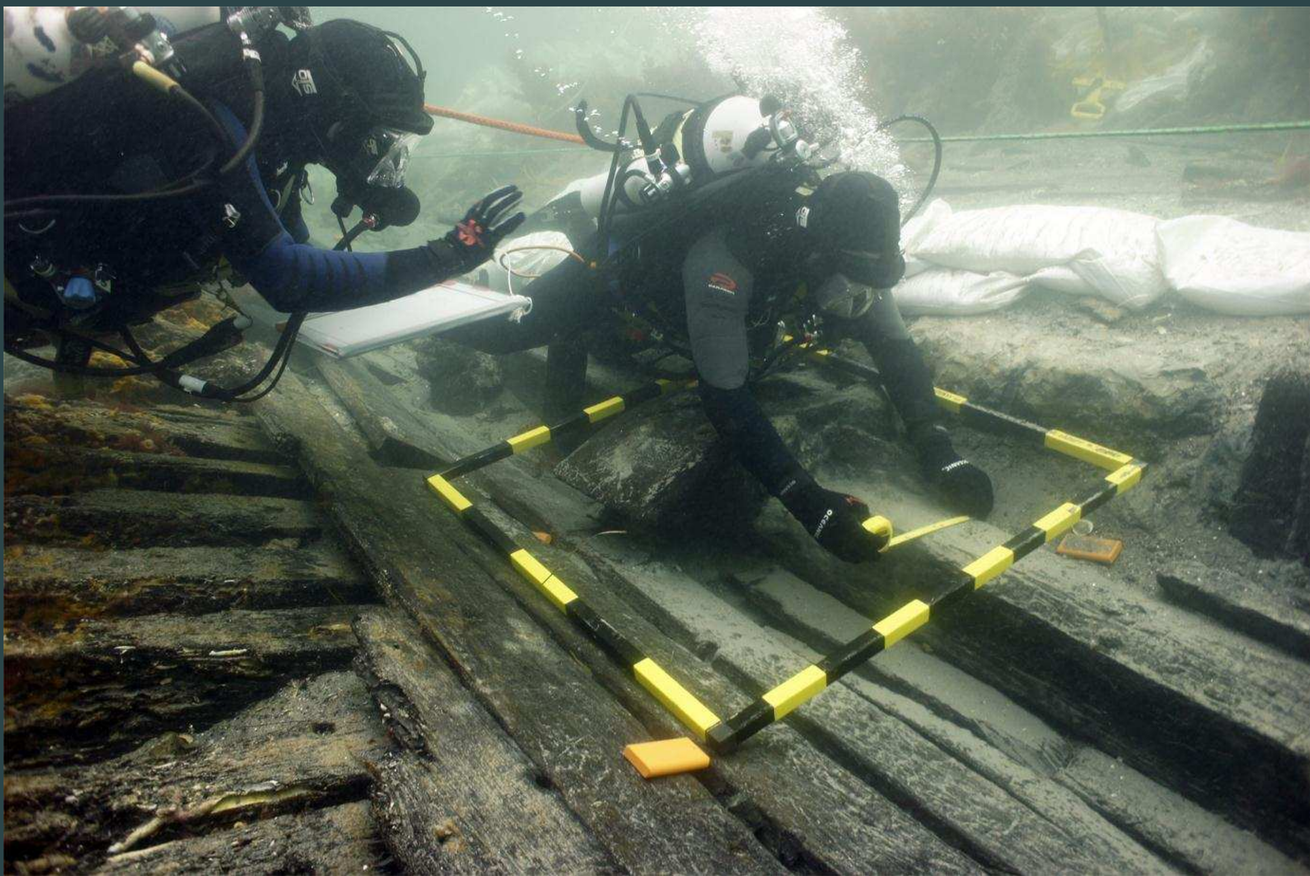
AUSTRALIAN
HISTORIC SHIPWRECK
PRESERVATION PROJECT

THE IN-SITU PRESERVATION & REBURIAL
OF THE COLONIAL TRADER CLARENCE (1850)

Excavation & Monitoring Programme Report

2012–2015



Cover image: Maritime Archaeologists Amer Khan and Andy Dodd recording the keelson on *Clarence*, April-May 2012. Photo by the Australian Historic Shipwreck Preservation Project (AHSPP).

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Abbreviations

ADAS	Australian Diving Accreditation Scheme
AHSPP	Australian Historic Shipwreck Preservation Project
AIMA	Australasian Institute of Maritime Archaeology
AFP	Australian Federal Police
ANU	Australian National University
ARC	Australian Research Council
CI	Chief Investigator
CPUCH	Convention on the Protection of the Underwater Cultural Heritage
CMA	*Coastal Management Act 1999*
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
HSNRP	Historic Shipwrecks National Research Plan
HV	Heritage Victoria
JUPB1	Jack-up Platform Barge 1
MAAV	Maritime Archaeology Association of Victoria
MAU	Maritime Archaeological Unit
NSW	New South Wales
NTM	Notice to Mariners
PDS	Professional Diving Services
PI	Partner Investigator
PV	Parks Victoria
PVC	Polyvinyl chloride
RAAR	Reburial and Analysis of Archaeological Remains
SASMAP	Survey, Assess, Stabilise, Measure and Preserve
SCUBA	Self Contained Underwater Breathing Apparatus
SR4	Site Recorder 4

SSBA	Surface Supplied Breathing Apparatus
UCH	Underwater Cultural Heritage
UW	Underwater
UWA	The University of Western Australia
VAS	Victoria Archaeological Survey
WAM	Western Australian Museum
XRD	X-ray diffraction

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Executive Summary

Over the last four years the Australian Historic Shipwreck Preservation Project (AHSPP) has focussed on the reburial and *in-situ* preservation of shipwrecks and colonial shipbuilding. In 2011 researchers identified a number of criteria that a research site should meet in addressing these topics including a) the shipwreck must be identified as 'at-risk'; b) the site should be logistically accessible; c) the site has been extensively researched, monitored, and perhaps partially excavated previously; and d) the current managing agency must supports the AHSPP and have the capcity to carry out the long-term monitoring of the site. *Clarence* (1841-1850), located off the coastal township of St Leonards on Victoria's Bellarine Peninsula, satisfied all these criteria. Another wreck site that also satisfied the criteria was *James Matthews* (1836-1841) lying off Woodman Point, in Cockburn Sound, WA. This site was eventually selected as a second case study by the AHSPP in 2013, and will be reported on separately (Richards et al. 2014; Richards et al. in press a). This project report is submitted in accordance with conditions listed in Heritage Victoria Shipwreck Permit SP217.

The project has involved four Australian universities and ten government agencies as well as the Australasian Institute for Maritime Archaeology (AIMA). It was funded by an Australian Research Council Linkage Grant (LP110200184) of which Peter Veth was the Lead Chief Investigator (CI) and The University of Western Australia, the Administering Organisation. Mark Staniforth and Tony Barham were Chief Investigators (Monash University and the Australian National University [ANU], respectively) while Vicki Richards and Ian MacLeod were Principal Investigators (PI) from the Western Australian Museum (WAM). Cassandra Philippou was the Project Manager for the majority of project, with Debra Shefi acting in the role for a short period. Heritage Victoria (HV) was the host agency for the *Clarence* study site and specifically vessel-based diver logistics.

The project was awarded $500 000 by the Commonwealth Government through the Australian Research Council (ARC), with a further $180 000 provided by the ten Partner Organisations. It is calculated that over AUD$1 million was provided in kind by Investigators, Partner Organisations, Research Associates and volunteers. AHSPP has already completed over twenty formal presentations and peer-reviewed papers and developed a significant resource for past and present *Clarence*-related activities that may be found at www.ahspp.org.au. It is expected that on-going monitoring, archaeological and conservation-related analyses will result in a decade of further publications and outputs—not the last of which is the forthcoming edited volume (Richards, Veth, Philippou & Staniforth) *Conserving and Managing Shipwrecks* In Situ*: the Australian Historic Shipwreck Preservation Project* to be published by Springer Press in 2017.

The Project formally commenced in February 2012. Sixty-five volunteer and professional maritime archaeologists and conservators were involved in the 2012 field season, including practitioners from Australia, New Zealand, Indonesia, Thailand, Cambodia, the Philippines and the United States of America (USA). A four-week field season began on 16 April 2012 and was marked by the establishment of a jack-up platform barge (JUPB1) to support diver, conservation, visualisation and finds processing directly adjacent to the wreck site. The workplace supervisor was Professional Diving Services (PDS) of Melbourne, led by maritime archaeologist and dive supervisor James Parkinson. During the preparatory phase and throughout the project Heritage Victoria (HV) provided a workplace, IT access and use of its vessel *Trim.*

In November 2012 a small, highly experienced team returned to the site to undertake one of the largest-scale *in-situ* shipwreck reburial programmes ever attempted. This involved laying 250 m^2 of shadecloth and c. 300 m^2 of polyvinyl chloride (PVC) tarpaulins over the site, thereby completely covering it. Over 3 500 sandbags filled with proprietary sand were used to backfill excavated areas and secure the shadecloth and tarpaulins to the seabed. Conservation actions included multiple sediment cores for geochemical and physico-chemical assays; reburial of cultural components, both *in situ* and to the stern of the wreck in a purpose built repository; reburial of experimental sacrificial wood and ferruginous samples; and, marine biology surveys prior to and following re-interral. Still and video runs were made of the larger site for Structure from Motion 3D modeling; models were later created using Agisoft Photoscan.

The project is a landmark study for *in-situ* preservation of submerged maritime archaeological sites, and builds on the Reburial and Analysis of Archaeological Remains (RAAR) (Nyström Godfrey et al. 2012) and Survey, Assess, Stabilise, Monitor and Preserve (SASMAP) projects (Gregory et al. 2013) underway in Europe.

Introduction

The Australian Historic Shipwreck Preservation Project (AHSPP) is a multi-organisational maritime archaeology research programme involving four Australian universities and ten agencies from the Australian Commonwealth, State and Territory governments as well as the Australasian Institute for Maritime Archaeology (AIMA). It has been funded by an Australian Research Council (ARC) Linkage Grant (LP110200184) with Professor Peter Veth as the Lead Chief Investigator and the University of Western Australia (UWA) the Administering Organisation. Mark Staniforth and Tony Barham were Chief Investigators (Monash University and the ANU, respectively) while Vicki Richards and Ian MacLeod were Principal Investigators from the Western Australian Museum (WAM). Heritage Victoria (HV) acted as the host agency for the *Clarence* study site. The project was awarded $500 000 by the Commonwealth with a further $180 000 provided by the ten Partner Organisations over a three year period.

This large ten-Partner Organisation Linkage Project was fully novated and began formally on 21 February 2012 following a delay in the transfer of the grant from the applicant institution, the Australian National University to the administering institution, UWA. The optimal fieldwork window for work on the wreck was judged by Chief Investigator (CI) Staniforth to lie between March and May. This was based on past weather patterns and current data from Port Phillip Bay. At the commencement of the grant, the team developed a roster for the 65 volunteer and professional maritime archaeologists and conservators for the 2012 field season. These included students and practitioners from Australia, New Zealand, Indonesia, Thailand, Cambodia, the Philippines and the USA. Accommodation was sourced and secured for this large group in Portarlington over a four-week period and food and logistics coordinated for fieldwork to begin on 16 April 2012. Following the key questions which formed the basis of the ARC grant concerning the rapid reburial and *in-situ* preservation and colonial shipbuilding, a modified research design for a permit to work on the wreck was developed and submitted to Heritage Victoria on 27 March 2012.

The workplace supervisor (Professional Diving Services of Melbourne) in collaboration with UWA Boating and Diving Safety Committee developed operation guidelines and a Dive Safety Plan (Parkinson & PDS 2012a) for the work site. The Australian Standard, AS2299.1 was used, and all diving conducted within this Victorian workplace was completed by practitioners using surface supply breathing apparatus (SSBA) and/or tethered self contained underwater breathing apparatus (SCUBA) with Australian Diver Accreditation Scheme (ADAS) 1 and 2 qualifications required for excavation and the water dredge. James Parkinson and Peter Veth held current ADAS Supervisor's qualifications and supervised the work site. In the lead up to fieldwork the building of the imaging equipment for X-ray, scanning and photography; X-ray container; surface supply communication chamber, air banks and a conservation laboratory, were completed. During this preparatory phase HV provided a workplace, IT access and use of its vessel. The University of Western Australia advertised and employed a Project Manager at 0.6 FTE for the project providing a six-week lead-time prior to the start of fieldwork. Numerous meetings were held with staff from the WAM, University of Canberra and HV. Finally, the architecture and content of the project web site was completed (www.ahspp.gov.au) and launched in time for the start of fieldwork.

The AHSPP researchers identified a number of case study criteria that should be met in selecting *Clarence* as the case study. These included: a) the shipwreck must be identified as 'at-risk'; b) the site should be logistically accessible using available project resources; c) the site should have been extensively researched, monitored, and perhaps partially excavated in the past; and, d) the current managing agency supported the AHSPP and had the capacity to carry out long-term monitoring of the site.

The *Clarence,* located off the coastal township of St Leonards on Victoria's Bellarine Peninsula (Fig. 1) satisfied all of these criteria. Another wreck site that also satisfied these criteria was *James Matthews*

(1841) lying off Woodman Point, in Cockburn Sound, WA. This was eventually chosen as a second study site by the AHSPP in 2013, and will be reported on separately (Richards et al. 2014; Richards et al. in press a).

Figure 1. Location map of *Clarence* in Port Phillip. Image courtesy Google Maps 2 November 2015.

The team of Australian and international participants commenced the month-long excavation of the historic shipwreck *Clarence* (1841–1850) on 16 April 2012. Throughout the month of fieldwork, a total of 65 people took part as divers, tenders, boat operators, logistics and conservation support. Core team members were on location for the entire month, while some local volunteers joined the team for just a few days. Most participants attended for a minimum of two weeks, and up to 33 people were involved with the project at any one time. The jack-up platform barge (JUPB1) was in survey for 25 people and thus divers, conservators and support staff had to be rostered and transported on and off the site, as required. While JUPB1 provided an excellent work platform directly adjacent the site, and housed all cultural materials in temporary storage, the transfer routine for all conservation specimens, serviced dive equipment and personnel from *Trim* to the platform, and return, was inevitably weather dependent.

In November 2012 a small, highly experienced team returned to the site to undertake one of the largest-scale *in-situ* shipwreck reburial programmes attempted to date. This involved laying 250 m^2 of shadecloth followed by 294 m^2 of PVC tarpaulins over the entire site, thereby completely covering it. An additional 2 m^2 of each material was laid over the reburial depot. Dredged backfill and proprietary sand from over 3 500 sandbags were used to rebury the excavation areas and reburial depot, and secure the shadecloth and tarpaulins to the seabed. The site was effectively mounded; the PVC tarpaulins 'stitched' together between prefabricated eyelets and heavy-duty fasteners used to close any seams between the final PVC cover. While the shadecloth kept the backfilled sediment in place, the addition of the PVC layer provided further physical protection from anchors and the like.

From April to November 2012, fieldwork at *Clarence* was divided into 15 stages: a) laying out the datum and reference points around the wreck for trilateration and Site Recorder 4 (SR4) mapping; b) pre-disturbance photography and videography; c) site condition and marine biology surveys; d) sediment coring both within and adjacent to the wreck; e) excavation of a 9 m trench along the starboard section; f) mapping of all cultural materials in 3D; g) finds processing and conservation assessment; h) temporary storage of artefacts on JUPB1; i) photography, materials testing and data entry on the artefact database; j) preparation of the off-site reburial repository, placement of the recovered artefacts and experimental wooden and ferruginous sacrificial samples on the wreck site and in the reburial repository; k) filling of approximately 3 500 poly-weave sandbags with proprietary clean, washed sand and placement around the site; l) reburial of all excavated areas using backfill and proprietary sand; m) laying of shadecloth over the site; n) final laying of PVC tarpaulins over the shadecloth with additional sandbag anchors; and, o) final backfilling and stabilization of the off-site reburial repository. This intensive programme was then followed by multiple visits for visual monitoring and to gather samples for conservation analyses.

Since the project commenced in 2012 there have been ten separate visits to the site involving surveying, mapping, visual recording, excavation, reburial and conservation monitoring. These visits were made by ARC Investigators and Partners, staff from HV and volunteers. In addition, HV has also undertaken compliance activities at the site as part of its regulatory responsibilities.

The project is a landmark study for *in-situ* preservation of submerged maritime archaeological sites, and builds on the Reburial and Analysis of Archaeological Remains (RAAR) (Nyström Godfrey et al. 2012) and Survey, Assess, Stabilise, Monitor and Preserve (SASMAP) projects (Gregory et al. 2013) underway in Europe.

Background

Creation of the Australian Historic Shipwreck Preservation Project[1]

Following some two years of discussion amongst the nation's maritime archaeology practitioners, conservation professionals and academic staff then at the ANU and Monash University, the ARC awarded a Linkage grant to the AHSPP, with Professor Peter Veth of UWA as the Lead Chief Investigator.

As part of the administration of the Historic Shipwrecks Program, the Commonwealth Government sought consensus from Historic Shipwrecks Act delegates and practitioners for a national collaborative project that would meet a range of objectives. The project needed to address a national issue faced by all Delegates, provide a research outcome, be relevant to the future ratification of the 2001 UNESCO *Convention on the Protection of the Underwater Cultural Heritage* (CPUCH), and provide training and professional development opportunities for practitioners and students in Australia and the Asia—Pacific region. Practitioners submitted project ideas to the Commonwealth, and then voted on them in order of preference.

A decision was made to pursue an *in-situ* preservation project on a submerged site that would address the study of *in-situ* preservation and reburial of shipwrecks subject to accelerated degradation. It was recognised that this research would be able to contribute to the innovative research on *in-situ* preservation being undertaken in Europe (Nyström-Godfrey et al. 2009, 2012) and Western Australia (Richards 2011; Richards et al. 2009). The next most highly-ranked project was for studies of Australian colonial shipbuilding.

The project groundwork was facilitated by Andrew Viduka of the Heritage Division of the Commonwealth Department of Environment, Water, Heritage and the Arts (now the Department of the Environment [DEH]) (Veth et al. 2011, 2012). The *Clarence*, located in Port Phillip Bay, was selected as the case study as it met a number of other aims of the (now defunct) National Maritime Heritage Strategy and the Historic Shipwrecks National Research Plan (HSNRP) (Edmonds et al. 1995). *In-situ* reburial work on *James Matthews* (1841) lying off Woodman Point in Western Australia was added to the AHSPP's programme in October 2013 and is ongoing. Research on *James Matthews* provides a comparative study in a different setting, and will be reported on elsewhere.

[1] Text in this section from Veth et al. (2013).

History of *Clarence*[2]

Clarence was built in 1841 on the Williams River in New South Wales (NSW). Current research suggests that the builder was William Lowe, and that *Clarence* was constructed at his Deptford shipyard (Fig. 2).

Figure 2. William Lowe's Deptford shipyard near Clarence Town, Williams River, NSW, c. 1842. Enlargment from a watercolour painting by Oswald Brierly—PXD 81 Folio 7 courtesy of Mitchell Library, Sydney, NSW.

The vessel was jointly owned by Thomas Ayerst and Gordon Sandeman from January 1842 until July 1842. *Clarence* was first registered (Sydney No 6. of 1842) as a wooden two-masted carvel-built schooner of 67 and 498/3500 tons and described as having a square stern, standing bowsprit, no galleries and one deck. Joseph Thomson was the master from 24 January 1842 until 7 October 1842 (Gesner 1984).

There are no records of *Clarence*'s voyages before 1845. Port Albert was its only known destination for the duration of 1845 and well into 1846. Between 22 July 1845 and 11 May 1846 it only made ten round trips to Hobart and Port Phillip Bay, mostly carrying passengers and general cargo. The vessel was used in the trade of timber, cattle, sheep, and other cargo between Sydney, Melbourne, Hobart and Geelong until it was stranded and nearly wrecked in Warrnambool in 1847. The stranding at Warrnambool at the time brought about allegations of insurance fraud. An investigation was launched, though documents on whether these accusations were proven have not been located.

After the vessel's repair there is some indication that it was refitted to accommodate passengers and it appears that was the main source of income in 1848. A female bust figurehead was added sometime during the period between 1842 and 1850, possibly after the vessel was stranded at Warrnambool in September 1847 and during its refit. After 1848, *Clarence* was again used as a cargo vessel in Bass Strait trade, sailing between Port Fairy, Port Philip and Launceston.

[2] Text in this section reproduced from http://www.ahspp.org.au/clarence/history.

On 2 September 1850, *Clarence* ran aground on a sandbank in Port Phillip Bay while transporting 132 sheep from Melbourne to Hobart. It had anchored in Coles Channel for the night, when the cable broke after a south-west to south-south-west wind blew up. The sheep on board were rescued by Geelong residents, who later entered into a dispute with the ship's owners. The result of the dispute is unknown. The loss of the vessel and cargo was estimated at £500.

Pre-disturbance site environment

Clarence lies on a sandy seabed in 4 to 5 m of water. The area is surrounded by sea-grass beds; however, very little sea-grass grows on the wreck site itself. On a day with good water visibility, the wreck can be seen from the surface with quite good definition.

The majority of the vessel's outline is exposed, apart from the starboard side at the stern, which is relatively well buried. The port side of the ship from bow to stern, and from keel to deck level is almost complete albeit buried. The paired frames used as the framework for the hull can be seen protruding out of the sand and outline the shape of the ship (although these have diminished in height and integrity since the discovery in 1982). At the time of its wrecking, *Clarence* was used to transport sheep. Part of the Baltic pine decking used to accommodate the animals can be seen at the stern. Some very fragile pieces of leather and rope have been found on the wreck site both in 1987 and in 2012. Other artefacts that were recovered in 1987 include a small glass deck light, ceramics and the ship's compass.

It is clear that the amount of sediment covering the wreck has decreased over time since first located; and, as of early 2012, the starboard side was significantly more exposed than previously recorded. It has been estimated that up to 30 cm of sediment has been scoured from the stern since excavation (Harvey & Shefi 2014). During visits to the site in early 2012, remains of previously placed artificial sea-grass (Cegrass™) matting were noted in the centre of the wreck. These were destoyed by anchors soon after their placement c. 1993. Pieces of copper sheathing and a brown glass bottle were also noted in this area. Part of a copper alloy gudgeon was recorded towards the stern of the wreck.

The site is subject to strong tidal currents as a result of its location in the southern part of Port Phillip, in proximity to Port Phillip Heads. The currents vary in strength from nil at slack water up to several knots, with most currents being between one and two knots. The direction of the current changes roughly every six hours; during the ebb, water empties from Port Phillip through the heads, and during the flood tide it funnels into the bay from Bass Strait. The strongest currents are known to occur during full and new moon cycles.

Legislative Protection[3]

Clarence was declared a Historic Shipwreck on 11 September 1985 under the Victorian *Historic Shipwrecks Act 1981.* Under Section 12(1) of the Act a 3.1 hectare (100 m radius) protected zone was declared around the site. Activities such as boating, diving, snorkelling, fishing and anchoring were prohibited under Section 20 of the Act and entry was prohibited without a permit. As the wreck was being targeted by anglers the zone was declared as an emergency measure to prevent anchoring over the wreck, which was damaging

[3] This section taken from http://www.ahspp.org.au/clarence/legislative-protection/.

the fragile hull remains. The site remains closed, and since 1995 has been protected by the provisions of the Victorian *Heritage Act 1995* which superceded the *Historic Shipwrecks Act 1981*. Section 103 of the 1995 Act prescribes a 100 m radius protected zone, which is simpler to define, understand and enforce than the previous description.

Provisions of the following Acts also apply:

Commonwealth—***Customs Act 1901***
Commonwealth—***Navigation Act 2012***
Commonwealth—***Protection of Movable Cultural Heritage Act 1986***

Location
Latitude: -38. 202570 (38° 12' 9.2520'' S)
Longitude: 144. 723253 (144° 43' 23.7108'' E)

Grid location
UTM 55H 0300562 / 5769232 (WGS 84 accuracy 4 m)

Previous archaeological recording, excavation and research

In September 1982 members of the Maritime Archaeology Association of Victoria (MAAV) located a shipwreck in the Coles Channel of Port Phillip some 300 m directly offshore of Edwards Point, in approximately 4 m of water. Subsequent research in 19th century Port Phillip newspapers for contemporary reports of shipwrecks in the area was carried out by MAAV members Tony Boardman and Terry Arnott (Heritage Victoria *Clarence* file).

Soon after the discovery of the wreck a number of inspection dives were carried out by the MAAV in conjunction with the Victoria Archaeological Survey's (VAS) Maritime Archaeological Unit (MAU). Subsequent research by the MAU indicated that the site was the earliest and best-preserved example of an Australian-built trading vessel yet located in Victoria.

A multi-phase research programme was designed for *Clarence* in the 1980s involving detailed documentary and historical research into the wreck and Australian shipbuilding generally.

In 1987 the VAS conducted a season of excavation on *Clarence* (Harvey 1989) following on from a pre-disturbance survey (Harvey 1986) and historical research in the mid-1980s (Gesner 1984). The 1987 fieldwork team excavated two trenches on the site, one at the bow and the other at the stern. The original excavation methodology initially prescribed three excavation trenches across the site (bow, stern and midships); however, the plan for the midships excavation was abandoned when it became apparent from trenches 1 (bow) and 3 (stern) that extensive hull remains and fragile organic artefacts were likely to be encountered (Fig. 3). Furthermore, the sediment was shallow and it was feared that a trench across midships might result in greater sand loss over the whole site, exposing the entire hull remains. Instead, the bow trench 1 was extended forward to include the port side of the bow and avoid the three trenches collapsing and causing total exposure of the site. The trench in the stern was larger than the bow trench and the excavated area amounted to approximately 12% of the site, or 19 m^2 (Veth et al. 2013).

These exploratory test-excavations were primarily aimed at examining the wreck's hull construction and fastening methods for comparison with British-built vessels of the same era. These comparisons aimed to provide information about the possible transfer of skills to the developing colony and the adaption of the early European settlers to their new environment and its available construction and fastening materials.

The survey and excavations further aimed to gather data on sediment movement at the site to inform future management activities (Harvey 1989).

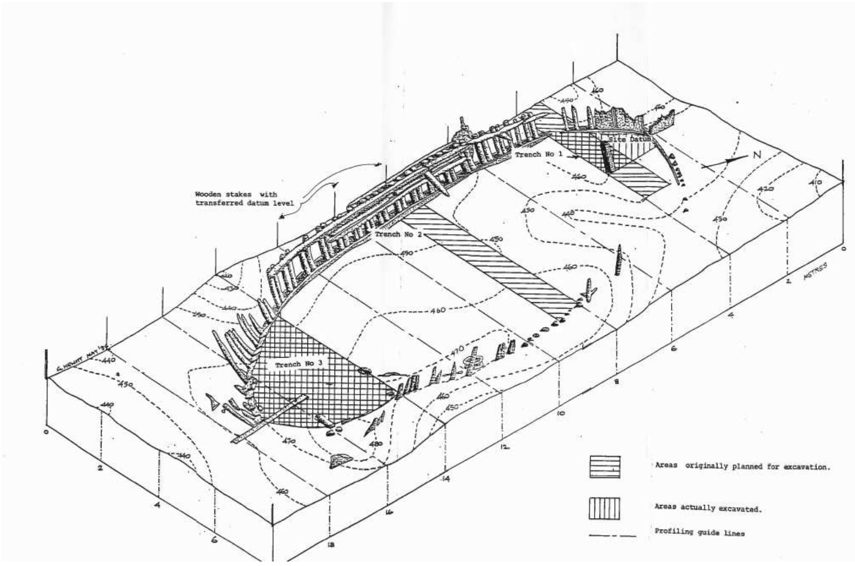

Figure 3. Position of trenches during 1987 excavation (Harvey 1989: 11).

Results of the 1987 excavation revealed that *Clarence* was not built in strict compliance with any particular construction rules (e.g. Lloyd's) for vessels of its size. Dimensions of the hull timbers, particularly the scantlings, also varied considerably from the standard specifications, and were usually undersized (Harvey 1989: 16–19). Notably, the total absence of hanging or lodging knees either *in situ* or loose in the sediment suggested that *Clarence* was built without them, which was contrary to traditional shipbuilding practices. The lack of knees would have reduced the strength and durability of the hull and may have contributed to the short working life of the vessel (Harvey 1989: 20). Hanging and lodging knees were often constructed of iron from the middle of the 18th century and especially where timber was not copious. These may have been in short supply/not available in the colony. This lack of use of this established shipbuilding technique represents a short-cut and speaks to expedient solutions to issues of isolation and limited supply chains (Stammers 2001). The 'archaeology of isolation' is one of the burgeoning theoretical areas in the discipline whereby a range of mid-level processes may be predicted to occur. These include: extreme forms of economising of scarce materials (such as fittings); lateral recycling of redundant materials into further use-lives (rigging); use of alternative timbers for traditional ones, such as oak (e.g. Blue gum); and pushing vessels well past their safe use-lives either through re-deployment or for use in novel ways (e.g. the *Xantho* in Western Australia, after McCarthy 2000). Unexpected construction techniques, short-cuts and 'solutions' may be predicted in these circumstances. The presence of a large kaolin ballast load on *Clarence* may be one such example (see below).

Following the research and excavation phases, VAS commissioned an on-going management plan for the site; details of the management plan can be found in Coroneos 1991.

Historical overview[4]

During the late 18th century and the first half of the 19th century, while many larger vessels over 100 tons arrived regularly in the Australian colonies from overseas, with some of them purchased by colonial merchants, very few smaller vessels arrived. This was largely a product of the economic viability (payloads) and seaworthiness of larger vessels enagaged in these trans-global missions. For most British merchants, the Australian colonies were simply too remote to dispatch vessels of under 100 tons. As a result, there was a growing need for smaller vessels to meet domestic needs for transport and trade between the newly established colonies. Furthermore, smaller vessels were required to meet the needs of the Australian-based maritime extractive industries, such as sealing and whaling, which rapidly became the most important income-generating industries in the colonies.

Due to the great distances between the new Australian colonies, boat and shipbuilding was vitally important to the development and sustainability of the colonists. As such, it has been identified as 'the first important manufacturing industry to develop' in Australia (Hudspeth & Scripps 1990: 55). Nevertheless, despite the fact that Australian boat and shipbuilding is seen as 'a significant industrial activity' (Alexander 2005: 331), the importance of this industry in the early colonies has not always been well recognised or appreciated, even by recent generations of mainstream historians. This is evident in the works of authors such as Lloyd Robson (1983), who scarcely mentioned shipbuilding in his classic work on the history of the early settlement in Tasmania and, more recently, James Boyce (2008) who did not mention shipbuilding at all in his history of the island.

From the earliest days of European settlement traditional British techniques of wooden boat and shipbuilding were transferred to the Australian colonies and have been presumed to be the primary source of shipbuilding knowledge. There have also been suggestions, however, that other vernacular shipbuilding traditions, including those from mainland European countries, including those that had already been adapted for use in the Americas or in Asia, may also have been significant (Bach 1976; Nash 2003; Orme 1988). Clear evidence of precisely where shipwrights in colonial period Australia came from or how well trained they were before arrival, has yet to be definitively established.

Initially, an order imposed on the original settlement at Port Jackson (Sydney) by Governor Hunter in 1797 prohibited boat and shipbuilding in the Australian colonies. This was a mitigation measure designed to limit the possibility of felons escaping from the penal institutions. This decree was later relaxed and vessels up to 14 ft (4.267 m) long could be constructed under a strict permit system. As late as fifteen years afterwards, however, on 8 February 1812, Governor Macquarie continued to provide instructions to Major Andrew Geils of the 73rd Regiment, and the commandant of the settlement at Hobart Town, stating the following:

> No. 20. You are also expressly commanded not to allow any vessels or small craft to be built in any part of the settlement under your command either by individuals residing in it or by foreigners without a written licence previously obtained from me for that purpose (HRA III.1: 471).

[4] Historical overview reproduced from Staniforth & Shefi (2014).

As a result, very few vessels were built before 1820 and significant shipbuilding activity in the Australian colonies did not initiate until the 1820s.

Australian colonial wooden shipbuilding

Kellie Clayton has suggested that 'Australian colonial shipbuilding is an important theme in Australian maritime archaeology' (Clayton 2012b: 55) and Rick Bullers has identified one of the fundamental research questions in Australian maritime archaeology as: How did domestic shipbuilders adapt their technical abilities to suit their new environment and utilise the timbers that were available to them? (Bullers 2007: 17). The excavation of *Clarence* was suggested as having the potential to add further knowledge of colonial shipbuilding techniques used on the vessel.

Wooden vessels constructed in the Australian colonies were often firmly based on pre-existing shipbuilding traditions that were brought by the immigrants as significant aspects of their parent culture and can therefore be seen in terms of cultural continuity. The archaeological evidence clearly indicates that *Clarence* derives many of the basic wooden shipbuilding methods used in the construction from the 'Northern European' tradition of wooden shipbuilding.

Clarence was almost certainly built by William Lowe, a shipwright who was apprenticed in the shipbuilding trade at Deptford, United Kingdom (UK) and who had experience in shipbuilding at Stettin (now Poland) before his arrival in NSW in 1828 at the age of 23. In some respects Lowe represents a stereotypical example of cultural continuity in that his training and early experience were primarily 'of the parent culture' and he clearly brought significant shipbuilding skills to the colony as a young man. Nevertheless, his time at Stettin reminds us that wooden shipbuilding methods were not just restricted to Great Britain and were common across Northern Europe.

Although William Lowe is considered to be the most likely builder of *Clarence* we can also consider James Marshall. Marshall's shipbuilding origins are less clear but we know that before arriving in NSW he was resident in Chile, in 1828 and probably before, so it is considered likely that he also derived some or all of his knowledge of shipbuilding from outside the Australian colonies. His biography is another reminder that wooden shipbuilding methods derived from Northern Europe also made their way into other colonial contexts, in this case South America, but in previous centuries also formed the basis for North American colonial shipbuilding (Crisman 1988; Evans 2015).

Interestingly William Lowe, James Marshall and John Cameron all had the capacity to build *Clarence* and at this stage any one of them may have done so, though Cameron is considered to be the least likely. The question of who did build *Clarence,* of course, may have important consequences in terms of the quality of building. Lowe, for example, would appear to be a highly trained, well-experienced shipwright capable of building a range of vessels types in different sizes whose career lasted more than thirty years. Marshall also appears to be a competent shipwright who built vessels for at least fifteen years but when building on his own he restricted his shipbuilding to small wooden sailing vessels under 100 tons (e.g. *Clarence*). We know so little about John Cameron, who may be an example of Michael Tracey's single-vessel-in-the-bush style of shipwright, that it is hard to judge his shipwright skills, although it is possible that Cameron had learnt to build vessels by working for either or both of Lowe and Marshall (Tracey 2007).

Who built *Clarence*?

In his report on the historical research conducted on *Clarence*, Gesner (1984: 13) was unsure as to who built the vessel and wrote that:

> There is no conclusive evidence which will answer by whom she was built, although it has been suggested by an authoritative source that she was most probably built by, or under the direction of, William Lowe at his Deptford shipyard.

The authoritative source in question was Ronald Parsons and, while his opinion may well prove to be correct, no definitive evidence has been yet found that actually proves that William Lowe built *Clarence*. The problem has always been that the British Register of Shipping for the Port of Sydney at this time did not always list the name of the shipbuilder and so it is often necessary to establish the builder from contemporary newspaper accounts which often, but not always, named the builder.

Tracey (2009: 35) has suggested that

> …wooden shipbuilding on the coast of New South Wales was often a short-term industrial activity where the shipwright selected a specific area in which to construct a single vessel.

In some cases this was undoubtedly true but in others, a shipwright would become firmly established in a single location and he would build vessels over a longer period of time. Both models for shipbuilding are known to have existed in the Williams River area during the 1830s and early 1840s. From the available records it appears that at least two, and probably three, shipbuilders constructed vessels close to the head of navigation on the Williams River near Clarence Town around the time *Clarence* was built in 1841—William Lowe, James Marshall and John Cameron. Each of these three individuals had different backgrounds, training, and levels of experience in the shipwright trade.

From recent research it is evident that at least 27 vessels were built on the Williams River between 1831 and 1843, with four shipbuilders operating there during this twelve-year period. In addition to Lowe, Marshall, and Cameron, John W. Russell built three vessels between 1833 and 1836. *Clarence* is by no means the only vessel built on the Williams River during this period for which the builder remains unknown or unconfirmed. For example, there is the steamer *Australia* (1834) and the cutters *Challenger* (1840) and *George* (1842), which all lack positive evidence regarding who built them (Australian National Shipwreck Database shipwreck ID numbers 340 and 2206; Register of British Ships, Port of Sydney, 1834–1842; *Sydney Monitor* 7 Mar. 1835; *The Australian* 13 Mar. 1838).

Recent biographical research into two of these Williams River shipwrights, William Lowe and James Marshall, suggests that Lowe was an experienced shipwright who was born on 21 July 1805 at Leith, Scotland, the second son of William Lowe, a 'landed proprietor', and Margaret, née Steel, of Stirling. At 14 years of age, William Lowe (junior) was apprenticed to the shipbuilding trade at the Royal Dockyard, Deptford and at age 19 he was sent to Stettin, Prussia, to work on the building of several ships where he stayed for nearly three years. He returned to Scotland, where his father gave him a considerable share of his estate and thereupon Lowe sailed to South America where he visited Ecuador, Peru and Chile (*Australian Dictionary of Biography*—entry for William Lowe).

To date, no evidence about James Marshall's life before 1828 has come to light, but archival records identify that he was in Chile in 1828. Both Lowe and Marshall embarked at Valparaiso, Chile on 18 July 1828 on board the 328-ton vessel *Tiger* for Sydney via Tahiti, where they arrived on Monday, 22 September 1828 (*The Australian* 24 Sept. 1828). During the voyage, Marshall and Lowe proved so useful in repairing damage suffered in a gale that Captain W. Richards refunded their passage money. This suggests that Marshall also possessed at least some shipbuilding knowledge and skills (*Australian Dictionary of Biography*—entry for William Lowe).

In early 1830, in partnership, James Marshall and William Lowe negotiated a contract with Joseph Hickey Grose to build a steam paddlewheel ship for the Sydney to Newcastle and Rivers trade (Ford 1995: 65). Grose had applied for, and much later on 6 September 1831, was authorized to possess, 10 acres of land within the Government Reserve for Clarence Town. The purpose of this was 'for the erection of a wharf and other suitable establishment for a steam packet' (Ford 1995: 45). It is likely that Lowe and Marshall had arrived on the Williams River sometime in 1830 perhaps a year or more before Grose had official permission for his venture. On arrival they had found the area to be too steep and 'totally unsuitable for the construction and launching of vessels' (Ford 1995: 65). Lowe and Marshall then established their shipyard, which they named the 'Deptford' shipyard, on the west bank of the Williams River adjacent to a small creek in the north-east corner of Francis Allman junior's grant of 640 acres, almost certainly without Allman's knowledge or permission. Subsequently Lowe and Marshall jointly purchased the Deptford shipyard site, consisting of 10 acres, from the Reverend J.J. Therry, which had originally formed a part of 640 acres in the Parish of Uffington that had been first granted to Francis Allman junior in July of 1829 (Ford 1995: 41). Lowe and Marshall built vessels at Deptford for about six or seven years until their partnership was officially dissolved in 1836 (Ford 1995: 65). At least six, and possibly eight, vessels were built by Lowe and Marshall at Deptford, including at least two steamers *William IV* (1831) and *Ceres* (1836), the horse ferry (and later steamer) *Experiment* (1832), the schooners *Earl Grey* (later *Edward*) (1833), *Delight* (1836), and possibly *Kate* (1838), the brig *Courier* (date uncertain) and possibly the cutter *Young Queen* (1839) (Australian National Shipwreck Database shipwreck ID numbers 488, 2486 and 7078; *Launceston Advertiser* 29 Mar. 1838; Register of British Ships, Port of Sydney, 1834–1842; *Sydney Gazette* 30 June 1831, 7 Mar. 1833, 21 Apr. 1835 and 16 Jan. 1836; *Sydney Herald* 19 Nov. 1835).

In 1832 William Lowe and James Marshall had jointly applied to purchase an area of 640 acres on the east bank of the river, opposite to the Deptford shipyard, from the Church and School Corporation, which was transferred to them on 13 June 1832 (Land Grant Index Serial 75: 46; Ford 1987: 10). On the dissolution of their partnership in 1836, William Lowe sold his interest in the 640 acres on the east bank, to James Marshall and purchased Marshall's interest in the Deptford shipyard on the west bank (Ford 1987: 11). In early 1837 the *Sydney Herald* newspaper reported that

> …a fine vessel the Delight, was launched from the building-yard of Mr. Marshall, at Williams' River…there are now two building yards at Clarence Town, which create a bustle and activity not to be found at any other of our embryo townships (Sydney Herald 9 Feb. 1837: 2).

It appears that Marshall and Lowe may have continued to collaborate on building vessels after their partnership dissolved in 1836, for example on the schooner *Kate* in 1838 and the cutter *Young Queen* in 1839. Unfortunately the records are not clear enough at this stage to determine if this was actually the case, nor to tell in which of the two shipyards (Deptford or Marshall's) these particular vessels were built (*Sydney Morning Herald* 17 Oct. 1842 and 16 Feb. 1843).

For nearly a decade, from 1836 until his death in January of 1845, James Marshall continued to build small schooners and cutters (all less than 100 tons) at his shipyard (Marshall's shipyard) (Mitchell Library Map Collection—Clarence Town 1864). Records suggest that at least six, and possibly eight small vessels were built by Marshall during this period, including: two schooners *Yarra Yarra* (1837) and *Mary Ann* (1841) and four cutters *Jane Williams* (1838), *Lucy Ann* (1842), *Comet* (1843), and *Elizabeth* (by 1843) (*Australasian Chronicle* 24 Mar. 1842; Australian National Shipwreck Database shipwreck ID numbers 2341, 7474 and 7934; Register of British Ships, Port of Sydney, 1834–1842; *Sydney Herald* 6 July 1841; *Sydney Monitor* 6 Oct. 1837; *Sydney Morning Herald* 1 Dec. 1842, 22 Apr. 1843 and 27 Feb. 1844; *The Australian* 13 Mar. 1838).

During this period (1836–1845), William Lowe also continued to build vessels at the Deptford yard, mostly, but not exclusively less than 100 tons. The Deptford yard had becomes a good-sized industrial complex by the 1840s. For example, in the 1841 Census Lowe reported 19 people (15 male and 4 females) at Deptford including 7 'mechanics' (including shipwrights and carpenters), 2 shepherds and 2 domestic servants (5 of the 19 were assigned convicts) living in three wooden houses, only one of which was described as 'finished' (Census 1841). Lowe died on 8 May 1878 and was buried in the Clarence Town cemetery (Fig. 4).

Figure 4. William Lowe's gravestone in the Clarence Town cemetery, September 2012. Photo by M. Staniforth.

In addition to the schooner *Kate* in 1838 and cutter *Young Queen* in 1839, which may have been built by Marshall, Lowe or both jointly, Lowe is known to have built at least six vessels around the time that *Clarence* was built. This included the schooner *Paul Pry* (1838), the brig *Victoria* (1840), the steamers *Aphrasia* (1840), *Harriet* (1842) and *Comet* (1843), and the cutter *Elizabeth* (1843) (*Australasian Chronicle* 29 Sept. 1842; Australian National Shipwreck Database shipwreck ID number 6488; *Hobart Town Courier*, 28 Feb. 1840 and 8 Dec. 1840; Register of British Ships, Port of Sydney, 1834-1842; *Sydney Gazette* 29 Sept. 1842; *Sydney Monitor* 8 Sept. 1840; *Sydney Herald* 5 Mar. 1838, 13 Nov. 1839 and 16 Nov. 1839; *Sydney Morning Herald* 29 Mar. 1843).

The third Williams River shipwright John Cameron, on the other hand, is far less well chronicled than either Lowe or Marshall, and records located to date only list him as the builder of a single vessel—the 104-ton schooner *Calypso*, which was built at the Williams River in 1842 (Register of British Ships, Port of Sydney, 1834-1842—entry for *Calypso* No.59 of 1842). Records also establish that Cameron appears to have worked as a shipbuilder for only a relatively short period (around 1841–1842), as he was declared bankrupt in late 1842 (*Sydney Gazette* 13 Oct. 1842).

Research Design and Methodology

The original research design for the project is outlined below. Some adjustments were made during the course of fieldwork to deal with issues that arose such as availability of sediment for back-filling; the nature, quantities and types of artefacts raised; and weather conditions which strongly determined the amount of time available for excavation and reburial. These adjustments are discussed at the end of this section.

The multi-faceted research design for the excavation of *Clarence* aimed to:

- Make significant advances on current international reburial and *in-situ* preservation approaches in near shore coastal zones where direct impacts on shipwrecks are the highest.
- Make significant contributions to understandings of site formation processes, colonial shipbuilding and specific lifeways and assemblages associated with a colonial trader.
- Add rapid capture 3-dimensional imaging of significant artefacts and objects.
- Research and innovate with conservation monitoring procedures following the reburial of shipwreck elements and objects on the site in stabilised conditions.
- Create a *virtual representation* of the site that will enable it to be re-interrogated over time with different research and conservation questions and issues.
- Develop *in-situ* preservation protocols in order to successfully stabilise and preserve this site and other sites deemed to be 'at risk' in the long-term.
- Produce a sustainable, cost-effective and strategic solution to a national shipwreck management crisis whereby wooden (organic) shipwreck elements are at risk.

The recovery, rapid recording and reburial (*in-situ* preservation) guidelines, in draft form at Appendix F, rely on understandings of archaeological site formation—generally for all sites—and specifically for wooden vessels in maritime contexts. While different aspects of maritime site formation models have been developed and profiled over several decades (Godfrey et al. 2005; Richards et al. 2009; Ward et al. 1999) their longitudinal evaluation via excavation, reburial and monitoring (including sediment coring and minimally intrusive sampling after reburial) had previously only been carried out on a few notable sites, such as as the Red Bay wrecks in Canada (Stewart et al. 1995), the Zakythos wreck in Greece (Pournou et al. 1999), the *James Matthews* in Western Australia (Richards et al. 2009).

It is now accepted that sites pass through many stages of deterioration towards eventual quasi-equilibrium—and that these processes are structural/physical, chemical and biological in nature. What is less well understood is the cyclical nature and reversibility of these taphonomic processes in contexts where the sedimentary budget may vary widely due to natural systems (such as episodic scouring) and cultural impacts such as dredging or changes in the morphology of shorelines and the construction of port facilities and the like (Quinn et al. 2016). The detailed mapping of seabed contours, recording of 3D relationships of artefacts and ship's structure, X-ray and optical imaging and the analysis of the physico-chemistry, geochemistry and microbiology of the site by the team during the recovery and reburial phase in Year 1 and subsequent monitoring phases in Years 2 and 3 represents the first multi-decadal longitudinal monitoring at this important site—for which there are benchmark studies beginning with the 1980s survey and excavation programme. This project represents the beginning of long-term physico-chemical and biological environmental monitoring of the site.

At *Clarence* some of the assumptions of these varied site formation models have been examined using photogrammetry of the wreck structures, fittings and objects; and, conservation assessment and imaging of the smaller artefacts. Sacrificial samples of metal and timber were placed on-site for continued future analysis of environmental changes in the reburial mound and in the off-site artefact repository. It was planned they would be monitored over time with measurements of pH, redox potential, dissolved oxygen content and sulphate/sulphide concentrations in the sediment using microelectrodes and other wet chemical techniques.

Sediment core samples were collected both on- and off-site to:

- describe bedloads across the site
- model sedimentary trends
- establish control on facies development
- assess any environmental changes that occur once the site and artefacts are reburied
- monitor the consolidation of the sediments.

Terrestrial signatures may occur in the form of pollen, dust, insect remains and similar fossils, as well as non-living traces, such as sediments and dung. On prehistoric and historic vessels these properties can be highly informative about voyaging tracks, ports of call and previous cargos.

In short, the efficacy of reburial (*in-situ* preservation) as opposed to excavation and *ex-situ* conservation—as a viable intervention—was tested. This will be judged on the actual conservation outcomes obtained through time, research insights afforded against opportunity and cost, the robustness of the protocol used to decide whether materials are conserved or reburied and the research ethics associated with excavation, recovery and conservation versus recovery, rapid recording and reburial (Harvey & Shefi 2014).

During the 2012 excavation it became clear that the detailed 1980s field programme had gathered most of the salient data available on the vessel's construction. These findings were essentially supported by the excavation in 2012. As a consequence the intention to glean more information about colonial shipbuilding was relegated to a secondary aim, and the *in-situ* preservation aims became the primary focus of the project (however see discussions on the vessel's cargo of kaolin below).

Research questions[5]

Colonial Shipbuilding

One of the fundamental research questions in Australian maritime archaeology is how domestic ship-builders adapted their technical abilities to suit their new environment and utilised the timbers that were available to them (Bullers 2007: 17). According to Bullers (2006: 62), 2 786 Australian-built vessels are recorded as having been wrecked on the Australian coastline, and the available databases indicate that only

[5] This section appears in part within Staniforth & Shefi (2014) and Veth et al. (2011).

271 vessels have been located to date (approximately 10% of the total number wrecked). Only 14 Australian-built vessels (about 0.5%) have been properly surveyed and/or excavated with the results published. One of the problems to date has been that Australian-shipbuilding research has been seriously constrained by state and territory boundaries, resulting in research that has been conducted on a case-by-case, single-site basis within individual jurisdictions usually lacking any comparative component (Richards 2006: 48).

In selecting *Clarence* as the primary case study site for the AHSPP, there was an opportunity to conduct additional excavation in parts of the site not examined during the 1987 excavation. This had the potential to provide further knowledge about colonial shipbuilding techniques used on the vessel.

In-situ preservation and reburial

The *in-situ* and reburial study adopted here is a significant shift away from the dominant maritime archaeological approach whereby the bulk of a vessel and its assemblage is raised, conserved and stored as a collection, often at great expense. Raising parts or all of a shipwreck is only justifiable where exceptional significance, representativeness and educational values are demonstrable: notable examples are the *Mary Rose*, *Vasa* and *Batavia*. For most shipwrecks, however, the bulk recovery approach is no longer sustainable, and not adequately funded by government, collecting institutions or developers. The issue of shipwrecks at risk due to degradation—both human and natural—needs to be approached in a systematic fashion with the same considerations that full recovery is often not desirable, affordable or sustainable.

Reburial as a strategy was first reported in 1979 from the Netherlands with the Lake Ijssel land reclamation and development project (de Jong 1979). It has since been applied widely. Notable sites are those which have included some form of on-site environmental monitoring as part of their ongoing management, such as the reburial of the Spanish Basque whalers in Red Bay, Canada (Stewart et al. 1995), the Zakynthos wreck in Greece (Pournou et al. 1999), the reburial of timbers at Lynaes Sands, Denmark (Gregory 1998), the Foundation Piles studies (Bacpoles 2002; Klaassen 2005) and North-European Shipwreck Sites Study (MoSS 2001; Cederlund 2004). Current best-practice examples are the Reburial and Analysis of Archaeological Remains Project (Nyström Godfrey et al. 2009; RAAR 2002; Richards & MacLeod 2007) and in Australia the *James Matthews* reburial project (Godfrey et al. 2004, 2005; Richards et al. 2009). Site formation models (e.g. Björdal 2000; Oxley 1998; Ward et al. 1999) in many respects are 'ground-truthed' by such detailed monitoring studies and one of the major outcomes for the current study is a further explication of these models. The AHSPP builds on these studies.

It is a fact that long-term conservation and storage of large cultural assemblages and vessel fabric, while a requirement under the 2001 UNESCO *Convention on the Protection of the Underwater Cultural Heritage*, is becoming prohibitively expensive and requires novel management approaches to mitigate these costs. This is now more necessary than ever, especially given the accelerating impacts within Australia's Exclusive Economic Zone (EEZ) and the large number of known significant shipwrecks at risk (Bergstrand 2002; Godfrey et al. 2004; Gregory et al. 2013; Harvey 1996; Nyström 2002; Oxley 1998; Stewart et al. 1995).

Ideally, the threat from varied impacts on shipwrecks should be mitigated via site management and protection—including rezoning use of the seabed, detailed recording, reburial, stabilisation and monitoring. Where it can be shown that natural processes are diminishing site integrity at an unacceptable rate, then a case may be made for stabilisation and/or excavation with the bulk of the artefact assemblage re-buried on site along with the shipwreck itself (the *in-situ* preservation option). If impacts on a shipwreck are inevitable (for example the construction of an iron ore shipping berth) then reburial of the shipwreck and its associated assemblage in proximal, stable marine sediments—the *reburial* protocol—would represent the next available option. These two inter-related methods allow the shipwreck and its associated assemblage to be available for analysis at a later date without incurring the expense of full conservation and ongoing collection management of all raised artefacts, including the ship's fabric.

Reburial directly addresses the conservation imperative; it allows for detailed and rapid *in-situ* recording on site; it provides for the ongoing integrity of the site's matrix and allows future access to the reburied materials. Comprehensive studies of the original shipwreck context, combined with ongoing monitoring of the underwater reburial site, are critical for a longitudinal evaluation of the reburial strategy (Caple 1994; Gregory 1999; Hogan et al. 2002; Nyström et al. 2009; Richards et al. 2009). Refining methodologies for on-going monitoring and identifying the effects of reburial on particular material types are some of the core issues addressed by this project.

Field Programme 2012—2014

Fieldwork - preparation and logistics

Members of the project team and Professional Diving Services (PDS) staff planned logistics, particularly plant mobilisation, during development of the ARC application and following award of the grant. PDS drafted a plan for much of the plant and logistical requirements for the diving component of the project, and their expertise in marine project management contributed significantly towards the required fieldwork Diving and Safety Plan (Parkinson & PDS 2012a); Health, Safety and Environmental compliances; and in collaboration with Peter Veth, the framework required for the UWA Boating, Diving and Safety Committee. Duplicate records of all diver competencies; diver support systems; safety protocols; diving medical clearances; and dives logged with repeat values were required both by PDS and the Administering Institution, UWA.

Initial field preparations and project logistics were undertaken by PDS in close collaboration with the AHSPP Project Manager and Investigators, and Heritage Victoria. In particular, PDS was responsible for organizing the fit out and mobilisation of the diving platform (JUPB1), a jack-up platform barge (18 m x 12 m) supplied by Fitzgerald Constructions (Fig. 5); the development of the risk management framework (Parkinson & PDS 2012b) and the supply of tethered SCUBA and SSBA equipment.

The project called for a number of items to be manufactured to meet the 'on-site recording and *in-situ* preservation' aims. This included an X-ray enclosure and the modified shipping container that was to house the equipment. Dudley Creagh of the University of Canberra worked closely with the engineering team at the ANU to design and build a lead-lined portable enclosure for the X-ray and 3D imaging equipment that was supplied gratis by the Australian Federal Police (AFP). Research was also undertaken to purchase and make custom modifications to the shipping container.

