In Situ Preservation – Application of a Process-Based Approach to the Management of Underwater Cultural Heritage

Vicki Richards[1]

Abstract

Over the past few decades, the archaeological community has been moving away from the more traditional methods of excavation and recovery of underwater cultural heritage (UCH) towards a less intrusive management approach, essentially involving the preservation of sites in situ. Over the years, different remediation strategies have been utilised in order to protect these sites in situ and most of the techniques involve reburial of sites. Reburial may be an appropriate means of stabilising and decreasing the deterioration rate of a site, however, there needs to be a holistic approach to the study of the environment, before and after reburial to gain a full understanding of the changes that are occurring on the site and determine the effectiveness of the technique.

This paper outlines a process-based approach to the development of appropriate long-term management strategies for UCH sites.

Introduction

Over the past 50 years, technology has advanced at such a rate that the development and exploitation of the seabed has increased exponentially, which has, in turn, led to the discovery of increasing numbers of UCH sites. Conditions often exist in these underwater environments that favour the long-term preservation of archaeological remains and valuable information regarding our past can be gained through comprehensive archaeological investigation of these submerged sites. In more recent times however the archaeological community has moved away from the more traditional excavation and recovery methods and further towards on-site examination and in situ preservation of UCH sites. This trend has been politically galvanised in the recently ratified *United Nations Educational, Scientific and Cultural Organisation (UNESCO) Convention on the Protection of the Underwater Cultural Heritage* (UNESCO 2001: Article 2), that states as a fundamental principle, 'the preservation of underwater cultural heritage in situ should be considered as a first option'. However, this does not preclude partial or even total excavation and recovery of sites if they are considered under threat.

Nonetheless, concerns have been raised regarding the application of in situ preservation techniques as a management tool for UCH sites. Those opposing in situ preservation often argue that the sites are 'out of sight and out of mind'. This is probably true to some extent and under certain circumstances, however increasingly, post stabilisation site monitoring is becoming an integral part of any on-site management programme (Caple 2004; Hogan *et al.* 2002; Nyström Godfrey *et al.* 2011; Richards *et al.* 2009). Others claim that the ability to preserve sites in situ has not currently been proven and that more scientific investigation is required (The Institute of Field Archaeologists 2008). Although this may be an accurate statement if the suitability of such practices are to be properly evaluated it is essential that more, not less, in situ preservation projects are initiated in order to provide information that will ultimately lead to a better understanding of this technique.

Reburial of an archaeological site following exposure either by natural causes, industrial interference or archaeological excavation may be an appropriate means of stabilizing and decreasing the overall deterioration rate of our underwater cultural resource

[1] Department of Materials Conservation, Western Australian Museum, Shipwreck Galleries, 45-47 Cliff St, Fremantle, WA 6160, Australia, TEL: +61 8 9431 8472: FAX: +61 8 9431 8489: email: vicki.richards@museum.wa.gov.au

by limiting dissolved oxygen, nutrients, etc and minimising the effects of water movement. This should ultimately decrease physical, chemical and biological degradation of the site. Unfortunately in the recent past, when sites were reburied there was often little, if any subsequent monitoring to determine the effectiveness of the technique (Gregory 1999). It is imperative that there be a holistic approach to the study of the environment, pre and post burial to gain a full understanding of the changes occurring in the reburial environment and the associated deterioration of the archaeological material (Caple 1994; Hogan, *et al.* 2002). This, in turn will allow an accurate assessment of the success or failure of the adopted remediation strategy on the long-term preservation of the site (Godfrey, *et al.* 2004; Godfrey, *et al.* 2005).

In order for any in situ preservation strategy to be successful the following points must be addressed in the overall management plan:

1. Ascertain the extent of the site.
2. Assess the most significant physical, chemical and biological deterioration processes occurring on the site.
3. Assess the pre-disturbed local burial environment and the major factors affecting the long-term stability of the site.
4. Identify the major material types present on the site and their extents of deterioration.
5. Implement an appropriate in situ preservation strategy to mitigate continued deterioration and stabilize the site long-term.
6. Implement a long-term monitoring programme to evaluate the efficacy of the implemented in situ preservation strategy.
7. Provide alternative plans and procedures if the implemented in situ preservation strategies are unsuccessful.
8. Provide resources for the conservation and storage of any recovered artefacts.

