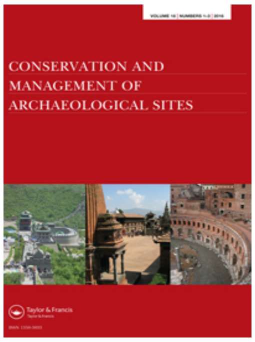

Conservation and Management of Archaeological Sites

ISSN: 1350-5033 (Print) 1753-5522 (Online) Journal homepage: http://www.tandfonline.com/loi/ycma20

The Australian Historic Shipwreck Preservation Project: In situ Preservation and Long-Term Monitoring of the Clarence (1850) and James Matthews (1841) Shipwreck Sites

Vicki Richards, Ian MacLeod & Peter Veth

CONSERVATION AND MGMT OF ARCH. SITES, Vol. 18 Nos. 1–3, February–August, 2016, 240–253

The Australian Historic Shipwreck Preservation Project: *In situ* Preservation and Long-Term Monitoring of the *Clarence* (1850) and *James Matthews* (1841) Shipwreck Sites

Vicki Richards and Ian MacLeod

Department of Materials Conservation, Western Australian Museum, Fremantle, Australia

Peter Veth

Centre for Rock Art Research and Management, School of Social Sciences, University of Western Australia, Crawley, Australia

Increasingly, archaeologists are opting for on-site examination, reinterment, and *in situ* preservation of underwater cultural heritage sites as the first option in the management of sites at risk, as opposed to the more traditional excavation, recovery, conservation, and display/storage methods. This decision will inevitably be based on significance assessment, degree of perceived risk, and resourcing issues. However, long-term monitoring must become an integral part of these management programmes in order to quantitatively evaluate the effectiveness of the *in situ* preservation techniques employed. In 2012 the Australian Historic Shipwreck Preservation Project (AHSPP) was awarded a large Australian Research Council (ARC) Linkage Grant, enabling ten partner organizations and three Australian universities to collaborate in one of the largest multi-organizational maritime archaeology projects to be undertaken in Australia to date. One of the major aims of the project is to develop a protocol for the excavation, detailed recording and reburial of significant shipwrecks under threat, fostering a strategic national approach for the management of underwater cultural heritage (UCH) sites at risk. Two historically significant shipwreck sites that are considered under threat were chosen for this longitudinal comparative study — the *Clarence* (1850)

 DOI 10.1080/13505033.2016.1182759

located in Port Phillip Bay, Victoria; and the *James Matthews* (1841) which lies in Cockburn Sound, Western Australia. Both sites have been preserved *in situ* using two very different but innovative remediation strategies. More importantly, long-term monitoring programmes have been implemented on both sites, which will characterize changes in the reburial environment and the effect on the reinterred materials. In this way, the efficacy of both *in situ* preservation techniques will be systematically tested, providing a comparative analysis of practical protocols for the long-term protection and management of underwater cultural heritage.

KEYWORDS *in situ* preservation, underwater cultural heritage, shipwrecks, monitoring, conservation management

Introduction

The early Australian-built wooden coastal trader, *Clarence* was considered an ideal site for the Australian Historic Shipwreck Preservation Project (AHSPP) for various reasons. The site was test excavated and surveyed in the 1980s (Harvey, 1989), providing a baseline for longitudinal comparative research. The small (16.5 m length; 6.2 m width), accessible site lies in 5 m of water close to Melbourne and is under serious threat from continuing anchor damage by illegal anglers as well as strong currents from Port Phillip Heads.

The wooden ex-slaver, *James Matthews,* laying in 2–3 m of water near Fremantle was selected as the second case study. Also relatively small (24 m length; 6 m width), it was totally excavated and recorded in the 1970s (Henderson, 1977). From 2000 it has been the subject of a long-term research programme with more than ten years of accumulated data on the efficacy of different reburial strategies trialled on-site (Richards, et al., 2009). The synergistic impact of industrial activity and natural near-shore sedimentary processes has resulted in continued deterioration of the site.

The implementation of appropriate *in situ* preservation strategies for both sites, supported by an extensive monitoring programme to assess the viability of the different methodologies, was of paramount importance (Veth, et al., 2013).

The characteristics of the pre-disturbed local burial environment and the extent of deterioration of the major material types were assessed by conducting on-site conservation surveys on both sites. The surveys included: pH profiles, pilodyn (density) measurements and maximum water contents of structural timbers, corrosion surveys of any metal features and physico-chemical, geological and microbiological analyses of the pre-disturbed sediments. This information enables the determination of site stability and the major deterioration processes so the most appropriate *in situ* preservation strategy can be selected. The results from these conservation surveys are also used as baseline data for long-term comparative analysis so the success of the applied mitigation strategy can be quantitatively assessed.