The X-ray unit required an insulated 20 ft (6.1 m) shipping container with an internal 2 mm steel partition to provide an X-ray system compartment, climate control and emergency exits to ensure compliance with strict regulations relating to the use of X-ray equipment. Furthermore, details of the enclosure were needed to enable a specific risk assessment to be developed for the permit to operate the unit. Creagh created the Occupational Health and Safety Manual for the X-ray unit, to be used under the AFP's Operator license.

The diving platform JUPB1 was fitted out early in April 2012 in preparation for mobilisation in advance of the 16 April 2012 start date. JUPB1 was capable of housing three shipping containers [the X-ray and finds processing container (Fig. 6), a storage container and the dive control room], as well as sundry plant and equipment including portable toilets, air compressors, a large water pump and conservation equipment. Over 600 filled sandbags on pallets were also placed on the barge prior to mobilisation. All plant and equipment needed to be secured prior to the barge being towed out to site.

Equipment was mobilised from the PDS depot in south-eastern Melbourne and Heritage Victoria's storage depot at Altona in the week prior to the Easter break. As a component of its in-kind support, the Port of Melbourne Corporation allowed use of its slipway for the preparation and fit out of JUPB1 by Fitzgerald Constructions at Victoria Dock in Port Melbourne's Docklands precinct.

Figure 5. Jack-up Platform Barge 1—the AHSPP's diving platform. Photo by A. Viduka.

Figure 6. X-ray and photography container. Photo by A. Viduka.

Diving safety planning

Senior team members met with PDS in March 2012 and collectively decided that, in general, two dive teams could be in the water simultaneously. The most efficient and safest way to accomplish this was to have the first dive team on SSBA (Fig. 7) and the second team on tethered SCUBA with bailout capacity and hard-wired communication cables. This allowed the Duty Dive Supervisor to have appropriate communications required to keep dive teams rotating through the tasks efficiently and safely.

All divers physically operating dredging equipment during the excavation phase of the fieldwork programme had to be qualified to AS2815.2 'Surface Supplied Diving to 30 m' (or equivalent) (Standards Australia 1992). As the dredge used for the fieldwork programme was surface powered it precluded divers trained only to AS2815.1 'Training and Certification of Occupational Divers: powered tools with diver-operated switches' (or equivalent) (Standards Australia 2008) from operating the water dredge. This did not preclude a second diver involved in diving operations from partnering and assisting the diver qualified to operate this tool. This requirement impacted on the excavation phase due to a shortage of AS2815.2 qualified personnel. Many professional maritime archaeologists in Australia at that time were only AS2815.1 qualified; almost all volunteers, including students, generally hold only recreational—albeit often more senior—qualifications. Furthermore, to comply with UWA's Diving Protocol all divers had to have a current Occupational Diving Medical (to AS2299.1), which unfortunately left some long-standing and highly experienced volunteers unable to dive with the project.

By using a combination of AS/NZS 2299.1: 2007 (Standards Australia/New Zealand 2007) and AS/NZS 2299.2: 2002 (Standards Australia/New Zealand 2002) the AHSPP team believe the project took all reasonably practicable steps to ensure the safety of diving personnel. The project promoted industry best practice by using AS/NZS 2299.1: 2007 as the main reference for planning diving operations during the fieldwork, and thus reduced risk and created an extremely safe and efficient working environment.

As the AHSPP's administering organisation, UWA was responsible for the main insurance during the project. Therefore, field activities also required the approval of UWA's Boating and Diving Safety Committee and the insurance underwriter. Using AS/NZS 2299.1: 2007 and AS/NZS 2299.2: 2002 meant that the formal qualifications required for diving personnel during the project surpassed the experience and qualification levels required by the UWA's Scientific Diving Procedures Manual (The UWA 2010). However, in order to comply with other aspects of this policy, and thereby also satisfy the insurer, all divers were required to undertake site and kit inductions and test dives to have their competency confirmed by the Dive Supervisors.

Figure 7. SSBA divers Michael Nash and Amer Khan preparing to dive. Photo by A. Viduka.

Some divers on SSBA were capable of diving for long periods (up to three hours) due to the shallow water and bearable water temperature averaging 16 ˚C. Divers on tethered SCUBA generally spent 30–70 minutes in the water and could complete a 1 x 1 m excavation or survey square in that time. Non-divers on the barge were tasked with dive tendering, assisting with surface communications, filling cylinders, artefact cataloging, photography, X-ray imaging, and preliminary conservation. The dive teams generally changed over around midday, with Heritage Victoria's vessel *Trim* transporting personnel and equipment between the barge and St Leonard's pier.

The participants staying at the accommodation throughout the month were assigned a variety of tasks when not on the barge or diving duty. On both diving and non-diving days personnel were involved with laboratory assistance, filling sandbags (Fig. 8), transportation of personnel, equipment and site inductions, transfer and naming of data and image archives, updating the website (www.ahspp.org.au), digitisation of research reports, media and community liaison, collecting field supplies and housekeeping.

Figure 8. AHSPP team filling sandbags to stabilise the site. Photo by J. Rodrigues.

During the fieldwork period, which included a total of 26 work days, the team completed 167 individual dives, and accrued 181 diving hours, during a possible 17 days of diving (with inclement weather and transfers being ongoing issues). A further two days of diving, (1 and 2 June 2012), were undertaken by Heritage Victoria, PDS and volunteers under the supervision of Partner Investigator Vicki Richards to complete the backfill of the trenches and the off-site artefact repository located to the stern of *Clarence*, and collect control sediment samples after reburial.

In November 2012 the final reburial and baseline monitoring took place over ten days with a small team of AHSPP and HV staff as well as volunteer maritime archaeologists and divers. The fieldwork was lead by Vicki Richards with planning assistance, guidance and dive supervision by James Parkinson of PDS. This fieldtrip focussed on actioning the reburial phase of the project. The team completed 83 dives with nearly 63 hours underwater. Transportation of an additional 1 800 sandbags to *Clarence* was contracted to a chartered commercial vessel. All diving took place from *Trim*, with the team using either SSBA or tethered SCUBA with hardwired communications, dependant upon individual qualifications.

In November 2013 and December 2014 monitoring was undertaken over four days by small teams of 10 to 12 people comprising a number of AHSPP investigators and researchers, PDS, HV staff and volunteers. The crew utilized *Trim* as the platform and diving was conducted using SCUBA and through-water communications in 2013, and using tethered SCUBA with hard-wired communications in 2014. In November 2013 the team completed 21 dives with just over 12 hours of diving time. December 2014's work was undertaken in just 16 dives and 9.5 hours underwater. Each trip was co-ordinated by Partner Investigator Vicki Richards in conjunction with the AHSPP Project Manager, in collaboration with senior team members. Diving activities were co-supervised by Peter Veth, Cassandra Philippou and/or Debra Shefi and, when present, James Parkinson.

Permits, consents and approvals

A number of legal Permits and Consents were required to excavate the seabed and the protected historic shipwreck, as well as position JUPB1 adjacent to the site. These included a Permit (SP217) from Heritage Victoria to undertake exploration (research excavation) of a historic shipwreck (within a protected zone) [s113 of *Heritage Act 1995* (Vic)]; a Works Permit (PV WP 07/12) from Parks Victoria (PV) that allowed excavation of the seabed and the temporary placement of the barge [R500(1) of the *Coastal Management Act 1999* (Vic); Notice to Mariners No. 079T-2012], and a Consent for Use and Development of Coastal Crown Land (SP443114) from the Department of Sustainability and Environment [s38 of the *Coastal Management Act 1999* (Vic)]. Heritage Victoria played a crucial role in commenting on and eventually ratifying the Coastal Management Act (CMA) consent application.

Due to the placement of a stationary platform for a period of time a Notice to Mariners (NTM) was required, which was linked to the Works Permit. The CMA Consent and the PV Permit both required risk assessments for work taking place on the barge and contingency planning in case of extreme weather events, and PDS was responsible for development of these documents (Parkinson & PDS 2012a, 2012b). Without the CMA Consent and NTM in place, the barge was legally unable to leave dock.

The fieldwork could have been classified as a 'scientific enterprise' and come under the provisions of AS/NZS 2299.2: 2002; however, the senior AHSPP researchers and PDS jointly decided to follow general commercial diving procedures (AS/NZS 2299.1: 2007) to increase the level of safety on site. In order to enable non-ADAS (or equivalent) qualified divers to participate in underwater components of the programme, PDS also utilized aspects of AS/NZS 2299.2: 2002; this was also in accordance with the UWA Boating and Diving Safety Policy.

A permit was also required for use of the X-ray equipment, and the AFP worked with Creagh to enable researchers on the project to work under its license with supervision from trained personnel.

Research methodology

Excavation

As the midships of *Clarence* remained undisturbed by previous fieldwork, the initial plan for the 2012 excavation was to create three 1 m x 3 m trenches in previously unexcavated portions of the site. The trenches were to be located on the N–S datum line points at 4–5 m S; 8–9 m S; and 12–13 m S (Fig. 9).

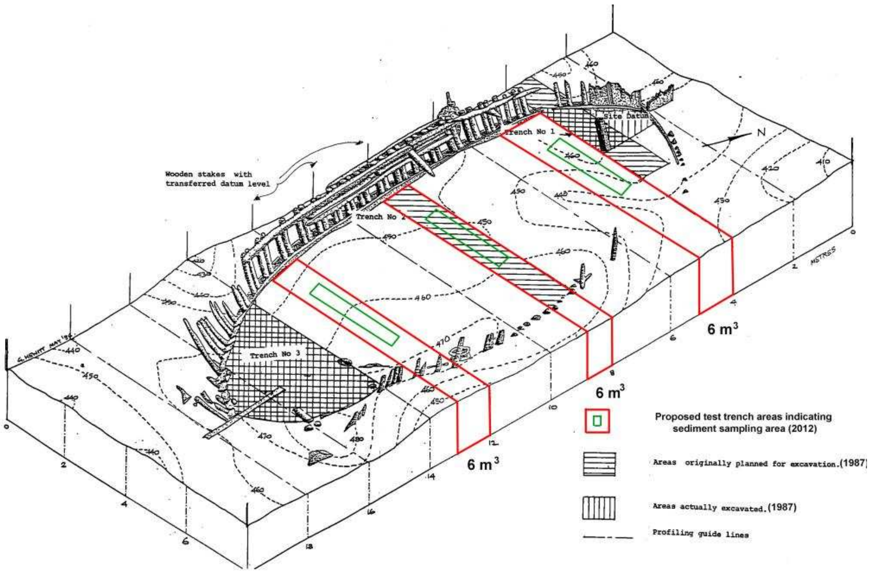

Figure 9. Original intended location of excavation trenches on *Clarence* 1987 site plan (after Harvey 1989: 11).

In recognition of the shallow sediment observed on site, the location of the previous excavations and the relatively small aerial extent of the hull, the excavation plan was adjusted to focus primarily on the undisturbed starboard portion of the hull (Fig. 10). The project team anticipated that some slumping of the sides of the trench could occur with possible loss of destabilised sediment in the strong current. In 1991, Coroneos (1991) noted that the natural sediment in the area of the *Clarence* was unstable and that considerable sediment loss had occurred following the 1987 excavations. Therefore the team considered the need to stabilise the centre line of the site to prevent slumping from the port side into the starboard trench to maintain integrity of the trench profiles. An interim stabilisation strategy was developed, consisting of sturdy polycarbonate sheeting held in place with a bund of sandbags to shore up the centre line.

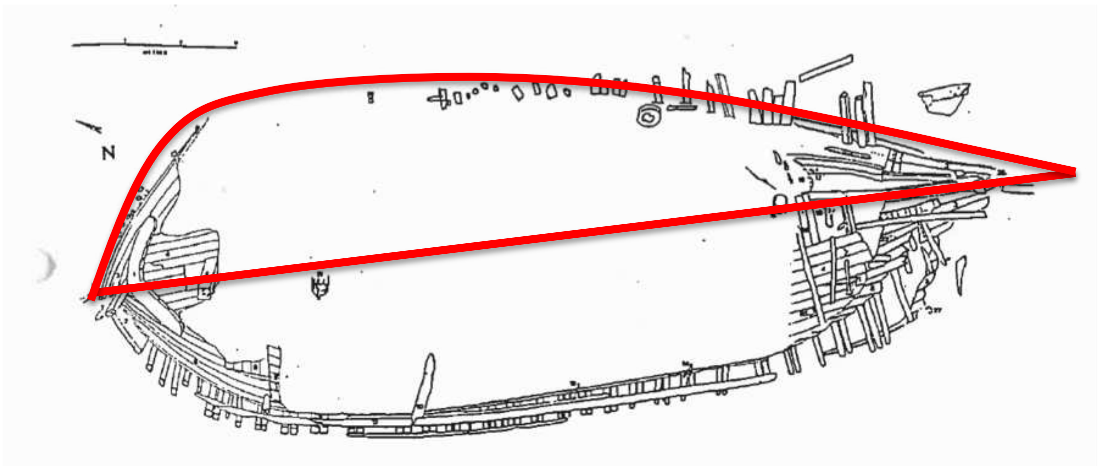

Figure 10. Final plan for 2012 excavation trench on *Clarence* outlined in red. Site plan after Harvey 1989: 17.

It was planned to carry out the following excavation methodology during the 16 April to 12 May 2012 fieldwork:

- excavate a starboard trench
- stabilise the port side deposits with UV stabilized polyethylene woven sandbags
- retain the port side of the excavation trench with sandbags and polycarbonate sheeting
- backfill with excavated sediment and proprietary sand from the sandbags and then stabilise the reburial mound with matting.

Current deflector experiment

Through local knowledge and past fieldwork experience at the site by members of the AHSPP team, the *Clarence* site was known to be strongly affected by tidal currents. The available diving hours were therefore predicted to be impacted by the strength of the current and at particular times during any given tide. In fieldwork planning discussions Chief Investigator Mark Staniforth highlighted this issue:

> The single biggest problem on the *Clarence* site is the tidal current, which vary in strength from nothing (at slack water) up to currents of several knots—the strongest currents occur during full and new moon cycles (during spring tides) and change direction every six hours or so from the ebb tide which heads approximately south (towards Port Phillip Heads) and the flood tide which heads approximately north (away from Port Phillip Heads) (M. Staniforth 2012, pers. comm. March 16).

In the months prior to fieldwork, real-time data on the strength of tidal currents on site was not available, so the team was reliant upon the local knowledge and past experience of team members. The team felt that a better understanding of the strength of the tidal current on the *Clarence* would enable productive and safe diving and they discussed options for reducing its strength.

Staniforth, with the assistance of volunteer Des Williams from the Maritime Achaeology Association of Victoria (MAAV) and PDS undertook additional research and developed a ‘current deflector’. Using Williams’ design, the deflector was manufactured by his colleagues at Melbourne’s Geoff Miller Pty Ltd. The deflector consisted of an inflatable floating tube attached to a shadecloth curtain and weighted to the seabed (Fig. 11). It could be deployed at either end of the site to act as a barrier for the divers, pushing the current around the periphery of the site.

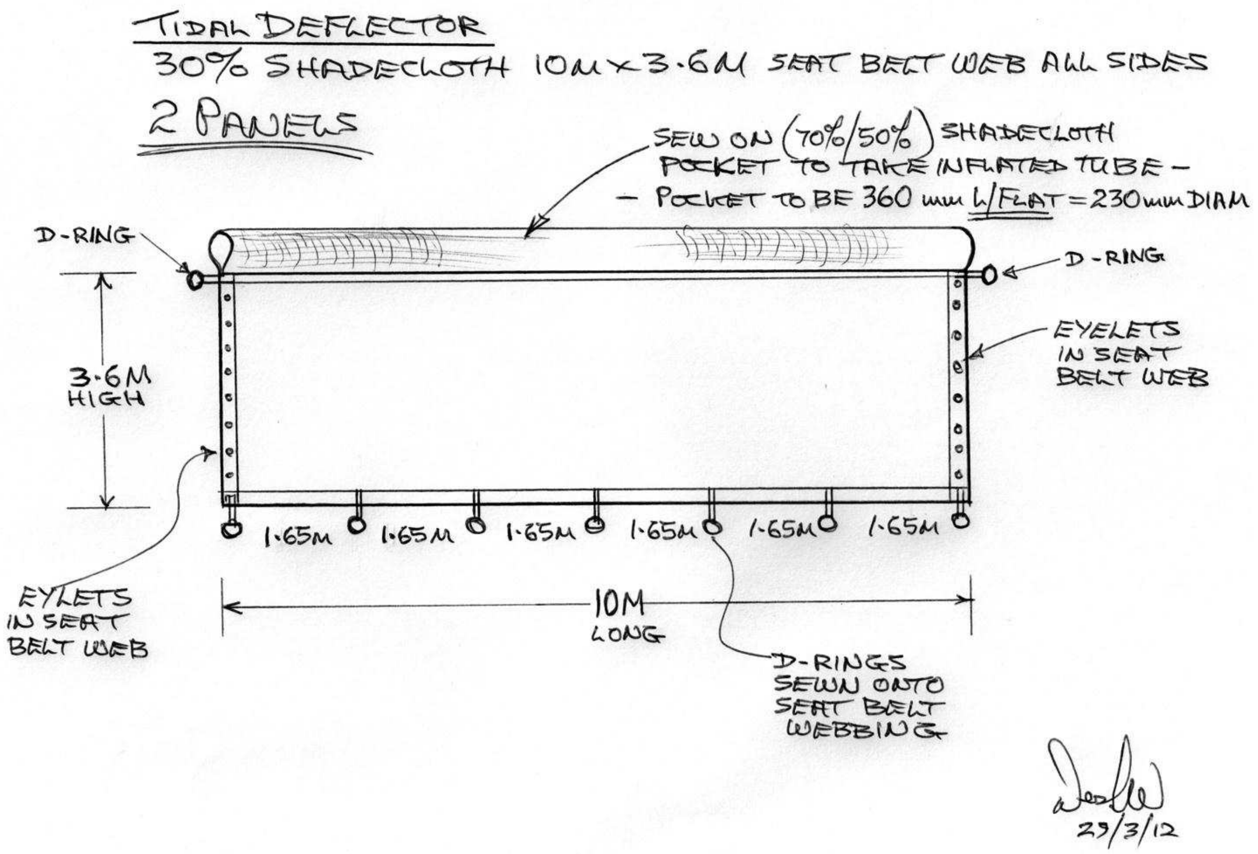

Figure 11. Shadecloth current deflector, designed for AHSPP by MAAV's Des Williams.

The team trialled the system on 22 March 2012 and it was deemed a success. Whilst labor-intensive and somewhat complicated to install, the divers noticed a significant reduction in current to well below one knot over the site.

Following the trials, two current deflectors were manufactured. However, at the end of March 2012 a Melbourne-based coastal engineering company, Cardno Victoria Pty. Ltd., provided modeling of the current in the area around *Clarence* gratis to PDS. The models showed that peak flow would be a maximum of 1.5 knots during short periods of time throughout April and May (Cardno 2011). Based on this data, the project team concluded that it was unlikely the current would be a significant impediment and therefore the current deflectors were not eventually deployed.

Marine ecology

The marine ecology on and around *Clarence* was surveyed in advance of disturbance works on the site. This was undertaken by marine ecologists as part of the ADAS Part 1 professional diver training programme being run by PDS in conjunction with the Project. The methodology selected was a basic qualitative presence/absence visual survey, aiming to catalogue marine flora and fauna (i.e. macroalgae, invertebrates and fish) inhabiting the shipwreck and surrounding area. A transect line was run from the bow of the vessel along the port side and 0.25 m x 0.25 m quadrats were placed randomly along the transect line.

The survey aimed to:

- describe the biota colonising the *Clarence* wreck
- describe the habitat and allocated biota
- list any species of ecological significance
- list any introduced species observed.

PDS collated the information from the ADAS Part 1 participants in April 2012 (Appendix B), and subsequently conducted another marine ecology survey in November 2012 (Appendix C). The methodology adopted for that survey was identical to the one used April 2012, and was undertaken to enable a final post-disturbance (post-excavation) understanding of the marine ecology of the site prior to the site being finally covered with the shadecloth and PVC tarpaulins.

A final, comprehensive marine ecology survey was carried out by John Ford and Dean Chamberlain of the University of Melbourne's Department of Zoology in January 2015 (Appendix D). This survey adopted a more comprehensive methodology, and also undertook comparative surveys in two nearby locations.

Recording systems

One of the major conservation objectives of the AHSPP was to ensure that the post-recovery integrity of artefacts was optimised prior to reburial or conservation intervention. The reburial methodology aimed to undertake a rapid and high level of documentation of all excavated artefacts topside on JUPB1 prior to their reburial. In researching rapid recording techniques, Andy Viduka strongly recommended and then the team chose to test the viability and effectiveness of X-ray imaging on recently recovered wet archaeological artefacts. The proposed imaging was intended to provide a greater understanding of the archaeological value of the artefact, the material composition and the extent of degradation.

In addition to X-ray and its associated 3D image captures, artefacts were to undergo full morphometric and geochemical recording, and their pre-recovery locations mapped using SR4 GIS positional data. This holistic approach was to maximise information gain (archaeological and conservation), while simultaneously minimising deterioration. Explanation of each of the methodologies for the recording systems is presented below.

X-ray and 3D imaging

The intention was to undertake 3D X-ray imaging and optical captures to enable an identical reproduction (3D print) to be made of excavated objects that had high interpretive value but were not going to be retained and conserved. Such a replica, made from a durable material such as resin, ensures ongoing possibilities for display and study after the object is repatriated into its original archaeological context or reburied safely off-site. The digital image data is also a permanent record of the condition of the artefact enabling further detailed analysis and interpretation without the original object in hand. 3D imaging is particularly valuable for organic objects that cannot be handled until significant and time-consuming conservation has been undertaken. Examples of such objects that could be digitally documented and reproduced are personal effects (e.g. combs, buttons, jewellery, tooth brushes), parts of the ship (e.g. timbers, fittings and fixtures) or cargo (e.g. bones from animals and textiles). Other inorganic objects such as ceramics, glass or small metal objects can also be photographed to enable display and interpretation.

X-ray imaging is a standard method used to document individual artefacts (Cronyn 1990; Hamilton 1996; Pearson 1987; Robinson 1998; Viduka 2012). By X-raying an artefact prior to making decisions on treatment, conservators can improve their understanding of the condition of the artefact, its method of manufacture, whether it is made of one or more materials (composite artefact), and determine whether an object is actually present within a given mass or concretion, or if a concretion has formed a negative impression of an artefact which has completely deteriorated (Viduka 2012: 296-7). However X-ray imaging is not always possible due to the size and or density of an artefact and or the limitations posed by the available equipment and the strength of the X-ray source (Cronyn 1990; Viduka 2012: 287 & 292).

X-ray recording device and format

An aim of this study was to develop a suitable 2D data capture methodology for both X-ray and artefact photographs to create 3D models for the purposes of conservation, archaeological interpretation and display. Noting rapid advances in 3D technologies using photogrammetry for sites (Barazzetti et al. 2011; Foley et al. 2009; Pollefeys et al. 2003; Sedlazeck et al. 2010; Skarlatos et al. 2012; Telem and Sagi 2010; Verhoeven 2011), the team set out to collate a series of 2D X-ray images of an artefact and convert these into a 3D X-ray model. At the same time as collecting X-ray images, or immediately thereafter, without moving the artefact from the proposed rotational stage, photographs of the artefact would be collected from the same view point of each X-ray image and these photos could also be converted into 3D images. Conversion of 2D X-ray and photographs to 3D images was proposed using a custom algorithm.

The AFP loaned the project a GE XR200 system that uses an X-ray source that can produce twenty-two 60 nanosecond duration pulses of 150 kV per second, which limits the penetration of the beam to only 15 mm of steel. Since it is an air-cooled source, the maximum number of pulses per hour is limited to 3 000. Each pulse delivers an X-ray dose of 31 µSv, so the total dose per hour is about 100 mSv. Knowing these parameters it became possible to design a radiation enclosure and to discuss this design with relevant Radiation Protection Agencies. The enclosure was tested in collaboration with the Radiation Protection Department of the Canberra Hospital and operation of the system was to be undertaken using the license for operation granted to the AFP who trained operators on site. The X-ray enclosure is described in detail in Appendix A.

The X-ray enclosure was housed in a modified, insulated 20-ft (6.1 m) shipping container. The container was partitioned with an internal 2 mm steel wall to provide an X-ray system compartment, climate control and emergency exits to enable its use on the barge as an X-ray shielding enclosure that complied with Australian radiation standards. An exclusion zone was also required around the container to remove any radiation hazard, hence the X-ray container's placement on one side of the barge furthest away from the operational dive deck.

Figure 12. Object placed on rotary stage. Photo by D. Creagh.

In use, each artefact of applicable size was imaged by placing the artefact on the rotary stage with the Imaging Processor (IP) set behind the object (Fig. 12). An X-ray exposure was then made, and the IP was removed and scanned in an IP scanner (Fig. 13). Artefacts imaged for a 3D model were progressively forwarded by 4° for each capture. Therefore a complete 360° series of one artefact required over ninety 2D images. For most artefacts of the appropriate size, only two X-ray images were acquired, being perpendicular to each other in orientation (Fig. 14). Once X-ray imaging was completed, again without moving the object on the rotational stage, photos were acquired for each angle shot by X-ray.

Figure 13. Andy Viduka using the Image Processing scanner. Photo by D. Creagh.

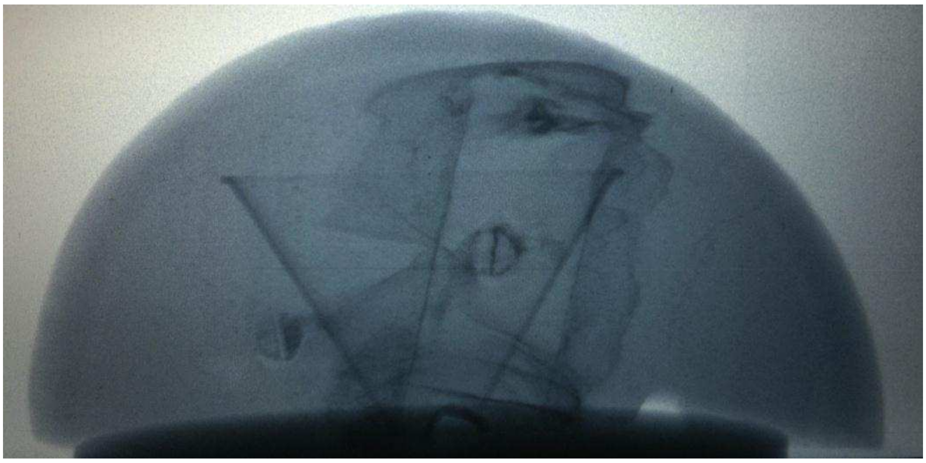

Figure 14. 2D X-ray image of the timber tierce cask head partions (CL12A-0007—127.00091). Image by D. Creagh.

Clear imaging was obtained for timber tierce cask head segments recovered from the excavation (Fig. 14) illustrating that they were in excellent preservation condition with little evidence for marine worm damage or porosity. These items were recovered from the interphase between the marine sediments and kaolin unit and the X-ray data provided independent confirmation that they were 'stable' and appropriate for reburial (see Preparation of artefacts pre-reburial section below). The X-ray imaging trial was successful in demonstrating that there is no technical barrier to imaging objects directly from a wet archaeological site prior to their conservation assessment and possible reburial. The use of a modified shipping container to house the imaging process and the portability of the X-ray unit and shipping container exemplify the potential utility of this method for any archaeological fieldwork.

For archaeological organic material, CT scanning will inevitably be superior than conventional 2D X-ray, with respect to acquisition time, rendering collected 2D data slices immediately into a 3D object and enabling longer and wider artefacts to be imaged. The CT scanning method was used to image wooden war clubs collected in the Pacific by the crew of HMS *Pandora* (1791) in 2004 (Piggott 2006) and is currently being used to image concreted iron artefacts from Kublai Khan's Mongol invasion fleet at Kyushu National Museum (Randy Sasaki 2015, pers. comm., 19 March). The cost of purchase of CT equipment, proprietary software issues and potential issues associated with the portability of such a unit, require further assessment.

As with any imaged object, data from an X-ray can feed into the decision making about treatment and will enable a better understanding of its condition. This in turn enables a clearer understanding of the potential cost associated with an artefact's treatment. An important aim of the project was to rapidly document and rebury artefacts with the option for later recovery. The wooden tierce cask head fragments provide an example where X-ray images were useful in final conservation assessment and in understanding site environment and preservation conditions. Importantly, early condition reporting by X-ray for organic and inorganic materials allows for a baseline assessment of condition and future quantitative assessment of condition change during reburial. For artefacts that are not easily recognizable, having just come from a deposit and being stained from anaerobic burial or clumped with other objects by a corrosion matrix or concretion, imaging provides one of the only ways to assess the nature of materials, conservation status and archaeological potential.

Although the X-Ray images of smaller wooden artefacts in 2D were successful in practice there were limitations in creating 3D visualization of X-ray images. The importance of attempting this approach has been born out in the immediate uptake and application of 3D imaging software in archaeology and for display since this trial. In the several intervening years 3D software has rapidly progressed and this component of the experiment has simply been overtaken by technological advances and the introduction of inexpensive user-friendly software, such as Agisoft Photoscan, that can undertake the external imaging function from a significantly reduced number of images and in full photogrammetry mode (Fulton et al. 2015). The logistics and costs associated with the construction of this specific system are now outweighed by the affordability and ease of use of photogrammetry programs.

Ex-situ artefact recording

A policy was developed in the Research Design, as submitted to Heritage Victoria for the Permit SP217, regarding options for recovered artefacts with respect to their information content (values) and vulnerability—as outlined below. Artefacts recovered from the site for imaging must be kept wet at all times, including during the imaging process. Excess biological growth (i.e. seaweed, sponges, etc) could be removed in order to better document the artefacts; however, no protective concretions or corrosion product layers should be disturbed. All artefacts should be stored in sea water while on deck and this water changed regularly depending on the amount of biological activity. No biocides should be added to the temporary storage solutions. The recovered artefacts should be exhaustively documented, labelled and packed for reburial with the option of transporting them to conservation facilities at the WAM should an artefact meet the significance threshold and/or conservation criteria outlined below.

The reburial of artefacts does not preclude the option of their subsequent exhumation for further analysis or for *ex-situ* conservation and display. Artefacts should be selected using an assessment of their significance (e.g. archaeological, historical, technical, scientific, interpretive, social, as well as their representativeness and rarity) and an evaluation of the cost associated with their conservation and ongoing collection management. In effect, moderation is required between the significance of an object or assemblage and the recurrent costs associated with its conservation and long-term storage. The assessment of significance of an object will be made through an evaluation of its archaeological values, as detailed below.

The hierarchy of archaeological values is as follows:

1. The ability of structures, fittings and assemblages to inform contemporary colonial shipbuilding techniques, lifeways and labour history
2. Conservation interventions predicated on furthering understandings of archaeological site formation and study of the integrity of the site towards physical, chemical and biological equilibrium
3. Artefacts which have outstanding scientific, representative, aesthetic and educational values and which are rare or at extreme risk. These will be recovered and processed through full conservation treatment at the WAM
4. In this project, reburial is the first conservation option with the placement of material into long-term conservation off-site by exception. These items will be accompanied by specific significance statements
5. The costs of conservation will be borne within the agreed ARC budget with short to mid-term storage at the WAM and options for local Victorian curation in the longer term (e.g. Museum of Victoria; Queenscliff Maritime Museum).

The decision as to whether to rebury any artefact or remove it for *ex-situ* conservation was to be made by ARC Investigators and Research Associates from the Partner Organisations. If agreement could not be reached, then external senior specialist advice would be sought with the agreement of the Principal Investigators.

It was decided that artefacts that may be affected from excavation on the starboard side of the wreck (but not recovered) would be moved adjacent to the site, protected by a layer of shadecloth/geotextile during the course of the excavation and then reburied in the off-site repository located close to the site.

The intention was that all artefacts recovered for imaging and recording would be returned to the site for reburial, with purpose-made labelling and packaging. Any artefacts deemed unsuitable for reburial or of very high archaeological significance would be conserved by the appropriate treatment regime applicable to that material type and extent of deterioration at the Department of Materials Conservation, Western Australian Museum in Fremantle, WA.

The project intended to examine the decay and wear patterns on previously treated artefacts recovered from the *Clarence* to assist in the assessment of significant physical, chemical and biological deterioration processes occurring on the site. However, the research team considered that sufficient information on site formation and major deterioration forces was collected during the monitoring programme and that analysing the previously conserved artefacts was unlikely to provide any new information. In addition, the site was significantly disturbed since the previously treated artefacts were recovered; decay and wear patterns would be very different to what was observed with artefacts excavated in 2012 and therefore difficult to compare and interpret.

Archaeological survey and mapping—Site Recorder 4 GIS

In preparation for the major field programme, a team of Project Investigators and researchers met to discuss the protocol and systems to be used for recording and storing data during the excavation. The core project team had already selected 3H's Site Recorder 4 as the preferred GIS for recording and mapping hull structure and artefacts *in situ*, as well as hosting layers for individual artefacts (extracted from the Project's stand-alone Filemaker Pro artefact catalogue) and conservation sampling data, such as sediment cores and timber samples. Site Recorder 4 prescribes how measurements must be obtained to gather accurate data for processing, including depth measurements for calibration across tidal changes and minimum numbers of lateral measurements for redundancy. Daily data input and post-processing was required throughout the field season to enable return visits to rectify erroneous measurements.

Survey and excavation data was scanned and digitised and images were transferred into the image archives and into the GIS platform at the end of each diving day. This ensured that appropriate data was collected and that all artefacts and site data retrieval would be on track for reburial by the first week of May 2012.

Sediment and wood surveys and reburial methodology

Three core locations are shown in Figure 15 and represent sampling points within, adjacent to the reburial depot and at a control point off the wreck site off the port side bow. At each location four replicate cores were taken (totalling 12 cores) for a range of physico-chemical, geochemical and geomorphological analyses. The sediment cores were generally 50 cm+ in length and were driven in by hand with the aid of a collar and soft rubber mallet. In addition, 12 short cores were also recovered from the marine sediments and archaeological deposits on the wreck site and surrounding seabed for geomorphological analysis (Fig. 47).

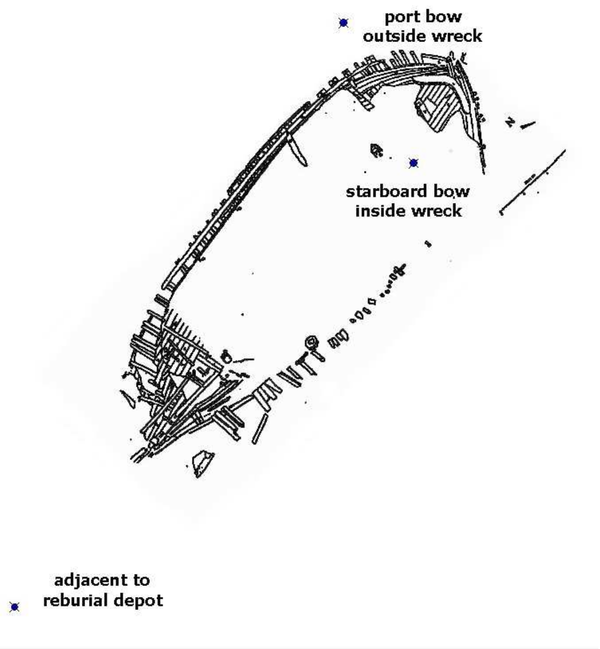

Figure 15. Core sampling locations for pre-disturbance sediment analysis. Image by A. Khan

Chemical parameters measured directly in the sediments via microelectrodes included:

- pH
- Redox potential (E_{redox})
- Dissolved oxygen
- Sulphide/sulphate

Wet chemical and geological analyses of the sea water and pore water within the sediments included:

- pH, sulphide, total sulphur, soluble iron
- Extractable organic matter (EOM) and extractable nutrients
- Water content and grain size distribution

In the initial sediment analysis methodology, core samples were also to be analysed for bacteria and fungi, however on consultation with the microbiologists at Promicro in WA it was decided that due to freezing of the core samples in Victoria for transportation to WA, this would compromise the microbiology of the samples and the results of any analyses would be meaningless, hence these analyses were abandoned.

Structural timbers within the excavated area were also measured *in situ* and samples recovered to identify wood species and the extent of degradation.

The degradation survey of exposed wooden structural members included:

- *In-situ* pilodyn measurements
- Wood samples for maximum water content (U_{max})
- Wood samples for species identification

The pilodyn measurements create 2 mm diameter holes with a maximum depth of 5 cm in the timber. The wood sample sizes will vary dependent on the method of sampling (i.e. wood corers (range 5–100 mm diameter x 5 cm maximum length) or saw samples (10 x 10 x 10 cm maximum).

It was planned to install sacrificial wooden samples [maximum three species/site; two eucalypts (*E. saligna* and *E. pililaris*) and one pine sample (*Pinus sylvestris)*] mounted on polymeric supports (polycarbonate or polyethylene) (major species determined by wood identification of the structural timbers on-site) at a depth of no less than 50 cm on the wreck site itself and in the planned organics off-site storage area. Similarly, sacrificial modern ferrous alloy coupons (cast iron and mild steel) mounted on polyethylene supports were to be placed on the wreck site at a depth of >50 cm and within the planned ferrous metal artefact repository.

At the end of the fieldwork period, the excavated areas (wreck site and the off-site storage areas) were to be backfilled with the dredged sediment from the site and the surrounding seabed in combination with filled, UV stabilized polyethylene woven sandbags if required to make up the shortfall in sediment load due to loss caused by the strong currents prevalent on the site. Previously exposed sections of the site (port side) were to be covered with a combination of UV-stabilized polyethylene woven sandbags, local sediment and geotextile to a minimum depth of 50 cm.

The resultant reburial mound on the wreck site and the off-site storage area was to be stabilised with shadecloth (50–75% UV rating) or geotextile (e.g. Terram 4 000 or equivalent), anchored with sandbags (UV-stabilised polyethylene woven). Finally PVC sheets, fastened together with toggles, would be placed over the reburial mounds and anchored with a combination of sandbags and concrete blocks.

Post-reburial monitoring programme

The plan was to cut access ports into the PVC tarpaulins and shade cloth on the wreck site and artefact holding areas to allow sediment monitoring and sacrificial sample recovery. The sacrificial samples in the reburial mound and the off-site storage areas are to be recovered and monitored at regular intervals (6–12 months). The same suite of analyses (see above) will be carried out on sediment cores also recovered at regular intervals from two locations on the wreck (bow and stern ends of the excavation trench), the off-site storage repository and the control site. Two replicate core samples from each location will be transported to the Department of Materials Conservation, WAM for microelectrode analysis whilst five other core samples recovered from the same location, will be sent to Geotechnical Services in WA for wet chemical analysis. The recovered sacrificial wood and iron samples will be sent to the Department of Materials Conservation, WAM for analysis to determine deterioration rates in the reburial mound and the off-site storage area(s).

Pre-disturbance Survey

An archaeological predisturbance survey of *Clarence* was undertaken by Heritage Victoria in 2009. Photographs and measurements were overlaid on the 1987 site plan, and provided evidence that the site was suffering continuing loss of sediment and structural remains (Fig. 16). Prior to excavation during the April-May 2012 fieldwork period, pre-disturbance recording and preparation was undertaken including: detailed photography, sampling of sediments for chemical analysis, basic marine biology survey, and positioning hundreds of sandbags on-site for site stabilization. In addition, sediment capture depots were created off the bow and stern, with an experimental shadecloth cover over the stern depot to help trap excavated sediment and prevent its loss into the water column.

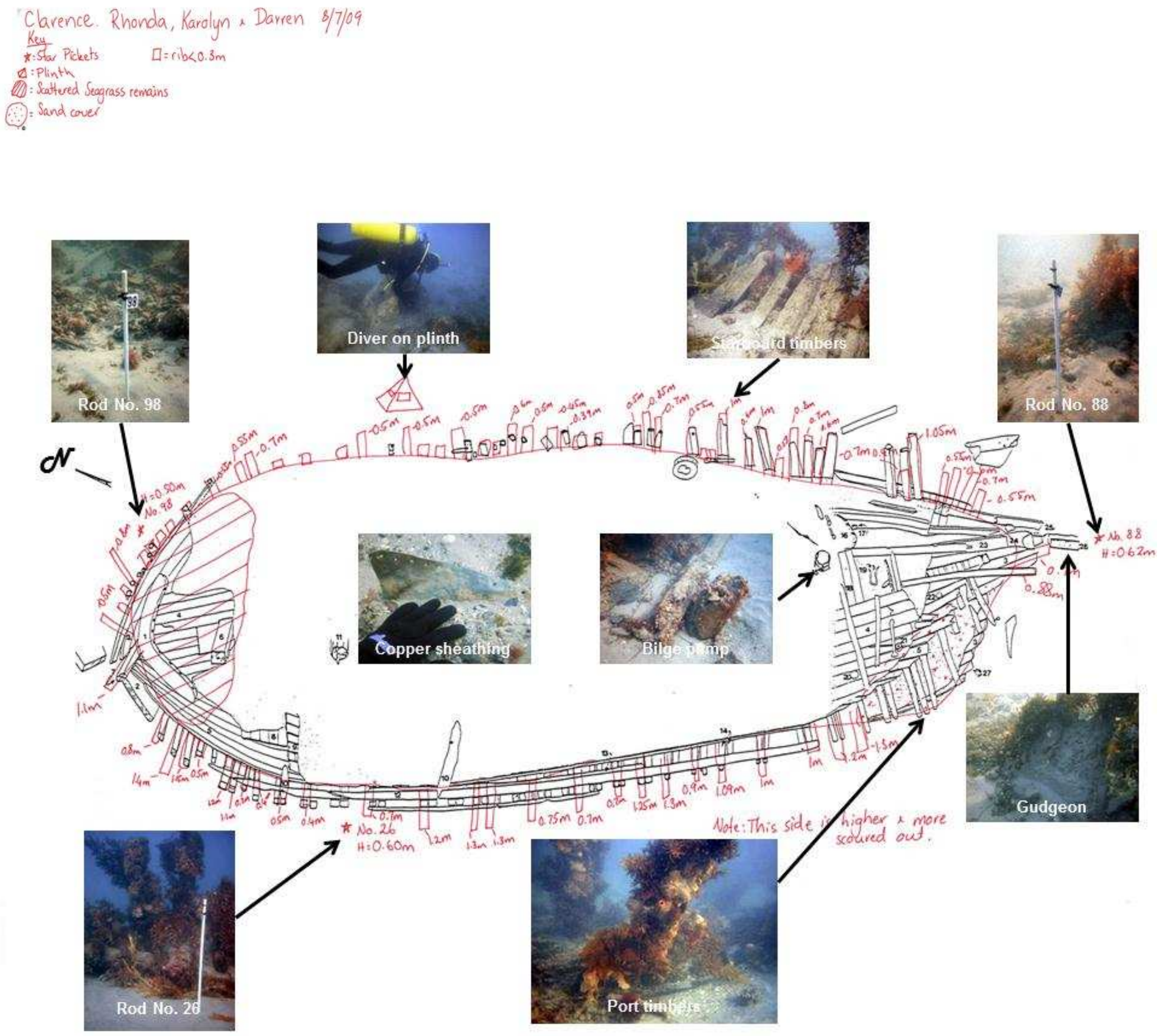

Figure 16. *Clarence* site survey July 2009. Plan by R. Steel, K. Gauvin, D. Kipping; photos by H. Steyne. After Harvey 1989.

Archaeological pre-disturbance survey—GIS[6]

Prior to excavation, the diving tasks involved setting up a network of star pickets as site datums around the perimeter of the hull. Once installed, tide-adjusted depth measurements were acquired and distances between each datum and at least five other datums were taken. With the datum network set up, it was possible to measure points inside and around the wreck. Each recording required measurements to at least three datums and a tide adjusted depth measurement.

The survey measurements on the site were primarily taken using Direct Survey Method (DSM or 3D tri-lateration). This technique was selected to avoid the limitations of using baseline-offsets and plumb bobs on sites with high vertical relief and very strong currents.

For the previous archaeological studies carried out in 1985 and 1987 investigators published 2D pre-disturbance and post-excavation site plans (Gesner 1984; Harvey 1986, 1989). In preparation for the 2012 excavation these plans were scanned from the reports and added to the Site Recorder 4 (SR4) *Clarence* project file.

The previous site plans were scaled, aligned and geo-referenced within SR4. Figure 17 shows the 1987 site plan (Harvey 1989: 17) overlaid with the 2012 datum points. Initial scaling and alignment was completed using the scale bar and north arrow on the site plans. A point coordinate for the site was used to locate the site approximately in space. Further refinement of the positioning of the site plans was possible once the 2012 survey was underway and identifiable points in the site plans were surveyed.

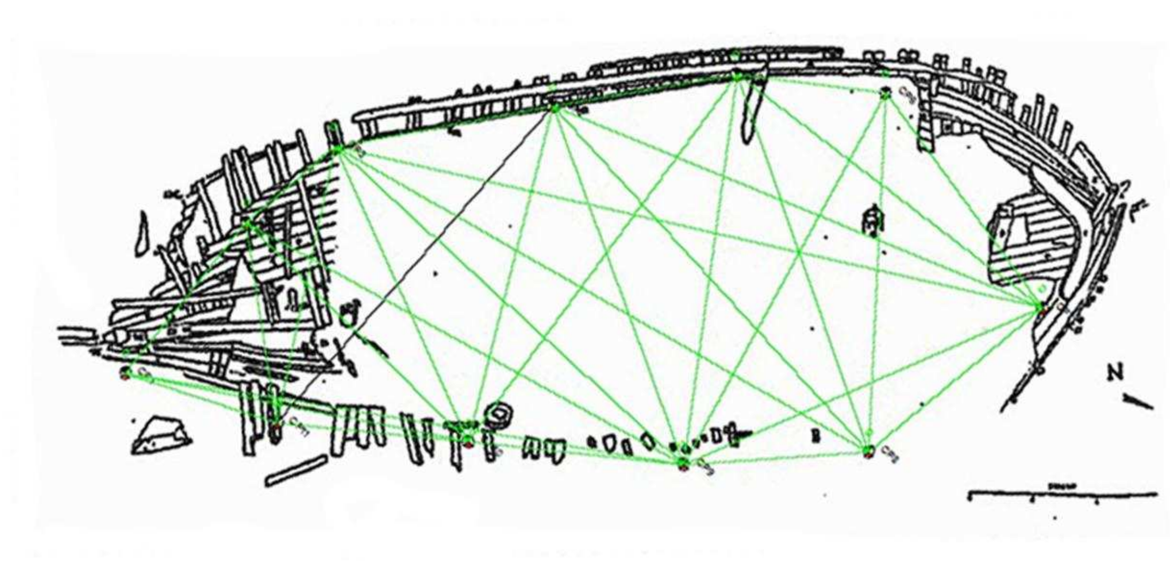

Figure 17. ***Clarence*** **1987 site plan overlaid with 2012 datum points in Site Recorder 4. Image by A. Khan.**

[6] Analyses in this section reproduced in part from Veth et al. 2013.

The 2D site plan for the excavation trench was assembled using data from a range of survey techniques, including DSM, feature measurements, drawing frames, and scaled and rectified photography.

At least one point on an artefact was surveyed in and the artefact photographed *in situ* to establish its orientation. *In-situ* photographs were also used to create digitised line drawings of the artefacts and added to artefact data layers. This allowed all artefacts to be scaled, aligned and accurately positioned within the site plan (Fig. 18).

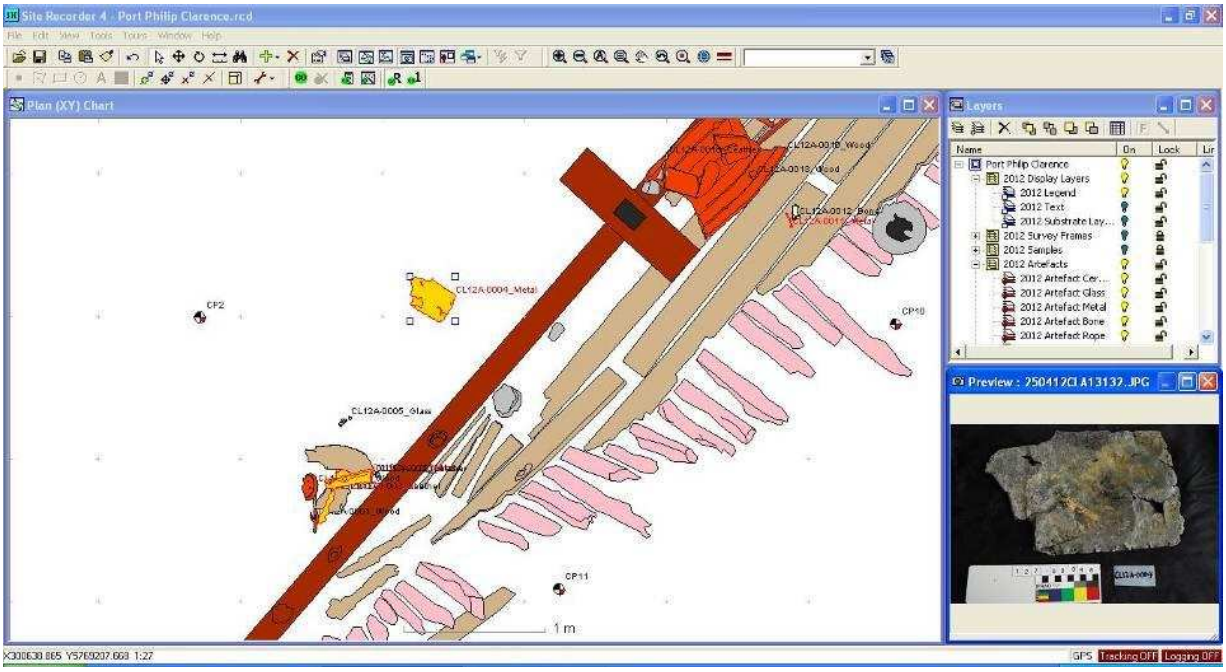

Figure 18. The 2012 excavation trench shown with artefacts and image preview in Site Recorder 4. Image by A. Khan.

Conservation survey

A pre-disturbance conservation survey was carried out collecting baseline sediment core samples prior to excavation. In addition, wood samples were recovered from different areas on the site after excavation for species identification, and extent of deterioration measurements. Data from this survey provides a baseline against which the results from the post-reburial monitoring programme may be compared and the success of the applied mitigation strategy properly assessed. These data are discussed later in conjunction with the results obtained from the post-reburial monitoring period (see Site Monitoring section).

Geomorphological survey

Sediment samples were obtained as part of the pre-disturbance activities and geomorphological analysis of the site. Core samples acquired in and around the wreck site were mapped in SR4 using Direct Survey Measurements (DSM). The sample sets enabled investigations into the micro-sedimentary and taphonomic environments in and around the wreck, as well as on shore sampling for terrestrial comparison. Sediment samples collected from the wreck and adjacent seabed in April–May 2012 (see Fig. 47) and from the surrounding onshore landscape in March 2013 (Fig. 46) were analysed at the Research School of Earth

Sciences (RSES) at the Australian National University (ANU) by a team comprising Master of Archaeological Science candidate, Adele Zubrzycka, Chief Investigator, Anthony Barham, and ANU XRD Laboratory Manager, Ulrike Troitzsch.

These analyses aimed to identify the extent of sediment preservation or damage within the wreck, and to compare the wreck samples with the surrounding environment to identify potential artefact signatures. One of the fundamental questions for wreck loss and preservation in high tidal regime embayments, such as *Clarence*, is whether the sediments within the wreck are local or from other sources. While it is well established that wrecks and their debris fields will attempt to settle down to hardpan, it is often less clear whether the matrix of the site is comprised of local sources or those entrapped by the introduction of a new structure. These sourcing studies can help address this question directly.

Initial analytical results indicated that the surface marine sediments on the *Clarence* site are dominated by well-sorted, fine and medium sands, consistent with the well-fluxed tidal-current dominated environment of the wreck site. The sands are variably mixed with biogenic carbonate and local shell. The facies at *Clarence* are typical of shallow waters around the periphery of Port Phillip and consistent with seafloor sediments mapped as nearshore and offshore sand-bar zones for the wreck area (Holdgate et al. 2001, adapted from Buckley and Clark 1987; Holdgate et al. 2011). The seafloor sediment train at the site is tidal current supplied, and a north-west extension of sands from the Nepean Bay Bar and West Channel to the south and south-west. The modal sizes, sorting and lack of binding fines make the sands around the wreck highly mobile as a shallow sand sheet, overlying the eroded transgressed surface of harder clayey Tertiary regolith basement at shallow depth.

Marine ecology survey

The April 2012 pre-disturbance survey noted that *Clarence* provided a habitat for both sessile and motile marine species that are common to Port Phillip. It briefly describes the biota and provides a species list of common fish, invertebrates and algae. A short discussion of the results, extracted directly from the April 2012 Marine Ecology Report by Kate Pritchard from PDS, appears below. The full report is reproduced in Appendix B.

Macroalgae and sponges

The habitat surrounding the *Clarence* is characterised by a high density of seagrass *Zostera muelleri* (Table 1). There were several ruffled globular orange sponges within the seagrass. There was a diverse range of algae species present on the shipwreck. The only canopy forming species observed was the common kelp *Ecklonia radiata,* which were observed in low abundances. The most dominant species observed along the wreck was *Sargassum fallax*, forming in relatively large brushes in most areas. Other common species observed were *Caulerpa brownii, Caulerpa trifaria, Codium spp* and several thallose red algae including *Rhodymenia australis* and *Erythroclonium sonderi*. All species observed on transects are listed below. There was a large number of sponge species present on the wreck. One common species was the prickly rose sponge *Dendrilla cactos*.

Table 1. Algae and sponges observed during marine ecology survey April 2012 (Pritchard & PDS 2012a: 4).

	Species Name	Common Name
Algae		
Brown	*Ecklonia radiata*	Common Kelp
	Dictyopteris muelleri	Mueller's forkweed
	Sargassum fallax	Broad-leafed sargassum
	Zonaria turneriana	Fanweed
	Zonaria spiralis	Spiral fanweed
Red	*Dictyomenia harveyana*	Harvey's leafweed
	Rhodymenia australis	Southern red forkweed
Green	*Caulerpa brownii*	Browns caulerpa
	Caulerpa trifaria	Three-cornered caulerpa
	Codium spp	
Sponges		
	Dendrilla cactos	Prickly rose sponge

Mobile invertebrates and cryptic fishes

There was a high abundance of invertebrates present in the sediments surrounding *Clarence* (Table 2). The abundance of invertebrates was dominated by parchment worms (*Chaetopterus* sp.) and bivalves. The most common species observed was the common sea urchin *Heliocidaris erythrogramma*. Three species of sea star (or starfish) were observed within the study area; *Meridiastra gunnii*, *Coscinasterias muricata* and *Uniophora granifera*. Other invertebrates present included the Swimming anemone, *Phlyctenactis tuberculosa*, the whelk *Cabestana spengleri,* and a single giant cuttlefish *Sepia apama*.

Table 2. Invertebrate species observed during marine ecology survey April 2012 (Pritchard & PDS 2012a: 4).

