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3DMAPPR

A community-based underwater
archaeological photogrammetry
program in Perth, Western Australia

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Introduction

The Maritime Archaeology Association of Western Australia (MAAWA), in collaboration with Tempus Archaeology (TA) and with the support of the Maritime Archaeology Department of the Western Australian Museum (MADWAM), recently initiated the 3D Maritime Archaeological Project—Perth Region (3DMAPPR). Intended primarily as a community-oriented capacity-building exercise, the overall objectives of the initial stage of the project were twofold: (i) to assess the viability of employing a low-cost underwater 3D photogrammetry package to document maritime archaeological sites; and, (ii) to provide MAAWA members with a set of operational guidelines, training, and experience in underwater 3D photogrammetric recording and data processing techniques. It was intended that avocational ‘citizen scientists’ would then be able to help address current management priorities by making meaningful contributions to the ongoing documentation and monitoring of maritime archaeological sites in the Perth metropolitan region. Combined with another MAAWA initiative (the Shipwreck WA website and smart phone application, <http://www.shipwreckswa.com>), this data has the potential not only to inform ongoing management of maritime archaeological sites, but also to be used as a resource for research, public education and outreach. This paper provides an overview of activities undertaken as part of 3DMAPPR during the first year of its operation. After outlining the project background and rationale, the authors review several case studies and highlight the opportunities afforded by the adoption of underwater multi-image 3D photogrammetry in a non-specialist context.

Project background

The idea of initiating a community-based underwater 3D photogrammetry project developed out of a series of informal discussions between the authors concerning the apparent lacuna in documentation of wreck sites and other aspects of the maritime archaeological heritage in the Swan and Canning river systems. While a considerable number of sites were identified and investigated by MAAWA and MADWAM during the 1980s and 1990s (Scrimshaw 1980), it has to be acknowledged that the current status and condition of many of these sites remain unknown.

The underlying reasons for this are manifold, but can primarily be attributed to:

- a. The lack of any formal or long-term monitoring program;
- b. A limited capacity to accurately document the cause(s), nature, and scale of changes to sites and their immediate environments; and
- c. Potentially too great a reliance on avocational involvement, with all of its concomitant pressures on time, money and expertise.

Given these issues, and the inherent limitations of traditional manual underwater survey and recording techniques, it became readily apparent that there was a need to explore alternative approaches that would enable the non-specialist membership of MAAWA to undertake rapid *in-situ* site assessments and documentation. Necessarily, any such approach would need to meet a number of basic requirements in order to make it ‘fit for purpose’ within the context of a not-for-profit community organisation. These requirements included low financial and technical overheads; appropriate degree of accuracy and precision; and, the ability to utilise inexpensive consumer-grade hardware wherever possible.

Viable low-cost 3D multi-image photogrammetry (3DMIP) in a non-specialist context?

A review of the relevant literature indicated that of the several potential methods available, 3D multi-image photogrammetry was the approach most compatible with the project requirements (Bruno *et al.* 2014; Drap *et al.* 2008; McCarthy 2014; McCarthy & Benjamin 2014; Skarlatos *et al.* 2012; Sorbi *et al.* 2014; Verhoeven 2011; for other techniques, see Drap 2012). The term 3D multi-image photogrammetry (3DMIP) is one of a number of often-unwieldy names that describe the use of 2D image datasets to reconstruct the 3D geometry of an object or scene (Remondino 2014: 63). Current implementations of 3DMIP have been demonstrated to be flexible, robust and accurate solutions for a wide range of heritage documentation projects (Doneus *et al.* 2011), and are increasingly becoming an integral component in archaeological fieldwork, planning and documentation (e.g. Olson *et al.* 2013, Reu *et al.* 2012).

In part, this can be attributed to the considerable number of potential advantages 3DMIP offers over traditional manual recording techniques (Fassi *et al.* 2013). These include:

- Rapidity, objectivity and relative simplicity of implementation;
- Scale independence (i.e. can be used to record objects or scenes of virtually any size);
- High accuracy and precision (under appropriate conditions);
- Ability to employ non-metric photographic equipment;
- Relatively low computing requirements;
- Can repurpose so-called ‘legacy’ imagery;
- Permits sites and their surrounding environments to be documented in a holistic fashion; and
- Reconstruction of an object or scene can be undertaken using data extracted solely from photographic images.

Photogrammetric techniques have long been employed in maritime archaeological contexts, beginning with the seminal work of Dimitri Rebikoff (1972) at the harbour site of Kenchreai near Corinth, Greece, and Donald Rozencrantz at Yassi Ada in Turkey (Bass & Katzev 1968; Rozencrantz 1975). The high costs and overall complexity of implementation at that time meant that these techniques were neither widely adopted nor fully realised in terms of their potential. There followed a considerable lull in the archaeological deployment of 3DMIP that effectively ended only within the last two decades owing in no small part to a series of convergent developments in the fields of computing, digital imaging, photogrammetry and computer vision. These developments served to drive down the cost of computer and imaging hardware, significantly improve instrumentation capability, and make possible highly automated (or ‘black box’) photogrammetry processing workflows. One corollary of this is that ‘photogrammetry... re-emerged as a competitive technology and a resurgence in automated photogrammetric methods’ (Remondino *et al.* 2014: 146; see also Van Damme 2015b: 236–7). Indeed, not only have recent years witnessed a rapid increase in the adoption of 3DMIP within heritage circles at large, but also its effective ‘democratisation’, with use migrating down from purely specialist academic and commercial applications into the public domain.

This latter movement is best characterised by the appearance of a number of community-based photogrammetric recording projects (e.g. Bryan & Chandler 2008; McCarthy 2014; Haukaas & Hodgetts 2016; Rodrigues-Echavarria *et al.* 2009), of which 3DMAPPR constitutes a logical extension.

Nevertheless, it would be misleading to suggest that the use of 3DMIP by non-specialists in underwater contexts is unproblematic. Whilst the technique does involve certain complexities not typically encountered in terrestrial applications, there is nevertheless a persistent but erroneous perception that underwater 3DMIP requires an expensive and somewhat specialised toolkit to implement successfully (McCarthy & Benjamin 2014: 97). For this reason, the authors’ initial objective was to undertake an informal program of testing and evaluating in order to address three broad issues, namely:

- a. Are low-cost software and imaging platforms ‘fit for purpose’?;
- b. What are the optimum operational parameters for recording different types of maritime archaeological sites in a diverse range of environments?; and
- c. What skills and resources are required to generate data suitable not only for the purposes of visualisation, but also to provide informed input into the management of maritime archaeological sites in the Perth region?

In addressing these relatively simple issues, 3DMAPPR can be seen to be concerned less about technological or methodological innovation than it is about establishing an effective ‘operational envelope’ for non-specialists working with limited fiscal and material resources.

Study sites

For the purposes of testing and evaluation, the team identified a number of primary and secondary study sites (Fig. 1 & Table 1). These sites were selected on the basis of representativeness (site size, type, complexity and setting), simple logistics (such as proximity and ease of access), and the provision of a diversity of recording subjects and scenarios. The primary study sites were intended to be the main focus of the testing and evaluation program, and include the iron-hulled SS *Omeo*, World War II landing craft ALC-40 and the remains of Robb Jetty (a wooden cattle handling facility).



Figure 1. Map showing the location of study sites mentioned in the text.

The secondary study sites, comprising the late 19th-century wooden-hulled shipwrecks of *Mayfield*, *City of Perth* and *Eva*, served both as ‘fall back’ options when access to primary sites was not possible, and provided an additional range of testing and training options. MAAWA members had previously recorded several of the study sites during the 1980s and 1990s, the data from which served as a valuable baseline reference for comparison against the results of the photogrammetry program.

SS Omeo (1858–1905)

This a clinker-built iron barque located approximately 40 m off Coogee Beach, where it lies in 2–4 m of water. The ship was wrecked in 1905, when it broke its moorings during a storm and was pushed ashore where it gradually broke up. The wreck site, which encompasses an area of approximately 75 m x 12 m, was provisionally mapped by MAAWA between 1990 and 1992, and has since been the subject of a conservation assessment undertaken by the Western Australian Museum. The wreck is currently protected under the *Historic Shipwrecks Act 1976*, and is set to become one of the metropolitan area’s premier ‘wreck access’ sites (see Koro Brown, 2017, Coogee dive trail opens. *Fremantle Herald*, 28.8: 9 [February 25]).

ALC40 (c. 1943–1944)

This wreck site (18.6 m x 5.4 m) comprises the remains of a 40-ton capacity Australian Landing Craft powered by four 100 hp inboard petrol engines, used to carry vehicles and troops. It is located in the Swan River, 50 m from the shore in approximately 10 m of water, immediately downstream from the East Fremantle Yacht Club. It came adrift in a storm in 1943–4 and sank after being towed back by the Royal Australian Navy and moored in the river. The site was recorded by MAAWA in 1990.

Robb Jetty (1893–1975)

Robb Jetty is located in North Coogee and was built c. 1893 to service the North West cattle trade. Extended to a length of some 166 m and provided with a cattle race and stockyards in 1894, the jetty continued to be variously repaired and extended until the 1960s, at which time it was condemned for shipping. The jetty was subsequently demolished in 1975 in the face of local opposition (Wilkinson 2013: 34–5).

Site	Context	Dimensions	Depth	Status
SS Omeo	Ocean (Coastal)	75 m x 15 m	0–3 m	Primary
ALC40	Sheltered waters (River)	18.6 m x 5.4 m	10 m	Primary
Robb Jetty	Ocean (Coastal)	180 m x 20 m	5 m	Primary
Mayfield	Sheltered waters (River)	22 m x 5 m	5 m	Secondary
City of Perth	Sheltered waters (River)	20 m x 6 m	1–2 m	Secondary
Eva	Sheltered waters (River)	20 m x 5 m	1.5–2.5 m	Secondary

Table 1. Details of study sites.

Mayfield (1899–1945)

The wreck of the *Mayfield* is located in the Swan River, at the base of the limestone cliffs on the western side of Rocky Bay in North Fremantle, and lies at an average depth of approximately 5 m of water. Originally built as an unpowered barge measuring 22 m long and 5 m across the beam, *Mayfield* was registered in 1899 and operated by the Swan Brewery Company. The barge was initially used to transport beer from the brewery to the port to be exchanged for raw materials such as sugar, hops and malt that were returned to the brewery (Wellborn 1987: 79). It finally sank for unknown reasons in Rocky Bay in 1945 where it lies today. The vessel was relocated in 1979 and was recorded by MAAWA in 1980 and 1990 (Cockram 1990).

City of Perth (1871–1908)

The remains of *City of Perth* are located next to the cliffs on the western side of Rocky Bay, lying in approximately 1 m of water and 15 m from the remains of the *Mayfield* (Cooper 2012). It was built as a wooden side-wheel paddle steamer in 1872, measuring 26.5 m long and 5 m across the beam with a displacement of 61.2 tons. The vessel was covered with Muntz metal sheeting, and powered by two 20 hp engines installed and fitted by G. Randell and Company (Dickson 1998: 108). It was used as an observation platform for the 1876 Perth Regatta, where it ‘thronged with gazers’ as it was moored off Mill Point (*The West Australian Times*, 21 April 1876). *City of Perth* was later converted into a lighter and registered with the Harbour and Lights Department in 1898 (Murray 2004: 6) before being abandoned c.1900 (Parsons 1980: 13). The vessel was relocated in 1979 and recorded by MAAWA divers in 1980 and 1990 (Cockram 1990: 22–3).

Eva (1897–1944)

The wreck of *Eva* (20 m x 5 m), located at Point Direction on the North Fremantle area of the Swan River, was first investigated in June 1980 by MAAWA. Built in 1897 as an unpowered wooden barge and lighter designed to transport goods between Fremantle and Perth, its career of cargo transportation ended in 1944 when it was scuttled and used as a slipway. During the 1980s the site was redeveloped, resulting in a jetty being built directly over it.

Methods

Photogrammetry software

A wide and rapidly expanding range of open-source (VisualSfM, the Bundler+PMVS2+CMVSassembly), web-based (123D Catch, Hyper3D/Cubify3D) and stand-alone (Photoscan, Photomodeller Scanner, 3DF Zephyr, RealityCapture) multi-image photogrammetry solutions are currently available. For the purposes of the present project the authors employed Photoscan by Russian developers Agisoft (www.agisoft.com). This package has become something of a *de facto* standard in the field of archaeological photogrammetric documentation, and has been employed in a considerable number of terrestrial and (increasingly) underwater scenarios (Verhoeven 2011; Drap 2012; De Reu *et al.* 2013; McCarthy & Benjamin 2014; Van Damme 2015). Unlike many of its competitors, Photoscan is a cross-platform (Windows X32/X64, OSX and Linux) package that is both simple to install and use, and has a semi-automated multi-stage workflow that can be user-adjusted, giving it a great degree of flexibility. Furthermore, the software is frequently updated and has a very active user-base and support network. Available in two versions that differ considerably in terms of price and capability, issues of cost dictated that the low-end Standard version (currently priced at USD\$179.00 for a stand-alone licence) be used. Extended functionality—including the ability to generate scaled and georeferenced output, orthomosaics, and digital elevation models—was added through the use of third-party open source software, such as Meshlab (Cignoni *et al.* 2008), SFM_Georef (James & Robson 2012) and SAGA GIS (<<http://saga-gis.org/en/index.html>>).

Camera selection

Image acquisition necessarily lies at the heart of any photogrammetry project. A multitude of factors, including the optical qualities of the camera and lens system (resolution, speed, sensitivity, optical correction), the nature of the underwater environment (variable lighting conditions, water quality, contrast loss from absorption, loss of colour information with depth), and the manner in which images themselves are acquired (video sequence or still images, recording strategy, stand-off distance, and image framing), can have a significant impact on the success and overall quality of the project (Hollick *et al.* 2013; Ludvigsen *et al.* 2006; McCarthy & Benjamin 2014; Skarlatos *et al.* 2012; Thoeni *et al.* 2014).

While a number of low-cost camera systems were initially considered for use on the project, the GoPro Hero line of ‘action cameras’ was ultimately selected for further testing and evaluation. The GoPro Hero 3, 3+ and 4 Black Edition models employed in 3DMAPPR are highly portable pieces of equipment, weighing in at approximately 150 g (with housing), and are equipped with a relatively fast f2.8 wide angle lens and 1/2.3-inch type 4:3 sensor capable of capturing images at a resolution of 12 megapixels (MP) and video at up to 4K at 60 frames per second (fps). Additionally, the cameras are waterproof to a depth of 40 m using the supplied housing, reducing the need for additional hardware. While these cameras (particularly older models) have been viewed in an unfavourable light by some researchers owing to issues with optical distortion and its impact on reconstruction accuracy (e.g. Capra *et al.* 2015; Thoeni *et al.* 2014), many of these issues have been addressed through the recent provision of software support for fisheye lens calibration and improved processing algorithms. Indeed, any potential loss of accuracy is likely to be outweighed by tangible benefits such as cost, simplicity of operation, and—above all—ubiquity, with a large number of the MAAWA membership either owning or being familiar with this type of camera.

Recording process

The documentation of each of the study sites using 3DMIP was accomplished in several stages. Initially, a preliminary inspection was made of the site or sites to be recorded, allowing members of the team to familiarise themselves with the location and identify any methodological, logistical or safety issues. This was then followed by one or several recording runs, each of which was carried out in accordance with Rules 3 and 4 of the General Principles of the 2001 UNESCO Convention on the Protection of the Underwater Cultural Heritage. This ensured that a strictly non-invasive approach was adopted for all field operations undertaken, irrespective of the legal status of the sites involved.

As noted above, the team employed various models of GoPro Hero action cameras for the purposes of image acquisition. These were configured using the in-built intervalometer function to automatically capture images at 0.5-sec intervals at a resolution of 12MP in ‘wide’ mode. While the use of video was considered (and trialled), the time-lapse function was preferred as it embeds EXIF data that can be used to perform camera calibration, requires less

processing (owing to the need to extract still image sequences from video files), and appears less susceptible to motion blur owing to higher shutter speeds (Yamafune *et al.* 2016: 12-13; see Mertes *et al.* 2014: 176, 187; Van Damme 2015b: 234). The use of the time-lapse function also served to reduce the task-loading on divers, allowing them instead to concentrate on other essential tasks such as navigation. As the general working depth of the study sites (and proposed future riverine targets) was less than 20 m, images were captured under ambient lighting conditions. This considerably simplified the recording rig and obviated issues arising from the use of artificial light sources, such as the creation of hard and changing shadows that can create issues for the feature detection and matching algorithms employed by Photoscan.

The recording strategy itself typically involved one or more members of the dive team making a series of longitudinal and transverse traverses (a pattern often referred to as ‘mowing the lawn’) across the site in question and capturing a contiguous series of top-down or ‘nadiral’ images with a substantial overlap (50–75%) and sidelap (50%) (Figs 2 & 3).



Figure 2. Nicolas Bigourdan preparing to record ALC40.

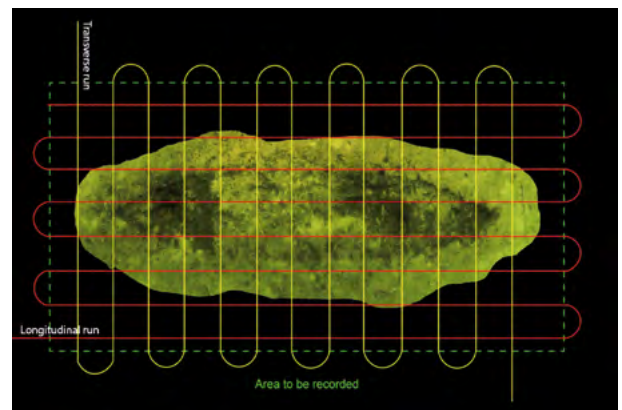


Figure 3. Survey recording strategy.

In the case of 'complex' sites (i.e. those with a significant upstanding remains), the traverses were supplemented with the capture of an additional series of oblique images of the site and/or any specific features (such as the two engines on the wreck of *Mayfield*) in order to provide coverage of any undercuts and/or self-occlusions. Necessarily, this approach was highly flexible, being adapted as and where required, in order to best meet the requirements of each site and its surrounding environment.

In order to maximise the clarity of images, it was initially proposed that a relatively constant stand-off distance of 1.5 m–2.0 m be adopted during recording (Leatherdale & Turner 1988: 35). In practice, however, it soon became apparent that stand-off distances would need to be modified in response to a variety of factors, including water quality/visibility and practical constraints arising from the situation of particular sites. This had a number of implications in terms of how recording was undertaken, given that a decrease in stand-off distance would necessarily reduce the ground sample distance (i.e. the effective photographic 'footprint'), requiring that divers change their swim rate relative to the sea floor/site and modify the spacing of their recording traverses in order to maintain adequate overlap and side lap. This issue was provisionally addressed by developing a set of charts and tables that detailed the relationship between swim speed, stand-off distance, and photographic coverage that allowed members of the dive team to better plan their recording runs. Nevertheless, the issue of successfully navigating sites while maintaining optimum survey coverage remained a constant bugbear, particularly when recording large sites at very close range.

The lack of support for ground control points (GCPs) in the *Standard* version of Photoscan meant that it was not possible to establish a survey network that could be used to constrain, orientate and scale 3D reconstructions (Agisoft 2014). While an attempt was made to employ open source software (SFM_Georef) to address this deficiency, this proved unsuccessful owing to various compatibility issues and overall complexity of implementation. Instead, reliance was placed on a number of very simple scaling controls, such as ranging poles and target markers set out with a known separation (which facilitated greater accuracy owing to the ability to employ longer baseline distances). While these simple methods proved adequate for the purposes of scaling, further elaboration



Figure 4. Simple rig to facilitate scaling and orientation of 3D models.

was required in order to provide a ready means to orientate the models correctly. This involved the creation of a simple demountable rig comprising two arms of unequal length (provisionally 2 m and 1 m respectively) joined at right angles in an 'L' shaped arrangement (Fig. 4). Each of the arms is fitted with a line level and photographic target markers. Mounted on fixed or adjustable legs (depending on the substrate of the site or feature in question), this rig, when manually levelled, is then recorded along with the subject site, where it will provide a visual reference for scaling and orientation transformations. A prototype of this rig has been successfully tested with a refined version to be deployed in future field operations.

Data processing

Primary processing was undertaken using *Photoscan Standard Edition*, which was hosted on an inexpensive Acer Aspire v3-571G laptop computer equipped with an Intel i7-3610QM quad core processor, 8GB of random access memory, and a discrete Nvidia GeForce GT640M graphics card. While this laptop proved suitable for previewing data in the field and processing relatively small batches of 700–800 images, larger datasets necessitated the use of a more powerful desktop computer. In these situations, data processing was undertaken by a Dell Precision T1600 workstation equipped with a 3.10 GHz quad core Xenon processor, 16GB of random access memory, and a Nvidia Quadro 2000 graphics card.

Processing of the images captured during each of the various recording runs was undertaken in several stages. As a preliminary step, all images in each set were manually reviewed, with any considered redundant or unusable owing to issues of quality being removed. In the case of image

sequences recorded under conditions of variable or adverse lighting, additional batch processing was undertaken using Adobe Photoshop. This followed the general procedures outlined by Mahiddine *et al.* (2012), which involved clipping and stretching image histograms to remove saturated highlights and shadows. The processed images were then imported into Photoscan as a single block or 'chunk' for initial alignment and scene reconstruction. Photoscan accomplishes alignment using a technique known as *Structure-From-Motion* (SFM), which is able to simultaneously solve camera pose and the three-dimensional geometry of an object or scene by matching features across multiple overlapping images (Westoby *et al.* 2012: 301–2). After running various point cloud and camera alignment optimisations, a dense point cloud was generated using Agisoft's proprietary implementation of *Dense Multi-View 3D Reconstruction* (DMVR) algorithms, which use the reconstructed camera poses to compute depth estimates for pixels in each pair of matched images. The dense point cloud was cleaned up to remove any extraneous data and then triangulated to form a continuous surface or 'mesh'. The model, which at this point aligned to an arbitrary coordinate system, was manually transformed and placed in its correct orientation using either visual approximation (less accurate) or simple spatial controls (more accurate).

The final step in the workflow involves the generation of a high-resolution surface texture. While the 3D model will itself have been assigned vertex-level colour values during reconstruction, the overall colour rendition and appearance will vary according to the level of detail. The use of high-resolution textures not only gives even low-polygon models a photorealistic appearance, but also allows the user to generate geometrically corrected orthophotos. Photoscan offers a number of different methods for building textures from the source images (e.g. generic, adaptive orthophoto, single photo), the suitability of which depends on the nature of the model and intended end-use(s). Photoscan also allows the user to output the 3D model and any associated texture files in a variety of industry standard formats, that can be used to effect additional processing (such as scaling of models) and generation of output (digital elevation models, contour plots, cross-sectional profiles), using open source third-part applications.

Results

Fieldwork was undertaken between April 2014 and August 2015. During this period, small teams of between two and five people carried out some 15 main recording runs (Table 2). A number of additional recording runs had to be abandoned owing to availability, weather or access issues. The duration of the recording runs (excluding mobilisation and set-up times) differed significantly, ranging from just 9min in the case of run Eva-15-1 to 1hr 3min for OME-15-2, with an average time of approximately 36min. In excess of 45 000 images were captured, with individual recording runs generating anywhere from just under 600 to over 10 000 images. The processing of the image sets for the purposes of 3D reconstruction was in many ways the most time and labour intensive aspects of the process (Table 3). In some cases, it was possible to reduce processing time by working with only a sample of images (there often being a considerable degree of redundancy) and using various combinations of software settings (such as using low accuracy alignment settings and enabling image pair pre-selection). Even so, the processing of a 'typical' set of 600 to 1 000 images at a 4 000 x 3 000 pixel resolution took between 1hr 40min and 4hr 5min to complete using a 64 bit system; larger data sets could take significantly longer (e.g. 11hr 39min in the case of recording run OME-15-3).

The outcomes of processing and 3D reconstruction were mixed. While the majority of data sets were successfully processed to yield a series of coherent, detail-rich and (apparently) geometrically correct 3D models of each of the study sites (Figs 5–7), there were a small number of complete or partial failures. In the case of recording run COP-14-1, processing issues were attributed to the presence across the site of caustic networks (i.e. the undulating patterns of bright light projected onto the sea floor by means of refraction), which are known to cause problems for the feature-matching algorithms employed by photogrammetry software. To address this, it was determined that *City of Perth* and similarly affected sites (such as the shallower portions of SS *Omeo*) be recorded either when the sun was relatively low on the horizon, or under conditions of cloud cover; the success of this simple expedient can be gauged by the outcomes of subsequent recording runs (see Fig. 6 below).

A broadly related problem is characterised by recording run ALC-15-1 (and to a much lesser extent, ALC-14-1), during which sudden short-term changes in water quality/visibility acted to obscure detail in several contiguous frames, creating gaps in photographic coverage. Possible solutions to this scenario include suspending recording until conditions improve or reducing stand-off distance and recording at close-range (e.g. Van Damme 2015b). This latter option, while viable, can nevertheless serve to create other issues in turn.

As discussed above, shallow sites such as *Eva*, *City of Perth* and *SS Omeo* imposed constraints in terms of the stand-off distances employed, requiring that divers reduce both relative swim speed and transect spacing in order to ensure that suitable overlap and sidelap was maintained. This necessarily imposed greater demands on the divers' ability to navigate the site—something that was not always accomplished successfully, as the variable results of OME-15-1, OME-15-2, OME-15-3 and (in particular) ALC-15-2 demonstrate (Table 3). On future recording runs, it is anticipated that a range of navigation aids, such as marker buoys and/or string lines should be employed to help alleviate this issue (see Henderson *et al.* 2013: 247 for a discussion of similar problems).

While it is recognised that problems were encountered with the capture and processing of several image datasets, this should not be construed as an indictment that low-cost photogrammetry is inherently unsuitable as a primary means of documenting maritime archaeological sites. Indeed, the results obtained to date only serve to highlight the several advantages that accrue from the adoption and implementation of low-cost photogrammetry in terms of efficiency, objectivity and accuracy as opposed to traditional manual methods of documentation. For example, using 3DMIP, it has proven possible for small teams to undertake primary documentation of maritime archaeological sites in very short timeframes (typically less than one hour), with processing and data reduction taking only a few hours more (cf. Henderson *et al.* 2013: 249). This stands in stark contrast to past documentation projects undertaken by MAAWA using traditional methods; *SS Omeo*, for example, took several years and hundreds of hours of dive time to complete, resulting in the production of a drawn plan of uncertain veracity (MAAWA 1992; Fig. 8). Similarly, 3DMIP can be seen to provide a far more objective and holistic method of documentation owing to the fact that photographic

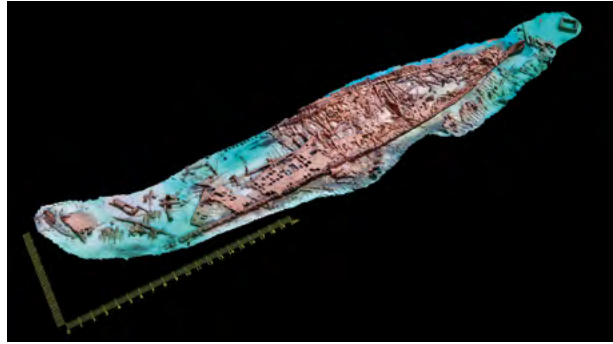


Figure 5. 3D model of *SS Omeo*.



Figure 6. 3D model of *City of Perth*.

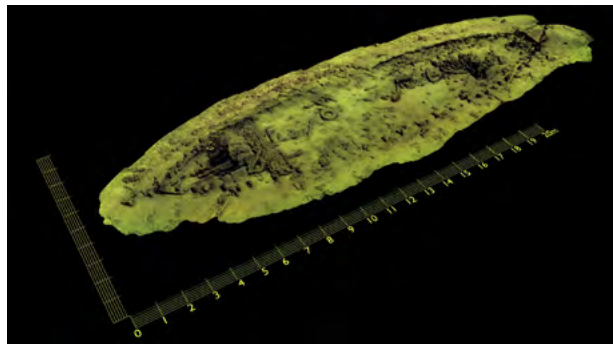


Figure 7. 3D model of *Mayfield*.

images 'provide an unbiased and unselective archive of information at known times independent of human memory or foresight' (Leatherdale & Turner 1988: 35; see Holt 2003). This latter point can be illustrated by reference to a line drawing of *ALC40* generated by MAAWA in 1990 (Fig. 9), which is not only somewhat 'idealised', but also misrepresents the condition of the fabric of the wreck (particularly in the bow area), thereby reducing its value to that of an artistic 'impression' rather than a document that can be used for scientific purposes.

The creation of simple line drawings such as these can be construed as a form of 'black-boxing' (Latour 1999) in which a series of complex three-dimensional

Recording run	Date	Site	Water conditions	Lighting conditions	Stand-off distance(s)	Camera images acquired	No. of control	Scaling	Duration
OME-14-1	30/04/2014	Omeo	Good	Bright/variable	0.5–2 m	GoPro Hero 3 Black	556	N/A	0h 14 m
OME-15-1	15/02/2015	Omeo	Good	Bright/variable	0.5–2 m	GoPro Hero 4 Black	3215	2-m pole	0h 36 m
OME-15-2	23/04/2015	Omeo (run 1)	Good	Bright/variable	0.5–2 m	GoPro Hero 4 Black	5570	2-m pole	1h 03 m
OME-15-3	23/04/2015	Omeo (run 2)	Good	Bright/variable	0.5–2 m	GoPro Hero 3 Black	4461	2-m pole	0h 40 m
ALC-14-1	12/12/2014	ALC40	Moderate	Dark/diffuse	1–1.5 m	GoPro Hero 3 Black	3670	1-m pole	0h 36 m
ALC-15-1	28/05/2015	ALC40	Moderate	Dark/diffuse	1–1.5 m	GoPro Hero 3 Black	5298	1-m pole	0h 46 m
ALC-15-2	5/06/2015	ALC40	Poor	Dark/diffuse	1–1.5 m	GoPro Hero 3 Black	5377	1-m pole	0h 44 m
ROB-14-1	4/12/2014	Robb Jetty	Good	Bright/diffuse	2-3 m	GoPro Hero 3 Black	5767	N/A	0h 56 m
ROB-15-1	16/10/2015	Robb Jetty	Poor	Bright/diffuse	2-3 m	GoPro Hero 3 Black	N/A	N/A	N/A
MAY-14-2	12/12/2014	Mayfield	Good	Bright/diffuse	1–1.5 m	GoPro Hero 4 Black	1438	N/A	0h 14 m
MAY-15-1	18/08/2015	Mayfield	Good	Bright/diffuse	5 m	GoPro Hero 4 Black	1128	N/A	0h 12 m
COP-14-2	12/12/2014	City of Perth	Good	Bright/dynamic	1–1.5 m	GoPro Hero Black 4	1-m pole	0h 14 m	0h 14 m
COP-15-2	18/08/2015	City of Perth (run 1)	Good	Bright/dynamic	1–1.5 m	GoPro Hero 4 Black	1872	1-m pole	0h 21 m
COP-15-3	18/08/2015	City of Perth (run 2)	Good	Bright/diffuse	1–1.5 m	GoPro Hero 3 Black	1516	1-m pole	0h 13 m
Eva-14-1	27/08/2014	Eva	Good	Variable/diffuse	1–1.5 m	GoPro Hero 3+ Black	736	2-m pole	0h 13 m
Eva-14-2	11/09/2014	Eva	Good	Variable/diffuse	1–1.5 m	GoPro Hero 3 Black	2452	2-m pole	0h 24 m
Eva-15-1	12/05/2015	Eva	Good	Variable/diffuse	1–1.5 m	GoPro Hero 3+ Black	966	2-m pole	0h 09 m

Table 2. Summary details of main recording runs.

Recording run	No. of images processed	No. images aligned	Alignment setting/ no. tie points	Dense cloud setting/ no. points	Mesh setting faces/vertices	Total time processing	Comments
OME-14-1	544	521	M+PD (69 595)	M (5 637 479)	M (1 120 827/562 053)	01h 17m 27s	Successful
OME-15-1	1 760	1 642	L+PD (235 095)	L (28 505 457)	L (5 579 918/2 794 928)	07h 24m 32s	Successful; some gaps in coverage
OME-15-2	1 996	1 843	L+PD (546 795)	L (38 397 315)	L (7 507 773/3 757 340)	10h 53m 13s	Successful; some gaps in coverage and possible deformation
OME-15-3	2 215	1 904	L+PD (415 059)	L (42 456 724)	L (7 122 098/3 567 566)	11h 39m 36s	Successful; some gaps in coverage
ALC-14-1	1 833	1 509	L+PE (132 293)	M (7 129 342)	L (16 304 255/8 156 458)	04h 18m 32s	Successful; minor gaps in coverage along south side of wreck
ALC-15-1	2 634	2 335	L+PD (182 151)	L (19 367 602)	L (3 873 519/1 941 930)	11h 32m 19s	Failure; reconstruction errors across port side of wreck
ALC-15-2	2 592	2 003	M+PE (410 297)	L (3 409 829)			Failure; significant gaps owing to sub-optimal coverage
ROB-14-1	914	911	L (280 233)	L (14 003 737)	L (2 769 933/1 388 079)	05 h 36m 02s	Successful
ROB-15-1	N/A	N/A	N/A	N/A	N/A	N/A	Failure; recording run discontinued owing to poor conditions
MAY-14-2	705	677	L (178 092)	L (18 390 175)	L (2 720 876/1 362 552)	03h 27m 14s	Successful
MAY-15-1	367	366	M (61 037)	M (11 010 534)	M (2 143 759/1 074 312)	01h 05m 48s	Successful
COP-14-2	613	37	N/A	N/A	N/A	01h 30m 08s	Failure owing to strong caustic networks
COP-15-2	934	718	L (89 381)	M (28 334 106)	M (5 660 083/2 832 809)	04h 05m 04s	Successful
COP-15-3	751	598	M+PE (163 220)	M (38 320 554)	M (7 698 908/3 853 651)	02h 27m 43s	Successful
Eva-14-1	647	647	L+PD (100 637)	M (14 991 687)	H (2 967 367/1 487 054)	03h 09m 58s	Successful
Eva-14-2	571	571	H+PE (379 616)	M (58 204 576)	M (11 541 103/5 776 765)	01h 40m 03s	Successful
Eva-15-1	966	963	M+PE (196 105)	M (34 164 517)	M (1 930 492/966 700)	02h 19m 30s	Successful

Table 3. Summary details of photogrammetric processing ('L'=low, 'M'=medium, 'H'=high, 'PE'=pair selection enabled, 'PD'=pair selection disabled).

spatial relationships are collapsed and simplified for the purposes of generalised description or depiction. The use of 3DMIP, on the other hand not only allows such relationships to be documented in considerably greater detail, but also facilitates scientific analysis and interrogation in a way that is not possible using two-dimensional data. For example, using nothing but open source software, it is possible to scale 3D models generated by the standard version of Photoscan (Meshlab), generate digital elevation models (SAGA GIS), create detailed contour plots and cross-sectional profiles (Quantum GIS), and undertake a wide variety of other analyses (including diachronic comparison sea floor and wreck surfaces) (Fig. 10). To make these types of analyses viable it is necessary to ensure that data generated by means of low-cost implementations of 3DMIP are both accurate and reliable. However, as noted by McCarthy and Benjamin (2014: 107):

The accuracy of a given multi-image photogrammetry work flow is difficult to assess as it depends on numerous factors including but not limited to the distance between the camera and the subject, the optical characteristics of the camera and the clarity of the images. The accuracy of the technique will not only vary from camera to camera and from site to site but may also vary within a single model.

While these issues will require further benchmarking under controlled conditions, some general observations can be made regarding the relative accuracy of models derived from photogrammetry in the absence of a survey control network. A case study reported by McCarthy and Benjamin (2014), involves a small cluster of cannon that were identified during a dive survey at Drumbeg in north-west Scotland. These items were recorded using photogrammetry and conventional techniques. A subsequent comparison of direct and photogrammetry-derived measurements showed a wide range of variance, ranging from 0 to 56%. Some of the larger errors were considered to have been the result of human error during recording; indeed, the error for the larger and more reliable measurements taken was found to fall within 1–3%. They concluded that the ‘consistency and accuracy of the model is sufficiently high for archaeological purposes’ (McCarthy & Benjamin 2014: 109; cf. Van Damme 2015b: 236). Mertes *et al.* (2014: 183–6), in their evaluation of using photogrammetry to generate 3D models of wrecks in the Great Lakes employing ‘legacy’ video footage, reported similar findings, with errors ranging between 1.6% and 18.89%; it was also observed that measurement

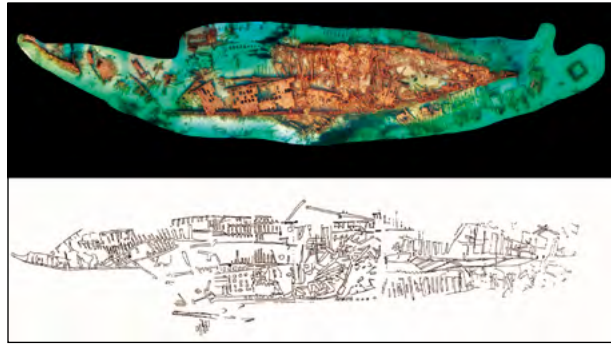


Figure 8. SS *Omeo*: comparison of textured photogrammetric model generated as part of 3DMAPPR (top) and a line drawing compiled by MAAWA during the 1990s (bottom).

