. & C.G. Björdal, 2008, Culturing wood-degrading erosion bacteria. International *Biodeterioration & Biodegradation* Volume 61, Issue 1, January 2008, Pages 3–1

Nilsson, Thomas, Charlotte Björdahl & Erik Fällman, 2008, Culturing erosion bacteria: Procedures for obtaining purer cultures and pure strains,*InternationalBiodeteriorationandBiodegradation*61, 17-23

Nilsson, T. & Adya P. Singh, 2004, *TunnelingbacteriaandtunnelingofwoodcellwallsIn:McGraw-HillEncyclopediaofScienceand Technology,Chapter:Tunnelingbacteriaandtunnelingofwoodcellwalls*, Publisher: McGraw-Hill, pp.395-399

Normann, Ø., 1987, *HetOostvoornsewrak.OnderzoekvaneenscheepsrestantinhetOostvoornseMeeruitgevoerddoorNederlandse sportduikers*,Lelystad.

Olsen, Olaf & Ole Crumlin – Pedersen, 1990, *FivevilingshipsfromRoskildeFjord*,Vikingeskibshallen.

Olsson, Andreas, 2009, Some reflections on underwater cultural heritage management, *MACHUReport* Nr.2, 48-50.

Ome Baron, Tatiana, 2008, '*ConstructingtheNotionoftheMaritimeCulturalHeritageintheColombianTerritory:ToolsfortheProtection andConservationofFreshandSaltAquaticSurroundings*'.Onwww.un.org/depts/los/nippon

Oost, Albert Peter, 1995, Dynamics and sedimentary development of the Dutch Wadden Sea with emphasis on the frisian inlet. A study of the barrier islands, ebb-tidal deltas, inlets and drainage basins, *ThesisuniversityofUtrecht*.

Oosting, Rob & Martijn Manders (red.), 2007, *Machureport*Nr. 1, Amersfoort.

Opdebeeck, J., 2015, *ProgrammavanEisenVerkennendOnderzoekBZN17*, Amersfoort

Ortmann, N., 2009, Exploring Practitioners' Attitudes Towards In Situ Preservation and Storage for Underwater Cultural Heritage. *MastersThesis,DepartmentofArchaeology,FlindersUniversity*, Adelaide.

Os, Bertil van, J. W. de Kort & Hans Huisman, 2012, A Qualitative Approach for Assessment of the Burial Environment by Interpreting Soil Characteristics; A Necessity for Archaeological Monitoring, *conservationandmgmtofarch.sites*, Vol. 14 Nos 1–4, 2012, 333–40

Os, Bertil van, en Menne Kosian, 2011, Sluipende degradatie van het archeologisch erfgoed. In: Lauwerier, de Groot, van Os en Theunissen(red.).VragenoverMalta.*RAM196*. Amersfoort 2011, 41-84.

Otte, Andrea, 2009, National practice in the Netherlands, In: Manders, Martijn, Will Brouwers & Rob Oosting (eds.), *FinalMACHUReport*, 2009, 16-21.

Overmeer, A.B.M., 2012, A Swedish man-of-war in Dutch waters. An archaeological field evaluation of the wreck of the Sophia Albertina, *RapportageArcheologischeMonumentenzorg(RAM)201*, Amersfoort

Oxley, I., 1998(1), The in situ preservation of underwater sites. In: M. Corfield, P. Hinton, T. Nixon and M. Pollard (eds.), *Preserving archaeological remains in situ*, London, 159-173.

Oxley, I., 1998(2), The environment of historic shipwreck sites: a review of the preservation of materials, site formation and site environmental assessment. *MasterofSciencesthesis*, University of St Andrews.

Paalvast, P., 2014, Onderzoek naar paalwormen in hout afkomstig van historische wrakken in het Oostvoornse Meer, *Ecoconsult rapportnr*. 2014-09.

Paalvast, P., G. van der Velde, 2011, Distribution, settlement, and growth of first-year individuals of the shipworm Teredo navalis L. (Bivalvia: Teredinidae) in the Port of Rotterdam area, the Netherlands, *International Biodeterioration & Biodegradation*, doi:10.1016/j.ibiod.2010.11.016

Paap, drs. B. & drs. M. de Kleine, 2009, Wrakkendetectie bij Texel met behulp van side scan sonar- en seismische chirp data. *Intern rapportDeltares,* i.o. Rijksdienst voor het Cultureel Erfgoed, 2009.

Palma , P, 2004 (1), Aims and goals, *MoSSnewsletter* 2/2004 Monitoring, 5

Palma, P. , 2004 (2), Final Report for the Monitoring theme of the MoSS Project,*FinalReportMoSSProject*, 8-38.

Palma, P., 2009, Environmental study for the in situ protection and preservation of shipwrecks: the case of the Swash Channel wreck. In:*ArsNautica,* 7-9 September 2009, Dubrovnik.