Each of these points will be discussed in more detail below and are integral to a process-based approach when assessing UCH sites and establishing successful long-term management plans.

Point 1

The first point to be addressed in preparing any in situ preservation plan is the extent of the site that is to be stabilised. Many wreck sites are not conveniently contained within the confines of the remaining hull structure and are often spread over a wider area. These problems become even more apparent when parts of the wreck assemblage lie buried in the sediment. Simple mechanical probing with long stainless steel rods and dredging of test trenches can be used to define the area of a site, however these techniques are time consuming and would not be suitable for sites dispersed over a large area or deeply buried. In addition, excavated areas must be adequately reburied post investigation.

More commonly, marine geophysical instrumental techniques, such as side-scan sonar, magnetometers and multi-beam sonar, which can be deployed over large areas, are used to detect sites exposed above the seabed. However, the use of sub-bottom profilers in conjunction with side-scan sonar has enabled the detection of both exposed and buried wreck material (Quinn, *et al.* 1998). These techniques can also provide invaluable information regarding the broader-scale sedimentary processes occurring on-site (Quinn 2006). Consideration of this type of information is vitally important when designing an appropriate long-term in situ preservation strategy for a site.

Point 2

The synergistic physico-chemical and biological processes that naturally occur underwater can significantly threaten the integrity of archaeological sites. For example, many sites are at risk of physical damage by exposure through dredging or sediment erosion. The exposed material is subjected to increased wave movement and elevated levels of dissolved oxygen, which lead to increased physical, chemical and biological deterioration.

Biological attack of organic materials is primarily dependent on the concentration of oxygen in the surrounding environment. When a site is disturbed, the increase in oxygen, water and nutrient contents will almost certainly lead to a more aggressive environment. Importantly, this also applies to the recent reburial environment. Under these conditions, marine borers will be excluded due to the limited supply of dissolved oxygen within the recently deposited sediment however, degradation would continue through fungal and bacterial attack, that are able to tolerate much lower oxygen levels (Björdal and Nilsson 2002). If the reburial sediment remains stable and is not subjected to continued or seasonal erosion then microbial processes will eventually consume the oxygen and near anaerobic conditions will prevail where organics will only be subjected to the relatively slow action of erosion bacteria (Nilsson 1999). Due to the manner of this microbial attack the strength of the organic structure is reduced but little archaeological information is lost.

Mary-Lou Florian (1987) reported that anaerobic bacteria only survive to a depth of approximately 60 centimetres (cm) in undisturbed sediments and other authors have shown that the extent of biological degradation of organic materials decreases significantly with burial depths greater than 50 cm (Björdal and Nilsson 2002; Gregory 1999; Nilsson 1999). This is directly related to the decrease in oxygen levels with increasing sediment depth. Lower oxygen levels adversely affect the activity of aerobic and facultative micro-organisms that cause significantly more damage than anaerobic bacteria that are more prominent at greater sediment depths.

Chemical processes can also affect the integrity of archaeological metal objects. One of the most common is the corrosion of iron and other metals. While it is generally accepted that the corrosion rates of most metals are significantly reduced under anaerobic conditions microbially induced corrosion of ferrous alloys can still be an issue in anoxic environments.

It is important to understand the natural deterioration processes occurring on underwater archaeological sites in order to reduce these effects and obviously the depth of burial and the stability of the local environment are two of the most important factors to consider when developing appropriate remediation strategies.

Point 3

The physico-chemical and biological characteristics of the pre-disturbed local environment should be assessed prior to excavation and/or reburial to assist in determining the inherent stability of the site, the major degradation mechanisms occurring on-site and the effect the local environment will have on buried materials. In addition, this pre-disturbance information will be used as baseline data to determine if and when the reburial environment returns to its original pre-burial state and the rate at which this occurs following the changes that necessarily accompany reburial. For example, during reburial via dredging, previously anaerobic sediments will be exposed to increased oxygen concentrations and an influx of nutrients when the sediments are initially deposited. This will lead to increased chemical and microbiological deterioration of the reburied materials before the sediment attains conditions that are conducive to long-term preservation again.