	Species Name	Common Name
Invertebrates		
	Heliocidaris erythrogramma	Common sea urchin
	Herdmania grandis	Red-mouthed ascidian
	Notomithrax ursus	Hairy seaweed crab
	Plagusia chabrus	Red bait crab
	Cabestana spengleri	Spengler's triton
	Meridiastra gunnii	Gunn's six armed star
	Coscinasterias muricata	Eleven armed sea star
	Uniophora granifera	Granular sea star
	Chaetopterus sp	Parchment worms
	Phlyctenactis tuberculosa	Swimming anemone
	Sepia apama	Giant cuttlefish
	Paguristes frontalis	Southern hermit crab

Fishes

The most common family of fish observed was the Monacanthidae, including the leatherjackets (Table 3). There were aggregations on and around the wreck of juvenile *Acanthaluteres vittiger*, toothbrush leatherjackets. Other leatherjacket species recorded were *Meuschenia freycineti,* the six spine leatherjacket, *Meuschenia flavolineata,* the yellow striped leatherjacket, and *Brachaluteres jacksonianus,* the pygmy leatherjacket. Another common species observed was the goat fish, *Upeneichthys vlamingii.* The spotted pipefish, *Stigmatopora argus* was commonly observed within the seagrass beds adjacent to *Clarence* and one potbellied seahorse, *Hippocampus abdominalis. Hippocampus bleekeri* was also observed both of which are listed species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC).

Table 3. Fish species observed during marine ecology survey April 2012 (Pritchard & PDS 2012a: 4).

	Species Name	Common Name
Fishes		
	Upeneichthys vlamingii	Goat fish
	Acanthaluteres vittiger	Toothbrush leatherjacket
	Meuschenia freycineti	Sixspine leatherjacket
	Meuschenia flavolineata	Yellow stripped leatherjacket
	Brachaluteres jacksonianus	Southern pigmy leatherjacket
	Diodon nicthemerus	Globe fish
	Tetractenos glaber	Smooth toad fish
	Neoodax balteatus	Weed whiting
	Notolabrus tetricus	Blue throat leatherjacket
	Sepia apama	Giant cuttlefish
	Parablennius tasmanianus	Tasmanian blenny
	Stigmatopora argus	Spotted pipefish
	Hippocampus abdominalis	Bigbelly seahorse

Introduced species

No introduced species were observed during the survey; however, several species are known to inhabit the area, including the Northern Pacific sea star, *Asterias amurensis.*

Excavation Description

Wreck site

With the midships undisturbed by previous fieldwork in the 1980s, the initial plan for the 2012 excavation was to create three 1 m x 3 m trenches in previously unexcavated portions of the site (Fig. 9). They were to be located on the N–S datum line at 4–5 m S; 8–9 m S; and 12–13 m S. Following several pre-disturbance dives this plan was changed. Contributing factors included the unexpectedly shallow sediment observed over much of the site, the location of previous excavations and the relatively small area of the hull. The plan was adjusted to an excavation on the undisturbed starboard portion of the hull (as noted above in 'Research methodology', Fig. 10).

Given the mobile nature of the upper portion of the marine sediment column noted in 2012 overlaying the hull timbers, the team predicted that the sides of the three proposed narrow trenches would slump with a resulting loss of sediment in the strong current. Even as early as 1991, Coroneos noted that the marine sediments in close proximity to the *Clarence* were unstable and that considerable sediment loss had occurred through erosion following the 1987 excavations (Coroneos 1991). Therefore the team decided to stabilise the centre line of the remaining site matrix to prevent it slumping in from the port side in order to maintain the integrity of the starboard trench. An interim stabilisation strategy was developed, consisting of sturdy PVC sheeting held in place with a bund of sandbags to shore up the centre line. However, once the divers commenced excavating it was apparent that there was only a shallow layer of loose marine sediment overlying a dense kaolinite-rich unit, which in turn lay directly against ceiling planking, dunnage and the frames and hull timbers. The final agreed strategy was the excavation of the starboard deposits from approximately the stern-post (where most sediment has been lost) to just past the Samson-post (at c. 9 m along a datum line established along the keelson).

Figure 19. Lead CI Peter Veth on SSBA recording the mast step. Photo by T. Massey.

Excavation commenced on 26 April 2012 after several days of inclement weather that prevented boating and diving operations (Fig. 19). A revised excavation, survey, photography, conservation and backfill strategy was designed by Peter Veth and James Parkinson, in consultation with the research team, and implemented in such a way that it ensured efficient diving operations with SSBA, optimal use of the time available for fieldwork with some 25% contingency built in for inclement weather. A conservative and staged approach to excavation was developed that ensured the site would be, at minimum, backfilled with sediment and the trenches covered with shadecloth and sandbags at the close of the fieldwork. Consultation with the project team and HV determined that a small group would return to the site at the end of May 2012 to ensure a minimum of 50 cm sediment coverage over the excavated area and inside the off-site artefact repository at the stern, and that the shadecloth placed *in situ* to stabilise these backfilled areas was secure. Sediment cores were taken in pre-disturbance mode and after reburial and the site was left covered with shadecloth until the final stage of stabilisation. In November 2012 the final phase of the *in-situ* preservation methodology was undertaken. The site was completely covered with a 250 m^2 pre-fabricated piece of shadecloth followed by three large PVC tarpaulins, which had reinforced eyes for stitching together and nylon straps for fastening sandbags around the perimeter and across the seams.

An excavation grid was established in real space and located against the datum points and aligned parallel to the keelson. Marker lead weights (coloured for 3D image capture) were placed from 0–9 m along the main datum line and excavation trenches gridded from this. Recording of all starboard deposits was carried out with 1 m square grid frames wired up in 10 cm^2 divisions with all cultural and natural features drawn in plan view on underwater (UW) slates. The underwater excavation recording proforma were developed by David Steinberg in collaboration with senior team members.

Less experienced practitioners and volunteers undertook dry-run familiarization exercises on land before carrying out underwater mapping. Buddy pairs of recorders were trained to measure and draw and their work was supervised both underwater and after return to JUPB1. Some grid squares were re-drawn to ensure completeness and consistency of information.

Excavation was by (venturi principle) water dredge with a 5 hp water pump on the proximal edge of the JUPB1. The dredge had an exhaust extension and this was directed into two backfill sediment repositories constructed to trap the dredged material and minimise sediment loss in the generally high currents experienced in this area of Port Phillip Bay. Gridded 1m quadrats were used to record all excavation squares on myler paper fastened on PVC plaques.

Excavation proceeded along the keelson in 1 m lateral sections, and sediment was removed down to the ceiling planking. Each 1 m section was excavated starting from the keel and out to starboard, with each section taking several lateral passes to complete (fully excavated down to the ceiling planks with each pass). Artefacts encountered were measured *in situ* from nearby datum points. The excavation worked its way along the starboard side in this fashion to the 9 m mark on the keelson baseline; the resulting trench was bounded by the remaining kaolin 'wall' extending towards the bow. Throughout the excavation trench the kaolin was covered by sand to varying degrees (sporadic cover, with no more than 25 cm of sand over it at any point). Due to the excavation technique described above, the kaolin layer was not exposed in its entirety at any time. Figure 20 shows the kaolin in profile above the keelson.

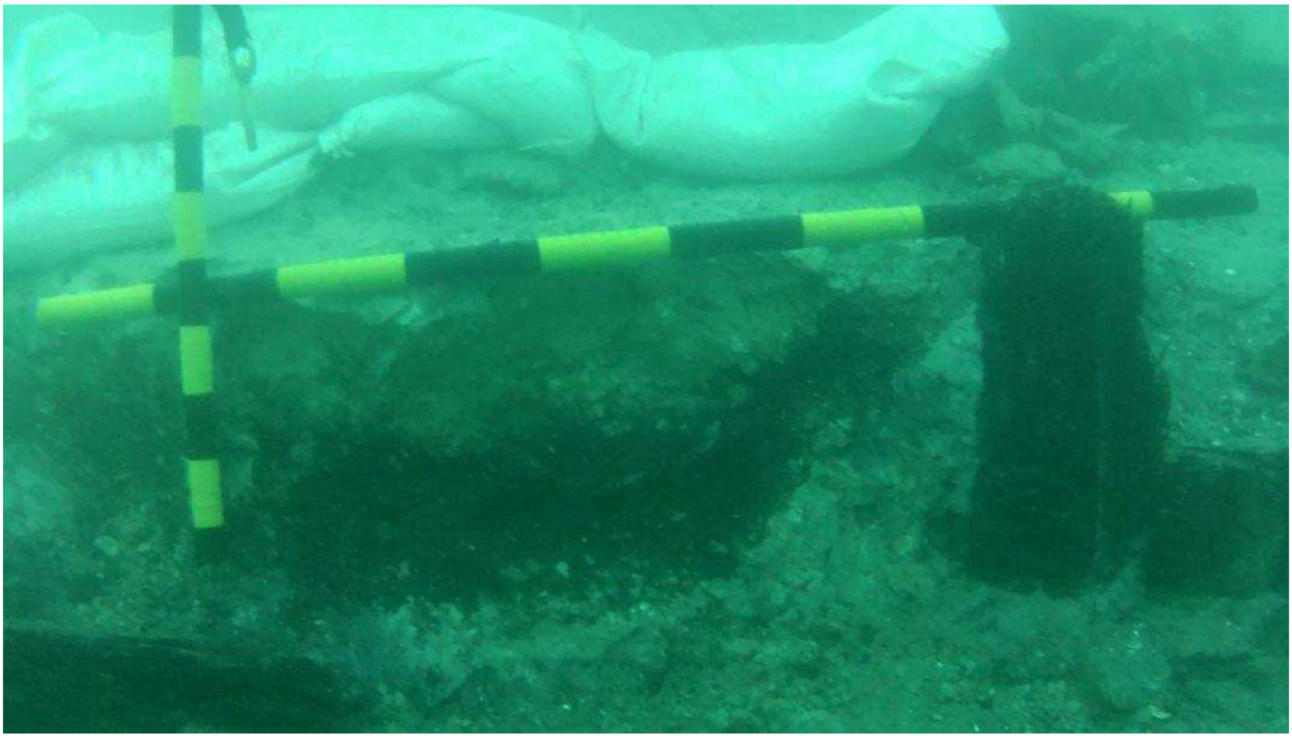

Figure 20. Kaolin clay deposit in profile above the keelson. Photo by C. Coroneos.

It was clear from the first excavation dive that generally loose marine sediments overlaid a dense, 'plastic' horizon that superficially appeared to be clay. This material could not be moved with the normal techniques of fanning and dredging. *In-situ* core samples were taken and inspected by the HV archaeologists and conservators on site. It was clear these were compacted clays (either endogenous or introduced) and that some other technique would be required to excavate this matrix. Different tools were trialled, with concrete bolsters proving the most efficient. They were used to wedge fist-sized portions of clay out, which then disaggregated enough to be transported down the dredge. This material, as described in detail below, was eventually analysed as kaolin, and appears to have been present within the hull in such a large volume that it is thought to have been loaded as ballast. Whether it was a payload in addition to its function as ballast, and possibly even a sealant, is uncertain. However, given it was co-extensive over most of the starboard section excavated and maintained stratigraphic features, such as bucket marks, its primary role as vessel's ballast seems most likely.

Significant structure proud of the sediments has diminished since the isometric renderings of 1987 (Fig. 16). This has presumably been accelerated by anchor damage—and indeed anchor chain has been removed off the wreck numerous times, and as recently at the time of the 2012 excavations. One of the authors (Philippou) noted that in 2004 part of a hatch cover was located some distance off the wreck site and this relocation was not due to natural processes.

Excavation of the starboard section revealed further evidence for double frame construction, the lack of hanging knees, partial inner ceiling remains and generally excellent outer hull planking condition, retaining makers' marks, such as details of adzing, cutting and joinery (Harvey 1989). Other features noted included the stern-post, mast step and Samson-post. A large concretion at CP10 remains unidentified. This feature was fixed and no attempt was made to remove it for further examination. Artefact classes recovered during the systematic excavation included broken glass, laminated leather, cordage, iron bolts/fittings and most conspicuously four wooden casks (these were tierce barrels with lids and staves). These casks were lying on their side with different elements exhibiting variable degrees of degradation, largely dependent on how comprehensively and deeply they were incorporated within the lower clay unit. These artefacts are described in detail below.

Two of the practitioners, Brad Duncan and Mike Nash, were part of the *Clarence* excavation in 1987 and excavated the stern area both in 1987 and again in 2012. The more recent work began close to the stern-post and progressed 3 m forward and exposed the floor timbers and bilge area. Both noted their surprise at how much of the wreck was missing since last excavated in 1987. At that time, the wreck extended approximately 3–5 ft (0.9 m – 1.5 m) off the seabed; it now appeared that only c. 0.3–0.5 m of the hull was still intact in the area they were excavating.

During the 2012 excavation, having removed a light layer of white marine sand in the excavation area (after re-surveying sections of the extant frames and other timbers first), they noted the excavation was hampered by the discovery of a thick gelatinous mud (light grey shade on top—darker as they proceeded downwards) with the consistency of ‘a cross between stiff toffee and custard, and sticky like condensed milk’, dense and quite homogenous. The mud was c. 30–50 cm deep and packed in tightly around the hull timbers. It could only be removed by cutting off sections of it with ‘knives’ and disposing it up the dredge pipe. Broken glass and spikes were recovered; and, an interesting timber construction was partially revealed on the port side of the keelson that might indicate a compartment. However, excavation was focused on the starboard side.

The *Clarence* Day Book of 21.10.1987: page 3 notes ‘in the excavation of the stern-section starboard trench at point 4) a small bag full of grey ‘gunk’—which I suspect is lime: it has a consistency like crumbly plasticine and is in a big lump on the timbers of the bow end of the hole [Trench 3]’. A leather belt, half-disc of timber and rope are noted *in situ* as well as structural elements including external strakes, frames, internal ceiling, deck timbers, battens with nails holes and ‘sheep deck’ timbers. Photomosaics from the 2012 excavation (Fig. 21) show many of these structural elements; however, marine growth on the outer portions of frames illustrates the net loss of sediment overburden and depletion of some superstructure. The scale site plan in Harvey (1989: 17) clearly shows these elements and the start of the clay unit at the stern of the vessel. This feature continued until the 9 m datum mark and was coeval with the entire length of the keelson.

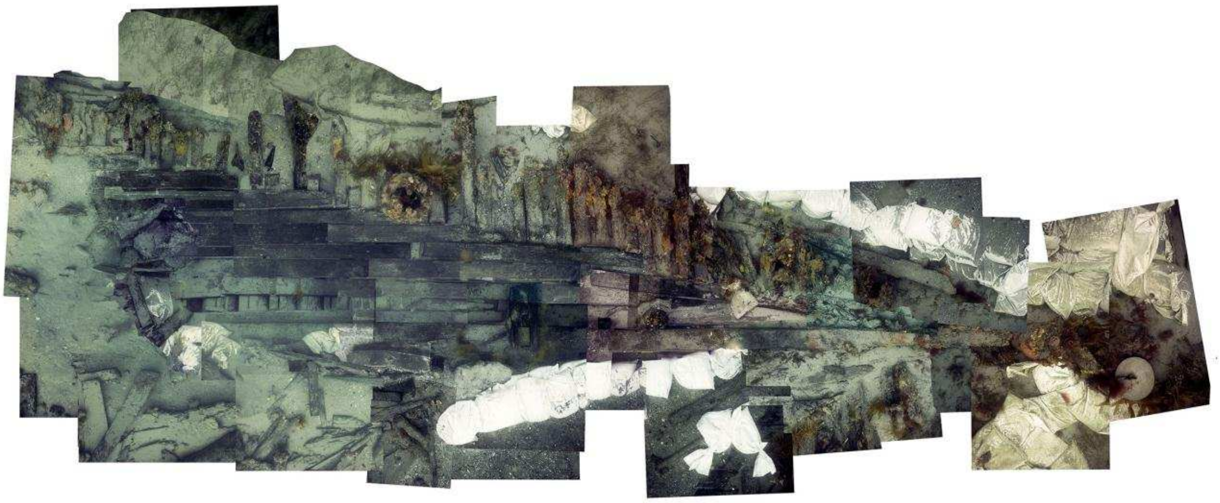

Figure 21. Photomosaic of *Clarence* post-excavation. Image created by D. Shefi.

Stills and video were taken of all excavation squares, and exposed features; multiple linear transits were made of the site and excavation area; and, complete mosaics were made at different flying heights over the site. Sufficient saturation and wrap-around runs were made to complete Surface from Motion 3D reconstructions and also photomoasics. Availability of AgiSoft Photoscan by the end of the project allowed more detailed 3D photogrammetry (Fig. 22) and heightfield data models (Fig. 23) to be completed by Kevin Edwards. Profiles across the hull can be reconstructed from these hightfield data.

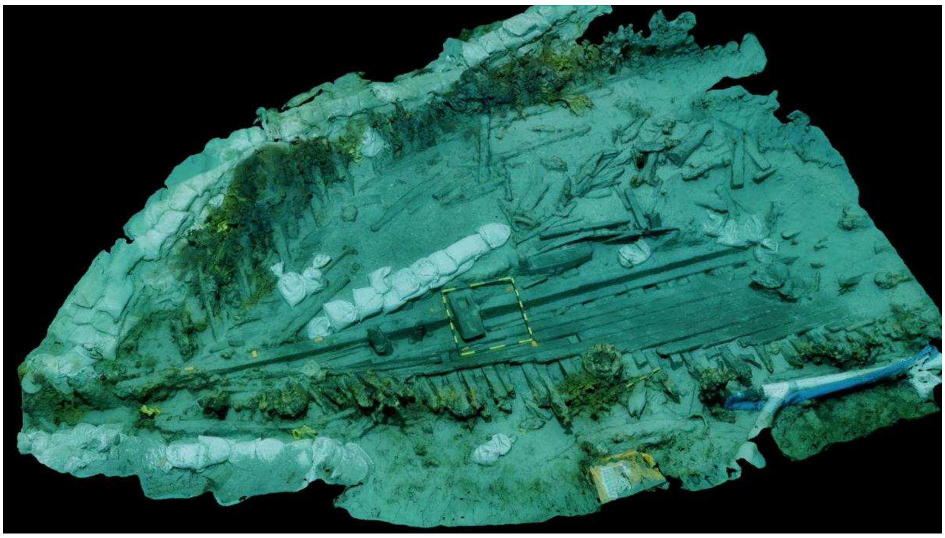

Figure 22. 3D model of exposed starboard side of *Clarence* after excavation. Created by K. Edwards.

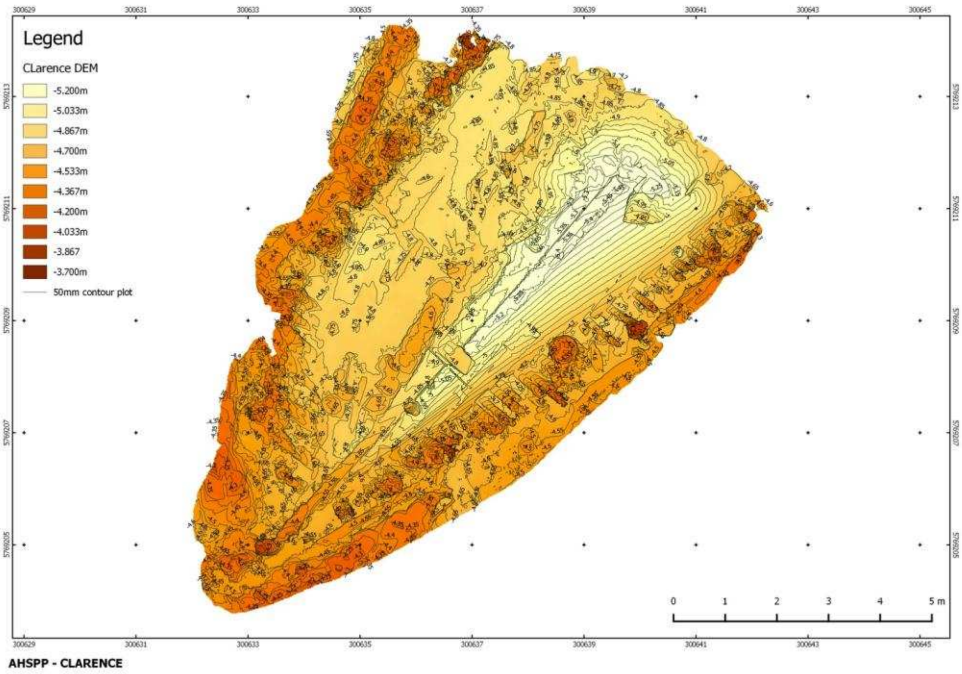

Figure 23. Heightfield data model of *Clarence* post-excavation. Created by K. Edwards.

Figure 24 below shows the 2012 excavation trench super-imposed over the 1987 site plan (Harvey 1989: 17). This demonstrates good concordance between original features and those plotted in by trilateration and processed in SR4. The main material cultural categories recovered in 2012 are similar to those recorded in the 1987 excavation of the stern Trench 3—namely fashioned oak sections (cask), cordage and leather as well as loose timber ceiling and dunnage.

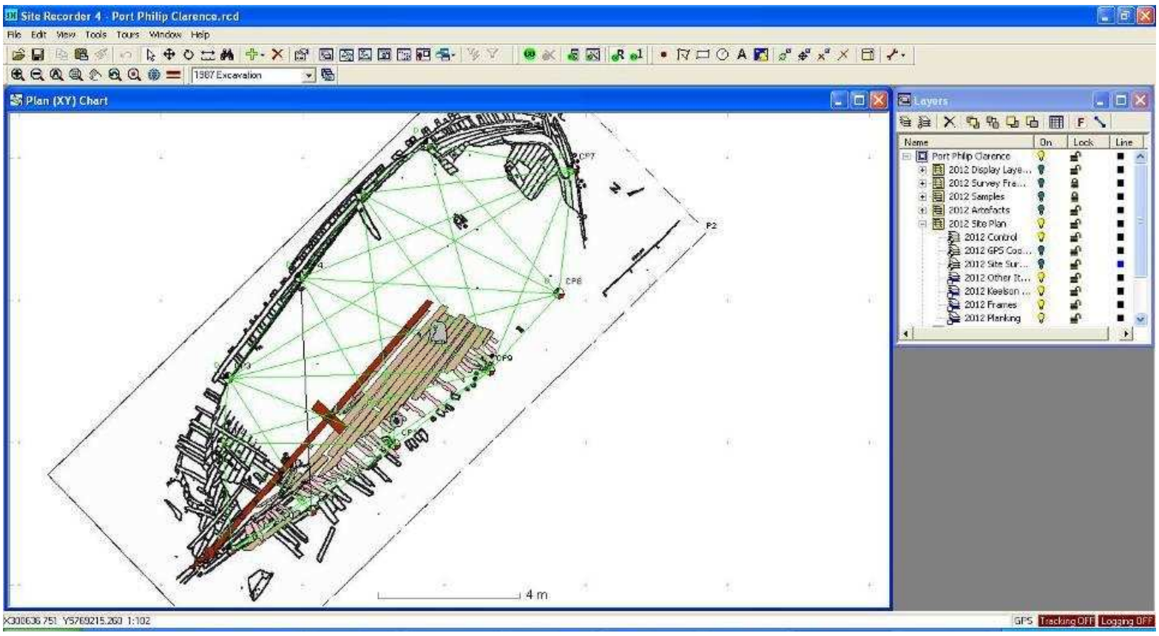

Figure 24. The 2012 excavation trench and datum points overlaid on the 1987 *Clarence* site plan (after Harvey 1989: 17). Image by A. Khan.

Artefacts

Artefacts and conservation summary[7]

It was found that the close collaboration between the finds recording and conservation teams and the close proximity of these two work stations resulted in the vast majority of processes for conservation and finds management running extremely smoothly. The close working relationship and good communication between the two teams from the preliminary design stages through to the field, and the flexibility inherent in the database methodology adopted, was critical to the success of the site recording and analysis in the available time frame.

The low density of artefacts from previous and current excavations suggests that this material has been lost from the site through past human and natural agencies. A significant layer of kaolin ballast was overlain by a poorly consolidated layer of marine sediments that is likely to have been reworked over time. The most diagnostic artefacts such as cask staves and lids, coir cordage, leather patches and ferruginous objects were recovered from within the kaolin unit and the marine sediment disconformity above it. The paucity of artefacts recovered from the marine sediments illustrates the instability of this upper sediment unit.

Over the course of the 2012 excavation, 109 individual pieces, totalling 35 artefacts, were recovered. Whilst the aretfacts remained *in situ* a minimum of four measurements were taken from nearby datums plus a depth measurement for importing to SR4 (Fig. 25). Sixteen of the 35 artefacts are thought to be dunnage. The artefacts were kept submerged in tubs containing sea water, cleaned, photographed, registered, tagged and then wrapped in polyester geotextile (Bidim A14), followed by a high density polyethylene shadecloth and placed in wet storage until the reburial phase of the project commenced (Shefi et al. 2014). All artefacts were returned to the site but organics were buried in the off-site storage depot situated 10 m south of the stern (Veth et al. 2013). Small samples were taken from the cordage (CL12RS-0012) and leather artefacts, CL12A-0008 and CL12B-0009, by the conservation team to identify the fibres and determine their extents of degradation (Veth et al. 2013). The analytical reports are re-produced in Appendices H and I, respectively.

[7] Parts of this section previously published in Richards et al. (2014), Shefi et al. (2014) and Veth et al. (2013).

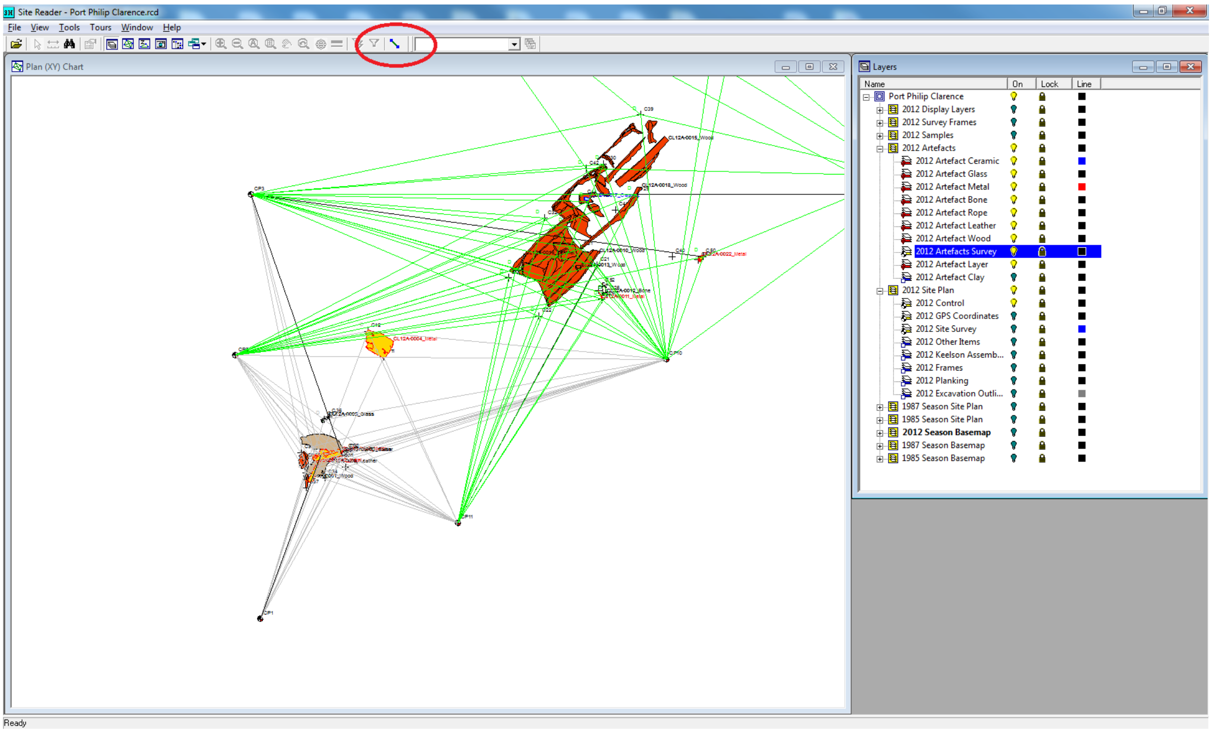

Figure 25. Site Recorder 4 screen shot showing measurements taken to points on artefacts *in situ*. Image by A. Khan.

The range of cultural materials found on site consisted of timber (most likely dunnage); a large number of cask components (staves and headpieces); concretions (including a concreted bolt); lead hull-sheathing; fragile pieces of leather; rope related to rigging; clear and olive-green glass pieces; a ceramic fragment; and an animal bone, which appeared to be burnt. A leather bag or satchel was also identified *in situ*, however the artefact was not raised. Research and analysis of the artefacts is presented in 'Artefact interpretation' within the Discussion section of this report. An artefact registration table with registration numbers, object names, descriptions and photographs is in Appendix G. All artefact images and the complete artefact database were supplied to Heritage Victoria on USB.

Preparation of artefacts pre-reburial[8]

Large areas are usually required for conservation artefact handling and storage. However the space on the barge was limited so the conservation workspace was located on the deck between two shipping containers, with an approximate area of 35 m^2 (Fig. 26). The conservation science preparation and materials/equipment storage area was located in the back half of the middle shipping container; an area of 7.5 m^2. Overall, the areas were adequate. However, had more artefacts (>50) been recovered the lack of space may have proved problematic.

[8] Parts of this section previously published in Veth et al. (2013).

Figure 26. Conservation area on JUPB1. Photograph by J. Rodrigues.

Polypropylene containers of various sizes (with their lids connected via cable ties) and padded lifting crates were prepared for the recovery of any artefacts exposed during the excavation phase. After the objects were recovered they were cleaned to remove clay deposits or biological growth that may obscure archaeological information prior to being transferred to the artefact documentation team for registration, recording and photography. Some objects were deemed suitable for X-ray and 3D photography. A few artefacts, such as the coil of rope, were extremely fragile and supports were made so the object could be handled with minimal damage during documentation. The artefacts were kept wet at all times with sea water to avoid osmotic shock when reburied.

After the artefacts had been registered and recorded they were prepared for reburial. Decisions on whether objects should be fully conserved for further analysis and/or display were based on archaeological significance assessments and an evaluation of the costs associated with their treatment and ongoing collection management (see Research methodology section above). Based on these criteria, no artefacts were selected for conservation treatment at the Department of Materials Conservation, Western Australian Museum, and all objects were reinterred onto the site or within the reburial depot.

The artefacts were wrapped in polyester geotextile (Bidim A14), followed by a high density polyethylene shadecloth protective wrapping (Coolaroo Exterior Fabrics—Extra Heavy 84-90% UV Block Heritage Green 3.66 m wide) secured by cable ties. Registration tags were placed in with the artefact and then a polyurethane cattle tag was attached to the outside of the shadecloth denoting an identification number, which related directly to the artefact on the database, and a brief description of the item so they could be easily identified in the future (Fig. 27). The artefacts were then placed in wet storage awaiting the reburial phase of the project.

The smaller artefacts were placed in the crates used for their initial recovery to transport the objects to the seabed for reburial, however the cask stave packages were too large so they were secured to the top of the crates for support.

Figure 27. Recovered rope wrapped, labelled and ready for reburial. Photo by K. Kasi.

Discussion

Wreck site—Colonial shipbuilding

Previous excavations in the 1980s suggested that *Clarence* was not built in strict compliance with any particular construction rules (e.g. Lloyd's) for vessels of its size (Harvey 1989). The 2012 excavations confirmed the total absence of hanging or lodging knees either *in situ* or loose in the sediment. This suggested that *Clarence* was built without them, which was contrary to traditional Northern European shipbuilding practices of the time. Hanging and lodging knees were often constructed of iron from the middle of the 18th century onwards, especially where timber was not copious. Iron knees may have been in short supply or not available in the colony. This lack of use of established shipbuilding techniques represents a shortcut and speaks to expedient solutions to issues of isolation and limited supply chains. A full discussion of the construction of the vessel and its archaeological context is not deemed necessary in relation to the 2012 excavation given that it has been previously analysed in detail by Harvey (1989).

Adaptation to the environment was clearly an important part of the development and evolution of wooden watercraft construction in a colonial setting (Crisman 2004). Adaptation is particularly important in terms of the use of endemic timbers in vernacular watercraft as ship and boat builders in Northern Europe had over many centuries developed detailed knowledge and understanding about shipbuilding including the most suitable timbers for particular tasks: oak for frames, beech for decks, ash for oars, fir for masts and spars. When these familiar and traditional timbers were not available the colonists had to use locally grown timbers instead, sometimes of unknown suitability.

Previous research has identified timber samples taken in 1981, 1985 and during the 1987 excavation (Harvey 1986, 1989; Clayton 2012a, 2012b). Additional timber samples were taken for analysis during the 2012 excavation but results were not available at the time of writing. The keelson, breasthook and stern-knee samples were identified as Eucalyptus species possibly Yellow Stringybark (*Eucalyptus muelleriana*) while the stern-post was identified as from the ash group of Eucalyptus possibly Messmate Stringybark (*Eucalyptus obliqua*). The treenails were identified as Flooded Gum or Rose Gum (*Eucalyptus grandis*) and the frames, bilge pump and a large post near the bow were reported to be Red mahogany (*Eucalyptus resinifera*). The platform decking in the bow was identified as from the gum group of Eucalyptus, possibly Tallow-wood (*Eucalyptus microcorys*) and the apron timber as possibly River Red Gum (*Eucalyptus camadulensis*) (Harvey 1987:43; Clayton 2012a: 25). The only non-local timber used in the construction of *Clarence* was Baltic pine (*Pinus sylvestris*), which was used extensively inside linings of the hull and bulkheads (Clayton 2012a: 25). All six Eucalyptus species, on the other hand, are endemic to NSW and grow in the general region where *Clarence* was built on the Williams River (Holliday 2002). As Clayton has pointed out *E. camaldulensis* was known for its strength implying that it was selected 'for a specific purpose' (Clayton 2012b: 55). She further argues that the builders of *Clarence* and other 19th century NSW-built wooden schooners 'broadly followed an established 19th century tradition of intentional Eucalypt species selection for shipbuilding[…]even if their choice did seem opportunistic due to their availability' (Clayton 2012a: 28).

Clayton has also pointed out that almost all historical references to Australian timbers used in shipbuilding before 1860 only used the local, or vernacular, names, not their scientific names, which makes the identification of specific timbers from historical records alone very difficult and potentially flawed (Clayton 2012b: 56–58). In later historical writings, Australian economic botanists (between 1867 and 1919) have provided some excellent information about the timber species used, primarily in NSW and Victoria at least, for shipbuilding (Clayton 2012b: 60–63).

The archaeological evidence for most of the timbers actually used in the construction of *Clarence* clearly supports the hypothesis that shipbuilders in NSW selected local timbers for the construction of their vessels (Bullers 2006: 17; O'Reilly 2006: 81; Clayton 2012b: 55). Nevertheless further research is needed to more fully understand the selection of timbers for shipbuilding, particularly in the first half of the 19th century when very limited historical evidence is available, as to date only two vessels built in NSW before 1850 (*Clarence* and *Alert*) have been located and archaeologically investigated (Nash 2004).

Artefact interpretation

Tierce casks (127.00094, 127.00099, 127.00102)

The wooden cask components made up the largest volume of materials raised from the wreck. After each individual piece was cleaned and measured, the lengths of the staves closely resembled the category referred to as tierce casks. A tierce is an old measure of capacity equivalent to 42 wine gallons, approximately 158 to 160 litres, one third of a pipe or half a puncheon. The US tierce was 42 US gallons (~160 litres) and an imperial tierce was 35 imperial gallons (~159 litres) (Kilby 1971).

According to the English cooper Kenneth Kilby (1971: 52), the English stave lengths for tierce casks were usually given at 31.5 in (~800 mm). The complete lengths for the *Clarence* staves averaged between 876 mm to 890 mm for the interior and 911 mm to 930 mm for the exterior. Based on these measurements, the staves found on *Clarence* depict slightly larger tierce casks than those traditionally described by the English. This variation is not surprising, as some tierce casks were made to store dry goods, in which case, they could be of a more rudimentary fabrication as opposed to wet casks, which required a higher level of skill and precision for storing liquids to prevent leakage.

Despite the variation from standard English cask sizes, those located on *Clarence* have similar features to casks found on other shipwreck sites from a similar time period. These include incised lines and circles (made by a scribe tool) for ease of reassembly (Fig. 28), branding marks and branded names (either complete or partial due to deterioration or breakage). The names would have been branded on the headpieces of the tierce casks for identification purposes or indication of their contents. There were also indentions, or hoop marks, on the exterior of some of the staves, indicating where the hoops would have been hammered in place. Additionally, there is evidence, however limited, of iron stains on a few of the staves, suggesting the use of iron hoops, which is to be expected for casks from the 19th century.

Figure 28. Assembly marks inscribed on a cask head (127.00099). Photo by J. Rodrigues.

The average diameter of headpieces raised was 55 cm (21.7 in), which closely coincides with tierce cask head diameters of 20.5 in (52.1 cm) as described by Kilby (1971: 52). As a result of the *Clarence* casks being slightly larger than the standard English dimensions of tierce casks, the slight difference in size is understandable. The widest mid-section of the cask, also known as the pitch, would be approximately 25¼ in (64.1 cm) in diameter.

Wooden dowels and dowel holes were visible along the joining edges of the headpieces. Dowels are almost always found along the straight flush joints or joining flat edges to connect the headpieces to each other. The outer circumference of the headpiece was bevelled in order to fit into the bite or croze groove of the staves upon assembly of the cask. Observed tool markings and striations suggest that the cask timber (both staves and headpieces) was machine worked rather than handmade, which was more common in earlier centuries. It was not until the start of the 19th century that machine woodwork began to gain popularity (Kilby 1971: 65). At this time, however, most of these machines were crude and inefficient, and were mainly used for cutting headpieces. Certainly by the end of the 19th century a number of cooperages were making well-constructed tierce casks and cheap dry casks by machine (Kilby 1971: 65).

The *Clarence* cask headpieces were branded with names that suggest these casks may have contained ale; however, it should be noted that coopers often re-used cask components for economic reasons. Some sets of headpieces, consisting of the cant and middle pieces, were branded with one of three names: 'J & R TENNENT' (Figs 29 & 30), as well as 'SAMUEL' and 'BURTON' (Fig. 31), which while branded separately, were on the same headpieces. These names, either partial or complete, were located on the topside. To date, at least one identity of J & R Tennent has been traced to Wellpark Brewery in Glasgow, Scotland, which was in operation in the 1840s. If some of the casks originated from an overseas brewery, it is possible that the casks and similar contents were continuing to be transported elsewhere along a trade route or the casks or some components were being re-used. The latter option was not an uncommon practice by coopers.

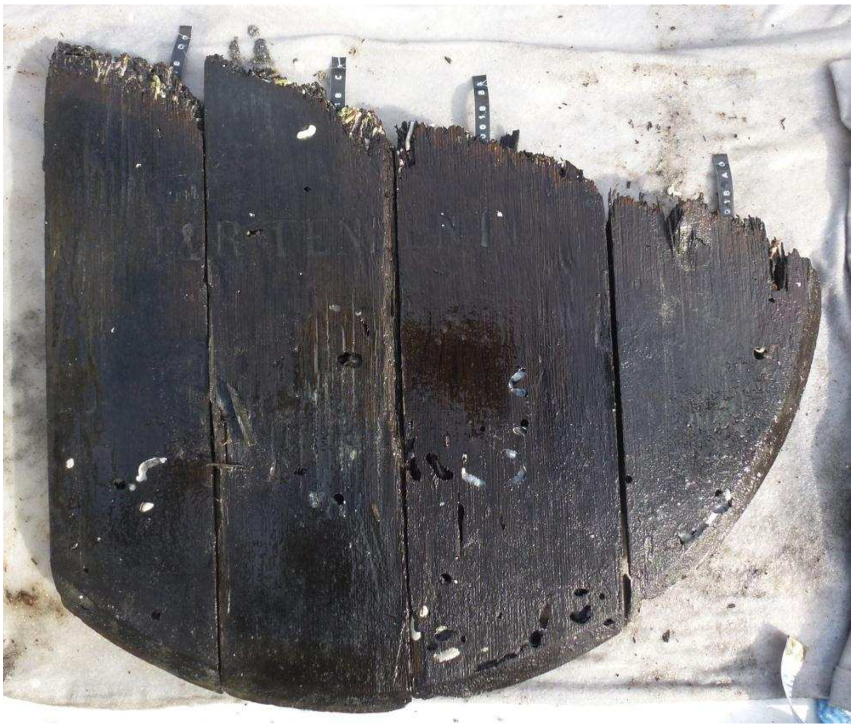

Figure 29. Headpiece (127.00102) branded with 'J & R TENNENT'. Photo by J. Rodrigues.

Figure 30. Detail of headpiece (127.00102) branded with 'J & R TENNENT'. Photo by J. Rodrigues.

Figure 31. Headpiece (127.00094) branded with 'SAMUEL' and 'BURTON'. Photo by J. Rodrigues.

With regards to the remaining two names branded into the timber assemblages, possible connections include a brewer named Samuel Allsopp and The Burton Brewery Company, both located at Burton upon Trent in Staffordshire, England. During the 1840s, Allsopp's Brewery produced India Pale Ale with an overwhelming superior reputation (Perkins 2012). However, this reputation may have developed too late to be linked to the casks located at the *Clarence* shipwreck site, as Allsopp did not supply ships heading to Australia until the early 1850s, by which time *Clarence* had already wrecked in Port Phillip Bay.

Contemporaneously, the Burton Brewery Company, founded in 1842, was one of the largest brewers in Burton upon Trent in the 19th century. Interestingly, and although it occurs well after *Clarence* wrecked, the *Sydney Morning Herald* reported on 11 June 1906 (p. 4) of the amalgamation of the Burton Brewery, Thomas Salt and Company Limited, and Samuel Allsopp and Sons Limited. Further research continues on these artefacts, as it is not yet clear whether the branded names on the casks' headpieces suggest the cargo was linked to the abovementioned breweries, or whether some components or entire casks were re-used from other sources.

Leather bag or satchel

A leather bag or satchel was also found on the site partially buried under a semi-circular timber artefact; the leather was left *in-situ* whilst the timber base (127.00091) was removed and X-rayed prior to reburial. Upon close examination of underwater images and based on discussions with divers who excavated and examined the artefact assemblage *in situ*, this is thought to be a bosun's bag (Fig. 32). The size and thickness of the leather satchel suggests it may have been used to carry tools (i.e. for repairing masts or rigging), as it appears to have a strap to sling over the shoulder. Interestingly, Kilby's (1971: 164) text on coopers and their craft illustrates a 19th century travelling cooper carrying an over-the-shoulder leather bag or basket containing tools.

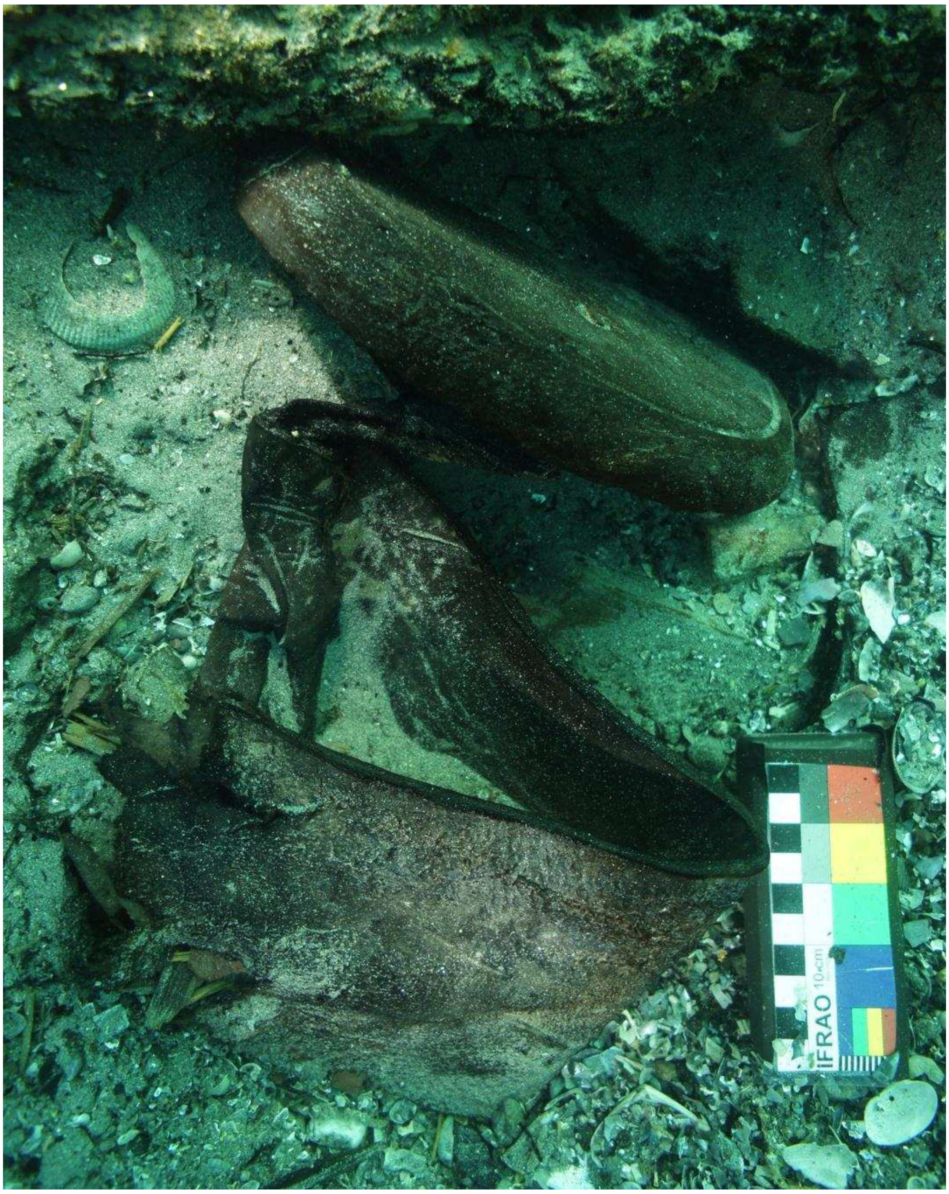

Figure 32. Leather bag or satchel *in situ*. Timber base (127.00091) visible at top of image. Photo by D. Shefi.

Kaolinite clay ballast[9]

Within the wreck structure, very firm to hard clay sediments were unexpectedly encountered during excavation. A shallow layer of loose marine sediment was found overlying a dense clay-rich unit located within the hull structure, approximately 30 to 50 cm in depth.

The clays were variable in composition, mostly dense and locally admixed with shelly inclusions and organics. Provisionally identified as clay ballast, other sediment samples were collected to compare mineral signatures in the 'ballast' to clay-rich sources on the seabed and coastal foreshores to confirm the likelihood of clay-rich sediments being ballast. The samples were analysed using a variety of techniques, including XRD analysis at the ANU and the clay 'ballast' was found to be kaolinite-rich. These clays could not be deposited from suspension in these well-fluxed waters, and consequently were interpreted as ballast. In addition, this kaolin ballast layer still sported marks in profile from the original bucketing of the material into the hold and was therefore, considered the site's largest single artefact.

Ballast could take the form of any heavy and freely available material, i.e. clay, rocks, gravel, stone or iron that was put into the hold to stabilize the ship and prevent capsizing. All, or part, of the ballast could be unloaded and replaced by cargo, which had the effect of balancing the ship again. The incidence of stone, rock and gravel has been widely reported as ballast found on shipwreck sites. Numerous stone ballast-dumping grounds have been recorded in Port Phillip Bay, off St Kilda Beach.

The use of clay ballast dates back until at least the early 18th century in Great Britain as this quote from 'An Act for the better regulation of lastage and ballastage in the river Thames (1733)' suggests:

> …any master of any ship or vessel, from time to time, to ship, transport and carry in his, their or any of their ships or vessels as ballast from London or any part of the river Thames, any…tobacco-pipe clay or any other clay, or any other goods or commodities now claimed to be furnished as ballast by the said Trinity House, subject nevertheless to the rates and duties, provisos and restrictions herein after mentioned, expressed and contained…(Pickering 1765: 420).

This practice continued through the 19th century as this extract from David Steel's book *The ship-master's assistant, and owner's manual* indicates:

> The master of any ship may ship as ballast from London or any part of the said river Thames…tobacco pipe clay, or other clay (subject to the payment of the rates and duties, &c. concerning the same)…(Steel 1832: 69).

The use of clay ballast was certainly not restricted to London and the Thames Estuary and appears to have been widespread in Great Britain. The ballast charges for the Port of Galway in Ireland during the early 1850s, for example, were reported as '1s 3d per ton for sand, chalk or clay ballast supplied in the floating dock' (Report of the Commissioners 1854–55: 38).

Nor was the use of clay ballast restricted solely to Great Britain as clay from China made its way to Great Britain in the 18th century as this comment about the origins of Chelsea porcelain from the *Sydney Morning Herald* newspaper reveals:

[9] Some discussion in this section reproduced from Veth et al. (2013).

> …English ships returning from China used a certain clay as ballast which was later dumped on the banks of the Thames. It was from this clay that the original Chelsea china was made…(*Sydney Morning Herald* 10 Aug. 1937: 13)

Clay ballast was clearly in use in the Australian colonies by the 1830s as the schooner *Industry* was reported to have been

> …proceeding in clay ballast, when, about four o'clock in the morning, she encountered a violent hurricane from the W. S. W., which continued with unabated fury for about eight hours; the vessel became leaky, and the pumps were put into requisition, but were soon choked up by the clay ballast and rendered useless… (*Sydney Gazette* 19 Jan. 1837: 2).

This also revealed one of the potential problems resulting from the use of clay ballast—choking the pumps on board a vessel. Another problem arising from the use of clay ballast was 'shifting' that could destabilize the vessel, which is exactly what happened to the ship *County of Clare* during a voyage from the Cape of Good Hope to Newcastle in 1891:

> The vessel on arrival had a slight list, which turns out to have been caused by the ballast shifting in a heavy gale in the Southern Ocean…throughout the passage the ballast though heavy clay gave great trouble by shifting (*Newcastle Morning Herald* Monday 21 Dec 1891: 4).

The loading and unloading of clay ballast was also a messy business which was discussed by the Launceston Chamber of Commerce reporting that:

> The filthy state of the wharves was referred to, one member suggested that contractors for the supply of clay ballast should be required to wash the wharf clean after loading (*Cornwall Chronicle* 18 July 1857: 4).

Clay ballast was clearly in use in the Hunter Valley region of NSW (where *Clarence* was constructed) during the 19th century. It is mentioned, for example, in the *Maitland Mercury* (20 November 1862: 4) and the *Newcastle Morning Herald,* which reported:

> The following tenders have been accepted by the Works Department:…supply of stone and clay ballast for Newcastle harbour works for year ending December 31, 1896, J. Dalton, Newcastle, 4d per ton (*Newcastle Morning Herald* 29 Apr. 1896, p.5).

Furthermore clay ballast was used as a form of 'paying cargo' that could be bought and sold as an advertisement for the sale of 'Building Materials' in the *Sydney Morning Herald* (1 June 1881: 2) reveals: 'About 350 tons clay ballast may be had aboard the schooner *Esmerelda*'.

Cos Coroneos, Researcher on the AHSPP, has hypothesized that the clay was most likely in bags or baskets as cargo or possibly as temporary ballast, evidenced by 'tip lines' seen in section on the port side edge of the excavation trench (Fig. 20). Alternatively, the clay may have been used as rough caulking for repairs before the event that finally saw the vessel wrecked (with the less likely option of being placed post-wrecking; however, there is no historical documentation that indicates any attempt to refloat *Clarence*).

Geomorphological analysis (see below) was undertaken on sediments both within the wreck, outside the wreck, and on shore for comparison. The composition of the kaolinite-rich layer is only evident within the wreck site.

Therefore, at present, *Clarence* is the first example of a clay-ballasted vessel to be located and sampled in Australia. The correlation with historic accounts is intriguing and serves to highlight innovative colonial practices both in tandem and at variance to donor shipbuilding cultures.

Attempts have been made to provenance the clay deposit. Comparisons were made with the mineralogical fingerprints of samples from *Clarence* and research samples of clay deposits from riverine sediments around Australia (Gingele & de Deckker 2004). Patrick de Deckker of the ANU's Research School of Earth Sciences believes the *Clarence* samples most closely match samples taken from the Clarence River in north-eastern New South Wales, which have a similarly high percentage of kaolinite (Patrick de Deckker pers. comm. 23 June 2015). This is compared with 24 other samples from around the Australian coast, and another 22 samples from the Murray Darling river system and its tributaries. The Clarence River (NSW Northern Rivers district) is located north of the Williams River in the Hunter Valley region (where *Clarence* was constructed).

A review of the voyages of *Clarence* as researched by Gesner (1984) shows that the vessel undertook New South Wales coastal voyages from 1841-1845, with some trips to Hobart and one each to Port Albert and Port Phillip. After 1845, the majority of journeys were Bass Strait crossings, including the Tasmanian ports of Hobart and Launceston and various Victorian coastal ports plus Port Phillip. Only occasionally did *Clarence* sail to southern New South Wales and Sydney in that period.

Therefore, it is difficult to determine the source of the clay and the port where it was loaded. It is likely that it came from at least two sources; Gingele and De Deckker's 2004 research does not provide a conclusive provenance, and with the majority of voyages being Bass Strait journeys in the later years of *Clarence's* working life, it is more likely that this ballast was collected in Victoria or Tasmania. In their 2004 paper, samples were not taken from Victorian coastal sites, other than a single location offshore from Portland, and the mineralogical signature from that location showed equally high proportions of kaolinite and illite/muscovite, which was not replicated in any of the cores recovered from *Clarence*.

With the considerable weight of the kaolin ballast, and the space occupied by it in the hold of the vessel (an area of approximately 9 m^2, with a volume of approximately 1.35 m^3, weighing nearly 2.5 tonne)[10], it seems unlikely that the kaolin was carried solely as long-term ballast.

In-situ preservation[11]

Previous research has established a 50 cm datum as the minimum depth of burial for the protection of recovered artefacts (Nyström-Godfrey et. al. 2012). Therefore, it was decided that the few recovered metal, glass and ceramic artefacts could be reburied on the wreck site as it would be possible to obtain this depth of sediment coverage when replaced directly adjacent to the keel. However, because they were different material types they had to be separated by at least 1 m to minimise the chances of unwanted chemical interactions. Owing to the size of the organic materials, especially the barrel staves, it was not possible to rebury the organics on-site as it would be impossible to obtain the 50 cm datum required to ensure their long-term protection. Therefore the organic materials were reburied in an off-site storage depot purpose built to obtain this depth of burial.

[10] These calculations are based on Mike Nash's estimation of the area and thickness of the clay being approximately 15 cm evenly over the keel, and fairly flat; the volume to weight conversion was complete online (http://www.aqua-calc.com/calculate/volume-to-weight), using the example of wet excavated clay.

[11] Parts of this section published in Richards et al. (2014), in press b.