Palma, P. & L.N. Santhakumaran, 2014, *ShipwrecksandGlobal'Worming'*. Archeopress

Parthesius, Robert (ed.), 2007, Excavation Report of the VOC ship Avondster, *CentreforInternationalHeritageActivities, Special Publication No.1*

Pater, Chris & Martijn Manders, 2009, The concept of decision Support Systems (DSS), In: Manders, Martijn, Rob Oosting & Will Brouwers (eds), *MachuReport* Nr. 2, Amersfoort

Peckham, R.S., 2003, Introduction: The Politics of Heritage and the Public Culture, In: R.S. Peckham (ed.), Rethinking Heritage: *CulturesandPoliticsinEurope* , London, 1–13.

Peeters, Hans, 2008, Een indicatieve, archeologische verwachting voor de grote Zeeuwse wateren. In: J.H.C. Deeben (red.): De Indicatieve Kaart van Archeologische Waarden, derde generatie. *RapportageArcheologischeMonumentenzorg* 155, Amersfoort.

Pešić, Mladen, 2011, VII I . In situ Protection of Underwater Cultural Heritage, In: Bekic, Luca (ed.), *Conservationofunderwater archaeological finds Manual*, 77-87.

Picket, Joseph P. (ex. ed), 2003, *AmericanHeritageDictionaryoftheEnglishLanguage*,4th edition, Houghton Mifflin Company

Plets, R.M.K., J.K. Dix, J.R. Adams, J.M. Bull, T.J. Henstock, M. Gutowski & A.I. Best, 2009, The use of high-resolution 3D Chirp sub-bottom profiler for the reconstruction of the shallow water archaeological site of the Grace Dieu (1439), River Hamble, *Journalof ArchaeologicalScience*, 36, 408-418.

Pournou, A., 1999, In situ protection and conservation of the Zakynthos wreck.*PhDThesisatPortsmouthUniversity.*
Pournou, A., M.A. Jones & S.T. Moss, 1999, In-situ protection of the Zakynthos wreck. In: C. Bonnot-Diconne, X. Hiron, Q. Khio Tran and P. Hoffman (eds*),Proceedingsofthe7thICOM-CCWorkingGrouponWetOrganicArchaeologicalMaterialsConference.* ARC Nucleart,Grenoble.

Pournou, A., A.M. Jones & S.T. Moss, 2001, Biodeterioration dynamics of marine wreck-sites determine the need for their in situ protection, *TheInternationalJournalofNauticalArchaeology*, vol. 30, no. 2, pp. 299-305.

Quinn, R., 2006, The role of scour in shipwreck site formation processes and the preservation of wreck-associated scour signatures in the sedimentary record, *JournalofArchaeologicalScience*, 33 (10), 1419-1432.

Rappard, charlotte van, 2014, Waarden aan de onderkant van museumcollecties, *Museumpeil* 41, voorjaar, 6-7

Rawlings, Douglas E., 2005, Characteristics and adaptability of iron- and sulfur-oxidizing microorganisms used for the recovery of metals from minerals and their concentrates, *MicrobialCellFactories*,4:13,

Regteren Altena, H.H. van, 1987: Derde voordracht, in: F.P. Brand, P.G.M. Diebels, H. Maurits, W.F.J. Mörzer Bruyns & W. Weber (eds.): *Plundering,ofverrijkingvandescheepvaartgeschiedenis?Cahier1Voordrachtenendiscussie,gehoudentijdenseendoordeSectie Scheepvaart-enMaritiemeMuseavandeNederlandseMuseumvereniginggeorganiseerdsymposiumop17september1986inhet Rijksmuseum'NederlandsScheepvaartMuseum'teAmsterdam*, Amsterdam, 12-14.

Reise, Karsten, 2013, A natural history of the Wadden Sea Riddled by contingencies, *Waddenacademie,Lectureseries* number 4, Leeuwarden.

Richards, V, I. Godfrey, R. Blanchette, B. Held, D. Gregory and E. Reed, 2009, In situ monitoring and stabilisation of the James Matthews shipwreck. In: K. Strætkvern and D.J. Huisman (eds), Proceedings of the 10th ICOM Group on Wet Organic Archaeological Materials Conference, *NederlandseArchaeologischeRapporten* 37, Amersfoort, The Netherlands, 113-160.

Ridderikhof, R., 1986:,Wrakken van oude schepen dreigen verloren te gaan,*deVolkskrant*6-2-86.

Rijksdienst voor het Cultureel Erfgoed: *WetgevingWaterbodems*, Oktober 2014

Rijkswaterstaat, 2012, *Beheer-enOntwikkelplanvoordeRijkswateren(BPRW)2010-2015*. (December 2009, revised version 2012).

RING Internal Report, 2009, *Number:2009023.DendrochronologicaldatingofshipframediscoveredatWreckMuseum*,Terschelling.

ROB, n.y .(1), Nederlands Instituut voor Scheepsarcheologie/ ROB (NISA). Organisatie en invulling van het Beleidsplan 1997-2000, *internalreport*, Amersfoort

ROBn.y.(2),*Geefdetoekomsteenverleden.Beleidsplan1997-2000*, Amersfoort.