The critical parameters to measure include the chemistry of the seawater, pore water and sediments [pH; redox potential (E_{redox}); dissolved oxygen, total iron and organic contents; sulphide, sulphate and carbon dioxide concentrations; nutrient levels], the type and nature of the sediments (loss on ignition; particles size distribution; porosity) and the level and type of microbiological activity within the sediment (Nyström Godfrey and Berstrand 2007; Richards, *et al.* 2009).

It is also strongly recommended that the broad scale and localised sediment and water movement is monitored at regular intervals over an extended period of time. As mentioned previously while some of this information may be obtained via marine geophysical techniques it is imperative that the current strength and direction, turbidity, tidal period, etc are also monitored. Extensive assessment of these site-related coastal processes and the physico-chemical and biological microenvironments present on the site will provide information regarding the major factors governing the stability of the site so that successful site specific in situ preservation strategies may be developed.

Point 4

It is important to obtain a full understanding of the extent of deterioration of the major material types present on a site when considering in situ preservation. For instance, if the remaining hull structure, whether constructed of wood, iron or a combination of both, is extensively degraded it may not be able to withstand the weight of large quantities of sediment required for reburial in order to minimise further deterioration. Similarly, totally corroded iron is not amenable to in situ preservation by cathodic protection using sacrificial anodes. Moreover, it is essential to collect this baseline data for long-term comparative analysis to quantify the effect the mitigation strategy has on the reburied materials. Knowing the state of preservation will also enable conservators to choose the optimal treatment regimes in those cases where the recovery of material is necessary.

In order to assess the extent of deterioration of the major material types a comprehensive on-site pre-disturbance conservation survey should be conducted. The range of measurements and analyses that are recommended is summarised below.

Metals

In Situ Measurements

corrosion potential (E_{corr}), pH, total depth of concretion and corrosion (d_{total}), total depth of corrosion (d_c), water depth and temperature at the measurement point.

Organic Materials

In Situ Measurements

Visual inspection, simple probing, pH profiles, pilodyn measurements, sample collection for ex-situ analysis.

Ex-situ Analyses

Maximum water content (U_{max}) – measure general extent of deterioration.
Microscopic analysis - wood species identification, measure extent and identify the type of microbiological attack.

Point 5

If the initial assessment of the pre-disturbed environment indicates that the site is unstable, the archaeological remains are severely degraded and at risk of exposure and further damage resulting in significant loss of the submerged archaeological record then different mitigation strategies need to be considered in order to ameliorate these problems. It is at this planning stage that an overall evaluation of whether it is both practically and economically feasible to leave the site in situ should be discussed. In situ preservation of a site in its original position is only one option. Dependent on the nature of the local environment, the effects of residential or industrial developments and the archaeological significance of a site, the entire site or parts thereof, may need to be excavated, recovered and possibly conserved or re-deposited in another area under similar or preferably improved environmental conditions. In the end the measures taken are always a compromise between the archaeological value of the site, the expected effects of the in situ preservation strategy, the time span over which it has to be effective, the effect on the local environment and the resources required.

There are a number of different in situ preservation techniques, or more commonly, combinations thereof, that may be used to protect underwater archaeological sites.