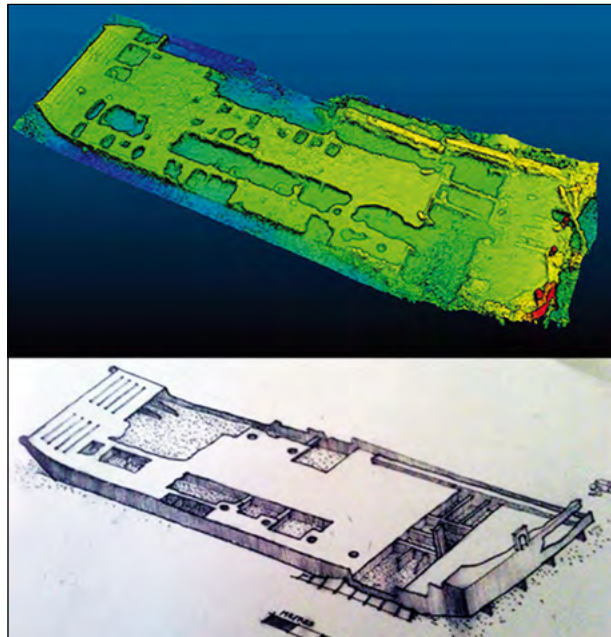


Figure 9. Comparison of photogrammetric model and artistic rendering of *ALC40*, highlighting the issue of objectivity in site recording.

error increased as an inverse function of object size.

The results obtained during the course of the present investigations are broadly consistent with these findings. For example, a comparison of several ‘blind’ measurements taken from scaled three-dimensional models of *ALC40* and *SS Omeo* and direct measurements taken independently by members of the recording team yielded errors of approximately 1% over distances between 0.64 m and 18.69 m (Table 4); the very low error estimates (equating to distances of 1–2 cm) can be attributed to the use of clear and unambiguous measurement points.

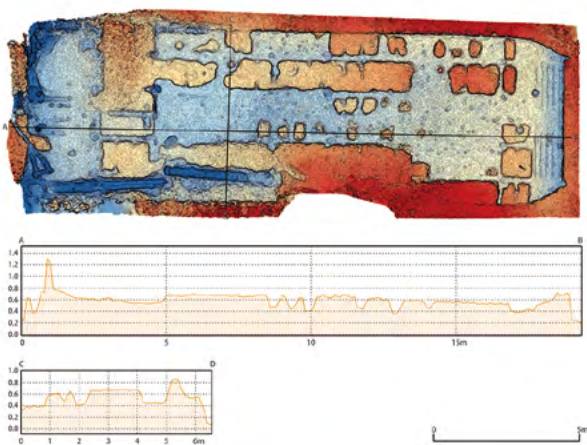


Figure 10. Contoured digital elevation model and profiles generated for *ALC40* using Quantum GIS (open source software).

The potential accuracy of photogrammetry-derived data was also demonstrated by the current authors' ability to successfully overlay datasets for *ALC40* and *City of Perth* that were captured several months apart. However, analysis of other models suggests that in some cases the lack of a survey control network has allowed non-linear errors to propagate.

In the case of *SS Omeo*, for example, the model generated from data captured during recording run OME-15-2 appeared to exhibit a degree of curvature not evident in other models (i.e. those from recording runs OME-15-1 and OME-15-3). In order to investigate this further, the three separate models were imported into Meshlab, where they were trimmed to a consistent spatial extent and aligned using 24 common features. The transformational matrix of the models was then 'frozen' in order to maintain their positions relative to one another, and the models exported. The models were then imported into the CloudCompare package, which was used to compute the 'distance' between each of the meshes, using OME-15-3 as the reference mesh.

The results indicated that while both OME-15-1 and OME-15-2 diverge from the reference mesh, this is particularly pronounced with the latter, which shows a deviation in the vertical plane of approximately +0.9 m at the bow and stern of the wreck (Fig. 11). This level of variation between meshes that otherwise appear geometrically accurate has troubling implications for the use of photogrammetry-derived models in monitoring maritime archaeological sites, given that changes in fabric and environment are likely to occur on the centimetre-scale. Necessarily, additional testing under controlled conditions will be required in order to better assess this issue.

Training and dissemination

Towards the end of the testing and evaluation phase of the project, two one-day workshops were convened at the Shipwreck Galleries of the Western Australian Museum, Fremantle, on 5–6 September 2015. These were undertaken primarily to facilitate the second major objective of 3DMAPPR, namely the provision of training to MAAWA members in underwater 3DMIP recording and data processing techniques. It was hoped that the provision of such skills would not only allow MAAWA members to meaningfully engage in the ongoing recording and preservation of local underwater and maritime cultural heritage, but also engender a sense of 'ownership'. As Muckelroy (1980: 186) explains, the concept of public ownership is a basic principle relating to cultural heritage generally, noting that 'the public (divers in particular) should be encouraged to become involved in the protection and investigation of underwater sites, particularly in order to maintain a public interest in them'. This is particularly important and relevant for Australia owing to the fact that it was this sector of the community (i.e. divers) that lobbied legislators 'to develop protective measures and provided the impetus for maritime heritage programs around the country' (Anderson *et al.* 2006: 139).

Site	Direct measurement	Measurement from Model	Difference
<i>ALC40</i> length	18.69 m	16.68 m	0.01 m (1%)
<i>ALC40</i> width	5.66 m	5.66 m	0 m (0%)
<i>SS Omeo</i> Pt A–B	2.28 m	2.28 m	0 m (0%)
<i>SS Omeo</i> Pt C–D	0.64 m	0.63 m	0.01 m (1%)
<i>SS Omeo</i> Pt I–J	2.06 m	2.08 m	0.02 m (1%)

Table 4. Comparison of direct measurements and measurements derived from scaled photogrammetric models of *ALC40* and *SS Omeo*.

The workshops were attended by a total of 12 participants, comprising divers and non-divers. Structured in two parts, the first component aimed to provide a non-technical introduction to 3DMIP, and touched upon issues ranging from data management and basic image processing through to techniques for generating scaled and oriented 3D models using open source software. This was accomplished using a combination of pre-compiled 'dummy' datasets and guided practical exercises on terrestrial targets. The second component involved a series of in-water practical exercises on the *City of Perth* and *Mayfield* wreck sites in Rocky Bay, North Fremantle. On this occasion, two boats were used to transport the participants to and from site. These were crewed by several qualified personnel who were on hand to provide dive and safety supervision and guidance on recording. In total ten participants dived or snorkelled *City of Perth* and *Mayfield*, completing a number of recording runs using either one of several provided GoPros, or their own personal cameras. Subsequently, participants were encouraged, where possible, to process their own data (using workshop training documents, open source software, and other materials hosted on a shared DropBox folder) and post the results on the MAAWA and other social media networks.

The use of social media has been an integral part of the project from its inception. In particular, the team has been keen to promote an 'open science' philosophy, with its emphasis on transparency, cooperation, skill-sharing, and capacity-building (Nielsen 2009: 32). Towards this end, a dedicated Facebook page (<<https://www.facebook.com/groups/687120911380215/?fref=ts>>) was established early in the life of the project (Fig. 12). With over 600 members at the time of writing, this page has provided a forum for sharing up-to-date news regarding 3DMAPPR, present challenges encountered and the solutions developed, invite participation and comment, and post photographs and video footage of each of the recording runs. Generated output, such as animations and 3D models were similarly uploaded, either to Facebook or Sketchfab (<www.sketchfab.com>), a website that enables users to display and share 3D content online. The results of the projects have also been promoted through academic and popular channels, such as public lectures, and conference presentations.

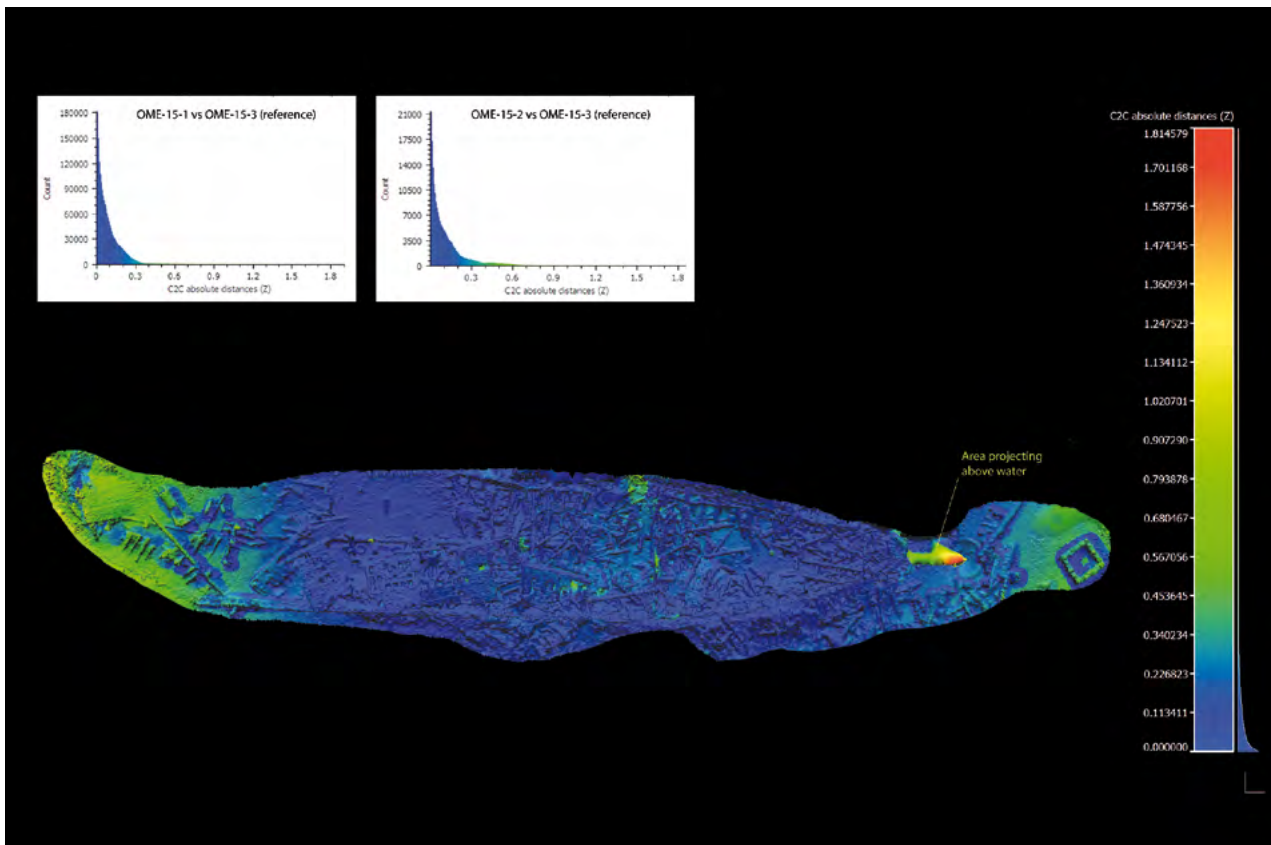


Figure 11. Comparison of 3D data captured for SS *Omeo* during recording run OME-15-2 against reference data from run OME-15-3. The maximum deviation is approximately +0.9 m in elevation (excluding areas projecting above water).

Implementation

The training workshops marked an important milestone in the life of 3DMAPPR in that they represented an informal transition from testing and evaluation to roll-out and implementation by the wider MAAWA membership. As part of this transition, the 3DMAPPR team has continued to provide advice and support to MAAWA members either planning or actively engaged in 3DMIP documentation projects. Indeed, since the completion of the workshops, MAAWA members have demonstrated considerable initiative, having employed 3DMIP to record several additional maritime archaeological sites in and around the Perth region, including *Petrel*, *Gay Dragon* and the *North Mole Barge*. It is hoped that future recording projects will be formalised through the creation of a number of working groups, each of which will be tasked with the ongoing documentation of a particular site or sites. These groups could additionally serve to enhance capacity-building within the MAAWA membership by providing an informal setting in which skills and experience can be disseminated.

The 3DMAPPR team has also provided training materials and technical support for two overseas projects, namely the Vietnam Maritime Archaeology Project (VMAP), and the 2015 Capacity Building in Safeguarding Underwater Cultural Heritage workshop held in Selayar and Makassar (South Sulawesi, Indonesia). These projects provided an excellent opportunity not only to deploy and refine training content developed as part of 3DMAPPR, but also to engage in a dialogue with overseas colleagues regarding the practicalities of employing low-cost 3DMIP for archaeological documentation, particularly in contexts where time, funding, and other resources may be at a premium.

Concluding remarks

The results of the present investigations highlight the potential of low-cost 3DMIP as a cost-effective, accurate and highly flexible means of enabling ‘citizen scientists’ to actively contribute to the documentation of wreck sites and other elements of maritime cultural heritage. Using consumer-grade ‘action’ cameras in tandem with a suite of open-source and commercial software, it is now possible for avocational maritime archaeologists with only a minimum of training and experience to objectively document even relatively large and complex underwater sites in a fraction of the time it would take using traditional methods—a fact clearly demonstrated in the case of *SS Omeo*. Moreover, the data generated using 3DMIP can be re-purposed to suit a variety of other uses, ranging from documentation and management, through to the creation of sophisticated visualisations and immersive virtual reality experiences. The latter in particular opens up the exciting possibility of providing people who have mobility constraints or lack appropriate dive training access to underwater cultural heritage sites. This potential to move beyond ‘pretty pictures’ (Falkingham 2014) makes low-cost 3DMIP a powerful tool for community education, outreach and research—and gives broader expression to Malraux’s (1967) concept of the *musée imaginaire* or ‘museum without walls’.

Nevertheless, while the use of low-cost 3DMIP can be seen to have broad and overlapping benefits for different sectors of the maritime archaeological community, several factors need to be acknowledged. Firstly, the technique, while robust, demands that users be aware of the limitations of both their equipment and the environment(s) in which they are working (McCarthy & Benjamin

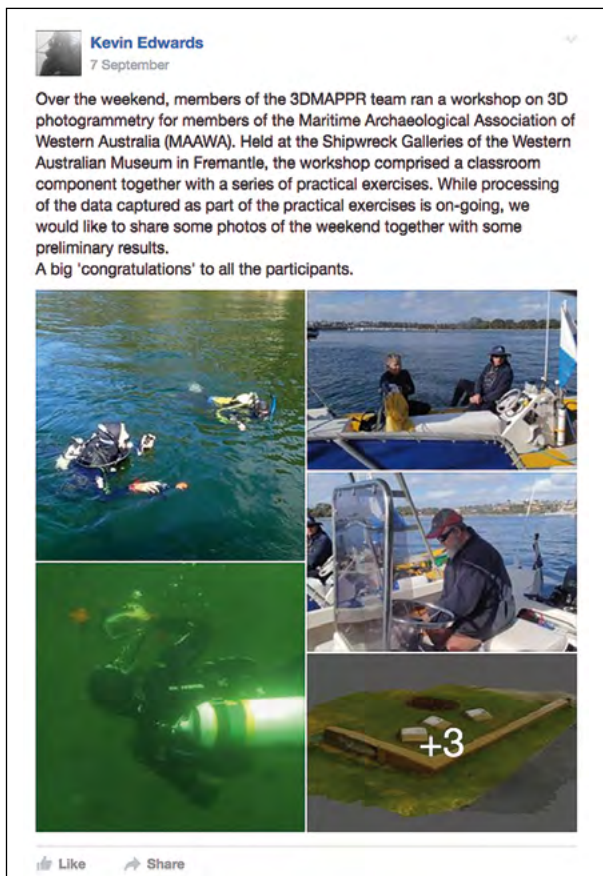


Figure 12. Screen capture of a post on the 3DMAPPR Facebook page.

2014: 112). Factors such as lighting and water quality necessarily impact on both the approach(s) taken to site documentation and subsequent processing requirements. Secondly, the overall quality and accuracy of 3D reconstructions of sites or features can be difficult to assess. While the significance of this will vary according to the intended use(s) to which the data will be put (visualisation versus erosion modelling, for example), appropriate controls and good recording practices should be implemented to minimise potential sources of error. Finally, incorporation of 3DMIP into an archaeological workflow requires

that adequate consideration be given to the issues of processing capability and long-term data management (Benne 2015; McCarthy 2014: 177). This is particularly critical considering that any given photogrammetric recording run can generate hundreds, if not thousands, of images. Taken together, these factors only serve to foreground the importance of fostering an 'open science' approach that encourages cooperation, skill-sharing, and capacity-building amongst practitioners in order to ensure successful and consistent outcomes. This is an approach that MAAWA, as part of its broader 3DMAPPR initiative, hopes to encourage.

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References

- Anderson, R., Philippou, C. and Harvey, P., 2006, Innovative approaches in Underwater Cultural Heritage Management. In: M. Staniforth and M. Nash (eds.), *Maritime archaeology: Australian approaches*. Springer, New York.
- Baker, P.E. and Green, J.N., 1976, Recording techniques used during the excavation of the *Batavia*. *International Journal of Nautical Archaeology* **5.2**: 143–158.
- Benne, M.J., 2015, Presentation on evaluating the creation and preservation challenges of photogrammetry-based 3D Models, UConn Libraries Presentations. Paper 44. Viewed 21 December 2016 <http://digitalcommons.uconn.edu/libr_pres/44>.
- Bryan, P.G. and Chandler J.H., 2008, Cost-effective rock-art recording within a non-specialist environment. *Paper presented at the International Society for Photogrammetry and Remote Sensing, ISPRS 2008, July 3–11, 2008*. Beijing, China.
- Cairns, L. and Henderson, G., 1995, *Unfinished voyages: Western Australian shipwrecks 1881–1900*. University of Western Australia Press, Nedlands.
- Capra, A., Dubbini, M., Bertacchini, E., Castagnetti, C. and Mancini, F., 2015, 3D reconstruction of an underwater archaeological site: comparison between low cost cameras. *Proceedings of the 2015 Underwater 3D Recording and Modeling, Piano di Sorrento, Italy, 16–17 April 2015; International Society for Photogrammetry and Remote Sensing: Piano di Sorrento, Italy, 2015*: 67–72.
- Cignoni, P., Callieri, M., Corsini, M., Dellepiane, M., Ganovelli, F. and Ranzuglia, G., 2008, MeshLab: an open-source mesh processing tool. *Proceedings of the Eurographics Italian Chapter Conference (2008)*. Solerno, Italy.
- Cockram, C., 1990, The *City of Perth* and the *Mayfield*. Maritime Archaeological Association of Western Australia Report, **4**: 22–23.
- Cooper, D., 2012, A study of the riverine and underwater archaeological landscapes of Rocky Bay, North Fremantle, Western Australia. Unpublished Masters Thesis, Department of Archaeology, Flinders University, Adelaide.
- De Reu, J., Plets, G., Verhoeven, G., De Smedt, P., Bats, M., Cherretté, B., De Maeyer, W., Deconynck, J., Herremans, D., Laloo, P., Meirvenne M. V. and De Clercq, W., 2013, Towards a three-dimensional cost-effective registration of the archaeological heritage. *Journal of Archaeological Science*, **40**: 1108–1121.
- Drap, P., 2012, Underwater photogrammetry for archaeology. In: D. Carneiro da Silva (ed.), *Specials Applications of Photogrammetry*. Intech, Rijeka: 112–36.
- Drap, P., Scaradozzi, D., Gambogi, P. and Gauch, F., 2008, Underwater photogrammetry for archaeology—the Venus Project framework. In: *GRAPP, Funchal, Madeira–Portugal*: 485–491.
- Drap, P., Long, L., Durand, A. and Grussenmeyer, P., 2001, From underwater photogrammetry to a web integrated documentation system: The case of the 'Grand Ribaud F' Etruscan wreck. In: *CIPA 2001 International Symposium, Germany*: 1–8.
- Falkingham, P.L., 2014, 'Not just pretty pictures...', August 28. Viewed 15 July 2016, <<https://pfalkingham.wordpress.com/2014/08/28/not-just-pretty-pictures/>>.

- Fassi, E., Fregonese, L., Ackerman, S. and De Troia, V., 2013, Comparison between laser scanning and automated 3D modelling techniques to reconstruct complex and extensive cultural heritage areas. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 3D-ARCH 2013 - 3D Virtual Reconstruction and Visualization of Complex Architectures, 25–26 February 2013*, vol. XL-5/W1. Trento, Italy: 73–80.
- Granshaw, S.I. and Fraser, C.S., 2015, Computer vision and photogrammetry: interaction or introspection? *The Photogrammetric Record* **30**: 149: 3–7.
- Hartley, R.I. and Mundy, J.L., 1993, Relationship between photogrammetry and computer vision, Proc. SPIE 1944. *Integrating Photogrammetric Techniques with Scene Analysis and Machine Vision*, vol. 92 (September 24, 1993).
- Haukaas, C. and Hodgetts, L.M., 2016, The untapped potential of low-cost photogrammetry in community-based archaeology: a case study from Banks Island, Arctic Canada. *Journal of Community Archaeology and Heritage* **3**: 1: 40–56.
- Henderson, J., Pizarro, O., Johnson-Roberson, M. and Mahon, I., 2013, Mapping submerged archaeological sites using stereo-vision photogrammetry. *The International Journal of Nautical Archaeology* **42**: 2: 243–256.
- Holt, P., 2003, An assessment of quality in underwater archaeological surveys using tape measurements. *International Journal of Nautical Archaeology* **32**: 2: 246–251.
- James, M.R. and Robson, S., 2012, Straightforward reconstruction of 3D surfaces and topography with a camera: Accuracy and geoscience application. *Journal of Geophysical Research*, **117**: F03017.
- Kenderdine, S., 1995, *Shipwrecks 1656–1942, a guide to historic wreck sites of Perth*. Western Australian Maritime Museum, Fremantle.
- Koutsoudis, A., Vidmar, B., Ioannakis, G., Arnaoutoglou, F., Pavlidis, G. and Chamzas, C., 2013, Multi-image 3D reconstruction data evaluation. *Journal of Cultural Heritage* **15**: 1: 73–79.
- Latour, B., 1999, *Pandora's hope: essays on the reality of science studies*. Harvard University Press, Cambridge, Massachusetts.
- Leatherdale, J. and Turner, J., 1988, Commercial Underwater Photogrammetry—the First Decade. Viewed 16 July 2016, <http://www.isprs.org/proceedings/XXVII/congress/part5/34_XXVII-part5-sup.pdf>.
- Mahiddine, A., Seinturier, J., Boi, D.P.J., Drap, P., Merad, D. and Long, L., 2012, Underwater image preprocessing for automated photogrammetry in high turbidity water: An application on the Arles-Rhone XIII Roman wreck in the Rhodano river, France. *Presented at the 18th International Conference on Virtual Systems and Multimedia*: 189–194.
- Malraux, A., 1967, *Museum without walls*. Secker and Warburg, London.
- Maritime Archaeological Association of Western Australia Reports, 1990–1992.
- McCarthy, J. and Benjamin, J., 2014, Multi-image photogrammetry for underwater archaeological site recording: an accessible, diver-based approach. *Journal of Maritime Archaeology*, **9**: 1: 95–114.
- McCarthy, J., 2014, Multi-image photogrammetry as a practical tool for cultural heritage survey and community engagement. *Journal of Archaeological Science* **43**: 175–185.
- Mertes, J., Thomsen, T. and Gulley, J., 2014, evaluation of structure from motion software to create 3D models of late nineteenth century Great Lakes shipwrecks using archived diver-acquired video surveys. *Journal of Maritime Archaeology* **9**: 173–189.
- Nielsen, M., 2009, Doing science in the open. *Physics World* **22**: 5: 30–35.
- Pierrot-Deseilligny, M., De Luca, L. and Remondino, F., 2011, Automated image-based procedures for accurate artefacts 3D modelling and orthoimage generation. *Geoinformatics FCE CTU Journal*, **6**: 291–299.
- Remondino, F., 2014, Photogrammetry—basic theory. In: F. Remondino and S. Campana (eds.), *3D Recording and modelling in archaeology and cultural heritage: theory and best practices*. BAR International Series 2598. Archaeopress, Oxford: 63–72.
- Rodriguez-Echavarría, K., Morris, D. and Arnold, D., 2009, Enabling users to create and document 3D content for heritage. Paper presented at the First International Conference on Creative Content Technologies, CONTENT 2009, Athens/Glyfada, Greece, 15–20 November, 2009. Athens/Glyfada, Greece.
- Scrimshaw, C., 1981, *Swan and Canning River wrecks*. Maritime Archaeological Association of Western Australia, Fremantle.
- Skarlatos D., Demestihia S. and Kiparissi, S., 2012, An 'open' method for 3D modelling and mapping in underwater archaeological sites. *International Journal of Heritage in the Digital Era* **1**: 1: 1–24.
- Sorbi, L., Scaradozzi, D., Conte, G. and Gambogi, P., 2014, Geoposition data aided 3D documentation of archaeological and biological sites. *Proceedings of Meetings on Acoustics* **17**: 1: 70–88.
- Van Damme, T., 2015a, Computer vision photogrammetry for underwater archaeological site recording: a critical assessment. Unpublished MA dissertation, Maritime Archaeology Programme, University of Southern Denmark.
- Van Damme, T., 2015b, Computer vision photogrammetry for underwater archaeological site recording in a low-visibility environment. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, vol. XL-5/W5: 231–238.
- Verhoeven, G., 2011, Taking computer vision aloft: archaeological three-dimensional reconstructions from aerial photographs with Photoscan. *Archaeological Prospection* **18**: 1: 67–73.
- Wellborn, S., 1987, *Swan: History of a brewery*. University of Western Australia Press, Nedlands.
- Westoby, M.J., Brasington, J., Glasser, N.F., Hambrey, M.J. and Reynolds, J.M., 2012, 'Structure-from-motion' photogrammetry: a low-cost, effective tool for geoscience applications. *Geomorphology* **179**: 300–314.
- Wilkinson, D., 2013, From beef to reef: the maritime cultural landscape of Robb jetty. Unpublished MA Dissertation, Department of Archaeology, Flinders University, Adelaide.
- Yamafune, K., Torres, R. and Castro, F., 2016, Multi-image photogrammetry to record and reconstruct underwater shipwreck sites. *Journal of Archaeological Method and Theory* (March). Springer, New York.

MANAGING A SIGH OF RELIEF

The wreck of USNS *Mission San Miguel*

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Introduction

The United States Naval Ship (USNS) *Mission San Miguel* wrecked at Maro Reef in the Northwestern Hawaiian Islands on 8 October 1957. A World War II (WWII)-era tanker with a distinguished career, the remains of the 159 m-long ship were discovered in August 2015 by a team of archaeologists conducting maritime heritage surveys in Papahānaumokuākea Marine National Monument (PMNM). The shipwreck site consists of the substantial and largely intact aft portion of the vessel, as well as numerous concentrations of disarticulated wreckage scattered over a relatively discreet area. The identification of the shipwreck as that of USNS *Mission San Miguel* was supported by its close proximity to the United States Navy's (USN) reported location of its loss, as well as numerous diagnostic features and the fact that no other large steel-hulled vessel of this type is historically known to have been lost at Maro Reef. While the location of this wreck is without doubt of intrinsic historical and archaeological value, perhaps the most important contribution that it makes is the environmental information that it revealed. This paper provides a brief overview of the history and loss of USNS *Mission San Miguel*, the location of the site and interpretation of archaeological data, and the significance of the site to the management of PMNM.

Historical background

Before WWII, oil companies used slow-moving tankers solely for commercial purposes. This practice changed, however, with the approach of international conflict and the subsequent high demand for cargo and fuel. Many oil companies were approached by the United States Maritime Commission to build bulk carriers and tankers for wartime purposes, should the need arise (Sawyer & Mitchell 1974: 89). As a result, several United States (US) shipbuilding firms were contracted for these purposes, and with ever increasing demand, new companies and shipyards were established. Among those companies was the Marinship Corporation, which was founded in March 1942 and headquartered in Sausalito, California (NavSource Naval History 1996). Though initially contracted to build cargo carrying 'Liberty' ships, the company shifted solely to tanker production in November 1942.

Marinship constructed three types of tankers: T2-SE-A1, T2-SE-A2 and T2-SE-A3. The T2-SE-A1 tanker was of typical commercial design and built

by Sun Shipbuilding Company for the Standard Oil Company of New Jersey. Due in large part to the installation of turbo-electric drive motors, which derived power from a turbine connected to a single shaft, these vessels produced speeds of up to 15 knots (Sawyer & Mitchell 1974: 94). Marinship engineers used the T2-SE-A1 as a prototype for the A2 and A3 type tankers, but increased the output of the motors to 10 000 shaft horsepower, which added an extra knot to the maximum speed. Thus, the T2-SE-A2 and A3 tankers were a physically identical and higher-powered version of the A1 type, with the main difference between them being that the A3 type was built to USN standards while the A2 type was modified to meet them after construction (Sawyer & Mitchell 1974: 97). Marinship Corporation ultimately produced 80 tankers for the USN, 43 of which were A2 types constructed on the West Coast of the US and given a 'Mission' prefix (Sawyer & Mitchell 1974: 95).

Among the tankers constructed under contract to Marinship was USNS *Mission San Miguel* (Fig. 1), which was built in Sausalito by the American Pacific Steamship Company (Sawyer & Mitchell 1974: 104, 173). One of the *Buenaventura* class of tankers, the hull was launched on 31 October 1943 and the ship was delivered on 19 February 1944 (NavSource Naval History 1996). *Mission San Miguel* was soon chartered to Pacific Tankers, Inc. and employed in carrying fuel to US overseas forces until 20 May 1946, when it was returned to the US Maritime Commission and laid up in the Maritime Reserve Fleet at Mobile, Alabama (World Public Library 2015). Though all tankers under USN control were decommissioned at the end of WWII, most A2 types were returned to service soon thereafter (Sawyer & Mitchell 1974: 103–4).

The contract-operated tanker *Mission San Miguel* was again acquired by the USN on 4 November 1947. It was then chartered to American Pacific Steamship Company and placed under the operational control of the Naval Transportation Service as *Mission San Miguel* (AO-129). Transferred to the control of the newly created Military Sea Transportation Service (MSTS) on 1 October 1949, the tanker was re-designated T-AO-129 USNS *Mission San Miguel* (Fig. 2). The ship served with the MSTS fleet until 22 March 1950, when it was taken out of service and laid up in the USN Pacific Reserve Fleet at San Diego, California (Naval History and Heritage Command 2015).

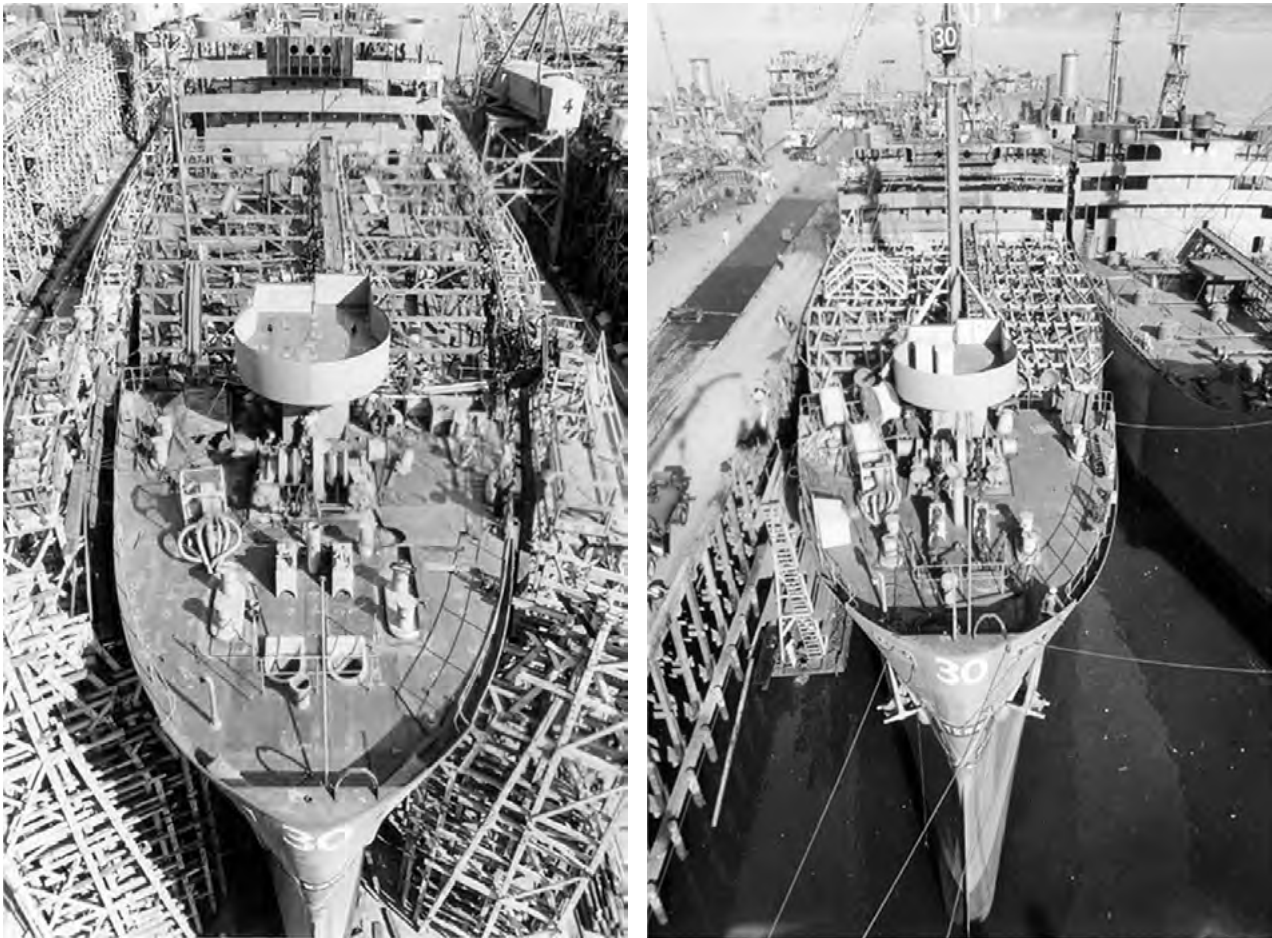


Figure 1. Historical photographs of USNS *Mission San Miguel*'s bow during construction (NavSource Naval History 1996).

On 24 July 1950 it was again placed in active service by MSTs to aid in supporting US troops serving in the Korean War. For its military service during that conflict, the ship was awarded a number of commendations including a National Defense Service Medal, a Korea Service Medal, a Republic of South Korea Service Medal (retroactive), and a United Nations Service Medal. The tanker continued to serve with MSTs until 28 May 1954, when it was again taken out of service and laid up in the San Diego Pacific Reserve Fleet (NavSource Naval History 1996).

In November 1956 the tanker was reactivated with the MSTs, and while serving in this capacity it ran aground at full speed on Maro Reef (Visser n.d.; Van Tilburg 2003). Carrying only ballast and a relatively small amount of fuel for operations, the tanker departed for Seattle, Washington, from Apra Harbor, Guam on 1 October 1957. Although sailing with a projected route set to pass 23 miles

south of Maro Reef in the Hawaiian Island archipelago, poor LORAN reception and stormy weather prevented the acquisition of a celestial position fix for several days. These conditions ultimately led to a miscalculation of the tanker's location and its subsequent grounding (United States Coast Guard 1958: 1–4).

Wrecking event and salvage efforts

According to a US Coast Guard (USCG) inquiry, prior to its loss the officers of USNS *Mission San Miguel* believed the ship to be well south of Maro Reef. While cruising through the night with inclement conditions, a target was revealed on radar. Believing it to be Laysan Island, the officers altered the vessel's course to 090° without reducing speed (United States Coast Guard 1958: 4). By 19:00, the Master determined that the

Tonnage	10 461 gross
Length	524 ft / 158.80 m
Beam	68 ft / 20.60 m
Max draft	30 ft / 0.90 m
Propulsion	Turbo-electric, single screw
Ship design	T2-SE-A2
Hull material	Steel
Hull fastenings	Riveted
Compliment	52 civilian mariners

Table 1. Specifications of USNS *Mission San Miguel*.

vessel was out of danger and left the bridge, when almost immediately the ship ran aground on Maro Reef. The impact ruptured the hull and caused the tanker to take on water. Although the engines were ordered full astern it was soon realized that the ship was lodged on the reef and at 22:08 the crew stopped the engines and radioed for assistance (United States Coast Guard 1958: 4). Pearl Harbor's Air Sea Rescue Centre launched PBY patrol aircraft at 22:40, which located the vessel aground on the reef the following morning (Van Tilburg 2002: 41).