Clarence

Reburial programme

Fieldwork on *Clarence* began in April 2012. A trench was excavated from the stern, forward for 9 m on the starboard side of the wreck. Recovered artefacts were fully documented, then wrapped in polyester geotextile (Bidim A14), followed by polyethylene shade cloth (Coolaroo 84–90% UV Block), secured by cable ties and stored in seawater awaiting reburial.

Once the excavated area was fully recorded, smaller metal, glass, and ceramic artefacts were placed in the base of the trench, separated by at least 50 cm to limit unwanted chemical interactions. Larger organic artefacts were reburied 10 m off-site in a storage depot, created using a polyethylene cylinder (1 m height; 1.2 m diameter) dredged into the surrounding seabed. Organic artefacts were placed in the bottom of the open based cylinder and then the site and depot were reburied to a depth of approximately 1 m with the dredged original overburden followed by proprietary sand emptied from some of the 1,700 polymeric sand bags placed on-site. The remainder of the sand bags were used to support exposed structural timbers. The reburied areas were covered with shade cloth and anchored with sand bags until the final phase of the *in situ* preservation strategy was implemented.

As re-exposure and sampling of the reburied wreck remains and artefacts is contrary to *in situ* preservation protocols, duplicate undegraded, modern wood samples (Baltic pine, Sydney blue gum and Blackbutt; identified during the 1980s excavations) were positioned in close proximity to the reinterred artefacts on-site and in the storage depot, prior to reburial. One of the duplicate samples was covered in geotextile to ascertain its protective effect on the reburied artefacts. These sacrificial samples will be recovered and analysed at regular intervals to ascertain the success of the strategy.

In November 2012, the final reburial phase commenced. A further 1,800 sand bags were placed on-site followed by a pre-prepared 250 m^2 shade cloth mat (3 × 25 m long × 3.66 m wide sections joined together by cable ties) deployed flush over the site. The shade cloth was folded in a concertina fashion, allowing the mat to be fanned out, starting down current, without recourse to deploying it in separate sections. The mat was anchored with 250 sand bags.

The site was finally covered with three polyvinyl chloride (PVC) tarpaulins (7 m × 14 m × 2 mm) to protect the shade cloth and wreck from further damage against anchors and strong currents. Each tarpaulin was deployed individually, with each end unrolled from the mid-section of the site. The three tarpaulins were then connected with cable ties and sand bags were tied in place with nylon straps along the seams and edges. Finally, the seams, edges and interior of the tarpaulins were covered with 1,300 sand bags to prevent water movement under the tarpaulin and potential lifting by anchors. The same procedure was followed for the off-site reburial depot (Shefi, et al., 2014).

Preliminary results

Over the next year, visual inspections of the site indicated that the *in situ* preservation strategy had been successful. All sand bags were in place and the PVC tarpaulins were mostly intact despite evidence of angler visitation. There was some entrapped sediment over the site and extensive colonization by marine organisms (Figure 1). The sediment under the shade cloth was grey in colour indicating a low oxygen environment.

A scientific monitoring programme was implemented analysing sediment core and sacrificial samples recovered from the reburied areas to quantitatively determine whether the applied mitigation strategy will be conducive to long-term site preservation. Analyses included the chemistry of the seawater, sediments and the associated pore water (pH;

FIGURE 1 *Clarence* in December 2014, two years after covering the site with PVC tarpaulins. *Photograph by Jon Carpenter*

redox potential, salinity, dissolved oxygen levels, total iron and organic content; sulphide and sulphate concentrations; nutrient [nitrogen and phosphorus] levels) and the type and nature of the sediments (moisture content; particle size distribution). The sacrificial samples were analysed for maximum water content (U_{max}). The methodology for these analyses has been previously published in Richards, et al. (2009).

The results of the sediment analyses can then be correlated to the extent of deterioration of the sacrificial samples. This information is compared with the pre-disturbance conversation survey results and extrapolated to the condition of the remaining archaeological material on-site to determine the success of the *in situ* preservation programme. Only the preliminary results from the reburied excavation trench will be discussed in this paper, although the results from the reburial depot are similar. Further results, interpretation, and comparative analyses will be presented in a final edited volume due mid-2017.