- Stabilization by land reclamation
- Reburial/backfilling by dredging surrounding sediment
- Sandbags – canvas, polymeric
- Deposition of rock, gravel, sediment
- Stabilisation after sediment deposition (e.g. using geotextile fabrics, shade cloth, rubber matting)
- Sediment encapsulation (e.g. cofferdams of wood, sheet metal, polymeric crash barriers filled with sediment)
- Sediment trapping (e.g. geotextile fabrics, shade cloth, debris netting and artificial seagrass used to trap suspended sediment through natural water movement)
- Cathodic protection of ferrous elements (sacrificial anodes, impressed current)

Obviously, simple reburial options are preferred but often they are fraught with post-deployment problems. For example, one potential problem with the sediment drop option is lateral dispersion of the sediment on dumping, which will significantly reduce the overall depth of coverage leading to a reburial area considerably larger than the actual wreck itself. Another issue with this option is, unless the physical environment on-site is relatively benign, that even short periods of increased water movement can cause significant loss of deposited sediment unless the reburial mound is stabilised by layers of geotextile or rubber matting (Manders, *et al.* 2008; Richards, *et al.* 2009). Sand bags are often used to stabilise underwater archaeological sites, however the choice of materials (e.g. cotton versus ultra-violet (UV) stabilised polymeric sand bags) and the method of deployment are very important. Therefore, under most circumstances the use of sand bags is not recommended for the medium to long-term preservation of a wreck site (Gregory 2010; Manders, *et al.* 2008; Richards, *et al.* 2009).

The more complicated techniques include sediment trapping methods, which rely on trapping suspended sediment in the water column resulting in the formation of an artificial sediment mound or sediment encapsulation methods where a cofferdam, usually made from wood, steel sheet or polymers, is filled with sediment to the required depth and covered with geotextile to minimise sediment loss during periods of high water movement.

Notable examples of the sediment trapping techniques are the use of artificial seagrass on wrecks, such as the *William Salthouse* (Figure 1) (Harvey 1996; Hosty 1988), the *James Matthews* (Figure 2) (Richards, *et al.* 2009) and the Hårbølle wreck (Gregory, *et al.* 2008) and different types of netting (shade cloth, debris netting, wind netting) used on several wrecks in the Netherlands (Manders 2004), Sri Lanka (Manders, *et al.* 2004) and also trialled on the *James Matthews* (Figure 3) (Richards, *et al.* 2009) and the Hårbølle wreck (Gregory, *et al.* 2008).

The use of sediment encapsulation techniques utilising cofferdams is not common as their deployment is complicated, labour intensive and usually expensive. In addition, cofferdams constructed of timber or steel sheet can deteriorate rapidly and adversely affect the delicate balance of the wreck ecosystem. However, Trevor Winton and Vicki Richards (2005) proposed the use of environmentally inert polymeric ‘crash barriers’ that interlock into a ring-like arrangement that can be placed around the periphery of a site and filled with sediment to the required depth. It is currently being trialled on the *James Matthews* site (Figure 4) (Richards, *et al.* 2009). This negates the need to increase the reburial area which is common with the sediment drop method and toe scouring problems that can arise with the other sediment trapping techniques.

Figure 1. Successful application of artificial Cegrass® on the *William Salthouse*, six weeks after installation. Photo: Heritage Victoria

Formatted: Centered

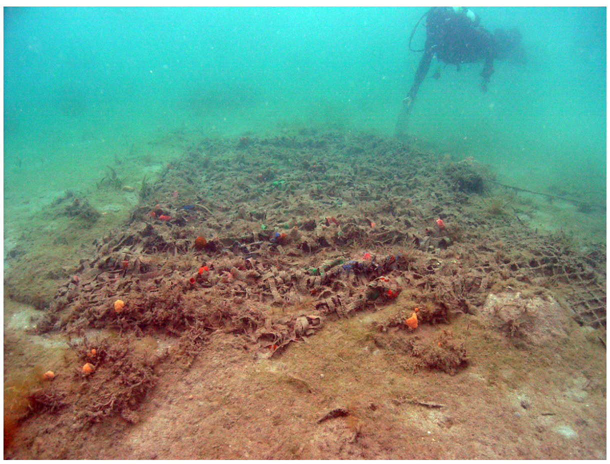
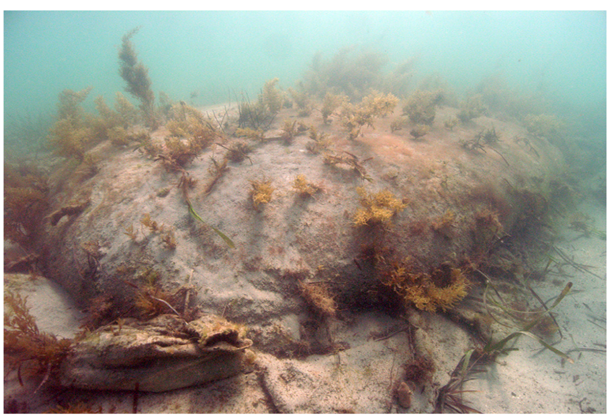