As a south-westerly swell pushed the ship further onto the reef, the port bow anchor was released in an attempt to impede movement. Crewmembers attempted to lighten the stern by transferring ballast from the aft tanks to the forward tanks; however, the main cargo suction line valves in all of the aft cargo tanks were jammed in a closed position. As a result, two fire hoses were placed in the forward tanks to transfer water and weigh down the ship. Since damaged internal bulkheads caused the vessel to list to its port side, efforts were made to transfer water to starboard tanks but proved unsuccessful. Despite the fact that a bilge pump and fire pump were employed in an attempt to keep water out of



Figure 2. Undated photograph of USNS *Mission San Miguel* (NavSource Naval History 1996).

machinery spaces, water levels continued to rise and therefore all watertight doors were secured as the ship settled by its stern (United States Coast Guard 1958: 5–6). Preparations were made and in the early morning hours of 10 October 1957, the Master of USNS *Mission San Miguel* gave the order to abandon ship. Fortunately for the crew, another USN vessel (T-LST 664) operating nearby was able to evacuate all 42 hands and transport them to Honolulu (United States Coast Guard 1958: 5–6).

USN ships *Safeguard* (ARS-25), *Reclaimer* (ARS-42) and *Lipan* (ATF-85) were soon deployed as a salvage task unit. Upon their arrival at the site, USNS *Mission San Miguel* was listing to port and down by the stern with the main deck aft submerged at 7 m. Despite rough sea conditions, efforts were made to refloat the vessel by placing patches on compromised sections of the hull but these proved unsuccessful due to heavy current and surge. Although the stern was lifted using air compressors, ruptured interior longitudinal bulkheads caused water to shift and the vessel listed further to port (Van Tilburg 2002: 41; 2003: 252). Salvors' notes indicate that the tanker was hard aground on a bearing of 075° true; that the forward part of the ship was reported to draw only 1.2 m while the after portion drew 25.2 m (with 10.7 m of water over the stern); and that the hull listed 17° to port (Van Tilburg 2003: 252).

The USN salvage team completed a damage assessment in October 1957 (Fig. 3) and found the stern cargo and gasoline tanks, especially on the port side, sustained the most damage (United States Coast Guard 1958). Salvage divers noted that three of the forward tanks on the port side were also damaged, but that the tanks on the forward starboard side remained intact. Some cargo tanks were found to contain considerable amounts of coral, suggesting a sizable puncture in the hull. Centre cargo tanks 2 through 7 were open to the sea and leaking, while wing tanks 5 and 6 on the port side had ruptured bulkheads (Van Tilburg 2003). As a result of its location on the reef, the wreck was not considered to be a navigational hazard and was recommended for abandonment (Van Tilburg 2002: 41; 2003: 252). It was declared unfit for further service or salvage, and was stricken from the US Naval Vessel Register on 20 December 1957 (Sawyer & Mitchell 1974: 174).

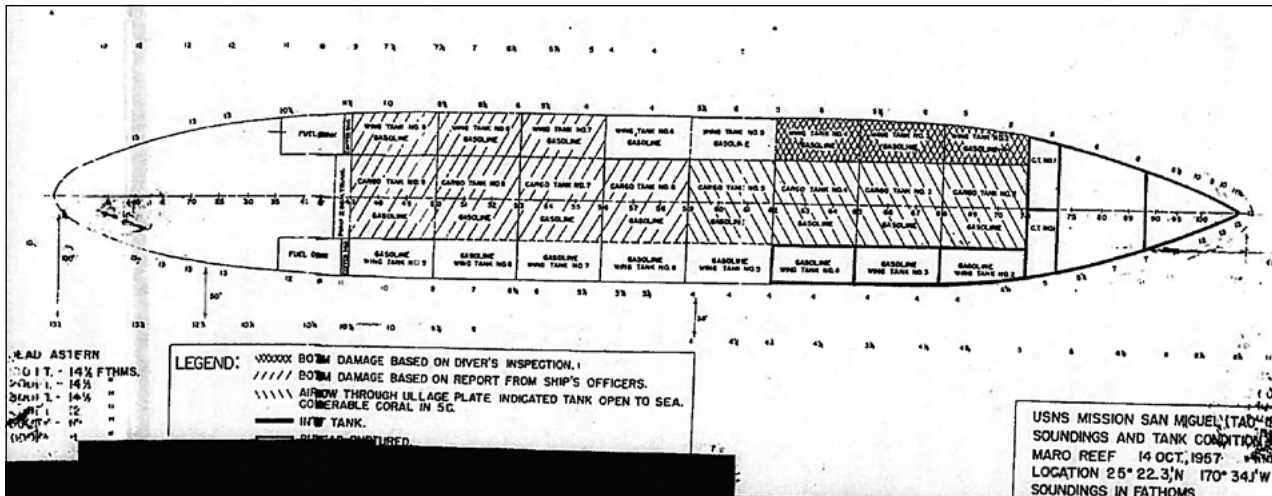


Figure 3. USNS *Mission San Miguel* damage assessment diagram (NARA, RG 19; Van Tilburg 2003: 251).

The US Coast Guard Marine Board of Investigation inquired into the loss of USNS *Mission San Miguel* in 1958 and eventually recommended that the Master, Chief Mate and Second Mate be charged with negligence due to miscalculation of the tanker’s position. Additionally, the Board recommended the Chief Engineer be reprimanded for his inattention to duty by failing to maintain equipment. Ultimately, human error and negligence—not machinery or equipment failure—were found to be the main factors that led to the loss of the vessel (United States Coast Guard 1958: 8).

Site investigation

Due to its remote location, National Oceanic and Atmospheric Administration (NOAA) research expeditions to the Northwestern Hawaiian Islands only occasionally visit Maro Reef. Maritime heritage surveys were conducted, however, in 2002, 2005, and 2009 with the relocation of the remains of USNS *Mission San Miguel* as the main priority. On each visit the latitude/longitude position recorded in the USCG Marine Board of Investigation report and NOAA Chart 19441 (which indicates a position for a submerged wreck at Maro Reef) were used to delineate survey areas. Researchers used methods including tow-boarding, drift diving, and depth sounding in areas closest to the reported locations of the wreck, but no material culture was located. Searches were also conducted by NOAA’s NMFS Coral Reef Ecosystem Division’s marine debris removal teams, who undertook opportunistic surveys in 2003, 2004, 2005, 2008, 2009 and 2014; however, none of these efforts produced any trace of the wreck.

In 2015, archaeologists participating in a Reef Assessment and Marine Program (RAMP) cruise to PMNM visited Maro Reef. After re-examining all known historical sources, previously unexplored search areas on the eastern portion of the reef were determined. Tow-board surveys in one of these areas produced evidence of the shipwreck that included steel cable, anchors and anchor chain, components of deck machinery, pumps, and mangled hull plating. Depth soundings taken along the last recorded bearing of the tanker indicated a large submerged structure, which later proved to be a substantial portion of the stern of a steel-hulled ship. Photographs, video, and measured sketches of significant artefacts and diagnostic features of the intact rounded stern section of the wreck were taken to assist in identifying it as that of USNS *Mission San Miguel*. Concentrations of hull plating, piping and a third anchor were noted over a large area located to the north and south of the initially identified artefacts, and all positions were recorded using global positioning systems.

Researchers from NOAA and the University of Hawai’i visited the site again in 2016 to collect detailed photographic imagery for the creation of three-dimensional (3D) reconstructions of portions of the wreck. Images were captured using methods developed specifically for high-resolution 3D reconstructions of underwater habitats (Burns *et al.* 2015). Overlapping photographs were taken from planar and oblique angles while swimming above sections of the wreck and associated artefacts, and ground control points were used to ensure accurate scaling and calibration of the resulting 3D models. All photos were taken with a Canon 5D Mark III digital SLR camera equipped with a

24–70 mm lens set at 24 mm and contained within an Ikelite Underwater Systems housing with an 8-inch (20 cm) hemispheric dome port. The 3D reconstructions of the wreck and artefacts were rendered using PhotoScan modelling software by Agisoft LLC. Images were uploaded into this software and camera calibration was performed internally to resolve the optical characteristics of the camera lens using information from the image metadata. Images were aligned in Photoscan using algorithms that detect invariant features from the overlapping image sequences, which enabled the creation of textured 3D digital surface models of the majority of the intact hull section of the wreck (Fig. 4) and some associated artefacts (Fig. 5) with spatial accuracy at the millimetre scale. This non-invasive technique provided comprehensive representations and enhanced the investigation and mapping of the site.

Observations

The shipwreck is scattered over an area approximately 330 m long by 350 m wide. The numerous diagnostic features associated with a tanker, and the fact that no other large steel-hulled vessel is historically reported to have wrecked

at Maro Reef, overwhelmingly suggest that the remains are those of USNS *Mission San Miguel*. Further indication of the wreck's identity is its close proximity of the position of the coordinates reported by the USN for the loss of the tanker (Fig. 6).

Depositional evidence supporting the identification of the wreck included its bearing of 080° and the fact that the largely intact stern section of the ship rests on its port side. That portion of the site rises from approximately 24 m at the sea-bed to a depth of 8.8 m below the water surface, while the aft cargo tank section—located directly forward of the stern

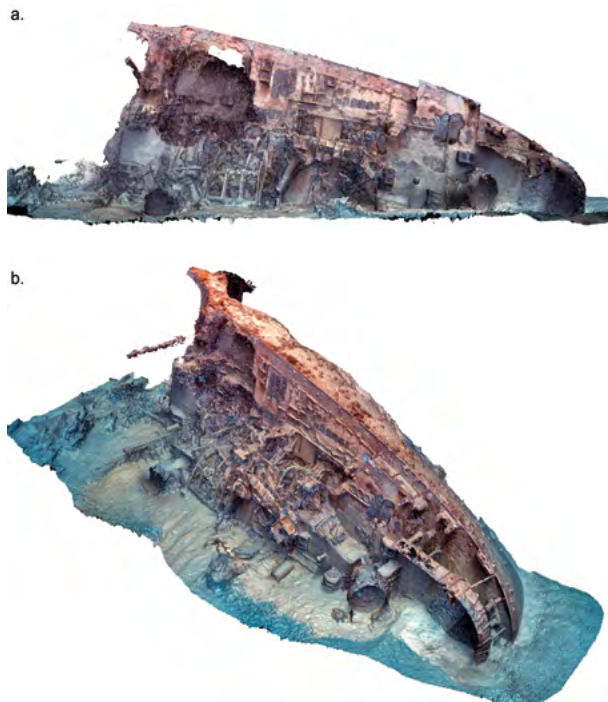


Figure 4. 3D reconstructions of the intact hull section of the wreck of USNS *Mission San Miguel* captured by University of Hawai'i researcher John Burns: a) planar view; b) oblique view (NOAA/PMNM 2016).

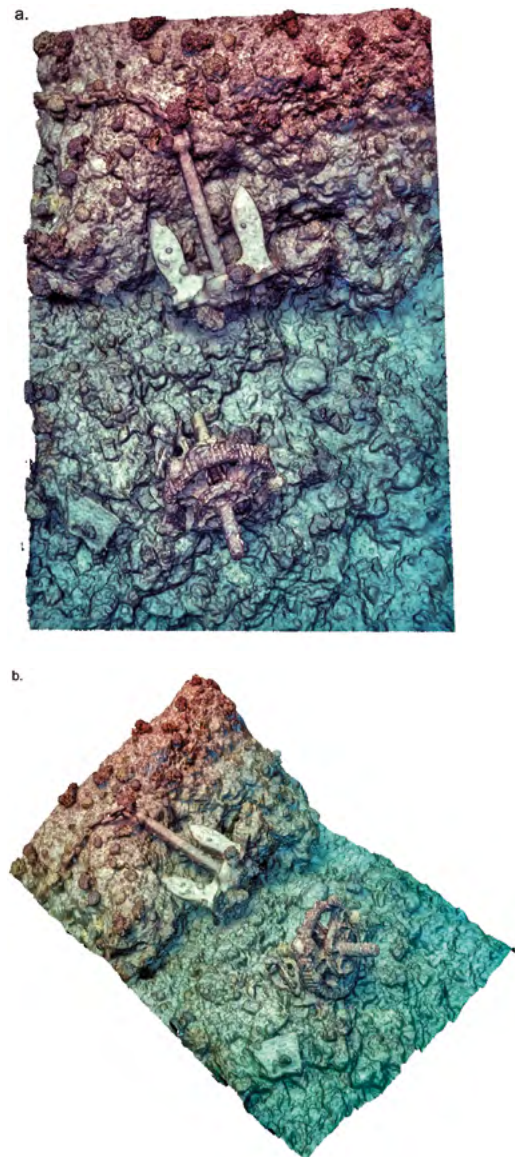


Figure 5. 3D reconstructions of an anchor and nearby windlass gear from the wreck of USNS *Mission San Miguel* captured by University of Hawai'i researcher John Burns: a) planar view; b) oblique view (NOAA/PMNM 2016).

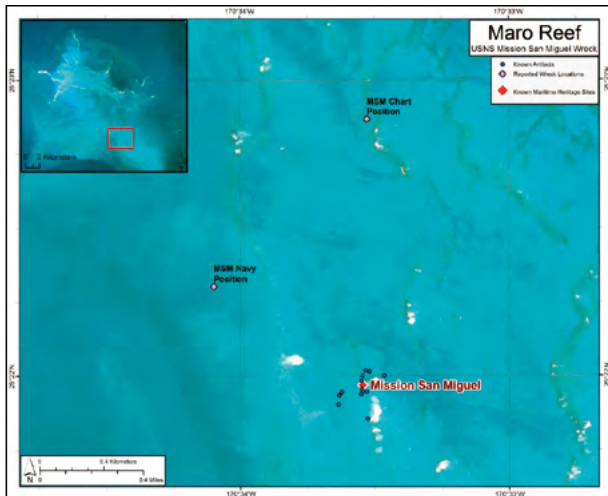


Figure 6. Location of USNS *Mission San Miguel* shipwreck compared to historically reported locations (NOAA/PMNM 2015).

section—is mostly collapsed. An area believed to represent the tanker’s bow is located approximately 165 m east and north-east of the stern section and in relatively shallow water. All of these depositional aspects are consistent with historical data pertaining to the USNS *Mission San Miguel* (United States Coast Guard 1958). Interestingly, one source also suggests that the United States Government used the tanker as a bombing target after it was stricken from the official USN register (Sawyer & Mitchell 1974: 173). Since the vessel’s bow likely projected from the water for some time after its loss, it would have almost certainly been the mark for these operations; this could be one explanation for the overall scatter of the bow section of the site.

The size of the wreck and methods used in its construction also support its identification as USNS *Mission San Miguel*. The intact stern section of the site measured approximately 35 m in length, while the collapsed aft cargo tank section measured approximately 49 m; both of these measurements match precisely to construction plans for T2-type tankers (Walker 2009). Furthermore, hull plating throughout the site was found to be riveted. This was the most commonly used method for fastening hull plates on steel ships in the first half of the 20th century and is known to have been used in the construction of USNS *Mission San Miguel* (NOAA 2013).

Many distinct diagnostic features documented at the site were later compared to historic photographs of USNS *Mission San Miguel* and provide further evidence for identification. The 2.8 m anchors were consistent with the general shape of stockless anchors used by the US Navy in the 1940s. Other features considered to be components of the bow included lengths of large stud-link anchor chain, a disarticulated 4.5 m wide windlass with 60-cm wide warping heads, and multiple gears and components possibly related to deck machinery. Features associated with the collapsed aft cargo tank section included multiple segments of piping (likely used for transferring oil); deck superstructure built above the tanks and used to support piping; the top portion of the aft mast; a distinctive cargo hatch that provided access to tanks; and components of the pump control room such as valves, pump manifolds, and switches. Features associated with the stern portion of the wreck included the rounded shape of the stern and the boat deck (Fig. 7); six consecutive portholes on the aft section of the hull; the distinctive curve of the gunnel at the transition from the aft cargo tank deck to the poop deck; the exhaust funnel and numerous intact intake/exhaust pipes extending from the boat deck; a large skylight frame originally situated on the boat deck; two lookout stations/gun positions mounted above the boat deck (Fig. 8); intact aft deck machinery situated on the poop deck in the stern; and aft mooring and line handling components such as bollards, bits, and fairleads attached to the poop deck in the stern. The presence of canvas hoses in the ship’s engine room (Fig. 9) provided an intriguing and tangible connection to anecdotal data from historical sources, as they are consistent with reported attempts to use fire hoses to pump water from the machinery spaces (United States Coast Guard 1958: 5–6).

All of these various lines of evidence provide a compelling case for the identification of the shipwreck as that of USNS *Mission San Miguel*. The fact that the reported location for the wreck is imprecise is unsurprising since the same navigational limitations experienced by the officers of USNS *Mission San Miguel* could likely have also prevented them from obtaining an exact fix for the wreck. The discrepancy in location could also be a result of the coordinates being taken from the ship that rescued the crew (USNS T-LST 664) or from one of the salvage vessels, which were most likely anchored in deeper water.

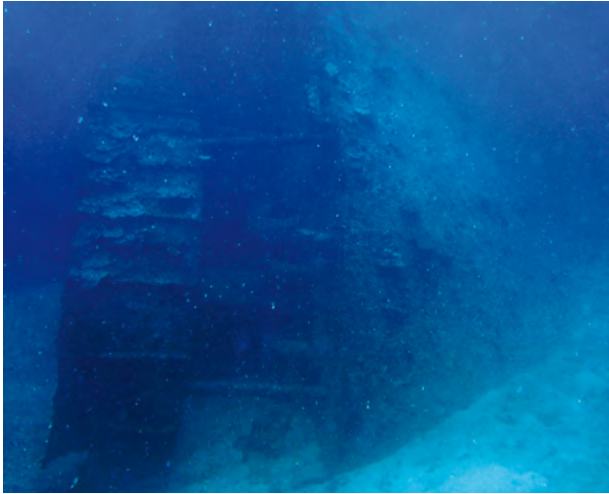


Figure 7. Rounded stern of USNS *Mission San Miguel* (NOAA/PMNM 2015).



Figure 8. Lookout stations/gun positions (NOAA/PMNM 2015).

Significance

The discovery of the USNS *Mission San Miguel* site is of great intrinsic value both historically and archaeologically. From an historical perspective, it allows for a dialogue about USN support vessels of its era and sheds light on the frantic pace of US wartime shipbuilding efforts. During the early to mid-1940s vast numbers of tankers, 'Liberty' ships, and 'Victory' ships were constructed and put

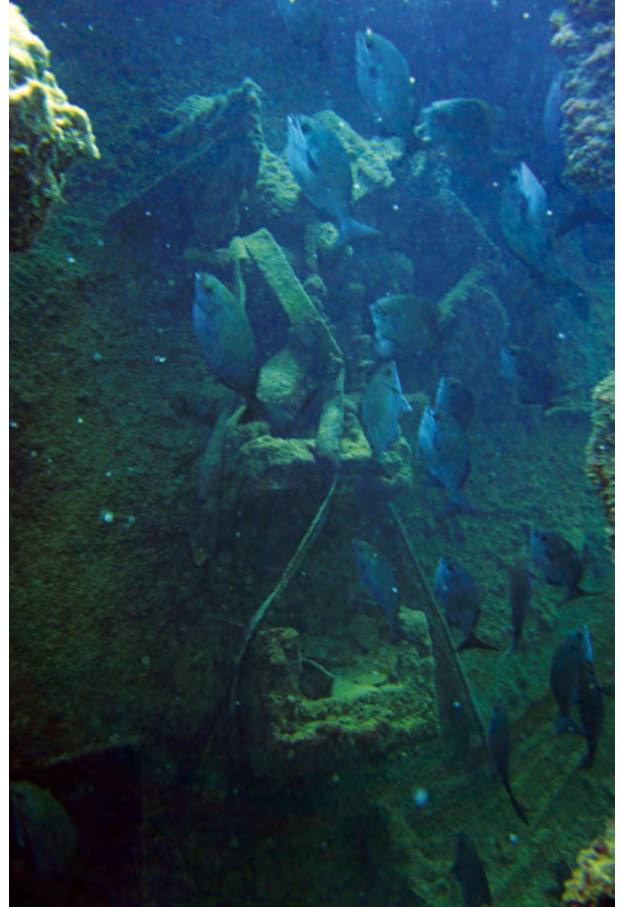


Figure 9. Fire hoses hanging inside intact stern portion (NOAA/PMNM 2015).

into service transporting ammunition and supplies around the world. Without these workhorse vessels the military system would not have functioned effectively. And while the remains of such support vessels have been identified in numerous locations, unfortunately they have largely become the unsung heroes of the war effort since, in most cases, their study has been passed over in favour of the wrecks of armed combat vessels. The USNS *Mission San Miguel* was one of many ships that carried much needed fuel to allied forces stationed around the world and the discovery of its remains brings renewed attention to the role that petroleum supplies played in military strategy during both WWII and the Korean War.

The USNS *Mission San Miguel* site is archaeologically significant since it represents one of the few known wrecks of a WWII-era tanker ship that has been so far investigated. Legally protected by the *Sunken Military Craft Act 2004* and the *National Marine Sanctuaries Act 1972*, as

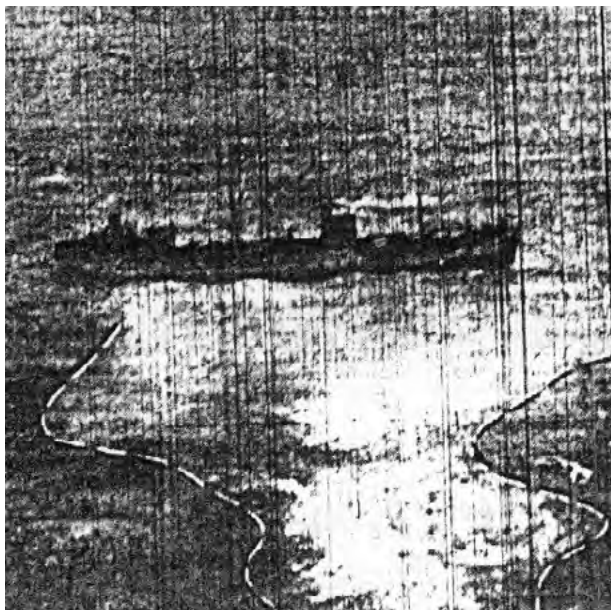


Figure 10. Historical image of fuel leak after grounding
(*Honolulu Star-Bulletin*, 11 October 1957).

well as its remote location in the Northwestern Hawaiian Islands, it is unlikely that the wreck has been disturbed by cultural activities since it was abandoned. Thus, the site holds the potential to enhance knowledge about a range of factors, including the deterioration process of massive steel-hulled ships in tropical environments.

From an environmental standpoint, however, the discovery of the wreck is perhaps most significant. Potentially devastating impacts resulting from petroleum leakage have long been a concern for the management of the site, and it was identified as a probable pollution threat by NOAA's Office of Response and Restoration RULET (Remediation of Underwater Legacy Environmental Targets) program (NOAA 2013). Based on available historical data about the vessel, it was evaluated against seven risk criteria relating to the amount and type of oil the tanker carried, the nature of the casualty, the effects of the grounding on its condition, and structural integrity of the wreck; it was assessed as a medium pollution risk (NOAA 2013). Although the tanker carried no oil cargo, it travelled with 14 500 barrels (approximately 600 000 gal./2 270 000 l.) of diesel fuel. An aerial photograph published in the *Honolulu Star-Bulletin* (1957) shows that some of this fuel leaked into the environment when the tanker grounded and that boom floats were deployed by USN salvage crews to contain it (Fig. 10). It was unclear, however,

exactly how much fuel escaped at the time of its loss and therefore how much was still contained in potentially intact tanks.

Preliminary archaeological investigations at the time of the discovery of USNS *Mission San Miguel* determined that it is unlikely fuel remains on the site, and no oil was noted in the vicinity of the wreck. Although there is the possibility that aft port cargo tanks are buried and potentially intact, this scenario is highly unlikely since the weight of the collapsed aft starboard tanks resting on the port tanks would most likely have distorted them and caused fuel to leak out. Thus, any oil contained in the aft cargo tanks was most likely released upon the tanker's grounding or subsequent deterioration. As a result of these observations, the site was reassessed as a low threat to the environment (Delgado & Symons 2015). Further investigation in the vicinity of the site could reveal any as yet undiscovered—and potentially intact—components of the vessel and could conclusively determine whether any oil remains at the site. Similarly, a thorough examination of the ecology and reef health in the area surrounding the wreck is recommended, as this could help to determine if past oil leakage resulted in any long term effects in this area of Maro Reef.

Conclusion

The discovery of the shipwreck at Maro Reef and its identification as that of USNS *Mission San Miguel* makes an important contribution to the maritime heritage and ecology of the Northwestern Hawaiian Islands. Despite the fact that the American military's critical need for petroleum led to the construction of scores of T2 tankers, this site represents one of the few extant examples of this important vessel type. Although support vessels such as this have received little attention from archaeologists studying sunken military craft, these unglamorous, yet hardworking ships played an important part in US maritime history. USNS *Mission San Miguel's* construction in Sausalito and subsequent use by both the USN and MSTs serve as a reminder of the frantic race to match wartime service demands and highlights the resulting infrastructure that emerged to support them.

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References

- Burns, J.H.R., Delparte, D., Gates, R.D. and Takabayashi, M., 2015, Integrating structure-from-motion photogrammetry with geospatial software as a novel technique for quantifying 3D ecological characteristics of coral reefs. *PeerJ* 3, pp. e1077.
- Delgado, J. and Symons, L., 2015, *Memorandum to Bill Marhoffer, incident management district 14*, USCG. Ref: USCG-NOAA MOA-2009-20/7848.
- National Oceanic and Atmospheric Administration, 2013, *Screening level risk assessment package USNS Mission San Miguel*. Office of National Marine Sanctuaries, Office of Response and Restoration.
- Naval History and Heritage Command, 2015, Dictionary of American naval fighting ships, *Mission San Miguel*. Viewed 4 August 2015, <http://web.archive.org/web/20121024203628/http://www.history.navy.mil/danfs/m12/mission_san_miguel.htm>.
- NavSource Naval History, 1996, NavSource Online: Service Ship Photo Archive. USNS *Mission San Miguel* (T-AO-129) ex *Mission San Miguel* (AO-129). Viewed 4 August 2015, <<http://www.navsource.org/archives/09/19/19129.htm>>.
- Sawyer, L.A. and Mitchell, W.H., 1974, *Victory ships and tankers: the history of the victory type cargo ships and of the tankers built in the United States of America during WWII*. Cornell Maritime Press, Inc., Cambridge.
- SS *Mission San Miguel*, tanker, found aground on Maro Reef. *Honolulu Star-Bulletin*, 11 October 1957.
- United States Coast Guard, 1958, *Commandant's action*. Marine Board of Investigation, *Mission San Miguel* (CG-INV 0.4; file held by Office of Marine Investigations and Analysis, US Coast Guard Headquarters, Washington, D.C.).
- Van Tilburg, H., 2002, *Maritime cultural resources survey: Northwestern Hawaiian Islands NOWRAMP 2002*. Submitted to National Oceanic and Atmospheric Administration National Ocean Service NWHICRER.
- Van Tilburg, H., 2003, U.S. Navy shipwrecks in Hawaiian waters: an inventory of submerged naval properties. *Naval Historical Centre Legacy Report*. Washington D.C. Naval Historical Centre.
- Visser, A., n.d., *Mission San Miguel*. Auke Visser's Famous T—Tankers Pages. Viewed 3 August 2015, <<http://www.aukevisser.nl/t2tanker/id931.htm>>.
- Walker, A.T., 2009, Historic American engineering record, Saugatuck (AO 75). HAER Maritime Recording Project (HAER VA-128). National Park Service, United States Department of the Interior. (File held by National Park Service, US Department of the Interior).
- World Public Library, 2015, USNS *Mission San Miguel* (T-AO-129). Viewed 4 August 2015, <[http://self.gutenberg.org/articles/USNS_Mission_San_Miguel_\(T-AO-129\)](http://self.gutenberg.org/articles/USNS_Mission_San_Miguel_(T-AO-129))>.

MILITARY-RELATED STUDIES BY THE DEPARTMENT OF MARITIME ARCHAEOLOGY AT THE WA MUSEUM

An overview after 45 years

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Introduction

As an adjunct to its better-known studies, the Department of Maritime Archaeology at the Western Australian Museum has been active in the inspection, and in some cases, the excavation of sites and objects, that have resulted from, or are linked (either directly or indirectly) to, war, battle and military conflict.

As the editors of the *Journal of Conflict Archaeology* (<<http://www.gla.ac.uk/schools/humanities/research/archaeologyresearch/battlefieldarchaeology/journalofconflictarchaeology/>>) observe on their homepage, there are numerous areas of study involving 'war', 'conflict' or 'battle' beyond the traditional battlefield. They cite, for example, the archaeology of industrial and popular protest, contested landscapes and monuments, nationalism and colonialism, class conflict, the origins of conflict and forensic applications in war zones. Thus, there are many connotations and the study of conflict-related sites encompasses both in the historic and pre-historic eras.

In narrowing the research focus, this particular work will concentrate on two military-related elements relevant to the Western Australian perspective, itself a relatively peaceful theatre of war compared with many places on earth (McCarthy 1996). One is the historical archaeology of submerged materials from a known region, or place of war, examining both military and civilian remains resulting from that conflict. The other is the study or recording of material remains constructed for war but not deposited during conflict. Though emanating from earlier military activity, or designed for war, these machines or objects were lost, or abandoned outside of that context in civilian, or other service. Notwithstanding their indirect and sometimes distant military links, these sites and objects have the potential to provide new evidence about the military, about its people and societies, their methods, equipment, organization and technology. The archaeological data can also be related to their new (non-military) role, equally as much as they can also provide hitherto unknown data related to their original or previous (military) purpose.

A self-evident example and one chosen to illustrate the global nature of the phenomenon, is *SubMarine Explorer* (1864–c.1870), a vessel conceived and designed as the Union answer to its Confederate

counterpart HL Hunley during the American Civil War. Being delivered too late to take part in the war, *SubMarine Explorer* was used thereafter in the pearling industry out of Panama before being abandoned. In this instance, archaeologists, corrosion scientists, historians and others concentrated on this vessel's highly innovative construction as a weapon of war; its visionary builder; the materials used; its intended and actual operating parameters; its (substantial) influence on subsequent submarine development after being delivered too late for conflict; and, its use in the Panama Pearl Fishery. There, in its final iteration *SubMarine Explorer* proved so successful, staying submerged at such depths and for so long that it killed or debilitated its crew via the then unknown malady caisson disease (decompression sickness [DCS]) (Delgado 2010).

While a number of elements in the *SubMarine Explorer* study can certainly be considered the archaeology of an object built for military purposes, others clearly are not, possibly creating semantic problems for those wishing to characterize the overall study, or wishing to apply an overarching term to quantify the research, e.g. military or military-related archaeology. Further, in considering what is the most appropriate term to apply to a multi-faceted study of this nature *SubMarine Explorer*, is one example that also falls into the realms of nautical (ship and boat building) archaeology, maritime archaeology, historical archaeology and industrial archaeology. The same considerations apply to the archaeological study of submerged or semi-submerged military materiel such as the objects lost in the Gallipoli landing in World War I (WWI) and aircraft lost in battle. They also apply to those objects originally built for conflict, but lost in commercial or recreational service. Here, in the case of aircraft the terms aviation archaeology, military aviation archaeology or underwater aviation archaeology, or permutations of the same, could equally apply. As with submerged ships and submarines, a particular researcher's emphasis serves to dictate the term chosen with which to categorise the thrust of the research, and this in turn serves to alert readers to a particular study's chief focus.

As indicated earlier, this work then will examine the historical archaeology of submerged and semi-submerged materials emanating from wartime Western Australia examining both military and civilian remains resulting from that conflict in a manner consistent with modern approaches to the subject (e.g., Geier *et al.* 2011). The other is

the study or recording of submerged and semi-submerged remains constructed for war but not deposited during conflict. As in the case of the *SubMarine Explorer*, though emanating from earlier military activity, or designed for war, these machines or objects were lost or abandoned outside of that context in civilian, or other service.

The beginnings

In 1978 while the Department of Maritime Archaeology at the Western Australian Museum was concentrating on the excavation of pre-European settlement wooden-hulled sailing vessels, a small team embarked on a pearling lugger for *Wreck Inspection North Coast* (WINC), a maritime precursor to the modern 'heritage inventory' (Sledge 1978). In this instance the study area was vast, encompassing the north-west Australian shore and the entire Kimberley coast, resulting in the recording of sites as diverse as pre-settlement maritime rock art, sailing vessels, pearling and survivors' camps, aircraft, steamships, and World War II (WWII) wrecks.

Of the sites inspected, an abandoned pre-war seaplane float, together with a Mitchell bomber and a Douglas DC3 from WWII joined to herald the Department's involvement in the then newly-emerging discipline of aviation archaeology (McCarthy 2004a). Although little of technical import was ever expected to come of either example of mass-produced types, in the DC3 case, the aircraft and its contents were of considerable social significance, despite only a wing spar remaining visible in 1978. As a civilian transport fleeing Java with refugees, it was strafed in the air north of Broome in 1942. After being forced down to lie awash in the breakers it was again attacked, resulting in loss of life. The aircraft was also carrying a cache of diamonds, which was later discovered and dispersed by a beachcomber who was later to become known as 'Diamond Jack'. His exploits, together with those of the aircraft's wounded Captain, Ivan Smirnoff, in getting the plane down in one piece, became the substance of aviation and North West legend. For its part, the Mitchell Bomber was a relic of the part northern Australia and its airfields had played in prosecuting the war (Sledge 1979).

Conversely, the float from German Aviator Han's Bertram's famous *Atlantis* was from the pre-war era Junkers JU W-33 seaplane as indicated. As a

result, its significance in the context of this article is limited to the involvement of the Museum's conservation scientists and restoration experts in the conservation-related elements of aviation archaeology for the first time (MacLeod 1983). This example is also pertinent given that the conservation and restoration work was followed by exhibitions at the Museum's Shipwreck Galleries in Fremantle, at the Aviation Museum in Bull Creek and at the Historical Society Museum in Broome. As the Department of Maritime Archaeology is a museum-based unit much of what follows also has had exhibition elements, or failing that, some form of public expression in accordance with the Museum's brief. This includes wreck access programs and interpretive materials including pamphlets, maps and popular articles.

As part of the preparation for the WINC expedition, information was also gathered on the wreck of the *MV Koolama*. This 106 m-long coastal motor vessel was attacked at sea in WWII, and after an epic voyage to safety sank alongside the Wyndham wharf. There, after an initial salvage attempt it was abandoned to remain, to this day, inaccessible due to tides, zero visibility and crocodiles attracted by the nearby meatworks. While these considerations combined to preclude an inspection, the research led to the realization that the aircraft and the *Koolama* were pointers to the existence of an entire suite of wartime sites, some where deaths had occurred. As a corollary of the inspection process these sites were brought to the attention of the Maritime Archaeology Advisory Committee advising the Museum's Director on issues such as the historic status (or otherwise) of what was inspected by staff. As a consequence, they and other heritage practitioners also came to understand that while some of the other wrecks and relics recorded on the 1978 expedition fell within the parameters of the *Maritime Archaeology Act 1973* with its pre-1900 stipulation, sites such as the aircraft wrecks and the *MV Koolama* lay in state waters and could not be protected under the *Commonwealth Historic Shipwrecks Act 1976*. It was also evident from institutional, public and other responses, that those remains lying submerged or in the water were generally (though quite incorrectly) presumed to be the responsibility of the Department of Maritime Archaeology. This in turn resulted in the Department taking a *de facto* lead in examining (sometimes searching for) and protecting wartime and military sites that were not legally protected under the aegis of its wreck inspection program.

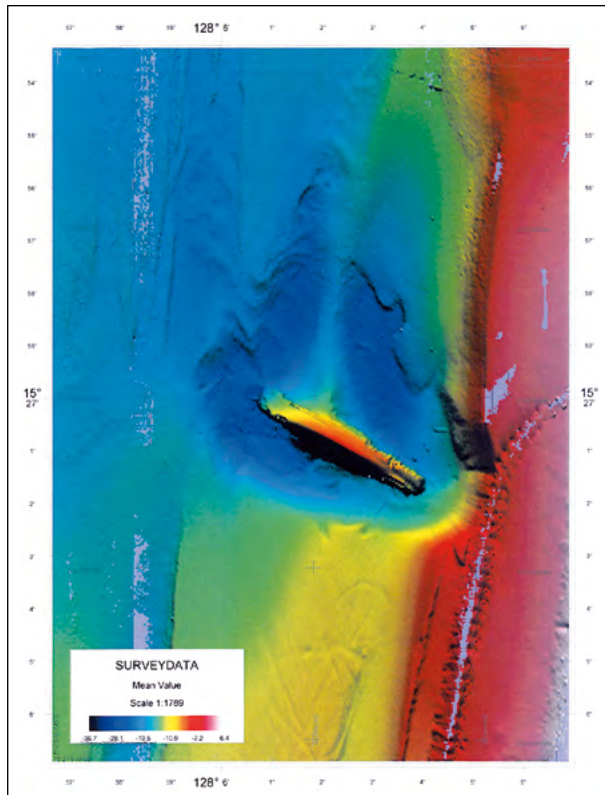


Figure 1. A multibeam image of the MV *Koolama* site in 2015 (Coastal Information Directorate, Department of Transport).