Sediments

The baseline sediment grain size distribution profile on the site prior to excavation in April 2012 is shown in Figure 2. Generally, the baseline sediment consisted largely of medium sands with some coarser grained inter-beds mainly in the upper 20 cm of the sediment column and higher proportions of fine-grained sand in the lower fraction (20–50 cm). The baseline sediment demonstrated a trend from poorly sorted in the upper fractions (0–20 cm) increasing to moderately sorted as the sediment depth increased indicating that the surface sediment is reasonably mobile and easily reworked by water movement. The level of skewness of the baseline sediment gradually increased from negative to more positive with increasing sediment depth. The negative skewness of the surface sediment (0–20 cm) is typical of winnowing, where fine components have been removed by persistent wave action and strong currents, however the increase in finer grained sand below this depth is indicative of a more stable, shallow shelf bed load, which is consistent with the mean grain size and sorting results.

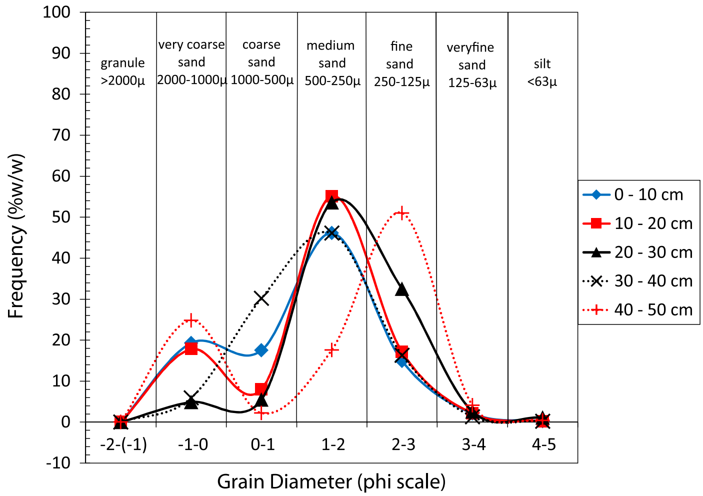

FIGURE 2 Grain size distribution of the baseline sediment on *Clarence* prior to excavation in April 2012.

The results imply that wreck remains located in this 0–20 cm sediment depth range are likely to be more degraded than deeper materials. They may also suffer further damage, especially during periods of excessive water movement, due to the unstable nature of these surface sediments. These results are supported by the wood samples recovered from structural timbers buried in this upper region that showed extensive marine worm depredation.

The redeposited sediment in the reburial trench (Figure 3) was predominantly coarse-grained sand but with significantly higher proportions of very coarse-grained sand throughout the sediment column compared to the baseline sample. The reburial trench was initially backfilled with dredged baseline sediment but there was significant loss of the medium-fine-grained sand during the excavation and backfilling process, causing higher proportions of coarser grained sand in the lower (30–50 cm) fraction of the reburial trench. After utilizing all the original dredged sediment, proprietary sand from sand bags was used to fill the excavated area to the required depth. This is evident from the similar histograms for the 0–30 cm fraction in the reburial trench compared to the proprietary sand distribution graph (Figure 4), however there was some loss of the medium-fine-grained sand when the sand was dumped into the trench. All stratigraphic fractions in the reburial trench were poorly sorted, a direct consequence of the more rapid and recent deposition compared to the baseline sediments.

Since grain size is often related to the amount of organic material within sediments (i.e. larger grain sized sediments generally have lower organic contents) the amount of extractable organic matter (EOM) in the baseline sediment and the reburial trench are shown in Figure 5. Generally, the baseline sediment contained higher quantities of organic material compared to the reburial trench. This is expected as there were higher proportions of smaller grain size particles in the baseline sediment. A possible explanation for the higher concentrations of EOM in lower fractions (20–40 cm) of the reburial trench analysed in 2012 (six months after reburial prior to covering) is this fraction mainly

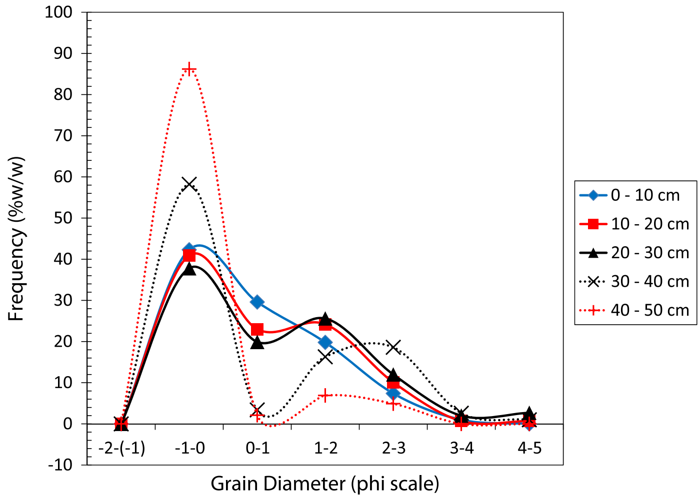

FIGURE 3 Grain size distribution of the reburial trench sediment in December 2014 (30 months after reburial; 25 months after covering).