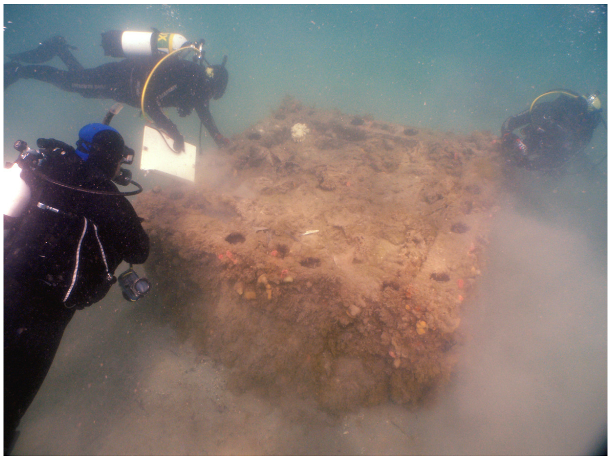
Figure 2. Unsuccessful application of artificial seagrass on the *James Matthews*, five years after deployment. Photo: Western Australian Museum

Formatted: Centered



Formatted: Centered

Figure 3. Successful application of a sediment trapping mat on the *James Matthews*, five years after deployment. Photo: Western Australian Museum



Formatted: Centered

Figure 4. Polymeric 'crash barrier' cofferdam trialled on the *James Matthews,* three years after installation. Photo: Western Australian Museum

Alternatively, if the local on-site environment is not conducive to in situ stabilisation of a site then excavation and reburial in another more suitable area may be necessary. Notable examples of this procedure are the *San Juan* in Red Bay, Canada (Stewart, *et al.* 1995; Waddell 2007), the *Day Dawn* in Cockburn Sound, Western Australia (Moran 1997) and the reburial of artefacts recovered from the *Fredricus* in Marstrand Harbour, Sweden (Berstrand, *et al.* 2005), which was the catalyst for the collaborative reburial research project, "Reburial and Analyses of Archaeological Remains" (RAAR) (Nyström Godfrey and Berstrand 2007; Nyström Godfrey, *et al.* 2011).

Finally, the corrosion rates of iron hulled vessels or structural features can be significantly lowered through cathodic protection using sacrificial anodes. The anodes, usually zinc or aluminium alloy, corrode in preference to the iron, effectively protecting the ferrous alloys from rapid decay. This technique has been used widely on many iron shipwrecks, with Australia being one of the world leaders in its application (MacLeod 1986; 2010; Heldtberg, *et al.* 2004).

Point 6

Good organic and metal preservation depends on the maintenance of a stable chemical environment characterised by an anoxic, reducing environment, with near neutral pH, low porosity, organic content and bacterial activity. Hence, long-term monitoring of a reburied site is a critical component of the overall management plan. The sediment levels and the biological and physico-chemical environment of the reburial mound should be monitored at regular intervals. Ideally, the same suite of analyses should be performed on these post reburial sediments as was previously described in point 3 for the pre-disturbed environment. As destructive sampling of reburied archaeological materials is contrary to the aims of reburial, it is recommended that sacrificial modern wood and metal samples be included in the reburial mound and retrieved and analysed (see point 4) at regular intervals (Gregory 1999; Richards, *et al.* 2009). The results of the biological and physico-chemical analyses can then be correlated to the extents of deterioration of the sacrificial samples and extrapolated to the condition of the reburied archaeological material thereby allowing the effectiveness of the adopted mitigation strategy on the long-term preservation of the wreck site to be properly assessed.

Point 7

An alternative and fully costed contingency plan must be developed in the event that the adopted in situ preservation strategy is unsuccessful.