World War II aircraft

Publications and the exhibition of recovered artefacts following avocational research and excavations conducted in the early 1980s brought a group of six WWII flying boats in the intertidal at Broome to the attention of the public and aviation enthusiasts. Nine others, from a fleet comprising Dornier, PBY Catalina and Short Empire types were thought to lie completely submerged further from shore (Prime n.d.). In 1989 expressions of concern from the Broome Historical society about looting from a previously-unknown site in deep water offshore (a machine gun and a child's doll) were reported to the Museum in the hope it could help stem the practice. This caused the Department to become closely involved after 1990 in developing a series of search, management and *ad hoc* protection strategies. (These developments are presented in Jung 2004.) With funds provided by a film company, a new remote sensing phase was entered into in 2001 utilising the Museum's side scan sonar out of its 7-m workboat. This resulted in the location of most of the missing flying boats, some producing remarkable side scan sonar images (Green 2002).

An oral history program was also conducted resulting in interviews with some of the WWII pilots gathered together by the filmmakers, and with the leader of post-war attempts to clear some of the wrecks for future flying boat activities (Souter 2003). A site inspection, test excavation and artefact analysis regime was then commenced and submissions made that resulted in the sites being protected under a Conservation Order issued under the *Heritage of Western Australia Act 1990* (McCarthy *et al.* 2002). Western Australia thus became the 'first state in Australia...to protect located, submerged aircraft' (Jung 2004: 76). Even though these reports were augmented with a web-based public product produced and sponsored by aviation specialist Jon Davison, there was unfinished business from that era. This was due to the collapse of an agreement to provide funds to mark the sites with above- and below-water interpretive signage post-excavation. While in abeyance until such time as the project can be resurrected and funded by Broome-based interests, some interpretive material has been prepared (Jung 2006). Work is continuing and an electronic archaeological report will present these disparate elements, including the work already published, into a coherent whole (McCarthy, *in prep.*). An important and clearly pertinent direction will concentrate on the personal items looted by divers. Examples are children's toys located amongst the assemblages, now on exhibition in the Broome Historical Society Museum and the child's doll and other objects recovered by the Museum expedition (See Department of Maritime Archaeology's online Artefact Database: <<http://www.museum.wa.gov.au/maritime-archaeology-db/artefacts>>). The report will focus on a concept central to the author's chief interests as the lead archaeologist during the 2001 survey and excavation entitled 'The Archaeology of the Refugee' focussing on what people take with them in those often abrupt and frightening circumstance (Shefi, *in prep.*). Finally, a large number of professionals, students and volunteers were involved, with the work of Jung (2004, 2007a, 2007b, 2008, 2012) personifying the Department's commitment to facilitating expert external researchers. There are many other examples, with sponsors, volunteers and expert contributors listed in the literature about the Broome project and in the studies mentioned in the following.

Wing Commander C.C. Learmonth's Beaufort bomber, which entered a terminal dive between Rottnest Island and Fremantle in January 1944, was another *de facto* focus for the Department. Like



Figure 2. Part of the Broome Historical Society collection from the WWII raid (M. McCarthy, WA Museum).

Broome, the story is well known with Learmonth heroically transiting information on the mysterious problem that had plagued the type as his aircraft descended out of control until it crashed into the sea, killing all on board. Learmonth (Exmouth) airport was named in his honour as a result. Following the receipt of historical information and a request to act from avocational tech-diver Peter Balalas and Learmonth's widow on its possible whereabouts a remote sensing sweep of the area was conducted out of the Museum's workboat in 2000. Though finding only an abandoned oil well and associated wreckage, the Department's search and the resultant report has set the scene for the time the wreck is found and/or for future searches (Balalas 2002).

Around this time it was understood that the Department was also responsible for the historic wrecks and relics in the Cocos and Christmas Islands. This led to a feasibility study that resulted in the location and inspection of a PBY Catalina JX 435 in the Cocos Lagoon, again with Jung's assistance. Lost in June 1945 as a result of pilot error, it was examined along with a number of shipwreck sites that were since declared historic and nominated to the Commonwealth Heritage list (McCarthy 2005). In 2009, the Museum received advice from researcher-diver James Miles of his team's location of a B24 Liberator bomber A 19-163 lost in WWII with its entire crew off Truscott Field, Anjo Peninsula in the Kimberley. Miles used bearings and other mathematical compilations

taken from historical images to link to Google Earth, finding the wreck within 100 m. of its projected position using side scan sonar imagery and then by diving. Three years later, Miles and his team located an RAAF Beaufighter A19-163 lost with its crew on take off from Broome airport in September 1944 (Miles, *in prep.*).

In the mid 1990s, at the request of the Catalina Club of Western Australia, the Royal Australian Navy (RAN) began conducting sweeps of the Rottneet Island ships' Graveyard in search of the remains of four PBY Catalina aircraft scuttled immediately after the war under the Lend Lease program. Called the 'Black Cats', the Catalinas, other than being stripped, were abandoned in their wartime state. They were also unique, famous for regularly travelling a WWII route from Fremantle to in Galle in Sri Lanka that was so long it was called the 'Double Sunrise' flight. In the expectation of success an approach was also made to the Museum in order to obtain advice on the feasibility of the location, recovery and conservation-related ramifications of the project. In essence, the Museum's report found that an attempt to raise the wrecks could not be justified, partly due to the extensive damage caused by the use of explosives in scuttling the aircraft and to the then unknown problems of conserving and exhibiting aluminium remains recovered from a saline environment. Instead, it was recommended that the Club should await evidence of the successful raising, conservation and long-term stability of similar craft. Awaiting that eventuality

the Club was urged to acquire one of a number of existing aircraft of the same type, preferably one with a verified service record. The Club was also advised that to continue the search was nonetheless 'warranted', but given the uncertainties it should be the result of opportunistic deployment by a vessel conducting trials or traversing the area such as the RAN or private firms testing their equipment. In conclusion and with reference to the importance of other wartime wrecks in the graveyard, it was recommended that,

A search could indirectly result in the location of the many hulks in the Rottnest Graveyard. The centring of a search area around the known coordinates of the Dutch submarine KXI, which lies well within the parameters for the Catalina search, could prove beneficial in that the possibilities are multiplied and the potential returns to the RAN at least are vastly increased (McCarthy 1997: 20).

The Rottnest Island graveyard and submarine studies

In the context of wrecks and relics having emanated from earlier military activity, but lost or some abandoned in civilian, or other service, the Rottnest Island graveyard has become an important, previously inaccessible, repository which with the advent of GPS, off-the-shelf remote sensing equipment and the 'tech-diver' has become increasingly visited.

These wrecks and relics (aircraft, RAN vessels, RNN *KXI*, arms and ammunitions), some abandoned in deep water as part of the Lend Lease Agreements may be able to provide archaeological data related to their original or previous (military) purpose. Examples are the Welman Type Submersibles about which little is known, rendering their remains of considerable significance and the Black Cats. Those former military vessels abandoned after years of civilian service post war may also provide hitherto unknown data. To that end and partly in order to conduct remote-sensing experiments (e.g. at HMAS *Derwent*) that might prove of benefit elsewhere the Department has been active in conducting remote sensing activities at the Graveyard (Green 2009a). The Department was also successful in liaising with the local 'tech-diving' community who are now regularly providing their reports and after obtaining considerable sponsorship staff also descended in a submersible. These developments have enabled the Department to ground truth magnetic strikes.

Royal Netherlands Navy submarines, including *KVIII* and *KXI* arrived at the Fremantle submarine base in WWII, joining their British and American counterparts in establishing what was to become one of the major submarine bases of the War (Cairns 2011). Aging and obsolete, RNN *KVIII* and *KXI* assumed training roles until being laid up. After sinking in Fremantle harbour after the war *KXI* was stripped and taken out to the ships' graveyard off Rottnest Island and scuttled. For its part *KVIII* blew ashore from its mooring off Garden Island and was abandoned on the shores of Jervoise Bay, becoming part of a collection of wrecks and hulks littering its shores. Over the years it was progressively demolished for scrap, albeit leaving much of the bilge intact beneath the sand. In 1980, along with the other wrecks in the bay that were all becoming endangered due to a burgeoning shipbuilding industry, *KVIII* and (because of its contemporary RNN associations) *KXI* were documented (McCarthy 1981). Thereafter, the Department's involvement with submarines grew as a result of research and fieldwork at Imperial Japanese Navy (IJN) submarine *I 124* lost with all hands off Darwin in WWII. Conducted as part of a combined Northern Territory and Western Australian wreck inspection regime, heavily sponsored by private, film and Commonwealth interests, this project succeeded in fixing the submarine's position, and utilised an ROV in a preliminary inspection. During the research phases, it was also proved that the wreck was not a mercury hazard as claimed by local persons who were apparently seeking to have it raised for exhibition as a 'trophy-of-war'. Equally importantly, the research showed that divers had not entered the wreck in WWII. Consequently, it could not have been the means whereby American code-breakers gained access to the Japanese codes as often claimed (McCarthy 1990).

These activities and the assistance provided to those studying the 'J' Boat type in Victoria (McCarthy 2009), underpinned the Department's early interest and involvement in submarines as a class of maritime archaeological sites (McCarthy 1998). Following the lead of Tim Smith, formerly of New South Wales, and in close association with corrosion specialist Ian MacLeod, the Department became part of the management team at HMA Submarine *AE2* and in that role was (as with HL Hunley) in America part of the investigations into whether it could or should be raised (Smith & McCarthy 2009). Department staff also became part of the *AE1* search committee, having led early institutional support (Foster & McCarthy 2009) and having conducted shallow water remote

sensing surveys for that group (Green 2009b). Staff also assisted at Submarine Explorer in Panama (McCarthy 2009).

Finally, while the entire west end of Fremantle contains structures and relics of the war, the Department had few reasons to enter what is already a very well serviced and comprehensively studied field—other than contributing to the Defence Gallery and the associated HMA Submarine *Ovens* on its WWII slipway as an exhibit. One exception has been the inspection and recording of the remains of Fremantle's WWII Submarine net infrastructure (Carter & Anderson 2010).

The *Sydney-Kormoran* engagement and its aftermath

The Department's involvement in the HMAS *Sydney-Kormoran* program is well known, its curator having been recognized at the 2008 Commission of Inquiry as 'an early and persistent campaigner for finding HMAS *Sydney*' (Cole 2008: 2–3). This decades-old involvement dates back to the realization that these two sites, when located would fall within the jurisdiction of the *Commonwealth Historic Shipwrecks Act 1976*. As a result, the Department's work commenced in 1981 examining oil survey indications of a wreck consistent with HMAS *Sydney* and thereafter, conducting numerous other site inspections. The Department also convened and /or backed an array of seminars designed to encapsulate all knowledge, rumour and speculation about the engagement and the whereabouts of the two wrecks (e.g. McCarthy & Kirsner 1991; McCarthy 2009a). Acting alone amongst Australia's other stake-holding institutions the Department also backed and encouraged bona fide study, resulting in numerous books and reports (Olson 1996), some award-winning (Olson 2000; MacDonald 2005). For a while the Museum also had the Woods Hole Oceanographic Institute on board as an equal partner in a proposed search. When it withdrew, citing insufficient evidence for a search, the Department provided every support to the private Trusts and Foundations formed to locate HMAS *Sydney*. So too, when the RAN concluded, in 2001, that a search was not warranted due to disagreements about where the wrecks lay (RAN Sea Power Centre 2001) the Museum provided every support for those who disagreed and sought to move forward (McCarthy 2009b). The Museum also initiated research into proving that the body found in a carley float at Christmas Island was from HMAS *Sydney* (Olson 1996) and

subsequently provided extensive support for those seeking to locate it. This all culminated when the Christmas Island body was found in 2006 and in 2008 when the wrecks of HMAS *Sydney* and HSK *Kormoran* were found (Mearns 2009; McCarthy 2010; McDonald 2016).

The Department and its affiliates' work is ongoing with data from the 2015 combined WA Museum-Curtin Centre for Marine Science and Technology-DOF SubSea still being analysed (e.g. Anderson & Bigourdan 2016; Olson 2016.). In the 2015 instance, corrosion science specialists from Curtin University and elsewhere joined the Museum's Ian MacLeod to conduct corrosion measurements and assessments of the biological and other drivers impacting on HMAS *Sydney* and HSK *Kormoran* (MacLeod 2016). These two wrecks, and the availability of a wide range of data gathering equipment and expert scientists, presented a rare scientific opportunity: contemporary sites, comparatively close to each other, in similar depths and with few other interfering variables bar the materials used in the construction, their service history and battle damage. As a result the corrosion data will eventually prove of significance in managing the potential oil spills from the thousands of wrecks in the world's oceans that are in danger of imminent collapse. As Monfils and Nawadra (2006) show, there are around 3 800 WWII wrecks in the Pacific and East Asian regions alone. Thus, the two ships and their lost men still 'serve' and the ethical considerations surrounding sampling at and around 'war graves' are arguably surmounted.

Emanating from the *Sydney-Kormoran* battle, but deposited to become archaeological sites elsewhere are two identical steel lifeboats from *Kormoran* that entered civilian service soon after the war and a pistol thrown into the sea from the shores of Red Bluff north of Carnarvon by survivors of the *Kormoran*. Despite on-going interest in its location together with a camera containing a record of the battle, the pistol was not located until 2007 when a surfer looking for fishing lures on the seabed found it. It was recovered and then conserved by a team from the Departments of Maritime Archaeology and Materials Conservation (Anderson & Garcia 2007).

Of the two steel lifeboats, purchased after the war one was used as a transport carrying wool and other station goods between Carrarang Station and Denham in Shark Bay before rusting out and being abandoned in the intertidal. The other entered



Figure 3. The Carrarang Lifeboat from HSK *Kormoran* in 1990 (M. McCarthy, WA Museum).

the fishing industry out of Bunbury where, after running out of fuel, it drifted ashore and was also abandoned. Responding to a request from the Shire of Shark Bay which was keen to recover the Carrarang boat for their museum, it was inspected by archaeologists and conservators and judged too fragile for anything but a wall mounted exhibit featuring its keel and lifting hooks. These were the only items that after deconcretion would have had enough residual metal to use in the proposed exhibit (McCarthy, MacLeod & Manera 1990). Local researcher Tom O'Brien deduced the location of the Bunbury boat and its position was 'proved' under metres of beach sand by a colleague with remote sensing expertise and equipment. The Department of Maritime Archaeology subsequently assessed it and a recommendation was made to leave it *in situ* for the future (O'Brien & Harewood 2002).

Joining these two vessels on the Department's horizon and in its shipwreck files after 1976 were a Sleeping Beauty submersible canoe lost with its operator at Careening Bay Garden Island in WWII; HMA Submarines *AE1* off Rabaul and *AE2* in the Dardanelles (as indicated earlier); SMS *Emden* in the Cocos Islands (all WWI), and relics from WWII HMAS *Perth* in the Sunda Strait. Responsibility for SMS *Emden*, which by delegation lay with the Director of the WA Museum for many years, has since passed to the Australian Commonwealth Government. Similarly, with the advent of both interest and capacity in examining and managing HMAS *Perth* and SMS *Emden* in the eastern states (the Commonwealth and the Australian National Maritime Museum), the Western Australian Museum has retired from the scene, other than to assist in the conservation and management of materials (a bell and ceramic plates) from HMAS *Perth*.

Military-related sites

The earliest example of the Department's involvement in sites and relics designed for military use, but lost or deposited in an unrelated context, is the examination and recovery of materials from the stranding site of the frigate HMS *Success* in 1971 (Henderson 2007). This Royal Navy (RN) vessel grounded with passengers and supplies for the new colony at the entrance to what was to become the port of Fremantle in 1829. The recovery of material from the grounding site, predominantly ship's fittings is reflected in what has been elsewhere characterized as 'Australian Approaches to Shared Heritage: Royal Navy Vessels in Australian Waters, HMB *Endeavour*, HMS *Sirius* 1790, HMS *Pandora* 1791', with two major excavations closely involving Department staff (Staniforth 2009). This sentiment is also reflected in the Department's location and examination of two Australian exploration ships, William Dampier's transport the former naval fireship *Roebuck* at Ascension Island (McCarthy 2004) and of the French naval corvette *L'Uranie* transport of the lovers Rose and Louis de Freycinet, both with Shark Bay links (McCarthy 2005). There, in the context of a broader study into the maritime heritage of the Bay, the Department also facilitated a study into the military history of the region (Cooper 1997).

The recovery and examination of the Crimean War-type gunboat engine recovered from the SS *Xantho* is a case very similar to that of *Submarine Explorer* examined earlier in this work. After ten years in RN service the engine was sold for scrap, fitted to the 23-year-old former paddle steamer and was lost in civilian service in Western Australia. Recovered from a tramp steamer and pearler, the engine is nonetheless the only known example of the high pressure, high revolution Crimean War-type Gunboat engines that, in being mass produced, utilized Joseph Whitworth's standard thread. Since being raised in 1985 this engine has provided the only known detailed first-hand information on the type and how they were operated, and is the subject of a working model and continuing study. The many existing publications, websites and exhibitions are now being augmented by GIS, 3D images, videos and other representations of the engine produced by expert volunteers now appearing on YouTube, websites and in hard copy form (Edwards & Cooper 2013; Edwards 2014 a, b & c) This instance is further manifestation of the debt the Department owes its sponsors and expert volunteers in pursuing military-related archaeology these past 40 years.

The future

Two naval vessels, one a minesweeper, lost during WWII and the other a frigate destroyed in an atomic bomb test post war join a WWII bomber and a fighter aircraft remaining to be found. The wooden-hulled minesweeper USS *SC 751* which ran aground on Ningaloo Reef, was refloated but sank soon after, with both it and its stranding site expected to provide useful archaeological and historical information (McCarthy 2011). The other vessel, the British frigate HMS *Plym*, was destroyed as an atomic test bed near Trimouille Island in 1952, rendering it an important site requiring study in a similar fashion to the WWII wrecks of Bikini Atoll. Its position was determined while investigating the wreck of the English East Indiaman *Trial* at the Monte Bello Islands and the Department commenced a remote sensing search for the frigate finding a number of anomalies and wreckage on the shore. In 2006 the Department obtained a modern GPS 'fix' for the site from the Department of Fisheries that will facilitate a future examination of the site and the nuclear test site infrastructure. Interest in this notion extends beyond the Department to the eastern states (Brad Duncan, pers. comm., 15 August 2016) where engagement in wartime and military sites and modified cultural landscapes is well-established.

Of the aircraft, a B-24A bomber that crashed with the loss of 19 lives in the waters off Broome during the WWII attack that destroyed the 15 flying boats in 1942 and the famous fighter ace and Melbourne footballer K.W. (Bluey) Truscott's Kittyhawk remain to be found. Of the two, Truscott's aircraft is of national significance being lost off Exmouth in 1943 with its famous pilot (Truscott's airbase was named

after him) when escorting a PBY Catalina into base. Remaining outside its jurisdiction, it is doubtful whether the Department will initiate a search for these aircraft unless specifically requested by Institutional (e.g. the RAAF) or regional stakeholders (e.g. The Broome Historical Society) who are able and willing to manage the site(s) and help protect them under the *Heritage of Western Australia Act 1990*.

Conclusion

Over a decade ago, it was reported that Australian maritime archaeologists, especially those in Western Australia, were taking an *ad hoc* holistic approach to historical and industrial-era maritime heritage by studying a wide, and in some cases quite unexpected, range of objects and sites underwater, in the intertidal and land areas (McCarthy 2003). A cursory glance at papers appearing over the ensuing years in the AIMA Bulletin and in allied journals, such as the Australian Association for Maritime History's *Great Circle*, indicates that this approach has continued and that it has widened. This paper, examining the historical archaeology of submerged and semi-submerged materials emanating from a wide range of conflict and military activities is but another manifestation of the holistic approach taken by Australian maritime archaeologists over the years. Often *ad hoc*, frequently responding to opportunity rather than a pre-conceived program, it is a surprisingly productive approach. Often leaving sites they are left virtually untouched and *in situ* the research was often preliminary at best, but all the while laying the foundations for future survey and research. As reported in 2003, it also continues to ignore the real and imagined boundaries between maritime archaeology and maritime history, especially when operating in a museum environment.

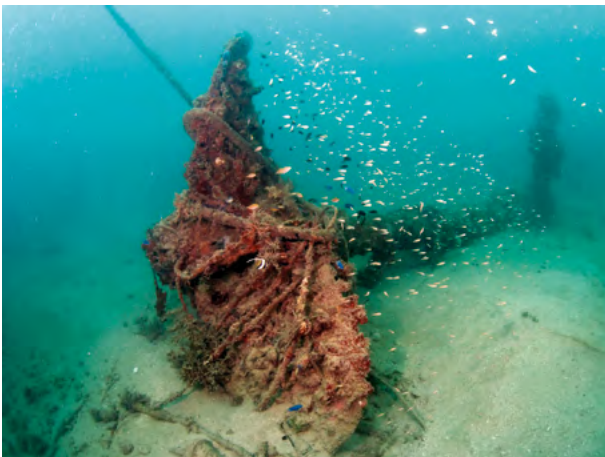


Figure 4. Propellor and shaft HMS *Plym* in recent times (Shannon Conway, WA Museum Collection).

References

- Anderson, R. and Bigourdan, N., 2016, *New discoveries and future direction*. In: M. McCarthy (ed.), *From great depths: the wrecks of HMAS Sydney (III) and HSK Kormoran*. UWA Publishing and the Western Australian Museum, Perth: 311–324.
- Anderson, R. and Garcia, R., 2007, *The landing of HSK Kormoran (1941) survivors at Red Bluff, Seventeen Mile Well, Quobba Station. Red Bluff pistol find and Conservation and identification of Red Bluff pistol*. Report—Department of Maritime Archaeology, Western Australian Museum, No. 226.
- Balalas, P., 2002, *Learmonth's Beaufort bomber. A study into the loss of Beaufort aircraft A9-J46 that crashed into the sea near Rottneest Island on January 6 1944, defining a search area, recommendations of search method and a discussion of related issues*. Report—Department of Maritime Archaeology, Western Australian Maritime Museum, No. 183.
- Cairns, L., 2011. *Secret Fleets: Fremantle's World War II Submarine Base*. Western Australian Museum, Fremantle.
- Carter, M. and Anderson, R., 2010, *Cockburn Sound's World War II anti-submarine boom net. Historical background and site inspections*. Report—Department of Maritime Archaeology, Western Australian Museum, No. 252.
- Cole, T.R.H., 2009, The loss of HMAS Sydney II. Viewed 15 August 2016 <<http://www.defence.gov.au/sydneyii/finalreport/index.html>>.
- Commission of Inquiry. Viewed 15 August 2016 <<http://www.defence.gov.au/sydneyii/gallery.html>>.
- Cooper, D., 1997, *A brief history on the military influences in Shark Bay*. Report—Department of Maritime Archaeology Western Australian Maritime Museum, No. 122. Western Australian Museum, Fremantle.
- Delgado, J.P., 2010, *Misadventures of a civil war submarine: iron, guns and pearls*. Texas A&M Press, College Station.
- Edwards, K. and Cooper, D., 2013, Digitizing Xantho: Notes on a project to digitally record an assemblage of common engine components from a 19th-century steamship. *Bulletin of the Australasian Institute for Maritime Archaeology* **37**: 42–47.
- Edwards, K., 2014a, Xantho engine a boiler fly-around. Viewed 15 August 2016, <<https://www.youtube.com/watch?v=5FsoAWQoGo0>>.
- Edwards K., 2014b, Xantho engine. Viewed 15 August 2016, <<https://www.youtube.com/watch?v=6FYPHvUNemE>>.
- Edwards K., 2014c, Xantho engine. Viewed 15 August 2016, <<https://www.youtube.com/watch?v=K1jtDmQizc>>.
- Foster, J. and McCarthy, M., 2009, The search for HMA submarine AE1. In: M. McCarthy, K. Hosty and C. Philippou (eds.), *Iron, steel and steamship archaeology. Papers from the 2nd Australian Seminar held in Perth, Melbourne and Sydney 2006*. Australian National Centre of Excellence for Maritime Archaeology, Special Publication Number 13. The Australasian Institute for Maritime Archaeology Special Publication Number 15. Australian National Centre of Excellence for Maritime Archaeology, Fremantle: 136–138.
- Garratt, D., 1999. Précis of the wrecks in the ship's graveyard, Rottneest. Report—Department of Maritime Archaeology Western Australian Museum, No. 148.
- Geier, C.R., Babits, L.E., Scott D.D. and Orr, D.G., (eds.), 2011, *Historical archaeology of military sites*. Texas A&M Press, College Station.
- Green, J., 2002, The application of side scan sonar and magnetometer to the location of archaeological sites. *Bulletin of the Australasian Institute for Maritime Archaeology* **26**: 119–130.
- Green, J., 2009b, The Fremantle deepwater graveyard. In: M. McCarthy, K. Hosty and C. Philippou, C., (eds.), *Iron, steel and steamship archaeology. Papers from the 2nd Australian Seminar held in Perth, Melbourne and Sydney 2006*. Australian National Centre of Excellence for Maritime Archaeology, Special Publication Number 13. The Australasian Institute for Maritime Archaeology Special Publication Number 15. Australian National Centre of Excellence for Maritime Archaeology, Fremantle: 23–6.
- Green, J., 2009a, *The 2009 magnetometer search for the Australian submarine AE1, Rabaul Harbour, East New Britain*. Report—Department of Maritime Archaeology, Western Australian Maritime Museum, No. 247.
- Henderson, G., 2007. *Unfinished voyages: Western Australian shipwrecks 1622–1850*. University of Western Australia Press, Nedlands.
- Jung, S.J., 2004, Artefacts from Broome's World War Two flying boat wreck sites: a survey of data collected 1979–2001. *Bulletin of the Australasian Institute for Maritime Archaeology* **28**: 63–80.
- Jung, S., 2006, *Broome's World War II flying boats: heritage trail guide for exposed wreck sites in Roebuck Bay*. Unpublished compilation, Charles Darwin University, Darwin.
- Jung, S., 2007a, Working Backwards: Broome's World War II flying boat wreck sites reconstructed from archaeological non-disturbance surveys, 2003 fieldwork season. *Bulletin of the Australasian Institute for Maritime Archaeology* **31**: 32–44.
- Jung, S., 2007b, A defabrication method for recording submerged aircraft: observations on sunken flying boat wrecks in Roebuck Bay, Broome, Western Australia. *Bulletin of the Australasian Institute for Maritime Archaeology* **31**: 26–31.
- Jung, S., 2008, Australia's great aerial armada: the aviation archaeology of World War II catalina, Dornier and Short Empire flying boats in Roebuck Bay, Broome Western Australia. Unpublished PhD thesis. Charles Darwin University, Darwin.
- Jung, S., 2009, Site formation process (wing inversion) at Catalina flying boat wreck sites lying in Roebuck Bay, Broome, WA. *Bulletin of the Australasian Institute for Maritime Archaeology*, **33**: 19–31.
- Jung, S., & Peters, N., 2012. The Broome Air Raid. 3 March 1942. In E. Verheijke (ed.) *Broome 3 March 1942–3 March 2012*. Embassy of the Kingdom of the Netherlands, Canberra & the Western Australian Museum, Canberra: 38–47.
- MacLeod, I.D., 1983, Stabilization of corroded aluminium. In: *Studies in conservation* **28**.1, February. International Institute for Conservation of Historic and Artistic Works, London: 1-7.
- MacLeod, I.D., 2016. Corrosion on Sydney and Kormoran. In: *New discoveries and future direction*. In M. McCarthy (ed.) *From great depths: the wrecks of HMAS Sydney (III) and HSK Kormoran*. UWA Publishing and the Western Australian Museum, Perth: 304–9.
- McCarthy, M., 1981, Jervoise Bay: a case study in the management of endangered wreck sites. *International Journal of Nautical Archaeology* **10**.3: 239–252.
- McCarthy, M., Macleod, I. D. and Manera, B., 1990, *Carrarang lifeboat (ex HSK Kormoran)*, Unpublished Wreck Inspection Report—Department of Maritime Archaeology, Western Australian Maritime Museum, No. 93.
- McCarthy, M., 1990. Report Japanese submarine / 124. Report—Department of Maritime Archaeology, Western Australian Museum, No. 43.
- McCarthy, M. and Kirsner, K., (eds.), 1991, Papers from the HMAS Sydney forum. Fremantle 21–23 November 1991. Report—Department of

- Maritime Archaeology, Western Australian Maritime Museum, No. 52.
- McCarthy, M., 1996, War on the doorstep. In: J. Gregory, (ed.), *On the homefront, Western Australia and World War II*. UWA Press, Nedlands: 109-18.
- McCarthy, M., 1997, The 'Black Cats'. Report into the feasibility of locating, raising and conserving one of the four Catalina flying boats scuttled off Rottneest Island in the years 1945–1946. Report—Department of Maritime Archaeology, Western Australian Maritime Museum, No. 125.
- McCarthy, M., 1998, The submarine as a class of archaeological site. *Bulletin of the Australian Institute for Maritime Archaeology* **22**: 61–70.
- McCarthy, M., Green, J., Jung, S. and Souter, C., 2002, The Broome flying boats. Papers relating to the nomination of a suite of flying boat wrecks at Broome to the Register of Heritage Places under the *Heritage of Western Australia Act 1990*. Report – Department of Maritime Archaeology, Western Australian Maritime Museum, No. 170.
- McCarthy, M., 2003, The holistic approach to the maritime heritage. *Bulletin of the Australasian Institute for Maritime Archaeology* **27**: 25–34.
- McCarthy, M., 2004a, Historic aircraft wrecks as archaeological sites. *Bulletin of the Australasian Institute for Maritime Archaeology* **28**: 81–90.
- McCarthy, M., 2004b, HM Ship Roebuck (1690–1701): Global maritime heritage? *The International Journal of Nautical Archaeology* **33.2**: 330–337.
- McCarthy, M., 2005, Rose de Freycinet and the French Exploration corvette *L'Uranie*, (1820): A highlight of the 'French Connection' with the 'Great Southland'. *The International Journal of Nautical Archaeology* **34.1**: 62–78.
- McCarthy, M., 2009, The 'J Boat' Study. In: M. McCarthy, K. Hosty and C. Philippou (eds.), *Iron, steel and steamship archaeology. Papers from the 2nd Australian Seminar held in Perth, Melbourne and Sydney 2006*. Australian National Centre of Excellence for Maritime Archaeology, Special Publication Number 13. The Australasian Institute for Maritime Archaeology Special Publication Number 15. Australian National Centre of Excellence for Maritime Archaeology, Fremantle: 143–146.
- McCarthy, M., 2009, The latest find! With Delgado, Johnson, Murphy *et al.* on *SubMarine Explorer* in Panama. In: M. McCarthy, K. Hosty and C. Philippou (eds.), *Iron, steel and steamship archaeology. Papers from the 2nd Australian seminar held in Perth, Melbourne and Sydney 2006*. Australian National Centre of Excellence for Maritime Archaeology, Special Publication Number 13. The Australasian Institute for Maritime Archaeology Special Publication Number 15. Australian National Centre of Excellence for Maritime Archaeology, Fremantle: 147–151.
- McCarthy, M., 2009b, Towards an understanding the importance of the HMAS *Sydney* and HSK *Kormoran* sites Part 1: the genesis and evolution of the controversies. *Bulletin of the Australasian Institute for Maritime Archaeology* **33**: 72–77.
- McCarthy, M. (ed.), 2010, HMAS *Sydney (II)*. Western Australian Museum Press, Welshpool.
- McCarthy, M., 2011, Submarine Chaser SC-751, 1943. In: J. Green (ed.), *Shipwrecks of the Ningaloo Reef: maritime archaeological projects from 1978–2009*. Special Publication No. 15. Australian National Centre of Excellence in Maritime Archaeology, Fremantle: 255–9.
- McCarthy, M., 2011, Archaeology and the HMAS *Sydney*. *Bulletin of the Australasian Institute for Maritime Archaeology* **35**: 18–27.
- McCarthy, M., 2013, SS *Xantho* Project: nearing completion. *International Journal of Nautical Archaeology* **43.1**: 196–7.
- McCarthy, M., 2015, 300 years on: the search for William Dampier and his elusive ship. In M. McCarthy (ed.), *The Great Circle*, **37.1**:1–15. Australian Association for Maritime History, Fremantle.
- McDonald, G., 2005, *Seeking the Sydney: a quest for truth*. University of Western Australia Press, Perth.
- Mearns, D., 2009, *The search for the Sydney; how Australia's greatest maritime mystery was solved*. Harper Collins, Sydney.
- Miles J., *in prep.* Report A72-80 Vansittart. Unpublished Report, Department of Maritime Archaeology, WA Museum, Fremantle.
- Miles J., Report Liberator bomber A 19-163 I. Unpublished Report. Department of Maritime Archaeology, WA Museum, Fremantle.
- Monfils, R., Gilbert, T. and Nawadra, S., 2006, Sunken WWII shipwrecks of the Pacific and East Asia: the need for regional collaboration to address the potential marine pollution threat. *Ocean and Coastal Management* **49**: 779–788. Viewed 15 August 2015, <<http://www.sciencedirect.com/science/article/pii/S0964569106000901>>.
- O'Brien, T.N. and Harewood, P.G., 2002, The Belvedere lifeboat wreck: originally from the German Raider *Kormoran*. Report—Department of Maritime Archaeology, Western Australian Maritime Museum, No. 217.
- Olson, W., 1995, HMAS *Sydney* (1934–1941) possible and probable cause of her loss. Report—Department of Maritime Archaeology, Western Australian Maritime Museum, No. 104.
- Olson, W., 1996, With all hands, a study of the circumstances surrounding the loss of the 645 officer and men aboard HMAS *Sydney* in November 1941. Report—Department of Maritime Archaeology, Western Australian Maritime Museum, No. 116.
- Olson W., 2000, *Bitter victory: the death of HMAS Sydney*, 2nd ed. University of Western Australia Press, Perth.
- Olson, W., 2016. *HMAS Sydney (II): in peace and war*. Wesley John Olson, Hilton.
- Prime, M.W. 1985, *WA's Pearl Harbour. The Japanese raid on Broome*. Western Australian Museum reprint.
- Royal Australian Navy, Sea Power Centre, 2001, *HMAS Sydney II. Proceedings of the wreck location seminar, 16 November 2001*. Department of Defence, Canberra.
- Shefi, D., *forthcoming*, *Portable but meaningful—the archaeology of the refugee. An examination of the artefact assemblage associated with the 1942 air raid in Broome, Western Australia*.
- Sledge, S., 1979, Wreck inspection North Coast (WINC). Report—Department of Maritime Archaeology, Western Australian Maritime Museum, no. 11.
- Smith, T. and McCarthy, M., 2009, AE2 silent ANZAC; Australia's lost Gallipoli submarine. In: M. McCarthy, K. Hosty and C. Philippou (eds.), *Iron, steel and steamship archaeology. Papers from the 2nd Australian Seminar held in Perth, Melbourne and Sydney 2006*. Australian National Centre of Excellence for Maritime Archaeology, Special Publication Number 13. The Australasian Institute for Maritime Archaeology Special Publication Number 15, pp. 139–141. Australian National Centre of Excellence for Maritime Archaeology, Fremantle.
- Souter, C., 2003, Archaeology and oral history of WWII flying boat wrecks in Broome. *Bulletin of the Australian Institute for Maritime Archaeology* **27**: 115–120.
- Staniforth, M., 2009, *Australian approaches to shared heritage: Royal Navy vessels in Australian waters*. In: J. Hayward and M. Williams (eds.), *Shared Heritage: joint responsibilities in the management of British warship wrecks overseas: International Seminar*. Portsmouth, UK. English Heritage, University of Wolverhampton.
- Western Australian Museum, Broome Aircraft Artefact Database. Viewed 2016, (<<http://www.museum.wa.gov.au/maritime-archaeology/db/category/ancod-wrecks/broome-aircraft-wrecks>>).

Apology to Wayne Colin Sampey

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In M. McCarthy's 2009 article appearing in the AIMA Bulletin on the controversies surrounding the loss of HMAS *Sydney* II, reference was made to 'diver Wayne Sampey' having claimed that he dived on the wreck of HMAS *Sydney* in a 'kelp bed' not far from the top end of Dirk Hartog Island. The reference is incorrect, the diver that the article should have referred to being Colin Sampey, Mr Wayne Sampey's father.

The author apologises unreservedly to Mr Wayne Sampey for the error, which was recently brought to the author's attention.