ROB,1995,*Het verleden zeker. Naar een meer effectieve archeologische monumentenzorg in Nederland*, Amersfoort

Roeper & Vonk Uitgeest (eds), 2002, *TexelendeVOC:schepenopdeRede,TexelaarsindeOost.Texel,*Maritiem en Jutters Museum, Stichting VOC 2002

Ruggenberg,Rob,1995,*DegriezeligeschatkamervandeNoordzee,*
www.ruggeberg.nlhttp://www.ruggenberg.nl/artikelen/wrakken.html

Ruiter, H. de, 2012, *MonitoringkwaliteitsimpulsOostvoornseMeer(2008–2011).* Waterschap Hollandse Delta.

Rullkötter, J., 2000, Organic Matter: The Driving Force for Early Diagenesis. In Schulz HD & Zabel M (editors), *MarineGeochemistry*: 129-153.Springer-Verlag,Berlin.

Sandström, M., F. Jalilehvand, I. Persson, U. Gelius, P. Frank & I. Hall-Roth, 2002, Deterioration of the seventeenth century warship Vasa by internal formation of sulphuric acid, *Nature* 415, 893 - 897

Sandström, Magnus, Yvonne Fors & Ingmar Persson, 2003, The Vasa´s New Battle. Sulphur, Acid and Iron, *VasaStudies* 19, Stockholm.

Sandström, M., F. Jalilehvand, E. Damian, Y. Fors, U. Gelius, M. Jones & M. Salome, 2005, Sulfur accumulation in the timbers of King Henry VIII's warship Mary Rose: A pathway in the sulfur cycle of conservation concern.*ProceedingsoftheNationalAcademyofScience* 102(40), 14165 - 14170

Sapignoli, Maria, 2014, Mobility, Land Use, and Leadership in Small-Scale and Middle-RangeSocieties,*ReviewsinAnthropology* , 43:1, 35-78

Scharff, Djurra, 2013, Leeft de geest van Faro? Een onderzoek naar het denken over de Faro Conventie als sociale praktijk, *MA-scriptie ArcheologieenPrehistorieUniversiteitvanAmsterdam*.

Schiffer, Michael Brian, 1973, Cultural Formation Processes of the archaeological record: applications at the Joint Site, East-Central Arizona. *A Dissertation Submitted to the Faculty of the Department of Anthropology in Partial Fulfilment of the Requirements for the DegreeofDoctorofPhilosophyintheGraduateCollegeTheUniversityofArizona*

Schiffer, Michael Brian, 1985, Is there a "Pompeii Premise" in archaeology? *JournalofAnthropologicalResearch* 41:18-41

Schoorl, Henk, 1999/2000, *DeConvexekustboog.Texel–Vlieland–Terschelling.Bijdragentotdekennisvanhetwestelijkewaddengebied endeeilandenTexel,VlielandenTerschelling,deel1totenmet4.*

Schulz, H.D., 2000, Redox Measurements in Marine Sediments, in: Schűring J, Schulz HD, Fischer WR, Bõttcher J and Duijnisveld WHN (eds.),*Redox:Fundamentals,ProcessesandApplications:*235-246.SpringerVerlag,Berlin.

Schute, I., M. Verbruggen & M. Lobbes, 2011, Wie wat bewaart, die heeft wat, Kanttekeningen bij de werking van de Wet op de archeologische monumentenzorg; *RAAPrapport2525*.Weesp.

Schute, I.A., M.E. Lobbes MA, drs. R. Kroes & drs. M. Verbruggen, 2013, *RAAP-rapport2618*, Archeologie voor de toekomst Kwantitatieve analyse van het behoud van archeologische waarden (2007-2011).

Shanks,Michael,1992,*ExperiencingthePast:OntheCharacterof.Archaeology*.Routledge,London.

Sier, M. M., 2002, *EenopgravinginhetveenbewoningssporenuitdeRomeinsetijd:gemeenteBorssele,provincieZeeland*. Archeologisch Diensten Centrum, Bunschoten.

Sigmond, J.P., 1989, *Nederlandsezeehavenstussen1500en1800*, Amsterdam

Skowronek, R.K., R.E. Johnson, R.H. Vernon & G.R. Fischer, 1987, The Legare Anchorage shipwreck site - grave of HMS Fowey, Biscayne National Park, Florida, *InternationalJournalofNauticalArchaeology,* vol. 16, no. 4, p 317

Smit, A., R.M. van Heeringen & E.M. Theunissen,2006, Archaeological Monitoring Standard. Guidelines for the non-destructive recording and monitoring of the physical quality of archaeological sites and monuments, *NAR33*, Amersfoort

Smyth, T.A.G. & R. Quinn, 2014, The role of computational fluid dynamics in understanding shipwreck site formation processes, *JournalofArchaeologicalScience* 45, 220-225

Soeters, G., & P. Stassen, 2002, Archeologisch onderzoek naar het verdronken kasteel van Elsloo,*ArcheologieinLimburg* 90, 15-19.

Sordyl H., R. Bönsch, J. Gercken, F. Gosselck, M. Kreuzberg & H. Schulze, 1998, Vorbreitung und Reproduction des Schiffsbohrwums Teredo navalis L. an der Küste Mecklenburg-Vorpommerns. *Deutsche Gewässerkundliche Mitteilungen* 42./1998, Heft 4.