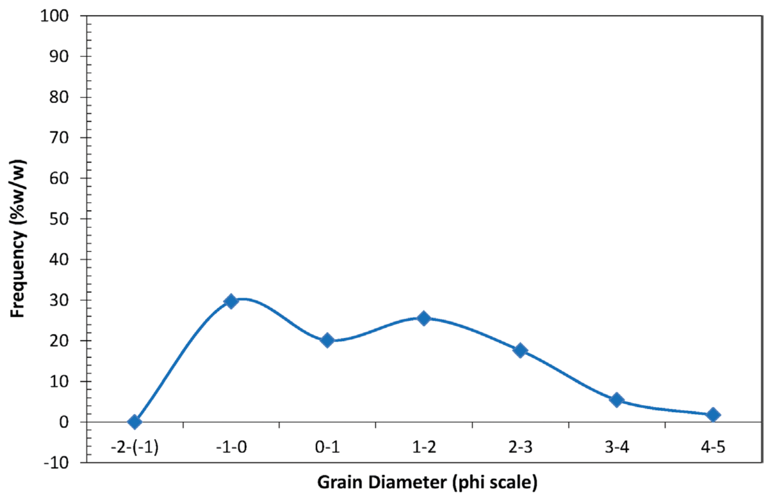

FIGURE 4 Grain size distribution of the proprietary sand.

comprised dredged baseline sediment which contained higher levels of organic material. The trench was then topped up with proprietary sand containing very low levels of EOM. This trend appears to reverse after the trench was covered with the concentration of EOM quite high in the upper fractions, then decreasing with increasing sediment depth. This may be explained by microbial activity in the lower fractions utilizing the residual organic material present in the dredged backfill but the aerobic biota trapped under the tarpaulin after installation would slowly degrade producing more EOM in the upper fractions of the reburied sediment column.

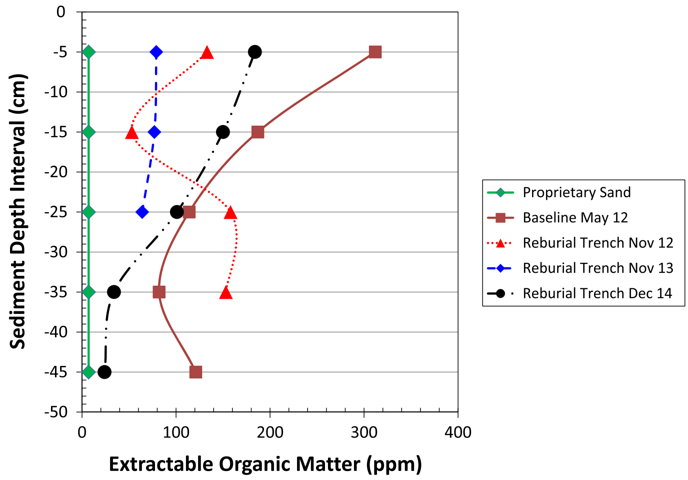

FIGURE 5 Extractable organic contents in the baseline and reburial trench sediments.

Generally, porosity decreases with increasing grain size and poorly sorted sediments have lower porosity than similarly sized well-sorted sediments. Sediments with lower porosity often have a lower hydraulic conductivity (less water flow) and generally lower organic contents (Nyström Godfrey, et al., 2011). This is significant as the amount of water, water flow, and organic material in the sediments will affect the type and rate of chemical and biological processes occurring in the sediments. Hence, based on the grain-size distribution and EOM results, it appears that the sediment in the excavation trench would be more conducive to the long-term preservation of the wreck remains than the original sediments present on-site prior to excavation.

Long-term organic and metal preservation depends on the maintenance of a stable physical and chemical reburial environment characterized by anoxic, reducing, near neutral pH conditions with low levels of organic matter and minimal biological activity.

The dissolved oxygen profile of the reburial trench decreased markedly from June and November 2012 after initial reburial to almost baseline levels in December 2014 (Figure 6). However, the lower 30–50 cm fractions that comprised the backfilled baseline sediment attained very low dissolved oxygen levels after one month. This rapid decrease would be due to biological mineralization of the higher amounts of EOM present in these lower fractions after initial reburial (Figure 5).