A proprietary 2000 L high density polyethylene water tank (1.8 m height; 1.2 m diameter) was purchased, the ends cut off and the tank sawn in half. This cylinder (1.0 m height) was then dredged into the seabed 10 m south of the site, just off the starboard stern. The sand was dredged from within the confines of the cylinder and the least degraded organic artefacts (i.e. two wooden barrels and leather artefacts) placed at the bottom of the depot, covered with 10 cm of surrounding sand then the more fragile organics (i.e. rope, dunnage and the most degraded barrel) were placed on top of this layer. The depot was then backfilled with surrounding sediment, covered with shadecloth and anchored with polypropylene sandbags (Fig. 33).

Figure 33. Off-site storage depot at the end of the May 2012 fieldwork period. Photo by J. Parkinson.

Since it is scientifically inappropriate to annually re-excavate a site to collect samples and/or recover the reinterred artefacts to ascertain whether the reburial strategy has been successful and not detrimental, replicate sacrificial modern samples were deposited in the same archaeological context as the reburied artefacts. Thus, sacrificial modern ferrous alloy (duplicate cast iron and mild steel coupons) and wood samples (duplicate samples of pine, Sydney blue gum and blackbutt) were reburied with the artefacts on-site and in the reburial depot. Four ferrous alloy and eight wood sample plates were manufactured. One of the duplicate iron or wood samples was wrapped in Bidim A14 geotextile to ascertain its protective effect on the iron and wood artefacts after reburial. The four iron alloy sample plates were positioned along the keelson, adjacent to where the iron artefacts were reburied on-site. Four wood sample plates were placed 1 m towards the stern to ensure there would be no influence of the metal corrosion products on the degradation of the wood samples (Fig. 34). The remaining four wood sample plates were placed around the internal perimeter of the off-site reburial depot.

Figure 34. Sacrificial iron and wood samples and wrapped metal artefacts on site prior to reburial. Image by K. Kasi after J. Parkinson.

These samples were recovered at regular intervals (November 2012, 2013 and December 2014) and analysed by a number of instrumental techniques in order to quantify the extents of deterioration and estimate their current degradation rates. By using the deterioration rates of the modern materials and extrapolating from the initial extents of deterioration of the wreck materials measured during the pre-disturbance survey, the effect of the reburial strategy on the wreck and the reburied artefacts may be determined (Richards et al. 2009).

Towards the end of the four-week fieldwork period, the excavated area was backfilled with dredged sediment from the site, which had been collected in two sediment traps positioned near the bow and the stern of the site. While the stern trap was extremely efficient is retaining sediments, the bow sediment trap only retained some of the spoil. Therefore the forward section of the excavation trench was backfilled with proprietary sand emptied from the polypropylene sandbags previously placed around the periphery of the site to stabilise the exposed higher profile frames. During this latter reburial phase the weather rapidly deteriorated and it was not possible to completely rebury the excavation trench and off-site reburial depot to the desired 50 cm datum. As a short-term remediation measure the areas were stabilised with a layer of shadecloth anchored with sandbags.

Three weeks later, in June 2012 a field trip was organised to further rebury the excavation and the reburial depot, again using proprietary sand emptied from the sandbags on-site. An average reburial depth of 1 m was achieved, which was significantly deeper than the original sediment depths; especially at the stern of the wreck (Fig. 35). Sediment core samples were then collected from the excavated area and the reburial depot as a baseline for future comparative analysis. The backfilled areas were then stabilised with a layer of shadecloth, anchored with more sandbags until the final phase of the remediation strategy could be completed in November 2012, which involved covering the entire site with a 250 m^2 shadecloth mat, followed by three (14 m x 7 m) PVC tarpaulins.

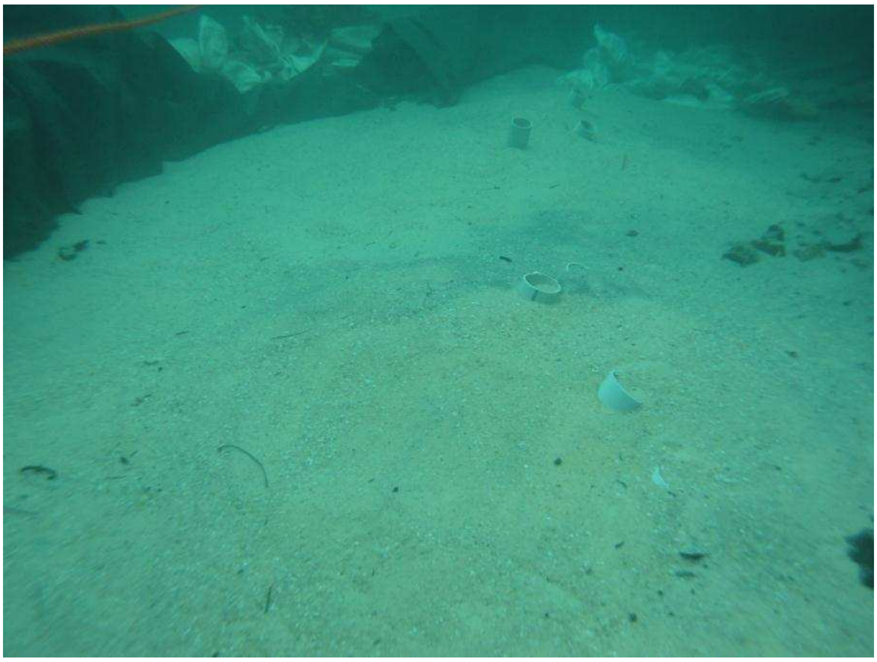

Figure 35. Sacrificial samples covered with 1 m of sand. Photo by AHSPP.

In November 2012, the final reburial phase commenced. A further 1800 sandbags were placed on-site followed by a pre-prepared 250 m^2 shadecloth mat (3 x 25 m long x 3.66 m wide sections joined together by cable ties) deployed flush over the site. The shadecloth 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 sandbags.

The site was finally covered with three polyvinyl chloride (PVC) tarpaulins (7 m x 14 m x 2 mm) to protect the shadecloth and wreck from further damage against anchors and strong currents. Each tarpaulin was deployed individually, with the ends unrolled from the mid-section of the site. The three tarpaulins were then connected with cable ties and sandbags were tied in place with nylon straps along the seams and edges. Finally, the seams, edges and interior of the tarpaulins were covered with 1300 sandbags to prevent water movement under the tarpaulin and potential lifting by anchors.

Site Monitoring

In-situ preservation site monitoring[12]

Over twelve months from November 2012, visual inspections of the site indicated that the *in-situ* preservation strategy had been successful. All sandbags 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 colonisation by marine organisms (Fig. 36). The sediment under the shadecloth was grey in colour indicating a low oxygen environment.

Figure 36. *Clarence* in December 2014, two years after covering the site with PVC tarpaulins. Photograph by J. Carpenter.

The scientific monitoring programme was implemented involving the analysis of sediment core and sacrificial samples recovered from the reburied areas in order to quantitatively determine whether the mitigation strategy was conducive to long-term site preservation. Analyses included the chemistry of the sea water, sediments and the associated pore water (pH; 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 with the deterioration profiles of the sacrificial samples. This information is compared with the pre-disturbance conversation survey results, then

[12] This section reproduced from Richards, et al. (in press a).

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 here, although the results from the reburial depot are similar. Further results, interpretation and comparative analyses will be presented in a final edited volume due in 2017.

Sediments

The baseline sediment grain size distribution profile on the site prior to excavation in April 2012 is shown in Figure 37. 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 indeed comparatively 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.

The results imply that wreck remains located in this 0–20 cm sediment depth range are likely to be more degraded than more deeply interred 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 (Fig. 38) 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 utilising all the original dredged sediment, proprietary sand from sandbags 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 (Fig. 39), 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 38. Generally, the baseline sediment contained higher quantities of organic material compared to the reburial trench. This is to be 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 (6 months after reburial prior to covering) is that this fraction mainly 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 utilising the residual organic material present in the dredged backfill. However, aerobic biota trapped under the tarpaulin after installation would slowly degrade producing more EOM in the upper fractions of the reburied sediment column.

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.

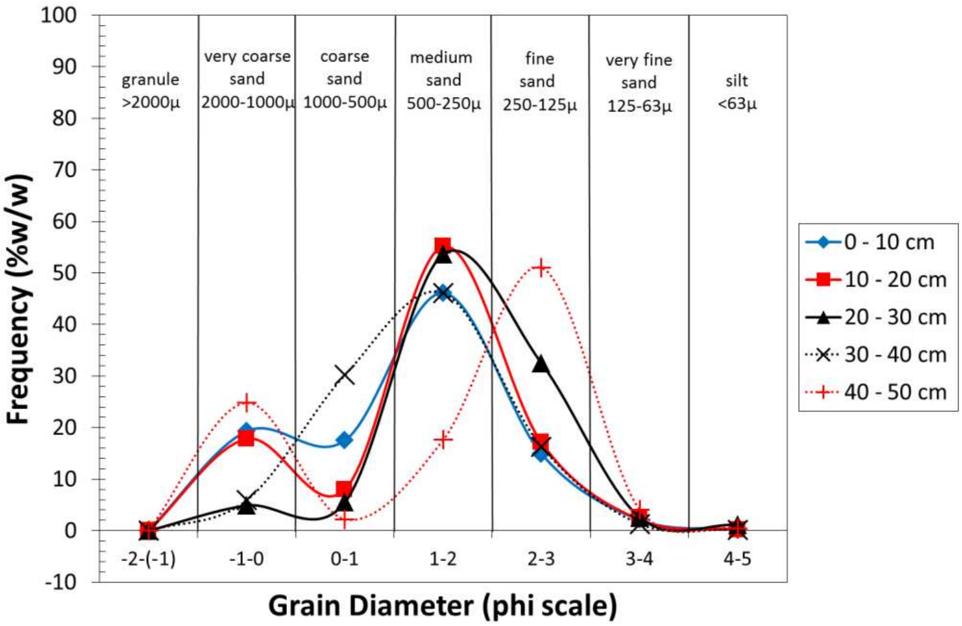

Figure 37. Grain size distribution of the baseline sediment on *Clarence* prior to excavation in April 2012.

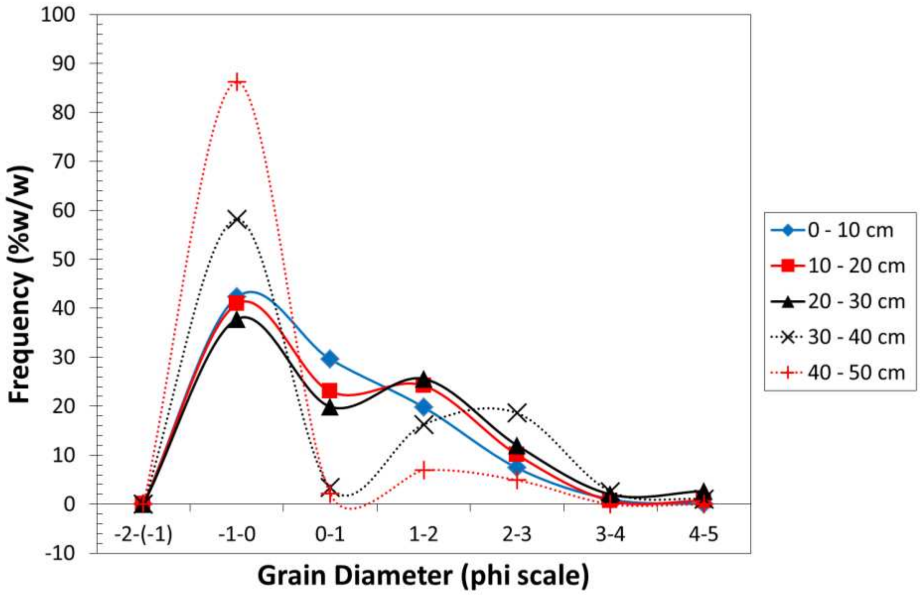

Figure 38. Grain size distribution of the reburial trench sediment in December 2014 (30 months after reburial; 25 months after covering).

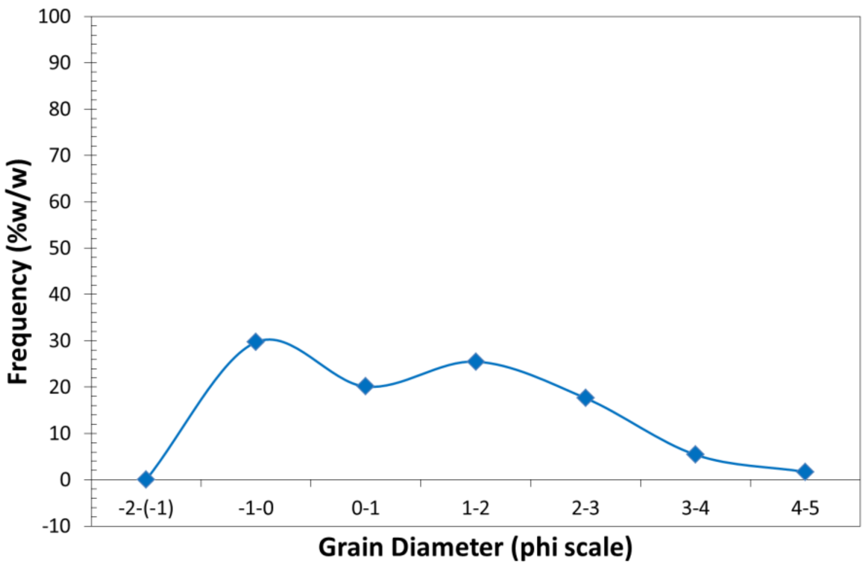

Figure 39. Grain size distribution of the proprietary sand.

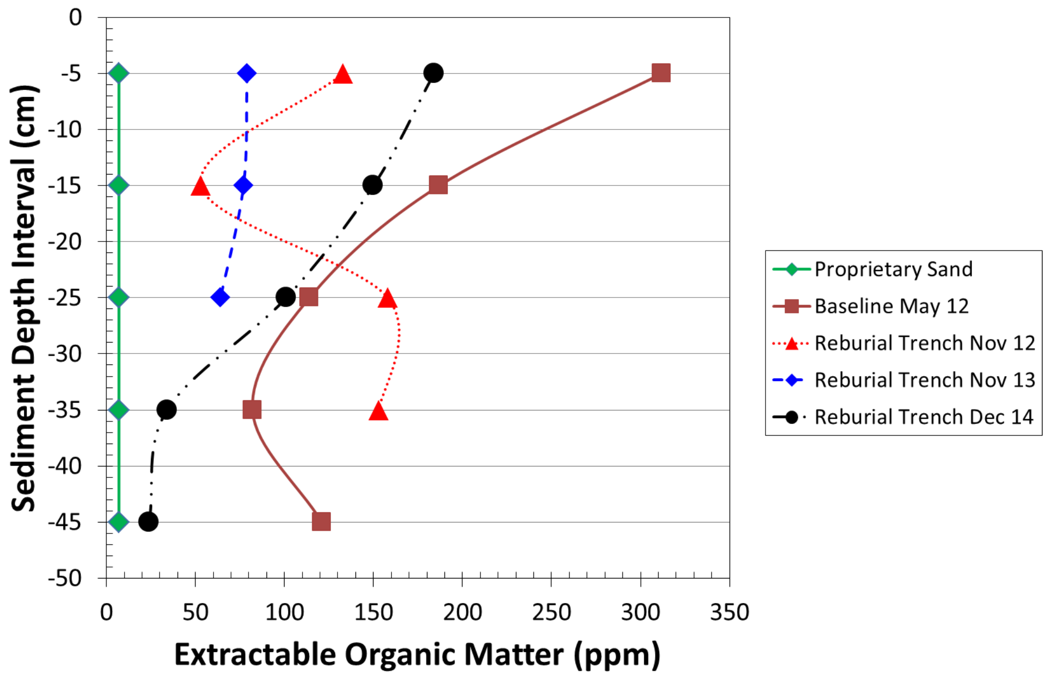

Figure 40. Extractable organic contents in the baseline and reburial trench sediments.

Long-term organic and metal preservation depends on the maintenance of a stable physical and chemical reburial environment characterised 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 (Fig. 41). However, the lower 30–50 cm fractions that comprised the backfilled baseline sediment attained very low dissolved oxygen levels after only one month. This rapid decrease would be due to biological mineralisation of the higher amounts of EOM present in these lower fractions after initial reburial (Fig. 40).

There were higher sulphide concentrations in the baseline sediment prior to excavation (Fig. 42), which is to be expected due to increased EOM levels in the upper sediment fractions (Fig. 40). 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 oxidising to more reducing conditions (Fig. 43). Again the interface between the 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.

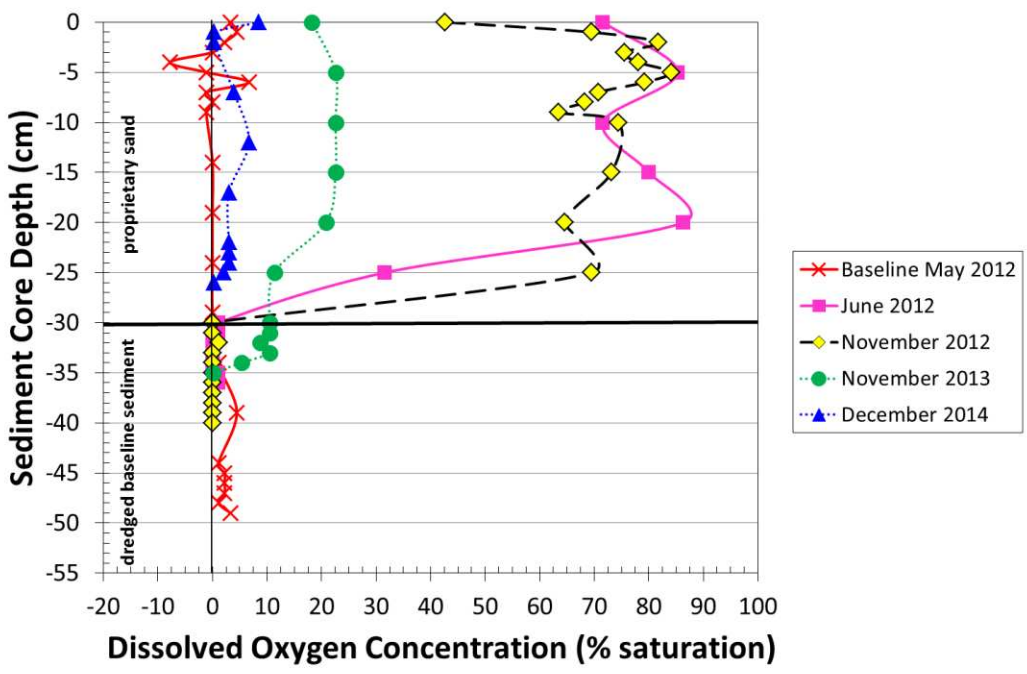

Figure 41. Dissolved oxygen concentrations in the baseline and reburial trench sediments.

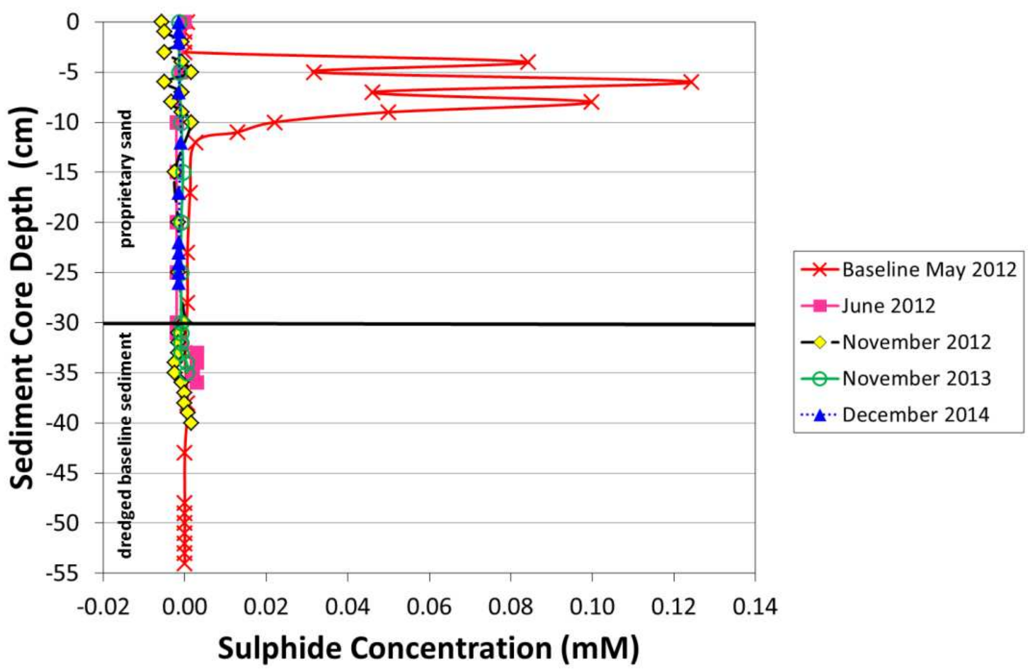

Figure 42. Sulphide contents in the baseline and reburial trench sediments.

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 (Fig. 44). Over time the pH increased with increasing depth and time interval due to the reduction of dissolved oxygen producing hydroxyl ions under less oxidising conditions and decreasing biological activity. Hence, the pH of the reburial trench sediment is slowly equilibrating to baseline levels after two years.

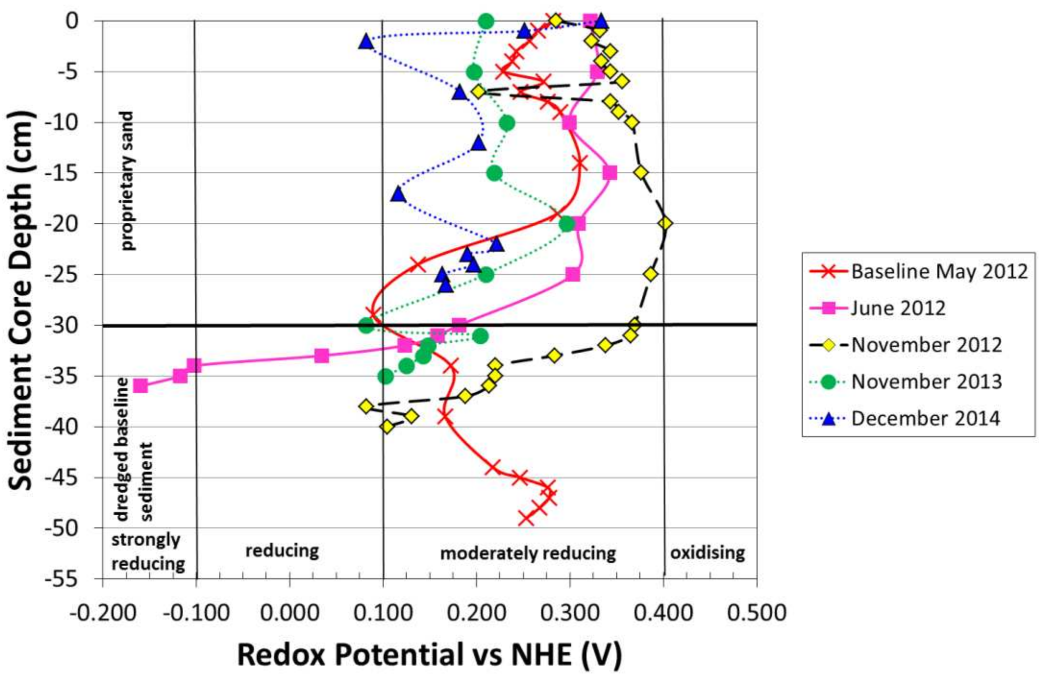

Figure 43. Redox potential profiles of the baseline and reburial trench sediments.

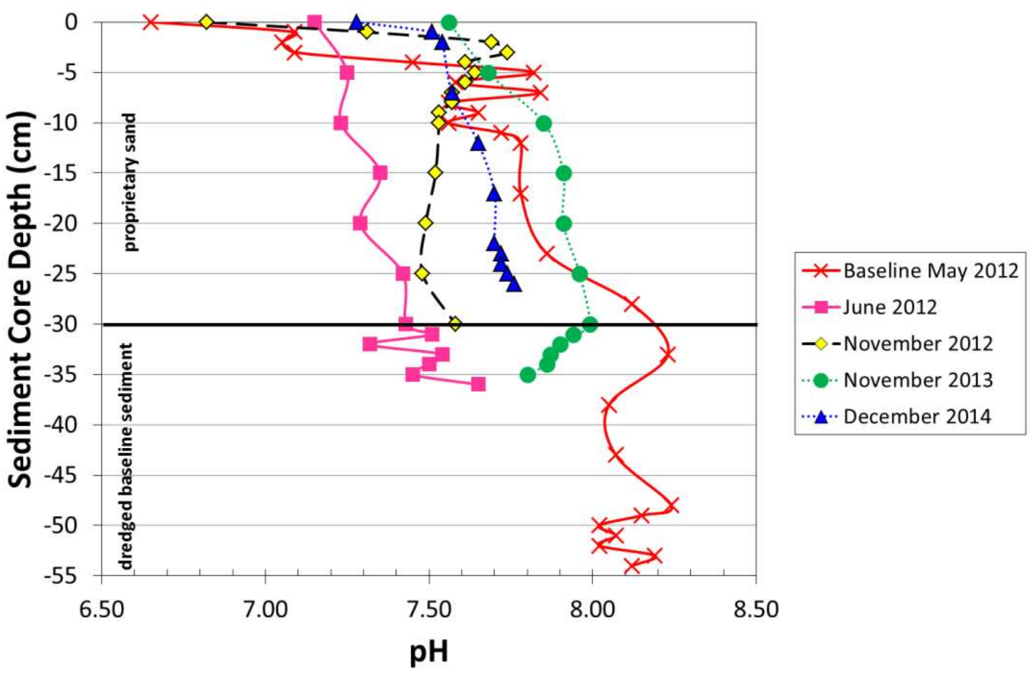

Figure 44. pH profiles of the baseline and reburial trench sediments.

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.

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%) (Fig. 45).

Two sacrificial sample plates were recovered from the excavation trench after 1.5 (November 2013) and 2.5 years (December 2014) after reburial (Fig. 45). 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 navalis (*shipworm).

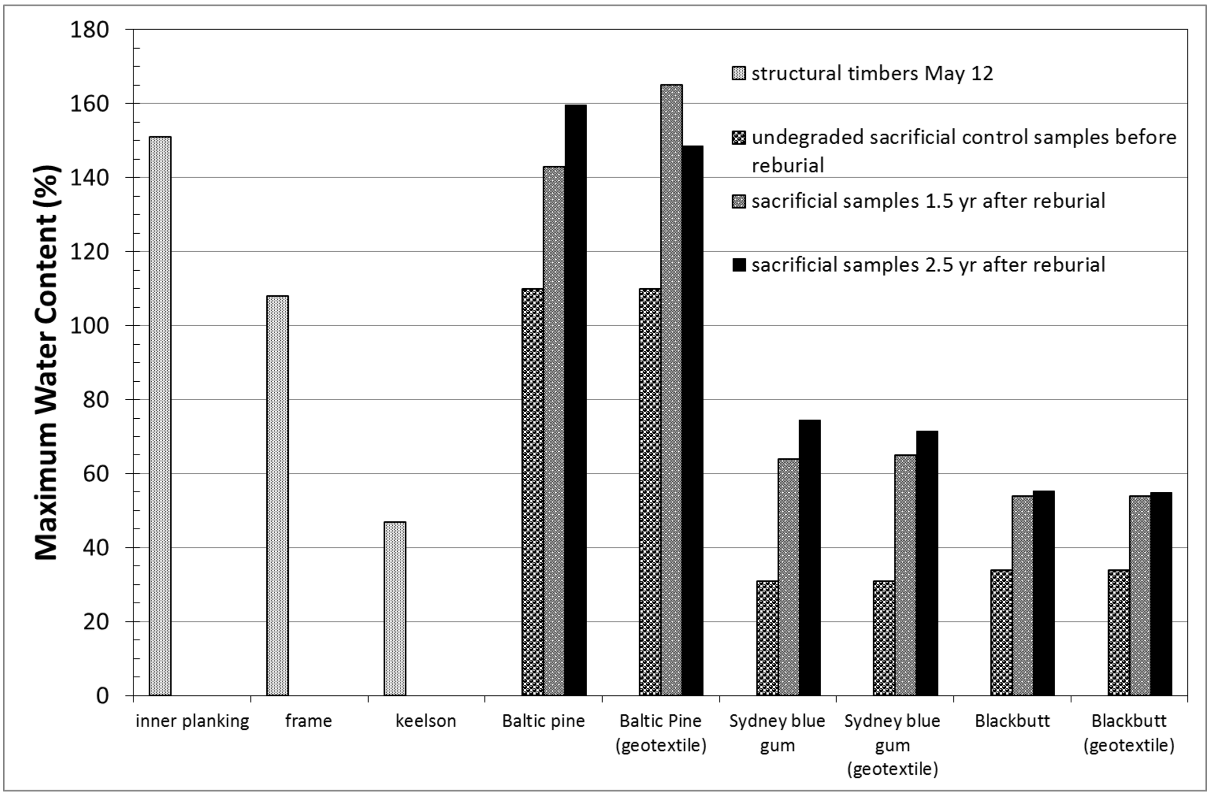

Figure 45. Maximum water contents of the structural timbers and modern undegraded and degraded sacrificial samples.

Marine ecology

As noted in the methodology section above, biological surveys of *Clarence* were undertaken on three occasions during the project: two presence–absence surveys in 2012 (pre-disturbance survey in April 2012, discussed above); a post-excavation survey in November 2012; and a final comprehensive survey conducted in January 2015 to compare the post-reburial environment of *Clarence* with two nearby locations.

November 2012 monitoring survey

Similar to the April 2012 report (Appendix B), the November 2012 report (Appendix C) describes the biota and provides a species list of common fish, invertebrates and algae. The results from both 2012 surveys show that juvenile toothbrush leatherjackets were identified on *Clarence* and in the nearby seagrass beds, suggesting that the environment on and around the site was a nursery for this species (Pritchard & PDS 2012a, 2012b).

A review of data from the pre-disturbance and post-excavation presence/absence surveys in 2012 identifies the average number of macroalgae, sponges and invertebrate species as comparable across this period, with the greatest variation in data observed in the diversity of fish logged on site. This variation showed a decrease in the diversity of fish species post-excavation; however, these surveys were conducted in different seasons and there is no mention within the report of the potential impact of natural seasonal variation. The report does note that diminished visibility during the later survey may have contributed to the lower density of fish observed. Furthermore, the second survey was undertaken by a single marine ecologist with a zoologist/maritime archaeologist as a buddy. The first surveys in April 2012 were undertaken by a team of four experienced marine biologists, so it is also possible that the additional expertise had some impact on the species diversity identifications.

Macroalgae and Sponges

The most abundant species colonising the wreck was the sea-grass *Zostera muelleri.* There were two canopy forming species observed, the common kelp *Ecklonia radiata* and the crayweed *Phyllospora comosa,* observed in low abundances. Other species observed were *Sargassum* sp., *Caulerpa* spp*. Codium* spp. and several *thallose red* algae including *Rhodymenia australis*. All macroalgae species observed on transects are listed in Table 4 below.

There was a large number of sponge species present on the wreck. One common species was the prickly rose sponge *Dendrilla cactos*.

Table 4. Macroalgae and sponge species observed on transects during November 2012 survey (Pritchard & PDS 2012b).

	Species Name	Common Name
Algae		
Brown	*Ecklonia radiata*	Common Kelp
	Phyllospora comosa	Crayweed
	Sargassum sp	Sargassum
	Dictyopteris muelleri	Meuller's forkweed
Red	*Dictyomenia harveyana*	Harvey's leafweed
	Rhodymenia australis	Southern red forkweed
	Champia viridis	Agardh's champia
	Thallose red	
Green	*Caulerpa brownii*	Browns caulerpa
	Caulerpa trifaria	Three-cornered caulerpa
	Codium spp	
Sponges		
	Dendrilla cactos	Prickly rose sponge

Mobile Invertebrates and Cryptic Fishes

The most common species observed was the common sea urchin *Heliocidaris erythrogramma*. Other invertebrates present included the swimming anemone *Phlyctenactis tuberculosa*, the cartrut shell *Dicathais orbita,* and the giant spider crab *Leptomithrax gaimardii*. All species observed on transects are in Table 5 below.

Table 5. Invertebrate species observed on transects during November 2012 survey (Pritchard & PDS 2012b).

	Species Name	Common Name
Invertebrates		
	Heliocidaris erythrogramma	Common sea urchin
	Herdmania grandis	Red-mouthed ascidian
	Leptomithrax gaimardii	Giant spider crab
	Sabella spallanzani	Giant fanworm
	Dicathais orbita	Cartrut shell
	Coscinasterias muricata	Eleven armed sea star
	Phlyctenactis tuberculosa	Swimming anemone
	Paguristes frontalis	Southern hermit crab

Fishes

The most abundant fish observed on the wreck was the toothbrush leatherjacket *Acanthaluteres vittiger*. Other common species included the goatfish *Upeneichthys vlamingii* and the weed whiting *Neoodax balteatus*. All fish species observed on transects are in Table 6 below.

Table 6. Fish species observed on transects during November 2012 survey (Pritchard & PDS 2012b).

	Species Name	Common Name
Fishes		
	Upeneichthys vlamingii	Goatfish
	Acanthaluteres vittiger	Toothbrush leatherjacket
	Meuschenia freycineti	Sixspine leatherjacket
	Meuschenia flavolineata	Yellowstriped leatherjacket
	Brachaluteres jacksonianus	Southern pigmy leatherjacket
	Diodon nicthemerus	Globe fish
	Neoodax balteatus	Little weed whiting
	Lotella rhacinus	Beardie

Introduced Species

The introduced fan worm *Sabella spallanzani* was observed on the wreck during this survey.

January 2015 monitoring survey

In January 2015, the final marine biology survey was conducted by John Ford and Dean Chamberlain of the Department of Zoology, Melbourne University. They used a more comprehensive sampling methodology, aiming to provide a final description of the various species colonizing the site, and comparing *Clarence* to two nearby locations for reference. They also utilized extensive in-house databases with information about the marine biology of the immediate vicinity as well as the wider Port Phillip region.

Ford and Chamberlain employed a modified version of the widely accepted Reef Life Survey method, which 'quantitatively estimates the biotic and structural composition of benthic marine communities' (Ford &

Chamberlain 2015: 7). Using this method, the divers conducted visual census surveys along 2 x 25 m transects at *Clarence* (bow to stern, commencing at the Samson post) as well as the two reference sites.

The transects were roughly 5–10 m apart, and along each transect the following was undertaken:

- five-metre swathe visual survey for mobile fish (2.5 m either side of the transect)
- cryptic fish and mobile invertebrates (>10 mm) counted in a 1 m strip to the right of the transect line, with abundances tallied in 5 m blocks (i.e. five counts per transect);
- point-intersect quadrat survey of 50 cm x 50 cm (seven horizontal and vertical string lines) to estimate benthic biota and substrate type. Quadrat laid down every 5 m and a total of 50 intersect points used to convert converted to percentage cover per quadrat; and
- identification of all benthic biota along each transect to produce a comprehensive species list (including biota not identified in the point-intersect method due to lower abundance).

Statistical comparisons of the biota and substrate of the three sites aimed to answer two questions (Ford & Chamberlain 2015: 7):

1) Does the biota of the rehabilitated *Clarence* wreck site differ from nearby reference sites?

2) Does the benthic biota composition explain differences in fish and invertebrate communities?

Full details of how the surveys were conducted, the methods employed to undertake the comparisons, statistics and complete tables of data are contained in Ford and Chamberlain's 2015 report at Appendix C. A summary of the report data is given below.

Sedentary benthic biota

Twenty-two species of sedentary benthic biota were recorded across the three sites, consisting of seagrasses, algae, sponges and ascidians. The seagrass *Zostera nigracaulis* was the dominant habitat-forming species colonising the sediment around the wreck (covering 69% of the *Clarence* wreck site, 29% of the southern and 31% of the western reference sites) (Ford & Chamberlain 2015: 9). The authors surmise that during the PDS surveys in 2012 this species was possibly misidentified as *Zostera muelleri* (Ford & Chamberlain 2015: 5–6).

Mobile fish

Eight species of mobile fish were recorded across the three sites, but five of these were only found at *Clarence*.

Cryptic fish

Nine species of cryptic fish were recorded across all three sites, with the greatest diversity (eight species) found at *Clarence*. Six species were observed at all three locations. The two most common species were the sand goby (*Nesogobius* spp.) and the common triplefin *Norfolkia clarkei*. The authors note that some extremely cryptic fish, such as pipefish, are likely to have been underestimated in the visual surveys.

Mobile invertebrates

Twelve species of mobile invertebrates were found across the three sites; with five species common at all three. At *Clarence*, the most abundant were glass shrimp *Macrobrachium intermedium* and the red rock crab *Nectocarcinus integrifons*.

There were significant differences in the biological diversity of the cryptic fish and mobile invertebrates across the three sites, with cryptic fish diversity significantly higher at *Clarence* compared to the southern reference site; and mobile invertebrate diversity significantly higher at the western reference site compared to the southern site.

There were no significant differences in diversity of benthic biota across the three sites.

Abundance and total cover comparisons

Significant differences were observed in the abundance of sand gobies, seagrass cover and total biota cover across the three sites, with the abundance of sand gobies significantly higher at the southern reference site compared to *Clarence*, and the cover of seagrass significantly higher at *Clarence* compared to the two reference sites. The total cover of biota was significantly higher at the wreck and western site compared to the southern site.

Comparisons with 2012 surveys

Ford and Chamberlain were unable to make quantitative or statistical comparisons with the *Clarence* biological surveys conducted in 2012 as the earlier surveys only provided a species list with no search time or clear area of survey specified. Furthermore, quantitative or statistical data was not available. Of the 52 species observed during Ford and Chamberlain’s study, only 14 were identified as present at the wreck site in November 2012. However, another ten species (three fish, three mobile invertebrate, one seagrass and three red algae) were identified in 2012 but not in the 2015 survey. This gave a total of 24 species identified in the 2012 surveys.

Geomorphology

The full report of the geomorphological research and analysis (Zubrzycka et al. 2014) can be found at Appendix E. A précis is presented below.

Key objectives of geomorphological research and analyses were to compare mineral signatures of the clay-rich sediment found within the wreck site, local seabed and coastal foreshore. This was undertaken in order to determine the likelihood that clay-rich sediment within the wreck had an anthropogenic origin (ballast) or had been naturally deposited from the surrounding landscape as terrestrial-derived fine grain sediments.

It was hypothesised that terrestrial-derived fine-grain sediments would primarily enter the near shore zone (potentially as far offshore as *Clarence*) as run-off plumes following heavy rainfall (Petschick et al. 1996; Gingele & Leipe 2001). Additional but minor contributions may have resulted from cliff collapse and direct wave erosion (Cardno 2011). Bedrock and saprolites were sampled for geomorphological analysis, all of which are similar to the range of deposits likely to influence the formation of seabeds around and beneath *Clarence*.

Recent studies show that natural processes such as El Nina related flooding events have a major influence on the deposition of sediments within the ocean (Stone & Auliciems 1992; Zhang & Casey 1992). Gingele and De Deckker (2004) suggest that there have been over a dozen El Nina related flooding events in the past decade that have influenced the clay mineral composition of offshore sediments. Therefore, Port Philip Bay, a catchment to various creeks and rivers—such as the Yarra River and Kananook Creek—has the potential to be susceptible to this form of sedimentary deposition. In addition, sediments deposited by these events have the potential to contain the unique clay mineral composition derived from their geographic location (Gingele et al. 2001).

Alternatively, clay-rich sediment found within *Clarence* may have an anthropogenic origin. For example, clay may have been transported and used as ballast, or as a raw trade product. During the 19th century, clay was often used for the manufacture of tobacco pipes, bricks and pottery. A number of early records suggest clay was commonly used as ballast in the form of raw material such as 'tobacco pipe clay, or other clay' (Willmore 1846: 585). The use of clay as a ballast has been recorded in New South Wales (*Newcastle Morning Herald and Miners' Advocate* Monday 21 December 1891: 4), New Zealand (*The Sydney Gazette and New South Wales Advertiser* Thursday 19 January 1837: 2) and England (Averdung & Pedersen 2012: 4).

Sample sets, sampling and preparation techniques[13]

In order to compare the mineral composition of clay-rich sediment found within *Clarence* and that derived from the Portarlington and St Leonards local geologies, sediment samples were collected from the wreck site and surrounding shoreline.

Fifteen samples were collected from five locations in Portarlington and St Leonards in March 2013 (Fig. 46). Locations sampled covered a range of exposures and sections along low-cliffed shorelines and one low

[13] Text in this section partially reproduced from Zubrzycka et al. (2014); tables reproduced in entirety from Zubrzycka et al. (2014).

elevation intertidal clay-pan (Zubrzycka et al. 2014: 4). These were analysed using XRD (X-ray Diffraction) and compared to nine samples collected within and around the wreck (Fig. 47) during the excavation period in 2012. Full details regarding the sampling locations, strategies and analytical systems and equipment are contained in Appendix E.

Figure 46.Locations of SPA1-15 sediment samples surrounding Port Phillip. Image Courtesy Google Earth, 2013. (Zubrzycka et al. 2014: 6).

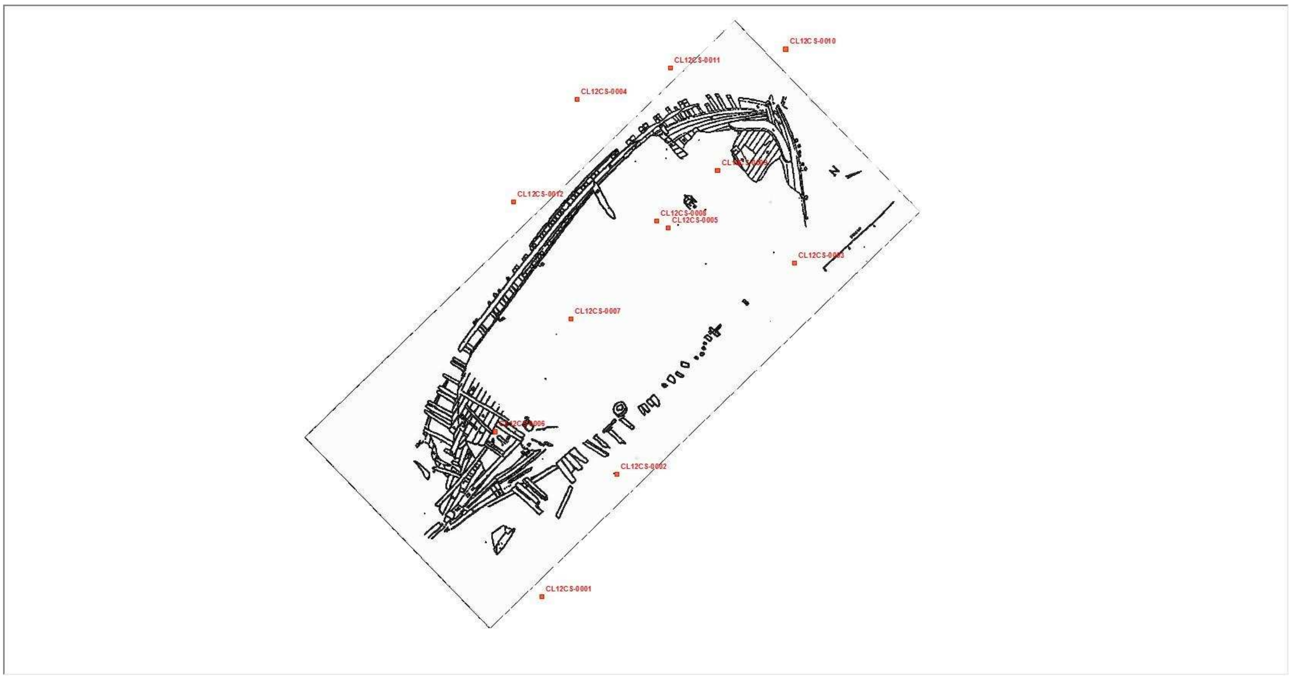

Figure 47. Short core and grab sample locations in the wreck of the *Clarence*. Image courtesy of A. Khan.

Results

Results of XRD analyses are shown in Tables 7, 8 and 9. Table 7 contains results from Set A (within the wreck), Table 8 contains results from Set B (sea-floor surrounding wreck site) while Table 9 contains results from Set C (surrounding coastal geologies in Port Phillip Bay). Figure 48 illustrates variations in mineralogical compositions in Sets A and B, specifically with regards to quantities of kaolinite, plagioclase and clinopyroxene (Zubrzycka et al. 2014: 8). Due to the presence of halite and/or calcite, the quantification of minerals and clays in the final stages of data analysis (particularly Set A and B) was inaccurate. To account for these irregularities, total clays with and without these minerals are included in all tables (Zubrzycka et al. 2014: 9).

Table 7. CLI1 samples collected from *Clarence* wreck site, April/May 2012.

	CLI1-0005	CLI1-0006	CLI1-0007	CLI1-0008	CLI1-0009
Location	Close to ceiling planking near foremast stump	Near keelson, stern end	Centre of wreck	Close to ceiling planking near foremast stump	Near ceiling planking, bow end
Goodness of fit X^2	**3.16**	**3.80**	**3.31**	**4.09**	**3.55**
Minerals					
Quartz	34.9	22.5	25.2	36.6	30.4
Plagioclase	-	3.9	2.3	20.2	7.9
K-feldspar	-	3.6	3.2	4.8	5.0
Halite	1.2	5.9	2.5	0.5	0.6
Calcite	-	-	-	-	5.1
Illite/smectite	5.6	-	-	-	-
Vermiculite	-	0.2	0.7	0.6	0.8
Aragonite	-	-	-	-	6.2
Gypsum	-	-	-	-	2.1
Illite/muscovite	10.4	7.0	5.5	2.4	1.9
Kaolinite	47.9	56.9	60.6	21.1	32.3
Clinopyroxene	-	-	-	**13.8**	**7.7**
Total	100	100	100	100	100
Total clay	**63.9**	**64.1**	**66.8**	**24.1**	**35.0**
Total clay w/out carbonates or halite	**64.7**	**68.1**	**68.5**	**24.2**	**39.7**

Table 8. CLI2 samples collected from adjacent sea-floor associated with Clarence wreck site, April/May 2012.

	CLI2-0001 0-2 cm	CLI2-0001 2-4 cm	CLI-0002	CLI2-0003 0-2 cm	CLI2-0003 2-4 cm	CLI2-0004	CLI2-0010
Location	Stern end, stb side.	Stern end, stb side.	Stern end, stb side.	Bow end, stb side.	Bow end, stb side.	Bow end, port side.	Bow end, port side.
Goodness of fit X^2	**2.76**	**2.55**	**2.52**	**2.43**	**2.47**	**2.29**	**2.38**
Minerals							
Quartz	28.5	30.6	28.4	28.7	25.4	24.8	26.1
Plagioclase	2.5	3.0	3.8	2.7	2.3	2.7	2.2
Halite	1.3	0.6	1.2	1.0	1.6	0.9	1.1
Calcite	51.3	48.7	48.2	49.3	53.6	54.7	52.5
Dolomite	1.6	1.1	1.1	1.2	1.0	1.0	1.2
Aragonite	12.5	12.5	14.2	14.7	13.6	13.3	13.9
Vermiculite	-	0.4	-	-	-	-	-
Illite/muscovite	1.3	1.0	1.5	0.5	1.2	1.0	1.8
Illite/smectite	-	1.0	0.5	0.3	0.4	0.3	0.3
Kaolinite	1.0	1.1	1.1	1.6	0.9	1.3	0.9
Total	100	100	100	100	100	100	100
Total clay	**2.3**	**3.5**	**3.1**	**2.4**	**2.5**	**2.6**	**3.0**
Total clay w/out carbonates and halite	**6.9**	**9.4**	**8.8**	**7.1**	**8.3**	**8.6**	**9.6**

Table 9. SPA samples collected from local geology, March 2013.

	SPA1	SPA2	SPA3	SPA4	SPA5	SPA6	SPA7	SPA8	SPA9	SPA10	SPA11	SPA12	SPA13	SPA14	SPA15
Goodness of fit X^2	2.97	2.55	3.39	3.57	4.85	4.51	5.15	4.32	4.07	3.42	3.04	3.89	3.99	4.59	4.51
Minerals															
Quartz	44.1	28.1	64.9	-	0.5	0.3	-	14.9	13.9	25.9	97.7	74.4	55.4	17.6	8.4
K-feldspar	-	-	1.8	-	-	-	-	-	-	-	-	-	-	-	-
Goethite	10.7	52.6	-	1.6	3.4	7.4	-	-	-	-	-	-	10.9	14.9	-
Hematite	-	-	-	14.8		3.1	-	-	-	-	2.3	2.8	-	-	-
Halite	-	-	-	5.4	1.8	0.7	0.6	14.7	42.8	9.4	-	-	-	-	1.9
Calcite	14.7	4.4	6.5	-	-	-	-	1.8	-	11.0	-	-	-	-	-
Aragonite	-	-	-	-	-	-	-	-	-	15.8	-	-	-	-	-
Gypsum	-	-	1.6	-	-	-	-	1.3	3.7	1.5	-	1.1	0.7	-	-
Smectite	-	9.6	-	-	-	-	-	-	-	-	-	-	-	-	-
Vermiculite	-	-	-	-	0.1	-	0.4	-	-	-	-	-	-	0.6	-
Illite/ muscovite	27.4	3	20.8	-	0.30	-	-	32.9	16.8	18.8	-	-	-	1.9	1.9
Illite/ smectite	-	-	-	-	-	-	-	17.5	10.6	7.5	-	-	-	-	-
Kaolinite	3.1	2.3	4.4	74.3	89.3	85.6	96.3	16.9	12.2	10.1	-	21.7	33.0	65.0	87.8
Anatase	-	-	-	3.9	4.6	2.9	2.7	-	-	-	-	-	-	-	-
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Total Clay	30.5	14.9	25.2	74.3	89.7	85.6	96.7	67.3	39.6	36.4	0.0	21.7	33.0	67.5	89.7
Total clay w/out carbonates and halite	35.8	15.6	27	78.5	91.3	86.2	97.3	80.6	69.2	57.1	0.0	22.3	33.0	67.5	91.4

Discussion

Comparisons of the mineral composition and clay quantities from all sample sets -especially those in Set A and B—do not support the hypothesis that clay-rich deposits accumulated in *Clarence* as a result of slack water 'fines settling' or sediment deposition from flooding events after the vessel became submerged in its present position.

Significantly CLI1-0008 and CLI1-0009 were the only clay-rich samples collected and analysed that contained clinopyroxene (Table 7, Fig. 48). According to Ulrike Troitsche, the presence of clinopyroxene could indicate that this is a less mature sediment (i.e. less weathered) compared to the samples that have only kaolinite and other clays, but no clinopyroxene (Ulrike Troitsche 2015, pers. comm., 3 June). This could therefore indicate that the clays were gathered from varying locations, and potentially deposited into the vessel at different times.

Kaolinite was present in high percentages in all Set A samples (Table 7, Fig. 48); however, CLI1-0008 and 0009 contained significantly less kaolinite (21.1% in CLI1-0009 and 32.3% in CLI1-0009) than samples collected within the wreck, which contained an average of 55.1±6.5% kaolinite.

CLI1-0008 and 0009 also contained higher quantities of plagioclase and K-feldspar than other samples (Table 7 and Fig. 48). Thus, clay-rich sediment, thought to be ballast, found near the vessel's ceiling planking contains a unique mineralogical composition compared to other sampled sediments within the wreck structure. The hypothesis that clay-rich sediments may have accumulated on the wreck over time, taking on the appearance of clay ballast, is also unlikely based on results from Set B. If clay rich sediments derived from the surrounding landscape had settled on the wreck via storm surges or tidal and current activity, it is likely that similar clay minerals would be present on the adjacent seabed. However, low quantities of kaolinite and absence of clinopyroxene in Set B suggest that this is unlikely (Fig. 48).

Additionally, XRD results from Set C indicate that there is no mineralogical relationship between sediments collected from surrounding coastal geologies and clay-rich sediments found within the wreck.

When taking the stability of sediments within the wreck into consideration, comparing mineralogical data from sample Sets A and B indicates that bioturbation and damaging ocean currents have had minimal effect on what may be in-situ clay sediments directly associated with the wreck. This can be observed via the presence of calcite in Set A where the mineral is only present in CLI-0009 (5.1%). However, biased sample preparation in the lab may be associated with this result, i.e. shell fragments and other material being removed from Set A and B samples prior to milling.

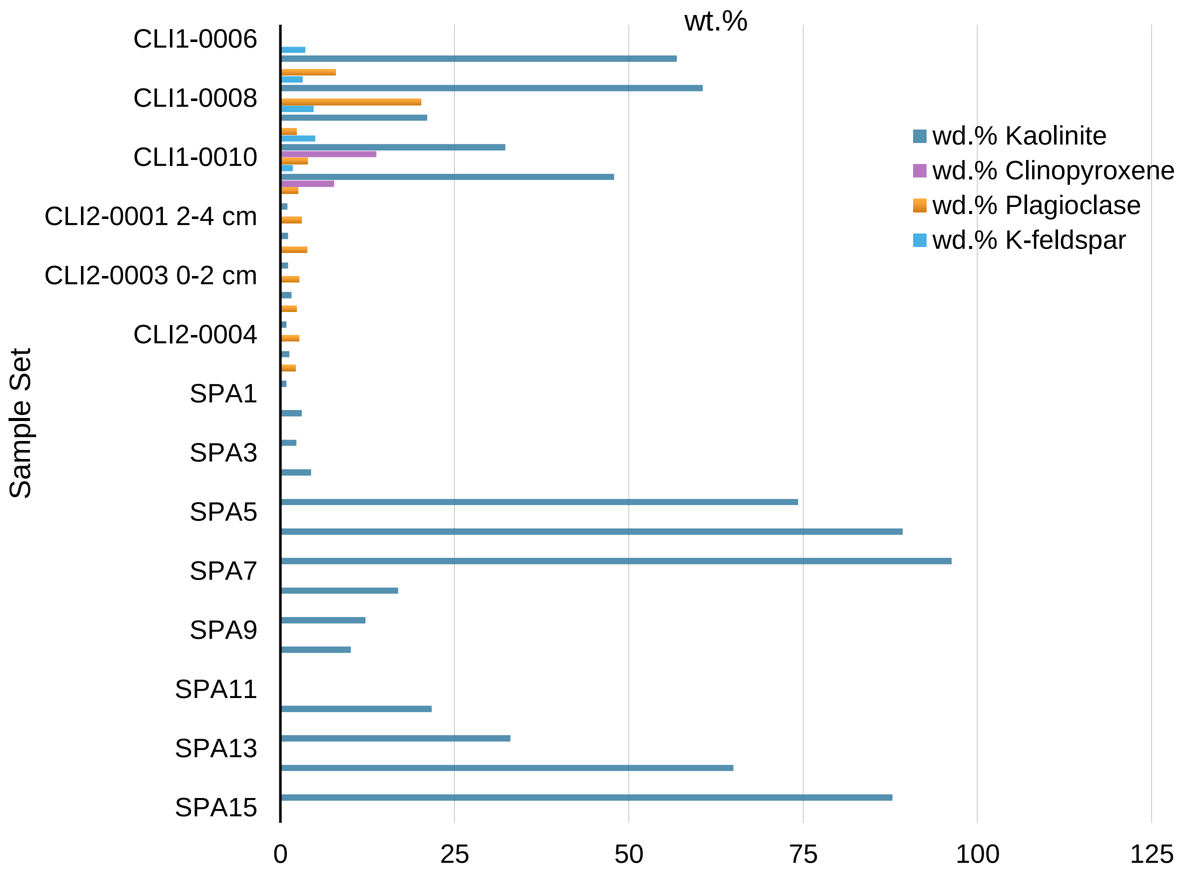

Figure 48. Mineralogical percentages of kaolinite, clinopyroxene, plagioclase and K-feldspar in Sets A, B and C.