Soulsby, R., 1997, Dynamics of Marine Sands, *Amanualforpracticalapplications.* Thomas Telford, London, 174-179.

Spennemann, Dirk H. R. ,1998 [2004], Conservation management and mitigation of the impact of tropical cyclones on archaeological sites, in: Dirk H. R . Spennemann & David W. Look (eds*),DisasterManagementProgramsforHistoricSitesSanFranciscoandAlbury: AssociationforPreservationTechnology(WesternChapter)andTheJohnstoneCentre,* Charles Sturt University. Pp. 113-132. Available on: http://csusap.csu.edu.au/~dspennem/PDF-Articles/SFO-19-Spennemann1.pdf [accessed 21-11-2010].

Spennemann, Dirk H.R., 2011, *PreservingthePastfortheFuture.ContemporaryRelevanceandHistoricPreservation.CRM:TheJournalof HeritageStewardship* , vol. 8, no 1&2, pp. 722

Spruit, Ruud & Martijn Manders, 2007, *DezoektochtnaardeHoorn.DewonderbaarlijkereisvanSchoutenenLeMaire,*DeBataafse Leeuw.

Stanev, E.V., J. Schulz-Stellenfleth, J. Staneva, S. Grayek, J. Seemann & W. Petersen, 2011, Coastal observing and forecasting system for the German Bight – estimates of hydrophysical states, *OceanScience* 7, 569–583

Staniforth, M. & D.Shefi , 2010, Protecting underwater cultural heritage: A review of In situ preservation approaches to underwater cultural heritage and some directions for the future", *2010WorldUniversitiesCongressProceedingsVolume* II, Canakkale Onseklz Mart University, Cannakale, Turkey, 1546-1552

Stassen, P., 2005, *Zandmaas:Proefproject2,Hanssumerweerd.Prehistorische,Romeinseenmiddeleeuwsevondstenopgebaggerd. Een verzwolgen cultusplaats*?,Maastricht.

Stewart, J., L.D. Murdock &P. Wadell, 1995, Reburial of the Red Bay wreck as a form of preservation and protection of the historic resource. In P.B. Vandiver, J.R. Druzik, J.L.G. Madrid, I.C. Freestone and G.S. Wheeler (eds), *MaterialsIssuesinArtandArchaeology*IV, 352: 791-805. Pennsylvania.

Steyne, Hanna & Ian D. MacLeod, 2011, In-situ conservation management of historic iron shipwrecks in Port Phillip Bay: a study of J7 (1924), HMVS Cerberus (1926) and the City of Launceston (1865) *BulletinoftheAustralasianInstituteforMaritimeArchaeology*,35: 67–80

Steyne, H., 2009, Cegrass, sand & marine habitats: a sustainable future for the William Salthouse. In V. Richards and J. McKinnon (editors),*Public,ProfessionalsandPreservation:ConservationofCulturalHeritage.ArchaeologyfromBelow:EngagingthePublic.AIMA/ ASHA/AAMHConference*24-28th September 2008, Adelaide.

Stoepker, H., & G. Soeters, 2005, Archaeological Heritage Management in the Dutch Meuse Valley. The Maaswerken Project, in: H. Stoepker (ed.): Archaeological Heritage Management in Riverine Landscapes. Papers Held at the Session 'Archaeological Heritage Management in Riverine Landscapes', 9 September 2004, 10th Annual Meeting of the European Association of Archaeologists, Lyon (France) *RapportageArcheologischeMonumentenzorg,126*, Amersfoort, 25-42.

Strick, Hein & Joke, 1986, Eenige aantekeningen betreffende de Lutine, Hoorn-Terschelling.
Huiskes, Bert & Gerald de Weerdt (eds), 1999: *DeLutine1799-1999.Deraadselachtigeondergangvaneenschipvolgoud*,Gent.

Sudaryadi, Agus, Judy Wahjudin & Martijn Manders, 2012, Het beheer van het maritiem Erfgoed in Indonesië, *Vitruvius*nummer 18, januari, 14-20.

Swiny, H.W. & M.L. Katzev, 1973, The Kyrenia Shipwreck: A Fourth-Century B.C. Greek Merchant Ship, in: D.J. Blackman (ed.), *Marine Archaeology*,London,339-355.

Sylvester, G.M., 1976, The problem of soft rot in wooden vessels, *TechnicalReportSeries oftheFishermen'sServicesBranch*Nr. 91, Ottawa, 1976

Talbot, Andy, 2006, Shallow Survey 2005 Common Data set Comparisons, Hydro International January/February Volume 10 number 1 (Article reprint).

Tilburg, Hans K. Van & Mark Staniforth, 2012, Unit 5 Desk-based Assessment,in: Martijn R. Manders & Christopher J. Underwood, *Training Manual for the UNESCO Course on the Protection and Management of Underwater Cultural Heritage in Asia and the Pacific,* UNESCO Bangkok

Tolson, H. & E. Gerth, 2009, Faith of our fathers: religious artefacts from the ss Republic (1865), *OMEPapers*9.

Toth, Gunilla B., Ann I. Larsson, Per R. Jonsson & Christin Appelqvist, 2015, Natural populations of shipworm larvae are attracted to wood by waterborne chemical cues, in: Christine Appelqvist: *ShipwormEcologyinSwedishCoastalWaters(PHD),Universityof Gothenburg*.