There were higher sulphide concentrations in the baseline sediment prior to excavation (Figure 7), which is to be expected due to increased EOM levels in the upper sediment fractions (Figure 5). However, at average concentrations around 0.08 mM the overall levels were still relatively low. All sediment cores recovered from the reburied excavation trench possessed negligible sulphide levels indicating that sulphate reduction by sulphate-reducing bacteria (SRBs) is not one of the major redox reactions occurring in these sediments after reburial.

The redox potential measurements portrayed the most variation; however, the general trend was decreasing redox potentials with increasing depth and time, indicating a change from oxidizing to more reducing conditions (Figure 8). Again the interface between the

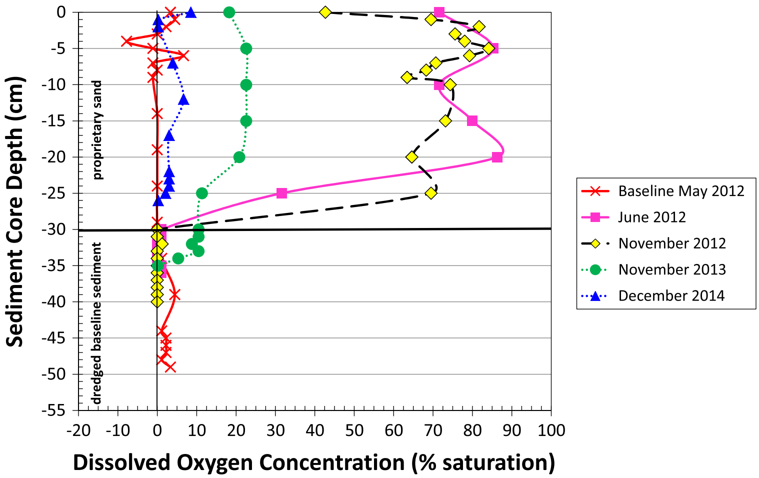

FIGURE 6 Dissolved oxygen concentrations in the baseline and reburial trench sediments.

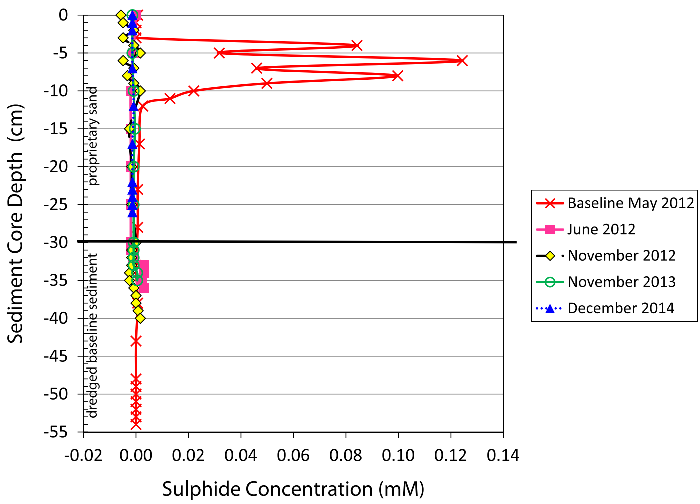

FIGURE 7 Sulphide contents in the baseline and reburial trench sediments.

dredged original baseline sediment and the proprietary sand is evident at about 30 cm where below this depth the redox potentials were marginally more negative, indicating more reducing conditions in the lower fractions.

After initial deposition of the backfilled baseline sediment and proprietary sand, the pH was slightly more acidic than the baseline due to an increase in dissolved oxygen content introduced during the dredging process and a corresponding increase in aerobic biological activity, which will produce hydrogen ions and acidic metabolites (Figure 9). Over time the pH increased with increasing depth and time interval due to the reduction of dissolved oxygen producing hydroxyl ions under less oxidizing conditions and

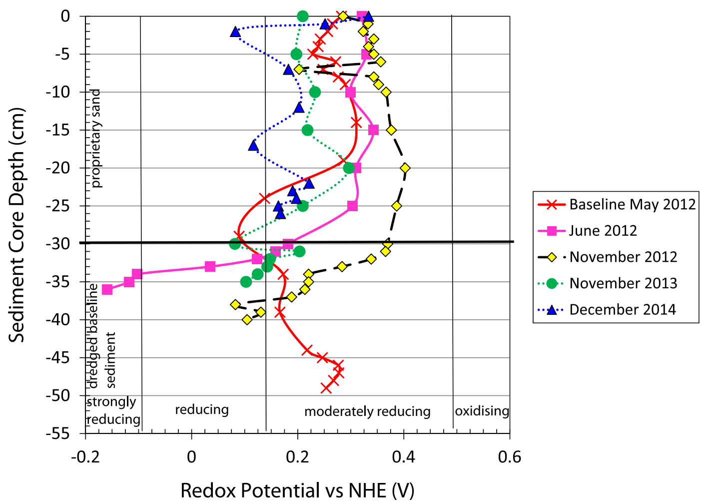

FIGURE 8 Redox potential profiles of the baseline and reburial trench sediments.