Conclusions

Geomorphology

Results from XRD analysis suggest that the clay-rich sediment found within *Clarence* is unlikely to have derived from the surrounding landscape, having settled on the wreck via storm surges or tidal and current activity. This is supported by the unique presence of clinopyroxene is sample sets CLI1-0008 and CLI1-0009, as well as the lack of relationship between the mineral composition of clays collected from the surrounding shoreline and those identified within the wreck during field work in April 2013.

The overall purpose of the clay-rich sediment, and time frame in which it was deposited could not be identified via this form of analysis, nor could the geographical location in which it was originally collected. However, observations made during excavations, in addition to historic accounts of clay being used jointly as a ballast and export good, suggest that the clay-rich sediment is likely to have been transported in the ship for such purposes, most likely as a temporary ballast to be removed once its port of trade was reached. Tip lines were observed in the profile of the sediment above the keelson on the port side of the excavation trench. The analysis of the five core samples indicates that the three samples taken from the stern to midships (CLI1-0005-0007) had similar composition of kaolinite and illite/muscovite; the two samples forward of midships (the mast step and in the bow), had lower levels levels of kaolinite but also contained clinoproxene, potentially evidence of being collected from a different location to the stern samples (as noted by Troitsche, above).

In addition, research published by Gingele and de Deckker (2004) suggests that the mineral composition of clay-rich sediment has the potential to be successfully analysed against known mineralogical fingerprints of various river systems in Australia. Presently, comparative analysis of these known data sets suggests the clay-rich sediment may have derived from NSW Northern Rivers (Patrick De Deckker 2015, pers. comm., 23 June).

Marine ecology[14]

Ford and Chamberlain (2015) identified a more diverse biotic community in the 2015 surveys than what was reported in November 2012 (Pritchard & PDS 2012b). In particular, no cryptic fish species were observed in 2012 and many invertebrate species were noted but not identified. It is therefore likely that the apparent increase in species diversity is linked to the change in survey methodology, where the 2015 surveys were more focused and rigorous. All species identified in 2015 are extremely typical for Port Phillip Bay sandy-sea-grass communities (Jenkins et al. 1997; Wilson et al. 1998) and it is unlikely there has been any significant change between the surveys. It is possible that the more mature habitat two years after the reburial now supports a more diverse community, but we cannot make that deduction conclusively on the information available.

[14] Reproduced from Ford & Chamberlin (2015).

In terms of the marine habitat, the *Clarence* site is an example of a successfully restored excavation site that not only resembles nearby habitats but also supports a more diverse biological community. For the purposes of ecological restoration, the *Clarence* reburial component can therefore be considered a success.

In-situ preservation[15]—preliminary conclusions

Based on various conservation analyses to date the *in-situ* preservation strategy applied to the *Clarence* has been successful after two years. The backfilled sections have stabilized; however, for the strategy to be successful long-term, continued monitoring of the site at regular intervals and during seasonal extremes is necessary.

As detailed by Veth et al. (2013) in the first progress report on the project inspections of the site conducted in March 2013 showed that at the structural level the *in-situ* preservation protocol appearred to have been successful; conservation monitoring inspections in November 2013 and December 2014 have also supported this. All sand and rock-bags have remained in place, and, overall, the stitched PVC covers were intact. Some higher profile frames on the port side of the vessel have partially torn through the tarpaulins, but the damage appears to be minimal. These frames will be wrapped in geotextile, followed by heavy duty polyethylene sheeting to minimise physical, chemical and biological degradation. The shadecloth and lower unit bags and sediments have remained in place with an encouraging growth of benthic fauna (Ford & Chamberlain 2015) and dark anoxic sediments entrapped over the site.

With respect to the overriding research regarding *in-situ* reburial and stabilisation, it is axiomatic that of the 2 786 colonial built vessels in Australian waters—of which only 0.5% have been adequately surveyed—many will be at risk and justify some kind of intervention. The current *in-situ* reburial and stabilisation experimental design should assist in scoping this task with sorely needed data on the efficacy of the approach adopted here; especially when conducted on this scale. The project had the expertise, infrastructure and funds to conduct this task to a high level on *Clarence.* Despite the high-end logistics of SSBA and commercial/scientific codes for this workplace, the safe execution of complex tasks, such as deploying the largest shadecloth cover (250 m^2) and the first ever stitched PVC tarpaulin on a wreck site to date, and the movement of 3 500 sandbags over a considerable distance, means it was appropriate.

Coring on and off the site, and along the adjacent shores of Port Phillip shows that the vessel settled down towards hardpan; having a significant layer of kaolin ballast or cargo overlain by a poorly consolidated layer of marine sediments which is likely to have been reworked over time. The low density of artefacts from previous and current excavations suggest that this material has been lost from the site through past human and natural agencies.

The most diagnostic artefacts, such as the cask staves and lids; coir cordage; leather patches and ferruginous objects were recovered from within—the kaolin unit and the marine sediment disconformity above it. The paucity of artefacts recovered from the marine sediments illustrates the instability of this upper unit. We conclude that targeted test-pitting/excavation of such a site, which was being scoured and losing much of its structure from anchor damage, was warranted. This was born out by the previously undocumented presence of the site's largest artefact—a kaolin ballast layer which still sported tip lines in

[15] Concluding discussion published in part in Richards et al in (press a), Shefi et al. (2014) and Veth et al.(2013).

profile from the original bucketing of the pipe clay into the hold. To re-inter a site without this baseline data being known is as perilous as conducting unwarranted excavation where a site matrix has integrity (not the case here and the reason for starboard sampling). The ethics and planning of (test) excavation must mesh with the site's research questions and the specifics of the site and, not the least, its unique site formation processes.

The X-ray design and implementation was successful. However we believe that Computed Tomography (CT) would be more flexible and deliver improved 3D images of larger objects. The time-consuming nature of IP captures, size limits on artefacts and inability to penetrate concretions renders such a system only relevant for interrogating the internal structure of specific organics, such as the tierce barrel lids. Here, variation in teredo worm damage, porosity and internal structure can be gleaned from the X-rays.

The jack-up barge was positioned directly adjacent to the site hosting three modified container laboratories for the diver air supply and communications systems; conservation and storage laboratory; and finds processing/X-ray chamber/photography area. The ability to have 25 archaeologists, conservators, photographers, finds managers and assistants on site at any one time (and to rotate during the day) created many efficiencies in processing finds, data and sequential actions on the wreck site. The logistics of transfer of people and equipment from the vessel to fixed platform was complex, and unquestionably vulnerable to foul weather. On balance, a barge on-site platform is relatively affordable, offers many benefits and did work in these partially protected waters. However, a moored platform with a protected diver egress bay would have allowed for easier transfers and been less subject to swell and fetch. The equivalent work platform on a charter vessel would cost approximately ten times the daily amount and is generally considered prohibitive by today's research grant levels. The team is still appraising the efficacy of a jack-up barge as the ideal working platform.

The excavation of the starboard section of *Clarence* was conducted from the stern-post, tracking the keelson (with stabilised deposits) to the outer frames from Datum 0 to 8.4 m N. Artefacts were encountered near the mast step, including staves and lid fragments from tierce casks (Figs. 28–31) partially embedded in the kaolin ballast, welded leather patches and coir cordage. Dunnage was common and appeared to be mobile over the site especially within the unconsolidated marine sediment unit. The lower kaolin unit and upper marine sediment unit ranged from 15 cm bsl from the stern to a maximum depth of 48 cm bsl along the keelson at the mast step.

Many of the earlier archaeological observations by Harvey (1986 & 1989) regarding the presence of paired-framing and lack of iron fittings such as knees were supported by further testing on *Clarence*. The major find was the presence of the ballast of kaolinite-rich clays, which is the first time this feature has been located, sampled and investigated in Australia. It is anticipated that this practice, known from the United Kingdom from at least the 1820s, may have occurred in other cases where vessels under 100 tons were transporting livestock and there was access to kaolinite clays.

What is clear from a critical analysis of the system tested so far is that:

- Wooden colonial built vessels which are 'at risk' deserve and will no doubt benefit to varying degrees from such interventions.
- The process of recovery, documentation and reinterral can only be expedited to a point (rapidity is a redundant descriptor).
- An ambitious programme of documenting the various archaeological, conservation, site formation and biological values of a wreck before total and comprehensive reburial with exhaustive monitoring can, and indeed has been, done in the case of the AHSPP.

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Appendix A: X-ray Enclosure Specifications

The source box itself was made from stainless steel, clad (internally) with lead. A beam-defining aperture restricted the beam so that it only illuminated the imaging plate (IP). Removal of the top of the source box allowed the camera to be positioned. The camera had to be removed to enable the X-ray source to be used when in position. The enclosure had a number of access doors (Fig. 1): a door at the top, front—to enable insertion and removal of the Sony DSC TX10 3D camera and the X-ray source (Fig. 2); two side doors to enable the artefact to be mounted on the rotary stage (Fig. 3); and a door at the top, rear—to enable the IP to be loaded and unloaded. Internally, the enclosure in which the source was placed, the rectangular beam-forming aperture, the rotary table, and the imaging plate holder were all mounted on a 50 mm thick aluminum plate. This was isolated from the outer enclosure by four isolation mounts to minimize transfer of external vibrations to the X-ray system. The resolution of the system as designed was better than 17 µm and transferred vibrations with amplitudes greater 10 µm would affect the resolution of the received image.

The Sony camera (seen positioned in the enclosure in Fig. 4) is present only when the photographic data set is being taken. The camera is a single lens device. The 3D effect is generated by the acquisition of two photographs, one focused on the specimen and the other focused on the background. This differs from conventional 3D cameras which use two spatially separated lenses. The axis, along which the camera views, is the axis of the X-ray system. After a rotational data set has been taken (at 4^{o} rotational increments) the camera's memory card is removed and the images uploaded into the designated computer file. Thereafter it can be viewed as a 3D image on a 3D monitor or a Sony 3D television set. As the artefact is rotated in steps of 4^{o} about the vertical axis the 3D image can be seen to rotate through the same amount on the screen.

Figure 1. X-ray enclosure showing the access doors for the X-ray source, the specimen stage, and the imaging plates. The X-ray source has been removed, and the camera inserted. The photographic image, presented on the viewing screen of the camera can be seen.

Figure 2. The X-ray source in the source box with the 3D camera removed. The beam-defining aperture can be seen.

Figure 3. Rotary table in its usual position. On the sample mounting spacers are the Spyder calibration tools used to calibrate the camera. The bolt in the baseplate indicates the position of the rotary stage when small items are examined.

Figure 4. X-ray source and camera in position. Note the camera is removed when X-ray images are to be acquired.

Appendix B: Marine Ecology Report April 2012

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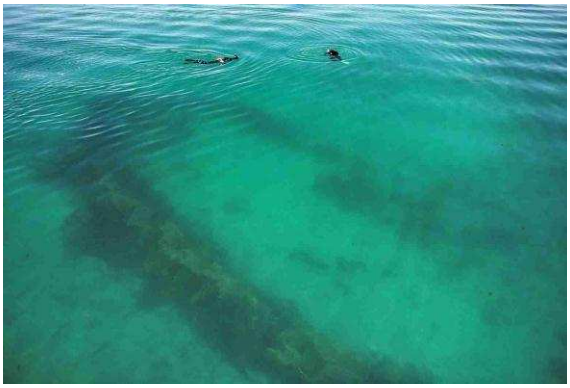
The Clarence Biological Survey



April 2012

Attention:
Cassandra Philippou
Project Manager - Australian Historic Shipwreck Preservation Project
School of Social Sciences
The University of Western Australia

This is to certify that under the direction of Cassandra Philippou of the Australian Historic Shipwreck Preservation Project, Professional Diving Services completed a biological survey of the Clarence shipwreck. Professional Diving Services completed the survey on 19 and 20 April, 2012. The following report presents the findings of the inspection.

Professional Diving Services forwards this report without favour or prejudice. This report presents a true and accurate representation of the findings. There were no reports of accident or injury during the works and all Victorian Work Safe, AS/NZS 2299.1: 2007 and Professional Diving Services operational and safety requirements have been complied with.

Kate Pritchard
Operations Manager
Professional Diving Services

1 Introduction

The Clarence is a shipwreck located 2.7km SSE of St Leonards in Port Phillip Bay. The vessel was built in 1841. It was a 67 tonne wooden schooner measuring 50 feet. On September 1850, en route Melbourne to Hobart the vessel ran aground. The Clarence is being used as a trial for the development of new techniques to uncover information and artefacts from partially or fully buried maritime shipwrecks. In doing so, the area will be excavated and later reburied to preserve the shipwreck in its original condition.

Shipwrecks provide an artificial hard substrate for marine organisms to colonise. The disturbance of the area may affect the biota colonising the Clarence wreck itself or nearby habitats. Professional Diving Services was asked to gather some information on species diversity

The survey aims to:

- Describe the biota colonising the Clarence wreck
- Describe the habitat and allocated biota
- List any species of ecological significance
- List any introduced species observed

2 Methods

Diving was run from a jack up barge. Once orientated on the bottom divers navigated their way to the shipwreck. Diver buddies were using standard SCUBA with hardwire communication to their supervisor on the jack up barge. The survey of the Clarence shipwreck was completed on 19 and 20 April, 2012, by a team of six divers. The two days offered ideal survey conditions with visibility approximately 6 metres, light winds and currents less than 1 knot.

A transect line was laid from the bow of the vessel along the port side of the wreck. Within this transect fish, invertebrates and macroalgae were recorded. Quadrates 0.25 m^2 were haphazardly placed along the transect line. All species were recorded as a presence absence.

3 Major Findings

3.1 Macroalgae and Sponges

The habitat surrounding the Clarence is characterised by a high density of seagrass *Zostera muelleri*. There were several ruffled globular orange sponges within the seagrass. There was a diverse range of algae species present on the shipwreck. The only canopy forming species observed was the common kelp *Ecklonia radiata,* observed in low abundances. The most dominant species observed along the wreck was *Sargassum fallax*, forming in relatively large brushes in most areas. Other common species observed were *Caulerpa brownii, Caulerpa trifaria*, *Codium spp* and several thallose red algae including *Rhodymenia australis* and *Erythroclonium sonderi*.

There was a large number of sponge species present on the wreck. One common species was the prickly rose sponge *Dendrilla cactos*.

Algae species observed

Brown

Species Name	Common Name
Ecklonia radiata	Common Kelp
Dictyopteris muelleri	Mueller's forkweed
Sargassum fallax	Broad-leafed sargassum
Zonaria turneriana	Fanweed
Zonaria spiralis	Spiral fanweed

Red

Species Name	Common Name
Dictyomenia harveyana	Harvey's leafweed
Rhodymenia australis	Southern red forkweed

Green

Species Name	Common Name
Caulerpa brownii	Browns caulerpa
Caulerpa trifaria	Three-cornered caulerpa
Codium spp	

Sponges

Species Name	Common Name
Dendrilla cactos	Prickly rose sponge

3.2 Mobile Invertebrates and Cryptic Fishes

There was a high abundance of invertebrates present in the sediments surrounding the Clarence. The abundance of invertebrates was dominated by Parchment worms (*Chaetopterus sp*) and Bivalves. The most common species observed was the common sea urchin *Heliocidaris erythrogramma*. Three species of sea star were observed within the study area; *Meridiastra gunnii*, *Coscinasterias muricata* and *Uniophora granifera*. Other invertebrates present included the Swimming anemone *Phlyctenactis tuberculosa,* the whelk *Cabestana Spengerli,* and a single giant cuttlefish *Sepia apama*.

Invertebrate species observed

Species Name	Common Name
Heliocidaris erythrogramma	Common sea urchin
Herdmania grandis	Red-mouthed ascidian
Notomithrax ursus	Hairy seaweed crab
Plagusia chabrus	Red bait crab
Cabestana spengleri	Spengler's triton
Meridiastra gunnii	Gunn's six armed star
Coscinasterias muricata	Eleven armed seastar
Uniophora granifera	Granular seastar
Chaetopterus sp	Parchment worms
Phlyctenactis tuberculosa	Swimming anemone
Cabestana spengerli	Spengler's triton
Sepia apama	Giant cuttlefish
Paguristes frontalis	Southern hermit crab

3.3 Fishes

The most common family of fish observed was the Monacanthidae, including the leatherjackets. There were aggregations on and around the wreck of juvenile *Acanthaluteres vittiger*, toothbrush leatherjackets. Other leatherjacket species recorded were *Meuschenia freycineti* the six spine leatherjacket, *Meuschenia flavolineata* the yellow stripped leatherjacket, and *Brachaluteres jacksonianus,* the pygmy leatherjacket. Another common species observed was the goat fish *Upeneichthys vlamingii.* The spotted pipefish *Stigmatopora argus* was commonly observed within the seagrass beds adjacent to 'The Clarence' and one potbellied seahorse *Hippocampus abdominalis, Hippocampus bleekeri* was also observed both of which are listed species under the Environment Protection and Biodiversity Conservation act 2007.

Fish species observed

Species Name	Common Name
Upeneichthys vlamingii	Goats fish
Acanthaluteres vittiger	Toothbrush leatherjacket
Meuschenia freycineti	Sixspine leatherjacket
Meuschenia flavolineata	Yellow stripped leatherjacket
Brachaluteres jacksonianus	Southern pigmy leatherjacket
Diodon nicthemerus	Globe fish
Tetractenos glaber	Smooth toad fish
Neoodax balteatus	Weed whiting
Notolabrus tetricus	Blue throat leatherjacket
Sepia apama	Giant cuttlefish
Parablennius tasmanianus	Tasmanian blenny
Stigmatopora argus	Spotted pipefish
Hippocampus abdominalis	Bigbelly seahorse

Hippocampus bleekeri Potbelly seahorse

3.4 Introduced Species

No introduced species were observed during the survey however several species are known to inhabit the area, including the Northern Pacific seastar *Asterias amurensis.*

4 Conclusion

The Clarence shipwreck has provided habitat for a range of sessile and motile marine species. The species observed are species common to Port Phillip Bay. It appeared the seagrass surrounding the wreck was a nursery for juvenile toothbrush leatherjackets *Acanthaluteres vittiger*. The shipwreck is located close to the channel, surrounded by seagrass beds, being the only artificial reef in the area, making a safe haven for the species that have colonised it. There were no introduced species were observed during the survey.

Figure 1. Green algae *Caulerpa trifaria*, three-cornered Caulerpa.

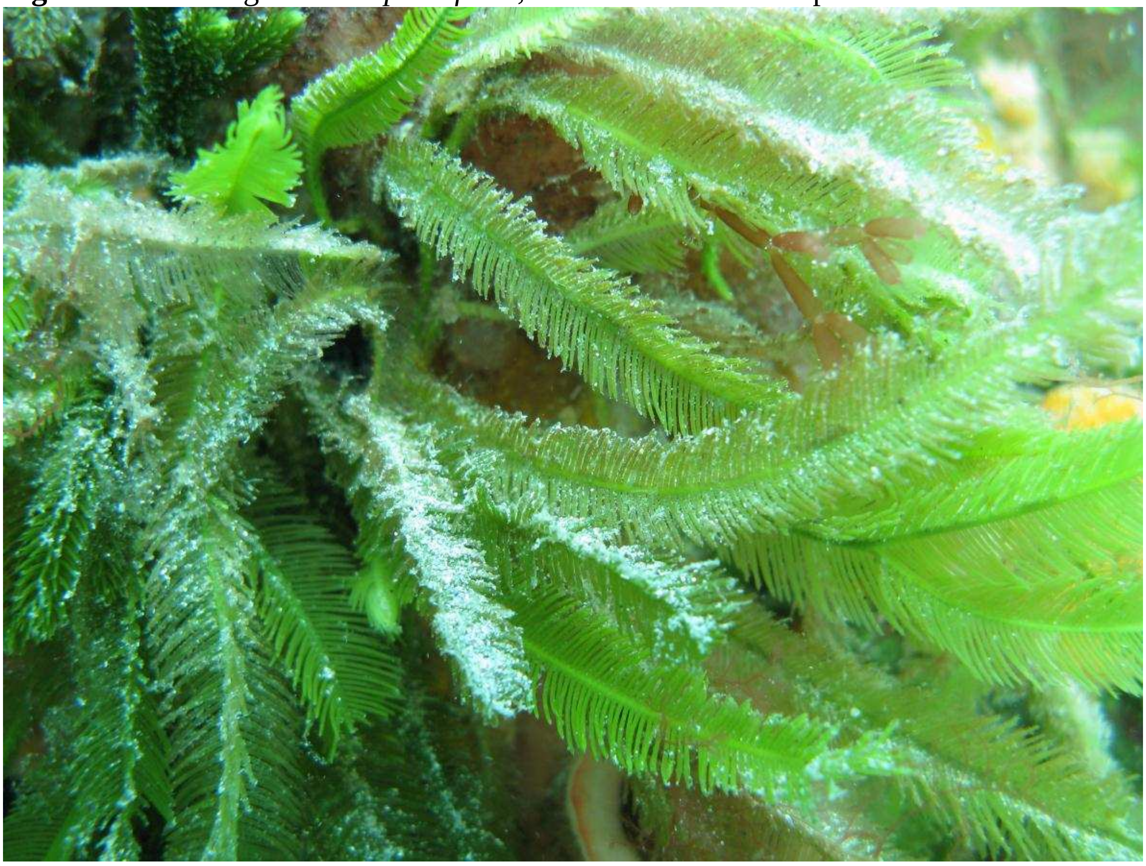


Figure 2. Seagrass *Zostera muelleri*.

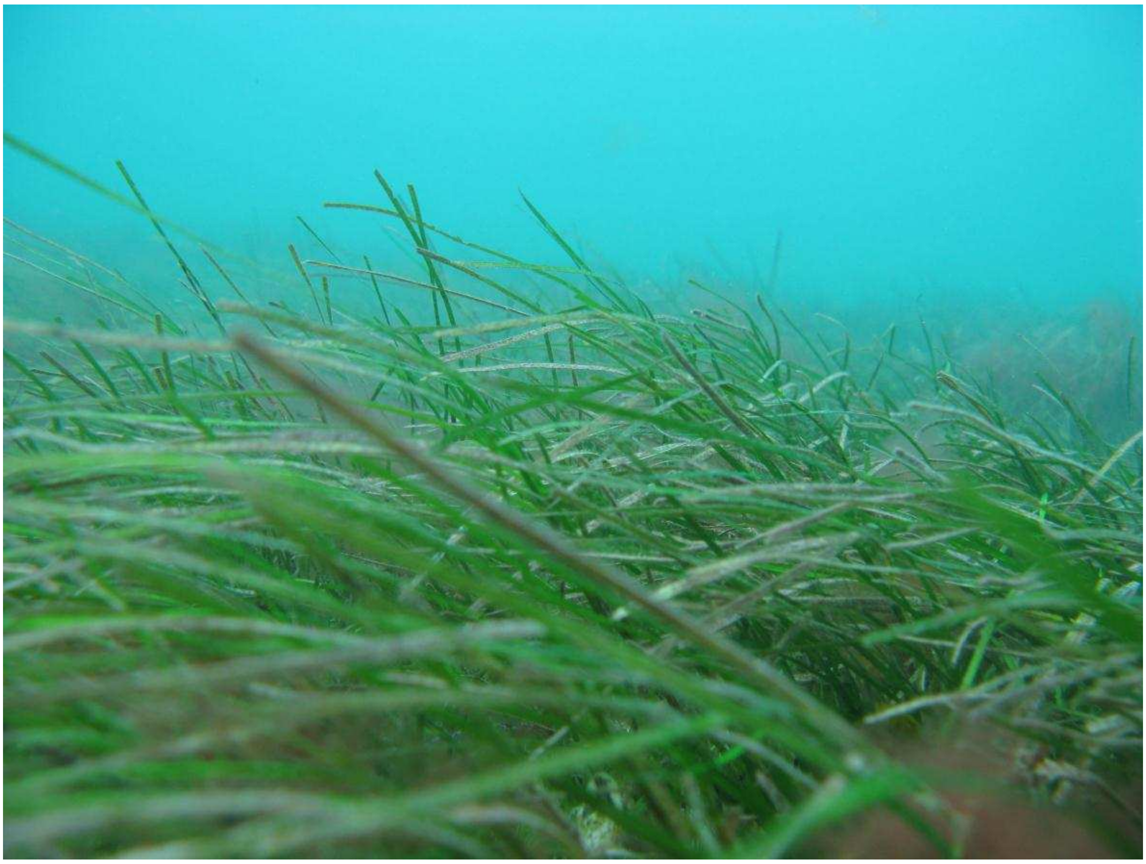


Figure 3. Common sea urchin *Heliocidaris erythrogramma.*

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Figure 4. Eleven armed seastar *Coscinasterias muricata* on a sandbag.

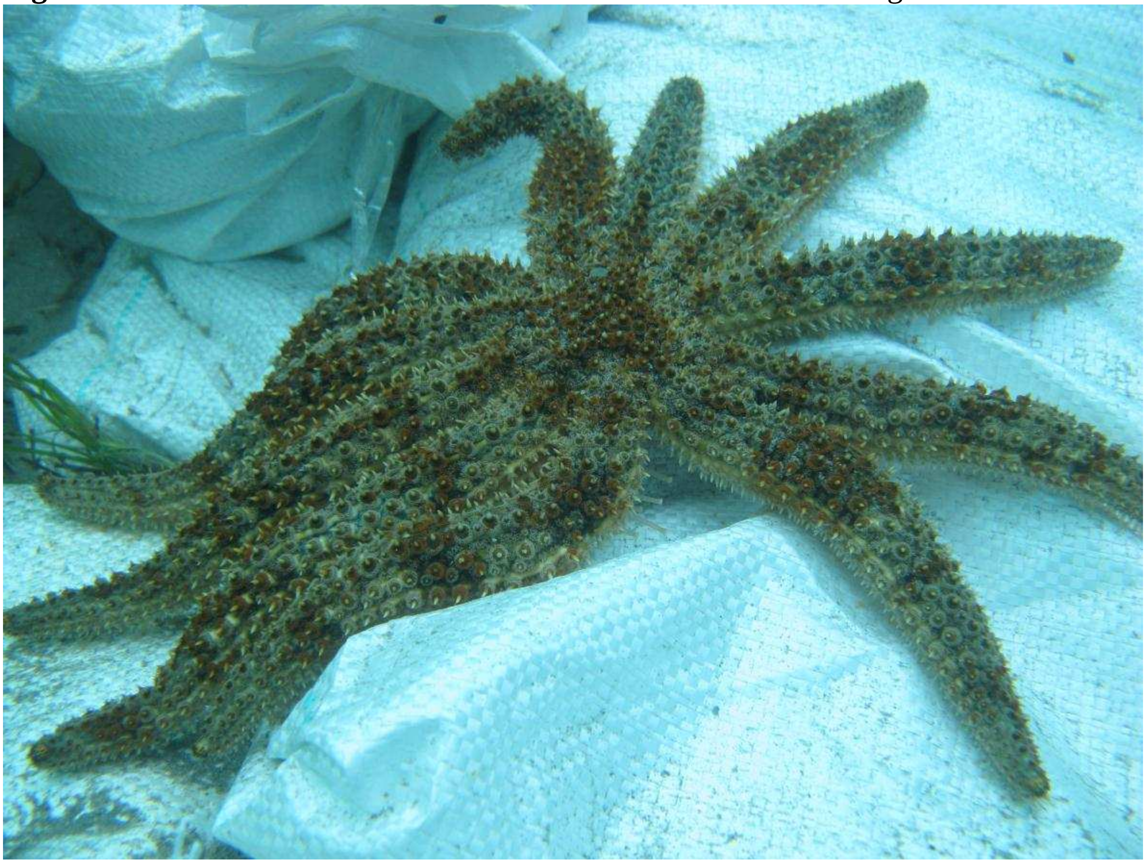

Figure 5. Cuttlefish *Sepia apama*.

Figure 6. Southern hermit crab *Paguristes frontalis.*

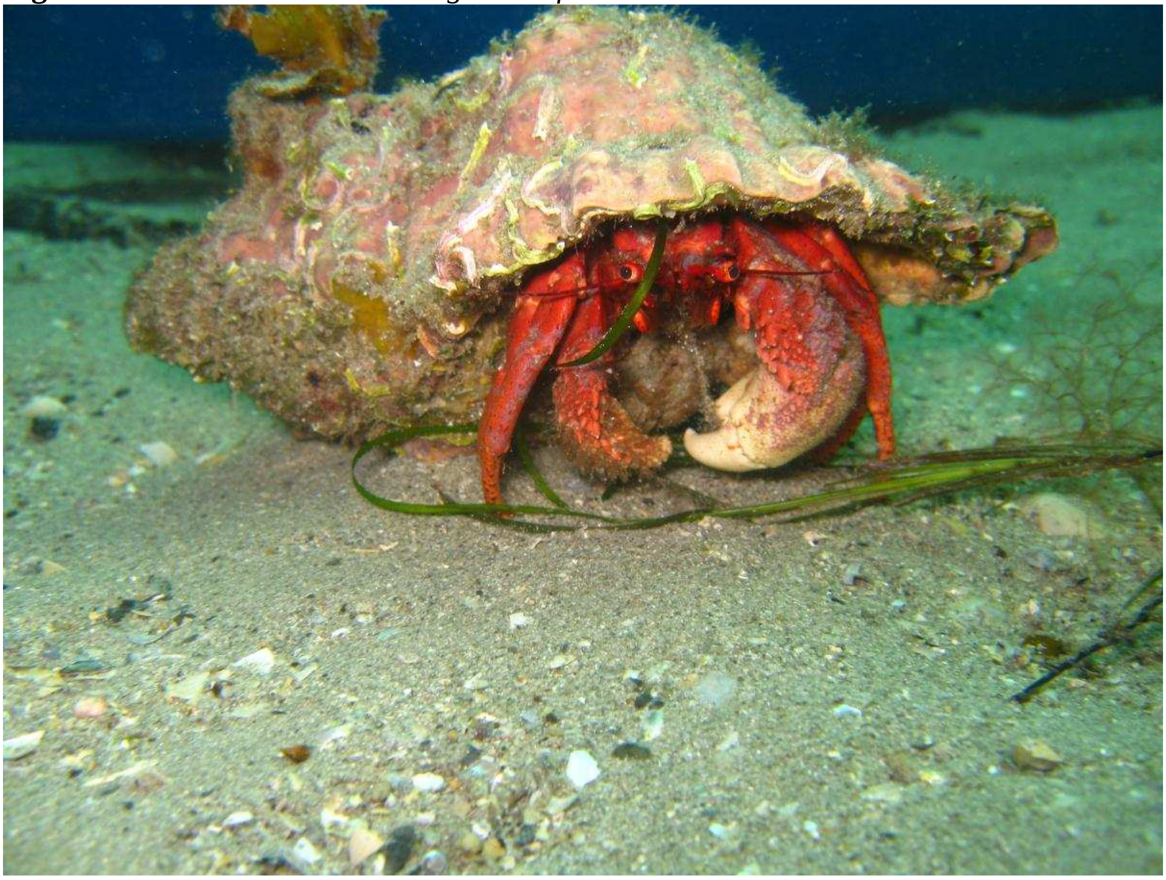

Figure 7. Goat fish *Upeneichthys vlamingii.*

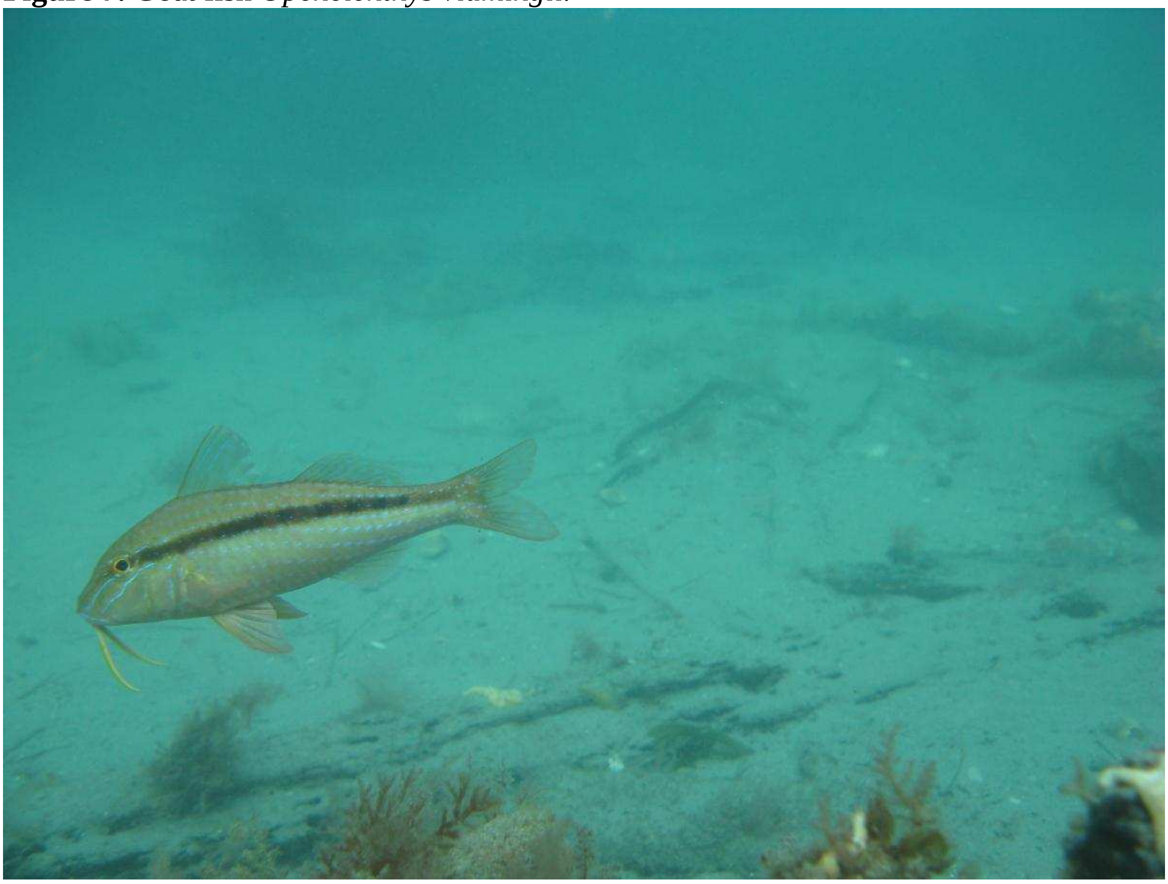

Figure 8. Six spined leatherjacket *Meuschenia freycineti.*

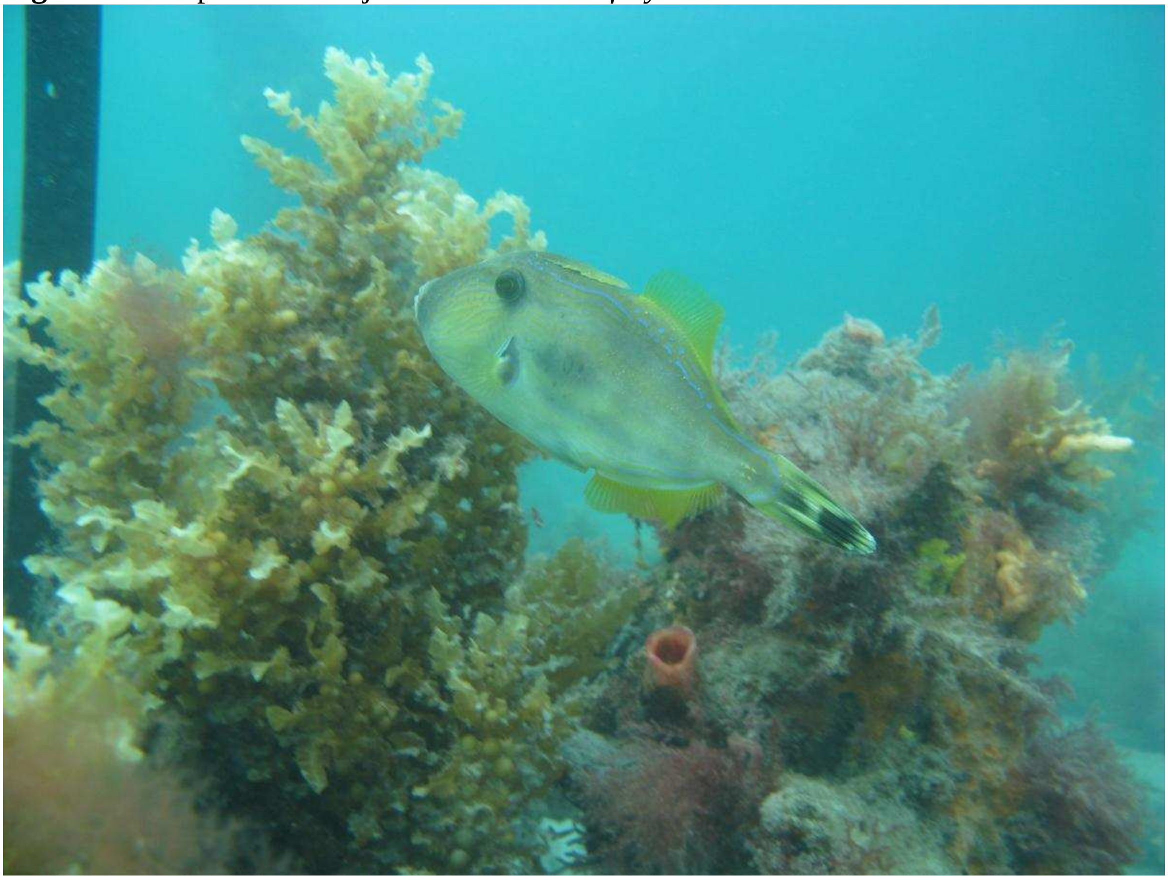

Figure 9. Spotted pipefish *Stigmatopora argus*

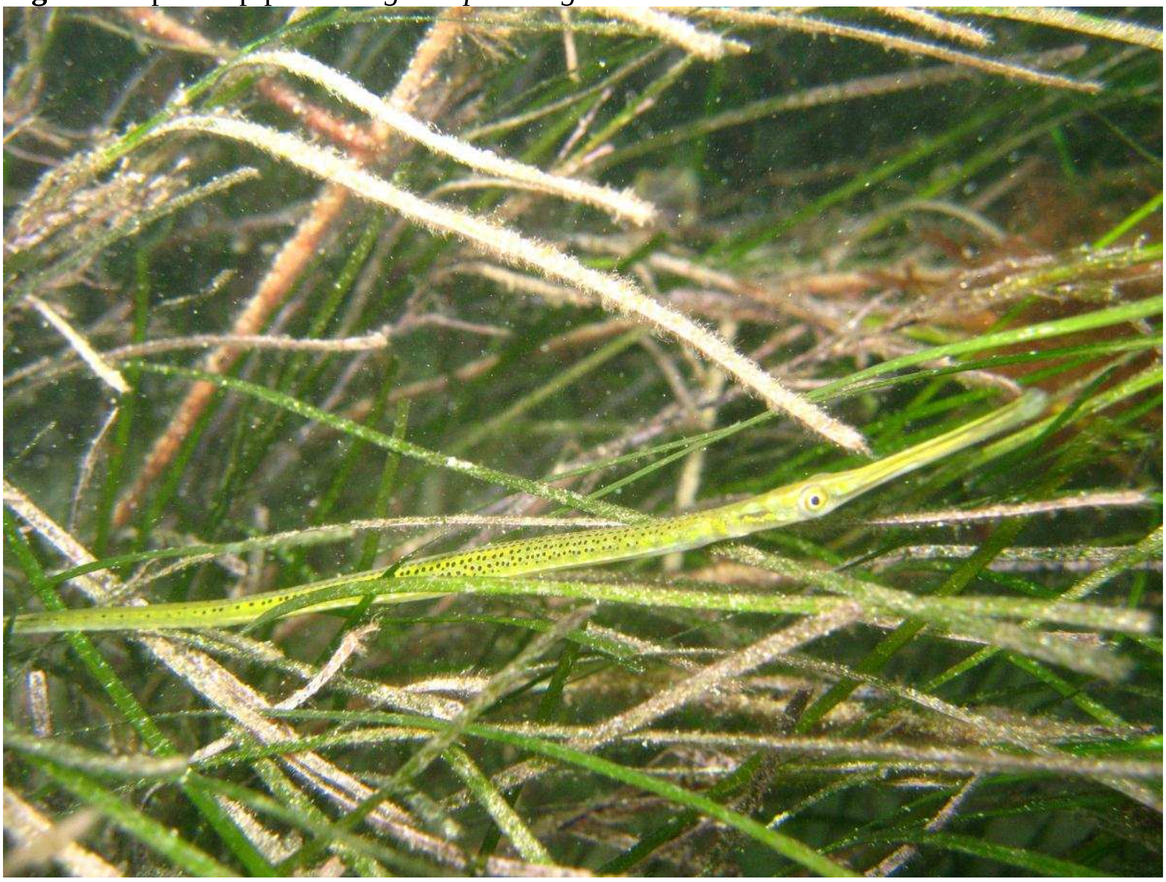

Figure 10. Globe fish *Diodon nicthemerus.*

Appendix C: Marine Ecology Report November 2012

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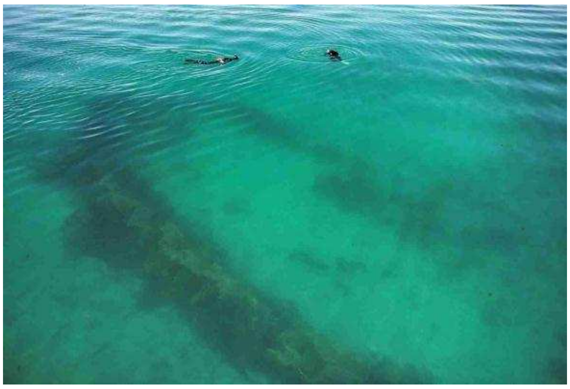
The Clarence Biological Survey Post Excavation



November 2012

Attention:
Cassandra Philippou
Project Manager - Australian Historic Shipwreck Preservation Project
School of Social Sciences
The University of Western Australia

This is to certify that under the direction of Cassandra Philippou of the Australian Historic Shipwreck Preservation Project, Professional Diving Services completed a biological survey of the Clarence shipwreck post excavation. Professional Diving Services completed the survey on 22 November, 2012. The following report presents the findings of the inspection.

Professional Diving Services forwards this report without favour or prejudice. This report presents a true and accurate representation of the findings. There were no reports of accident or injury during the works and all Victorian Work Safe, AS/NZS 2299.1: 2007 and Professional Diving Services operational and safety requirements have been complied with.

Kate Pritchard
Operations Manager
Professional Diving Services

1 Introduction

The Clarence is a shipwreck located 2.7km SSE of St Leonards in Port Phillip Bay. The vessel was built in 1841. It was a 67 tonne wooden schooner measuring 50 feet. On September 1850, en route Melbourne to Hobart the vessel ran aground. The shipwreck of the Clarence is being used as a trial for the development of new techniques to uncover information and artefacts from partially or fully buried maritime shipwrecks. In doing so, the area will be excavated and later reburied to preserve the shipwreck in its original condition.

Shipwrecks provide an artificial hard substrate for marine organisms to colonise. The disturbance of the area may affect the biota colonising the wreck itself or nearby habitats. Professional Diving Services was asked to gather some information on species diversity post-excavation but prior to the shade cloth & tarps being deployed.

The survey aims to:

- Describe the biota colonising the wreck
- Describe the habitat and allocated biota
- List any species of ecological significance
- List any introduced species observed

2 Methods

Professional Diving Services completed the works on 22 November, 2013. The diving was carried out by Kate Pritchard and Rhonda Steel. The diving operations were conducted from Heritage Victoria vessel, in Transport Safety Victoria survey, MV *Trim*, skippered by Peter Harvey. During the survey the visibility was approximately 5 metres, light winds and currents less than 1 knot.

Two transect lines were laid from the bow of the vessel, along the port side and then the starboard side of the wreck. Within this transect fish, invertebrates and macroalgae were recorded. Quadrates 0.25 m^2 were haphazardly placed along the transect line. All species were recorded as a presence absence.

3 Major Findings

3.1 Macroalgae and Sponges

The most abundant species colonising the wreck was the seagrass *Zostera muelleri*. There were two canopy forming species observed, the common kelp *Ecklonia radiata* and the crayweed *Phyllospora comosa*, observed in low abundances. Other species observed were Sargassum sp, *Caulerpa spp*, *Codium spp* and several thallose red algae including *Rhodymenia australis*. All species observed on transects are listed below.

There was a large number of sponge species present on the wreck. One common species was the prickly rose sponge *Dendrilla cactos*.

Algae species observed

Brown

Species Name	Common Name
Ecklonia radiata	Common kelp
Phyllospora comosa	Crayweed
Sargassum sp	Sargassum
Dictyopteris muelleri	Meuller’s forkweed

Red

Species Name	Common Name
Rhodymenia australis	Southern red forkweed
Champia viridis	Agardh’s champia
Thallose red	

Green

Species Name	Common Name
Ulva australis	Southern sea lettuce
Codium spp	
Caulerpa spp	

Sponges

Species Name	Common Name
Dendrilla cactos	Prickly rose sponge

3.2 Mobile Invertebrates and Cryptic Fishes

The most common species observed was the common sea urchin *Heliocidaris erythrogramma*. Other invertebrates present included the swimming anemone *Phlyctenactis tuberculosa*, the cartrut shell *Dicathais orbita*, and the giant spider crab *Leptomithrax gaimardii*. All species observed on transects are listed below.

Invertebrate species observed

Species Name	Common Name
Heliocidaris erythrogramma	Common sea urchin
Herdmania grandis	Red-mouthed ascidian
Coscinasterias muricata	Eleven armed seastar
Phlyctenactis tuberculosa	Swimming anemone
Paguristes frontalis	Southern hermit crab
Leptomithrax gaimardii	Giant spider crab
Sabella spallanzani	Giant fanworm
Dicathais orbita	Cartrut shell

3.3 Fishes

The most abundant fish observed on the wreck was the toothbrush leatherjacket *Acanthaluteres vittiger*. Other common species included the goat fish *Upeneichthys vlamingii* and the weed whiting *Neoodax balteatus*. All species observed on transects are listed below.

Fish species observed

Species Name	Common Name
Upeneichthys vlamingii	Goats fish
Acanthaluteres vittiger	Toothbrush leatherjacket
Meuschenia freycineti	Sixspine leatherjacket
Meuschenia flavolineata	Yellowstriped leatherjacket
Diodon nicthemerus	Globe fish
Neoodax balteatus	Little weed whiting
Lotella rhacinus	Beardie

3.4 Introduced Species

The introduced fan worm *Sabella spallanzani* was observed on the wreck during this survey.

4 Conclusion

The habitat that had colonised the Clarence shipwreck was dominated by the seagrass *Zostera muelleri*. As during the first survey it appeared the seagrass surrounding the wreck was a nursery for juvenile toothbrush leatherjackets *Acanthaluteres vittiger*. There were a few species observed that were not recorded during the original survey, including the introduced fan worm *Sabella spallanzani*.

Figure 1. Common kelp *Ecklonia radiate*.

Figure 2. Small patch of seagrass *Zostera muelleri* growing on the wreck.

Figure 3. Crayweed *Phyllospora comosa*.

Figure 4. Canopy algae and sponges.

Figure 5. Spengler's triton, *Cabestana spengleri*

Figure 6. Red mouthed ascidian *Herdmania grandis* and seagrass *Zostera muelleri*.

Figure 7. Giant spider crab *Leptomithrax gaimardii*.

Figure 8. Toothbrush leatherjackets *Acanthaluteres vittiger*.

Figure 9. Goats fish *Upeneichthys vlaminghii*.

Figure 10. Goats fish *Upeneichthys vlaminghii*.

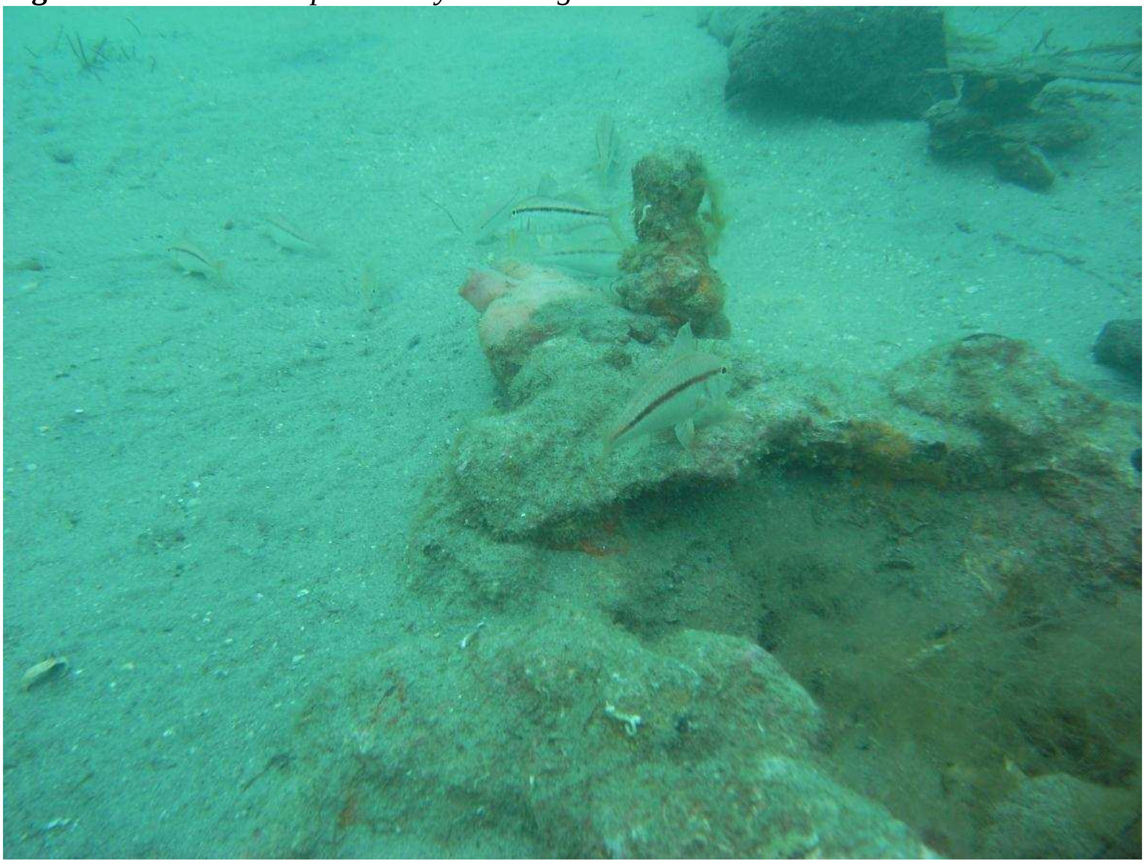


Figure 11. Globe fish *Diodon nicthemerus.*

Figure 12. Velvet leatherjacket *Meuschenia scaber*.

Appendix D: Marine Ecology Report March 2015

Biological Survey of the Clarence Shipwreck

St Leonards, Port Phillip Bay, Australia

March 2015

Report prepared by Dr John Ford and Dean Chamberlain at the University of Melbourne for the University of Western Australia and Heritage Victoria.

Scope of the report

The University of Western Australia commissioned the University of Melbourne to conduct a biological survey of the *Clarence* shipwreck site and a scientific report detailing the findings. This document reports on the general biotic and abiotic environment on and surrounding the *Clarence* site, provides quantitative measures of mobile fish, cryptic fish, mobile invertebrates and benthic biota cover, and statistically compares the biota to two reference sites approximately 150 m from the *Clarence*. A qualitative comparison of results is made to previous biological surveys in 2012.

About the authors

Dr John Ford is a marine research fellow at the School of Biosciences at the University of Melbourne. He is an expert on the biota of Port Phillip Bay and has conducted over 500 scientific SCUBA dives around Melbourne and the Victorian coastline. He undertakes a variety of marine research work including biological surveys, habitat restoration and fisheries sustainability.

Dean Chamberlain is senior technical officer at the School of Biosciences at the University of Melbourne. He is an expert SCUBA diver and boat operator, and has conducted thousands of scientific SCUBA dives, most in Port Phillip Bay. Dean has an in depth knowledge of local fish, invertebrates and algae.

Executive Summary

A comprehensive biological survey of the *Clarence* shipwreck site and nearby habitats was carried out in January 2015 by SCUBA divers using the benchmark Reef Life Survey monitoring methodology. The *Clarence*, initially excavated then reburied by a research team 2012, was almost completely covered in soft sediment at the time of the survey with the only visible sections the Samson post and some port side frames. Because the wreck had been actively buried to a height greater than the surrounding sediment and then covered with a tarpaulin and sandbags, the site had greater relief than surrounding areas and the

presence of half-buried sandbags added a unique level of structural benthic complexity. However, such details are only visible on close inspection and the *Clarence* site now strongly resembles the surrounding sandy seagrass habitats. A total of 39 species of algae, seagrass, fish and invertebrates were observed at the *Clarence* site, all typical for southern Port Phillip Bay. The benthic biota was dominated by the seagrass *Zostera nigracaulis* which grew in dense patches on the sandy sediment over the wreck. Also dominant was the sand ascidian *Molgula manhattensis* which grows mostly submerged in the sandy sediment and provides small scale relief and crevices for cryptic fish and invertebrates. Comparisons of biological diversity and the abundances of the key species revealed the *Clarence* wreck site to have significantly higher total biota cover, seagrass cover, cryptic fish diversity and macro invertebrate diversity than at least one of the surrounding reference sites. Only one species, the sand goby, was significantly more abundant at a reference site. In summary, the rehabilitated *Clarence* wreck site was a more biodiverse and vegetated site than those surrounding, likely due to the increased relief and complexity provided by the burial works and sandbags. These results demonstrate the rapid re-establishment of the soft sediment-seagrass community and the success of the burial works on the *Clarence*.

Background

The ecological role of shipwrecks

Shipwrecks offer a novel habitat for marine communities. The variety of hard surfaces that shipwrecks can provide; both vertical and horizontal, along with cavities, overhangs and caves, can produce one of the most complex and diverse habitats in the marine environment (Perkol-Finkel et al. 2005, Pawlik et al. 2008, Consoli et al. 2015). However in many cases the habitat offered will be partially sunken, decomposed or even deliberately buried and hence only provides a minor habitat change to surrounding environments.