Tromp, A.E., 1835, *Overeenigeverbeteringenindezamenstellingderschepenvanoorlog,Tijdschrifttoegewijdaanhetzeewezen* ,4 de deel, Amsterdam, 116-125.

Turner,R.D.,1966,*AsurveyandillustratedcatalogueoftheTeredinidae(Mollusca:Bivalvia).* The Museum of Comparative Zoology, Harvard University, Cambridge. .

UNESCO, 1987, Archaeology Under Water, The Courier Nr. 11, ParisVecco, Marilena, 2010, A Definition of Cultural Heritage: From the Tangible to the Intangible, *JournalofCulturalHeritage*11(3):321-324.
Vellinga, M & R.A.Wood, 2008, Impact of termohaline circulation shut-down in the twenty-first century, *ClimaticChange*91,43-63.

Venkatasamy, R., R. Mouzouras, E.B.G. Jones & S.T. Moss, 1990, Micromorphological aspects of the microbial decay of wood, in: P. Howsom (ed.), *Microbiologyincivilengineering.ProceedingsofthefederationofEuropeanmicrobiologicalsocietiessymposiumheldat Cranfield Institute of Technology, UK, E&F.N.Spon.,* 172-177.

Verlinde, A.D., 1979, Archeologische kroniek van Overijssel over 1977/1978, *OverijsselseHistorischeBijdragen*94, 99-117.
Viduka, Andy J., 2012, Unit 11. Conservation and finds handling, in: Manders, Martijn R. & Christopher J. Underwood,*TrainingManualfor the UNESCO Foundation Course on the Protection and Management of Underwater Cultural Heritage in Asia and the Pacific, UNESCO.*

VLIZ, 2013, *DeGroteRede* ,nr.35,22

Volkenborn, N., S.I.C. Hedtkamp, J.E.E. van Beusekom & K. Reise, 2007, Effects of bioturbation and bioirrigation by lugworms (Arenicola marina) on physical and chemical sediment properties and implications for intertidal habitat succession,*Estuarine,Coastal andShelfScience74*,331-343

Vos, A.D., 2004, Resten van Romeinse Maasbruggen in de Maas bij Maastricht,*RapportageArcheologischeMonumentenzorg100*, ROB, 2004.

Vos, Arent & Jeroen van der Vliet (eds), 2005, *Natuurlijkeprocessenalsverstoorder;archeologischerfgoedbedreigddooreenverstoorder dienietbetaalt* , SNA Amsterdam.
Vos, Arent, 2009, Wrak Ritthem, een onverwacht oud scheepswrak in de Westerschelde. Resultaten van het waardestellend onderzoek,*RapportageArcheologischeMonumentenzorg* 174, Amersfoort-Lelystad

Vos, Arent D., 2012, Onderwaterarcheologie op de Rede van Texel. Waardestellende onderzoeken in de westelijke Waddenzee (Burgzand*).NederlandseArcheologischeRapporten041*, Rijksdienst voor het Cultureel Erfgoed, Amersfoort.

Vos, P., J. Bazelmans, M. van der Meulen & H. Weerts, 2011, *AtlasvanNederlandinhetHoloceen.* UitgeverijBertBakker.

Vos, P. & S. de Vries, 2013, *Tweede generatie palaeografische kaarten van Nederland* (versie 2.0). Deltares Utrecht. Gedownload van www.archeologieinnederland.nl.

Vroom, Leon, 2014, Scheepswrak Burgzand Noord 10. *Monitoringenfysiekebescherming,zomer2010* ,Rijksdienstvoorhet CultureelErfgoed, Amersfoort

Vroom, Leon, 2017, Handboek duikprocedure, *rapportMaritiemProgrammaRCE*, Amersfoort

Vroom, Leon & Frank Koppen, 2003, On the use of the data logger system WaterWatch 2681 at marine archaeological site BZN 10, *MoSSNewsletter* 4,12-15

Waddell, Peter J.A., 1994, Long range shipwreck timber storage [online]. *BulletinoftheAustralianInstituteforMaritimeArchaeology*, Vol. 18, No. 1, 1994: 1-4

Wadhams, Peter, n.y., *HowdoesArcticSeaIceFormandDecay?* Available on: http://www.arctic.noaa.gov/essay_wadhams.html [assessed 21-11-2010].

Waldus, Wouter Bastiaan (ed), 2009, 'De Jonge Jacob' : de lichting en het onderzoek van een hektjalk, vergaan op 23 juli 1858 in de monding van de Dordtsche Kil, *ADC Monografie* 6, Amersfoort

Waldus, Wouter, Seger van den Brenk & Robert van Lil, 2009, Bureauonderzoek Zoekgebieden Mosselzaadinvanginstallaties, *Periplus Archeomare Rapport* 09_A006A, 5

Waldus, W.B. (ed.), 2010, Wrak VAL7, Buiten IJ, De opgraving, lichting en het onderzoek van een 16e-eeuws waterschip, *ADCRapport* 2064, Amersfoort

Wallinga, J., C.A. Johns & A.J. Versendaal, 2009, *NCLopticaldatingreport9108-9208* , Netherlands Centre for Luminescence Dating.