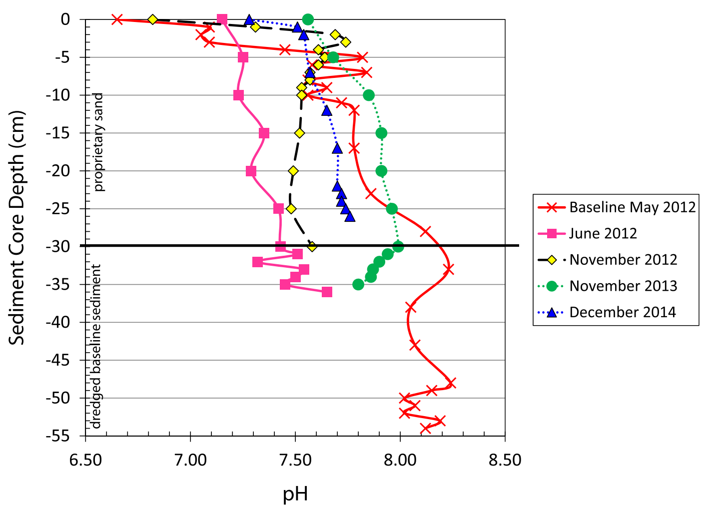

FIGURE 9 pH profiles of the baseline and reburial trench sediments.

decreasing biological activity. Hence, the pH of the reburial trench sediment is slowly equilibrating to baseline levels after two years.

Based on the results presented above, after two years, the sediment in the covered, reburied excavation trench is stable, anoxic, moderately reducing, has a near neutral pH, low porosity and organic content and negligible sulphide levels indicating low biological activity. Therefore, the reburial environment in the excavation trench is conducive to the long-term preservation of the wreck remains.

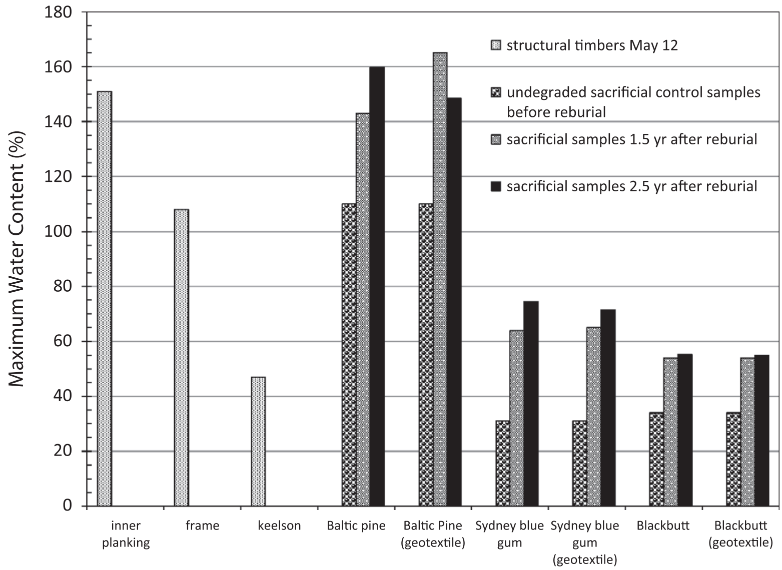

FIGURE 10 Maximum water contents of the structural timbers and modern undegraded and degraded sacrificial samples.

Wood samples

Samples of the major structural timbers exposed during the excavation were recovered and identified as *Eucalyptus*, however species has yet to be determined. The average U_{max} of the inner planking (151%), frame (108%), and keelson (47%) recovered from the lower (40–50 cm) fraction indicated that they were relatively undegraded (0–185%) (Figure 10).

Two sacrificial sample plates were recovered from the excavation trench 1.5 (November 2013) and 2.5 years (December 2014) after reburial (Figure 10). The reburied sacrificial samples have shown only slight increases in U_{max} compared to the undegraded control samples. The geotextile seems to have had very little protective effect on the samples. The U_{max} of the Sydney blue gum and Blackbutt sacrificial samples are either similar to the U_{max} of the keelson, or significantly lower than the other structural timbers, indicating that the reburial regime has had minimal effect on the wreck itself.