There is some debate as to the ecological and conservation role of shipwrecks in the marine environment. Shipwrecks are fundamentally an artificial structure, and often considered beneficial in a conservation role if they can mimic natural habitats and promote the establishment of native communities (Genzano et al. 2011). Wrecks can meet this requirement only if they possess similar structural features to nearby natural habitat (Perkol-Finkel et al. 2006), and clearly would provide greater benefit when replacing a habitat that is otherwise lost. However, artificial structures such as shipwrecks can assist the spread of invasive species by providing “stepping stones” or hard surface habitat amongst soft bottom communities (Gewing et al. 2014). As many invasive marine species are fouling organisms and often spread to new areas on the hulls of ships, it is unsurprising that these sunken habitats provide ideal hubs for invasion.

Biological surveys appear to accompany relatively few archaeological surveys of shipwrecks (e.g. McCarthy 1988), but can add value by characterising the ecological role of wrecks, providing estimates of age, and identify the biological and physical processes affecting and surrounding the wreck (Randell 1998). Methodology and quality of biological information about shipwrecks are highly variable and it is hence difficult to quantify their roles in the marine ecosystem. More targeted surveys have often occurred on deliberately sunk vessels in recent decades to better understand fouling and colonisation processes (Pawlik et al. 2008).

The *Clarence* shipwreck

The *Clarence* was a 67 tonne, 50 ft wooden schooner that ran aground off St Leonards in Port Phillip Bay, Victoria in 1850. The wreck was mostly buried in the sandy sediment until it was rediscovered in 1982.

Some minor excavations were carried out in 1987, and as the site became more exposed, artificial seagrass matting was deployed in 1993. It was not until April 2012 that a full excavation and archaeological survey of the *Clarence* was undertaken. At this time the sides of the wreck were exposed and the seagrass matting had mostly deteriorated. During excavation, sand and biota above and around the wreck was removed and works undertaken as described in Veth et al. (2013). The *Clarence* was then reburied between May and November 2012 in order to better preserve the wreck and artefacts. After initial sand burial to an average depth of 1m, a tarpaulin and sandbags were placed above the wreck. In time, sand has migrated over the tarpaulin and created a long hill or mound over the wreck site.

Biological surveys were conducted pre- and post- excavation (Professional Diving Services 2012a, 2012b). These surveys briefly describe the biota and provide a species list of common fish, invertebrates and algae. The sediment around the wreck was dominated by the seagrass *Zostera nigracaulis* (possibly mis-identified as *Zostera muelleri* in the November 2012 survey), and the fish and invertebrate communities were diverse and very typical for the southern areas of Port Phillip Bay. All species were listed as presence-absence and sampling intensity was not standardized, therefore it is not possible to make quantitative statistical comparisons between the surveys, or with any subsequent surveys. There is no discussion of impacts of the excavation or analysis of change observed and hence we cannot conclude whether the excavation works affected the ecological community at the site.

Whilst the reburial of the *Clarence* was done to preserve the wreck itself, a desirable outcome of the reburial process is to successfully restore the biological community around it. Whilst we could not compare the current biological community with that prior to excavation, we can investigate the similarity to surrounding natural habitats. With this aim in mind, we undertook a comprehensive biological survey of the *Clarence* wreck site, asking the following questions:

1. Does the *Clarence* site quantitatively differ to surrounding reference sites with respect to fish, mobile invertebrates and benthic biota?
2. Can the differences in fish or mobile invertebrates be explained by variation in benthic biota?
3. Does the species composition of the *Clarence* site qualitatively differ to the 2012 surveys?

Methodology

Visual census surveys were carried out by divers on SCUBA at the *Clarence* wreck site (38°12.154'S 144°43.395'E) and two nearby references locations 100-150 m from the wreck, one immediately to the south and another to the west. The wreck was surveyed on 23 January 2015 and the reference sites surveyed on 3 February 2015. The dive team used a modified version of the Reef Life Survey methods (see Edgar and Stuart-Smith 2009), a widely used and respected methodology that quantitatively estimates the biotic and structural composition of benthic marine communities. The surveys estimated the abundance of four groups of biota: mobile fish, cryptic fish, mobile invertebrates and benthic (attached) biota.

Surveys were carried out by a dive team pair along 25 m transects. At the wreck site, two transects were laid out parallel along the length of the wreck approximately 5-10 m apart, starting from the exposed Samson post. Reference sites were chosen randomly but were at least 100 m from the wreck site and outside of the historic shipwreck protected zone. A transect was laid out in two random directions from the drop point at each reference site, resulting in two transects for each site (wreck, reference 1 and reference 2).

Along each transect, a single visual survey was conducted for mobile fish along a 5 m swathe (2.5 m either side of the transect). Cryptic fish and mobile invertebrates (>10 mm) were counted in a 1 m strip to the right of the transect line, and abundances tallied in 5 m blocks (i.e. five counts per transect). Benthic biota and substrate type were estimated using a point-intersect method with a 50 x 50 cm quadrat with seven horizontal and vertical string lines. The quadrat was laid down every 5 m along the line and the benthic biota and substrate type calculated at each point where the string intersects, as well as the top right hand corner, summing to 50 intersect points. These 50 points were converted to percentage cover per quadrat. Furthermore, divers identified all benthic biota along the transect line to produce a comprehensive species list, including those that were not abundant enough to be picked up in the point-intersect method.

We conducted statistical comparisons of the biota and substrate of the three sites to answer the questions: 1) does the biota of the rehabilitated *Clarence* wreck site differ from nearby reference sites? And 2) does the benthic biota composition explain differences in fish and invertebrate communities?

Due to the small size of the *Clarence* wreck, we were unable to obtain sufficient replication of mobile fish counts for statistical analysis and we present presence-absence data only.

For counts of cryptic fish, mobile invertebrates and benthic biota, we calculated Shannon's diversity index, which effectively represents the occurrence, abundance and evenness of species in the community, and is a widely accepted method in comparing ecological communities (Spellerberg and Fedor 2003). The index is based on the premise that as the number of species increases, or the distribution of species becomes more even, the larger the value and the better the biodiversity. We compared values of Shannon's H amongst the three sites using ANOVA and ran post-hoc Tukey's test to investigate any significant differences.

We compared the abundances of the two most common species of cryptic fish (common triplefin and sand goby), two most common mobile invertebrates (red crab and glass shrimp), the most common benthic biota (seagrass *Zostera nigracaulis*) and total benthic biota cover amongst the sites using ANOVA and ran post-hoc Tukey's test to investigate any significant differences.

We attempted to explain any significant differences in cryptic fish and mobile invertebrates amongst sites by running regression analysis of any significant variable against benthic biota and seagrass cover.

All statistics were carried out using JMP 11 (SAS 2014).

Results

General environment description

The *Clarence* wreck is situated in a shallow, gently undulating sandy environment dominated by the seagrass *Zostera nigracaulis.* The substrate is almost exclusively medium grain sand mixed with broken shell material. Benthic relief is characterised by shallow hills and hollows, suggesting that the substrate is reasonably mobile and there is likely some shifting of these features through time. The site has a very strong tidal influence and hence the water clarity is generally good due to the regular input of coastal water. In summary, the environment is very typical for the southern coast of the Bellarine Peninsula and many of the southern areas of Port Phillip Bay.

Benthic biota

A total of 22 sedentary benthic species were identified across the three sites: two seagrass species, six brown algae, five red algae, four green algae, two sponges and three ascidians (Table 1a-c). The dominant habitat-forming species at all locations was the seagrass *Zostera nigracaulis*, covering 69% of the *Clarence* wreck site, 29% of the southern and 31% of the western reference sites. Particularly abundant were two brown alga species of the family Dictyotaceae: *Dictyopteris muelleri* (15, 12 and 23% respectively) and *Lobospira decipiens* (7, 29 and 27% respectively). Also of note was the significant coverage of the introduced sea grape ascidian *Molgula manhattensis* (12, 10 and 14% respectively). *M. manhattensis* was mostly buried in the sandy sediment and often only the siphon was visible. It also formed an attachment point for some brown and red algae, and hence the point-intersect method was likely to under-estimate the actual coverage of this species. Large amounts of drift algae were present at all sites, mostly large browns that grow predominantly on the open-coast and Port Phillip Heads such as *Phyllospora comosa.* These drift algae were not counted in the species present as they were not attached to substrate.

Mobile fish

Eight mobile fish species were identified across the three sites, with five of these found only on the *Clarence* wreck site (Table 2). Only the southern goatfish *Upeneichthys vlamingii* was found at all three sites and was the most abundant species. Mobile fish species were either benthic feeding species (goatfish, dusky morwong, rock flathead and southern fiddler ray) or seagrass-algal associated (leatherjacket, wrasse), with no pelagic species observed.

Cryptic fish

Nine species of cryptic fish were observed at the three sites, with the highest diversity of eight species found at the *Clarence* wreck site (Table 3). Compared to mobile fish the cryptic species were evenly distributed, with six species were observed at all three sites. The most common species was the sand goby *Nesogobius* spp. (# gobies m^{-2} = 0.5 ± 0.1 SE) which was observed on sand patches between seagrass habitat, and the common triplefin *Norfolkia clarkei* (# triplefins m^{-2} = 0.36 ± 0.07 SE) which was observed amongst seagrass, small holes and crevices. Some extremely cryptic fish such as pipefish and weedfish were likely to be underestimated in the visual surveys, and require a high disturbance technique such as netting or anaesthetic to accurately sample.

Mobile invertebrates

Twelve species of mobile invertebrates were identified with high diversity observed at all sites (Table 4). Five species – commercial scallop, red rock crab, hermit crab and common anemone – were observed at all three sites. Most abundant at the *Clarence* site was the glass shrimp *Macrobrachium intermedium* (# shrimp m^{-2} = 0.3 ± 0.1 SE) observed exclusively within the seagrass canopy, and the red rock crab *Nectocarcinus integrifons* (# crabs m^{-2} = 0.2 ± 0.1 SE) which inhabited small crevices and holes in the sand.

Table 1. Presence-absence of benthic biota species amongst sites.

a) Seagrasses and brown algae

	MAGNOLIOPHYTA - Seagrasses			PHEAOPHYTA - Brown algae						
	Zostera nigracaulis	*Halophila* spp.	*Seagrass spp. diversity*	*Dictyopteris muelleri*	*Lobospira bicuspidate*	*Sargassum vestitum*	*Cystophora* spp.	*Ecklonia radiata*	*Dictyota marginatus*	*Brown algae spp. diversity*
Clarence wreck	Y	Y	2	Y	Y	Y	N	Y	N	4
Reference South	Y	Y	2	Y	Y	N	Y	N	N	3
Reference West	Y	Y	2	Y	Y	N	Y	Y	Y	5
2012 *Clarence* surveys	N	N	1*	Y	N	Y	N	Y	N	4**

* 2012 surveys identified the intertidal seagrass *Zostera muelleri* which is most likely a mis-identification.

**2012 surveys also identified *Phyllospora comosa*, which was present in the 2015 survey but was considered drift and not counted as benthic biota.

Red and green algae

	RHODOPHYTA – Red algae						CHLOROPHYTA – Green algae				
	Gloiosaccion brownii	*Botryocladia Sonderi*	*Laurencia filiformis*	*Polysiphonia decipiens*	*Plocamium mertensii*	*# red algae spp.*	*Codium fragile*	*Codium harveyi*	*Calerpa remotifolia*	*Ulva australis*	*Green algae spp. diversity*
Clarence wreck	Y	Y	Y	Y	Y	5	Y	N	N	Y	2
Reference South	Y	N	N	Y	Y	3	N	Y	Y	Y	3
Reference West	N	N	N	N	Y	1	Y	Y	N	Y	3
2012 *Clarence* surveys	N	N	N	N	N	3*	Y	N	Y	Y	3

* 2012 surveys identified *Champia viridis,Rhodomenia australis* and an unidentified thallose red.

Sponges and ascidians

	PORIFERA - Sponges			*ASCIDICEA – Sea squirts*			
	Darwinella australiensis	*Tethya* spp.	Sponge spp. diversity	*Molgula manhattensis*	*Pyura stolonifera*	*Herdmania grandis*	Ascidian spp. diversity
Clarence wreck	N	Y	1	Y	N	N	1
Reference South	Y	Y	2	Y	Y	Y	3
Reference West	Y	Y	2	Y	N	Y	2
2012 *Clarence* surveys	N	N	*	N	N	Y	1

*2012 survey notes that there were many sponge species observed but not identified.

Table 2. Presence-absence of mobile fish species

	Southern goatfish *Upeneichthys vlamingii*	Toothbrush leatherjacket *Acanthaluteres vittiger*	Dusky morwong *Dactylophora nigricans*	Rock flathead *Platycephalus leavigatus*	Six spined leatherjacket *Meuschenia freycineti*	Velvet leatherjacket *Meuschenia scaber*	Rosy wrasse *Pseudolabrus psittaculus*	Southern fiddler ray *Trygonrrhina guaneria*	Mobile fish species diversity
Clarence wreck	Y	Y	Y	Y	Y	Y	Y	N	7
Reference South	Y	N	N	N	N	N	N	N	1
Reference West	Y	Y	N	N	N	N	N	Y	3
2012 *Clarence* survey	Y	Y	N	N	Y	Y	N	N	7*

*2012 surveys also identified the globefish *Diodon nichtherus,* little weed whiting *Neoodax balteatus* and beardie *Lotella rhancina.*

Table 3. Presence-absence of cryptic fish species

	Common triple fin *Norfolkia clarkei*	Sand goby *Nesogobius* spp.	Pygmy leatherjacket *Brachaluteres jacksoniansus*	Crested weedfish *Cristiceps australis*	Common weedfish *Heteroclinus perspicillatus*	Pipefish *Stigmatopora* spp.	Painted stinkfish Ecollionymus *papilo*	Velvetfish *Aploactisoma milesii*	Snake blenny Ophiclinus spp.	Cryptic fish species diversity
Clarence wreck	Y	Y	Y	Y	Y	Y	Y	Y	N	8
Reference South	Y	Y	Y	Y	Y	Y	N	N	Y	7
Reference West	Y	Y	Y	Y	Y	Y	Y	N	N	7
Nov 2012 *Clarence* survey	N	N	N	N	N	N	N	N	N	0

Table 4. Presence-absence of mobile invertebrate species

	Scallop *Pectens fumagatus*	Red crab *Nectocarcinus integrifons*	Glass shrimp *Macrobrachium intermedium*	Sea Cucumber *Australostichopus mollis*	Hermit crab *Paguristes frontalis*	Red clawed glass shrimp *Palaemon serenus*	11-arm star *Coscinasterias muricata*	Swimming anemone *Phlyctenactis tuberculosa*	Doughboy scallop *Chlamys asperimus*	Common anemone *Anthothoe albocincta*	Decorator crab *Naxia aurita*	Southern pygmy squid *Idiosepius Notoides*	Invert species diversity
Clarence wreck	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	N	9
Reference South	Y	Y	Y	Y	Y	N	N	N	Y	Y	Y	Y	9
Reference West	Y	Y	Y	N	Y	N	Y	Y	Y	Y	N	Y	9
Nov 2012 *Clarence* survey	N	N	N	N	Y	N	Y	Y	N	N	N	N	6*

*2012 surveys also identified the common sea urchin *Heliocedaris erthrogramma,* giant spider crab *Leptomithrax gaimardii* and the catrut shell *Dicathais orbita.*

Comparisons of assemblages amongst sites

Diversity: Shannon's H

We observed significant differences ($p < 0.05$) in biological diversity of the cryptic fish and mobile invertebrate community amongst the three sites (Figure 1a, Table 5). Cryptic fish diversity was significantly higher at the *Clarence* wreck site (Shannon's H = 0.95 ± 0.08 SE) compared to the southern reference site (Shannon's H = 0.47 ± 0.09). Mobile invertebrate diversity was significantly higher at the western reference site (Shannon's H = 0.79 ± 0.13 SE) compared to the southern site (Shannon's H = 0.3 ± 0.14 SE). There were no significant differences in diversity of benthic biota amongst sites.

Abundance and total cover comparisons

We observed significant differences ($p < 0.05$) in the abundance of sand gobies, seagrass cover and total biota cover amongst the three sites (Figure 1b-c, Table 5). The abundance of sand gobies was significantly higher at the southern reference site (# gobies m^{-2} = 1.2 ± 0.2 SE) compared to the *Clarence* wreck site (# gobies m^{-2} = 0.5 ± 0.1 SE). The cover of seagrass was significantly higher at the *Clarence* wreck site (% seagrass cover = 63 ± 6.7 SE) compared to the southern (% seagrass cover = 29 ± 8.6 SE) and western (% seagrass cover = 30.6 ± 8.5 SE) reference sites. The total cover of biota was significantly higher at the wreck (% biota cover = 85 ± 5.8 SE) and western sites (% biota cover = 85 ± 5.9 SE) compared to the southern site (% biota cover = 57.2 ± 6.3 SE).

Comparisons with 2012 surveys

Unfortunately no quantitative or statistical comparisons can be made with the *Clarence* biological surveys conducted in 2012 (Professional Diving Services 2012a, 2012b). These surveys did not quantitatively survey the sites and present only a species list compiled over an unknown search time and without a clear area of survey. We present in tables 1 - 4 the species observed in the November 2012 survey. Only 14 of the 52 species observed in our study were identified as present at the wreck site in the November 2012 survey. However, three species of fish, three species of mobile invertebrate, one species of seagrass and three species of red algae were identified in 2012 and not in the current survey, for a total of 24 species identified in 2012.

Table 5. ANOVA results of comparisons amongst sites of diversity (Shannon's H) and the two most abundant species in each biota group. P-values marked with an * indicate significance at α = 0.05.

Group	Source	df	SS	MS	F-ratio	p-value
Cryptic fish	Diversity	27	1.18	0.59	6.16	0.006*
	Triplefin	27	7.47	3.7	2.2	0.12
	Sand goby	27	34.1	17	4.3	0.02*
Mobile invertebrates	Diversity	27	1.46	0.73	3.9	0.03*
	Red crab	27	0.23	0.12	0.34	0.72
	Shrimp	27	1.7	0.86	0.82	0.47
Benthic biota	Diversity	27	0.49	0.24	2.2	0.13
	Biota cover	27	51.5	25.8	7.1	0.003*
	Seagrass	27	74.5	37.3	5.1	0.01*

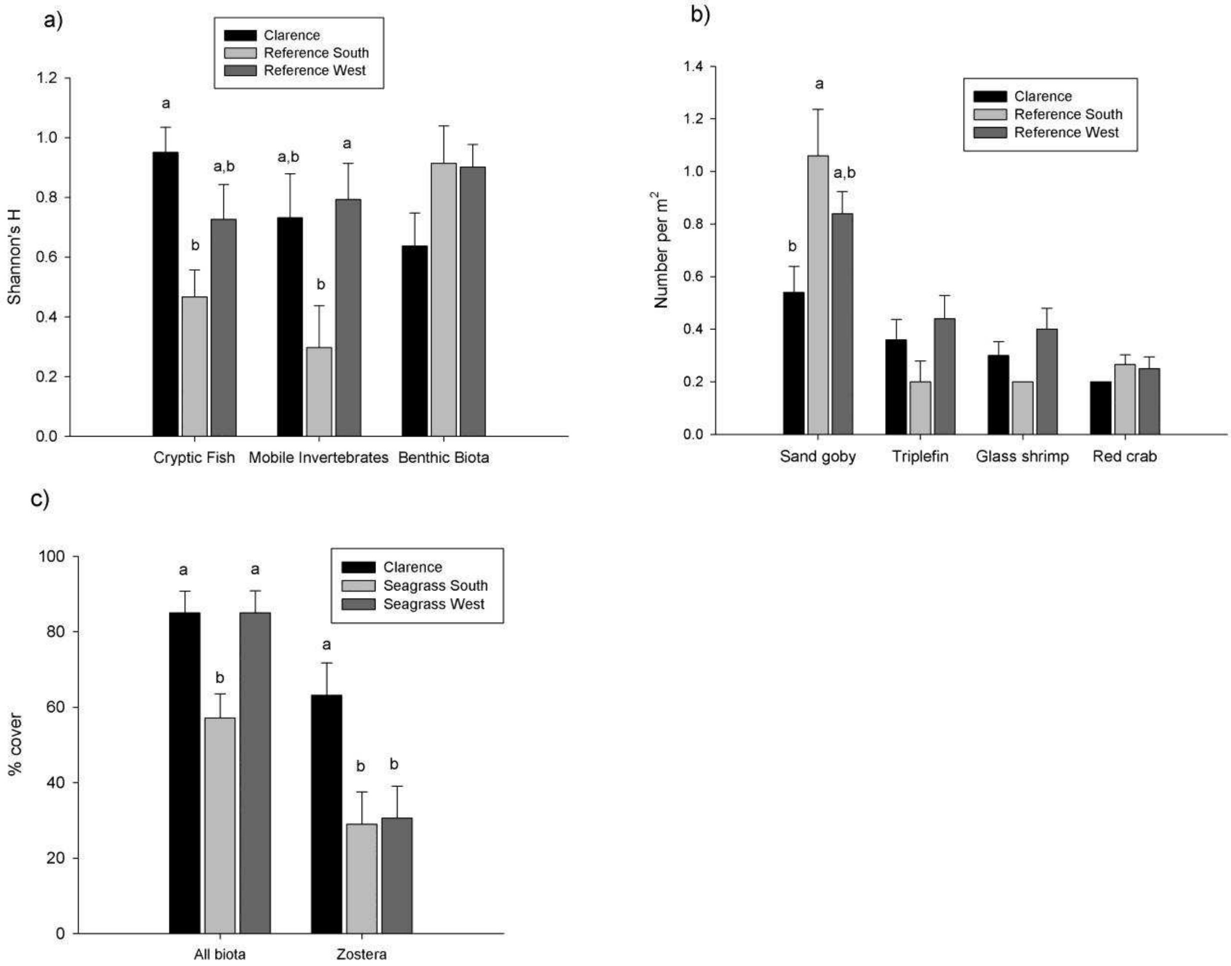


Figure 1. Comparisons of: a) Shannons-H diversity index for cryptic fish, mobile invertebrates and benthic biota, b) abundances of the two most common cryptic fish and invertebrate species, and c) total % cover of biota and the seagrass *Zostera nigracaulis* amongst the three locations. Statistical comparisons were made with ANOVA and post-hoc Tukey's tests at α=0.05. Bars with different lettering indicate a significant difference between sites, and groups with no lettering indicate no statistical significance.

Discussion

The buried *Clarence* wreck site supported a natural soft-sediment seagrass community with greater diversity of fish and invertebrates and a higher cover of seagrass than nearby reference sites. This difference is likely linked to the increased relief and complexity of the *Clarence* site compared to nearby flat sandy environments. We observed much greater species diversity than the 2012 surveys, most likely due a combination of an improved methodology and a more mature and stable community having developed over time. Overall, the results indicate a successful reburial process of the *Clarence* shipwreck that has enabled the establishment of a diverse natural biological community.

The link between substrate and benthic habitat complexity promoting species diversity and productivity is strong in marine systems (Thrush and Dayton 2002, Lohrer et al. 2004, Bouma et al. 2009). The increased sediment relief provided by the burial of the *Clarence*, along with the complexity provided by semi-exposed sandbags and ship structures provided a greater diversity of habitats than nearby sandy sediments. Whilst not explicitly measured in this report, the substrate complexity is likely to be the causal link to higher biota cover and species diversity at the *Clarence* wreck site. The seagrass cover at the *Clarence* site was over twice that of the reference sites, and seagrass systems are well documented as supporting greater diversity of fish and macro-invertebrates than soft sediment communities (Orth et al. 1984, Beck et al. 2001). Curiously, we did not see a predictive linear relationship between the benthic biota or seagrass cover and species diversity, however most species were found in low abundance and it is possible that any relationship was not simply linear. Furthermore, every point-intersect quadrats at all sites recorded some cover of seagrass and algal biota, and therefore differences may be stronger when comparing fundamentally different habitats, e.g. seagrass vs bare sand vs rock reef.

Cryptic fish and mobile invertebrate species diversity was higher at the *Clarence* site than at least one of the reference sites, likely linked to increased abiotic and biotic habitat complexity as discussed above. However one species, the sand goby *Nesogobius* spp. was in higher abundance at one reference site. This site also had the lowest cover of benthic biota and hence the highest cover of open sand, the preferred habitat for *Nesogobius.* We failed to detect any significant differences in other species abundances amongst plots, however this may be due to the generally low abundances detected, particularly of the larger mobile invertebrates.

Two invasive species were identified during the surveys: the European fan worm *Sabella spallanzanii* and the sea grape *Molgula manhattensis. S. spallanzanii* is a widespread invader in Port Phillip and while its invasion is considered irreversible (Currie and Parry 1999), it is not predicted to have large effects on the benthic environment (Ross et al. 2007). *Molgula manhattensis* is also widespread in Port Phillip Bay but unlike *S. spallanzanii* it is not well studied and little is known if its distribution and ecological impact. We observed a clear increase in soft sediment microhabitat complexity where *M. manhattensis* was present, and the holes and crevices were often inhabited by fish and invertebrates. Such bio-engineering species can significantly increase structure of benthos and complexity and productivity of food webs in soft sediment communities (Reise 2002).

We identified a more diverse biotic community in the 2015 surveys than what was reported in November 2012 (Professional Diving Services 2012b). In particular, no cryptic fish species were observed in 2012 and many invertebrate species were noted but not identified. It is therefore likely that the apparent increase in species diversity is linked to the change in survey methodology, where the 2015 surveys were more focused and rigorous. All species identified in 2015 are extremely typical for Port Phillip Bay sandy-seagrass communities (Jenkins et al. 1997, Wilson et al. 1998) and it is unlikely there has been any significant change between the surveys. It is possible that the more mature habitat two years after the reburial now supports a more diverse community, but we cannot make that deduction on the information available.

In summary, the *Clarence* site is an example of a successfully restored excavation site that not only resembles nearby habitats but supports a more diverse biological community. For the purposes of ecological restoration, the *Clarence* reburial component can therefore be considered a success.

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Appendix E: Geomorphology and XRD Analysis (Zubryzcka et al. 2014)

Tracking environmental and historical footprints on *Clarence*: Comparative XRD analysis of clay-rich sediment samples from a 19th century wreck site in Port Phillip Bay, Victoria, Australia

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Abstract

Little is known about shipbuilding in Australia in the early to mid-19th century. Under the Australian Research Council (ARC) funded Australian Historic Shipwreck Preservation Project (AHSPP) (www.ahspp.org.au), underwater excavations were carried out in April-May 2012 on the historic trading schooner Clarence, wrecked in shallow waters at Port Phillip Bay, Victoria in September 1850. During excavations, cores collected by lead investigator Peter Veth and principle investigator Vicki Richards were found to contain clay-rich sediment, thought to be ballast. This discovery stimulated investigations of the micro-sedimentary environments and taphonomy associated with the vessel, especially fine-grain sediment supply to the wreck and current and tidal influences on the stability of sediments lodged in and around the site. In order to address these questions, sediment samples were collected from the wreck, seabed and adjacent shorelines. Clay fractions were analysed at the Australian National University (ANU) using X-Ray Diffraction (XRD). Key objectives were to compare mineral signatures in the 'ballast' from clay-rich sources on the seabed and coastal foreshores possibly incorporated as the vessel foundered. Results successfully *differentiate a) individual samples by seabed location and b) "ballast" samples in the wreck structure from sampled points around the wreck. The findings suggest that fine sediment within the Clarence shipwreck is likely to be clay ballast, emplaced at some point during the schooner's working life. The results also inform questions regarding the longer-term conservation of Clarence and similar wrecks located in Australian and Southeast Asian shallow-water settings.*

Introduction

Clarence, one of Australia's best preserved carvel-built, two-masted wooden trading schooners (Gesner, 1985), was constructed on the Williams River in New South Wales by Sydney merchants Gordon Sandernais and Thomas Ayers in 1841 (Coroneos, 1991). At the time, the Williams River shipbuilding industry was in its early stages of growth, producing unique examples of early shipbuilding techniques in Australia (Taylor, 1977). Small wooden coastal trading vessels were integral to the survival and development of Australia in the early to mid-19th century before the adoption of steam transport (Taylor, 1977). For the next nine years, *Clarence* worked as a trade vessel, transporting goods and passengers to and from Victoria, New South Wales and Tasmania. On the 2nd of September 1850, the vessel foundered on a sand bank in Port Phillip Bay while transporting sheep and other goods from Melbourne to Hobart. The vessel remained partially submerged for a number of years until eventually retreating to the sea floor (Gesner, 1985).

In the mid-1980s the wreck, now protected under the *Victorian Heritage Act 1995,* was rediscovered and its historical and archaeological significance acknowledged as a result of investigations conducted by the Maritime Archaeology Association of Victoria (MAAV) (Gesner, 1985; Harvey, 1986, 1989). These findings were subsequently reported to the Maritime Archaeology Unit (MAU) of the Victoria Archaeology Survey (VAS). In turn, an environmental monitoring program and report was compiled by Coroneos (1991). Today the wreck is located in shallow waters (4-5 metres deep) where natural processes and small vessel anchorage are negatively impacting the vessel's structural preservation.

In April-May 2012, in accordance with the United Nations Educational, Scientific and Cultural Organisation (UNESCO) *Convention on the Protection of the Underwater Cultural Heritage*, the first phase of excavation, reburial and *in-situ* preservation of *Clarence* was undertaken by the ARC funded AHSPP. During excavations, it was apparent that there was a shallow layer of loose marine sediment overlying a dense clay-rich unit (appearing to have retained marks possibly produced by bucketing of clay into the hold of the schooner) (Veth et al, 2013) lodged within the vessel structure on top of the schooner's ceiling timbers, between 30-

50 cm in depth (Taylor, 2013). A number of finds including cask staves and lids; coir cordage; leather patches and other items were also found within the clay deposit (Veth et al, 2013). Chief investigators Peter Veth, Vicki Richards and project diver Mike Nash, collected cores of the deposit and sediment in and around the wreck. Although clay is proposed to have been a popular form of ballast material in the 19th century (Taylor, 2013), little contemporary or historic material exists regarding its use in Australia. This material makes it difficult to pinpoint particular locations in which clay was collected or how widespread the practice was. If clay-rich sediments are confirmed to be ballast, *Clarence* could be the first example of a clay ballasted vessel to be located and sampled in the country (Veth et al, 2013).

This discovery and questions surrounding future preservation of the wreck stimulated investigations into micro-sedimentary environments and taphonomy associated with the site and the stability of sediments lodged in and around the wreck. Key objectives were to compare mineral signatures in the 'ballast' from clay-rich sources on the seabed and coastal foreshores to confirm the likelihood of clay-rich sediments being ballast. In order to address these questions, sediment samples were collected from the surrounding onshore landscape and analysed using XRD in March 2013 along with samples collected in April-May 2012 from the wreck and adjacent seabed at the Research School of Earth Sciences (RSES), ANU. This analysis was also undertaken to identify the extent of sediment preservation or damage within the wreck.

XRD is considered a cheap, fast and relatively effective method for identifying and analysing clay minerals. Although some criticisms have been made in regards to its overall accuracy, if correct precautions are taken it can be a useful tool in identifying clay mineral variations in sediments (Kahle et al., 2002).

Procedures and Methods

Sample Sets and Sampling and Preparation Techniques

Initial XRD analysis was carried out on nine sediment samples collected by project divers as part of the *Clarence* excavations.

- **Set A:** CLI1-0006-9. Samples retrieved as either grab samples or undisturbed cores from the wreck site. Locations are shown in Fig. 1.
- **Set B:** CLI2-0001-4 and CLI2-0010. Samples retrieved as either grab samples or undisturbed cores from the seabed surrounding the wreck. Locations are shown in Fig. 1.

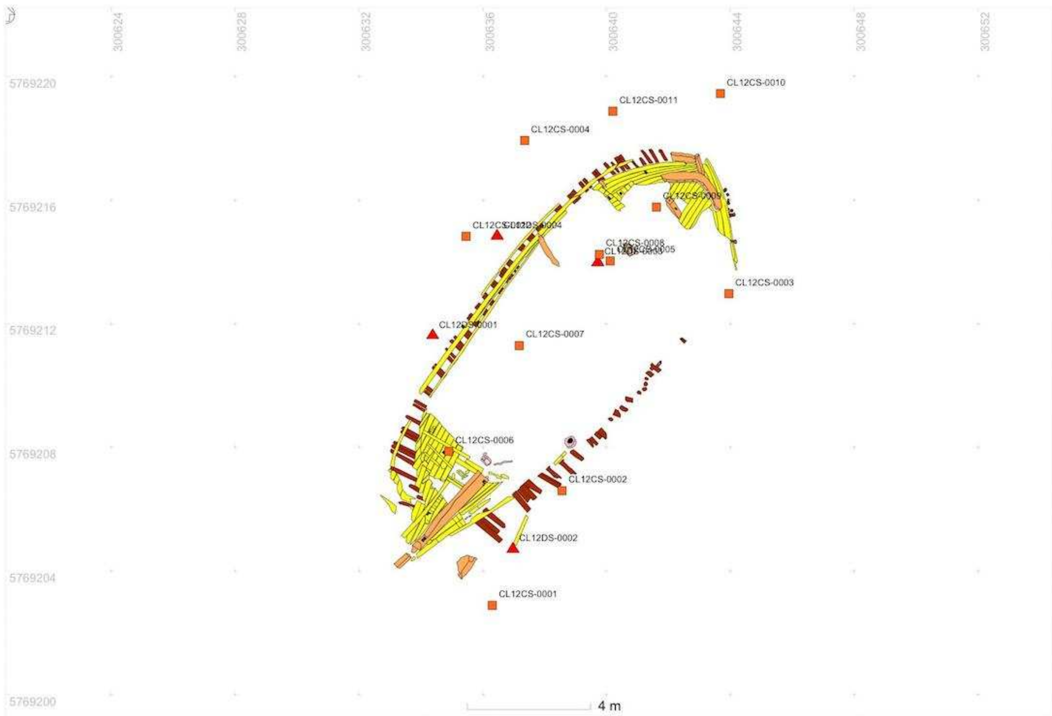

Figure 1. Short core and grab sample locations in the wreck of the *Clarence* (A. Khan).

XRD analysis was then carried out on 15 samples taken from offshore geography directly associated with Port Phillip Bay during a field trip to the area in March 2013. At the *Clarence* site, the major mechanism by which terrestrial-derived fine grain sediments enter the near shore zone will be run-off plumes after heavy rain. Cliff collapse and direct wave erosion of regolith at cliff bases will make minor contributions (Cardno, 2011). The bedrock and saprolites sampled also approximate the range of deposits likely to be forming seabeds around and beneath the locations where *Clarence* foundered. The following samples were collected based on the above assumptions.

- **Set C:** SPA1-15. 50-200g of well sorted deposits were collected from five locations across the headlands of Port Arlington and St Leonards (Fig. 2) and stored in clear zip-lock bags. Samples were retrieved from exposures and sections along low cliffed shorelines and one low elevation intertidal clay-pan. Locations and sampling design aimed to produce representative examples of sediments in the complex weathered geology and regolith of Bellarine shorelines, which are actively eroding and releasing sediments into the near shore zone.
- SPA1-5 and 12-15 were collected from eroding cliff sections.
- SPA 6 and 7 were collected from an intertidal weathered outcrop.
- SPA 8, 9 and 10 were collected from Edwards Point, where a salt-pan and mudflat are situated. This site was chosen and sampled as an example of a sediment sink where fine clay-silts have settled from an intertidal water column behind a bay bar sand barrier. These provide a first-order proxy for sediments/clay mineralogies likely to deposit out of the Port Phillip Bay water column.
- SPA11 was sampled from St Leonards Beach, seaward of the adjacent mudflat at Edwards Point.

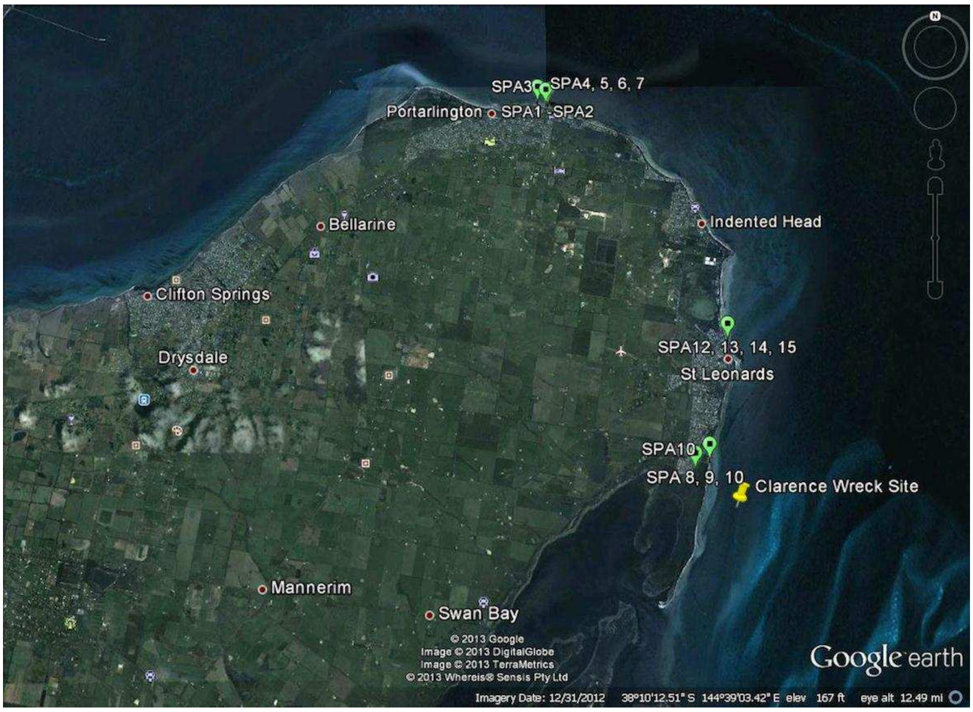

Figure 2. Locations of SPA1-15 sediment samples surrounding Port Phillip Bay (Google Earth 2013).

Methods

Analysed sediment from Set A was carefully removed from cores in order to avoid contamination of clay-rich deposits with overlying loose marine sediment. Analysed sediment from Set B was sampled at 2cm intervals in order to collect a representative sample of surface and underlying sediments on the sea floor. Therefore, XRD analysis on all Set B samples (except CLI2-0004 and CLI2-0010) was conducted twice per core and conducted on all aspects of the sample, including miscellaneous marine sediment. Analysed sediment from Set C was prepared in order to produce an accurate representation of coastal landscape formations. All remaining sediment from Sets A, B and C were retained in separate storage containers at the RSES, ANU. All sample sets were prepared and analysed using powder XRD and clay separation methods.

Powder XRD was carried out with a SIEMENS D501 Bragg-Brentano diffractometer equipped with a graphite monochromator and scintillation detector, using CuK□ radiation. Bulk samples were milled for 10 min in ethanol with a McCrone Micronizing Mill, and dried at 40°C. Samples were suspended on a side-packed sample holder and analysed from 2 to 70° 2-theta, at a step width of 0.02° and a scan speed of 1° per minute. Clay separation was performed by the settling method and samples prepared according to the Millipore Filter Transfer Method (Moore and Reynolds, 1997). Clay samples were analysed after Mg-saturation (scan range 2-42° 2theta, step width 0.02°, scan speed 1°/min), saturation with ethylene glycol (2-32°, 0.02°, 1°/min), and heating to 350°C (2-28°, 0.02°, 1°/min) and to 550°C (2-28°, 0.02°, 1°/min). Results were interpreted using the Bruker AXS software package Diffrac*plus* Eva 10 (2003) for identification, and Siroquant V3 for quantification (using the bulk scan).

Results

Results are shown in Tables 1, 2 and 3 and Fig. 3. Table 1 represents results from Set A, collected from within the wreck. Table 2 represents results from Set B, collected from the sea floor surrounding the wreck site. Table 3 represents results from Set C, collected from surrounding coastal geologies in Port Phillip Bay. Fig. 3 illustrates variations in mineralogical compositions in Sets A and B, specifically with regards to kaolinite, plagioclase and clinopyroxene quantities.

Small quantities of vermiculite were present throughout all sample sets: Set A contained an average of 0.50 ± 0.03%, one sample in Set B contained 0.4% vermiculite and three samples in Set C contained traces of the mineral (SPA5, 0.1%, SPA7, 0.4% and SPA 14, 0.6%). Calcite and aragonite were not well represented in Set A, however CLI-0009, contained 5.1% calcite and 6.2% aragonite. Quartz, likely to be associated with loose sand particles from the surrounding seabed, was abundant in Sets A (Mean (M) = 29.9 ± 6.0%) and B (M = 27.5 ± 1.0%). Sets A and B contained halite that can be attributed to trace levels of salt water retained in samples during preparation.

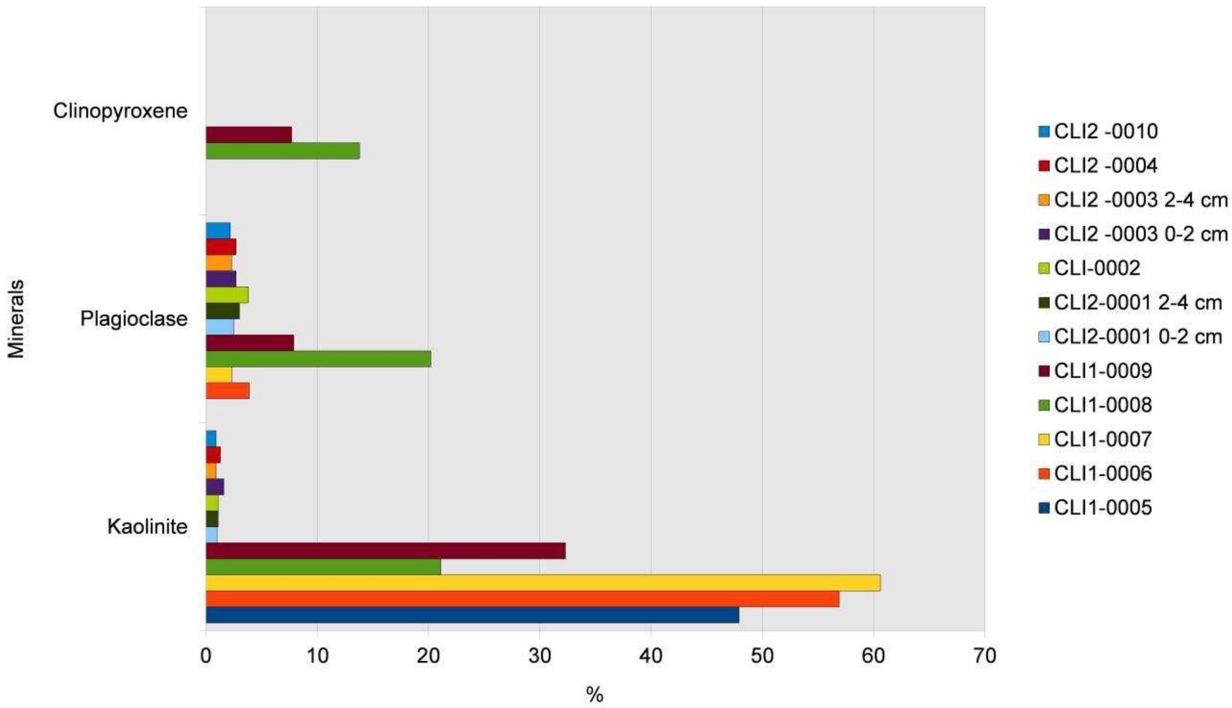

Figure 3. Mineralogical percentages of kaolinite, plagioclase and clinopyroxene in sets A and B (A. Zubrzycka).

Small quantities of illite/smectite were present in the majority of Set B samples (M = 0.4 ± 0.3%) while only one sample in Set A, CLI-0005, contained the clay mineral (5.6%). The presence of clinopyroxene was unique to Set A samples Cl10008 (13.8%) and CLI10009 (7.7%), which were collected in direct association with clay-rich deposits in the wreck (Fig. 3). Large quantities of kaolinite were present in Set A (M = 43.7 ± 16.7%). In comparison, Set B samples were clay poor, containing only trace levels of kaolinite (M = 1.1 ±

0.2%) (Fig. 3). Plagioclase was present in both Set A and B with Set A containing an average of 6.8 ± 7.9% and Set B an average of 2.7 ± 0.5% (Fig. 3). Calcite and aragonite were found in abundance in Set B (M = 51.2 ± 2.5% and 13.5 ± 0.8%, respectively).

All Set C samples, except SPA11 (beach sand), were clay rich and contained little to no traces of feldspars, such as plagioclase (0%) and K-feldspar, which was only present in SPA3 (1.8%). In comparison, Set A contained an average of 3.3 ± 2% K-feldspar. Only one sample in Set C, SPA10, contained aragonite (15.3%) probably associated with a midden deposit or activity associated with higher sea levels or storm surges. Clay fractions from SPA1 and 8 were dominated with illite/muscovite (27.4% and 32.9%, respectively). Clay fractions from SPA4 (74.3%), SPA5 (89.3%), SPA6 (85.6%) and SPA15 (87.8%) were dominated by kaolinite. SPA7 contained the largest quantity of kaolinite at 96.3%. Overall, the mean quantity of kaolinite within Set C was 40.1 ± 37.8% (as opposed to M = 43.7 ± 16.7% in Set A and 1.1 ± 0.2% in Set B). SPA2 was dominated by goethite (52.6%), which was not present in Set A or B. Set C contained a mean average of 24.8 ± 25.3% quartz. This average was reached by excluding SPA11, a sample of beach sand containing 97.7% quartz. Average quartz quantities in Set C including SPA11 is 29.7 ± 30.8%. Anatase was present in SPA4 (3.9%), SPA5 (4.6%), SPA6 (2.9%) and SPA 7 (2.7%), all collected from low lying cliff sections. Because a number of samples, especially those within data sets A and B contained halite and/or calcite inaccurate results relating to quantification of minerals and clays in the final stages of data analysis were present. In order to account for these irregularities total clays with and without these minerals have been included in all tables.

Discussion

The hypothesis that clay deposits accumulated in *Clarence* after becoming submerged in its present position as a result of slack water "fines settling" within the vessel is inconsistent with data accumulated from the XRD analysis of all samples. This can be observed by comparing mineralogical variability and clay quantities from all sample sets, especially those in Set A and B. Some of the most significant results came from samples CLI1-0008 and CLI1-0009, collected from clay-rich deposits thought to be ballast. These were the only collected and analysed samples to contain clinopyroxene. All samples in Set A contained high percentages of kaolinite, however, CLI1-0008 and 0009 contained significantly less kaolinite (21.1% in CLI1-0008 and 32.3% in CLI1-0009) than analysed samples collected from the wreck, which contained an average of 55.1 ± 6.5% kaolinite (Fig. 3). CLI1-0008 and 0009 also contained higher quantities of plagioclase and K-feldspar than other samples (see Table 1 and Fig. 3). Thus, clay-rich sediment, thought to be ballast, found near the schooner's ceiling planking contains a unique mineralogical composition compared to other sampled sediments within the wreck structure.

The hypothesis that clay-rich sediments may have accumulated on the wreck over time, taking on the appearance of clay ballast, is also unlikely based on results from Set B. If clay rich sediments derived from the surrounding landscape had settled on the wreck via storm surges or tidal and current activity, it is likely that similar clay minerals would be present on the adjacent seabed. However, low quantities of kaolinite and a complete lack of clinopyroxene in Set B suggest that this is not the case (Fig. 3).

XRD results from Set C also indicate that there is no mineralogical relationship between sediments collected from surrounding coastal geologies and clay-rich sediments found within the wreck.

In regards to the stability of sediments within the wreck, comparing mineralogical data from sample Sets A and B indicates that bioturbation and damaging ocean currents have had minimal effect on what may be *in situ* clay sediments directly associated with the wreck. This can be observed via the presence of calcite in Set A where the mineral is only present in CLI-0009 (5.1%). However, biased sample preparation in the lab may be associated with this result, i.e. shell fragments and other material being removed from Set A and B samples prior to milling.

Conclusion

The wreck of the *Clarence* can provide researchers with valuable information on the history of shipbuilding and ballast use in Australia during the early to mid-19th Century. The location of the wreck also carries the potential to inform researchers of the detrimental effect environmental and anthropogenic activity may have on the survival of the *Clarence* and other wrecks in similar locations. The discovery of clay-rich sediment during the 2012 excavation gave researchers a unique opportunity to investigate both of these questions using identical methodologies.

Results from XRD analysis successfully differentiated samples collected from the seabed adjacent to the wreck, clay-rich sediments collected within the wreck and sediment collected from the surrounding coastline. This suggests that clay-rich sediments are unlikely to have been transported to the wreck via factors such as storm surges or ocean currents carrying fine grained sediments from the adjacent coastline. Findings suggest that clay sediment within the *Clarence* shipwreck is likely to be clay ballast or another form of clay material, emplaced in the vessel at some point during its working life. Results were further emphasised due to the presence of clinopyroxene, plagioclase and kaolinite in samples directly associated with clay-rich deposits found near the hull of the vessel. The survival of clay-rich sediment within the wreck suggests that although natural and anthropogenic activity can have a detrimental effect on the preservation of underwater cultural heritage, it is possible for archaeologically significant material to be well preserved within these contexts.

In order to reach a more definitive conclusion on the likelihood that clay-rich deposits are indeed ballast, more data from Australian built wrecks and archival material is required. It is also suggested that further comparative analysis of clay-rich sediments found on the wreck and the surrounding landscape be undertaken using alternative analytical methods.

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Table 1. CLI1 samples collected from *Clarence* wreck site, April/May 2012.

	CLI1-0005	CLI1-0006	CLI1-0007	CLI1-0008	CLI1-0009
Location	Close to ceiling planking near foremast stump	Near keelson, stern end	Centre of wreck	Close to ceiling planking near foremast stump	Near ceiling planking, bow end
Goodness of fit X^2	**3.16**	**3.80**	**3.31**	**4.09**	**3.55**
Minerals					
Quartz	34.9	22.5	25.2	36.6	30.4
Plagioclase	-	3.9	2.3	20.2	7.9
K-feldspar	-	3.6	3.2	4.8	5.0
Halite	1.2	5.9	2.5	0.5	0.6
Calcite	-	-	-	-	5.1
Illite/smectite	5.6	-	-	-	-
Vermiculite	-	0.2	0.7	0.6	0.8
Aragonite	-	-	-	-	6.2
Gypsum	-	-	-	-	2.1
Illite/muscovite	10.4	7.0	5.5	2.4	1.9
Kaolinite	47.9	56.9	60.6	21.1	32.3
Clinopyroxene	-	-	-	**13.8**	**7.7**
Total	100	100	100	100	100
Total clay	**63.9**	**64.1**	**66.8**	**24.1**	**35.0**
Total clay w/out carbonates or halite	**64.7**	**68.1**	**68.5**	**24.2**	**39.7**

Table 2. **CLI2 samples collected from adjacent sea-floor associated with Clarence wreck site, April/May 2012.**

	CLI2-0001 0-2 cm	CLI2-0001 2-4 cm	CLI-0002	CLI2-0003 0-2 cm	CLI2-0003 2-4 cm	CLI2-0004	CLI2-0010
Location	Stern end, stb side.	Stern end, stb side.	Stern end, stb side.	Bow end, stb side.	Bow end, stb side.	Bow end, port side.	Bow end, port side.
Goodness of fit X^2	**2.76**	**2.55**	**2.52**	**2.43**	**2.47**	**2.29**	**2.38**
Minerals							
Quartz	28.5	30.6	28.4	28.7	25.4	24.8	26.1
Plagioclase	2.5	3.0	3.8	2.7	2.3	2.7	2.2
Halite	1.3	0.6	1.2	1.0	1.6	0.9	1.1
Calcite	51.3	48.7	48.2	49.3	53.6	54.7	52.5
Dolomite	1.6	1.1	1.1	1.2	1.0	1.0	1.2
Aragonite	12.5	12.5	14.2	14.7	13.6	13.3	13.9
Vermiculite	-	0.4	-	-	-	-	-
Illite/muscovite	1.3	1.0	1.5	0.5	1.2	1.0	1.8
Illite/smectite	-	1.0	0.5	0.3	0.4	0.3	0.3
Kaolinite	1.0	1.1	1.1	1.6	0.9	1.3	0.9
Total	100	100	100	100	100	100	100
Total clay	**2.3**	**3.5**	**3.1**	**2.4**	**2.5**	**2.6**	**3.0**
Total clay w/out carbonates and halite	**6.9**	**9.4**	**8.8**	**7.1**	**8.3**	**8.6**	**9.6**

Table 3. SPA samples collected from local geology, March 2013.

	SPA1	SPA2	SPA3	SPA4	SPA5	SPA6	SPA7	SPA8	SPA9	SPA10	SPA11	SPA12	SPA13	SPA14	SPA15
Goodness of fit X^2	2.97	2.55	3.39	3.57	4.85	4.51	5.15	4.32	4.07	3.42	3.04	3.89	3.99	4.59	4.51
Minerals															
Quartz	44.1	28.1	64.9	-	0.5	0.3	-	14.9	13.9	25.9	97.7	74.4	55.4	17.6	8.4
K-feldspar	-	-	1.8	-	-	-	-	-	-	-	-	-	-	-	-
Goethite	10.7	52.6	-	1.6	3.4	7.4	-	-	-	-	-	-	10.9	14.9	-
Hematite	-	-	-	14.8		3.1	-	-	-	-	2.3	2.8	-	-	-
Halite	-	-	-	5.4	1.8	0.7	0.6	14.7	42.8	9.4	-	-	-	-	1.9
Calcite	14.7	4.4	6.5	-	-	-	-	1.8	-	11.0	-	-	-	-	-
Aragonite	-	-	-	-	-	-	-	-	-	15.8	-	-	-	-	-
Gypsum	-	-	1.6	-	-	-	-	1.3	3.7	1.5	-	1.1	0.7	-	-
Smectite	-	9.6	-	-	-	-	-	-	-	-	-	-	-	-	-
Vermiculite	-	-	-	-	0.1	-	0.4	-	-	-	-	-	-	0.6	-
Illite/ muscovite	27.4	3	20.8	-	0.30	-	-	32.9	16.8	18.8	-	-	-	1.9	1.9
Illite/ smectite	-	-	-	-	-	-	-	17.5	10.6	7.5	-	-	-	-	-
Kaolinite	3.1	2.3	4.4	74.3	89.3	85.6	96.3	16.9	12.2	10.1	-	21.7	33.0	65.0	87.8
Anatase	-	-	-	3.9	4.6	2.9	2.7	-	-	-	-	-	-	-	-
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Total Clay	30.5	14.9	25.2	74.3	89.7	85.6	96.7	67.3	39.6	36.4	0.0	21.7	33.0	67.5	89.7
Total clay w/out carbonates and halite	35.8	15.6	27	78.5	91.3	86.2	97.3	80.6	69.2	57.1	0.0	22.3	33.0	67.5	91.4

Appendix F: *In-Situ* Preservation Protocols and Guidelines (DRAFT)

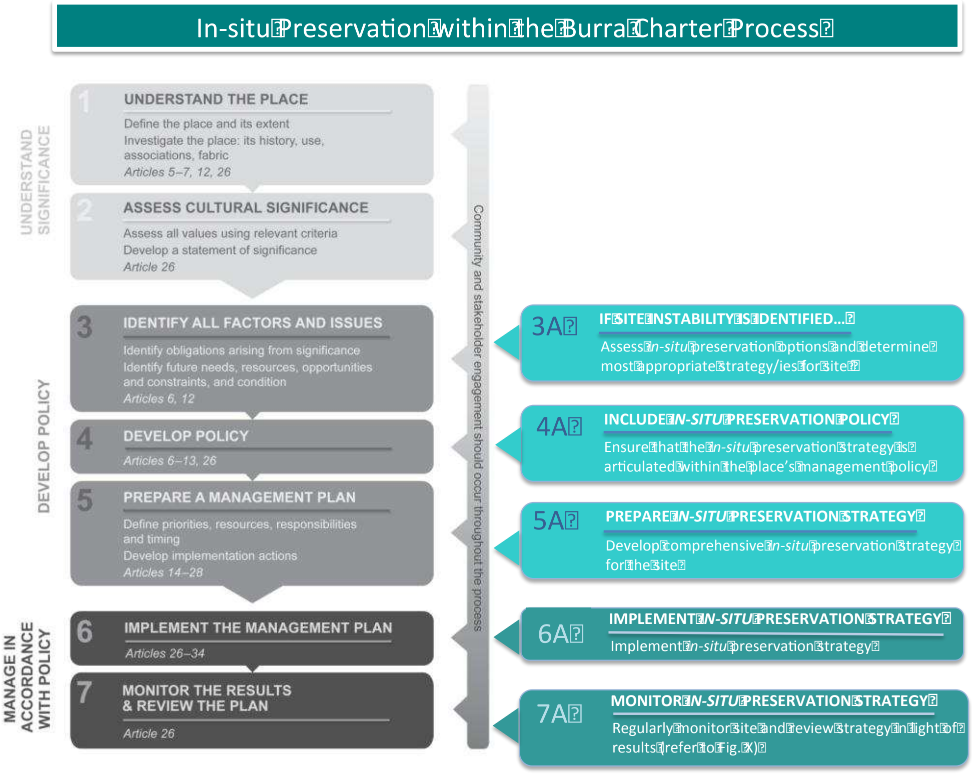
Preserving Shipwrecks *In Situ*: Protocols and guidelines for Australian underwater cultural heritage

Prepared for the Australian Historic Shipwreck Preservation Project by Philippou, C., Richards, V., Veth, P. and D. Shefi 2015

Introduction

The discovery of a new cultural heritage place whether submerged, coastal or terrestrial should at the outset prompt research into the archaeological, historical and contemporary importance to assist in developing an understanding of the cultural heritage significance of the site. In Australia, the accepted guiding document for establishing cultural significance and developing conservation management policies and plans is the Australia ICOMOS *Burra Charter* (2013) (Australia ICOMOS Inc. 2013). As a well-established and accepted set of conservation principles, the *Burra Charter* assists place managers and people working in the field of heritage conservation to methodically assess the significance of places. It is therefore recommended that place managers always refer to this document and implement its suggested processes when considering using the following set of guidelines and protocols for *in-situ* preservation of Underwater Cultural Heritage (UCH) sites (Fig. 1). Any preservation action needs to be informed by the significance of the place in addition to legislative and permitting requirements.