M. McCarthy 14 March 2017.

REFINING CONSERVATION TREATMENTS FOR IRON SHIPWRECKS

Lessons learned from experiences with the
USS Monitor (1862) and the *SS Xantho* (1872)

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Introduction

This review was presented at an international seminar in Hasselt University in Belgium in 2009 which was assessing what archaeological and conservation options were applicable to the wreck of the Belgian Antarctic exploration ship *Belgica* (1897–1901). The *Belgica* was a barque-rigged sailing vessel with reinforcing iron plates on the bow and a steam engine to assist with propulsion. In the last phase of her life she was being used for storing high explosives and was scuttled in 1940 by the Allies as the German forces advanced on Norway. The engine and large parts of the drive train had been removed but the overall construction of iron knees and timber planking make it a massive composite conservation challenge. The combined experiences of the Mariners' Museum team with the USS *Monitor* (1862) and the Western Australian Museum team on the SS *Xantho* (1872) were considered to be relevant to the *Belgica* project and to other composite vessels. A comparison of the corrosion processes found on the USS *Monitor*, and the Australian colonial steamship SS *Xantho* provides a useful introduction into the complexities of conserving large items recovered from historic shipwrecks, and the potential issue of conserving complete iron shipwrecks. Under the guidance of the UNESCO charter on the management of submerged cultural resources, it is essential that appropriate preparations are made to receive the artefacts prior to any recovery of a major shipwreck or the recovery of significant objects from the site (UNESCO 2001). The *Monitor* site was the first historic shipwreck zone to be declared a protected sanctuary under the control of NOAA, the National Oceanic and Atmospheric Administration. The *Monitor* sank in a storm off Cape Hatteras as it was being towed to assist in the blockading of Fort Sumter in Charleston on New Year's Eve in 1862. Two of the crew were entombed in the turret, which separated and descended first and sank upside down, and the upturned hull descended half on top of the turret. Under the auspices of NOAA the site was carefully examined, documented and some basic *in-situ* conservation measures were adopted prior to any recovery of major materials. In order to ensure that small 'at risk' objects were not lost a number of portable and socially significant items were taken to the conservation laboratory of The Mariners' Museum in Newport News, Virginia, for treatment before the major recovery operations involving the turret, engine and condenser being removed from the site. Details of the progress on the treatments over the past decade can be found

in the conservation literature (Cook & Peterson 2005; Brossia *et al.* 2007; Rémazeilles *et al.* 2010) but the operational challenges will remain for more than 15 more years as large objects undergo final stages of treatment (Hand *et al.* 2005; Johnson *et al.* 2011). It is noted that there is a continuing battle for recognition of the long-term conservation needs of massive cast and wrought iron objects that last well beyond the tenure of many directors of museums and of their employees, as well as that of corporate sponsors.

Corrosion of iron in sea water

By examining the wrecks prior to excavation conservators have access to corrosion experiments that have been running since the metals were deposited in the sea at the time of the wreck formation process. Simulation of long-term marine corrosion phenomena in a laboratory situation is very difficult and there are many problems involved in the extrapolation of data from short-term studies (Taylor & MacLeod 1985). Because chloride ions alter the rates of electrode processes, such as metal oxidation, the standard electrode potentials (E°) of the metals in 'standard sea water' are different from those in ordinary water. Iron and, less commonly, copper and its alloys are often covered with a layer of marine growth, which effectively places the metal in an environment, which is different from normal sea water (North 1976; MacLeod 1982). Such environments tend to have a higher chloride concentration, lower pH and much lower oxygen concentration than ambient sea water since the concretions essentially act as a semi-permeable membrane, which inhibits rapid transport of some ions and gases.

When a metal is corroding, one of two processes limits the rate of the corrosion reaction: it is either the rate of the cathodic process (which is commonly reduction of dissolved oxygen or hydrogen evolution) or the rate of the anodic process (metal dissolution). For buried iron artefacts or sections of a ship lying under a layer of concretion, sand, sediment or silt alternative cathodic processes becomes dominant owing to the diminished supply of oxygen. Examples of these steps include the reduction of hydrogen ions to hydrogen gas and the reduction of sulphate to sulphide ions. This latter process is notoriously slow in aqueous solution unless it is catalysed by the presence of specific enzymes in anaerobic bacteria. For most cases involving aerobic concreted metals the rate of

oxygen supply to the corroding interface is what controls the overall corrosion rate. The voltage of a metal object in sea water will be dependent on how fast the metal is corroding and this is interdependent on the pH of solution adjacent to the corroding object. If we have a knowledge of the pH and the voltage of the corroding metal (commonly called the corrosion potential, E_{corr}) we can tell from the relevant Pourbaix diagram whether the metal is immune (cannot corrode), is passive (very slow corrosion), or if it is actively corroding. Since the literature values used in the construction of Pourbaix diagrams are based on the normal hydrogen electrode the actual voltage of the reference electrode used in collecting the E_{corr} data must be calibrated to facilitate use of these aids. Since the voltage is dependent on both the metal oxidation and cathodic reduction processes the voltage is also known as a 'mixed' potential. Such electro-chemical data are conveniently presented in a Pourbaix diagram (Pourbaix 1974).

USS Monitor turret

The USS *Monitor* (1862) was the world's first iron battle ship with a rotating gun turret which held two 11-inch (27.94 cm) Dahlgren cannon, which were muzzle loading guns firing solid iron cannon balls. Although it took ten minutes for one full rotation of the turret, the steam engines that provided this movement proved to provide a significant enhancement in the manoeuvrability of the fire power. The battle of Hampton Roads in Virginia took place on 9 March 1862 when the USS *Monitor* engaged the CSS *Virginia* in close call with barrages of cannon fire at point blank range. Each vessel took many direct hits but the overall result was a stalemate, and at the end of the day the *Virginia* receded up the Elizabeth River while the *Monitor* kept steaming up and down across the mouth of the river. Thus trapped, the Confederate captain scuttled his ship by blowing it up to prevent it falling into Union Navy hands. After a further nine months of service the *Monitor* was being towed to Charleston for the relief of Fort Sumter when a fierce storm off Cape Hatteras caused the vessel to founder on 31 December 1862. The remains of the *Monitor* became the only tangible reminder of the battle between the first ironclad warships.

Apart from the physical loss of the warship, 16 of the 56 sailors on board perished. The *Monitor* was remarkable for having been constructed in only 147 days: it was 173 ft (52.7 m) in length and

41 ft (12.5 m) wide. Its flat deck was armour-plated with 1-inch (2.54 cm) thick wrought iron, and the water-line armour consisted of five layers of 1-inch wrought iron plates bolted together. The cylindrical turret was 20 ft (6.1 m) in diameter, 9 ft (2.7 m) high, and weighed 120 tons and consisted of 8 layers of 1-inch (2.54 cm) wrought iron plate bolted together. The unique engine and turret mechanism had been designed by the Swedish engineer Ericsson. The wreck was found in August 1973, 16 miles (25.7 km) East of Cape Hatteras, and at a depth of 240 ft (73 m) upside down and overlying part of the turret which retained the ship's guns and many artefacts.

Evidence of the value of *in-situ* stabilization of the turret

A year before the turret was recovered the maritime archaeologist in charge of the *Monitor* project installed two 36 kg zinc anodes on the turret and parts of the armour belt (Broadwater 2005). The anodes lost half their weight during the one-year stabilisation program (see Fig. 1). The effectiveness of the pre-treatment could only be gauged after recovery when the object was in the laboratory at The Mariners' Museum. By drilling into areas of concretion that remained undisturbed during the recovery and first stages of conservation treatment it was possible to show that for areas which had direct access to the surrounding sea water, a 1 000 fold reduction in chloride activity took place because of the presence of the anodes. Even within the confines of the turret, with very restricted access to external sea water, there was a 23-fold reduction in surface chloride. Areas of the turret exposed with the highest chloride loss had a surface pH of 9.3 ± 0.1 that extended 40 mm into the concretion. The areas some distance from the anode had a surface pH of 8.0 up to 15 mm from the metal, which then fell to a steady 7.0 at distances greater than 25 mm. For positions such as the rear of the turret, (nut guards 15 & 16) the pH was between 6 and 6.5, which shows there had been little impact of the external anode attachment (Fig. 2).



Figure 1: View of the USS *Monitor* on the seabed at 73 m showing zinc anodes.

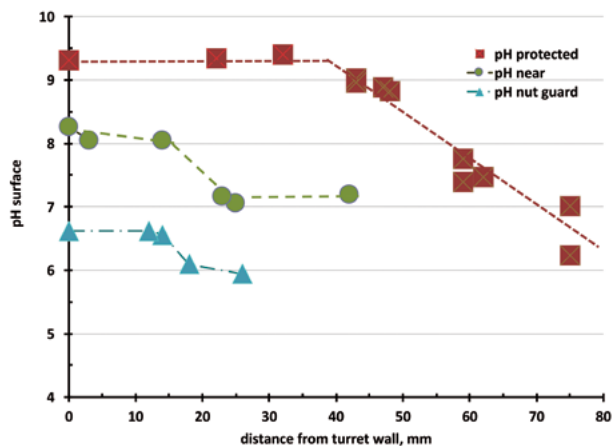


Figure 2: Effect of pre-treatment of turret with sacrificial anodes producing an alkaline fronts which are stronger for locations closest to the anodes.

After recovery the engine and condenser were stored in sodium hydroxide solutions while the turret was kept in fresh water since conservators and archaeologists were routinely working on excavation of the interior of the turret. The main problem with prolonged periods of deconcretion activity in tap water is that the reaction of the underlying iron (II) corrosion products with atmospheric oxygen results in telltale bright orange-red FeOOH corrosion products which stifle the future release of chloride ions, since the matrix is quite impermeable to treatment solutions (see Fig. 3). The additional problem is that the partly deconcreted object sets up massive differential aeration corrosion cells, which exacerbate the rate of decay. However, it must be noted that owing to the size of the object and the number of staff available for the work there is nothing that could be done to overcome this issue other than to spray the object with solutions containing non-toxic corrosion inhibitors.

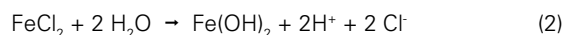


Figure 3: Internal walls of the *Monitor* turret showing the nut guards in position and the steaking patina of FeO . OH on areas cleared of concretion.

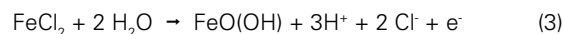
Following a successful internship at the WA Maritime Museum, Eric Schindelholz requested a detailed examination of the turret, engine and condenser and the details of the studies, using a combination of chloride, pH and E_{corr} profiles on the concreted metal matrices, have recently been reported (MacLeod *et al.* 2008). Data gained from drilling into the turret concretions and recording the pH, chloride and depth profiles gave maritime archaeologists the first proof of the direct relationship between pH and chloride ion concentration. Linear relationships exist between the pH (acidity) and the chlorinity, as shown in Equation 1,

$$\text{pH}_1 = 6.89 - 0.08[\text{Cl}] \quad (1)$$

As the chloride increased from 0 to 14 ‰ (parts per thousand) the pH fell by 1.12, which equates to an increase in acidity of 13.2 times. The acidity comes from either hydrolysis of the primary corrosion products of ferrous chloride (Equation 2), viz.



This reaction produces one proton per chloride ion, or from a combination of hydrolysis and oxidation. With oxidative hydrolysis (Equation 3) the chemical reaction produces 1½ times as much acid per chloride ion.



The slope of equation 1 is equivalent to noting that the hydrogen ion concentration increases by a factor of 1.2 times per chloride ion increase. Solving the simultaneous equations 2 and 3, shows that our *Monitor* turret slope is made up of 70% of the hydrolysis of FeCl_2 and 30% from the oxidative hydrolysis reaction.

It has not been possible to conduct such measurements *in situ* since there are no commercially available pressure-compensated chloride ion electrodes. Direct measurements obtained on the *Monitor* artefacts have enabled verification of the fundamental chemical processes controlling the ingress of chloride ions and the build-up of acidity underneath the concretion layers. Extensive *in-situ* pH data when combined with depths of graphitisation of the corroded cast iron shows that at $5 < \text{pH}$ the artefacts are extensively corroded and that appropriate treatment facilities need to be prepared to receive the same and so minimize post-excavation problems (Carpenter & MacLeod 1993). The chloride and pH profiling on the

Monitor objects began at the solution-concretion interface at measured depths into the concretion from the surface layer. Once the total depth of each profile was known the data was corrected to showing the distances from the metal surface in the plots shown in Figure 2.

The Monitor engine

Archaeological imperatives had driven the program to partly deconcrete the novel steam engine, which had been fashioned by its Swedish designer Ericksson. The exposed non-ferrous valves and steam pipes set up galvanic corrosion cells with the rest of the engine. An impressed current system was set up to stop this process but configuration difficulties meant that it was discontinued after some months since stray current was corroding the steel storage tank. Given the above complex treatment history it is not unexpected that the profiles of chloride, pH and voltage in the engine corrosion matrix were very different from the turret (Fig. 4). Plotting the chloride and concretion thickness data for the engine followed parabolic gradients, which were linearized with plotting the square of the thickness. The higher slope (Equation 4) where the chloride concentration falls from 43 parts per thousand (‰), to zero at the interface

with the treatment solution, at a distance of 32 mm (1024 mm²), reflects those parts of the engine where there was no connection to the impressed current system.

$$\text{diffusion}[\text{Cl}]_{\text{ppt}} = 42.6 - 0.04 d^2 \tag{4}$$

The initial value of 42.6 ‰ is roughly 2.3 times the background levels of the wreck site at Cape Hatteras, North Carolina, USA. This is consistent with the normal accumulation of chloride ions to balance out the Fe²⁺ ions resulting from iron corrosion on the site. The parabolic rate of reduction in chloride concentration is consistent with the normal diffusion controlled processes associated with movement of chloride away from a point source to the soaking caustic solution in the treatment tank. The second linear relationship (equation 5) has a much lower R² value (0.493) due to data scatter.

$$\text{impressed current}[\text{Cl}]_{\text{ppt}} = 8.4 - 0.0024 d^2 \tag{5}$$

This equation represents the parts of the engine that benefitted from the impressed current treatment as seen in Figure 4. The chloride concentration at the engine surface is one fifth of the untreated area while the mean chloride concentration at the solution interface was 4.8±1.8 ‰, which

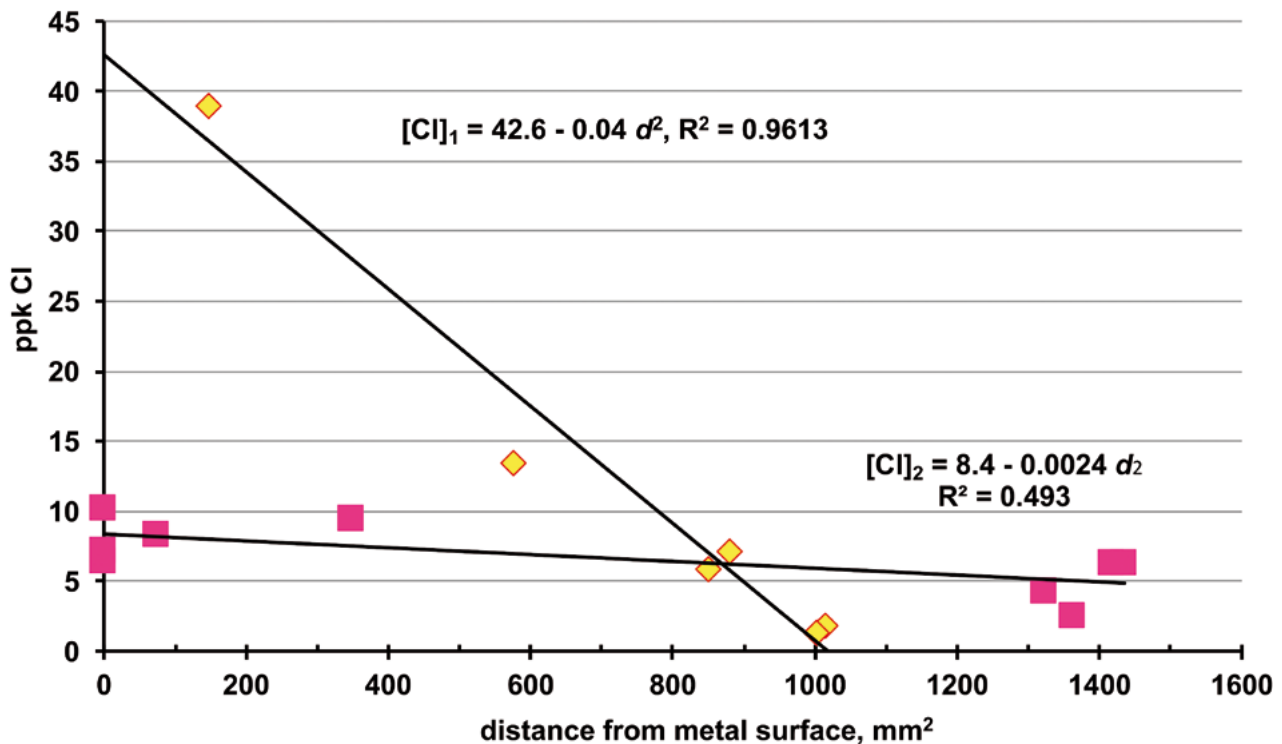
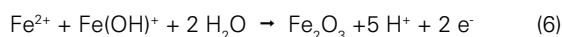


Figure 4: Two chloride concentration profiles in the USS Monitor engine concretion due to varying effectiveness of impressed current system.

will reduce with increased treatment time. The areas, which benefitted by the impressed current treatment, included the port cylinder with a chloride concentration of only 1.0 ‰ and the metal pH was 6.30, whereas the mean pH was 5.82 ± 0.11 for areas where the current did not penetrate. The E_{corr} and pH data from the cored profiles in the engine had positive slopes for the pH vs. d^2 plots which shows that the impressed current system had also been removing acidic solutions as well as pushing out the chloride ions. The archaeological implications of these observations are that even though it may be years since objects were recovered, so long as they are kept wet the concretion layers will still provide a unique insight into the microenvironment of the artefacts.

The *Monitor* steam condenser

The massive condenser of the *Monitor* was stored in sodium hydroxide solutions from the time of its recovery. It had two distinctly different types of concretion; one hard and the other soft, which reflect two corrosion microenvironments. The less permeable (hard) matrix had more acidic (pH 5.53) values for the metal interface than the 6.60 of the more permeable matrix. The more acidic pH values shows that there had been very limited penetration of the alkaline storage media to the metal surface. The slope of the pH versus distance gradient for the hard magnetite matrix was half of the soft mud-like concretion. Two hard concretion cores had E_{corr} values of -0.602 ± 0.009 V and the other soft profiles gave E_{corr} values of -0.487 ± 0.009 V that are very similar to the values for sound and corroded metal sections recorded in the pre-disturbance survey. It appears that the different types of concretion resulted in markedly different corrosion. The E_{corr} vs. pH plots for the condenser profiles gave a slope of -146 mV/pH with an R^2 of 0.9901, which is consistent with the oxidation of partly hydrolysed iron(II) ions (FeOH^+) to hematite, as shown in equation 6 (Pourbaix 1974).



Such reactions of conversion of a soluble iron corrosion product into a solid form mean that there will be significant pressure on the interface, which will make the concretion tend to disbond.

Summary of the impacts of different storage regimes on the *Monitor* components

The overall results from the various treatments on the condenser, engine and turret after more than four years from the time of the excavation are summarised in Figure 5. The most acidic areas are seen in the mean pH of the condenser, which is due to the low permeability of the mud-like concretion towards inward diffusion of the sodium hydroxide solutions. The next most acidic microenvironment was found for the engine, which had received varying degrees of protection and treatment with an impressed current system that was not fully established to ensure that there was even current distribution. The interfacial pH of the engine was within the range of variations of the value of the condenser.

The mean pH of the interior of the turret and the interior interface reflect the fact that owing to its massive size and only two attachment points being possible for the anodes, there is a big difference in the microenvironment of the turret close to and distant from the original exposed section. The most marked effect of the anodes was noted on the mean and the interfacial value for the pH, which was the most alkaline of all the measurements. This improved conservation outcome was due to the fact that these sections of the turret were directly attached to the anodes and these areas had free access to flowing surrounding seawater. Pre-treatment of iron shipwreck elements on the seabed leads to much better conservation outcomes both in the field, during transport and during deconcretion and post treatment stages of the work program.

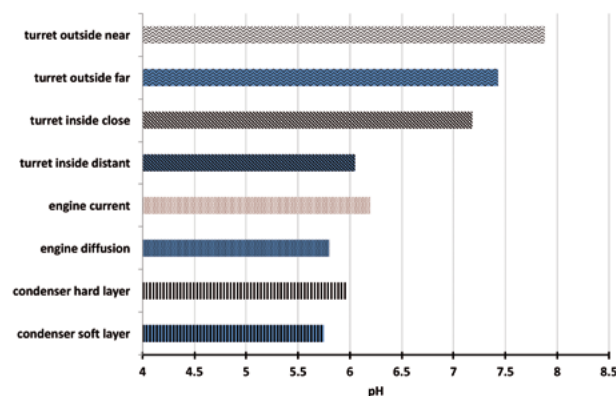


Figure 5: *Monitor* mean pH values of the average microenvironment and surface values of the components.

The *Xantho* shipwreck

Background

The SS *Xantho* (1872) was Western Australia's first coastal steamer that sank at Port Gregory, when a storm opened seams at the refitted stern and let in sea water. Unfortunately the steam pumps to remove water were located amidships and were powered by the engine, so by the time the water level reached the pumps the stern section was full of water. This wreck site was the first steamship in Australia to have a suite of electrochemical, biological and physical oceanographic measurements conducted before excavation (MacLeod *et al.* 1986). Other *in-situ* corrosion studies (MacLeod 1989; 1996) have shown that the logarithm of the corrosion rate is linearly dependent on the E_{corr} value, so small changes in corrosion potential result in a moderate change in corrosion rate. Thus simple monitoring of the corrosion potentials provides a sensitive indicator of the environment. Repeated measurements on the boiler over 30 years have shown that the constant E_{corr} of the boiler (-0.526 ± 0.003 volts vs. Ag/AgCl) means that this part of the site is stable. Addition of carbon to iron elevates the voltage of the alloy to less cathodic i.e. more anodic values. It is therefore normal to expect that corroded cast iron artefacts will have a more positive (less negative) E_{corr} than corroded wrought iron or steel, which is corroding at the same rate (MacLeod 1989).

For concreted and corroded marine iron a less negative E_{corr} value means an increased rate of corrosion as the iron alloys are corroding in a film-free environment. By way of contrast, iron with passive adherent coatings corrodes faster at lower voltages, such as in reinforced concrete.

Effects of engine removal and *in-situ* conservation of the SS *Xantho*

The marine biological assessment of the *Xantho* site showed that the corroding iron provided significant nutrients to the colonising marine organisms, compared with the nearby reef, which was dominated by eelgrass (*Zostera marina*) communities with a large fauna of carnivores feeding on the organisms that lived in the grass. The wreck site was a tunicate-dominated community with sedentary filter feeders being the major

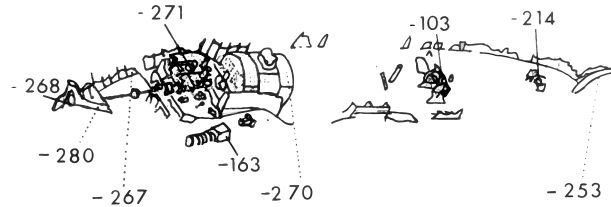


Figure 6: Site plan of the wreck of the SS *Xantho* with corrosion potential readings at Port Gregory, Western Australia.

colonizing organisms, with upright and encrusting sponges and a few encrusting bryozoa. Small algae were found in the light-rich areas (water depth 2.9–3.3 m) while large algae were abundant in water deeper than 3.3 m. The site is characterised by strong currents (knots 1.5–2.6 m/sec) flowing from the bow to the stern (MacLeod *et al.* 1986). A plan of the wreck site with the initial corrosion potentials is shown in Figure 6.

The boiler was approximately 3.2 m long, 2.8 m wide and 2.6 m high (Fig. 7), and the initial apparent complexities of the marine biology of this dominant site feature were latterly explained by the periodic and rapid changes in the level of the sea floor.

The *Xantho* site averages a seven-year turn periodic burial and exposure cycle associated with cyclonic rain-bearing depressions, which cause flooding of a nearby river and deposition of masses amounts of sediment during such extreme events.



Figure 7: View of the *Xantho* boiler on site prior to removal of the historic horizontal trunk engine.

Metal corrosion in shallow shipwreck sites

Other than being the first Australian detailed corrosion survey of an historic shipwreck the *Xantho* site also provided opportunities to analyse the gas that is frequently evolved when concentration layers are penetrated for the first time in over a century. The gas is mainly hydrogen and methane as well as other lightweight hydrocarbons, which are formed as a result of the corrosion process (North 1982; MacLeod 1988). The corrosion potential and pH showed that the *Xantho* frame plates lie on the hydrogen discharge line of the Pourbaix diagram for iron in sea water, which readily explains the presence of hydrogen gas. The iron corrosion potentials were remarkably uniform, with seventeen of the 25 areas giving a corrosion potential of -0.268 ± 0.006 volts vs. NHE (or -0.539 vs. AgCl seawater. The windlass E_{corr} was -0.103 volts vs. NHE, i.e. it was 165 mV more anodic than the average values, which indicates that it is largely a corroded matrix with little or no solid metal present. All the potentials observed for the copper and brass fittings attached to the wreck showed they were immune from corrosion while the lead on crankshaft counterbalances was in the passive zone with a 2.5 mm layer of lead sulphate (anglesite).

The *Xantho* site was also very useful for providing many examples of the thin protective concretion layer observed on all the brass and copper fittings. Because these artefacts are acting as cathodic sites for reduction of oxygen, while the engine or wreck is the anode, the surface pH becomes more alkaline than sea water and so CaCO_3 precipitates as inorganic calcium carbonate. The CaCO_3 layer acts as an oxygen diffusion barrier, allowing formation of Cu_2S through the action of sulphate reducing bacteria. The less negative potential for the copper

tubes and case on the Chapman distiller is simply due to the relatively small mass of iron attached to the copper tubing, which has a large surface area (Fig. 6).

Analysis of the corrosion data collected in the pre-disturbance survey of the *Xantho* site lead to the installation of aluminium sacrificial anodes on the engine and on the propeller shaft (MacLeod *et al.* 1986). The plan was to minimise any further damage from corrosion and to begin *in-situ* conservation treatment. During the recovery operations in 1985, which saw the 7.5-tonne concreted mass of the engine recovered from the sea-bed, corrosion potential measurements were used to gauge the impact of the excavation on the remaining parts of the stern.

Corrosion rates on cast iron objects are determined by drilling into the graphitised material, noting the penetration depth of graphitisation then by dividing this depth of corrosion by the number of years of immersion in sea water, the corrosion rate can be calculated in terms of mm/year. Data from many wreck sites (MacLeod 1989b) showed how the relationship observed on the *Xantho* site between the corrosion rate and the E_{corr} is dependent on the dissolved oxygen, which is interdependent on the temperature and the salinity of the sea water (MacLeod 1995). Based on the local salinity and temperature the slope for the connection between the log of the corrosion rate and the E_{corr} values on the *Xantho* site is 2.70 volts^{-1} , which equates to 370 mV per ten-fold change in corrosion rate. Using this relationship, the changes in the values of the E_{corr} for stern plates and the propeller shaft of the *Xantho* during cathodic protection from the anodes can be expressed in terms of the percentage reduction/increase in the corrosion rate. Inspection of the E_{corr} values in Table I show that the application of the

Condition	E_{corr}	% change in i_{corr}	Date
Pre-disturbance-propeller shaft	-0.269	initial	15/03/83
Propeller shaft with anode	-0.319	37 ↓	18/04/85
Propeller shaft, spent anode	-0.246	14 ↑	15/05/86
Propeller shaft, new anode	-0.380	100 ↓	15/05/86
Pre-disturbance-stern plate	-0.280	initial	15/03/83
Iron plates not protected	-0.232	35 ↑	24/04/85
Iron plates on the stern	-0.261	12 ↑	15/05/86
All stern sections	-0.384	91 ↓	19/02/88

Table 1. Effect of site disturbance and conservation measures on the stern of the SS *Xantho* (1872).



Figure 8: The stern of the SS *Xantho* following installation of anodes and removal of the engine.

anodes to the propeller shaft was sufficient to bring about a 37% reduction in the corrosion rate of the drive train (MacLeod 1998). Because the propeller shaft is electrically connected to large parts of the remaining structure of the wreck it is not surprising that the voltage drop was much less than would be expected if the shaft was an isolated element. Visual inspection of the site confirmed that the stern was in a more stable condition following the removal of the engine and the application of the sacrificial anodes to that section of the vessel (Fig. 8).

Because this anode remained attached during the engine recovery process, we cannot ascertain the impact of the excavation on this part of the wreck, except to note that at the end of the anode life in May of 1986, the corrosion rate had increased by 14% above the pre-disturbance level. The attachment of new anodes in 1986 saw the initial corrosion rate cut in half—the schematic for the anode attachments to the rear of the *Xantho* is shown in Figure 9 to assist maritime archaeologists in determining how to set up such systems on other wreck sites.

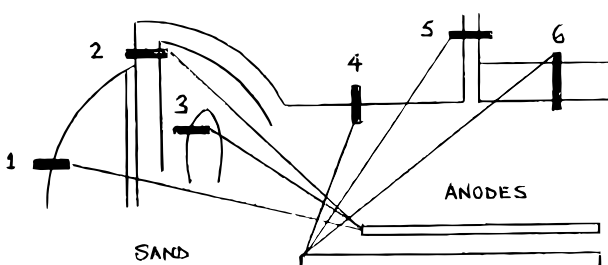


Figure 9: Schematic showing anode arrangements on the stern of the *Xantho*.

Corrosion potential measurements established that the decay rate of the stern fell by 12% after a year of increased sand coverage following the removal of the engine. The beneficial effects of the anodes on the stern were demonstrated in 1997 when measurements showed that the stern corrosion rate had fallen by 91%. Although current archaeological practice precludes the original plan to recover the stern section for exhibition purposes, the regular replacement of the sacrificial anodes will ensure that the metal is actively conserved on the sea-bed and that it is available for future exhibitions in another museum.

Xantho engine post excavation corrosion processes

In the final analysis the success of a maritime archaeological excavation is best gauged by artefacts being on exhibition and available to the public, and in a stable condition. Corrosion and decay of marine iron objects can be controlled by removal of oxygen and moisture, neither of which is practical in an open exhibition gallery. The only way to protect objects is by lowering the level of chloride ions, since chloride ions accelerate the rate of decay. Preventing corrosion reactions at the interface of the graphitised and sound of metal is essential since the conversion of water-soluble corrosion products into solid minerals results in exfoliation of the corroded surface of the cast iron artefacts (MacLeod 1999). Impregnation of corroded cast iron with thermoplastic resins, which keep out moisture, is one way of ensuring that residual chlorides do not cause accelerated decay. Conservation research at the National Museum of Australia and at the Australian War Memorial has shown that a wide range of oils are effective in discharging water from the metal surface thereby lowering corrosion rates (Hallam *et al.* 2004).

If the Garcia Method had been developed before the mechanical deconcretion of most of the *Xantho* engine it would not have suffered from as much mechanical damage. Fracturing rock-hard concretion on top of fragile extensively graphitised cast iron is fraught with problems. During the flame deconcretion processes the liberal application of the water displacement marine grade CRC[®] was the most effective way of keeping water and the dissolved oxygen contained therein away from the delicate interface (Garcia 2006). This work produces voluminous amounts of smoke so the work needs to be done in the open air or with an

'elephant trunk' extraction system to protect the conservator from adverse Occupational Safety and Health risks. Research in the USA is focusing on a water dispersant based on soya beans extract, since this product has been found to have very low human toxicity and it is effective in penetrating the corroded matrix. An additional advantage is that it does not present a problem for effluent disposal and it can be applied with either a pump pack or as spray over the freshly deconcreted surface (Renner 2006).

Risk management of structural change in the *Xantho*

One of the very real issues facing conservators dealing with technological items is the possibility that the dismantling of the component elements may lead to the collapse of the integrity of the structure. The question as to whether or not one should undo bolts or remove rivets from a wrought iron structure is one that ultimately has to be guided by practicalities. As part of the decision-making process it is essential for conservators to become fully immersed in their objects and understand the physical stresses placed on all the components. Residual concretion can function as barriers between individual components. Unless the treatment solution can have free and unhindered access to the corroded matrix at the interface, it will not be possible to get effective treatment and stabilisation of the object within a reasonable timeframe. The ability of restricted spaces to trap and contain high concentrations of chloride iron was demonstrated with the *Xantho* engine when it was found there was 14 000 ppm chloride underneath a flange plate on the steam pump even after seven years of treatment in sodium hydroxide solution (MacLeod 1999). The net outcome of this observation was that the only way to preserve the steam engine was via the path of total disassembly and then re-erection following stabilisation.

There is a real dilemma between the desire to communicate the nature of the corroded and concreted object to the public and the need to remove the marine debris to achieve effective desalination and stabilisation of the metal. Most recently, this has been expertly managed in the display that opened at the Mariners' Museum in Newport News in 2014. In the main exhibition hall, which will ultimately contain the conserved turret, engine and condenser of the USS *Monitor*, the exhibition team has developed a mock-up of the

concreted turret exactly how the object looked just after its recovery. When the final exhibition opens in about ten years' time, it will be an amazing and informed experience for the public to view the before and after objects right before their eyes.

Effect of impurities and conservation treatments on corrosion and residual chloride

Practical experience of conservators who are well versed in the treatment of maritime archaeological iron objects has demonstrated that not all the chloride ions have to be removed in order to obtain stable objects. One of the problems of assessing when a treatment has reached a conclusion or a satisfactorily low concentration of salts is that this normally involves taking a drilled sample of solid metal, dissolving it and analysing the solution for chloride. By using a surface Cl⁻ ion electrode and applying a drop of a weak, inert electrolyte solution, for contact with the surface, a surface chloride activity reading can be obtained in 1–2 minutes.

Data obtained from conservation records in the Western Australian Museum laboratories provided reference to wet chemical analyses so that it was a straightforward approach to measure the surface chlorides of the treated objects. A common ratio was found for materials treated in the hydrogen furnace (North & Owens 1981) at 400°C with the drilled sample being 2.09±0.19 times higher than the surface readings for both wrought and cast iron objects.

Electrolytic treatment in 0.5M sodium hydroxide solutions produce different ratios for cast and wrought iron owing to the underlying differences in the microstructures of wrought and cast iron. Electrolysed cast iron objects have 2.52±0.11 times as much chloride in the metal as on the surface while electrolysed wrought iron metal has 1.09±0.04 times as much chloride in it as compared with the electrode reading. By using these relationships a large amount of conservation treatment time can be saved and the approach is far less intrusive. Additionally, this methodology has very real applications to surveys of collections in storage and exhibition areas to check on which objects are presently vulnerable and should be sent to conservation for treatments. Through judicious use of protective coatings it is possible to prevent corrosion in ambient conditions in the maritime

archaeological storage areas of the Western Australian Museum. The hydrogen-furnace treated cast iron objects still had internal chloride concentrations of 150 ± 75 ppm but were stable for more than five years in ambient storage conditions (with initial coatings of Rusticide® followed by a top coat of Ferroguard®).

Areas of concern and future promise

Conservators at conferences have been heard to comment that there have been no fully successful treatments of cannon by electrolysis and so the popular myth is that this class of object is very problematic and should be left on the sea-bed. The experience of the Western Australian Museum is contrary to this commonly expressed view, for Jon Carpenter has managed to conserve 18 cannon over the past 30 years and none of them have ever needed re-treatment. The key ingredient in the success of this program is allowing sufficient time to let the chlorides diffuse out of the corroded cast iron mass. Conservation of our maritime heritage is not something that can be rushed in to meet corporate deadlines. The complete treatment of a 1.5 tonne cannon from the *Batavia* (1629) took six years. When deconcreting complex iron objects such as the *Xantho* steam engine or the engine from the USS *Monitor*, conservators are mindful of the need to minimise damage to the artefact when

using percussive methods of removal of the marine encapsulation around the object. The greatest promise lies just over the horizon with the work being done on the medium temperature and high-pressure use of caustic solutions to extract chloride from cast and wrought iron objects (Drews *et al.* 2004; Mardikian *et al.* 2009). There is a real chance of a major breakthrough in the treatment times and in the treatment outcomes for the first time in two generations. Rather than whining criticism that these methods are unproven, it behoves all practitioners of conservation and their supervising maritime archaeologists to attempt this, and then observe if the new future of high temperature and moderate pressure caustic leaching will provide 'sick' artefacts the best chance of recovery.

Conclusion

It was agreed that while the project of recovering the vessel *Belgica* was a feasible option and undertaking a 15–20 year conservation program was achievable, there were good management outcomes in building a replica vessel and conserving the wreck *in situ* in Norway, and offering it as an international conservation management site for future generations of maritime archaeologists. A well-constructed replica in Belgium would provide for great public support and engagement with the overall *in-situ* conservation process being managed in the coastal waters of another nation.