The reburial regime has probably improved the preservation conditions for the wreck remains in the excavation area since previously exposed timbers are now buried under at least 10 cm of stable sand, which will halt any further depredation by *Teredo* worms.

Preliminary conclusions

The *in situ* preservation strategy applied to the *Clarence* has been successful after two years. The backfilled sections have stabilized physico-chemically but further interpretation of the data from the wet chemical analyses is necessary to understand the biological processes occurring in these reburied areas. However, for the strategy to be successful long-term, continued monitoring of the site at regular intervals and during seasonal extremes is necessary.

James Matthews

Background

Following the discovery of the *James Matthews* in 1973, archaeological excavations were carried out annually until 1977, with the site reburied after every excavation period (Henderson, 1977). In 2000 it was observed that previously buried sections were exposed and timbers were being rapidly degraded by marine borers. An extensive on-site conservation survey was conducted to establish the state of preservation of the wreck and provide information regarding the nature of the environment prior to the implementation of any mitigation strategy (Godfrey, et al., 2005). Surveys in 2003 confirmed further exposure of the site and it was apparent that an appropriate *in situ* preservation strategy was urgently required.

In 2005, reburial experiments were implemented using polymeric sand bags, an artificial seagrass mat, and shade cloth mats to trap sediment, and a cofferdam made of plastic road crash barriers (RCBs). The experiments were monitored until 2010 when it was concluded that the RCB method would be the most appropriate for this site (Richards, 2012; Richards, et al. 2009). In 2012 sufficient funds became available, under the aegis of the ASHPP, to implement this strategy.

Reburial programme

The initial plan was to deploy 40 RCBs in a semi-elliptical arrangement surrounding the site and then fill the cofferdam with sand to a depth of at least 50 cm. This large-scale reburial programme was undertaken over five days in November 2013 (Richards, et al., 2014).

Aggregate was placed inside the RCBs (20 kg) and locking pins (5 kg) which allowed them to sink. One RCB weighed about 15 kg underwater so they were easily manoeuvred on the seabed. The barriers and connecting pins were transported to the site using a small tender. Three snorkelers sank the RCBs via air displacement. Two divers received the RCBs and moved them into position on the seabed, locking them in place with the pins; thirty-six RCBs were deployed on-site using this procedure. A further 120 kg of aggregate was added to each barrier. The gaps between the barriers were sealed with plastic roof damp coursing and anchored with zinc alloy 'tek' screws. A purpose-built sand barge was loaded with clean, washed sand via 20 kg sand bags. Using this method, 28 tonne of sand was dumped inside the cofferdam, resulting in a 5–10 cm sterile sand layer over the site at the conclusion of the fieldwork period (Figure 11).

A further 230 tonne of sand was required to achieve the minimum sediment depth of 50 cm, impossible with the equipment and personnel remaining after the fieldwork concluded. Hence, shade cloth was placed over the cofferdam in December 2013 to prevent ingress of extraneous organic matter, minimize loss of deposited sediment, and possibly trap sand suspended in the water column. After four months the barriers and shade cloth were totally covered with algae and the sediment in the cofferdam was grey in colour indicating a lower oxygenated, reducing environment, conducive to long-term preservation.

In June 2014 a meteorological tsunami ravaged the coast, destroying the shade cloth, damaging one of the RCBs and opening up the stern end of the cofferdam. Resulting

FIGURE 11 *James Matthews* site surrounded by the cofferdam in November 2013. *Photograph by Patrick Baker*

water movement caused a tunnelling effect, transporting the deposited sterile sand and original sediment towards the bow, totally exposing the structural timbers at the stern and the reburied sacrificial samples.

The cofferdam was repaired in November 2014; replacing the damaged RCB and adding two extra RCBs to minimize stress on the cofferdam. All RCBs and pins were totally filled (~250 kg) with aggregate and the wreck's interior covered with shade cloth to minimize further sediment loss and protect the exposed stern. The reburial programme will recommence with backfilling the exposed area with dredged local sediment containing minimal organic content. Once the site has stabilized, the monitoring programme will commence, similar to the *Clarence* for comparative analysis.

Conclusions

It is difficult to predict the efficacy a particular mitigation strategy may have on the long-term preservation of an underwater cultural heritage site without establishing a scientifically based monitoring programme. Here, the information gained from a national collaboration through the *Clarence in situ* preservation project will inform new national protocols and guidelines for the successful protection and management of Australia's underwater cultural heritage.