Once significance has been established, management policy can be developed that is both practical and aspirational. The level of significance of the place should be a primary consideration in making management decisions but it has to be viewed in the context of relevant legislative requirements. These guidelines should be read with the understanding that place managers have a thorough knowledge of the UCH resources within their jurisdiction. This includes but is not limited to, an understanding of the cultural significance of individual and groups of places, combined with systematic management strategies, which assist in the development of good preservation outcomes. Guidelines by their very nature do not replace the need for close consultation with a conservation scientist/conservator who can provide specific skills that assist in the development of relevant management programmes. Managers should also be aware that certain scientific analyses mentioned within the document require a conservation expert to gather and/or interpret data.



Original flow cart (in grey at left) from The Burra Charter 2013

Figure 1: The Burra Charter Process and UCH *in-situ* preservation.

In-situ preservation policy in context

Maritime archaeology in Australia and abroad has gradually shifted its focus from 'excavation and display' to 'recording and preservation'. One of the aims of the Australian Historic Shipwreck Preservation Project (AHSPP) was to explore options that allow research and rescue excavations to take place without the long-term conservation and storage issues associated with total recovery of artefacts, which can become prohibitively expensive. Increasingly researchers and practitioners acknowledge that excavation of submerged sites can have cumulative impacts, which when combined with other anthropogenic and environmental processes, can lead to partial or total loss of the remaining structure. The development of appropriate reburial methodologies to arrest or mitigate degradation is becoming critical due to the increasing industrial and residential development of coast-lines, internal waterways and other port-related structures and natural phenomena (e.g. cyclones, tsunamis, droughts) exacerbated by climate change.

In May 2009, the WreckProtect project was initiated in the Baltic to investigate *in-situ* preservation of wooden shipwrecks underwater, noting an increasing prevalence of the destructive marine bivalve, *Teredo navalis* (shipworm). The project published guidelines for implementing physical interventions for the preservation of wooden sites *in situ* (Manders 2011a, 2011b), but highlighted that they were mainly based upon literature reviews and the unpublished experiences of the authors. The editor acknowledged that there was great potential for the research and development of thorough, scientifically tested *in-situ* protection methodologies, as very few studies of that nature had been undertaken (Manders 2011a: 6).

Globally, maritime archaeologists have been actively preserving UCH *in situ* since the 1960s. Overseas examples that have been well documented and used as references for modern programmes include Lake Ijssel land reclamation and development project in Holland (de Jong 1975, 1979), and the *San Juan*, Red Bay, Canada (Stewart et. al. 1995; Waddell 1994). In Australia, there are a number of sites that have been subjected to various *in-situ* preservation and *in-situ* conservation strategies. Some early examples of *in-situ* preservation strategies were implemented on *Solway* (1837) in South Australia (Coroneos 1996, 2006), *William Salthouse* (1841) in Victoria (Harvey 1996, Hosty 1988, Staniforth 2006, Steyne 2010) and more recently, relocation of the former Hovell Pile Light (Raupp et al. 2010). These strategies were all based on the premise that re-establishing a stable environment (whether *in-situ* or in another location) through returning the disturbed remains to an anaerobic state (or close to) by whatever means (usually reburial under sediment) would assist in preserving them long-term. Unfortunately, many management plans for UCH post-implementation of *in-situ* preservation strategies have not included appropriate monitoring programmes to assess the ongoing effect of the applied mitigation strategy on the site and reinterred artefacts.

Lake Ijssel Land Reclamation, Netherlands

In 1918 the Dutch Government began building a barrier dam to separate the Zuyderzee from the North Sea. This was completed in 1932 after which they began to construct five polders in the resulting freshwater lake, Lake Ijssel. From the early 1930s to the late 1960s, the reclamation and development operations in the new polders revealed many archaeological finds and 350 shipwrecks were located. The rate of discovery of the shipwrecks far exceeded the capacity of local authorities to excavate, research recover and conserve each site hence, the most viable option was to preserve the sites *in situ*. However, during the reclamation works, lowering of the ground water table caused considerable subsidence of the lake bottom sediments and introduced oxygen into the upper levels of the reclaimed soil, which significantly increased deterioration rates of any wooden remains located in these areas through aerobic degradation processes.

A number of sites were monitored for some years and the method developed to counteract these negative effects was based on the maintenance of a high ground water table above the level of archaeological remains. In the clay sediments of the Lake Ijssel polders this was achieved by removing the sub-surface drainage pipes near the wrecks and placing plastic sheeting around and above the remains. The plastic sheeting was perforated and concave in shape, which allowed rainwater to be collected. In this way a high water level was maintained around the wreck site and encouraged the formation of an anaerobic burial environment (de Jong 1975, 1979).

***San Juan*, Red Bay, Canada**

In the early 1980s, Parks Canada excavated the remains of the *San Juan* (1565), a Basque whaler wrecked in Red Bay, Labrador. The wreck was recovered, documented and the timbers were reburied. This project was one of the earliest examples of an *in-situ* preservation programme that included monitoring of the reburied timber remains and the surrounding reburial environment. The site has been monitored through regular visual and chemical analysis, and examination of buried sacrificial modern timber samples. Whilst reburial of archaeological sites had been practiced in Canada many times before, this was the first attempt to scientifically monitor the effects of reburial upon the material remains.

Importantly, Stewart, Murdock and Waddell (1995) note that 'reburial is not second-class conservation' employed where funding for *ex-situ* conservation is lacking, but an 'appropriate form of preservation to assure the continued survival of the timbers'. The timbers were buried as deep as possible to eliminate oxygen and place the site in a location in the harbour that would avoid physical impacts. The original excavation site was selected as the reburial location as it was certain to be culturally sterile and was in a position unlikely to be affected by icebergs.

The reburial pit was lined with plastic bags, filled with local sand, and a rock wall was constructed at the perimeter. The pit was finally covered with a synthetic rubber tarpaulin that was secured in place with concrete-filled tyres.

Monitoring ports were created in the reburial mound to enable access to water samples, and for the recovery of the modern timber samples. These samples were compared with their 'twins' that had been frozen as controls. Monitoring and analysis undertaken at one, three and seven years after reburial showed that the chemical environment in the pit was suboxic, with low biological activity. The analytical technique employed on the modern wood samples could not detect any significant deterioration after seven years indicating that the reburied timbers had suffered minimal degradation since their reburial in 1985.

Some minimal physical damage to the tarpaulin was observed in 1992 and the researchers concluded that the tears and lifting of the tarpaulin were the result of direct impact from icebergs. The study report in 1995 emphasised that monitoring of reburial sites is an on-going programme that requires flexibility to adapt sampling techniques with advances in technology.

***Solway*, South Australia**

The *Solway* (1837) is one of South Australia's earliest known shipwrecks and the first inspection of the site in 1982 indicated it was extremely well-preserved, which led to the site being declared a historic shipwreck the same year. In 1994, further archaeological investigations (test excavations and a review of the significance assessment) found that considerable parts of the hull remained buried and the site had significant archaeological and research potential. However, it was noted that there was some loss of sediment and increased deterioration of the site had occurred since the early 1980s. It was obvious to the State Heritage Branch that the site was at risk but other sites under their jurisdiction were assessed to be under greater threat so a low cost mitigation strategy had to found (Coroneos 1996).

It was decided to stabilise the site with synthetic fabric sand bags pending additional funds to further investigate and protect the site. One thousand sand bags were filled with proprietary clean sand and placed over the exposed sections of the site. In conjunction with this mitigation strategy, a monitoring programme was initiated. This included measuring sediment levels on-site, noting any exposure or reburial of structural timbers and the condition of the sand bags, taking photographs from pre-determined locations and collecting meteorological data for three days before each inspection. After six months a further 300 sand bags were positioned over areas that had recently become exposed and another 500 sand bags were deposited adjacent to the site to be used in the future if required. Regular inspections of the site after the initial deployment allowed the mitigation strategy to be refined over time thereby optimising the protection of the site in the long-term (Coroneos 2006).

The sandbagging of the *Solway* was a not a unique or innovative form of *in-situ* preservation, however it did highlight the fact that a monitoring programme is a critical part of any UCH management plan.

***William Salthouse,* Victoria, Australia**

The *William Salthouse* (1840) is one of the earliest and most significant historic shipwrecks in Victoria, and has been the subject of archaeological research since its discovery in August 1982. The site was highly intact when it was first discovered during a drift dive; it is likely that underwater rock blasting for a channel widening and deepening program that commenced in May of that year caused the site to scour out of the sand bar in a depth of 9 m of water.

Soon after the discovery of the site, it became apparent that loose material was being interfered with by divers and also moved about by the strong currents. Test excavations in March 1983 found that the wreck remained intact to just below deck level; assessment of the artefacts confirmed that it had only recently become exposed (Hosty 1988). The weight of the sand inside the wreck was forcing the hull planking to collapse, resulting in the abundant, fragile contents spilling out of the wreck and onto the seabed. It was clear that emergency stabilisation was required to prevent the total loss of this significant historic shipwreck.

Early attempts at stabilisation included: installation of wire mesh fences fixed to the seabed at right angles to the hull, to trap weed and sediments; dredging of local sand into scour holes; mass deposition of a cargo-load of dredged spoil from a hopper barge; creation of hessian sand bag embankments to fill scour holes and support the collapsing hull (Steyne 2010). This strategy, involving 1 500 sand bags filled with a small amount of cement mixed with sand, was the most successful of the early attempts until the hessian degraded and the contained sand began eroding away in the current (Hosty 1988, Steyne 2010).

With degradation of the hull and loss of portable artefacts continuing, the Maritime Archaeology Unit of the Victoria Archaeological Survey consulted with marine engineers and hydrographers to develop options to stabilise the site. It was important to employ a method to support the hull as well as trap sand, with the aim of reburying the site. The recommendation was to install artificial seagrass mats (known as Cegrass™) that had been developed to prevent and control erosion on subsea oil and gas plant in the North Sea (Harvey 1996). The Cegrass™ consists of groups of multi-length buoyant polypropylene fronds secured to the seabed and the ends floating up into the water column, thereby slowing the current and enabling mobile sediment suspended in the water column to drop down to the seabed.

The product was expensive at approximately $101.50 per m^2 and the project required 450 m^2 to enable adequate coverage around the hull (Cebo U.K. Ltd 1989). The total cost of the mats was about $50 000 out of an overall budget of $108 000 (Strachan 1988). In 1990, varying length fronds of Cegrass™ were attached to reinforcing steel mesh sheets and deployed around the site. Within weeks sediment gain was measurable on the site, and after six months the fronds (the longest of which were 150 cm) were barely visible above the accumulated sand mound. The sand levels were regularly monitored and in 1996 the site was considered stable with no signs of erosion or toe scouring (Harvey 1996). The site was visited annually from 1996 to 2006 and no noticeable changes in sediment levels were observed. The Cegrass™ was mostly buried with only the tips of the fronds visible and heavily colonised by marine organisms. However, a visit in 2008 indicated large areas of exposure especially at the stern and on the starboard side between mats, where the fronds and steel mesh frames were fully exposed along with some structural timbers on the site itself. The bow section and port side appeared unaffected. In 2009, recreational divers noted that the site was again extensively covered with very few timbers visible.

The changes in site exposure/accretion are thought to be seasonal, however there may still be continuing loss of previously preserved cargo (e.g. wooden barrels) therefore, it may be necessary to investigate new methods of *in-situ* preservation to prevent further deterioration and protect the site in the long-term. This project highlights the importance of regular monitoring of any applied *in-situ* preservation technique even after the site is thought to be stable.

Hovell Pile Light, Victoria, Australia

In 2005, during the Victorian Government's Port Melbourne Channel Deepening Project, the remains of the former Hovell Pile Light (1924-1938) were located in Port Phillip Bay. It was determined that these remains and any associated artefacts would be severely impacted by the proposed dredging operations. A decision was made that the site should be excavated, recorded, recovered and then reburied at another location in the Bay, which would not be affected by the planned dredging programme (Raupp et al. 2010).

The site was excavated by commercial divers in collaboration with maritime archaeologists. All artefacts found on the site were recorded, photographed and recovered. Some artefacts were chosen for conservation based on their condition, suitability for interpretation and display and representativeness of the site and/or uniqueness. The remainder of the artefacts were to be reburied with the main structural section. Once the site was thoroughly recorded, additional dredging occurred under the remaining structure, so lift straps could be attached in order to recover the intact structure via a crane aboard a jack up barge positioned adjacent to the site.

The pile remains and the associated artefacts were reburied in the South East Dredged Material Ground (DMG) at a precise, designated position, approximately 7 km north east of the original site at a water depth of 20 m under 4-5 m of locally dredged sand. It was assumed that this depth of sediment would encourage the formation of an anaerobic environment in the long-term and preserve the remains *in situ*. Unfortunately, no monitoring of this reburial area has been planned but it is anticipated that even if there is some loss of sediment in the future the archaeological material will be secure remaining differentially buried under such a thick layer of dredged overburden.

Scientifically validated reburial case studies

More recently, practitioners and scientists from varying disciplines have been undertaking further research into *in-situ* preservation methods including very sophisticated monitoring programmes to form a strong scientifically validated basis for these practices (Bacpoles 2002, Keller 2014, MACHU 2006, MoSS 2001, RAAR 2002, SASMAP 2012, WreckProtect 2009). A brief discussion of some of these projects is presented below.

MoSS

MoSS (Monitoring, Safeguarding and Visualising North-European Shipwreck Sites) was a research project organised by six European countries: Finland (co-ordinator), Sweden, Germany, Denmark, The Netherlands and Great Britain, funded by the organising countries and through the Culture 2000 Programme of the European Commission (MoSS 2001). The project was initiated in July 2001 and ended in June 2004. The main objectives were to increase public awareness and encourage involvement in protecting European underwater cultural heritage and eventually develop practical guidelines and tools to manage the same (Cederlund 2004, Manders 2004, Palma 2005).

The project has three main themes: **monitoring** the condition of wrecks by developing and improving the methodology and instrumentation for measuring the physical, chemical, biological and environmental conditions affecting the deterioration processes occurring on a shipwreck site; **safeguarding** by outlining, developing and trialling different models to protect shipwrecks in the long-term and finally **visualising** by exploring different techniques (e.g. 3-D modelling, sub-bottom profiling, underwater photography, etc) to better understand site formation and degradative processes occurring on-site. In addition this information would be used in such a way that the general public can visually observe previously inaccessible shipwrecks, which should then lead to greater public ownership, understanding, appreciation and ultimately active participation in protecting UCH in European waters.

The project is based on four shipwrecks all of which are significant to the European community. The wrecks are located in the Netherlands (BZN-10, 17th C, saline Wadden Sea, 7 m depth), Germany (Darsser Cog, 13th C, saline and brackish entrance to Baltic Sea, 6 m), Finland (*Vrouwe Maria*, 18th C, brackish Baltic Sea, 36 m) and Sweden (*Eric Nordevall*, 19th C, fresh water Lake Vattern, 45 m) and represent different vessel types, ages and local underwater environments.

The first three wrecks (BZN-10, Darsser Cog and *Vrouwe Maria*) were used for the **monitoring** theme to assess the different environments (both in-water and in-sediment) of each site that directly influence the state of preservation of the archaeological material. Data loggers were used on each site to measure salinity, pH, dissolved oxygen, temperature, turbidity, current and sediment flow at regular intervals over an 18 month period. Sacrificial wood samples (modern pine and oak; archaeological oak) were placed on each site with four samples wrapped in different grades of geotextile (Terram 500, 1000, 2000 and 4000) to assess the effectiveness in preventing biological degradation. The samples were attached to steel frames and placed on the seabed above the sediment surface. Five complete frames were deployed on each site to be recovered after 3, 12, 24, 36 and 48 months of exposure. In order to assess the biological processes occurring beneath the sediment sacrificial modern samples of pine and oak housed in perforated plastic pipes were buried 50 cm below the sediment surface adjacent to the BZN-10 and Darsser Cog sites. Due to the difficulties encountered inserting the samples pipes into the sediment on the *Vrouwe Maria* site they were placed just below the sediment surface. Samples were recovered after 3, 12 and 24 months of exposure.

The sacrificial samples exposed to the aerobic environment on each site were analysed by photography, x-ray spectroscopy, scanning electron microscopy (SEM), light microscopy, weight loss and wood density. The type and extent of any biological attack was also identified. The reburied sacrificial samples were analysed by SEM and wood density only.

The information obtained from the data loggers and the analyses of the aerobic sacrificial samples indicated that the environment on the *Vrouwe Maria* site was the most benign with respect to overall water movement and marine borer activity, followed by the Darsser Cog site with the BZN-10 site being the most dynamic with concomitant extensive marine borer damage observed on the wood samples. The results obtained from the analyses of the anaerobic sacrificial samples indicated a similar degradation gradient for the sites except that the samples analysed from the *Vrouwe Maria* site were more degraded than would normally be expected as they were buried near the seabed surface and not to a depth of 50 cm.

The **safeguarding** of shipwrecks consists of legal and physical components that should be intrinsically linked. The countries involved in the MoSS project all have laws and regulatory systems to protect UCH, however it was found that there is no uniformity in legal safeguarding within the European Union (EU). The project suggested that the introduction and implementation of international regulations protecting and managing UCH could be the way forward.

Physical **safeguarding** was the main focus of this theme and the use of polypropylene debris nets were tested on the BZN-10 and Darsser Cog sites. This inexpensive method was successful in trapping suspended sediment in the water column thus forming sand mounds over these sites, where the sediment was reducing in nature, protecting any exposed timbers from the depredation of fungi and shipworms and minimising artefact displacement and potential diver intervention. However, the project realised that testing only one methodology was a narrow base in which to evaluate preservation *in situ* but it was hoped to open further research and discussion.

In addition, a management plan was developed which consisted of four sections; the first an administrative section that could be used by the general public, heritage managers, policy makers, etc; the second part including the archaeological and environmental information and an assessment based on this data; a third section consisting of a cultural and historic evaluation and a final section including a site management plan with planned actions and cost-benefit analysis.

All four shipwrecks were used in the **visualising** theme but the scope of the visualisation and the methodology employed differed for each site dependent on the conditions on-site (i.e. in-water visibility), the state of preservation of the wreck, the extent of exposure and the actual visualisation requirements. For example, both the *Vrouwe Maria* and the *Eric Nordevall* are in an excellent state of preservation, lying proud of the seabed, therefore video and photographic documentation can be used immediately to visualise these wrecks. On the other hand, with the Darsser Cog and BZN-10 only sections of their hulls' remain and especially for the BZN-10, most of the remaining structure is buried in sediment. Hence, the documentation of these wrecks requires specialist archaeological 'translation' prior to being visualised as ships by the general public.

For example, due to poor visibility on-site, the general site map of the BZN-10 was produced by using standard archaeological measurements in a purpose-built CAD programme and then adding the results of the video and photography to the drawings for more detail. The Darsser Cog site had the best visibility and for this reason was chosen to test and develop underwater photogrammetry so the need for time consuming underwater archaeological measurements and subsequent drawings may be minimised or made redundant in the future. The *Vrouwe Maria* at a depth of 36 m lies in darkness for most of the year so a digital camera mounted on a ROV and a video camera operated by a diver was used to document the wreck and produce a 3-D model using the Rhinoceros programme. From this rendering a physical model was manufactured for exhibition in the Maritime Museum in Finland. Finally, similar documentation was collected on the low visibility *Eric Nordevall* site but the visualisation process has progressed even further with a full-scale replica of the ship being built.

Other methods of documenting the sites were also trialled and developed which had the capacity to both record wreck remains lying proud of the seabed and also material buried in sediment (e.g. side scan sonar, underwater georadar and multibeam side scan sonar). The results from the visualisation study hub were not only used to transfer information to the general public but also to gain a better understanding of site formation processes (i.e. sediment movement) to improve monitoring and safeguarding of UCH.

The MoSS project proved that combining the three themes (monitoring, safeguarding and visualising) within a multi-disciplinary approach is crucial in effective management of UCH. Monitoring assists in the selection of the most appropriate strategies to safeguard a site and provides longitudinal data on the effectiveness of strategies. However, visualisation is also a form of monitoring that can provide new information that may improve *in-situ* preservation strategies whilst creating public awareness that is essential in the long-term protection of UCH.

BACPOLES

BACPOLES (Preserving Cultural Heritage by Preventing Bacterial Decay of Wood in Foundation Piles and Archaeological Sites) was a European Commission funded project (EVK4-2001-00043) involving scientists from Germany, Great Britain, Italy, The Netherlands and Sweden, which commenced in February 2002 and concluded in January 2005 (Bacpoles 2002). For many years it was thought that wood located under the ground water table did not suffer from extensive biological deterioration, however in the 1990s major bacterial degradation was observed on waterlogged Dutch wooden foundation piles with very limited information available on this type of deterioration. Hence, one of the main objectives of the project was to provide knowledge on bacterial degradation of wood located in different environments, namely wooden piles and archaeological wooden remains found in both fresh and marine waters and waterlogged sediments (Klaason 2005, Manders 2004).

A standard procedure was developed and research was carried out on 27 sites in 6 European countries; 13 piling sites, 5 marine sites and 9 archaeological sites, where wood, sediment and water samples were collected and analysed. Microbiologists developed new techniques to isolate and identify wood degrading bacteria from the wood samples recovered from the sites. In addition, laboratory experiments were carried out to simulate bacterial degradation of wood under different sedimentary conditions.

The results from the 27 sampling sites showed that there was some form of bacterial degradation on all samples recovered and therefore, the consequences of this type of deterioration were widely underestimated in the European setting. More specifically, the new analytical techniques isolated a wide variety of wood degrading erosion bacteria that belonged to the *Cytophaga-Flavobacterium-Bacteroides* (CFB) complex. These bacteria occur under a wide range of environmental conditions. Based on field and laboratory measurements, erosion bacteria thrive under anoxic conditions with low levels of nitrogen and although no relationship was observed between the extent of wood degradation and the surrounding environment, an increase in the dynamic water flux throughout the wood seemed to promote bacterial deterioration of wood. Furthermore, the degree of degradation differed with wood species. Wood structures with low permeability and high lignin and chemical extractive contents were less susceptible to bacterial decay.

Further work is necessary to identify the most common erosion bacteria and gain more knowledge on the individual species and their physiological requirements to assist in developing more appropriate *in-situ* preservation strategies in the future.

RAAR

In 1998 and 1999 extensive archaeological investigations were carried out on the wreck of the *Fredricus* (1719) and cultural remains dating back to the 17th century in Marstrand harbour, Sweden. The wreck was excavated and preserved *in-situ*, however approximately 10 000 artefacts were recovered from both sites. Conservation treatment of these material finds was considered impractical and unnecessary and therefore, alternative preservation methods were sought so that the collections would not be discarded. Ninety percent of the finds were reburied in a culturally sterile and stable area on the opposite side of the harbour, which was not accessible by the general public. Metal objects were reburied in one trench whilst organics, ceramics and glass were interred in a separate trench with all finds covered by at least 50 cm of surrounding local sediment (Bergstrand 2002, Nyström 2002, Olsson 2002).

This archaeological programme was the catalyst for the international research project 'Reburial and Analyses of Archaeological Remains' (RAAR), which commenced in 2001 (RAAR 2002). The main objective of the RAAR project is to evaluate reburial as a method for long-term storage and preservation of waterlogged archaeological remains. The major aims of the project are to monitor the reburial environment in the 'storage' trenches in Marstrand harbour, to determine the effects of this reburial environment on a range of material types common to UCH sites and to provide information which links environmental parameters with the extents of degradation of these different materials.

The project is divided into six sub-projects where co-ordinators from Sweden, Denmark, Norway and Australia are in charge of a particular sub-project. The first four sub-projects investigate the effect of the burial environment on reburied modern sacrificial samples analogous to the artefacts on-site including: wood (pine, oak and spruce); ceramics and glass; metals (copper and ferrous alloys) and other organics (vegetable tanned leather, wool, silk, hemp rope, antler, horn and bovine bone). The fifth sub-project investigates the stability of modern packing and labelling materials typically used to separate and identify archaeological materials during excavation, wet storage and reburial (e.g. high density polyethylene or polypropylene, polyester, polyurethane, nylon, synthetic rubber, polyvinyl chloride, text written with pencil, waterproof marker and ballpoint pen). Since any area where archaeological artefacts are documented, relocated and reburied is akin to any above water storage area then it is important that the methods and materials used to store and identify the objects underwater are stable in the long-term. The sixth sub-project involved monitoring the reburial environment (e.g. dissolved oxygen, sulphide, pH, redox potential, organic and iron content, porosity, microbial activity) in comparison to an undisturbed control site to determine if and when the reburial environment comes to resemble the pre-excavation environment. Furthermore, the measured parameters can then be correlated to the extents of deterioration of the reburied sacrificial samples placed in the trenches, thereby allowing evaluation of the effectiveness of reburial as an *in-situ* preservation technique.

The modern sacrificial samples (and some archaeological ceramic and glass samples) were buried in 2002, with the exception of the metal samples which were buried in 2003. The samples units from each sub-project were buried to a depth of 50 cm directly adjacent to the reburial trenches, except for the wood and metal sample units, where samples were left exposed above the sediment surface, buried just under the sediment surface and 50 cm below the sediment surface. In order to determine the long-term effects of the reburial environment on the different material types, sufficient samples were reburied to allow sampling to continue for 48 years. The retrieval timeline was divided into phases as follows: Phase 1 = 1 (2003), 2 (2004) and 3 (2005) years; Phase 2 = 6 (2008) and 12 (2014) years; Phase 3 = 24 (2026) and 48 (2050) years. Sufficient funding was secured from a number of Nordic granting bodies and the collaborating institutions to complete Phase 1 of the project, however, less funds were available for the analyses of all recovered samples after 7 years in 2009 so the project focussed on gaining information about the effect of reburial on material types where very little or almost no research had been carried out previously (e.g. metals, ceramics and glass, other organics with the exception of wood and polymers) and/or the results obtained after the completion of Phase 1 were inconclusive (e.g. metals and particular ceramics, other organic materials and polymers). Unfortunately, funding applications for the 12 year retrieval in order to complete Phase 2 of the project have been unsuccessful to date.

The results from Phase 1 and part 1 of Phase 2 are published in full on the RAAR web site (RAAR 2002), however a brief summary of the findings after seven years are presented below. It should be noted that the suitability of the material types for long term reburial are only applicable to the type of sediments in the reburial trenches in Marstrand harbour and these predictions are to be confirmed through future retrievals.

Sediment - Environmental Parameters

The results from the RAAR project have shown the importance of understanding the ongoing physico-chemical and biological processes within the local sedimentary environment prior to implementing any reburial programme. The optimal depth of reburial has been a point of discussion throughout the project, especially with respect to organics and metals. The results after 7 years indicated that it is not simply a matter of reburial depth, but the type of sediment used, its properties and the processes ongoing within it – all of which vary from sediment to sediment. Based on the results to date - the implications for reburial are that sandy sediments, which are less porous and naturally contain less organic material due to their larger particle size, appear to have lower rates of mineralisation when the dominant process is sulphate reduction. This contrasts with the higher rates of mineralisation in more porous, finer grained sediment with higher organic contents.

Generally speaking, good organic and metal preservation in sediments depends on the maintenance of a stable chemical environment characterised by an anoxic, reducing environment, with near neutral pH, and low porosity, organic content and bacterial activity.

In order to classify sediments for their potential use in future reburial programmes the RAAR project recommended that the following parameters, at least, be measured and that the time (season) of sampling be considered:

Pore water parameters: Dissolved oxygen, redox potential, pH, dissolved and total iron, sulphate and sulphide content, temperature.

Sediment parameters: Particle size, porosity, organic content.

Metals

Copper alloys could be recommended for reburial in these types of sediments for a period of six years. It is probable that pure copper and brass alloy types may be buried for longer periods of time and at shallower depths, however more information is required to support this inference. On the other hand, it is not possible to recommend longer term reburial times for bronze alloys. Ferrous alloys could not be recommended for reburial even in the medium term, based on their extensive corrosion after six years.

Ceramics and glass

Reburial cannot be recommended for any type of glass or low-fired earthenware. However, the resistance of earthenware to deterioration in a marine environment varies, largely dependent on the firing conditions during manufacture. High-fired ceramic wares, such as porcelain, stoneware and also clay pipes are highly stable and should survive reburial in the long-term, however consideration should still be given to the problems of over-glaze decoration and gilding on these types of ceramics.

Wood

A burial depth of at least 50 cm is recommended for wooden artefacts but further studies on the extent of degradation versus the optimum depth of reburial in different sediments types is required.

Other Organics

Burial is not recommended for fibre artefacts, with the possible exception of large tarred ropes. Soft and hard animal products like leather, bone and antler can be considered for reburial, however reburial should be avoided if artefacts have decorative surfaces or show traces of manufacture or wear.

Packing and Labelling Materials

Generally, zip-lock polyethylene bags seemed to offer the best protection against degradation and/or infiltration of salts. Polyester geotextile possibly offers some protection from micro-organisms within the sediment and isolates the material inside from some micro-structural alteration, but it does not appear to protect against chemical alteration. Polyethylene netting offers the least protection and should be avoided. Appropriate containers for separating groups of finds include high-density polyethylene crates, polyethylene bags and geotextile envelopes, with the former the most highly recommended. Polyethylene, polyamide and polyester cords are suitable to tie and secure artefacts and labels for short term reburials (at least 7 years). For longer term reburial polyethylene ropes are recommended at this stage. The preferred options for identifying finds include the use of polyurethane tags (livestock 'ear tags'), embossed polyvinyl chloride labels (e.g. Dymo® labels), pencils or black permanent markers. Ballpoint pens, even those labelled as 'archival' should not be used.

The findings from this project have confirmed and revealed interesting information regarding the reburial of many different materials types, which has not been so thoroughly researched by any other project to date. However, seven years of reburial is an insufficient time scale for some materials to exhibit any noticeable degradative changes or for other materials to stabilise. Therefore, some conclusions regarding the suitability of certain material types for reburial are pending awaiting the results of the next experimental phase.

MACHU

Building on the findings from the MoSS project, the MACHU (Managing Cultural Heritage Underwater) project involved cultural heritage agencies from seven European countries: United Kingdom, Sweden, Germany, Poland, the Netherlands, Belgium and Portugal. It was funded by the Cultural 2000 Programme of the European Union (MACHU 2006). The project ran from September 2006 to August 2009. The project aimed to support the development of new and more effective ways of managing Europe's underwater cultural heritage by making the information more accessible to researchers, policy makers and the general public. This was achieved through the construction of a GIS based Decision Support System, which integrated the process-based knowledge with information on the legal and management status of any site as well as the potential human impact on any site or environment. The system simultaneously combined a scientific database with a web-based interface accessible by the general public.

The GIS application combined archaeological and historical data from sites with information on the burial environment (e.g. geophysical, geochemical, sedimentological and oceanographic data) and perceived threats to the sites in the short (e.g. erosion, infrastructural works, mining, fishing, etc) to long term (e.g. erosion due to climate change and chemical deterioration). Data was acquired by both desk-top based studies of extant resources and the acquisition of new data using recent technology and models that, until now, have only been sporadically utilized by the cultural sector. Particular emphasis was placed on the physical controls for site management, including the development of sophisticated erosion-sedimentation models.

The specific benefits for the academic research community will be to aid in the exchange of data and information and thereby assist in developing research networks between different countries. Policy makers can use the information to develop better *in-situ* management plans. In addition, making site information available to the general public will inevitably engender a greater public commitment to the protection of underwater cultural heritage sites.

WreckProtect

The WreckProtect project was funded by the European Commission's Seventh Framework Programme (FP7-ENV-2008-1) and involved a number of research institutions and cultural heritage agencies from Denmark, Sweden, The Netherlands and Greenland (WreckProtect 2009). The inter-disciplinary consortium involved researchers with expertise in maritime archaeology, conservation, chemistry, wood technology, microbiology, marine biology and GIS. The project's primary foci was studying the biological deterioration of submerged wooden heritage, especially by the marine borer, *Teredo navalis*, predicting the possible spread of this notoriously damaging marine organism into the Baltic Sea and assessing the methods available for the long-term protection of these sites *in situ* (Björdal & Gregory 2011). The project commenced in May 2009 and ended in April 2011.

The project highlighted the diversity and distribution of the rich cultural resource in the Baltic Sea and hence, the potential threat by biological attack. This was further illustrated by a number of case studies briefly describing the archaeological remains on the wreck site and the general state of preservation. In contrast, information relating to sites located in the Wadden Sea and the Mediterranean were also discussed, emphasizing the difference in the marine environments of these bodies of water with higher salinities in comparison to the brackish Baltic Sea. The problems in preserving underwater cultural heritage in those particular areas where shipworm are more prevalent were also highlighted.

The project focuses on the biological degradation of wood in marine environments and the spread of the marine-boring bivalve *Teredo navalis* or 'shipworm' throughout the Baltic Sea both from a historical perspective and from the more recent results of the project obtained through the development of a GIS-base modelling study. The project described different *in-situ* preservation techniques that can be used to protect shipwrecks from biological and physical deterioration and discusses advantages and disadvantages of each technique based on literature surveys and organised seminars.

Most importantly, the follow-up monitoring of the site after its stabilisation was emphasized as an essential part of the overall management program for any underwater cultural heritage site. There was also useful discussion regarding the cost effectiveness of *in-situ* preservation versus recovery, conservation and storage/display.

Finally, two sets of guidelines, aimed at archaeologists, conservators and cultural resource managers, were produced by the project. The first guideline provided tools for assessing and predicting the future spread of *Teredo navalis* in the Baltic Sea (Manders 2011a) and the second guideline recommended practical methods that could be used to preserve underwater cultural heritage sites *in situ* (Manders 2011b).

The project recognised that further research was required including determination of the decay status of historic wrecks in the Baltic Sea, continued tracking of *Teredo navalis* by testing and refining the GIS model and further studies into which parameters are relevant to monitor in terms of estimating decay rates for wood degradation.

SASMAP

The SASMAP (Development of tools and techniques to **S**urvey, **A**ssess, **S**tabilise, **M**onitor **a**nd **P**reserve underwater archaeological sites) project, partly sponsored by the European Commission's Seventh Framework Programme (FP7-ENV.2012.6.2-6), began in September 2012 and was scheduled for completion in November 2015 (Gregory et al. 2013; SASMAP 2012). The research consortium consists of seven research institutes and four private companies from seven European countries (Denmark, Greenland, The Netherlands, Sweden, Italy, Greece and the United Kingdom). Many of the research partners have been involved in previously funded and successfully completed projects, such as MoSS, Bacpoles, MACHU and WreckProtect. The institutional partners provide a synergistic group of expertise including marine archaeology and conservation, *in-situ* preservation, wood degradation, marine geochemistry and marine geophysics. The industry partners possess expertise in the development and production of state of the art marine geophysical instruments, equipment for measuring bio-geochemical parameters in the marine environment, hand held diving tools and methods to prevent erosion of the seabed.

The main aim of the project is to develop and assess tools, techniques and methods in order to develop best practice for the cost effective and successful investigation and management of underwater cultural heritage. SASMAP has a number of objectives in order to achieve the main aim of the project and they are divided into eight integrated work packages (WP).

WP1 develops regional specific geological models for two case study areas in Denmark and Greece in order to understand palaeogeographic developments then use them to assess the probability of finding submerged archaeological sites and evaluate their stability. WP2 will incorporate the two study areas into their own GIS systems. Based on the models developed in WP1 and the GIS, target sites in the case study areas, which are most likely to contain archaeological remains, will be surveyed with a suite of non-destructive remote sensing geophysical tools, including a 3D sub-bottom profiler specifically developed for the project. These survey results and hydrodynamic and sediment regime data will be incorporated into the GIS to provide tools for localising, mapping, monitoring and evaluating site stability and preservation status of underwater archaeological sites.

WP3 concentrates on the development of tools and technologies to assess the biogeochemical parameters in sediments both *in situ* and *ex situ.* These measurements will then be related to the extents of degradation of organic archaeological materials and used to assess the preservation potential of the sediments. WP4 focusses on the development of tools for assessing the state of preservation of waterlogged archaeological wood. If a site is investigated and deemed not suitable for *in-situ* preservation then WP5 is developing innovative techniques to raise complex and heavily degraded waterlogged organic archaeological artefacts. WP6 will investigate, develop and monitor the efficacy of using artificial seagrass and other synthetic materials to stabilize archaeological sites. The durability of the polymers most frequently used when preserving sites *in situ* will be also be assessed.

WP7 focusses on dissemination of the project results including the transfer of knowledge and training in the use of the newly developed technologies through a field school and workshop. Finally WP8 is devoted to the management of the project.

All information and experiences obtained during the course of the project will be used to enhance existing legislation and develop best practice for mapping and preserving Europe's underwater cultural heritage, ultimately resulting in a set of guidelines at the end of the project. In this way SASMAP hopes to improve current best practice for protecting underwater cultural heritage.

HMS *Fowey*

HMS *Fowey* (1748) located in the Biscayne National Park, Florida has been the subject of archaeological investigation and site monitoring by the National Park Service (NPS) for the last 30 years (Keller 2014). The practice of *in-situ* preservation has long been preferred alternative for the NPS archaeology program, particularly when working with submerged cultural heritage. Since 1978, the *Fowey* site has long been subjected to illicit treasure hunting, however in 1980 the custody of the site was awarded to the NPS and non-disturbance archaeological investigations were carried out to confirm the identity of the shipwreck. In 1983, experiments were initiated in test areas in close proximity to the site using sand bags, ground cloths and artificial seagrass nets in an attempt to stabilise the site but none were deemed suitable.

In 1993, NPS reinvestigated the site in an attempt to document damage caused by Hurricane Andrew and produced an updated site plan that provided more detail regarding the structural timber remains. Since that time, NPS archaeologists have been regularly monitoring the site several times per year and always after significant storm events. Every monitoring visit (especially those that followed storms) reported the same situation: that seagrass beds surrounding the main hull section were retreating. As the beds eroded, new artefacts were exposed and removed from their archaeological context and the exposed wooden structural remains were deteriorating due to physical and biological factors. However, no permanent or long-term stabilisation plan was developed or implemented.

In 2005 and in 2012, the site was again ravaged by hurricanes, which negatively impacted the protective sediment layers and site stability. Hence, in 2013 a management plan was implemented with the primary objectives to perform an assessment of the environmental conditions affecting the site and composition of the remaining sediment protecting the site and to develop several potentially viable stabilization plans to protect the HMS *Fowey* site for future generations.

Since large scale *in-situ* stabilisation and conservation of underwater cultural heritage sites remains a relatively undeveloped practice in the United States, several *in-situ* preservation projects, namely the *San Juan* reburial project in Canada, the Swedish RAAR project, the Queen Anne's Revenge in North Carolina and finally the *James Matthews* reburial project in Western Australia were reviewed in order to develop a sustainable *in-situ* stabilization strategy for HMS *Fowey*. The methodologies identified as most likely to succeed given the site specific conditions encountered on-site included reburial with 30 cm of sand followed by a 50 cm layer of limestone rocks (25-30 cm in diameter); deposition of a layer of clay, followed by a protective layer of sand with a 'donar pile' of sand placed on the seaward side of the remaining structure, which would migrate slowly over the site through wave and current action, especially during storms and finally covering the entire site with burlap sandbags to seal the site.

In 2015, the third option utilising the sandbag methodology was implemented with regular site monitoring an integral part of the on-going archaeological management plan.

Testing of *in-situ* preservation in the Australian marine environment was critical to informing managers of appropriate strategies in the face of ongoing marine-based development. Furthermore, nearly 20 years had passed since the practitioners, Australian Government and the Australasian Institute for Maritime Archaeology had jointly developed the Historic Shipwrecks National Research Plan (Edmonds et al. 1993) and the Guidelines for the Management of Australia's Shipwrecks (AIMA & ACDO 1994). Australia-wide, maritime archaeology practitioners agreed that it was appropriate to undertake research into *in-situ* preservation and foster a strategic national approach for the management of at-risk historic shipwrecks. The AHSPP was designed, in part, to fulfil this issue through the production of national policy – with a protocol and technical guidelines.

The Australian Historic Shipwreck Preservation Project (AHSPP) investigated two Australian historic shipwrecks, *Clarence* (1850) in Port Phillip, Victoria and *James Matthews* (1841) in Cockburn Sound, Western Australia, to test *in-situ* preservation methodologies in southern waters (Veth et. al. 2013; Richards et. al. 2014). *Clarence* was selected as the location to deploy a 'rapid recording and reburial' strategy and *James Matthews* has allowed the development and investigation of innovative reburial strategies (Shefi et al. 2014). Both sites have been extensively recorded and monitored over dmany years so the present stability / instability can be gauged in a long term context. This is a very significant difference to the data obtained in the EU which covers time periods much shorter than many decades.

What is *in-situ* preservation?

In-situ preservation can be carried out on a range of sites in differing stages of physical, chemical and biological transition. Usually an intervention is made when the site shifts out of dynamic equilibrium and there is demonstrable loss of fabric, context and spatial integrity. An *in-situ* preservation strategy should aim to return the site to pre-exposure conditions or to provide a more stable protective environment.

Until recently, the terminology pertaining to *in-situ* preservation has often been ambiguous, which made it difficult to find agreement on planned outcomes, practices and procedures. Through examination of instruments relating to Underwater Cultural Heritage, such as the 2001 UNESCO *Convention on the Protection of the Underwater Cultural Heritage* (the UCH Convention) (UNESCO 2001) and its precursor, the 1996 ICOMOS *Charter for the Protection of Underwater Cultural Heritage* (ICOMOS 1996), Shefi (2013) found that *in-situ* preservation was interpreted variously across the discipline. Global survey results enquiring into practitioners' perspectives on *in-situ* preservation found that the term was interpreted generally as either 'passive' or 'active' management, but also as 'preservation in the site's original location', or in a 'safer' nearby submerged location, or even a combination of the two (Ortmann 2009). Others equate the term with the literal translation of the Latin *in-situ* – meaning *in place*. Therefore for the purposes of this document the following definitions are prescribed below.

Definitions

Anthropogenic: Human impacts on the environment and cultural fabric, such as coastal development, resource production, dredging, anchor damage and site visitation. These actions may directly or indirectly impact the site, and therefore can be either intentional or unintentional.

Preservation: Maintaining a place in its existing state and retarding deterioration (Australia ICOMOS Inc. 2013). For UCH, this can include a carefully planned set of processes for removal of UCH from its original context, with attention to the recording of structural, spatial, environmental and physico-chemical context.

Protection: Aims to prevent harm to UCH from anthropogenic sources. This is often achieved through the enactment of domestic and local legislation and international guidelines that establish procedures and boundaries to mitigate human impacts, including access to vulnerable sites.

Stabilization: Returning a site to as close to stasis as possible. This refers to the pre-disturbance or reburial environment where degradation of cultural material has plateaued.

Conservation: The processes of looking after a place so as to retain its material fabric in its current condition. For UCH, this can include the stabilization and, when appropriate, the recovery, treatment and restoration of associated artefacts. Applied methodologies will vary considerably dependent on the material types, however the primary outcome is to minimise further deterioration in the long-term.

***In-situ* management**: This describes the development of an UCH management plan, which is informed by the individual archaeological site details. The plan identifies the significance of the site and prioritizes the level of intervention. In an integrated *in-situ* management regime, *in-situ* protection, preservation and conservation methodologies will be applied according to the legislative requirements, level of significance, the local environment and available resources.

***In-situ* protection**: Enforcing laws that prevent human impacts on UCH, with the primary aim of leaving the site underwater, in its original context.

***In-situ* preservation**: A method that aims to leave a site in its original context, with the overall objective of prolonging the existence of the cultural fabric and assemblages by retarding degradation from physico-chemical, biological and/or anthropogenic factors. This may require a combination of accepted methods to return the site to semi-stasis with ongoing monitoring. Should the site be at risk of damage or destruction from anthropogenic or environmental factors, relocating the site and re-establishing a suitable environment for the safeguarding of the materials – on-site or as proximal to the original site as appropriate – can still be considered *in-situ* preservation. Cathodic protection of larger metal objects or assemblages, such as entire ships, that *will not* be recovered in the future would be considered as *in-situ* preservation.

***In-situ* conservation**: Often confused with *in-situ* preservation, *in-situ* conservation includes physical and chemical measures that mitigate degradation and extend the life of cultural materials. In some cases the site is used as the 'conservation laboratory', with the final outcome being to eventually recover the artefacts. This term is also often associated with *in-situ* cathodic protection of metal artefacts, usually ferrous alloys, using sacrificial anodes, and can have a positive bearing on stability of the artefact or site.

Rapid intervention: Timely, prioritised and active intervention. The timeframe is determined by the specifics of the UCH site, overall management plan and available resources. Rapid actions can be undertaken within a single field season, or when under immediate threat the field interventions will be determined by the scale and severity of external impacts (e.g. days and weeks as opposed to staggered actions over a serial program perhaps lasting months or years).

Rapid reburial: A physical intervention to stabilize a site in 'urgent' circumstances when a wreck is deemed to be at significant risk or where intrusive methods are being used to assess the fabric of the site. (Note: 'urgent' is identified as an atypical, unidirectional and cumulative impact that increases the rate of degradation of a site). Under these circumstances, an assessment of the physical and archaeological context of the site will be made as quickly as possible to the standards identified in the research design and management plan.

Quantitative monitoring: This type of monitoring enables analysis to be undertaken in a form that provides for longitudinal comparative, measurable assessment of a variety of visual, and/or scientific data. This may include photogrammetry, archaeological surveys, 3D modelling, physico-chemical and biological sediment sampling and corrosion testing. For a list of the types of analysis useful for *in-situ* preservation studies, see Appendix 1: On-Site Conservation Survey data form, Appendix 2: On-Site Corrosion Survey data form and Points 3 and 4 of the *In-Situ* Preservation Protocol below.

The demonstrated benefits of ongoing monitoring is an important outcome of this project. An excellent opportunity exists in the future to carry out a longitudinal quantitative and qualitative study of representative sites around Australia, whereby data from each site can be linked to the sites record within the relational Australian National Shipwrecks Database and dedicated search query questions built to facilitate research outcomes.

Qualitative monitoring: A passive, less stringent approach to site monitoring that relies upon trained professionals or avocational archaeologists to employ their expertise to make visual assessments (observations) of changes to a site's condition. Photography or video may be used to record sites, and photographic scales should be used to assist interpretation of images, but the resulting data may not be directly comparable or measurable. This monitoring method should only be used independently for sites of low significance, or sites at low risk of detrimental impacts. It can be used in conjunction with quantitative methods for a more holistic approach that is less time and cost intensive than full quantitative monitoring.

Selecting sites for an *in-situ* preservation strategy

The primary document widely utilised by Australian maritime heritage managers since the mid-1990s is the *Guidelines for the Management of Australia's Shipwrecks* (AIMA & ACDO 1994). This document defined principles for site, artefact and collections management; how management programs should be implemented; and funding and programme outputs. Comprehensive guidelines were provided to inform and assist with meeting the principles. Within the document, Principle 1.2 (p. 10) relates to current *in-situ* preservation practices, requiring environmental (physico-chemical) assessment as part of management plans (point 1.2, p. 10). The preservation of shipwreck material with minimal interference with the fabric as the primary conservation objective (point 2.6 p. 14) relates only to recovered artefacts. With changes in the approaches taken to shipwreck management these guidelines should now be extrapolated to the site or hull remains. The AHSPP's *in-situ* preservation guidelines and protocols aim to further develop this conservation and preservation objective.

Not all UCH sites or management situations require complex *in-situ* preservation interventions. Following initial site assessment, guidelines should prompt managers to review the range of management options available to them and determine whether *in-situ* preservation is the optimal strategy if the site is at risk. For example, unavoidable and severe risk at a significant site may be best mitigated through systematic excavation and recovery of all assemblages, followed either by *ex-situ* conservation or reburial in another location (Fig. 2).

The UCH Convention intends that sites should be preserved *in situ* as the first and preferred management option (Article 2.5 and Annex Rule 1); however it also notes that activities directed at underwater cultural heritage 'should be for the purpose of scientific studies or for the ultimate protection of the underwater cultural heritage' (the Convention Annex Rule 4). Rule 4 also states that the 'methods and techniques used must be as non-destructive as possible and contribute to the preservation of the remains'. The UCH Convention does not provide explicit guidelines on what activities fall under the umbrella of *in-situ* preservation nor whether these activities should ideally be active or passive.

The UCH Convention is opposed to the commercial exploitation of UCH and establishes a best practice framework, as outlined in the Annex, for engaging in activities directed at UCH. A primary rationale for engaging in activities, other than for the purposes of preservation and protection, is for making a significant contribution to the knowledge about, and protection and enhancement of, UCH. As highlighted above, the

UCH Convention does not define '*in-situ* preservation', and consequently practitioners globally have taken this term to include a variety of preservation strategies, ranging from active interventions, such as reburying a site in its original location or relocating and reburying a site and/or its associated artefacts to simply monitoring the site's environment and physical remains at regular intervals, which would constitute passive intervention.

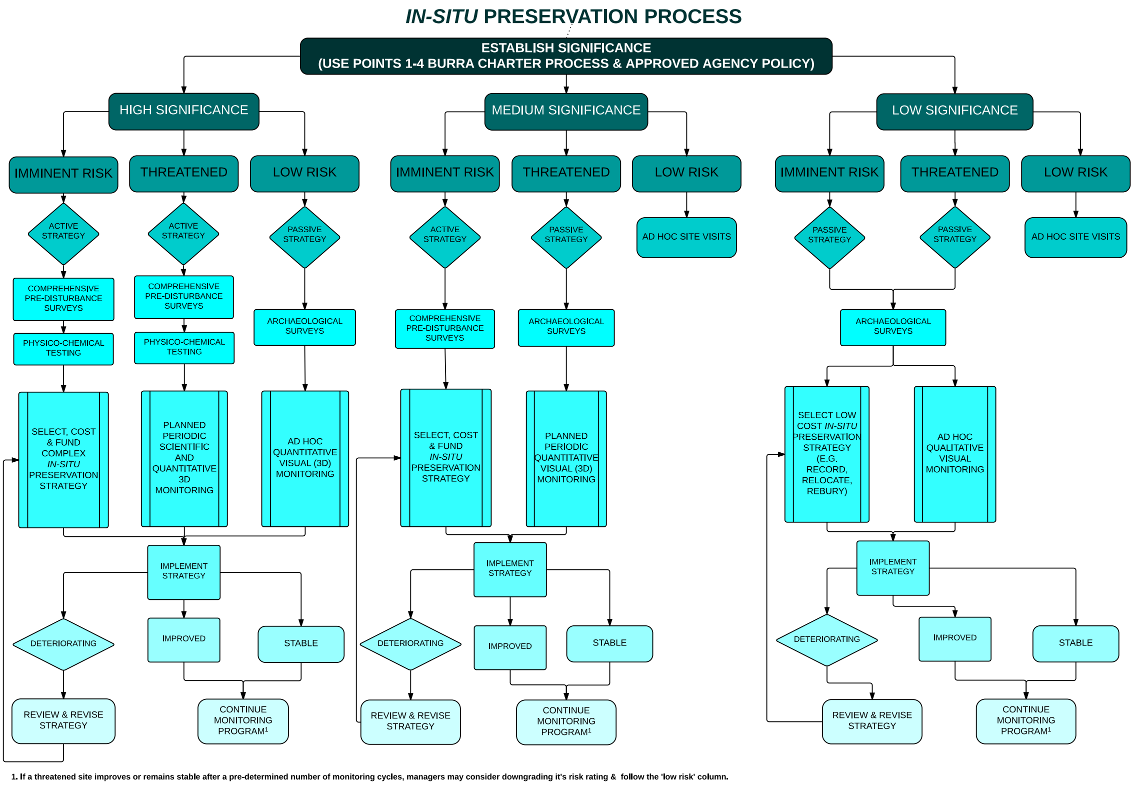


Figure 2: Flow chart for *in-situ* preservation processes.

When should heritage managers select *in-situ* preservation as a management strategy to encourage the longevity of a site?

In accordance with the UCH Convention, a site should be preserved *in situ* as the first option. An idealised sequence of significance assessments of a site, threats and actions is presented in Figure 2 as the remediation strategy. This could include reburial but may not specifically require intrusive management. Methods for *in-situ* preservation are varied, and must be assessed with reference to the constraints of the site type, its environment and availability of funding and personnel. Ultimately the measures taken will always be a compromise between the significance 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.