References

- Brossia, C.S., Yunovich, M., Hill, D., Lawson, K.M., Denzine, R., Schmidt, J.T., Klechka, E., Schindelholz, E., Nordgren, E., Krop, D. and Baboian, R., 2007, Corrosion condition assessment, mitigation, and preservation of USS *Monitor* artifacts, *NACE Corrosion2007*, Paper, (07239).
- Carpenter, J. and MacLeod, I.D., 1993, Conservation of corroded iron cannon and the influence of degradation on treatment times. *ICOM-Committee for Conservation, Preprints 10th Triennial Conference, Washington*, Vol. II: 759–66.
- Cook, D.C. and Peterson, C.E., 2005, April. Corrosion of submerged artifacts and the conservation of the USS *Monitor*. *AIP Conference Proceedings*, 765, p. 91. IOP Institute of Physics Publishing Ltd, USA.
- Drews, M.J., de Viviés, P., González, N.G. and Mardikian, P., 2004, *A study of the analysis and removal of chloride in iron samples from the Hunley*. In: J. Ashton and D. Hallam (eds.), *Metal 2004 Proceedings of the International Conference on Metals Conservation, Canberra, October 2004*. National Museum of Australia: 247–60.
- Garcia, S.R., 2006, Dismantling and reconstructing the SS *Xantho* engine (1872). In: M. McCarthy, K. Hosty, C. Philippou (eds.), *Iron, steel and steamship archaeology. Papers from the 2nd Australian Seminar held in Perth, Melbourne and Sydney 2006*. Australian National Centre of Excellence for Maritime Archaeology, Special Publication Number 13. Australasian Institute for Maritime Archaeology Special Publication Number 15. Australian National Centre of Excellence for Maritime Archaeology, Fremantle: 105–109.
- Hallam, D.L., Thurrowgood, D., Otieno-Alego, V., Creagh, D., Viduka, A. and Heath, G., 2004, Studies of commercial protective petrochemical coatings on ferrous surfaces of historical and museum objects. In: I.D. MacLeod, J.M. Theile and C. Degriigny (eds.), *Metal 2001, Proceedings of the International Conference on Metals Conservation, Santiago, Chile, April 2001*. Western Australian Museum: 297–303.
- Hand, S.D., Mongon, W.J., Clark, J.F. and Schindelholz, E., 2005, July. Measurement of the USS *Monitor* propeller using structured light and coherent laser radar scanning technologies. *Proceedings of the CMSC 2005 Coordinate systems measurement conference. Austin (Texas, USA)*: 1–8.
- Johnson, D.L., Medlin, D.J., Murphy, L.E., Carr, J.D. and Conlin, D.L., 2011, Corrosion rate trajectories of concreted iron and steel shipwrecks and structures in seawater—the weins number. *Corrosion, the Journal of Science and Engineering* **67**.12: 125005-1.

- MacLeod, I.D., 1981, Shipwrecks and applied electrochemistry. *J. Electroanalytical and Interfacial Electrochemistry*, **118**: 291–303.
- MacLeod, I.D., 1982, Formation of marine concretions on copper and its alloys. *International Journal of Nautical Archaeology*, **11**: 267–75.
- MacLeod, I.D., 1988, Conservation of corroded concreted iron. *Proceedings of Conference 28, Australasian Corrosion Association*. Perth. Vol.1: 1–9.
- MacLeod, I.D. 1989, The electrochemistry and conservation of iron in seawater. *Chemistry in Australia* **56**: 227–229.
- MacLeod, I.D., 1989b, The application of corrosion science to the management of maritime archaeological sites. In: *Bulletin of the Australian Institute Maritime Archaeology* **13.2**: 7–16.
- MacLeod, I.D., 1995, *In-situ* corrosion studies on the Duart Point wreck. *International Journal of Nautical Archaeology* **24.1**: 53–59.
- MacLeod, I.D., 1996, *In-situ* conservation of cannon and anchors on shipwreck sites. *Conservation of Archaeological Sites and its Consequences, IIC*. Ashok Roy and Perry Smith (eds.), London: 111–115.
- MacLeod, I.D., 1998, *In-situ* corrosion studies on iron shipwrecks and cannon: the impact of water depth and archaeological activities on corrosion rates. *Metal 98 Proceedings of the ICOM – CC Metals Working Group Conference, Draguignan-Faginère, France*. Mourey, W. and Robbiola, L. (eds.), James & James, London: 116–124.
- MacLeod, I.D., 1999, Conservation of the SS *Xantho* engine: lessons learnt. *AICCM Bulletin* **24**: 10–19.
- MacLeod, I.D., North, N.A. and Beegle, C.J., 1986, The excavation, analysis and conservation of shipwreck sites *Preventative measures during excavation and site protection*. ICCROM, Rome: 113–132.
- MacLeod I.D., Cook D. and Schindelholz, E., 2008, *Corrosion and conservation of the American civil war ironclad USS Monitor (1862)*, Preprints for ICOM – CC Triennial Meeting, New Delhi, India, September 2008: 279–285.
- Mardikian, P., Drews, M., Gonzalez, N., de Vivies, P. and Hunter, J., 2009, Searching for a diamond in the rust; a review of large-scale archaeological iron conservation project, 1980-2006. In: M. McCarthy (ed.), *Second International Seminar on Iron Steamships*: 82–88. See Garcia above for full reference.
- North, N.A., 1982, Corrosion products on marine iron. In: *Studies in Conservation* **27**: 75–83.
- North, N.A., 1976, The formation of coral concretions on marine iron. *International Journal of Nautical Archaeology* **5.3**: 253–8.
- North, N.A. and Owens, M., 1981, Design and operation of a furnace for H₂ reduction of marine iron. *International Journal of Underwater Archaeology* **10.2**: 95–100.
- Pourbaix, M. 1974, *Atlas of electrochemical equilibria in aqueous solutions*, NACE, Houston, 2nd edn.
- Rémazeilles, C., Saheb, M., Neff, D., Guilminot, E., Tran, K., Bourdoiseau, J.A., Sabot, R., Jeannin, M., Matthiesen, H., Dillmann, P. and Refait, P., 2010, Microbiologically influenced corrosion of archaeological artefacts: characterisation of iron (II) sulfides by Raman spectroscopy. *Journal of Raman Spectroscopy*, **41.11**: 1425–33.
- Renner, M., 2006, Unpublished report from the workshop on the conservation options and treatments of the USS *Monitor*, 1862. The Mariners Museum, Newport News, Virginia.
- Taylor, R.J. and MacLeod, I.D., 1985, Corrosion of bronzes on shipwrecks: a comparison of corrosion rates deduced from shipwreck material and from electrochemical methods. *Corrosion* **41**: 100–4.
- UNESCO, 2001, *Convention on the Protection of Underwater Cultural Heritage*. UNESCO, Paris.

WORLD WAR II GRAVEYARD OF THE PACIFIC

Palau

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Introduction

The Pacific is well known amongst wreck diving enthusiasts, World War II (WWII) veterans and military historians for its impressive collection of wartime heritage. This paper focuses on the Republic of Palau, located within the geographical region of Micronesia. Palau was a powerful Japanese naval base during the Pacific conflict (1941–1945). Today, the region's waters contain over sixty sunken Japanese ships and its islands' jungles and caves are a treasure trove of wartime memorabilia. The focus of this paper is primarily on the small island of Peleliu, an island state of Palau and the site of one of the most brutal battles in the Pacific.

The battleground of Peleliu contains an impressive labyrinth of Japanese constructed subterranean chambers some of which serve as crypts for Japanese military personnel killed during 'Operation Stalemate II' (US National Parks Service [NPS] 2003). It is estimated that 2 000 Japanese soldiers' remains are still entombed on the island (Oceania TV News 2015; Ryall 2015). For many Japanese, the island is a necropolis and, as such, is a revered place (Knecht *et al.* 2015: 229). To the United States (US), the battleground is an historic landmark associated with the US strategy of neutralising Pacific island military strongholds (Murray 2016: 191–2). In 1985, the NPS listed the battleground in its National Register of Historic Landmarks. The battleground is also an important source of revenue for the local economy, particularly for tourist operators who depend on war tourism for their livelihoods (Knecht *et al.* 2012: 7, 515; Yamashita 2000: 440). Today, the island's historic caves are under threat from locals scavenging for small wartime trinkets like Japanese porcelain to sell to tourists and professional relic hunters searching for valuable WWII relics such as Japanese Samurai swords and Nambu type 14 pistols (Knecht *et al.* 2015: 230; Knecht *et al.* 2012: 220; Price & Knecht 2012: 14–5). The seriousness of the problem cannot be overstated. Not only do villagers searching for wartime memorabilia loot caves, but Japanese skeletal remains are often disturbed and vandalised by the robbers, including human skulls deliberately smashed for their gold teeth (Knecht *et al.* 2012: 220).

In April 2015, Emperor Akihito and Empress Michiko of Japan visited the infamous battleground to mark the 70th anniversary of the end of WWII. To commemorate the imperial visit the Governor of Palau's Peleliu state agreed to unseal 200 Japanese

occupied caves on Peleliu in order to allow Japan's government to repatriate human remains of Japanese soldiers killed during 'Operation Stalemate II' (Oceania TV News 2015). The publicity of the imperial visit and the unprecedented event of a supervised opening of Peleliu's subterranean cave systems attracted significant world attention. As a result, war tourism is likely to increase, in particular, battleground visitation. Consequently, it will become even harder for Palau's government to safe-keep its cultural wartime heritage. Therefore, it is vital that consideration be given to how best to safeguard the historic sites of Peleliu's battleground for future generations.

The NPS has been pursuing the viability of establishing a WWII-themed historic park on Peleliu in cooperation with the Peleliu War Historical Society (Price *et al.* 2013: 228). Similar historic sites have been established by the US NPS on Guam and Saipan (O'Neill & Spennemann 2002: 5). This paper examines the notion of setting up a WWII-themed park on Peleliu to protect the historic site from unsupervised tourists and unregulated development and farming practices. The establishment of a historic park would also safeguard locals and tourists from the dangers posed by unexploded ordnance (UXO) and abandoned ordnance (AXO). Today, Peleliu's dense tropical jungles, caves and territorial waters conceal a vast quantity of WWII weapons such as grenades, mines and mortars (Knecht *et al.* 2012: 10–1; Price; Knecht 2012: 15). The jungle also contains napalm canisters that were used by the US forces during 'Operation Stalemate II' (DeCioccio & Blair 2011: 182; Hammel 2012: 237; Knecht *et al.* 2012: 217). UXO are also a threat to the *in-situ* preservation of Pacific Island wartime sites (Spennemann 2006: 234).

Background

Geographical location

Micronesia is a region of the Pacific made up of over 2 000 small islands and tiny coral atolls. It is politically divided into sovereign nations including: Guam (a unincorporated territory of the US), the Commonwealth of the Northern Marianas, the Federated States of Micronesia (FSM), the Republic of the Marshall Islands, and the Republic of Palau. Geographically, Micronesia is divided into three main island chains: the Marianas (Guam, Saipan, Rota, Tinian), the Marshalls and the Carolines. The

Carolines consist of two nations: the FSM (Yap, Chuuk [Truk], Pohnpei and Kosrae) and the Republic of Palau (Petersen 1998: 180; Leonard 2001: 18). The Caroline Islands are usually divided into eastern (Chuuk, Kosrae, Pohnpei) and western (Yap and Palau) (Fitzpatrick 2007: 916) (Fig. 1).

The Republic of Palau is an island chain stretching approximately 160 km long and in a generally north to south-west direction (Richard 1957: 151). It consists of approximately 350 volcanic and coralline islands (Lal & Fortune 2000: 598; Liston & Reith 2010: 401; Pregill & Steadman 2000: 138). The archipelago’s main islands include Babeldaob, Koror, Ngerkebesang, Ngerukdabel, Mecherchar, Peleliu, Anguar and Ngeruangl. The central and southern waters of the island chain contain the World Heritage listed Rock Islands (UNESCO World Heritage Centre, Republic of Palau Nomination for Inscription 2012). These tiny mushroom-shaped limestone islands are the most prolific type of land mass in the region, extending 30 km in length

between the southern island of Peleliu and its northern neighbour, Koror (Fitzpatrick 2007: 916; Pregill & Steadman 2000: 138).

The population of the Republic of Palau is approximately 20 000 (Veenendaal 2015: 171). The most populous island is Koror with a population of 13 000 inhabitants (Veenendaal 2015: 170). The capital Ngerulmud is located in Melekeok state on the nearby island of Babeldaob (Veenendaal 2015: 171).

The Republic of Palau is politically divided into sixteen states, each with its respective constitution, elected governor and legislature (Graham & Idechong 1998: 154; Youngblood-Coleman 2015: 45–8). On 1 October 1994 the small island community became an independent nation.



Figure 1. Map of Micronesia showing cluster of sovereign States (courtesy of Bill Jeffery).

Colonialism: history of Palau up to WWII

The islands were first visited by Europeans in the 18th century (McGrath 2010: 35–6). In 1783, an English explorer, Captain Henry Wilson, and his crew aboard the East India Company ship *Antelope* became the first westerners to visit Palau (Clark & de Biran 2010: 346; Nero 1990: 121; Youngblood-Coleman 2015: 7). During this period, Palau was politically part of the Caroline Islands and under Spanish dominion (Barnett 1960: 2). In fact, Pope Leo XIII upheld Spain's claim to the Caroline Islands, including Palau, in 1885 (Clyde 1935: 17–8; Hezel 1995: 3; Peterson 1998: 181). However, by 1881, Spanish colonial presence was limited to infrequent visits by passing Spanish ships and Spanish missionaries (Nero 1990: 121). In 1899, following the Spanish American war, Spain sold the Carolines and the Northern Marianas to Germany (Youngblood-Coleman 2015: 7). In 1914, Japanese forces invaded the Caroline Islands, ending German occupation of Micronesia.

In 1920, the League of Nations recognised the capture and mandated the former German Micronesian territories to Japan (Garrand & Strobridge 1971: 55). Under Japanese administration, the island of Koror, in the western Carolines, served as the region's administrative headquarters (Clyde 1935: 10, 67; O'Neill & Spennemann 2001: 46; Rottman 2004: 9). By the early 1930s, Japanese colonists far outnumbered the Indigenous islanders (Moran & Rottman 2002: 10). Japan withdrew from the League of Nations in 1935 and made Palau a closed military zone in 1938 (Higuchi 1986: 146; Moran & Rottman 2002: 10; Pomeroy 1951: 107; Youngblood-Coleman 2015: 7).

Between 1938 and 1942, Japan embarked on a military campaign of fortifying Palau's major commercial islands like Koror, including constructing naval docks, ship repair yards, airstrips and a submarine base (Zeiler 2004: 106). In the lead-up to the Pacific conflict, Japan introduced large quantities of war weaponry and new technologies like radar. It also undertook limited military installation work on smaller and more remote islands like Peleliu and Anguar. In 1939, the Japanese Fourth Fleet was sent to Palau to defend the Japanese naval and submarine bases and airfields that were being built on Babeldaob, Koror and Peleliu (Moran & Rottman 2002: 10). The presence of the Japanese navy ensured that supply lines and shipping lanes between Palau and the Japanese

mainland remained operational and thereby aided the ongoing Japanese importation of weaponry, building equipment and labour into the region. The arrival of the Japanese fleet transformed Palau from a Japanese commercial outpost into a Pacific island naval stronghold.

Palau—the Gibraltar of the Western Caroline Islands

Palau's natural environment lent itself towards defensive fortifications against amphibious army and marine incursion. The Palauan islands and tiny atolls are located in a large semi-enclosed lagoon (Carrell 1991a: 44). The reef's perimeter is broken in only five locations meaning that these narrow channels through the coral shoals can be easily mined (Clyde 1935: 214). The lagoon's still waters and deep harbour offered excellent anchorage for the Japanese fleet. Additionally, there are numerous concealed places for ships inside the lagoon due to the islands' many inlets and tiny bays. The lagoon also contains hundreds of little limestone rock islands that make for excellent lookouts and bunkers. The volcanic islands of the Palauan archipelago like Babeldaob, Koror and Peleliu are mountainous, with high cliffs and ridges, perfect for gun placements.

When war broke out between the Allies and Japan on 8 December 1941, following Japan's dramatic attack on Pearl Harbour, Palau's capital, Koror, had been transformed into a major Japanese naval base (Poyer *et al.* 2001: 46). Between 1941 and 1942 Koror took on the role of supply base and training ground for Japanese military personnel (Gailey 1983: 7). The Palauan islands also served as the 'jumping-off' point for Japan's attack on the Philippines (Garrand & Strobridge 1971: 67). However, intensive militarisation of Palau's islands did not occur until 1943, that is, after Japan's defeat in the Guadalcanal campaign (Poyer *et al.* 2001: 46, 91). The Japanese military failure to retake Henderson Field situated on the Guadalcanal Island in the Solomon Islands forced Japan to go on the defensive. Accordingly, in early 1944, the Japanese High Command decided that Palau would become part of the Japanese National Defence (otherwise known as the inner defensive perimeter). This decision meant that the region had to be heavily fortified in order to prevent the islands falling under US control (Bailey 1991: 41; Hoyt 1986: 343; Moran & Rottman 2002: 9). Increased soldiers, construction workers and military supplies, including weaponry

and aircraft, were diverted to Palau. Importantly, it was during this period that the small island of Peleliu became the site of an extensive Japanese underground fortification system. By mid 1944, the Japanese had transformed the western Caroline's Peleliu into an island fortress (Hough 1947: 294; United States Strategic Bombing Survey [USSBS] 1947: 30).

The fortification of Peleliu

The island of Peleliu is located at the southern tip of the Palauan archipelago, approximately 55 km from Koror. The island from north to south is approximately 9.5 km long and 3 km wide (Garrand & Strobridge 1971: 57). Peleliu contains a number of natural defences, including a fringing reef and a huge mountain range that stretches from one end of the island to the other, effectively partitioning the island. Umurbrogol (Omleblochel) Mountain and its underground caves provided a natural terrain favourable to the Japanese defenders (Garrand & Strobridge 1971: 75; Leibowitz 1996: 20). The island's physical features meant that any attempt by the US to take the island and its airfield would be a slow and costly campaign (Knecht *et al.* 2012: 14).

Peleliu's airstrip's construction began under the direction of the Imperial Japanese Navy in 1938 and was operational by 1940 (Gailey 1983: 17). It required the evacuation of two Indigenous villages (Poyer *et al.* 2001: 46). The airfield was primarily constructed from 'crushed coral and had one runway over 1 000 yards [914 m] long and one shorter fighter strip intersecting the main runway at 90 degrees' (Camp 2008: 6; Gailey 1983: 43). The importance of Peleliu's airfield was that it had the technological and physical infrastructure to serve as a runway for heavy long-range bomber planes and smaller fighter aircraft (Garrand & Strobridge 1971: 58; Hough 1950).

In early 1944 a vast labyrinth of underground caves, numbering no less than 500, were constructed to protect Peleliu's airfield. Within the underground-like city, were placed some 10 500 soldiers, including some of Japan's most battle-hardened fighters (Price & Knecht 2012: 7; Zeiler 2004: 101). It is the vastness of the island's underground fortification system that distinguishes Peleliu from Palau's other islands' fortification works. The Japanese military dug strategically positioned underground chambers in order to defend Peleliu from the anticipated US marine invasion and Allied aerial bombardment.

Most caves were designed with multiple entrances and interconnecting tunnels (Bailey 1991: 93; Millet 1991: 420), while cave sizes varied from one man crevices to complexes capable of accommodating a battalion of 1 000 men (Camp 2008: 8; Price & Knecht 2012: 40). Under Umurbrogol Mountain, for instance, Japanese engineers constructed an eleven-cave complex that could accommodate 1 000 men, supplies and hospital facilities (Price & Knecht 2012: 8, 40).

By mid-1944, the Japanese had constructed a maze of underground passages that connected the island's numerous natural, human-improved and artificial caves (Bailey 1991: 32; Hough 1947: 302, 308; Phelan 1945: 2). The caves served as air-raid shelters, barracks, hospitals, storage areas, observation points and artillery gun emplacement sites (Phelan 1945: 14–8, 20–1, 23–5, 28, 33, 38). The interconnected subterranean tunnels had the strategic advantage of allowing troop deployment and movement between caves, while heavy weapons and artillery guns could be moved from one position to another free from the threat of US sniper fire (Hough 1947: 308; Phelan 1945: 25–6). To aid the movement of the large artillery guns, the Japanese installed railway tracks in many of the caves. Numerous caves also contained telephones, radios, lighting and ventilation (Hough 1947: 308; Phelan 1945: 36; Zeiler 2004: 101).

Fortification of Peleliu was aided by the island's natural rugged and rocky terrain, especially its vertical cliffs and precipitous slopes pockmarked with natural caves and littered with boulders and stony outcrops (Camp 2008: 8–9). These sites provided excellent platforms for observation points across the lagoon and for carefully positioned machine guns pre-sighted to cover the beaches below. The Japanese utilised the island's natural assets to their fullest, while also relying on conventional military hardware like tanks, aircraft and machine guns, and traditional building materials such as cement, steel and wood. They placed landmines and tripwires under the dense jungle terrain, especially near entrances to caves and along beaches and around the coastline (Giaffao 2013: 128). Long-range artillery guns were positioned inside caves or placed high on cliff tops in order to fend off naval attack. Most defensive structures were concentrated in and around the airbase. The construction of gun emplacements, ammunition dumps, communication centres and command centres involved the Japanese pouring tons of concrete into various defensive installation projects while large fuel tanks were placed underground. Consequently, the airbase

became the most fortified area, while the northern part of the island was mined. Anti-tank ditches and log barriers were another popular defensive strategy (Garrand & Strobridge 1971: 73). Many of the perimeter defence emplacements around the island were covered by barbed wire. The island's mangrove swamps, populated with saltwater crocodiles, served as a natural bulwark against incursion from the south-east (Price & Knecht 2012: 8; Knecht *et al.* 2012: 14). Human-made obstacles like steel stakes and tetrahedrons were placed in the shallow waters around the coastline to protect the main approaches to the island (Camp 2008: 26; Knecht *et al.* 2012: 14). As an extra precaution, the Japanese deployed depth charges in the island's territorial waters (Camp 2008: 28).

The Battle of Palau

'Operation Desecrate I'

The battle for Palau opened with a destructive US aerial bombardment codenamed 'Desecrate I'. As WWII wreck diver and author Klaus Lindemann states, "Operation Desecrate literally meant the desecration or destruction of a major Japanese naval base" (Lindemann 1988: v). The surprise aerial attack on Palau was designed to destroy naval ships and air forces (USSBS 1946: 207). On the mornings of 30 and 31 March 1944, the inhabitants of the small Micronesian Islands located in the Palauan archipelago awoke to an intensive Allied aerial bombardment. The attack lasted two days and involved fighter planes taking off from American aircraft carriers situated off the Palauan coast. Priority targets for the US carrier raid included Japanese aircraft stationed on runways at Airai Airfield, float planes at anchorage in the lagoon and shipping in Malakal Harbour (Lindemann 1988: v; Rechebei *et al.* 1997: 187). Secondary targets were aircraft installations and fleet serving facilities (Lindemann 1988: 156). At the end of the US bombardment, the region's physical landscape was dramatically transformed from lush tropical jungle and vegetation to one of burnt and barren surfaces. Domestic crops and livestock were destroyed and military structures were bombed beyond recognition. The commercial hub, Koror, became a ghost town; the locals forced to take refuge on nearby 'rock islands', while the Japanese military was left with no choice but to abandon Koror for Aimiliik located on the island of Babeldaob (Hezel 1995: 235). Although 'Operation Desecrate I' was devastating for military facilities, aircraft and ship losses, it would take a second assault, using US

marines supported by naval bombardment, before the Japanese base was fully taken out of the war.

'Operation Stalemate II' (Battle of Peleliu)

Peleliu's airstrip was the major reason the US navy and marine planners in 1944 wanted the island (DeCioccio & Blair 2011: 11, 121; Gailey 1983: IX; Hough 1947: 297). As the airbase was within range of the Philippines, it was deemed by US High Command to be a strategic asset (Y'Blood 1991: 183). A surviving diary belonging to a captured Japanese recruit on Peleliu potently illustrates the importance of the airfield in the minds of the Japanese defenders, including the high morale of the Japanese soldiers. He wrote:

Now when I think what my comrades in other parts of the Pacific Ocean must be going through, I cannot help feeling that fate is closing in on us who are in the Palau sector. But we will defend Peleliu! We are imbued with the firm conviction that even though we may die, we will never let the airfield fall into enemy hands. Our morale is sky high (Gailey 1983: 50).

The battle for Peleliu was one of the bloodiest battles of the Pacific War. US marines and US intelligence were unaware that the Japanese had turned Peleliu into a sophisticated underground fortress armed with maximum military strength and fire power (Camp 2008: 8; Moran & Rottman 2002: 12–3; Richard 1957: 155). The battle was fought between 15 September and 25 November 1944 (Nero 1990: 126). On the first day, nearly 18 000 men of the 1st US Marine Division launched the amphibious assault on Peleliu (Price & Knecht 2012: 9).

The entrenched Japanese belief in their mission to defend Peleliu, combined with the island's natural and man-made defences, resulted in the battle of Peleliu becoming one of the most furious and inhumane Pacific campaigns (Leonard 2001: 92; McGrath 2010; Moran & Rottman 2002; Thompson 2002). The battle for Peleliu's small airfield resulted in 1864 US military personnel killed and 6 459 wounded (Richard 1957: 160). In comparison over 12 500 Japanese soldiers were killed defending the island (Leonard 2001: 88). The prolonged war of attrition also resulted from the fact that both warring parties deemed Peleliu a strategic military asset that had to be secured at all cost. The scorched battleground, burnt cave walls and

charred Japanese skeletal remains, along with the extensive loss of life on both sides, shows just how far Japan and the US were prepared to go to secure an airfield.

The Palauan archipelago's World War II cultural heritage

Palau Lagoon's WWII underwater cultural heritage

Palau Lagoon's underwater cultural heritage (UCH) showcases the aftermaths of 'Operation Desecrate I' and 'Operation Stalemate II'. Palau is rich in WWII UCH (Carrell 1991b: 279; Lindemann 1988: 291). Most WWII wrecks are located in the Rock Island southern lagoon and the states of Peleliu and Angaur (Bailey 1991; Carrell *et al.* 1991: 399). As Palau was a Japanese naval base, the majority of sunken vessels and aircraft belong to the Imperial Japanese Navy (Fig. 2).

There are a number of sources available summarising the Japanese shipping and aircraft losses from 'Operation Desecrate I'. The US Strategic Bombing Survey (USSBS) (1946: 207), titled *The Campaigns of the Pacific—Carrier Attack on Western Carolines*, 30 March–1 April 1944 states that 'confirmed losses included two old destroyers and four escort vessels, and 20 naval auxiliary and merchant vessels grossing 140 000 tons; of the latter, six were tankers, totalling 47 000. Japanese aircraft losses included 150, in comparison to the US 25'. The USSBS (1947: 30) titled *Air Campaigns in the Pacific* records that 'in the two day attack at Palau, carrier aircraft sank virtually all of the shipping'.

Newspaper articles of the day also tell of the significant loss of Japanese shipping in Palau lagoon. In Australia, *The Argus* in Melbourne reported that 'Operation Desecrate I' resulted in the sinking of 'two Japanese destroyers, one unknown identified warship, two large cargo vessels, six medium cargo vessels, eight small cargo vessels, five other vessels, and one patrol boat' (*The Argus* 1944: 3). The US raid also left a destroyer damaged,



Figure 2. Jake (Japanese Seaplane) (Photo: Graeme Henderson, 2013).

while beaching 'a large repair ship, three oilers, and twelve cargo ships' (*The Argus* 1944: 3). Aircraft losses included '93 aircraft shot down and a further 39 destroyed on the ground or water' (*The Argus* 1944: 3). In comparison, US losses amounted to 25 planes and 18 pilots (*The Argus* 1944: 3; *The Mail* 1944: 1).

Today, it is possible to dive on a number of these WWII wrecks scattered throughout the Rock Islands. The sunken vessels are a popular destination for wreck diving (Ayres 2006: 575; Bailey 1991; Lindemann 1988: 291). A number of the Japanese vessels, such as the sunken oil tanker, the *Iro Maru*, still have structural integrity (Ishimura 2011). Built in the 1920s, *Iro Maru* is 470 feet [143 m] long and armed with large deck guns mounted on the stern and foredeck (Carrell *et al.* 1991: 424). The vessel sits upright on the lagoon's floor making it an imposing wreck to dive (Carrell *et al.* 1991: 426). The bridge is intact, although all fittings and instruments have been salvaged (Carrell *et al.* 1991: 426). Another popular diving wreck is *Chuyo Maru*. This vessel is structurally intact, while also containing a large quantity of its crew's artefacts (Bailey 1991: 131). Dan Bailey (1991: 131) states, 'remains of tables, chairs, and probably bunks can be found in the deep sediment along with a stack of records. A number of cups with the logo of the ship's owner, Toyo Kisen Kaisha, have also been found here along with bowls, ashtrays, a crystal soy sauce bottle'. The wreck is heavily overgrown with coral, providing a safe refuge for hundreds of tropical reef fish. Another vessel, the merchant ship *Ryuko Maru*, provides an opportunity for divers to explore a substantially intact ship, although its navigational instruments have been removed (Carrell *et al.* 1991: 420). In comparison, the transport vessel, T.1, is split into three sections on the sea floor. Despite the significant structural damage inflicted on the wreck from the prolonged US aerial shelling, the vessel's guns are still intact (Carrell *et al.* 1991: 414).

The waters around Peleliu are rich in WWII UCH. They contain four Allied ships sunk during the US amphibious marine invasion of the island (Carrell *et al.* 1991: 402). The sea floor also contains numerous bomb craters still visible to divers (Lindemann 1988: 10). Embedded within the island's fringing coral reef are numerous bullets and other pieces of scrap metal. The island's non-marine waters, like its swamps and sink-holes also contain numerous WWII relics, especially bullets.

Peleliu

The island of Peleliu is one of the best preserved WWII battlefields in the Pacific (Knecht *et al.* 2012: 4; Price *et al.* 2013). The physical remains of 'Operation Stalemate II', such as the ships, planes and tanks are still visible above ground and beneath the lagoon's tropical waters. The dense jungle canopy and vegetation hide the ageing hulks of amphibious tracked landing vehicles (LVTs), jeeps, trucks, bulldozers and aircraft. Large concrete bunkers, storage tanks and communication complexes dot the island's tropical landscape as they did some 72 years ago. Rusting bullets, shells, napalm containers and shrapnel litter the island's surface, while discarded coils of barbed wire testify to the Japanese and US efforts to partition Peleliu into defensive zones. Other discarded wartime remnants include hand grenades, large aerial bombs, mortars and mines (Francis & Alama 2011: 47). Peleliu's caves also contain a wealth of WWII reminders, including human remains of Japanese personnel killed during 'Operation Stalemate II' (Price & Knecht 2012: 20). It is estimated that some 2 000 Japanese soldiers' remains are still entombed on Peleliu (Oceania TV News 2015; Ryall 2015). The sheer quantity of human remains found on Peleliu makes the island an important wartime memorial site. As previously stated, in April 2015, Japan's Emperor Akihito and Empress Michiko visited the battleground in honour of the island's war-dead (Oceania TV News 2015). The imperial couple's visit renewed talks between Palau and Japan regarding the unsealing of 200 caves in order for Japan to repatriate its war-dead (Sydney Morning Herald 2015).

Site surveys and archaeological investigations

WWII UCH

Klaus Lindemann, an enthusiastic diver, is credited with rediscovering and documenting many of the lagoon's lost Japanese wrecks (Ishimura 2011). Lindemann's (1988) comprehensive work titled *Desecrate 1: operation against Palau by carrier task force 58 and the shipwrecks of World War II* contains descriptions of various Japanese vessels, along with maps and charts listing their location in the lagoon. Dan Bailey (1991) also provides an authoritative account of the individual shipwrecks and lost aircraft sites, including weaponry and machinery located within the hulls of the sunken

Japanese vessels. Bailey's text provides a wealth of site surveys and detailed maps, together with archival photographs of the two American carrier aircraft raids on Palau. Additionally, ever-growing numbers of WWII archival documents have been declassified and include intelligence data, field reports, photographs and maps produced throughout the Pacific conflict. There are also archival photographs of the strafing of Peleliu's airfield and the bombardment of Malakal (Palau) harbour, along with other archival reconnaissance photographs of the Palauan archipelago held by the Bishop Museum in its geography and map collections. Popular diving magazines and websites provide colourful photographs of the region's sunken vessels.

In 1988, Toni Carrell (1991), an underwater archaeologist with the NPS Submerged Cultural Resources Unit (now Submerged Resource Center), undertook fieldwork in Micronesia in association with US Navy divers. The report titled *Micronesia: submerged cultural resources assessment* provides a survey of Micronesia's unique underwater cultural resources, including its WWII wrecks. The Micronesian study focuses on UCH located in the territorial waters of the Marshall Islands, Guam, Kosrae, Rota, the Republic of Palau and Chuuk. In respect to Palau's UCH, the report assesses the structural integrity of various wrecks, while also providing suggestions on their long-term management. The need for a detailed inventory of Palau's existing WWII underwater sites was recommended, including a greater investigation of Malakal's harbour. A remote sensing survey of the harbour's main channels is suggested in order to locate additional wrecks. It is further recommended that these activities should be led by an underwater archaeologist acquainted with WWII vessels (Carrell 1991c: 551).

Peleliu

Peleliu has been the focus of two extensive archaeological surveys and assessments. In 1981, archaeologist Duane Colt Denfeld undertook an extensive one-month archaeological survey for the Trust Territory of the Pacific Islands (Denfeld 1988). Denfeld's archaeological survey of Peleliu lists 46 sites and includes illustrations and photographs of military hardware and infrastructure. The report was utilised by the NPS during its preparation of a draft report for the establishment of a WWII-themed historic park on Peleliu (US NPS 1991). In his study, Denfeld discusses the Japanese cave construction strategy and assesses various physical

remnants found within the survey sites. Denfeld also outlines the US wartime tactics developed to overcome the island's natural terrain and man-made defences, including the common practice of dynamiting cave entrances in order to entomb the Japanese occupants.

In December 2010, archaeologists Rick Knecht, Neil Price and Gavin Lindsay from the University of Aberdeen in cooperation with the Peleliu War Historical Society undertook a nine-day archaeological survey of Peleliu's WWII cultural resources (Knecht *et al.* 2012; Price & Knecht 2012: 33). The battleground survey documented 285 WWII sites, including 118 individual caves and tunnel systems (Price & Knecht 2012: 33; Knecht *et al.* 2012: 3). The photographs detailing each site's physical integrity are contained in the research team's report titled: *WW II battlefield survey of Peleliu Island* (Knecht *et al.* 2012). The inventories of each cave's contents, plus the condition reports on the island's tanks, aircraft and buildings, can be compared to Denfeld's 1988 survey of the battleground. Although the researchers acknowledge the significance of Peleliu's UCH, the 2010 survey did not extend underwater (Price & Knecht 2012: 17).

Threats to Palau's War World II sites

Palau's WWII wrecks

The rise in contemporary tourism is a significant factor contributing to site disturbance above ground and in the lagoon's waters. Palau's sixty sunken wrecks are at risk not only from recreational divers, but also are under threat from treasure hunters searching for fabled Japanese wartime treasure troves. During WWII Japan's military looted banks, palaces, private residences, galleries and museums of numerous conquered nations (Lee 2004: 247). The large-scale removal of private and public property by the Japanese military created a belief, often still held by many contemporary treasure hunters, that sunken Japanese wrecks contain stolen treasure. A Palauan legend holds that during 'Operation Desecrate I' a Japanese hospital ship was sunk in Malakal harbour with a precious cargo of gold, gems and other valuables stolen from the conquered governments of Singapore, Malaya, Korea, Thailand and Burma (Bailey 1991: 213). The perception that Japanese sunken wrecks are a source of lost WWII treasure has not helped in the protection of these vessels and has undoubtedly

contributed to ongoing site management issues surrounding vandalism of WWII wrecks. In addition, the threat to sunken WWII Japanese wrecks has increased in recent years through the availability of declassified military documents which perpetuates the belief that beside their military hardware, Japanese vessels, in particular, submarines, carried gold and other valuable cargo destined for Germany to assist with Hitler's war efforts (McCurry 2005). Apart from professional treasure hunters, the region's wartime UCH is at risk from divers seeking wartime memorabilia and rearranging artefacts for opportunistic photography.

Peleliu

(i) Construction and farming

Peleliu is today untouched by large scale farming activities, modern development and urbanisation projects (Price & Knecht 2012). Undoubtedly, the battleground's physical integrity is due to the large tonnage of UXO scattered across the island and waterways. The threat from live ammunition, including mines has protected the battleground from major site disturbance, including farming. The unexploded and abandoned weaponry left behind from 'Operation Stalemate II' also serves as a deterrent to local development projects, such as the construction of roads and underground pipelines (Francis & Alama 2011: 46–8; Reklai 2016). However, in recent years, landmine-clearing programmes have been introduced to facilitate the removal of mines, hand-grenades, chemical canisters and large shells from Peleliu's jungles and territorial waters (Austin 2011; Gerundio-Dizon 2012; Palau Government 2015). This means that if Peleliu's historic sites are to be preserved, it is necessary that both Palau's federal government and Peleliu state government act promptly and cooperatively to find a solution. Arguably, once the island's soils and waters are cleared of their deadly wartime contents, the former WWII battleground will likely succumb to urbanisation.