Point 8

A provisional budget must be allocated for the conservation of any recovered artefacts that are deemed unsuitable for reburial.

Conclusion

Application of this process-based approach should hopefully provide a better understanding of the major deterioration processes occurring on-site and assist in the application of the most appropriate in situ preservation strategies customised to accommodate the unique qualities of each site. Long-term monitoring feeds back into this system, quantitatively evaluating the effectiveness of the remediation strategy and providing evidence for alternative measures to be sought if the chosen technique is unsuccessful. In this way, the current uncertainties surrounding in situ preservation as a management tool for UCH sites can be addressed and ultimately lead to a better understanding of this technique in the future.

Bibliography

The Institute of Field Archaeologists, 2008	The Institute of Field Archaeologists, Maritime Affairs Group Bulletin. Winter 2008, United Kingdom. Available at: <http://ifamag.wordpress.com/mag-bulletins/>
Bergstrand, T., Björdal, C.G., Bohm, C., Christenssen, E., Gregory, D., MacLeod, I.D., Nilsson, T., Nyström, I., Peacock, E., Richards, V.L., Turner, G., 2005	"Reburial as a method of preserving archaeological remains. A presentation of the Marstrand Project", in *Proceedings of the 9th ICOM Group on Wet Organic Archaeological Materials Conference, Copenhagen, 7-11 June 2004*, Per Hoffmann, Kristiane Strætkvern, James Spriggs and David Gregory (eds), The International Council of Museums, Committee for Conservation Working Group on Wet Organic Archaeological Materials, Bremerhaven, pp. 9-39.
Björdal, C., Nilsson, T., 2002	"Decomposition of waterlogged archaeological wood", in *Proceedings of the 8th ICOM Group on Wet Organic Archaeological Materials Conference, Stockholm 11-15 June 2001*, Per Hoffmann, James Spriggs, Tara Grant, Cliff Cook and Andrea Recht (eds), International Council of Museums (ICOM), Committee for Conservation, Working Group on Wet Organic Archaeological Materials, Bremerhaven, pp. 235-244.
Caple, C., 1994	"Defining a reburial environment: Research problems characterising waterlogged anoxic environments", in *Proceedings*

	of the 5th ICOM Group on Wet Organic Archaeological Materials Conference, Portland, Maine 16-20 August 1993, Per Hoffmann, Thomas Daley and Tara Grant (eds), The International Council of Museums (ICOM), Committee for Conservation, Working Group on Wet Organic Archaeological Materials, Bremerhaven, pp. 407-421.
Florian, M-L.E., 1987	"The underwater environment", in Colin Pearson (ed.), *Conservation of Marine Archaeological Objects*, Butterworths, London, pp. 1-20.
Godfrey, I.M., Gregory, D., Nyström, I., Richards, V., 2004	"*In situ* preservation of archaeological materials and sites underwater", in *Mediterraneum*, Fabio Maniscalco (ed.), Massa Editore, Italy, pp. 343-351.
Godfrey, I.M., Reed, E., Richards, V.L., West, N.F., Winton, T., 2005	"The *James Matthews* shipwreck – Conservation survey and *in situ* stabilisation" in *Proceedings of the 9th ICOM Group on Wet Organic Archaeological Materials Conference, Copenhagen, 2004,* Per Hoffmann, Kristiane Strætkvern, James Spriggs and David Gregory (eds), The International Council of Museums, Committee for Conservation Working Group on Wet Organic Archaeological Materials, Bremerhaven, pp. 40-76.
Gregory, D., 1999	"Reburial of ship timbers in the marine environment as a method of in situ preservation", in *Proceedings of the 7th ICOM-CC Working Group on Wet Organic Archaeological Materials Conference, Grenoble, France 1998*, Céline Bonnet-Diconne, Xavier Hiron, Qhoc Khoi Tran and Per Hoffmann (eds), The International Council of Museums (ICOM), Committee for Conservation, Working Group on Wet Organic Archaeological Materials, France, pp. 78-83.
Gregory, D., 2010	"In situ preservation of marine archaeological sites: Out of sight but not out of mind", in *In situ Conservation of Cultural Heritage: Public, Professionals, and Preservation*, Vicki Richards and Jennifer McKinnon (eds), PAST Foundation Publications, pp. 1-16.
Gregory, D., Jensen, P., Matthiesen, H., Strætkvern, K., 2007	"The correlation between bulk density and shock resistance of waterlogged archaeological wood using the pilodyn", in *Studies in Conservation*, Vol. 52, pp. 289-298.
Gregory, D., Ringgaard, R., Dencker, J., 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*, Thijs Maarleveld (ed.), Syddansk Universitet, Vol. 23, pp. 15-23.
Harvey, P., 1996	"A review of stabilisation works on the wreck of the *William Salthouse* in Port Phillip Bay", in *Bulletin of the Australasian Institute for Maritime Archaeology*, Vol. 20, No. 2, pp. 1-8.
Heldtberg, M., MacLeod, I., Richards, V., 2004	"Corrosion and cathodic protection of iron in seawater: A case study of the *James Matthews* (1841)", in *Metal 04: Proceedings of the International Conference on Metals Conservation, Canberra, 4-8 October 2004,* John Ashton and David Hallam (eds), National Museum of Australia, Canberra, pp. 75-87.
Hogan, D.V., Simpson, P., Jones, A.M., Maltby, E., 2002	"Development of a protocol for the reburial of organic archaeological remains", in *Proceedings of the 8th ICOM Group on Wet Organic Archaeological Materials Conference, Stockholm 11-15 June 2001*, Per Hoffmann, James Spriggs, Tara Grant, Cliff Cook and Andrea Recht (eds), International Council of Museums (ICOM),