Acknowledgements

The AHSPP is supported by the Australian Research Council through Linkage Partner Grant LP110200184. The Administering Organization is the University of Western Australia. The partner organizations are Western Australian Museum; Australian Government Department of Sustainability, Environment, Water, Population and

Communities; Victorian Department of Planning and Community Development; Australasian Institute for Maritime Archaeology; NSW Office of Environment and Heritage; Tasmanian Parks and Wildlife Service; Northern Territory Government; Queensland Department of Environment and Heritage Protection; Norfolk Island Museum; and the Australian National Maritime Museum. We are grateful to our partner organizations, their staff, and to our many volunteers for contributing their time, expertise, and equipment to the project.

Bibliography

Harvey, P. 1989. Excavation of the Shipwreck *Clarence*: Port Phillip Bay, October 1987. Unpublished Report. Melbourne: Victoria Archaeological Survey.

Henderson, G. 1977. Four Seasons of Excavation on the *James Matthews* Wreck. The First Southern Hemisphere Conference on Maritime Archaeology. Perth. Western Australian Museum.

Godfrey, I., Reed, E., Richards, V., West, N. & Winton, T. 2005. The *James Matthews* Shipwreck – Conservation Survey and *In-situ* Stabilisation. In: P. Hoffmann, K. Strætkvern, J. A. Spriggs and D. Gregory, eds. *Proceedings of the 9th ICOM Group on Wet Organic Archaeological Materials Conference, Copenhagen, 2004*. Bremerhaven: The International Council of Museums, Committee for Conservation Working Group on Wet Organic Archaeological Materials, 40–76.

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*. Udevalla, Sweden: Bohusläns Museum and Studio VästSvensk Konservering.

Richards, V. 2012. *In Situ* Preservation and Monitoring of the *James Matthews* Shipwreck Site. *Conservation and Management of Archaeological Sites*, 14(1-4): 169–181.

Richards, V., Godfrey, I., Blanchette, R., Held, B., Gregory, D. & Reed, E. 2009. *In-Situ* Monitoring and Stabilisation of the *James Matthews* Site. In: K. Straetkvern and D. J. Huisman, eds. *Proceedings of the 10th ICOM Group on Wet Organic Archaeological Materials Conference, Amsterdam, 10–15 September 2007*. Amersfoort: Rijksdienstvoor Archeologie, Cultuurlandschap en Monumenten (RACM), 113–160.

Richards, V., MacLeod, I. & Veth, P. 2014. The Australian Historic Shipwreck Preservation Project – *In-situ* Preservation and Long-term Monitoring of the *Clarence* (1850) and *James Matthews* (1841) Shipwreck Sites. In: H. van Tilburg, S. Tripati, V. Walker Vadillo, B. Fahy and J. Kimura, eds. *Proceedings of the 2nd Asia-Pacific Regional Conference on Underwater Cultural Heritage, 13–16 May 2014, Honolulu, Hawaii, 2014*. Hawai'i, Honolulu: Asia-Pacific Regional Conference on Underwater Cultural Heritage Planning Committee, pp. 469–482.

Shefi, D., Veth, P., Philippou, C., Rodrigues, J., Richards, V., Harvey, P. & Carpenter, J. 2014. The Australian Historic Shipwreck Preservation Project: An Interim Progress Report. *Bulletin of the Australasian Institute for Maritime Archaeology*, 38: 31–40.

Veth, P., Philippou, C., Richards, V., Staniforth, M., Rodrigues, J., Khan, A., Creagh, D., Viduka, A., Barham, A. & MacLeod, I. 2013. The Australian Historic Shipwreck Preservation Project 2012: First Report on the Background, Reburial and *In-Situ* Preservation at the *Clarence* (1841–50). *Bulletin of the Australasian Institute for Maritime Archaeology*, 37: 1–19.

Notes on contributors

Vicki Richards is a conservation scientist in the Materials Conservation Department of the Western Australian Museum. One of her primary research areas is devising and implementing appropriate on-site management plans for the long-term *in situ* preservation of shipwreck sites.

Correspondence to: Vicki Richards. Email: vicki.richards@museum.wa.gov.au

Ian MacLeod has extensive experience in the analysis and interpretation of corrosion products and *in situ* corrosion measurements on historic shipwrecks and archaeological

sites. His current role is Executive Director, Fremantle Museums and Collections, Western Australian Museum.

Peter Veth has directed numerous archaeological projects on the evolution of maritime societies in Australia, Maluku, and East Timor. He has published widely on site formation models and heritage conservation strategies. He is Winthrop Professor of Archaeology at the University of Western Australia.