(ii) Looting

Despite the existence of legislation protecting wartime heritage, the illicit removal of WWII relics remains a significant problem in Palau (Ayres 2006; Knecht *et al.* 2012). Local villagers present a serious threat to *in-situ* preservation of Peleliu's historic sites and burial grounds due to their activities of cave breaking and battleground looting (Price & Knecht 2012; Knecht *et al.* 2012; Price *et al.* 2013).

Unsupervised visitors also are a threat to the historic battleground's historical integrity. In particular, the illegal activity of cave breaking is a serious threat to the protection of the region's skeletal remains (Knecht *et al.* 2012: 38). In September 2004, a sealed Japanese cave was illegally opened by a Canadian film maker (Knecht *et al.* 2012: 38). The cave breakers were apprehended by local police and issued with a large fine and the cave was resealed. Although all objects were recovered from the perpetrators, the attempted theft resulted in significant damage to the cave's contents. During the initial opening of the cave, a Japanese skull and helmet were shattered by collapsing debris (Knecht *et al.* 2012: 38).

Sadly, Peleliu's numerous caves contain large quantities of Japanese skeletal remains. Therefore, looters enter caves searching for human skulls for the sole purpose of removing gold teeth for financial benefit (Knecht *et al.* 2012: 220). In addition, the battleground is being targeted for its abundant collection of UXO and AXO, including its rare collection of napalm canisters (Knecht *et al.* 2012: 217–8).

Managing Palau's World War II heritage sites

Peleliu

The NPS has been pursuing the viability of establishing a WWII-themed historic park on Peleliu (Price *et al.* 2013: 228). For instance, in 1986, the NPS initiated public discussions and consultations with both Palau's government and Peleliu state government, together with the island's clans over their plan to establish a national park. The NPS proposal involved the integration of 15 separate battle sites located on Peleliu into a National Park (NPS 1991). In 1991, a draft report was submitted by the NPS to Palau's government, including Peleliu's Council of Chiefs (NPS 1991). Although the initial consultation with Peleliu's Council of Chiefs was highly favourable, in subsequent discussions, enthusiasm for the project dissipated (NPS 1991). By 2003, after years of community consultation and data gathering by the NPS, the project was deemed not feasible by the US federal government (NPS 2003). A significant stumbling block was the lack of local support for the project because of the park's impact on access to traditional lands and fishing grounds (NSP 2003).

The benefit of a historic park on Peleliu is that it would allow for the establishment of a governing body to manage the island's unique cultural assets, including protection from vandalism. If the battleground is to be monitored, funding is vital to pay for security, site assessment and condition reports. An effective means for the Palauan government to obtain funds in order to increase site monitoring is through forging a partnership with the NPS. A further advantage offered by NPS management of the battleground is that it would increase visitor safety. Currently, visitors are at risk from the enormous quantities of UXO that are situated in the jungle's undergrowth and hidden within Peleliu's numerous caves (Price & Knecht 2012: 15; Francis & Alama 2011: 46–8). Importantly, the status of 'historic park' would essentially generate community awareness and engagement whilst providing the local indigenous population with employment opportunities.

However, if a historic park is to be established there remains the issue of land ownership. Under Palau's Constitution foreign individuals and other legal entities are barred from purchasing land (Republic of Palau Constitution 1979: XIII § 8). As the federal government does not own the land it cannot gift the land in perpetuity for historical park purposes to the US federal government without first obtaining the state of Peleliu's permission. A final hurdle is the island's traditional leaders and chiefs. Palau's constitutional arrangement is a mixture of contemporary democratic institutions operating within a long established traditional governance structure (Vennendaal 2015: 178). In some states, traditional village leaders hold more sway than democratically elected state officials (Vennendaal 2015: 179). In other words, kinship, traditional titles and customary practices relating to land ownership, continue to control Palauan life and politics (Vennendaal 2015: 178). These factors proved divisive when the US federal government first put forward the idea of establishing a historic park on the island of Peleliu (Knecht *et al.* 2012: 3; US NPS 1991; US NPS 2003). However, similar land tenure systems are also found in other regions of Micronesia. The Constitution of the Federated States of Micronesia and Chuuk State Code restrict foreign ownership of land (Harding 1996: 68; FSM Constitution Art. 8 [4]; Chuuk State Code, Title 24: s 1608). The legacy of colonialism and the effects of neo-colonialism make many Micronesian communities reluctant to relinquish control of their lands and traditional fishing grounds.

Future recommendations

Peleliu

It is estimated that some 2 000 Japanese soldiers' remains are entombed in the underground chambers on Peleliu (Oceania TV News 2015; Pearlman 2015; Ryall 2015). In 2015, the Governor of Peleliu agreed to cooperate in efforts to help Japan recover Japanese soldiers killed during 'Operation Stalemate II'. Therefore, any future management plan of the battleground may need to include measures to repatriate the extensive quantity of Japanese skeletal remains still sealed in Peleliu's caves. The speculation of the possibility of the discovery in the near future of a mass Japanese grave on Peleliu illustrates the need for a site management plan that prioritises respect for human remains (Oceania TV News 2015; Pearlman 2015; Ryall 2015). The ethical question of whether the bones should be left on the island in perpetuity or repatriated to Japan is best resolved through collaboration between the governments of Japan and Palau.

Palau Lagoon's UCH

There are a number of proactive measures that could be explored in respect to the future management of the Republic of Palau's WWII relics. Palau and other small island developing States should consider ratifying the *2001 UNESCO Convention on the Protection of the Underwater Cultural Heritage* (UNESCO 2014). Furthermore, Palau's sunken WWII wrecks should be observed for possible oil leakages. Already, a number of Micronesian WWII wrecks have commenced seeping oil (Jeffery 2012; McKay 2005: 115). Many small island communities across the Pacific are concerned that sunken WWII vessels are turning into environmental time-bombs (Cervi 1999: 357; Federated States of Micronesia Press [FSM] Release 2011; Jeffery 2012: 27–8; Woodward 2008). In July 2001, a tropical storm caused USS *Mississinewa* to leak significant amounts of oil into the surrounding waters of Yap's Ulithi lagoon in the western Caroline Islands (Jeffery 2012: 27; McKinnon 2010: 38). Alarming, the *Mississinewa* incident highlights the threat posed by ageing wartime vessels to local fisheries and the well-being of Indigenous communities. If Palau's marine environment is to be protected from pollution, its vast collection of WWII wrecks should be regularly monitored for corrosion and

oil secretion. Such a strategy though, should be a collaborative approach, given the legal ownership and moral obligations Japan and the US have with these sites (*United Nations Convention on the Law of the Sea 1982, articles 95 & 96; Sunken Military Craft Act 2004, sections 1401–8*).

Conclusion

The cultural landscape of Micronesia is ancient (Athens 1980; Clark 2005; Liston & Rieth 2010). WWII for many Micronesian Indigenous communities is merely a small part of their long history. However, the tangible remains of the Pacific conflict dominate the cultural landscape of many small Micronesian communities. The Palauan archipelago is a potent example of an *in-situ* wartime heritage site. WWII relics can be found buried beneath the ground and lying discarded amongst lush tropical vegetation. Importantly, the region's numerous caves and underground tunnels contain reminders of the Pacific war. Palau's tropical waters conceal over sixty WWII wrecks that today attract diving enthusiasts from around the world (Bailey 1991; Lindemann 1988). These sunken wrecks are the legacy of the intensive US aerial bombardment codenamed 'Operation Desecrate I'.

Irrespective of whether the Republic of Palau's WWII sites are located underwater or on land; together they form a valuable source of undocumented knowledge of the Pacific war and should be protected for future generations (Boyer 1991: 266). Palau has demonstrated a strong commitment to combating looting through legislation like 'Palau Lagoon Monument' and related law enforcement initiatives. For example, in 2006 two divers who were found guilty of committing grand larceny and related property offences under the Palau National Code, Title 19, Chapter 3 'Palau Lagoon Monument', were sentenced to three and six months imprisonment, respectively (Carreon 2006). Furthermore, US\$5 000 and US\$12 000 fines were imposed. The then Assistant Attorney General, Christopher Hale, said, "the message is loot Palau's historic shipwreck and you go to jail" (Carreon 2006).

Despite the government's strong commitment to protecting wartime heritage, the illicit removal of WWII relics remains a significant problem in Palau (Ayles 2006; Knecht *et al.* 2012). Removal of any object from Palau's sunken shipwrecks

or any further vandalism of the region's historic battlegrounds and caves will diminish the cultural value and significance of Palau's WWII heritage to a level that the collective integrity of these sites will be lost. Therefore, in order to preserve the diversity of Palau's wartime collection of artefacts, it is vital that the region's historic sites, whether located on land or underwater, are monitored for theft and site disturbance.

The primary focus of this paper has been on the extensive underground fortifications located on Peleliu, an island state of Palau. The island of Peleliu is arguably one of the best-preserved WWII Pacific battlefields (Knecht *et al.* 2012: 4; Price *et al.* 2013). As Knecht *et al.* (2012: 263) states, 'on Peleliu we can go beyond the conventional histories of the commanders and troop movements and understand what war was like for the common soldier'. As the island's underground fortress is somewhat intact, it affords visitors an opportunity to experience what life was like for the thousands of Japanese soldiers living there. The charred skeletal remains inside some of the caves vividly illustrate the danger of cave warfare (Denfeld 1988: 38; Phelan 1945: 33; Price & Knecht 2012: 33).

Peleliu's battleground is important and should be preserved as it records the long war of attrition fought between the US and Japan during the months of September to November 1944. Furthermore, its sea floor represents an important tangible reminder of the destructive power the US aircraft carriers brought to naval battles during the central Pacific conflict. The region's extensive fortifications reflect the power of the Japanese in the Pacific, including their engineering achievements. However, these WWII sites are also part of the history of Palau. Therefore, it is important that these sites be preserved *in situ* not only for war veterans and their families, and history enthusiasts, but also for the younger generation of Palauans.

The world has 'rediscovered' Palau due to popular television programs such as *Survivor* and the 2010 mini-series *The Pacific* (Knecht *et al.* 2012: 9). In 2015, Palau was again in the media spotlight when Japan's Emperor Akihito and Empress Michiko made their inaugural visit to the WWII battleground. This recent international attention leading to an increase in unsupervised visitors will no doubt prove a threat to the historic sites of Peleliu (Knecht *et al.* 2012: 9).

Due partially to inherent reminders of the horrors of the Pacific war, Peleliu's Indigenous communities have been reluctant to relinquish their communal ownership rights over the island's land and coastal waters (NPS 2003). However, this does not mean that the Republic of Palau's government in cooperation with Peleliu's state government and tribal chiefs should not re-evaluate the benefits of a proposed historic park. Although the original investigation by the NPS into the viability of such a partnership concluded that the establishment of a WWII-themed park was not feasible at that time, it did leave open the option to review the decision at a later date (NPS 2003). Importantly, the US Department of Interior continues to work cooperatively with the Indigenous islanders (US Congress Record 2004; Knecht *et al.* 2012). In particular, the Palau Historic Preservation Office, partly funded by the US Historic Preservation Fund, is working on many of these issues in association with the UNESCO Office in Samoa (Tucker 2012: 2).

It is vital that the Palauan government continues to work cooperatively with Peleliu's state government, the Peleliu War Historical Society, the people of Palau, the Japanese government, war-veterans and the NPS. What remains now is for the federal and state governments, the people of Palau, the NPS and Japan to come together to discuss conservation and management strategies, ultimately developing collaborative projects devoted to Peleliu's war past. A politically sensitive issue that is yet to be fully

resolved is the repatriation of Japanese skeletal remains located on Peleliu. A collaborative approach towards the site's management is important, as it is highly possible that there are undiscovered caves, graves and objects of historical significance.

Finally, with respect to future collaborative projects, there is scope to build on the 2010 Peleliu Battleground Survey Report that was instigated by the Peleliu War Historical Society. Importantly, as Japan seeks repatriation of its war dead, including human remains in potentially booby-trapped caves, UXO is an urgent site management matter that must be addressed in the immediate future. Hopefully, the recent 70th anniversary of the end of the Pacific war will continue to foster collaborative engagement in honouring and preserving an incredible war legacy devoted to three nations, that of Palau, Japan and the United States.

References

- Athens, J.S., 1980, Pottery from Nan Madol, Ponape, Eastern Caroline Islands. *The Journal of the Polynesian Society*, **89**:1: 95–99.
- Austin, K., 2011, Legacy of death, destruction lingers in Pacific. *Pacific Islands Report*. 13 October 2011. Viewed 10 July 2016, <<http://www.pireport.org/articles/2011/10/13/legacy-death-destruction-lingers-pacific>>.
- Ayres, W.S., 2006, Archaeological training programs in emerging *Micronesian Island nations*. *Micronesian Journal of the Humanities and Social Sciences*, **5**:2: 568–579.
- Bailey, D.E., 1991, *WWII wrecks of Palau*. North Valley Diver Publications, Redding.
- Barnett, H.G., 1960, *Being a Palauan: case studies in cultural anthropology*. Holt, Rinehart and Winston Inc., New York.
- Boyer, D., 1991, World War II. In: T. Carrell (ed.), *Micronesia: submerged cultural resources assessment*. Southwest cultural resources centre professional papers, number 36. National Park Service, Santa Fe: 197–266. Viewed 20 March 2015, <<http://marshall.csu.edu.au/Marshalls/html/SCRU/micro1.pdf>>.
- Camp, R.F., 2008, *Last man standing: the 1st marine regiment in Peleliu*, September 15–21, 1944. Zenith Press, Minneapolis.
- Carrell, T., 1991a, Assessment area background. In: T. Carrell (ed.), *Micronesia: submerged cultural resources assessment*. Southwest cultural resources centre professional papers, number 36. National Park Service, Santa Fe: 9–44. Viewed 20 March 2015, <<http://marshall.csu.edu.au/Marshalls/html/SCRU/micro1.pdf>>.
- Carrell, T., 1991b, Shipwrecks: the historical record. In: T. Carrell (ed.), *Micronesia: submerged cultural resources assessment*. Southwest cultural resources centre professional papers, number 36. National Park Service, Santa Fe: 279–326. Viewed 20 March 2015, <<http://marshall.csu.edu.au/Marshalls/html/SCRU/micro1.pdf>>.

- Carrell, T., 1991c, Management recommendations and conclusions. In: T. Carrell (ed.), *Micronesia: submerged cultural resources assessment*. Southwest cultural resources centre professional papers, number 36. National Park Service, Santa Fe: 549–553. Viewed 20 March 2015, <<http://marshall.csu.edu.au/Marshalls/html/SCRU/micro1.pdf>>.
- Carrell, T., Lenihan, D.J., Lotz, D.T. and Miculka, J.E., 1991, Shipwrecks: the archaeological record. In: T. Carrell (ed.), *Micronesia: submerged cultural resources assessment*. Southwest cultural resources centre professional papers, number 36. National Park Service, Santa Fe: 327–426. Viewed 20 March 2015, <<http://marshall.csu.edu.au/Marshalls/html/SCRU/micro1.pdf>>.
- Carreon, B.H., 2006, Palau artefact thieves get jail terms. *Pacific Islands Report*. 7 April 2006. Viewed 10 July, 2016, <<http://www.pireport.org/articles/2006/07/04/palau-artifact-thieves-get-jail-terms>>.
- Cervi, G.A., 1999, War wrecks and the environment: who's responsible for the legacy of war? A case study: Solomon Islands and the United States. *Journal of Environmental Law and Litigation*, **14**: 351–399.
- Chuuk State Code, 2001. Viewed 3 July, 2016, <<http://fsmlaw.org/chuuk/code/index.htm>>.
- Clark, G., 2005, A 3000-year culture sequence from Palau, Western Micronesia. *Asian Perspectives*, **44**:2: 349–380.
- Clark, G. and de Biran, A., 2010, Geophysical and archaeological investigations of the survivor-camp of the Antelope (1783) in Palau Islands, western pacific. *The International Journal of Nautical Archaeology*, **39**:2: 345–356.
- Clyde, P.H., 1935, *Japan's pacific mandate*. Kennikat Press, Washington.
- Denfeld, D.C., 1988, *Peleliu revisited: an historical and archaeological survey of World War II sites on Peleliu Island*. Micronesian Archaeological Survey Number 24. Historic Preservation Office, Saipan.
- DeCioccio, J.P. and Blair, B.C., 2011, *Victory at Peleliu: the 81st Infantry Division's Pacific Campaign*. University of Oklahoma Press, Oklahoma.
- Federated States of Micronesia Constitution, 1979, Pohnpei. Viewed 3 July 2016, <<http://www.fsmlaw.org/fsm/constitution/constitution.htm>>.
- Federated States of Micronesia Press Release, 30 September, 2011. Viewed 4 September 2015, <http://www.fsmpio.fm/RELEASES/2011/september/09_20_11.html>.
- Fitzpatrick, S.M., 2007, Anthropogenic impact to coral reefs in Palau, western Micronesia during the late Holocene. *Coral Reefs*, **26**: 915–930.
- Francis, S. and Alama, I., 2011, WWII unexploded ordnance—a study of UXO in four Pacific Island countries. Pacific Islands Forum Secretariat. Viewed 4 September 2015, <<http://www.forumsec.org/resources/uploads/attachments/documents/UXO%20final.pdf>>.
- Gailey, H.A., 1983, *Peleliu 1944*. The Nautical and Aviation Publishing Company of America, Annapolis.
- Garrand, G.W. and Strobridge, T.R., 1971, *Western Pacific operations: history of the U.S. Marine Corps Operations in World War II*. Vol IV. U.S. Government Printing Office: Washington.
- Giaffo, L., 2013, *Gooch's marines: American first marines: from royal marines to the US marines*. RoseDog Books, Pittsburgh.
- Graham, T. and Idechong, N., 1998, Reconciling customary and constitutional law: managing marine resources in Palau, Micronesia. *Ocean and Coastal Management*, **40**:2: 143–164.
- Gerundio-Dizon, A., 2012, Palau acts on Pacific Forum's unexploded ordnance plan. *Pacific Islands Report*. 24 October, 2012. Viewed 10 July, 2016, <<http://www.pireport.org/articles/2012/10/24/palau-acts-pacific-forum%E2%80%99s-unexploded-ordnance-plan>>.
- Hammel, E., 2012, *Marines on Peleliu: a pictorial record*. Pacifica Military History, Pacifica.
- Hezel, F.X., 1995, *Strangers in their own land: a century of colonial rule in the Caroline and Marshall Islands: Pacific Islands Monograph Series*, 13. University of Hawaii Press, Honolulu.
- Harding, E., 1996, Federated States of Micronesia. In: B. Boer (ed.), *Environmental law in the South Pacific – consolidated report of the reviews of environmental law in the Cook Islands, FSM, Kingdom of Tonga, Republic of Marshall Islands and the Solomon Islands*, IUCN, Cambridge.
- Higuchi, W., 1986, *Micronesia and the Pacific War: the Palauans*. Micronesian Area Research Centre, Mangilao, Guam.
- Hough, F.O., 1947, *The island war—the United States marine corps in the Pacific*. J.B. Lippincott Company, Philadelphia.
- Hough, F.O., 1950, *The assault on Peleliu*. Historical Division Headquarters US Marine Corps, Washington.
- Hoyt, E.P., 1986, *Japan's war—the great Pacific conflict: 1853–1952*. MacGraw-Hill, New York.
- Ishimura, T., 2011, Investigations of abandoned WW II wrecks in Palau. *The MUA Collection*. Viewed March 2015, <<http://www.themua.org/collections/items/show/1228>>.
- Jeffery, B., 2012, The future of Chuuk Lagoon's submerged World War II sites. *Bulletin of the Australasian Institute for Maritime Archaeology*, **36**: 15–30.
- Knecht, R., Price, N. and Lindsay, G., 2015, The sacred and the profane: souveniring and collecting behaviours on the WWII battlefields of Peleliu Island, Palau, Micronesia. In: G. Carr and K. Reeves (eds.), *Heritage and memory of war: responses from small islands*. Routledge, New York.
- Knecht, R., Price, N. and Lindsay, G., 2012, WWII battlefield survey of Peleliu Island, Peleliu state, Republic of Palau. Final Report, July 2012. National Park Service Battlefield Protection Program, Washington. Viewed 3 September 2015, <http://www.peleliuhistorical.org/Peleliu_REPORT.pdf>.
- Lal, B.V. and Fortune, K., 2000, *The Pacific Islands: an encyclopaedia*. University of Hawaii Press, Honolulu.
- Lee, J.T., 2004, Treaties, time limits and treasure trove: the legal protection of cultural objects in Singapore. *Art, Antiquity & Law*, **9**:3: 237–280.
- Leibowitz, A.H., 1996, *Embattled Island: Palau's struggle for independence*. Praeger Publishing, Westport.
- Leonard, D., 2001, *Diving the Pacific: Vol. 1 Micronesia and the Western Pacific*. Periplus, Hong Kong.
- Lindemann, K.P., 1988, *Desecrate 1: operation against Palau by carrier task force 58 and the shipwrecks of World War II*. Pacific Press Publications, Belleville.
- Liston, J. and Rieth, T., 2010, Palau's petroglyphs: archaeology, oral history, and iconography. *The Journal of the Polynesian Society*, **19**:4: 401–414.
- McCurry, J., 2005, Sub wreck could reveal Japanese peace offer. *The Guardian*, 16 April, 2005. Viewed 25 August 2013, <<http://www.theguardian.com/world/2005/apr/16/usa.secondworldwar>>.
- McGrath, R.D., 2010, All for naught: the battle of Peleliu. *The New American*, **26**:9: 35–39.

- McKay, L., 2005, An unwanted legacy of war: sunken warships in the Pacific—the environmental and human threat. *Asia Pacific Law Review*, **13**: 115–146.
- McKinnon, J., 2010, Federated States of Micronesia. In: U. Guérin, B. Egger and V. Penalva (eds.), *UNESCO, Underwater Cultural Heritage in Oceania*: 37–42. Viewed 5 September 2015, <<http://unesdoc.unesco.org/images/0018/001887/188770e.pdf>>.
- Millet, A.R., 1991, *Semper Fidelis: the history of the United States Marine Corps*. Freedom Press, New York.
- Moran, J. and Rottman, G.L., 2002, *Peleliu 1944—the forgotten corner of hell*. Osprey Publishing, Oxford.
- Murray, S.C., 2016, *The battle over Peleliu: Islander, Japanese, and American memories of war*. University of Alabama Press, Tuscaloosa.
- Nero, K.L., 1990, Hell in the Pacific. In: G. White and L. Lindstrom (eds.), *The Pacific Theater—Island Representations of World War II*. Melbourne University Press, Carlton: 117–147.
- Oceania TV News, March 26, 2015, Japan's imperial couple's historical visit to Palau approaches. Viewed 30 March 2015, <<http://www.oceaniatv.net/2015/03/26/japans-imperial-couples-visit-to-palau/>>.
- O'Neill, J.G. and Spennemann, D.H.R., 2001, German colonial heritage in Micronesia. *Cultural Resources Management*, **24**: 1: 46–47.
- O'Neill, J.G. and Spennemann, D.H.R., 2002, Preserving colonial heritage in postcolonial Micronesia. *Pacific Studies*, **25**: 3: 1–15.
- Palau Government, 2015, Palau detonates two tons of unexploded ordnance. *Pacific Islands Report*. 26 June, 2015. Viewed 10 July, 2016, <<http://www.pireport.org/articles/2015/06/26/palau-detonates-two-tons-unexploded-ordnance>>.
- Pearlman, J., 2015, Japan searches for Second World War soldier's remains in sealed caves of Palau. *The Telegraph*, 28 March. Viewed 16 April 2015, <<http://www.telegraph.co.uk/news/worldnews/australiaandthepacific/palau/11501770/Japan-searches-for-Second-World-War-soldiers-remains-in-sealed-caves-of-Palau.html>>.
- Petersen, G., 1998, Strategic location and sovereignty: modern Micronesia in the historical context of American expansionism. *Space and Polity* **2**: 2: 179–205.
- Phelan, W.C., 1945, Japanese military caves on Peleliu: know your enemy. *CinCPac-CinCPOA Bulletin*, 173–45. Viewed 3 September 2015, <<http://cgsc.cdmhost.com/cdm/ref/collection/p4013coll8/id/1367>>.
- Pomeroy, E.S., 1951, *Pacific outpost: American strategy in Guam and Micronesia*. Stanford Press, Annapolis.
- Poyer, L., Falgout, S. and Carucci, L.M., 2001, *The typhoon of war. Micronesian experiences of the Pacific War*. University of Hawaii Press, Honolulu.
- Pregill, G.K. and Steadman, D.W., 2000, Fossil vertebrates from Palau, Micronesia: a resource assessment. *Micronesia*, **33**: 1: 137–152.
- Price, N. and Knecht, R., 2012, Peleliu 1944: the archaeology of a South Pacific D-Day. *Journal of Conflict Archaeology*, **7**: 1: 5–48.
- Price, N., Knecht, R., Ballinger, S., Cypra, S., Emesiochel, C., Hesus, T., Kloulechad, E., Lindsay, G., McQuillen, D. and Ngirmang, S.O., 2013, After the typhoon: multicultural archaeologies of World War II on Peleliu, Palau, Micronesia. *Journal of Conflict Archaeology*, **8**: 3: 193–248.
- Rechebei, E.D., McPhetres, S.F. and Emesioch, M., 1997, *A history of Palau: heritage of an emerging nation*. Ministry of Education, Republic of Palau, Koror.
- Reklai, L.N., 2016, Erosion exposes unexploded ordnance at Palau hospital. *Pacific Islands Report*. 9 March, 2016. Viewed 10 July, 2016, <<http://www.pireport.org/articles/2016/03/09/erosion-exposes-unexploded-ordnance-palau-hospital>>.
- Richard, D., 1957, *US naval administration of the Trust Territory of the Pacific Islands*, Vol 1. The wartime military government 1942–1945. US Government Printing Office, Washington.
- Republic of Palau Constitution, 1979, Koror. Viewed 20 March 2015, <<http://www.palii.org/pw/constitution.html>>.
- Rottman, G., 2004, *Saipan and Tinian 1944: piercing the Japanese Empire*. Osprey Publishing, Osceola.
- Ryall, J., Soldiers remains sought on Pacific island. *South China Morning Post*, 17th Feb, 2015 <<http://www.scmp.com/news/asia/article/1715748/soldiers-remains-sought-pacific-island>>.
- Spennemann, D.H.R., 2006, Managing unexploded ammunition at and near cultural heritage sites. *Micronesian Journal of the Humanities and Social Science*, **5**: 1: 234–267.
- Sunken Military Craft Act*, 2004 Pub. Law 108–375, 10 USC 113.
- Sydney Morning Herald*, 2015, US clues to Japanese war graves on Pacific Island of Palau. 16 February. Viewed 4 March, 2015, <<http://www.smh.com.au/world/us-clues-to-japanese-war-graves-on-pacific-island-of-peleliu-20150216-13fmsb.html>>.
- The Argus*, 1944, Task Force record raid on Palau (Melbourne, Vic.: 1848–1957), 10 April. Viewed 13 July, 2015, <<http://nla.gov.au/nla.news-article11812037>>.
- The Mail*, 1944, 28 Jap ships sunk, battleship hit at Palau. (Adelaide, SA : 1912–1954), 8 April. Viewed 13 July, 2015, <<http://nla.gov.au/nla.news-article55881845>>.
- Thompson, C., 2002, *Twenty-five best World War Two sites*. Greenline Publications, San Francisco.
- Tucker, H., 2012, *Historic preservation funds grants, cultural partnership programs, Pacific west region National Park Service, Department of the Interior*. 2012 Senior Plenary Session of the Interagency Group on Insular Areas, 15 February, 2012. Viewed 4 July, 2016, <<https://www.doi.gov/sites/doi.gov/files/migrated/oia/igia/2012/upload/19-NPS-Historic-Preservation-2012-Fund-Grants-and-Programs-in-Pacific-West-Region.pdf>>.
- UNESCO, 2001 Convention on the Protection of the Underwater Cultural Heritage, 2 November, 2001, Paris. EIF 2 January 2009 [2562 UNTS 3]. Viewed 6 November 2015, <http://www.unesco.org/new/en/culture/themes/underwater-cultural-heritage/2001-convention/official-text/>>.
- UNESCO, World Heritage Centre: Republic of Palau, 2012, The Rock Islands Southern Lagoon nomination for inscription on the World Heritage List. Viewed 15 February 2015, <<http://whc.unesco.org/en/list/1386>>.
- UNESCO, 2014, Underwater cultural heritage small island development states: 3rd UN international conference on small island development states. Apia Office for Pacific States, UNESCO. Viewed 4 July 2016, <<http://unesdoc.unesco.org/images/0023/002312/231218e.pdf>>.
- United Nations Convention on the Law of the Sea*, 1982 (UNCLOS III) December 1982. EIF–16 November 1994 [1833 UNTS 397].
- United States Congress Record: extensions of remarks, 30 September, 2004. Viewed 3 April 2016, <<https://www.congress.gov/crec/2004/09/30/CREC-2004-09-30-pt1-PgE1741-2.pdf>>.

- United States National Park Service, 1991, Biliou (*Peleliu*) *historical park study—preliminary draft 1/91* (January, 1991). Prepared by the Government of Palau and the National Park Service. Viewed 20 March 2015, <<http://www.nps.gov/pwro/piso/peleliu/title.htm#contents>>.
- United States National Park Service, 2003, *Special resource study: Peleliu battlefield national historic landmark*. Viewed 20 March 2015, <<http://www.botany.hawaii.edu/basch/uhnpscesu/htms/Palau2/index.htm>>.
- United States Strategic Bombing Survey, 1946, *Campaigns of the Pacific War*. Pacific War Series. US Navy, Washington. Viewed 12 March 2015, <<http://babel.hathitrust.org/cgi/pt?id=mdp.39015010380668;view=1up;seq=311>>.
- United States Strategic Bombing Survey, 1947, *Air campaigns of the Pacific War*. Military Analysis Division, Washington. Viewed 12 March 2015, <<http://babel.hathitrust.org/cgi/pt?id=mdp.39015002229527;view=1up;seq=1>>.
- Vennendaal, W., 2015, *Politics and democracy in Micronesia*. Routledge, Abingdon.
- Yamashita, S., 2000, The Japanese encounter with the south: Japanese tourists in Palau. *The Contemporary Pacific*, **12.2**: 437–463.
- Woodward, T., 2008, Pacific World War II wrecks pose risk of toxic leak. *National Geographic News*, 10 December. Viewed 3 September 2015, <<http://news.nationalgeographic.com/news/2008/12/081210-pacific-shipwrecks-missions.html>>.
- Y'Blood, W.T., 1991, Securing MacArthur's flank. In: B. Nalty (ed.), *War in the Pacific: Pearl Harbour to Tokyo Bay*. Salamander Books, London: 172–194.
- Youngblood-Coleman, D., (ed.), 2015, *Country Watch Review: Palau*. Country Watch Publications, Houston: 1–219. Viewed 4 September 2015, <www.countrywatch.com/Content/pdfs/reviews/B3ZM6ZM9.01c.pdf>.
- Zeiler, T.W., 2004, *Unconditional defeat: Japan, America, and the end of World War II*. Scholarly Resources, Wilmington.

CULTURAL RESOURCE AND ACOUSTIC SURVEY OF THE AUSTRALIAN KETCH *JOHN ROBB*

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Introduction

This article represents an historical overview of the site history and the results of a geophysical survey, confirming or denying the presumed location of the ketch *John Robb*. A team from Flinders University, in partnership with the Department of Environment, Water and Natural Resources (DEWNR), undertook the geophysical survey in an ongoing site-*Monitoring* project. Methods, results and management implications are presented and discussed.

The Gulf St Vincent is a large expanse of water, which facilitates all sea traffic into Adelaide, South

Australia, and connects the Yorke Peninsula to both the mainland and to the Fleurieu Peninsula (Fig. 1). Within Gulf St Vincent, there are 173 known shipwrecks (Table 1; Fig. 2), which is a testament to its significance in South Australia's maritime heritage (Australian National Shipwreck Database [ANSD] 2015). The management and protection of these shipwrecks and all others in South Australian (SA) waters fall to the DEWNR.

The ANSD record for the *John Robb* describes the vessel as an iron-hulled 'ketch' and 'barge'. Records indicate that the vessel was 76.7 ft (23.3 m) long, with a beam of 18.7 ft (5.7 m), and a draft of 6.5 ft (2 m) deep, (Australian Government Department of the Environment 2015). Two masts were fitted to the ketch and it was later adapted to facilitate the transportation of various types of cargo (Pioneer 1954).

According to the South Australian DEWNR records, *John Robb's* resting place is found at one of five possible locations within Gulf St Vincent. All five shipwreck locations are within the vicinity of a major shipping channel that services Port Adelaide. In 2015, community dive expeditions failed to find the wreck in an ongoing effort to monitor sites. However, while the divers were on their surface interval, in between dive operations, a working trawler was allegedly viewed in the vicinity of the



Figure 1. Navigation plot of South Australia and Gulf St Vincent. Coordinates are in metres based on the Universal Transverse Mercator Coordinate System, Zone 54S.

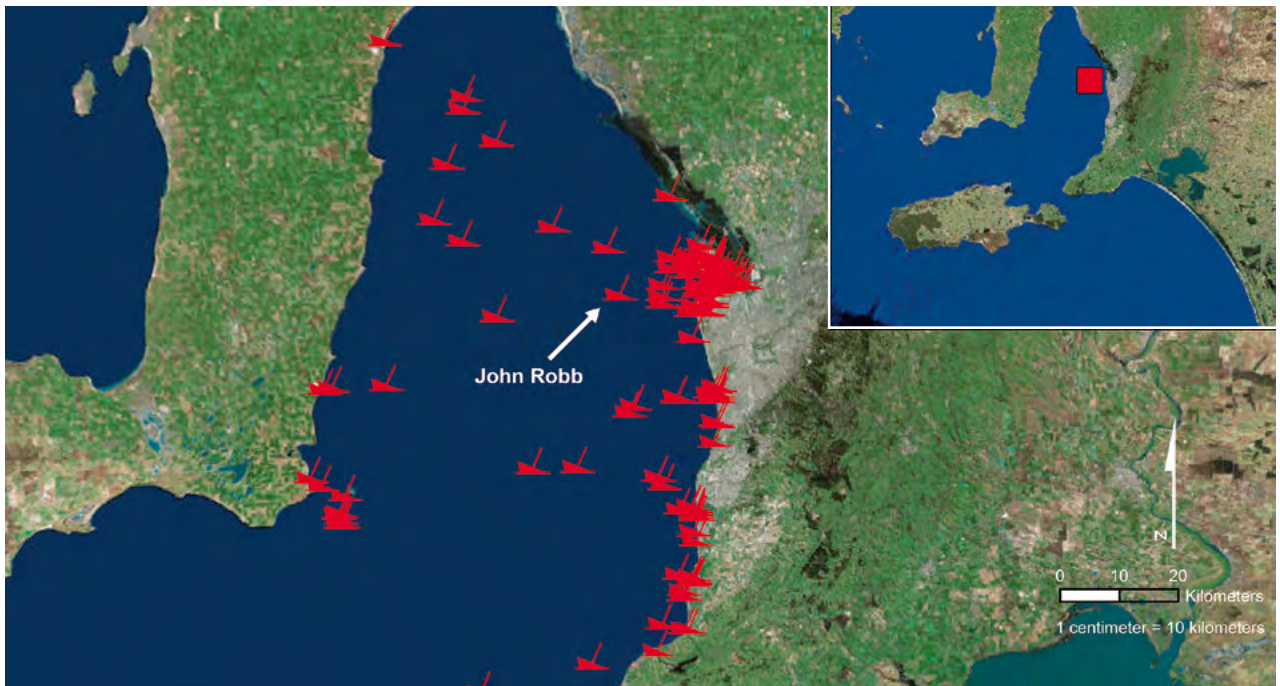


Figure 2. Navigation plot of the *John Robb* and surrounding shipwrecks found around Gulf St Vincent. Coordinates are in metres based on the Universal Transverse Mercator Coordinate System, Zone 54S.

five possible wreck site locations; it was feared that the trawler may have compromised the wreck. Sight of the alleged trawler within the wreck's presumed locations is cause for concern in relation to its protection.

The significance of ketches in the economic environment of South Australia

A ketch is a two-masted vessel, typically fore-aft rigged, where the foremast is taller than the mizzenmast (Pioneer 1954). This simple rigging allows the ketch to be operated by two to three crew members, making it relatively low cost to run. While ketches were used in other parts of the world, including the United Kingdom, South Australia's adaptations to the ketch included a lengthening of the hull, resulting in a vessel that had a shallow, flat draft relative to its length (Buller 2009). This allowed for the vessel to operate in shallow coastal waters without a need for docking at jetties and wharves, as seen in Figure 5 at Victor Harbor. This was an important consideration during the early settlement of South Australia where outposts were largely underdeveloped and far apart (Buller 2009). The addition of a retractable centre-board allowed the vessel to ride up onto shore and then refloat at high tide, thus allowing for goods and people to be transported to areas otherwise inaccessible to larger, deeper drafted vessels. Once back in deep water, the ketch's centre-board could be lowered again to improve the vessel's handling under sail.