	Committee for Conservation, Working Group on Wet Organic Archaeological Materials, Bremerhaven, pp. 187-212.
Hosty, K., 1988	"Bagging the William Salthouse: Site stabilization work on the William Salthouse", in *Bulletin of the Australasian Institute for Maritime Archaeology*, Vol. 12, No. 2, pp. 13-16.
MacLeod, I.D., 1986	"Conservation of the steam ship *Xantho*", in *AICCM Bulletin*, Vol. 12, Nos. 3 & 4, pp. 67-94.
MacLeod, I.D., 2010	"Assessment of the impact of scallop dredging, site clearance and cathodic protection on the *City of Launceston* (1865) in Port Phillip Bay", in *Final Report on* SS City of Launceston *(1863-1865) excavation and conservation 1997-2009, Australasian Institute for Maritime Archaeology, Special Publication,* Ross Anderson (ed.), pp. 94-103.
Manders, M.R., 2004	"Protecting common maritime heritage. The Netherlands involved in two EU-projects: MoSS and BACPOLES", in *Mediterraneum*, Fabio Maniscalco (ed.), Massa Editore, Italy, pp. 279-292.
Manders, M.R., Chandraratne, W.M., Dayananda, A.M.A., Muthucumarana, R., Weerasena, K.B.C., Weerasingha, K.D.P., 2004	"The physical protection of a 17th century VOC shipwreck in Sri Lanka", in *Current Science*, Vol. 86, No. 9, pp. 101-107.
Manders, M., Gregory, D., Richards, V., 2008	"The *in situ* preservation of archaeological sites underwater. An evaluation of some techniques", in *Proceedings of the 2nd Heritage, Microbiology and Science Conference, 28 June – 1 July 2005, Portsmouth*, Eric May, Mark Jones and Julian Mitchell (eds), RSC Publishing, pp. 179-203.
Moran, V., 1997	"Some management options for the perched hull, *Day Dawn*", in *Bulletin for the Australasian Institute of Maritime Archaeology*, Vol. 21, Nos. 1 & 2, pp. 129-132.
Nilsson, T., 1999	"Microbial degradation of wood – An overview with special emphasis on waterlogged wood", in *Proceedings of the 7th ICOM-CC Working Group on Wet Organic Archaeological Materials Conference, Grenoble, France 1998*, Céline Bonnet-Diconne, Xavier Hiron, Qhoc Khoi Tran and Per Hoffmann (eds), The International Council of Museums (ICOM), Committee for Conservation, Working Group on Wet Organic Archaeological Materials, France, pp. 65-70.
Nyström Godfrey, I., Bergstrand, T., (eds), 2007	*Reburial and Analyses of Archaeological Remains – Studies on the effect of reburial on archaeological materials performed in Marstrand, Sweden 2003-2005. The RAAR project*, Bohusläns Museum and Studio VästSvensk Konservering, Udevalla, Sweden. Available at: <http://www9.vgregion.se/vastarvet/svk/reburial/index.htm>
Nyström Godfrey, I., Berstrand, T., Gjelstrup Björdal,	"Reburial and analysis of archaeological remains – The RAAR project. Project status and cultural heritage management implications based on the first preliminary results", in *Proceedings*