Walraven, N., B.J.H. van Os, G.Th. Klaver, J.H. Baker & S.P. Vriend, 1997, Trace element concentrations and stable lead isotopes in soils astracersofleadpollutioninGraft-DeRijp,theNetherlands,*JournalofGeochemicalExploration* 59 , 47-58.

Wang, Z.B., T. Louters & H.J. de Vriend, 1995, Morphodynamic modelling for a tidal inlet in the Wadden Sea Marine Geology 126, 289-300.

Wang, Z.B., P. Hoekstra, , H. Burchard, H. Ridderinkhof, H.E. De Swart, M.J.F. Stive, 2012, Morphodynamics of the Wadden Sea and its barrier island system, *Ocean & Coastal Management* 68 (2012) ,39-57

Wang, Z.B., J. Vroom, B.C. van Prooijen, R.J. Labeur & M.J.F. Stive, 2013, Movement of tidal watersheds in the Wadden Sea and its consequences on the morphological development, *InternationalJournalofSedimentResearch*, Vol.28(2), pp.162-171

Ward, I., P. Larcombe, A. Firth & M. Manders, 2014, Practical approaches to management of the marine prehistoric environment. *NetherlandsJournalofGeosciences* , 93, pp 71-82 doi:10.1017/njg.2014.2

Ward, I., P. Larcombe& P. Veth, 1999, A new process-based model for wreck site formation, *JournalofArchaeologicalScience*26, 561–70.
Westerdahl, Christer, 1992, The maritime cultural landscape, *IJNAVolume* 21, Issue 1, 5–14

Westerdahl, Christer, 1996, From land to sea, from sea to land. On transport zones, borders and human space. *Internationalsymposiumonboatandshiparchaeology*, Gdansk, 11-20.

Westerdahl, Christer, 1998, *Themaritimeculturallandcape.Ontheconceptoftraditionalzonesoftransportgeography* , https://www.abc.se/~pa/publ/cult-land.htm [accessed 18-1-2016]

Weij, Reinier van der, 2005, De Markermeerstranden onderzocht. Kansen voor schelpenstranden, *Afstudeeronderzoekinhetkader vandeopleidingCivieleTechniekenManagementaandefaculteitConstruerendeTechnischeWetenschappenvandeUniversiteitTwente,* alkmaar.

Whitehouse, Ruth (ed), 1983,*MacmillanDictionaryofArchaeology*(DictionarySeries),London.

Whitehouse R.J., J.M. Harris, J. Sutherland & J. Rees, 2011, The nature of scour development and scour protection at offshore windfarm foundations, *MarPollutBull.* 2011 Jan;62(1):73-88.

Wiemer, R., 2002, Standardisation: the key to archaeological data quality. In: García Sanjuan, L. & Wheatley, D.W. (ed.), *Mapping the Future of the Past, Managing the Spatial Dimension of the European Archaeological Resource*, Sevilla.

Willems, W.J.H., 1999, De koers van de archeologische monumentenzorg: nieuwe ontwikkelingen in vogelvlucht, in: W.J.H. Willems,Nieuwe ontwikkelingen in de Archeologische Monumentenzorg, *Nederlandse Archeologische Rapporten*, 20, Amersfoort, 9-17.

Willems, W.J.H., 2012, the problems with preservation in situ, In: Bakels, Corrie & Hans Kamermans (eds): *Analecta Praehistorica Leidensia* 43/44, 1-8.

Willems, W.H. & R.W. Brandt, 2004, Dutch Archaeology Quality Standard, *RIA rapport*, Rijksinspectie voor de Archeologie, Den Haag

Winton, M., S. Griffies, B. Samuels, J. Sarmiento & T. Frolicher, 2013, Connecting Changing Ocean Circulation with Changing Climate, *Journal Of Climate*, Vol.26(7), 2268-2278

Wit, G. de & A. Sloos, 2008, *De interpretatie van archeologische waarnemingen in Archis: een concept voor een nieuwe set complextypen*, Amersfoort.

Wyeth, Paul, 2004, Appendix 1. Tensile Testing of Buried Cotton samples, *final report MoSS*, 29-32.

Yang Yuanyuan, Zhang Shuwen, Yang Jiuchun, Chang Liping, Bu Kun & Xing Xiaoshi, 2014, A review of historical reconstruction methods of land use/land cover, *J. Geogr. Sci.*, 24(4): 746-766
Zeiler, Manfred, Klaus Schwarzer, Alexander Bartholom� & Klaus Ricklefs, 2008, Seabed Morphology and Sediment Dynamics, , *Die Küste*, 74 ICCE, 31-44