During the 1860s, many coastal ketches that operated in South Australia were originally built in Tasmania (Woodford 2007). Often referred to as 'barges' when built, these vessels would come to be known locally as ketches once put into service and registered in South Australia (Parsons 1983). The term 'barge', is otherwise commonly understood as a vessel without sails and no means of movement other than being towed. In South Australia, barges were typically used to transport goods and commodities near the protected waters of ports and harbours or along the rivers (Thiele 1987). Similar to ketches, these vessels also tended to be longer relative to their beam and had a flat, shallow draft to traverse the lengths of the river during drier months when the water levels were lower. Shipbuilders and operators noticed this similarity in hull profile, with conversions between barges and ketches often only requiring a modest refit of masts and a centre-board (Thiele 1987). It is common to find references to the same vessel

being described as a barge or a ketch and operating in both riverine and coastal marine waters.

The versatility of the ketches led to them not only being operated in local waters but also for voyages ranging from Western Australia to Tasmania. The fleet of coastal vessels in South Australia, often referred to as the 'Mosquito Fleet', peaked between the 1880s and 1890s with over 70 such vessels trading out of Port Adelaide (Parsons 1986). Competition from steam power and rail transport meant that their use began to decline by the start of the 20th century. With the prevalence of steam power, reliable transportation became less susceptible to the favourability of seasonal winds, thus relegating ketches and other small craft, such as schooners and cutters, to localised lightering roles (Woodford 2007). Furthermore, the improvement of land transportation resulted in the decline of smaller outposts and the consolidation of regional centres that invested in access of larger vessels. However, in response to these changing economic circumstances, auxiliary motors were introduced into ketches, creating the 'auxiliary ketch'. This relatively modest innovation was insufficient to stem the inevitable decline of these coastal maritime traders; by the time bulk containerisation was introduced in the 1950s, only 30 ketches were still operating in South Australia.

The ketch remains an important component of South Australia's maritime history. Many seafarers working out of the State's international harbours such as Port Victoria, Port Lincoln, and Port Adelaide, often began as ketch hands, and a number of them have published books about their experiences on these smaller coastal vessels. The South Australian Ketch Preservation Society was formed in 1970 and today the South Australian Maritime Museum curates an important collection of relics and memorabilia associated with these vessels.

The ketch *John Robb*

The 64-ton ketch *John Robb* was constructed in 1879 in Port Adelaide, South Australia, at the height of the colonial period (1788–1901) (Fig. 3). This era, one of the most prominent in Australian maritime archaeology, demonstrated advances made in exploration, scientific discoveries, commerce and the colonisation of Australia (Buller 2009). The ketch *John Robb*, was originally owned by a South Australian contractor named Mr *John Robb* (Lack 1976). Robb owned the ketch and his associated business until his death in 1896, when

he suffered a stroke (Australian Dictionary of Biography 1976). Prior to his death, Robb and the ketch's subsequent owner, J.H. Murch, used the vessel to transport goods.

The ketch *John Robb* serviced a need for transportation relating to commerce, shipping goods such as cereal products, barley and copper ore between local South Australian and foreign ports, which would be transported from Adelaide's main market (*The Narracoorte Herald* 1936). At the time of the construction of the *John Robb* in 1879, roads and railroads were virtually non-existent, and maritime shipping became the major form of transportation (*The Advertiser* 1947). Even with the advent of steamers, sailing vessels retained their favourability among smaller ports. One of its first shipments, placed for the *John Robb*, was an export of 300 barrels of barley in 1879, shortly after its construction (*The Advertiser* 1879).

Similar to other Australian ketches, *John Robb* was operated by one captain and two crew members throughout its life span. It is reputed that J.H. Murch of Largs Bay, South Australia, obtained *John Robb* in 1931, and from that point he operated the vessel as master, and employed crewmen Messrs. Bob Edenberg and Ray Dolly (*Barrier Miner* 1954). Figure 4 depicts Murch and his son working to upgrade the ketch for future cargo transportation (Pioneer 1954). In 1938 and 1939 the ketch was laden with cargo for the South Australian Farmers Union, and construction items such as 4- and 5-inch (10.1- and 12.7-cm) piping and engines for the construction of a jetty at Kingscote, Kangaroo Island (*Pioneer Kangaroo Island Currier* 1938). The wide variety of material transported by the ketch added to its usefulness. The local South Australian newspaper, *The Advertiser*, reported the ketch at one time transporting a rare commodity—explosives—to Whyalla.

On 24 April 1954, the *John Robb* was crossing Gulf St Vincent with 1 000 bags of barley when it collided with the 134 ton (121.5 metric ton) tug, *Falcon*, owned by Hurdart Parker Ltd (*Barrier Miner* 1954). According to local newspaper reports, *Barrier Miner*, the *John Robb* reportedly floundered ten miles (16.1 km) off of Outer Harbor and 5.3 miles (8.5 km) west of the Wolonga light beacon. The *Falcon* sustained only minor damage, and was therefore able to rescue the *John Robb* crew members—Murch, Edenberg and Dolly. At the time of the collision the tug was towing a barge carrying



Figure 3. Map of South Australia and Gulf St Vincent, 1859 (State Library of South Australia 2007).

700 tons (635 metric tons) of rock from Klein's Point to Birkenhead for the Adelaide Cement Company (*Barrier Miner* 1954). It was learnt that the impact occurred on the starboard side of the *John Robb* and the portside of the *Falcon* (*The Advertiser* 1954).

Shortly after the incident, the South Australian court would deliver judgment on the collision. Although Murch was judged as justified when he left his crewman, Edenberg, at the helm, it was not desirable for one man to be at the helm throughout the night (*The Advertiser* 1954). In order for the night's helmsman to operate the vessel's engines, he would have to neglect the helm, leaving the vessel vulnerable to any obstruction. It was this neglect and the number of tasks for one individual to accomplish in hazardous conditions that left the *John Robb* at the bottom of Gulf. The court ultimately found that the ketch had been handled in an unseaman-like manner at the time of the collision, in hazardous conditions. Ultimately, however, no charges were laid against Murch or the captain of the *Falcon* (*The Advertiser* 1954).

The wreck of the *John Robb* came to rest 5.3 miles (8.5 km) out of Wonga Shoal, a major entrance for shipping into and out of Adelaide. After the incident, the Harbor Board officials attached a warning light on the sunken ketch to prevent any navigational hazards (*Chronicle* 1954). It was reported that Murch was going to attempt to salvage the vessel but if the attempts proved unsuccessful then the vessel would be broken up to reduce or eliminate the remains becoming a potential hazard for shipping vessels (*The Advertiser* 1954). Just two weeks after the incident, the buoy marking the sunken vessel had drifted off the site. Later, the lack of a marker buoy plus inclement weather prevented frogmen from locating the ketch, in an estimated 62 feet (18.8 meters) of water (*Chronicle* 1954). From this time forward, the *John Robb* would become an infamous wreck from which it was lost and found, time and time again.



Figure 4. Captain J.H. Murch and son upgrading the *John Robb* (Port Lincoln Times 1931).



Figure 5. Victor Harbor docked ships, and the *John Robb* (State Library of South Australia 1879).

Research tools

Acoustic geophysical techniques are non-destructive research tools for analysing archaeological and geological sites in their current state with the addition of environmental effects caused by varying water salinity, temperatures, currents, wave height, water depths and winds (Cowley 2010). Typically, effects such as these are seen as deteriorating factors on archaeological sites, potentially eliminating historical records. Although these conditions are studied for their environmental conditions, and potentially destructive properties, they can be used to preserve a site for the next millennia (Spalding 2011). Further geophysical techniques can be used to identify geologic conditions deemed suitable for the preservation of submerged archaeological sites.

Modern advances in technology, such as remote sensing, reveal the condition of archaeological sites. Despite skepticism by some within the archaeological community, the use of geophysical techniques has grown and in many cases, proving to be advantageous and economical for large-scale surveys and research operations (Dix 2008). These methods are particularly useful with sites deeper than 100 m, beyond the reaches of divers (Foley 2002). Any and all submerged cultural heritage sites are deemed as non-renewable resources, stressing their need for documentation and preservation (English Heritage 2013). Without the assistance of remote sensing techniques, wrecks like the *John Robb* might have never been located or reached for further research (Ward & Ballard 2001).

Methods

A remote sensing survey was conducted on 24th November 2015. Prior to the survey, DEWNR provided five recorded coordinates for the presumed location of the *John Robb* within Gulf St Vincent (Fig. 6). These coordinates have been converted into UTM WGS84 and are listed in Table 1. The coordinates are a compilation of locations provided by a number of institutions, including the South Australian Police (SAPOL); Department of Environment, Water, and Natural Resources (DEWNR); The Register—South Australian Gazette and Colonial Register; The Scuba Diving Federation of South Australia (SDFSA); and the South Australian recreational scuba diving club (Sea Wolves). Anecdotal reports of possible damage to the wreck, due to trawling activities, were received

Gulf St. Vincent, SA, Shipwrecks

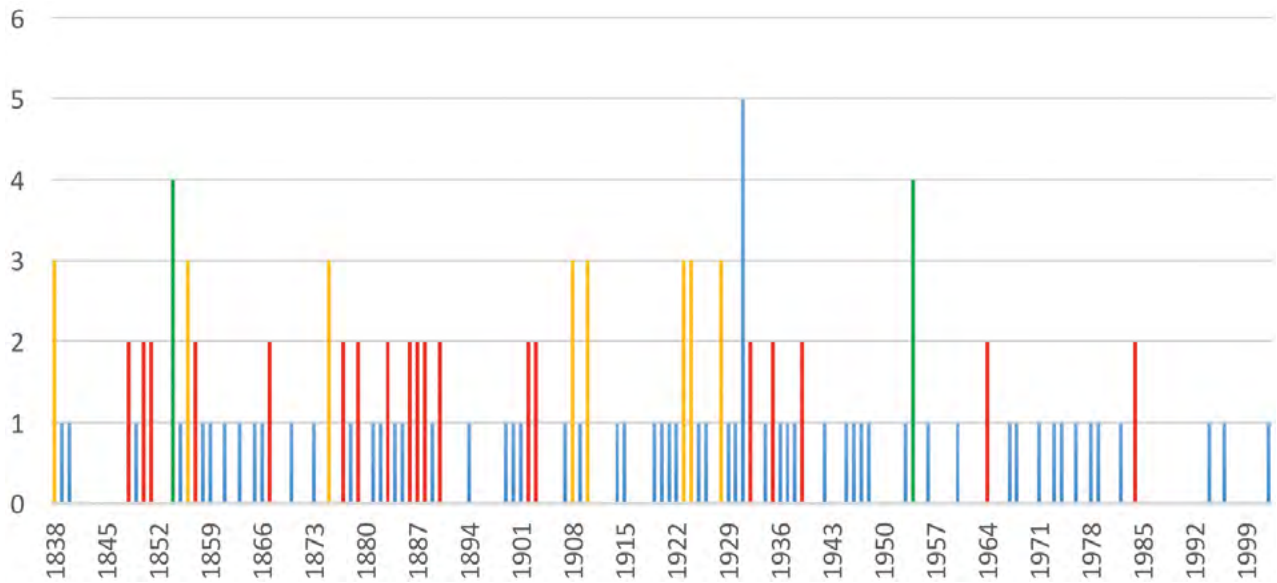


Table 1. Recorded shipwrecks per year in Gulf St Vincent, South Australia (Australian National Shipwreck Database, 2015).

after a fishing trawler was observed within the vicinity of the presumed site. These reports of the potential damage to the wreck prompted Flinders University’s Department of Archaeology staff and students, in conjunction with DEWNR, to conduct a geophysical investigation, in an attempt to locate and identify the wreck.

Remote sensing investigations of the *John Robb* were conducted using an Imagenex Sportscan side scan sonar to acquire data in the vicinity of the presumed shipwreck site. A Garmin global positioning system (GPS) unit, with a standard NMEA string, was incorporated into the navigation software and sonar acquisition software. Hypack (2015) was used as the acquisition software and made automatic location corrections for the sonar. UTM NAVD 83 54S was used as the geodetic parameters throughout the entirety of the survey.

Flinders University’s rigid hulled inflatable boat (RHIB), the *Tom Thumb*, was used to conduct the survey. The boat speed averaged 4 knots throughout the survey, for optimal resolution and the sonar sensor was towed with a 9.8 ft (3 m) layback off the tow-point on the vessel. Offset corrections and laybacks were entered into the on-board acquisition computer, the offset tow-point was 4.1 ft (1.2 m) below the GPS device with no horizontal offsets, and the GPS was set 6.5 ft (2 m) above the water line. Although a depth sounder was used as a

reference for *Monitoring* water depths over the survey area, once the survey was underway it was powered off due to possible interference within the side scan imagery. Depths throughout the survey area were estimated to be 62.3 ft (19 m).

Survey track lines were pre-planned and set infield for the survey. They were based on the *English Heritage Guidance Notes* for archaeological requirements within the acquisition software. Created to increase quality and consistency in underwater archaeology surveys, the *English Heritage Guidance Notes* represents a globally respected set of advice and techniques in geophysical processes (Dix 2008). For wreck site survey designs, these guidelines recommend that a maximum line spacing of 98.4 ft (30 m) be created with alternate lines running in the opposite direction (Dix 2008). Once the track lines were compiled and the shipwreck site was located, tie lines were created across the site, focusing on areas that were identified as anthropogenic material. A total of 27 survey lines were recorded at a line spacing of 82.0 ft (25 m) (Fig. 6). Full coverage across the nadir gap (centralised region of the side scan data display, representing the sonar signal through the water column) adjacent lines were obtained, gaining over 200 % coverage of the seafloor (Fig. 7). High (330 kHz) and low frequency (800 kHz) ranges were used throughout the entirety of the survey. A recorded range of 98.4 ft (30 m) was used on both the starboard and port side of the



Figure 6. Navigation pre-plot track lines for the *John Robb* geophysical survey, with presumed GPS locations. Coordinates are in metres based on the Universal Transverse Mercator Coordinate System, Zone 54S.

side scan in high frequency mode and a recorded range of 196.8 ft (60 m) was used on both starboard and port transducers when operating the side scan in low frequency mode. The survey covered an area of 0.6 sq. miles (1.6 km²) throughout the defined survey area for presumed location of the shipwreck site. Although the 330 kHz frequency was used to obtain the best range while searching for the *John Robb*, it decreased image resolution. Therefore, once the site was located the side scan was operated in high frequency, 800 kHz, to obtain the highest resolution possible.

Once data was acquired, post-processing of the side scan imagery was conducted to account for varying gains, slant range corrections, bottom tracking, and target identification. A full mosaic of the survey was completed using Sonarwiz processing software with high frequency for data quality in high resolution. Dual frequencies sonar settings were used in the processing stage of the survey to review the surveyed area in its entirety and at a higher image resolution. The use of high frequency ensured the detection of any and all potential artefacts that may have drifted from the site as a result of natural or anthropogenic causes. Side scan imagery that presents high-amplitude backscatter depicts a hard return and a lighter image, including objects such as a piece of a wreckage (steel or wood) or reef structures. Low-amplitude backscatter is typically seen as a darker image or potential shadow if the sound was blocked by high backscatter regions (Fish 1990). All data was analysed in both high and low frequency waterfall displays with its associated coverage map to assure a full and in-depth investigation to the site.

For an example of the side scan mosaic depicting the wreck within Gulf St Vincent, see Figure 7. For visual purposes, the mosaic and the water fall displays were slant range corrected once the nadir was reviewed for any potential anthropogenic material within the water column.

Results

As stated previously, a survey of the proposed region within Gulf St Vincent incorporated five possible locations for the wreck of the ketch *John Robb* and identified material believed to be associated with the vessel (Fig. 6). Supplied coordinates reported by SDFSA and Sea Wolves indicate the closest position to the actual wreck, while those proved by DEWNR were observed at a further distance.

From the side scan imagery, the wreck appears to be broken up and scattered about the sea floor. Although some small scour markings were identified within the vicinity of the wreck, no large scouring resulting from trawling scars were noted in any other portions of the surveyed region. In relation to the Australian National Shipwreck Database record for the *John Robb*, which lists the vessel as 76.7 ft (23.3 m) in length and having a beam of 18.7 ft (5.7 m), the main portions of the wreck observed from the side scan imagery were found to be 65.6 ft (20 m) in length and 32.8 ft (10 m) in width. Of the 27 survey lines recorded, dispersed wreckage was identified in 11 of these. Each observed anthropogenic feature was recorded as a target within the processing software for further analysis. A total of 29 anthropogenic targets were identified in total and the dimensions of these targets were measured to determine length, width and height. Targets identified from the side scan imagery reveal a high degree of debris within the vicinity of the wreck. Due to the close proximity and general trend of the debris, targets were identified as potential *John Robb* wreckage.

The target depicted in Figure 7 (actual position) is identified as the major anomaly and most likely represents the *John Robb*. The outline of the wreck can be seen with low reliefs in and out of the wreck. A long shadow from the centre of the wreck material represents a tall, possible mast-like structure standing approximately 9.5 ft (2.9 m) from the seafloor. The wreckage appears to be broken into two sections or potentially partly covered with sediment. Scattered debris can be viewed over an approximate 1 076 sq. ft (100 sq. m) area, which

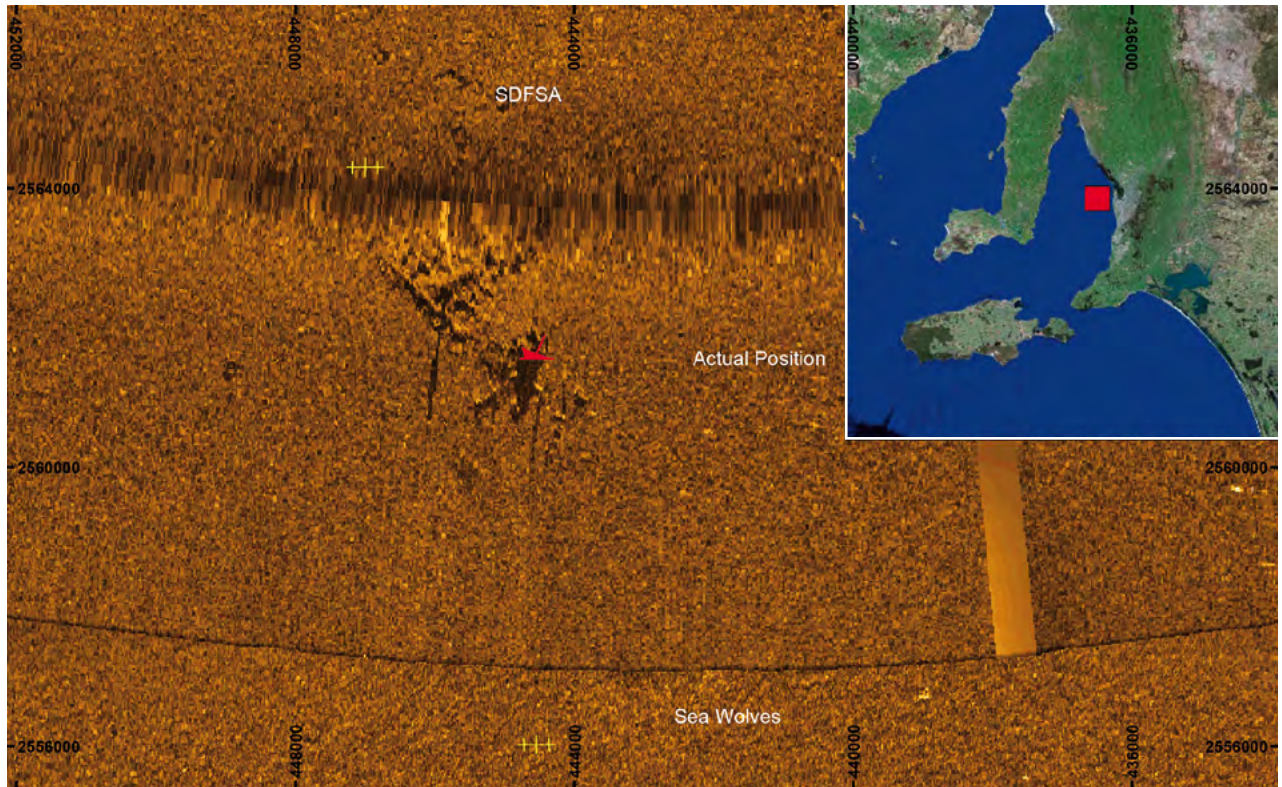


Figure 7. Sidescan mosaic of the *John Robb* with actual GPS location of the wreck, and presumed GPS locations. Coordinates are in metres based on the Universal Transverse Mercator Coordinate System, Zone 54S.

includes a cylindrical item. High backscatter imagery is also observable on both the natural geological seafloor material and the wreckage.

Management opportunities

Ascertaining the precise location of historic shipwreck remains is essential for the successful management and protection of such underwater cultural heritage sites. Community knowledge can be crucial in locating wrecks and corroborating historical accounts of vessel losses. Such knowledge may include information about popular fishing spots, dive sites or areas where anchors are commonly lost or entangled. Before the wide-scale availability of GPS technology, however, reports were provided using approximate bearings taken from a chart and often resulted in errors sufficient enough to hinder attempts to relocate the reported sites. The opportunity to investigate *John Robb* was considered a priority due to the significant discrepancies in reported loss locations for the ketch. The survey anomalies identified through the survey may constitute the primary location of the *John Robb's* remains and will help focus further

attempts in determining the extent of the site. Despite reports from community members to the contrary the survey found no obvious evidence of trawler damage. This remains inconclusive, and diver inspection is still required to assess the site for recent damage. It may be possible for subsequent *Monitoring* of the site to be undertaken primarily using side scan surveys once the baseline data has been established.

Conclusion

Although sites, such as *John Robb*, are often considered lost due to the significant discrepancies in reported wrecking locations, geophysical methods, such as side scan sonar, can identify features in an efficient manner. Results from the 2015 side scan sonar survey show features that likely indicate the true location of the *John Robb*. Situated between the GPS locations of SDFSA and Sea Wolves, the side scan imagery (Fig. 7) of the presumed wreck site, the *John Robb*, can be assessed for future studies, which may include diver investigations and excavations. The wreck, observed in the side scan imagery, was observed

to be highly deteriorated and scattered about the seafloor. As noted previously, a 1954 report in a local newspaper called for the wreck to be broken up due its potential as a navigational hazard. Although no historical record was found about the vessel's degradation, it is the potential result for the wreck's deteriorated state within the side scan imagery. Natural weathering events and other anthropogenic forces, since 1954, could also be destructive causes to the wreck, resulting in scattered debris.

More detailed monitoring and investigation of the wreck's condition and evolution should be carried out. Annual archaeological surveys, including consultation with local divers and dive shops, should be conducted to obtain any and all available information on the wreck's condition in an economical fashion. These annual investigations of the wreck's current condition will add a degree of detailed information for future monitoring purposes. Any information gathered can be used with future geophysical monitoring.

The survey of the *John Robb* shipwreck site demonstrates how information gathered from archaeological sites can be collected in a timely and economic manner that benefits both historical and archaeological research goals. The side scan targets identified through the survey may constitute the

primary location of *John Robb's* remains and help focus further attempts in determining the full extent of the site. Further geophysical investigations at the *John Robb* could include the use of a sub-bottom profiler and a magnetometer. The use of these equipment can further identify items that may be buried. A full geophysical survey should be completed on the *John Robb* wreck site, including consultation with DEWNR and local archaeologists for the purpose of identification, documentation and preservation of the wreck.

Precise geographical locations and diver investigations of historic shipwreck remains, such as those of *John Robb*, are of key importance in the protection of archaeological sites. Community knowledge, scientific diving operation and geophysical methods should continue to be utilised for locating shipwreck sites and for corroborating historical accounts of lost vessels. In the case of the *John Robb*, accounts from community members recorded in local newspapers, reports from local fisherman, and geophysical surveys contributed to the wreck finding, including its history. With the current data collected and with further investigations at the site, a protective mechanism with proper identifications can potentially be included in navigational charts, thereby further protecting these archaeological sites.

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References

- Australian Government Department of the Environment, Australian National Shipwreck Database. Viewed 1 December 2015, <<https://dmzapp17p.ris.environment.gov.au/shipwreck/public/wreck/wreck.do?key=5466>>.
- Australian Lloyds, 1864, *Rules and regulations with registration tables applicable to the varieties of colonial timbers used in shipbuilding, scale of fees, etc.* Mason & Firth Printers, Melbourne.
- Barrier Miner, National Library of Australia. Viewed 2 February 2016, <<http://nla.gov.au/nla.news-article/49424569>>.
- Bullers, R. and Shefi, D., 2009, Mary Ellis (1897–1907): workhorse of the South Australian Mosquito Fleet. In: *International Journal of Nautical Archaeology* **38**.1: 58–70.
- Chronicle, National Library of Australia. Viewed 2 February 2016, <<http://nla.gov.au/nla.news-article/93915266>>.
- Collier, J. and Brown, C., 2004, Correlation of sidescan backscatter with grain size distribution of surficial seabed sediments. In: *International Journal of Marine Geology, Geochemistry and Geophysics*. Marine Geology, **214**: 431–449.
- Cowley, D., 2010, *Remote Sensing for archaeological heritage management*. EAC Occasional Paper No. 5. Occasional publication of the aerial archaeology research Group No. 3B.
- Dix, J., Bastos, A., Plets, R., Bull, J. and Henstock, T., 2008, *High resolution sonar for the archaeological investigation of marine aggregate deposits*, University of Southampton, England.

- Fish, J. P. and Carr, H. A., 1990, *Sound underwater images: a guide to the generation and interpretation of sidescans sonar data*. Lower Cape Pub Co; Special limited edition.
- Foley, D. and Mindell, D., 2002, *Precision survey and archaeological methodology in deep water*. Massachusetts Institute of Technology.
- Harbison, J., Kirkegaard, I., Cugley, J. and Gackle, A., 2009, *Gulf St Vincent: a precious asset*. Friends of Parks Inc./Friends of Gulf St Vincent, Adelaide.
- Jeffrey, W., 1992, *Maritime archaeological investigations into Australian-built vessels wrecked in South Australia*, *IJNA* **21.3**, 209–19.
- Lack, J., 1976, 'Robb, John (1834–1896)', *Australian Dictionary of Biography*, National Centre of Biography, Australian National University.
- Parsons, R., 1983, *Ketches of South Australia: a record of small sailing ships on the coast of South Australia 1836–1970*. Rev. 3rd ed. Magill, S.A.
- Parsons, R., 1986, *Southern passages: a maritime history of South Australia*. South Australia. Department of Marine and Harbors. Netley, South Australia Wakefield Press.
- Port Lincoln Times, National Library of Australia. Viewed 3 February 2016, <<http://nla.gov.au/nla.news-article/96609667>>.
- Reconciliation Australia 2012, Viewed 3 February 2016, <<http://www.reconciliationsa.org.au/learn/map—of—aboriginal—australia>>.
- Reynolds, J.M., 1997, *An introduction to applied and environmental geophysics*. Wiley, Chichester.
- Spalding, M., 2011, *Perverse sea change: underwater cultural heritage in the ocean is facing chemical and physical changes*. *Cultural Heritage & Arts Review*.
- State Library of South Australia. Viewed 2 February 2016, <<http://collections.slsa.sa.gov.au/resource/BRG+42/119/83>>.
- Thiele, R., 1987, *Ketch hand: the twilight of sail in South Australian waters*. Mainsle Books, Portland, VIC.
- The Advertiser, National Library of Australia. Viewed 3 January 2016, <<http://nla.gov.au/nla.news-article/48116255>>.
- The Advertiser, National Library of Australia. Viewed 3 January 2016, <<http://nla.gov.au/nla.news-article/74153445>>.
- The Advertiser, National Library of Australia. Viewed 3 January 2016, <<http://nla.gov.au/nla.news-article/47611149>>.
- The Kangaroo Island Courier (Kingscote, SA: 1907–1951), National Library of Australia. Viewed 02 January 2016, <<http://nla.gov.au/nla.news-article/191417409>>.
- Ward, C. and Ballard, R., 2004, Deep-water archaeological survey in the Black Sea. In: *International Journal of Nautical Archaeology* **33.1**: 2–13.
- Woodford, Z., 2007, *An archaeological study of Hecla: a complete wooden ketch from South Australia's Mosquito Fleet*. Unpublished Masters thesis, Flinders University, S.A.

THE USE OF HISTORICAL IMAGES TO DATE ARCHAEOLOGICAL SITES

An answer to 'A response to the article, 'A possible pre-Tasman canoe landing site, or *tauranga waka*, in Golden Bay, South Island, New Zealand', by Rüdiger Mack and Rosanne Hawarden' published in the *Bulletin of the Australasian Institute for Maritime Archaeology* (2015), 39: 131–138

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Introduction

This response to the article by Wallace, Anderson, Jenkin and Horry (2015) clarifies the approach needed when using early historical images to interpret and date archaeological evidence in the Pacific. To summarise briefly, Mack and Hawarden (2014) surveyed a possible *tauranga waka*, or canoe landing site (Fig. 1) in Wainui Bay, Golden Bay, as they had hypothesised that it was possibly of pre-Tasman origin. The earliest images (Fig. 2) of the vicinity of the surveyed site are an engraving in the 1705 edition of *Noord en Oost Tartarye* (NOT) (Witsen 1705 I: 173), and two illustrations copied by hand into edited journals of Abel Tasman's voyage, which were produced in Batavia in 1643 (Fig. 3) (Heeres 1898: 21; Sharp 1968: 130). The archaeological investigation itself is not questioned but Wallace *et al.* (2015) have challenged Mack and Hawarden's claim that the NOT image contains supplementary information, which is not found in the illustrations of the Tasman journal still extant, in particular Māori canoes at the surveyed *tauranga waka* site. They questioned the artistic merit of the NOT image which is different in perspective and proportions, and shows a more detailed coastline.

Criticism of historic images when triangulated with text and archaeological data

The use of images is an established way of providing evidence in a historical context, as 'images record acts of eye witnessing' (Burke 2001: 14). It is necessary to use great care when critically assessing which aspects of an image can be used



Figure 1. Canoe landing site or *tauranga waka* at Taupo Point, Wainui Bay, Golden Bay, South Island of New Zealand.



Figure 2. *Vaertuig en Gedaente der inwoonders van Selandia Nova*. Vessel and appearance of the inhabitants of New Zealand (Witsen 1705: 171).

as evidence of a place or for an event and therefore linked to the archaeology of that place. Howell and Prevenier (2001: 61–8) have determined the main elements of source criticism to be:

1. The historiography, genealogy and genesis of the document, and whether it is original, a copy, or a copy of a copy and describing the circumstances related to its production;
2. The authorial authority of the document, and the relationship of the author to the subject matter including the competence and trustworthiness of the author; and
3. The originality of the document, and whether it contains new information or conveys what is already known and the multiple interpretations that can be made of the text and images.

Wallace *et al.* (2015: 131) start from the assumption that the NOT illustration is 'an engraving [...] after the images generally attributed to Gilsemans of



Figure 3. *Aldus verthoont de Moordenaers Baij*. Thus Appears the Murderers Bay (Journaal van Abel Tasman Jansz. 1642, scan 65; Sharp 1968: 125–126).

some 60 years earlier'. They note that the NOT image 'fails to fall into any documentary category' and that it adds 'clouds, coastline and shoreline [...] as features designed to create a pleasing package, rather than to ensure documentary precision' (Wallace *et al.* 2015: 134). They assert that all elements in the NOT illustration of New Zealand, except the large canoe or waka in the foreground, are 'based on fabricated content'. However, their assumption is not based on an investigation of the genealogy of the Witsen illustration. They should have considered whether the three illustrations were copied separately from one or several original sources, or alternatively the NOT image was a copy from the images in one of the copies of Tasman's journal. Their references indicate that Mack's (2004; 2006) earlier research was not consulted. Mack made the point that the NOT image is derived from an original coastal drawing included in the journal of Francois Jacobszoon Visscher, the pilot major of the expedition (Mack 2006: 77–78; Sharp 1968: 171; Heeres 1898: 83). In noting the differences in details in the images, a check to validate these against external reference points is the first step to assess whether these new details are derived from additional original sources. In the case of the NOT image this can be done by comparing the coastline in the image with the topography and known archaeological sites of Wainui Bay. Another step is to compare the vessels near the shore with textual references from the surviving written records of Tasman's voyage. This was done by Mack (2004; 2006), and Mack and Hawarden (2014).

Following on from their unsupported assumptions, Wallace *et al.* (2015) see no need to reflect on the identification of topographical features of the Wainui Bay coast in the NOT illustration. Unlike Mack and Hawarden (2014: 114), they have no photographic evidence of a visit out to sea to assess what Tasman's artists would have observed. Wallace *et al.* (2015: 137) state that there is no 'written or graphic evidence to show vessels near the shoreline' in Golden Bay. However, Tasman's journal specifically mentions indigenous vessels near the shore on 18 and 19 December 1642 (Sharp 1968: 120–123).

Rather than validating the images against external reference points, Wallace *et al.* (2015) attempt to link the differences in the images to developments in Dutch art history in the 17th century. This is arguing by analogy with all the pitfalls of that methodology where conclusive arguments cannot be reached. In the images of Tasman's contact

with Tongatapu, Wallace *et al.* (2015) argue that the NOT engraving is flawed as it shows hills in the background. They use this as an analogy to develop a hypotheses about the Wainui Bay image. Another interpretation of the NOT image of Tongatapu is that these are a low bank of heaped clouds where the island reaches 30 m above sea level. Both Mack and Hawarden have made trips out to sea to view the topography and have observed this phenomenon. Wallace *et al.* (2015) determine that the images belong to a genre known as 'history painting' but fail to provide conclusive evidence that the NOT illustrations were engraved in the style of this genre. History painting is a term which is used for large frescos and oil paintings depicting a moment in a biblical or mythological story, or allegorical scenes, but the term is not used for engravings in works of geography, maritime exploration, anthropology or science (Stechow 1988).

Wallace *et al.* (2015) do briefly mention Nicolaes Witsen, the wealthy and influential Dutch author and publisher of the book but do not critically assess his authorial authority. He did not produce the two volumes of NOT for entertainment but with an intent that we would identify today as scientific in nature (Witsen 2017; Peters 2010: 77).

Conclusion

Wallace *et al.* (2015) develop their arguments without following the principles of source criticism, which leads them to flawed results. They do not analyse the genealogy and originality of the NOT image. They fail to critically assess the author and his intended purpose in producing the work. There is no analysis of Dutch schools of maritime art or the engraving conventions of the time. Greater care needed to be taken by Wallace *et al.* (2015) before rejecting the NOT images as admissible evidence in the context of the archaeological investigation by Mack and Hawarden.

References

- Burke, P., 2001, *The use of images as historical evidence*. Reaktion Books, London.
- Heeres, J.E., 1898, *Abel Janszoon Tasman's Journal*. Frederik Muller, Amsterdam.
- Howell, M. and Prevenier, W., 2001, *From reliable sources*. Cornell University Press, Ithaca.
- Journal van Abel Tasman Jansz., 1642, Nationaal Archief, The Hague, Aanwinsten Eerste Afdeling, nummer toegang 1.11.01.01, inventarisnummer 121. Viewed 5 February 2017 <www.gahetna.nl/en/collectie/archief/inventaris/gahetnascans/eadid/1.11.01.01/inventarisnr/121>.
- Mack, R., 2004, Did Dutch sailors land in Wainui Bay on 18 December 1642? The first printed illustration of New Zealand. *Turnbull Library Record* **37**: 13–28.
- Mack, R., 2006, The source of the first printed illustration of New Zealand. *Turnbull Library Record* **39**: 75–82.
- Mack, R. and Hawarden, R., 2014, A possible pre-Tasman canoe landing site, or *tauranga waka*, in Golden Bay, South Island, New Zealand. In: *Bulletin of the Australasian Institute for Maritime Archaeology* **38**: 111–124.
- Peters, M., 2010, *De wijze koopman. Het wereldwijde onderzoek van Nicolaes Witsen (1641–1717), burgemeester en VOC-bewindhebber van Amsterdam*. Uitgeverij Bert Bakker, Amsterdam.
- Sharp, A., 1968, *The Voyages of Abel Janszoon Tasman*. Oxford University Press, Oxford.
- Stechow, W., 1988, *Dutch landscape painting of the seventeenth century* (2nd edn.) Phaidon Publishers Inc., New York.
- Wallace, P.T., Anderson, G., Jenkin, R. Horry, D., 2015, A response to the article, 'A possible pre-Tasman canoe landing site, or *tauranga waka*, in Golden Bay, South Island, New Zealand' by Rüdiger Mack and Rosanne Hawarden, published in the *Bulletin of the Australasian Institute for Maritime Archaeology* (2014), 38: 111–124. In: *Bulletin of the Australasian Institute for Maritime Archaeology* **39**: 133–8.
- Witsen, N., 1705, *Noord en Oost Tartarye*. Vols. 1 and 2 (2nd edn.). Francois Halma, Amsterdam.
- Witsen, N., 2017, *Noord en Oost Tartarye*. B. Naarden (ed.), Facsimile editie met transcriptie in twee talen (Nederlands en Russisch). Viewed 5 February 2017, <<http://resources.huylgens.knaw.nl/witsen>>.

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