C., Nilsson, T., Bohm, C., Christenssen, E., Gregory, D., Peacock, E. E., Richards, V., MacLeod, I. D., 2009	*of the 10th ICOM Group on Wet Organic Archaeological Materials Conference, Amsterdam, 10-15 September 2007*, Kristiane Straetkvern and Hans (D.J.) Huisman (eds), Rijksdienst voor Archeologie, Cultuurlandschap en Monumenten (RACM), Amersfoot, pp. 169-196.
Nyström Godfrey, I., Bergstrand, T., Petersson, H., (eds), 2011	*Reburial and Analyses of Archaeological Remains – Phase II results from the 4th retrieval in 2009 from Marstrand, Sweden. The RAAR project*, Bohusläns Museum and Studio VästSvensk Konservering, Udevalla, Sweden. Available at: <http://www9.vgregion.se/vastarvet/svk/reburial/index.htm>
Quinn, R., 2006	"The role of scour in shipwreck site formation processes and the preservation of wreck-associated scour signatures in the sedimentary record", in *Journal of Archaeological Science*, Vol. 33, No. 10, pp. 1419-1432.
Quinn, R., Adams, J.R., Dix, J.K., Bull, J.M., 1998	"The *Invincible* (1758) site – An integrated geophysical assessment", in *International Journal of Nautical Archaeology*, Vol. 26, No. 3, pp. 126-138.
Richards, V., Godfrey, I., Blanchette, R., Held, B., Gregory, D., Reed, E., 2009	"In situ monitoring and stabilisation of the *James Matthews* site", in *Proceedings of the 10th ICOM Group on Wet Organic Archaeological Materials Conference, Amsterdam, 10-15 September 2007*, Kristiane. Straetkvern and Hans (D.J.) Huisman (eds), Rijksdienst voor Archeologie, Cultuurlandschap en Monumenten (RACM), Amersfoot, pp. 113-160.
Stewart, J., Murdock, L.D., Waddell, P., 1995	"Reburial of the Red Bay Wreck as a form of preservation and protection of the historic resource", in *Materials Issues in Art and Archaeology IV*, *Materials Research Society Symposium Proceedings 1994, Mexico*, Vol. 352, pp. 791-805.
UNESCO, 2001	*Convention on the Protection of the Underwater Cultural Heritage*, United National Educational, Scientific and Cultural Organisation (UNESCO), Paris.
Waddell, P.J.A., 2007	"Timber reburial", in *The Underwater Archaeology of Red Bay. Basque Shipbuilding and Whaling in the 16th Century, Volume I Archaeology Underwater: The Project*, Robert Grenier, Marc-André Bernier and Willis Stevens (eds), Parks Canada, pp. 149-152.
Winton, T., Richards, V., 2005	"*In situ* containment of sediment for shipwreck reburial projects", in *Proceedings of the 9th ICOM Group on Wet Organic Archaeological Materials Conference, Copenhagen, 7-11 June 2004*, Per Hoffmann, Kristiane Strætkvern, James Spriggs and David Gregory (eds), The International Council of Museums, Committee for Conservation Working Group on Wet Organic Archaeological Materials, Bremerhaven, pp. 77-89.