Site managers must identify the significance and stability of the site (e.g. Australia ICOMOS Inc. 2013, Gregory 2010; Richards 2011) and consider public engagement and education factors prior to developing and executing an intervention plan. Site significance should be established using accepted criteria (values such as historic, aesthetic, rarity, representativeness, environmental, scientific, technological, social or spiritual). Public engagement and education may be complementary to physical interventions or alternative to physical intervention where it is considered that they will re-direct human visitation and reduce anthropogenic impacts.

In-situ preservation may be selected as a management tool if the site is identified as being inherently unstable and at risk of continual or seasonal degradation for one or more of the following reasons:

- **Environmental Processes**: Continual physical degradation of exposed structural elements from water and sediment movement and sediment impingement through significant tidal changes or currents; increased deterioration of material in the intertidal zone, through oscillating wet/dry cycles; increased physical, chemical and biological deterioration of submerged materials through seasonal exposure/reburial cycles or from significant loss of sediment after meteorological events, such as storms, cyclones, etc.

- **Loss of Equilibrium**: When there is evidence of a previously stable site becoming increasingly unstable, which is observed via radical or rapid increases in the extent of deterioration of both exposed and submerged material caused by a significant change to the local environment. For example, significant decreases in sediment coverage or the large scale loss of seagrass beds via anthropogenic sources, such as dredging, industrial activity, coastal development, etc.

- **Anthropogenic – Direct and Indirect Impacts**: A site is at imminent risk of damage from past or proposed anthropogenic causes. Such causes could be direct: for example recreational angling or diving activities, commercial fishing, harbour dredging; pipeline maintenance or construction, shipping activities (i.e. newly discovered or existing site within active shipping channel); or indirect: nearby activities, such as harbour developments or resource exploitation that may have incidental effects on a site (e.g. increasing nutrient and suspended sediment levels in the water column, which adversely affects the growth of seagrass and protective colonizing organisms).

- **Excavation**: A site has been intrusively investigated in the past and is showing signs of increasing deterioration from either natural or anthropogenic sources, identified from legacy data and previous archaeological records. There is a direct increase in the deterioration rate of the site due to exposure through contemporary archaeological excavation.

- **Diver Visitation and Interference**: A site is at risk from visitation and potential souvenir hunting/looting and cannot be regularly monitored to ensure legal compliance. This is important when there is obvious surface scatter of artefacts or archaeological content that could lead divers to believe there are rich sub-surface finds.

Eight-Point Protocol for *in-situ* preservation programs

An eight point *In-situ* Preservation Protocol has been developed by conservation scientists drawing from observations and testing of UCH preservation programs (Gregory 2010; Richards 2011). These points are integral in a process-based approach to UCH management and can assist in developing and implementing *in-situ* preservation strategies for a particular site if required. Meeting these requirements could involve multi-year pre-disturbance assessments and continued monitoring through archaeological test-pitting, geomorphological and physico-chemical analyses of the local sedimentary and pelagic environment. This is likely to be beyond the budget and expertise of most cultural heritage management agencies, yet these are the first principles that should ideally be realised before the context of a site is substantially altered.

The Protocol is listed below, and a detailed explanation of each point follows:

1. Ascertain the extent of the site and likelihood of potential archaeological deposits;
2. Assess the most significant physical, chemical and biological deterioration processes occurring on the site;
3. Assess the pre-disturbance 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 the extent of their deterioration;
5. Implement the optimal *in-situ* preservation strategy to mitigate continued deterioration in order to stabilise the site long-term (refer to guidelines to select an appropriate strategy);
6. Implement a long-term monitoring programme to evaluate the efficacy of the *in-situ* preservation strategy;
7. Provide alternative plans and procedures if the implemented *in-situ* preservation strategies are unsuccessful; and
8. Provide resources for the reburial and/or conservation of any recovered artefacts.

If these initial requirements are not met (Points 1-4) and an *in-situ* preservation strategy is implemented due to the site being at imminent risk, then the monitoring programme (Point 6) must be conducted at more regular intervals. This will allow for a more rapid evaluation of the applied intervention so any deterioration of the site can be identified and ameliorated (Point 7). In such an instance, it is recommended that the applied *in-situ* preservation strategy is simple and cost effective to reverse if points 1-4 of the Protocol have not been met.

How to select the best *in-situ* preservation method (or combination of methods)

Fields, variables and attributes that need to be assessed and considered when selecting optimal *in-situ* preservation methods, or a combination of methods are outlined below in more detail.

1. Ascertain the extent of the site and likelihood of potential archaeological deposits.

Archaeologists working with submerged sites are familiar with regular site inspection and pre-disturbance survey requirements and tools that are employed to identify a site and develop a preliminary understanding of the remains and their environment. In addition to recording the site name and wrecking date (if known), and basic site information such as: primary vessel construction materials (wood, composite, iron, steel); previous interventions (if known or identified); site dimensions; and location (coordinates, depth, distance from land, seabed), to move towards an *in-situ* preservation approach further information is required that many not be ordinarily gathered during these initial surveys. These are: degree of exposure (maximum, minimum, average height of material remains above seabed) and degree of burial (maximum, minimum, average depth of burial of material remains). The site dimensions, exposure and burial data can be obtained and monitored using either minimal intervention techniques, such as seabed probing or archaeological test pits (which would require post excavation stabilisation – see point 5 below), or remote sensing tools such as magnetometer, multi-beam/side-scan sonar, and sub-bottom profilers.

2. Assess the most significant physical, chemical and biological deterioration processes occurring on the site.

To select the appropriate *in-situ* preservation materials and strategy, an understanding of the environmental processes on the site is critical. The site orientation, tidal (or other) currents and their rate, and the seabed topography may suggest use of shade cloth as a stabilisation procedure. Sediment composition may help to determine whether suspended sediment could be encouraged to drop out of the water column and fill a loose-fitting porous cover (e.g. shade cloth) over time. Regular human interference may require site managers to look at additional, more robust materials, such as covering the site with impermeable membranes, such as PVC tarpaulins.

Details including weather and sea conditions, underwater visibility, site orientation, seabed topography, human interference and whether the site has been subject to or has potential for impacts from extreme weather events are all relatively easily gathered by archaeologists. Some environmental data may require additional expertise such as identifying sediment composition and marine life.

Other details may require limited interference such as identifying the depth of matrix to reach stable sediment (usually delineated by a grey/black sediment interface), evidence of seasonal exposure and evidence of marine borer activity (which may be active on exposed timbers, and become obsolete at a particular depth of burial).

Ideally the team investigating the site will have a broad range of individual experiences, skills and background knowledge in order to cover most of these assessments; however site managers should be aware that personnel with additional expertise may need to be engaged on a seasonal or contractual basis.

3. Assess the pre-disturbance local burial environment and the major factors affecting the long-term stability of the site

An assessment of the local burial environment and the long term stability of the site may require more specific scientific expertise, although some data can be gathered by archaeologists under the guidance of, or with specific training from, a conservation expert.

For this point and point 4 below, it is noted that the level of scientific analyses undertaken at a site should be driven by the significance ranking of the site and the risk of deterioration, which, as a matrix, should direct the level of funding allocated (See Figures 2 and 3). As scientific analysis can be costly, the availability of in-house expertise, or volunteer/in-kind support, may also be relevant to the application of these actions.

Both the local water and local sediment environments need to be analysed. Some of this data is obtained *in situ*, such as temperature, salinity, dissolved oxygen, pH and redox potential; for comparison these need to be taken at depth and at the surface. Additional and comparative data requires samples taken from the site for *ex-situ* analysis, such as further pH details, soluble iron, sulphur species, and nutrient composition.

Core samples can be gathered by experienced divers with specific equipment and training, but need to be handled and stored appropriately and sent to a laboratory for *ex-situ* analysis. The laboratory will undertake micro-electrode analysis to determine dissolved oxygen content, sulphide content, redox potential and pH, and examine the pore water for pH, soluble iron, sulphur species (sulphide, sulphate, total sulphur) and nutrient composition (ammonia nitrogen, nitrate nitrogen, total nitrogen). The laboratory will also examine the core sample sediment for particle size and distribution, porosity and microbiology (identification and abundance of major fungi and bacteria species). However, like all chemical analysis, a thorough briefing by the manager of the samples detailing the specific handling issues, matrix complications, expected range of data will greatly enhance the quality of and the usefulness of the data obtained.

4. Identify the major material types present on the site and the extent of their deterioration

After identifying the dominant material types extant as hull remains (timber, composite, iron, steel) and artefacts (materials, condition, distribution, exposure, mobility), a variety of measurements and scientific analyses are relevant to further inform the appropriate level of intervention.

Timber or composite sites benefit from an understanding of the depth of burial, wood density and pH profiling. *Ex-situ* analysis of timber samples from these sites will examine the maximum water content, density and undertake microscopic analysis of the wood including species identification

Sophisticated instrumental techniques such as Fourier transform infra-red (FT-IR), solid state carbon 13 nuclear magnetic resonance (^{13}C-NMR), spectroscopic analyses and Sulphur K-edge x-ray absorption near-edge spectroscopic (XANES) are used to identify changes in the ultrastructural wood chemistry and sulphur species in the wood. These require specialist expertise to obtain and interpret the data. However the results can provide important additional information regarding the extent and type of deterioration, degradation mechanisms and the on-site environment. Hence, they are considered desirable rather than essential in the assessment of site deterioration processes.

Metal hull remains, or the metal components of a composite site, should be analysed for their corrosion potential, surface pH, and depths of the concretion and corrosion layers. These measurements can be obtained by appropriately trained divers, however interpretation of the data requires specialist expertise. Further *ex-situ* analyses of samples employing XRF, XRD and wet chemical techniques will identify the composition of the concretion and metals.

It is also important to note that wood species and metal composition identification can serve two purposes; the data is useful for *in-situ* preservation or conservation decisions, and can also identify further archaeological details relating to the history and construction of a vessel.

5. Implement the optimal *in-situ* preservation strategy to stabilise the site in the long-term

Accepted *in-situ* preservation methods include, but are not limited to, the techniques described below (refer to flowchart in Figure 2 to assist in selecting an appropriate strategy). It may be appropriate to test a strategy or range of strategies on site to determine the best method and materials to protect the site in the long-term.

Lower-cost stabilisation of a site may be achieved via land reclamation, reburial by backfilling (using the wreck's own ballast – after documentation and/or dredged local sediment), or deposition of proprietary rock/sediment or sandbags (preferably made of synthetic polymers as organic materials, such as cotton or hessian are not viable long-term). These techniques are more labour-intensive, but use less or lower-cost materials.

In addition to sediment deposition, it may be desirable to secure a close-fitting layer of shade cloth, debris netting or geotextile (e.g. Terram 4000, Bidim); and/or added physical barriers in the form of rubber or polyvinyl chloride (PVC) tarpaulins (such as used on *Clarence* to protect shade cloth from anchor damage). This requires an increased level of funding however it will ensure that the sediment remains in place and encourages a more rapid development or return to an anaerobic state.

Sediment trapping using polymeric geotextile fabrics (e.g. Terram 4000), shade cloth, debris netting or artificial seagrass can be used to trap suspended sediment through natural water movement. These may have a greater financial outlay for materials, but utilise the local environment to undertake the reburial process. This method is suitable for sites with a higher water movement (tidal or current) and that contain suspended sediment that can be encouraged to drop out of the water column. Studies at *William Salthouse* (Steyne 2010) indicate that sediment may move out of these deposition materials, therefore continued monitoring is vital as is the operational flexibility to change approaches (see specialist comparative studies above).

Sediment encapsulation is a more expensive stabilisation method that has been trialled and deployed on a large scale at *James Matthews* (Richards et al. 2009, 2014). It can be achieved through creating a cofferdam (preferably constructed from polymeric material), which is then filled with dredged or deposited proprietary sediment and covered with shade cloth. Alternative cofferdams, such as those made from wood or sheet metal are not recommended due to the rapid biological deterioration of wood in aerobic marine environments, and the corrosion of sheet metal which will adversely affect the local ecosystem.

In some instances, the most appropriate solution to preserve a site *in situ* may be to relocate the entire wreck and/or associated artefacts to a more suitable or stable area. Whilst this involves intensive recording and excavation, the pressures on a site (e.g. marine/habour development) may mean that relocation is the best or only option. Some of the aforementioned strategies would then be applied to stabilize the relocated materials. The significance, size and the dominant materials all have a major impact on the feasibility of relocation as a management outcome. Prior to determining if a site is appropriate as a reburial area, a complete set of pre disturbance studies (as outlined in points 2 and 3 above) must be performed to establish baseline information and the suitability of the site for reburial.

Some points to consider when selecting a re-deposition site are listed below:

- Accessibility to reburial and control sites
- Relatively stable marine environment (very little or no sediment movement)
- Minimal disturbance by shipping traffic
- Environmental conditions are similar or better than the existing archaeological site
- Anchorage and diving closely monitored or prohibited
- Reburial will have no adverse effects on the local marine environment (destroy seagrass beds, affect the ecosystem, etc)
- No other cultural layers have been registered in the reburial deposition site
- Site proximity for surveillance/monitoring.

For stabilization, conservation and/or preservation of metal elements of a site, cathodic protection using sacrificial anodes or impressed current may be employed.

6. Implement a long-term monitoring programme to evaluate the efficacy of the *in-situ* preservation strategy

Good organic and metal preservation depends on the maintenance of a stable physical and chemical environment characterised by an anoxic, reducing environment, near neutral pH conditions with low porosity, organic content and bacterial activity. Hence, long-term monitoring of a wreck site at regular intervals, especially a reburied site, is a critical component of the overall conservation management plan. Ideally, the same suite of observations and analyses should be performed on these post reburial sediments as was previously described under points 2 to 4.

As destructive sampling of reburied archaeological materials is contrary to the aims of reburial, it is recommended that sacrificial modern samples, such as wood blocks and metal coupons, be included in the reburial mound and retrieved and analysed (see point 4) at regular intervals to determine the impact of the environment on the sacrificial materials. The results obtained through the analyses described under points 2 and 3 can then be correlated to the extents of deterioration of the sacrificial samples (point 4) and extrapolated to the condition of the reburied archaeological material thereby allowing the effectiveness of the adopted mitigation strategy (point 5) on the long-term preservation of the wreck site to be properly assessed (point 6).

Obviously if cathodic protection has been used to protect a site or parts thereof then the anodes require monitoring and when exhausted, replacement.

If only limited funding for physical intervention is available, activities may be restricted to surveying, regular visual and archaeological monitoring, and reburial of portable artefacts if/when these become exposed. Depending on the level of human impacts, increased legal protection (such as declaration of a protected zone), public engagement and education programs and compliance monitoring may also be appropriate management strategies in place of, or complementary to physical intervention.

Conservation monitoring of *Clarence* post-reburial: sacrificial samples

Conservation Scientist Vicki Richards developed the reburial and conservation monitoring methodology for the AHSPP. Replicate sets of sacrificial samples were manufactured for the monitoring program – four sets of iron alloy coupons (two cast iron and two mild steel) and eight sets of wood coupons (two pine, two Sydney blue gum and two blackbutt, selected for their close match to timber samples taken from *Clarence* in the 1980s).

Each sample coupon had holes drilled at either end and were attached with plastic cable ties to a rectangular piece of inert high density polyethylene to act as a backing plate. On each set of samples, one of the duplicate iron or wood coupons was wrapped in Bidim A14 geotextile. This was to ascertain its protective effect on the iron and wood artefacts after reburial. The backing plates were secured to 1 m long PVC tubes which were placed on the shipwreck site and within the reburial depot. The four iron alloy sample plates were placed along the keelson and four wood sample plates were placed 1 m towards the stern to prevent metal corrosion products from impacting the degradation of the wood samples. The remaining four wood sample plates were placed around the internal perimeter of the off-site reburial depot. No iron samples were placed in the reburial depot as this location was only for organic materials.

The samples/coupons could be periodically accessed via small ports cut into the PVC and shade cloth covers and pulled up through the reburial sediment using an air bag.

Use of photogrammetric surveys in combination with 3D modelling programs to visually monitor sites is becoming increasingly common and accessible for heritage managers. When calibrated photographs are taken (use of scales and runs undertaken at consistent depth/height from seabed) these 3D models can provide height monitoring of the wreck structure and the surrounding seabed, as well as recording other physical changes over the site (e.g. extent of biological growth). New photogrammetric software and use of multiple in-phase cameras now even obviates the need for stable geometry of approach to subject. Changes in marine environment conditions may improve or obscure visibility, therefore regular monitoring in pre-determined seasons are important to remove as much cyclical or season variation as possible.

7. Provide alternative plans and procedures if the implemented *in-situ* preservation strategies are unsuccessful

An alternative and fully costed contingency plan must be developed prior to the application of any remediation technique/s in the event that the selected *in-situ* preservation strategy proves to be unsuccessful. This should include removal of introduced materials and restoration of the site environment in accordance with Article 15.2 (Australia ICOMOS Inc. 2013: 6) and Article 26.4 (Australia ICOMOS Inc. 2013: 8) of the Burra Charter. Such interventions are understood to have their own impact on the short term stability of the wreck site.

8. Provide resources for the reburial and/or conservation of any recovered artefacts.

For most artefacts, *in-situ* preservation and/or reburial will be the most cost effective and appropriate intervention from a cultural heritage management perspective. As part of the initial registration of artefacts into an artefact database or catalogue, they must be comprehensively recorded using accepted archaeological photographic and measurement techniques. Once catalogued, they can be prepared for reburial. Wet artefacts should be placed in site-specific submerged holding treatment until reburied. The recommended reburial method should follow the procedure for the reburial of artefacts on the *Clarence* in 2012 (the Clarence Model), as outlined below.

Preparation of artefacts prior to reburial *in situ*

Following recovery from the site, artefacts should be wrapped in polyester geotextile (e.g. Terram 4000 or Bidim), followed by a high density polyethylene shade cloth protective wrapping (on *Clarence* an 84-90% UV block shade cloth was used) and secured by cable ties. Registration tags should be placed with the artefact inside the wrapping as well as attached to the outside of the shade cloth (polyurethane cattle tags are recommended). The tags should display the catalogue/registration number as well as a brief description of the item to easy identification should it need to be recovered from the reburial site/depot in the future.

Metals should be separated from organic materials, silicates and ceramics. Metals of differing compositions (e.g. ferrous and copper alloys) should also be separated. If any like artefacts or fragments of a single artefact are to be contained within the same piece of shade cloth, the individual components should be wrapped in geotextile to minimize abrasion and direct contact with other artefacts.

Ideally, multiple reburial locations or depots should be selected to cater for differing artefact materials. If a single reburial depot is to be used, artefacts of differing materials must be separated by a minimum of 50 cm of sediment. The reburial location should have a minimum of 50 cm of sediment covering the shallowest artefacts, with a preference of 80 – 100 cm.

Principles for organising interventions and conservation as assessed against significance values

Moderation between values and possible actions will be required when assessing the significance of an object or assemblage and the recurrent costs associated with its conservation and long-term storage. Recovery and *ex-situ* conservation may be appropriate when artefacts are assessed as of State or National significance (at a minimum) and the managing agency has firm commitments for appropriate conservation, storage and exhibition facilities. Alternative interpretation options, such as virtual models and/or 3D printing of scale replicas, should be considered in lieu of artefact recovery where possible.

The significance of artefacts should be assessed using accepted criteria (archaeological, historical, technical, scientific, rarity, representativeness, social, spiritual) and selection prioritised according to the costs associated with their conservation and ongoing collection management prior to recovery for *ex-situ* conservation. Highest importance should be given to research values unattainable through *in-situ* analysis (measurements, imagery, etc) in order to comply with the UCH Convention.

Specific selection criteria for recovery and conservation of artefacts:

1) Artefacts which are of high educational and exhibition value and embody outstanding scientific, representative, rarity or aesthetic values may be recovered and processed through full conservation both on site and at an appropriate conservation facility.
2) Artefacts that are of outstanding significance and which are at extreme risk.
3) Small artefacts at risk of damage or loss due to excessive water and sediment movement – preference to rebury unless they meet Criterion 1.
4) Extensively degraded artefacts that would deteriorate rapidly post-reburial.
5) Fragile artefacts that would not be able to withstand the compressive force of the sediment bed-load after reburial.
6) Artefacts where the conservation cost is considered acceptable in relation to the archaeological significance and funds have been allocated for this purpose.

In conclusion it is worth stressing that site formation processes are complex and that net sediment loads, site integrity and geochemical systems may not necessarily be unidirectional or unilineal (Ward et al. 1999). It will always be best-practice to gather historic data and monitor, at least yearly if not seasonally, to assess variability in site formation processes before the preferred intervention is chosen.

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Appendix 1

ON-SITE CONSERVATION SURVEY DATA FORM

Date of Survey

Time of Survey

Aim of Survey

Personnel

Site (name, date and type)

Location

Distance from Land/Reef

Site Classification

Site Dimensions (length, width, area)

Site Orientation

Seabed Topography

Marine Macrofauna and Flora (type and abundance) (photograph)

Wreck Specific Types of Marine Life (photograph)

Composition of Dominant Wreck Material (in-situ observation, cargo influence)

Exposed Artefacts (type, material, apparent condition, degree of completeness, distribution)

Degree of Site Exposure (area, height above seabed)

Evidence of Seasonal Exposure

Evidence or Potential for Storm, Cyclone Influence

Evidence of Human Disturbance (salvage, pollution, modern contamination, water activities)

Weather Conditions

Sea Conditions

Swell

Current (rate, direction, speed)

Tidal Information

Freshwater/Saltwater Influence (rivers, springs, sea water)

Water Temperature (surface, at depth)

Salinity/Conductivity Water (surface, at depth)

Dissolved Oxygen Content Water (surface, at depth)

pH Water (surface, at depth)

Redox Potential Water (surface, at depth)

Water Depth (minimum, maximum)

Visibility (material type in suspension)

General Sediment Composition (in-situ observation)

Mobility of Sediment Surface (rippling, direction and frequency)

Sediment Slope

Probe Depth to Wreck Material (extent of burial)

Depth to Stable Seabed (evident by black/anaerobic layer)

Sediment Gradation (changes in colour)

Sediment Photography (surface, gradation, at depth)

Sediment Sampling (sample all significant layers)

Sediment Analysis (particle size distribution, inorganic elements, organic content, nutrients, micro-organisms)

pH Sediment (measure all significant layers)

Redox Potential Sediment (measure all significant layers)

Timber Infestation by Marine Borers (active, depth to non activity)

Probe Depths of Timbers (exposed, buried)

pH Profiles of Timbers (exposed, buried)

Timber Samples (wood identification, maximum water content, FT-IR, ^{13}C-NMR, py-gc-ms)

Corrosion Potential Metals (concretion/metal interface)

Surface pH Metals (concretion/metal interface)

Depth of Concretion and Graphitisation

Depth of Concretion

Depth of Graphitisation

Sample Concretion (optional)

Sample Metals (optional)

Appendix 2

ON-SITE CORROSION SURVEY DATA SHEET

Date of Survey:

Time of Survey:

Personnel:

Site (name, date and type)**:**

Location & GPS Co-ordinates:

Weather and Sea Conditions:

Swell and Tidal Information:

Current (rate, direction, speed)**:**

Water Temperature:

Water Depth to Wreck (minimum, maximum)**:**

Visibility (metres)**:**

Distance from Land/Reef:

Freshwater Influence (e.g. rivers, springs, rain water run off)**:**

Site Dimensions (length, width, area)**:**

Site Orientation (e.g. upright, list to port or starboard, upside down)**:**

Composition of Dominant Wreck Material (e.g. iron, aluminium)**:**

Dominant Encrusting Organisms on Surface (type, abundance) (photograph)**: Y/N**

Evidence of Active Corrosion (depth & photograph)**: Y/N**

Dominant Encrusting Organisms on Surface (photograph)**: Y/N**

Evidence of Dynamite and/or Storm Damage (depth & photograph)**: Y/N**

Dominant Encrusting Organisms on Surface (photograph)**: Y/N**

Evidence of Human Disturbance (e.g. salvage, pollution, modern contamination) (depth & photograph)**: Y/N**

Evidence of Structural Collapse (depth & photograph)**: Y/N**

Appendix G: Artefacts from 2012 Excavation

HV Registration ID	SR4 ID	Suffix	Artefact Name	Description	Material	Item Qty	Images
127.00086	CL12A-0002		Fastening	Concreted bolt.	Iron	1	
127.00087	CL12A-0003		Concretion	Strap, quite heavy.	Iron	1	
127.00088	CL12A-0004		Sheathing	Hull sheathing, nearly complete section with one side (along width) slightly crumpled or folded. Tack holes visible along the edges where tacks were nailed through.	Lead	1	
127.00091	CL12A-0007		Possible base (of satchel)	Possibly half a cask lid, with 2 circular 'bung type' holes with 2 treenails embedded. Within these a possible thin, small wedge hammered in at centre. Has 2 half 'nail' holes visible along straight edge. Underside has a feature of a strap/brace (possibly metal). Bevelled edge along circumference; topside has engraved circular pattern along interior circumference possibly as decoration.	Wood	1	
127.00092	CL12A-0008		Leather pieces	1x large piece of flat leather, lighter brown underside, and darker on other side + 1x smaller piece. Big piece is folded in half, the edges are soft and fragile. Possible pump flap. Overall very fragile.	Leather	2	
127.00089	CL12A-0005		Glass fragments	Clear glass fragments, base of a hexagonal drinking tumbler.	Glass	3	
127.00090	CL12A-0006		Glass fragment	Dark olive green, bottle, slightly curved glass fragment, most likely from a wine bottle.	Glass	1	

127.00085	CL12A-0001		Timber	Timber with iron stain and bolt hole. Possibly ship's timber or part of rigging.	Wood	1	
127.00093	CL12A-0009		Leather	Thick, stiff piece of leather, with straight line scratches criss-crossing on one face.	Leather	1	
127.00094	CL12A-0010	A	Cask head	Mid section of cask head, with branded words '...AMUEL' '...RTON'. Very degraded caused by shipworm. Broken off. Appears to be machine made, sawn. Striations along bevelled edge. Line incisions on branded face.	Wood	1	
127.00094	CL12A-0010	B	Cask head	Line scratches on topside of head face. No branded letters. Bevelled around circular edge. Very degraded and worm eaten. One possible dowel hole along 1 straight edge.	Wood	1	
127.00094	CL12A-0010	C	Cant piece, cask head	About 80% complete, one edge broken off. Branded word on topside 'S..' and part of an 'A' visible; below: 'BU..'. Long curved striations visible along underside/interior bevelled edge. Visible lip along bevelled edge.	Wood	1	
127.00094	CL12A-0010	D	Cask head	One the middle pieces. About 80% complete. One end broken off, other end bevelled with tool striations visible along the curve. Branded words 'NO' with possible '.' just below. Straight and curved scratches visible on topside.	Wood	1	
127.00094	CL12A-0010	E	Cask head, cant piece	Incomplete, 80% complete. Bevelled edge has visible lip. Branded letters 'BUR', with curved and straight incised lines on top surface. Possibly one dowel hole visible along straight edge.	Wood	1	

127.00094	CL12A-0010	F	Cask head	One of the mid section pieces, incomplete, about 12–15% remaining. Possible small branded ‘H’. Bevelled curved edge has lip. (Overall diam. approx. 55 cm).	Wood	1	
127.00097	CL12A-0013		Bung, stave	Bung associated with 1st cask (127.00094 / CL12A-0010). Sides are not visibly tapered.	Wood	1	
127.00094	CL12A-0010	G	Stave	Stave, complete with some concretion at the side of one end. Iron hoop marks visible on exterior.	Wood	1	
127.00094	CL12A-0010	H	Stave	Stave, complete with some concretion at the side of one end. Iron hoop marks visible on exterior.	Wood	1	
127.00094	CL12A-0010	I	Stave	Stave. Scratches across the interior width by cooper to indicate position of staves for reassembly.	Wood	1	
127.00094	CL12A-0010	J	Stave	Stave. Faint scratches across the interior width by cooper to indicate position of staves for reassembly just visible. Concretion on hoop remains on exterior.	Wood	1	
127.00094	CL12A-0010	K	Stave	Stave. Visible hoop marks on exterior.	Wood	1	
127.00094	CL12A-0010	L	Stave	Stave. No visible scratches observed.	Wood	1	
127.00094	CL12A-0010	M	Stave	Stave. No visible scratches observed. Part of stave still attached by concretion. Concretion remains on exterior as a result of iron hoop corrosion.	Wood	1	

127.00100	CL12A-0016		Leather strap	Leather piece, almost ‘bow’ shaped. Coarser on one side and smoother on the other. Smoother side has a few faint line impressions.	Leather dyed	1	
127.00095	CL12A-0011		Fastening	Copper fastening, bent.	Copper	1	
127.00101	CL12A-0017		Ceramic	Ceramic fragment, bowl. Underside base support is squarish with defined blue transfer print (possibly of clouds) on inside and some visible on the exterior body section.	Ceramics	1	
127.00102	CL12A-0018	A	Cant headpiece	Cant headpiece of a cask, incomplete (part of B, C and D). No branding on this piece. Bevelled edge along circumference.	Wood	1	
127.00102	CL12A-0018	B	Middle headpiece	Middle headpiece of a cask, incomplete (part of A, C and D). Part of branded words on this piece, topside, ‘ENT’. Bevelled edge along circumference.	Wood	1	
127.00102	CL12A-0018	C	Middle headpiece	Middle headpiece of a cask, incomplete (part of A, B and D). Part of branded words on this piece, topside, ‘R TENNENT’. Bevelled edge along circumference.	Wood	1	
127.00102	CL12A-0018	D	Middle headpiece	Middle headpiece of a cask, incomplete (part of A, B and C). Part of branded words on this piece, topside, ‘J&’. Bevelled edge along circumference.	Wood	1	

127.00102	CL12A-0018	E	Headpiece; cant and middle piece	Two headpieces (cant and middle piece) joined by dowels. Part of F; middle piece of this head missing. Middle piece has branded words on topside ‘J&..’ with part of an alphabet missing and looks like ‘I’, probably an ‘R’. Words likely spell ‘J&R TENNENT’ like on other headpiece.	Wood	2	
127.00102	CL12A-0018	F	Headpiece; cant and middle piece	Two headpieces (cant and middle piece) joined by dowels. Part of E; middle piece of this head missing. Middle piece has branded words on topside ‘NT’. Words likely spell ‘J&R TENNENT’ like on other headpiece.	Wood	2	
127.00096	CL12A-0012		Bone, animal	Animal bone, possibly cow, black, possibly burnt.	Bone	1	
127.00102	CL12A-0018	G	Stave	Stave, complete.	Wood	1	
127.00102	CL12A-0018	H	Stave	Stave, complete.	Wood	1	
127.00102	CL12A-0018	I	Stave	Stave, complete. Concretion remains and parts of another stave to the middle and one of the ends.	Wood	1	
127.00102	CL12A-0018	J	Stave	Stave, complete.	Wood	1	
127.00102	CL12A-0018	K	Stave	Stave, complete.	Wood	1	
127.00102	CL12A-0018	L	Stave	Stave, complete.	Wood	1	
127.00102	CL12A-0018	M	Stave	Stave, complete.	Wood	1	

127.00102	CL12A-0018	N	Stave	Stave, complete. 6 hoops marks visible on outside.	Wood	1	
127.00102	CL12A-0018	O	Stave	Stave, complete. Appears to have 8 hoop marks visible (4 to each end).	Wood	1	
127.00102	CL12A-0018	P	Stave	Stave, incomplete. Only 1 end remains, about 45% complete. Evidence of marine worm damage present.	Wood	1	
127.00102	CL12A-0018	Q	Stave	Stave, incomplete, only one end; small piece hanging off.	Wood	1	
127.00102	CL12A-0018	R	Stave	Stave, incomplete, only one end. About 30–40% complete.	Wood	1	
127.00102	CL12A-0018	S	Headpiece	One of middle pieces of cask head, complete, no markings. 3 dowel holes: 1 along longest flat edge, and 2 along shorter edge.	Wood	1	
127.00102	CL12A-0018	T	Headpiece	Middle piece of cask head, complete, good condition. Scratch marks visible on interior face. Branded letters on exterior 'R TENNE' across the width. Both ends are bevelled. 4x dowel holes present, 2 along each of the straight edges. A big nail hole present through the piece near one end.	Wood	1	
127.00102	CL12A-0018	U	Cant headpiece	Cant from a cask headpiece. About 95–98% complete, no markings or branded letters. Bevelled along curve.	Wood	1	
127.00102	CL12A-0018	V	Cant headpiece	Cant piece from a cask head, complete. 2 dowel holes visible along flat edge, no markings or brands on surface.	Wood	1	
127.00099	CL12A-0015	A	Headpiece	Cant headpiece, one dowel hole towards one end, good condition.	Wood	1	

127.00102	CL12A-0018	W	Cant headpiece	Stave.	Wood	1	
127.00102	CL12A-0018	X	Cant headpiece	Stave, incomplete. About 40% remains. No markings, poor condition.	Wood	1	
127.00102	CL12A-0018	Y	Cant headpiece	Stave, incomplete. About 40% remains. No markings, poor condition.	Wood	1	
127.00099	CL12A-0015	B	Headpiece	One of off-centre headpieces. No dowel holes visible along straight sides but possibly worm eaten. Has two circles scratched on topside, overlapping each other.	Wood	1	
127.00099	CL12A-0015	C	Headpiece	Possible centrepiece, with one circled scratched on top face.	Wood	1	
127.00099	CL12A-0015	D	Headpiece	Possible middle piece, poor condition. Has incised lettering 'II R S' and a straight line diagonally downwards over the first 2 characters.	Wood	2	
127.00099	CL12A-0015	E	Cant	Cant piece of a cask head, no visible markings. One dowel hole towards one end along flat edge. Possibly part of E, F,G, H, I & J.	Wood	1	
127.00099	CL12A-0015	F	Headpiece, off centre	2nd piece next to a cant. Possibly part of E, F, G, H, I & J.	Wood	1	
127.00099	CL12A-0015	G	Headpiece	3rd piece from cant. Some evidence of the name 'TENNET' scratched (rather than branded) on the topside, also 'CC' and straight lines along and across these. Evidence also of straight and curved scratched marks for aiding assembly. Two dowel holes present. Possibly part of E, F, G, H, I and J.	Wood	1	

127.00099	CL12A-0015	H	Headpiece	Middle piece. 2 dowel holes. One bunghole, sealed but not entire bung is present. Scratched with ‘NNE’. Possibly part of E, F, G, H, I & J.	Wood	1	
127.00099	CL12A-0015	I	Headpiece	Possibly part of E, F, G, H, I and J.	Wood	1	
127.00099	CL12A-0015	J	Cant	Several curved and straight line scratched visible to aid assembly. Possibly part of E, F, G, H, I and J.	Wood	1	
127.00099	CL12A-0015	K	Bung	Bung, about 98% complete. Almost circular.	Wood	1	
127.00099	CL12A-0015	L	Bung	Bung, about 50% complete.	Wood	1	
127.00099	CL12A-0015	M	Stave	Stave, complete. Evidence of concretion and timber across stave near one end at hoop section.	Wood	1	
127.00099	CL12A-0015	N	Stave	Stave.	Wood	1	
127.00099	CL12A-0015	O	Stave	Stave, about 98% complete. Iron stains visible where hoops were.	Wood	1	
127.00099	CL12A-0015	P	Stave	Stave.	Wood	1	
127.00099	CL12A-0015	Q	Stave	Stave, split through centre nearly all the way. Some hoop marks visible.	Wood	1	
127.00099	CL12A-0015	R	Stave	Stave, complete. Some hoop marks visible especially at one end.	Wood	1	
127.00099	CL12A-0015	S	Stave	Stave, complete. Some hoop marks visible especially at one end. Faint hoop marks.	Wood	1	

127.00099	CL12A-0015	T	Stave	Stave, complete, narrower than other staves. Faint hoop marks visible. Iron hoop corrosion present, indicating where hoops were.	Wood	1	
127.00099	CL12A-0015	U	Stave	Stave, complete. Hoop marks and iron hoop corrosion visible.	Wood	1	
127.00099	CL12A-0015	V	Stave	Stave, complete. Hoop marks and iron hoop corrosion evidence visible. Conservation conducted pilodyn test on this timber.	Wood	1	
127.00099	CL12A-0015	W	Stave	Stave, complete. No clear hoop marks visible, only very faint.	Wood	1	
127.00099	CL12A-0015	X	Stave	Stave, about 98% complete, missing croze end. Very faint hoop marks can just be made out.	Wood	1	
127.00099	CL12A-0015	Y	Stave	Stave, complete. Iron hoop corrosion visible.	Wood	1	
127.00099	CL12A-0015	Z	Stave	Stave, complete. Iron stains at one end, faint hoop marks towards the other end.	Wood	1	
127.00099	CL12A-0015	AA	Stave, complete	Stave.	Wood	1	
127.00099	CL12A-0015	BB	Stave, complete	Stave, complete. Faint hoop marks visible.	Wood	1	
127.00099	CL12A-0015	CC	Stave	Stave, complete.	Wood	1	
127.00099	CL12A-0015	DD	Stave	Stave, about 40% complete, some hoop marks.	Wood	1	

127.00099	CL12A-0015	EE	Stave	Stave, about 10% complete.	Wood	1	
127.00099	CL12A-0015	FF	Stave	Stave, about 15% complete. Some iron stain on the exterior face.	Wood	1	
127.00103	CL12A-0019		Rope	Rope, probably related to rigging.		1	
127.00104	CL12A-0022		Concretion	Concretion from a fastening with a square shank.	Concretio n	1	
127.00105	CL12A-0023		Pick	Spiral pick, bent and mostly covered in concretion.	Iron	1	
127.00106	CL12A-0024	A	Timber	Flat piece of timber, thought to be dunnage. Extensive marine worm damage.	Wood	1	No image
127.00106	CL12A-0024	B	Timber	Flat piece of timber, thought to be dunnage. One side is flat and the other is curved along the length.	Wood	1	No image
127.00106	CL12A-0024	C	Timber	Flat piece of timber, thought to be dunnage.	Wood	1	No image
127.00106	CL12A-0024	D	Timber	Flat piece of timber, thought to be dunnage.	Wood	1	No image
127.00106	CL12A-0024	E	Timber	Long piece of timber, thought to be dunnage.	Wood	1	No image
127.00106	CL12A-0024	F	Timber	Flat piece of timber, thought to be dunnage. Very badly damaged by marine worms.	Wood	1	No image
127.00106	CL12A-0024	G	Timber	Flat piece of timber, thought to be dunnage. Very badly damaged by marine worms.	Wood	1	No image
127.00106	CL12A-0024	H	Timber	Flat piece of timber, thought to be dunnage. Very badly damaged by marine worms.	Wood	1	No image

127.00106	CL12A-0024	I	Timber	Timber fragments, thought to be dunnage. Very badly damaged by marine worms.	Wood	2	No image
127.00106	CL12A-0024	J	Timber	Timber, thought to be dunnage. Very badly damaged by marine worms.	Wood	1	No image
127.00106	CL12A-0024	K	Timber	Flat, long piece of timber, thought to be dunnage. Appears in better condition but could still be internally damaged by marine worms.	Wood	1	No image
127.00106	CL12A-0024	L	Timber	Flat piece of timber, thought to be dunnage.	Wood	1	No image
127.00106	CL12A-0024	M	Timber	Flat, long piece of timber, thought to be dunnage. Appears in better condition than other pieces.	Wood	1	No image
127.00106	CL12A-0024	N	Timber	Flat, long piece of timber, thought to be dunnage.	Wood	1	No image
127.00106	CL12A-0024	O	Timber	Flat, piece of timber, thought to be dunnage.	Wood	1	No image

Appendix H: Rope Fibre Analysis Report

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FTIR ANALYSIS REPORT

WAM CONSERVATION JOB. NO.	13/17
OBJECT REG. NO.	CL12RS-0012 rope sample
DATE:	14 February 2013
ANALYSIS BY:	Inger Nyström Godfrey and Kalle Kasi

FIBRE ANALYSES

Job no. 13/17

A rope sample CL12RS-0012 from the wreck site of the Clarence was analysed.
Reference sample of coir (coconut fibre) from Oman and from Sydney Cove were used for comparison.

The fibres were analysed using:

- The twist test
- Microscope with polarized light (X50, X125, and X250). They were mounted in glycerol.
- FTIR

CL12RS-0012

The sample fibres are light buff in colour, stiff and break easily. The latter features could be because of degradation. The sample is difficult to break up into ultimates (fibre cells). The fibres do not twist during drying, neither clockwise nor anti-clockwise. The streaky and slightly wavy appearance of the fibre (X50, X125) indicates that a bundle of ultimates (fibre cells) make up the fibre. The streakiness is enhanced by rectangular stave like features of different lengths. This could be granules within the lumen of each ultimate. No evident cross markings or dislocation can be seen.

REFERENCE SAMPLE

The fibres are reddish brown and rather stiff. A coir fibre (bundle) constitutes of smaller ultimates and this can be seen as a streaky, slightly wavy appearance under all three magnifications. The streakiness is enhanced by rectangular stave like features of different lengths. This could be granules within the lumen of each thread, however they are not dark or filled, but look void. Brown “cells” (from roundish to long and thin) are visible on what seems to be the outside of the fibre.

One fibre was crushed for better viewing. This was hard, since the fibres are very tough and difficult to break; however, it was then possible to see distinct lumen and cell walls within the threads. Cell walls are thinner than lumen. No cross markings or dislocation can be seen. The same void rectangular features can be within the threads.

RESULTS

It seems very likely that the rope from the Clarence (sample CL12RS-0012) is made of coconut fibres (coir). The microscopic resemblance to the coir reference sample is close and the fact that the samples do not twist in any directions exclude any other fibre represented in the reference literature. The fact that our sample is light and not red or golden brown point to it being “white coir”, which according to Wikipedia is “harvested from coconuts before they are ripe” they are “smoother and finer, but also weaker. They are generally spun to make yarn used in mats or rope. The coir fibre is relatively waterproof, and is one of the few natural fibres resistant to damage by saltwater”.

The FTIR analyses agree with the above result (Figure 1). The spectrum of the rope sample (red) is almost identical with the spectrum of the Oman coir (blue), except for the missing peak of hemicellulose at 1730 cm^{-1}. The missing hemicellulose is due to degradation of the rope fibres on the wreck site.

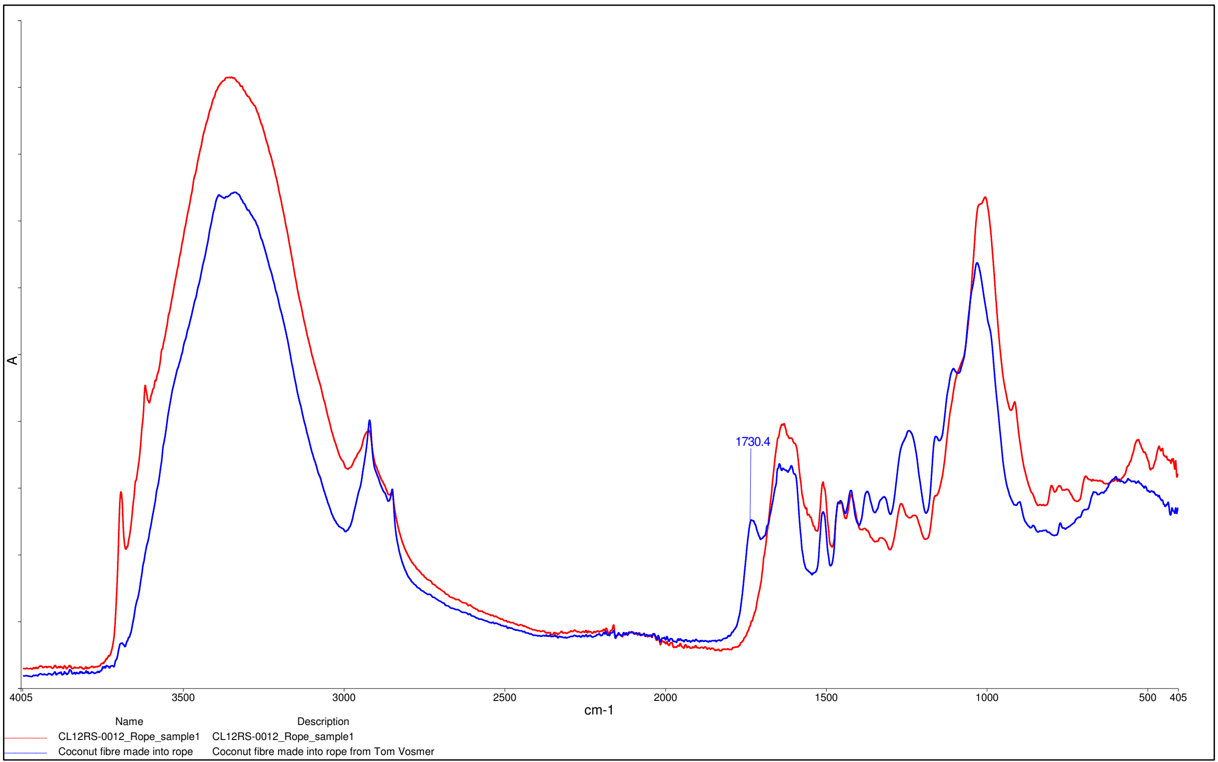

Figure 1. FTIR spectra of the CL12RS-0012_Rope_sample1 (red) compared to the spectra of coconut fibre made into rope (blue).

REFERENCES

Caitling, D. & Grayson, J. (1982) Identification of vegetable fibres. Chapman and Hall, London, New York.

Identification of textile materials. (1970) The textile institute, Manchester, 6th edition, London and Prescot.

http://en.wikipedia.org/wiki/Coir

Appendix I: Leather Analysis Report

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FTIR ANALYSIS REPORT

WAM CONSERVATION JOB. NO.	13/17
OBJECT REG. NO.	CL12LS-0013A; CL12LS-0013B; CL12LS-0013C and CL12LS-0014
DATE:	26 June 2015
ANALYSIS BY:	K. Kasi

SAMPLE DESCRIPTION

The selected two waterlogged leather artefacts CL12A-0008 and CL12A-0009 were excavated from close proximity in the sandy shell deposit, with burial depth of 31 cm and in 7.4 m of water, from the *Clarence* (1850) wreck site in Port Phillip Bay and sampled for FTIR analyses on 26 April 2012 and on 05 May 2012 respectively as follows:

- Three small samples: CL12LS-0013A; CL12LS-0013B and CL12LS-0013C were cut from a stiff and thick leather artefact CL12A-0009; and
- One sample: CL12LS-0014 was taken from a fragile thin leather artefact CL12A-0008.

All samples were air dried and prepared for the FTIR analyses in duplicates.

Figure 1. Leather artefacts CL12A-0008 and CL12A-0009 from the *Clarence* (1850) wreck site.

ANALYSIS REQUEST

FTIR analysis of waterlogged leather artefacts to ascertain the extent of deterioration by examining the processes of aggregation of collagen fibrils and the changes that occur on denaturation of the collagen triple helix in aqueous solution. In the former case, aggregation of collagen fibrils (fibrillisation) is resulting in the enhancement of the 1242 cm^{-1} peak with a concomitant reduction in the 1257 cm^{-1} peak while denaturation of soluble collagen in water leads to a reduction in the intensity of the amide I peak centred at 1660 cm^{-1} and an increase in the intensity of the peak centred at 1633 cm^{-1}.

METHOD OF FTIR ANALYSIS

The duplicates of the small leather samples (~2 mm^2) were examined using a PerkinElmer Spectrum 100s Fourier transform infrared (FT-IR) spectrometer. The sample spectra were collected using a Universal Attenuated Total Reflection (UATR) accessory with 1 bounce Diamond/KRS-5 (Thallium Bromo-Iodide) crystal combination, accumulated over 4 scans. The spectral range was 4000-400 cm^{-1} (2-20 µm) with a resolution of 4 cm^{-1}. No sample preparation was necessary except for application of good contact between the sample and the ATR crystal under the ATR pressure arm. The Spectrum v10.03 software package from PerkinElmer Inc. was used to collect the spectra with the ATR correction applied and conversion from transmittance (%T) as its ordinate to absorbance units (A).

Spectra were deconvolved for each sample using the Spectrum v10.03 software and a Bessel type apodisation function with settings of Gamma (γ) = 2 and Smoothing Length (%) = 40 for the region 1300-1200 cm^{-1} and Gamma (γ) = 2 and Smoothing Length (%) = 55 for the region 1800-1600 cm^{-1}. Baselines were drawn between the minima at approximately 1680 cm^{-1} to that at approximately 1600 cm^{-1} and between the minima at approximately 1295 cm^{-1} to that at approximately 1215 cm^{-1} for each sample. Intensities were determined for all peaks between approximately 1680-1600 cm^{-1} and 1280-1213 cm^{-1}. The extent of denaturation was determined for each artefact by calculating the intensity ratio for the peaks at approximately 1630 cm^{-1} and 1660 cm^{-1}. The extent of defibrillisation was calculated using the ratio of the peaks at approximately 1257 cm^{-1} and 1242 cm^{-1}. The mean intensity values of all peaks of interest were determined from the duplicate spectra and used in subsequent calculations. No data was excluded. A reference sample from modern leather (vegetable tanned cow hide) was used to calculate the Relative Degree of Defibrillisation (%) and the Relative Degree of Denaturation (%) for marine archaeological samples. An FTIR spectrum of CL12LS-0013A_Leather_sample (red) compared to the modern leather (vegetable tanned cow hide) is shown below (Figure 2).

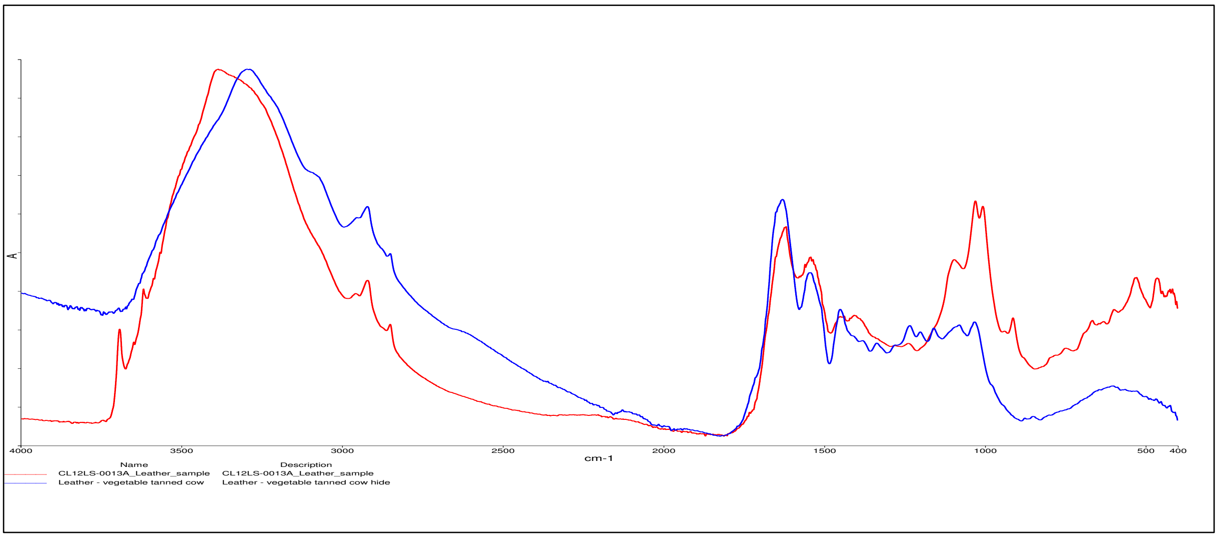

Figure 2. FTIR spectra of CL12LS-0013A_Leather_sample (red) and the modern leather (blue).

METHOD OF XRF ANALYSIS

X-ray Fluorescence (XRF) spectra were acquired with a Bruker AXS Handheld Tracer III-SD (SNT3S2520) with channel resolution of 2048 and operating parameters: Rhodium tube X-ray source and 10 mm^2 XFlash® SDD peltier cooled detector with typical resolution of 145 eV at 100,000 counts per second (cps) over an area ~8 mm^2. All analyses conducted at Tube Voltage of 40keV; Tube Current of 30µA with the vacuum applied and no filter in the X-ray path and a 300 second live-time count.

An XRF spectrum of CL12LS-0013C_Leather_sample (red) compared to the spectrum of CL12LS-0014_Leather_sample is shown below (Figure 3). The thick leather artefact CL12A-0009 (red spectra) has significantly more iron present than the thin leather artefact CL12A-0008.

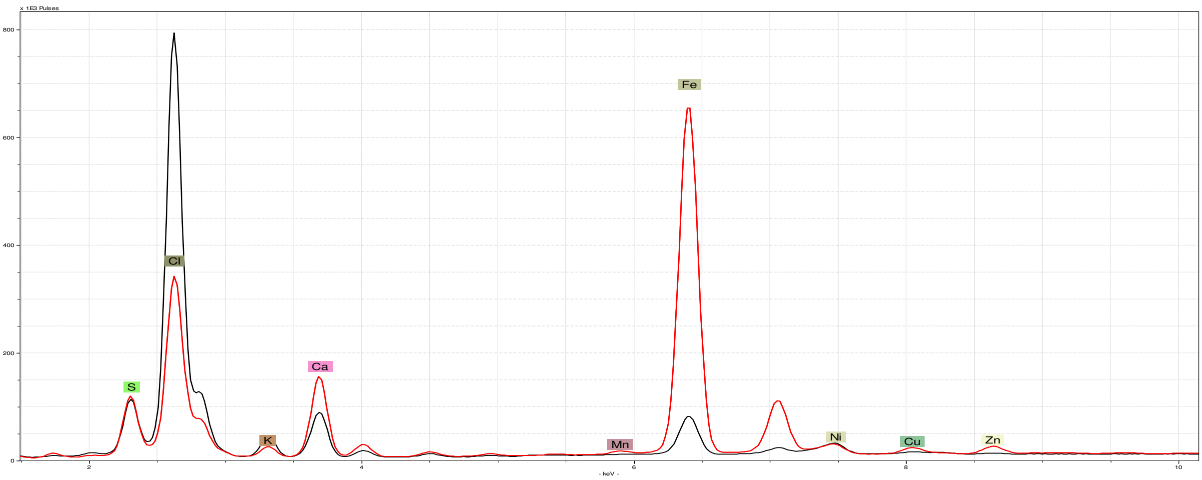

Figure 3. XRF spectra of the CL12LS-0013C Leather sample (red) and the CL12LS-0014 Leather sample (black).

RESULTS OF ANALYSIS

The Relative Degree of Defibrillisation and The Relative Degree of Denaturation of the leather:

	Relative Degree of Defibrillisation (%)	Relative Degree of Denaturation (%)
CL12A-0008 thin leather artefact	62	*27
CL12A-0009 thick leather artefact	47	50

* The anomalous result recorded for the thin leather (CL12A-0008) relative degree of denaturation 27% maybe due to artificially enhanced amide I (medium to strong absorption of C=N stretching vibrations) by the anaerobic oxidation of ammonia (from the organic compounds and open ocean bacterium) reacting with the functional classes of organic compounds. It is also possible (although less likely) that the thin leather artefact was in fact less denaturated with high fibrillisation of collagen fibrils present compared to the thick leather and the visually observed fragility of the thin leather was due to the thinness of the leather.

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