Consulted websites
www.archeologieinnederland.nl

http://www.digibron.nl/search/detail/012de633f71e9267e36810ba/dukaten-mosterdgas-en-lugubere-ladingen

http://www.ruggenberg.nl/artikelen/wrakken.html

www.verganeschepen.nl

http://nl.wikipedia.org/wiki/DECCA

www.machuproject.eu

http://www.rwsgeoweb.nl/GeoWeb41/Viewer.html?Viewer=ZD_Contacten

http://www.english-heritage.org.uk/discover/maritime/map/

http://www.shipwrecks.uk.com/info1_2.htm

http://www.saudiaramcoworld.com/issue/196406/diggings.in.the.deep.htm

http://www.coe.int/t/dg4/cultureheritage/heritage/Identities/default_en.asp

http://www.periplus.nl/home/nl/referenties/projecten/nationaal-contactnummer-ontsluit-databases-met-wrakken-en-obstructies-onder-water

www.periplus.nl

www.machuproject.eu

www.sikb.nl

http://www.waddenacademie.nl/GeoTOP_in_de_Waddenregio.565.0.html

http://www.rwsgeoweb.nl/GeoWeb41/Viewer.html?Viewer=ZD_Contacten

http://www.coe.int/t/dg4/cultureheritage/heritage/Identities/default_en.asp

[www.planarch.org: Guiding principles for Cultural Heritage in Environmental Impact Assessment (EIA)

www.iaia.org: Principles of Environmental Impact Assessment Best Practice.

Under water Data logger suppliers
http://www.ysi.com/applicationsdetail.php?Ocean-and-Coastal-Monitoring-

Digitale Geomorfologische kaart van Nederland: http://www.wageningenur.nl/nl/show/Geomorfologische-kaart.htm.

http://ec.europa.eu/environment/pubs/studies.htm: Here you can find all sorts of publications on EIA's, like: European Communities: Guidelines for Assessment of Indirect and Cumulative Impacts as well as Impact Interactions, May 1999
European Communities: Guidance on EIA, EIS Review, June 2001, and many more.]

Management plans used by English Heritage: http://www.english-heritage.org.uk/content/imported-docs/p-t/mgmtplan-rooswijkaug09.pdf [accessed 21-11-2010]
Planarch: Guiding principles for Cultural Heritage in Environmental Impact Assessment (EIA): www.planarch.org [accessed 21-11-2010]

http://www.hmssirius.com.au/recovery/conservation on the 1790 shipwreck of HMS Sirius

Reburial and Analyses of Archaeological Remains : http://www.svk.com/reburial/news/news.htm,

http://www.ahspp.org.au/

http://www.ahspp.org.au/the-project/conservation-and-submerged-storage-methodology/

http://www.uri.edu/artsci/his/mua/project_journals/swash/swash.pdf

http://www.historic-scotland.gov.uk/duartpointsitedescription.pdf

http://www.mardeespaña.es/archivos/guiones/ingl%C3%A9s/038%20El%20naufragio%20fenicio%20de%20Mazarr%C3%B3n%20-%20Ing.pdf

http://icua.hr/images/stories/publikacije/Exploring_Underwater_Heritage_in_Croatia.pdf

Korteweg, Niki, 2014, Paalworm is blij met warmte, NRC 14 april 2014.

[http://www.nrc.nl/handelsblad/2014/04/14/paalworm-is-blij-met-warmte-1367295]

Samenvatting

Samenvatting

De gelaagde geschiedenis van de Westelijke Waddenzee. Hoe we het onderwater cultureel erfgoed kunnen behouden.

Nederland is een maritieme natie met een enorm rijk verleden waarvan vele resten nog altijd – veelal goed bewaard – op en in waterbodems liggen. Dit onderwater cultureel erfgoed - onder andere kades, bruggen en vooral veel scheepswrakken - wordt bedreigd. Het biedt echter ook kansen voor een beter begrip van een rijk verleden, de huidige maatschappij en het kan ons zelfs helpen in het creëren van een beeld naar de toekomst toe. Als we die kansen willen benutten is het wel noodzaak zorgvuldig om te gaan met dit erfgoed.

Dit proefschrift laat door middel van een testgebied – het Westelijk deel van de Waddenzee rondom de oude rede van Texel – zien waar de bedreigingen voor het onderwater cultureel erfgoed liggen, hoe deze zijn te mitigeren en op welke wijze gebruik kan worden gemaakt van het erfgoed. Onderwater erfgoed is voor velen onzichtbaar en veelal geldt dan ook de uitdrukking 'uit het oog uit het hart'.

Ondanks het feit dat het maar weinigen gegeven is om duikend de bodem van de Waddenzee af te speuren en te onderzoeken, kunnen we op basis van veel reeds bekende informatie over het gebied een goede inschatting maken waar we wel en waar we geen cultureel erfgoed op en vooral in de bodem kunnen aantreffen. Met behulp van een Geografisch Informatie Systeem (GIS) waarmee we de kaarten in de Historisch Geomorfologische Kaartenset (HGK) kunnen vergelijken, kunnen we op gebiedsniveau uitspraken doen over de mogelijkheid voor het aantreffen van bijzondere vindplaatsen. Dit is voor de Westelijke Waddenzee uitvoerig getest. Bekende voorraad (de vindplaatsen die al bekend zijn), mechanische, chemische, biologische en menselijke bedreigingen, geologische gelaagdheid en het gebruik door de eeuwen heen, vertellen allemaal over de kans om vindplaatsen aan te treffen.

Het erfgoed onderwater kan goed bewaard blijven, maar er zijn veel processen die het erfgoed bedreigen. We kunnen de cultuurhistorische vindplaatsen daartegen beschermen. De manier waarop wij dat doen hangt af van de waarde die we de vindplaats toedichten; is het ons puur om de wetenschappelijke waarde te doen, willen we ervan genieten, of is het ook een plek van herinnering?

Informatie over het verleden die ligt opgesloten in de locaties op en in de zeebodem kunnen we bewaren door de vindplaatsen op locatie te beschermen en te beheren. Dat noemen we *in situ* bescherming. Dit kan met verschillende methoden, om verschillende redenen en voor verschillende lengtes van perioden. Dat hangt mede af van de redenen waarom we de vindplaats primair willen beschermen en wat de omstandigheden zijn waarin we dit kunnen en willen doen. Vaak wordt het *in situ* beheer aangehaald als een goedkopere optie. Wanneer we het beheer echter op een verantwoorde manier willen doen, dan valt die kostenbesparing nog maar te bezien. Immers, bij *in situ* beheer hoort ook een - soms intensieve - verantwoordelijkheid. Het effect van de juridische en/of fysieke bescherming moet in de gaten worden gehouden om zodoende te kunnen reageren op veranderingen. Dit noemen we monitoren en dit is dan ook gelijk een belangrijke reden waarom *in situ* beheer niet direct een goedkope optie kan worden genoemd. Het in de gaten houden van archeologische vindplaatsen op de zeebodem is namelijk niet eenvoudig en (dus) ook niet goedkoop.
Monitoring, fysieke bescherming en andere beheersactiviteiten kunnen de kosten flink opdrijven.

In situ beheer en opgraven zijn beiden belangrijke en onmisbare stappen in het archeologisch erfgoedbeheer waarin we het erfgoed beschouwen als een bron van kennis over het verleden, een bron om van te genieten en een bron voor herdenking en overdenking. Erfgoed midden in de samenleving dus en met een maatschappelijke rol.

We moeten keuzes maken: wat we beschermen, wie dat doet, hoe we dat doen, voor wie en voor hoe lang. Dit betekent ook dat we op verschillende niveaus verschillende keuzes kunnen maken. Dit past goed bij het gedecentraliseerde erfgoedbeleid waarin meer stakeholders dan ooit participeren, waarbij coördinatie voor en besluitvorming over het beheer op verschillende overheidsniveaus plaatsvinden.

Technisch gezien blijft het tot op heden lastig om volledig bedekte vindplaatsen te lokaliseren in de bodem. De vindplaatsen die we aantreffen zijn veelal vrij gespoeld en worden sterk bedreigd door erosie en andere degradatieprocessen. *In situ* bescherming vormt dan een onmiddellijke uitdaging, nog voordat we überhaupt over opgraving kunnen gaan praten. De HGK kan ons helpen bij het beschermen van gebieden met een hoge potentie, voordat deze ten prooi vallen aan allerlei degradatieprocessen. In plaats van op vindplaatsniveau zouden we hele gebieden aan kunnen wijzen als potentieel belangrijk. Gebiedsgewijze aanpak heeft als voordeel dat meer wordt gekeken naar de samenhang van de vindplaatsen en de rol die het gebied in de cultuur speelt en heeft gespeeld. Ook dit zou aantrekkelijk kunnen zijn voor regionale overheden.

Er is dus actief beleid nodig om erfgoed onderwater goed te kunnen beheren. Daarvoor is geld en draagvlak nodig. Draagvlak creëren voor iets dat je niet ziet is lastig. Toch zijn er methoden om het onderwater cultureel erfgoed in Nederland toegankelijk te maken voor het publiek. We kunnen de vindplaats naar het publiek brengen zonder het in eerste instantie op te graven, door onder andere het gebruik van de nieuwste digitale technieken. We kunnen ook het publiek naar de vindplaats brengen zonder hen direct met duikapparatuur onderwater te sturen. En als we dat wel doen, dan kunnen we ervoor zorgen dat deze bezoekers er iets van opsteken en kunnen genieten door hen (op de plaats) van informatie te voorzien. Zo maken we het cultureel erfgoed onderwater inzichtelijk, toegankelijk en creëren we daarmee ook een groter draagvlak voor een beheer waarin *in situ* bescherming, monitoring én opgraving geaccepteerd en ook mogelijk zijn.

Curriculum Vitae

Curriculum Vitae

Martijn René Manders was born on the 19th of March 1970 in Vleuten-De Meern, the Netherlands. After finishing the "Atheneum" at Eemland College Zuid in Amersfoort in 1988, he studied Archaeology at the University of Leiden where he graduated (MA) in 1996. This was already quite some years after he started to work in the field of maritime archaeology in 1990. Currently, Martijn is head of the Maritime Programme at the Cultural Heritage Agency of the Netherlands (Amersfoort). Additionally, he teaches maritime and underwater archaeology and heritage management at the University of Leiden and the University of Applied Sciences Saxion in Deventer. He also is a trainer in maritime and underwater archaeology and cultural heritage management for UNESCO.