Bulletin of the Australasian Institute for Maritime Archaeology (2013), **37**: 26–32

Exploring the potential for the archaeological application of remotely operated underwater vehicles (ROVs) in the Australian context

Iain Gately
Maritime Archaeology, Faculty of Humanities, University of Southern Denmark, Stormgade 69, Room 16, 6700 ESBJERG, Denmark
Email: icgately@gmail.com

Background

Since the first major archaeological investigations by remotely operated vehicles (ROVs) in maritime archaeology in the late 1980s and early 1990s (McCann & Freed 1994; McCann & Oleson 2004), they have steadily gained prominence. Recent volumes such as *Archaeological Oceanography* (Ballard 2009) and *Ships from the Depths* (Søreide 2011) have further increased the standing of this new field of archaeological science, and all the while archaeologists are looking for new ways in which the technology can be put to use (Søreide & Jasinski 2008; Webster 2009; Bingham *et al.* 2010; Ford *et al.* 2010). Yet although efforts have been undertaken internationally to both make use of and explore the potential of ROVs in archaeology, the same cannot be said of Australia. With the exception of David Mearns' (2009) well-publicised search for the HSK *Kormoran* and *Sydney II*, most efforts by archaeologists making use of ROVs in Australian waters have passed relatively unnoticed.

There are a number of reasons for this, notably that most Australian academic institutions do not have the resources at their disposal to deploy the kinds of ROVs that regularly make headlines. ROVs such as *Hercules*, used by the National Oceanographic and Atmospheric Administration (NOAA), or the Comanche Sub-Atlantic ROV used by Mearns to find the *Sydney* are massive vehicles, weighing in excess of two tonnes (Newman *et al.* 2009: 29), and which require dedicated support vessels and crew. The total costs for getting such an ROV in the water have therefore been estimated at upwards of AUD $60 000.00 a day (Irion *et al.* 2008: 80).

Costs of this magnitude may give some insight into why ROVs have such a poor representation in Australian maritime archaeology. However, there are a number of tasks and situations where smaller, more affordable ROVs can make significant contributions. The purpose of this paper is to highlight these areas where the archaeological application of a small, commercially available ROV has the potential to provide significant benefits, making a case for more widespread use of the technology within the Australian maritime archaeological sphere. In particular this paper focusses on the application of ROVs in underwater cultural heritage management and underwater imaging, as well as highlighting examples of work where ROVs have already been used with excellent results.

Heritage management

Shipwrecks older than 75 years in Australian waters are automatically granted protection under the *Historic Shipwrecks Act 1976*, while the Australian Government Minister of the Environment can also make a declaration to protect any wreck, articles and relics, which are less than 75 years old, if they are deemed to be historically significant. Importantly, the legislation provides guidelines for the protection of a wreck deemed to be of historical value. Section 7(1) of the *Historic Shipwrecks Act 1976* specifically states that:

> …the Minister may, by notice published in the *Gazette*, declare an area (not exceeding 200 hectares) consisting of sea or partly of sea and partly of land within which a historic shipwreck is, or a historic relic is or historic relics are, situated to be a protected zone.

When first created, this Act did not explicitly provide any guidelines for the management of wrecks once they had been granted protection. This, however, was subsequently rectified following the publication of *Guidelines for the Management of Australia's Shipwrecks* (Henderson 1994).

Standard practice for guiding the protection of cultural heritage sites in Australia is done through the application of Conservation Management Plans (CMP) based on principles established in the Burra Charter. Although originally intended as a means of managing terrestrial cultural heritage sites, elements of the Burra Charter are applicable to underwater cultural heritage, in particular the articles dealing with Conservation Principles (Articles 2-13), Conservation Processes (Articles 14–25) and Conservation Practice (articles 26–28). Much like terrestrial sites of cultural significance, submerged sites can be assessed with respect to their significance, specific fabric and potential threats in order to formulate a CMP for the site. The guidelines for the formulation of management plans for shipwreck sites are addressed in Henderson (1994: 9–14).

Importantly, some of the guidelines stated in the Burra Charter are similar to those in the UNESCO 2001 *Convention on the Protection of the Underwater Cultural Heritage* (CPUCH). Although Australia is not yet a signatory to the CPUCH, it is stated in Section 4.1(a) of the *Australian Underwater Cultural Heritage Intergovernmental Agreement* (AUCHIA) that Australia maintains best practice with the 'Rules' outlined in the CPUCH.

With regards to the management of underwater cultural heritage, Rule 1 in the Annex of the CPUCH states that 'the protection of underwater cultural heritage through *in-situ* preservation shall be considered as the first option'. In addition it is also stated in Rule 4 that 'activities directed at underwater cultural heritage must use non-destructive techniques and survey methods in preference to recovery of objects', although it goes on to note that recovery is permitted if required to provide for effective protection of underwater cultural heritage.

Consistent with this thrust, Article 28.1 of the Burra Charter states that

> …disturbance of significant fabric for study, or to obtain evidence, should be minimised. Study of a place by any disturbance of the fabric, including archaeological excavation, should only be undertaken to provide data essential for decisions on the conservation of the place, or to obtain important evidence about to be lost or made inaccessible.

In both cases, the preferential choice is *in-situ* management of the cultural heritage.

Recently the Australian Historic Shipwreck Protection Project (AHSPP) has undertaken research to determine the viability of reburial as a means of preservation and management, in particular 'to try and develop a protocol for the rapid excavation, detailed recording and subsequent *in-situ* preservation of significant shipwrecks and their associated artefacts' (Veth *et al.* 2011: 753). Nevertheless, such an approach may not be viable for a number of the wrecks found in the waters off Australia's coast. Other approaches, able to be easily and affordably implemented, must also be investigated in order to safely manage, monitor and protect Australia's underwater cultural heritage.

Such an approach is the Monitoring, Safeguarding and Visualising North-European Shipwreck Sites (MoSS; initially known as The Monitoring of Shipwreck Sites) project, a joint venture begun in 2001 by Finland, the Netherlands, Germany, Sweden, Denmark and the United Kingdom. The project was 'instigated with the aim of developing a methodology for monitoring protocols, to form a standard for the management of European historical wreck-sites' (Palma 2005: 323). A major part of the project involved visualizing the sites to achieve a better understanding of the habitat and degrading conditions as well as the production of images representing the wreck (Palma 2005: 323). Importantly, the project saw the development of management plans for the four wrecks assessed during the project, the *Vrouw Maria,* the *Burgzand Noord,* the *Eric Nordevall* and the Darss Cog.

A key element of each of the plans is the monitoring of the wrecks themselves. In the case of the *Vrouw Maria,* the wreck is monitored through the use of a series of controlled photographs, which have been taken since 2000 (Tikkanen *et al.* 2004: 22). A similar system of photograph logging has been put in place for the wreck *Burgzand Noord* (Manders 2004: 19), while the management plan for the *Eric Nordevall* also notes the need to introduce 'continuous or intermittent sampling and data logging at the site and on the ship, taking in data on the environment there, as well as on the condition of the ship' (Cederlund 2004: 21).

For an Australian example, there is the recent survey and assessment of shipwrecks located in Torres Strait and the northern extents of the Great Barrier Reef (Illidge *et al.* 2004). Much like the MoSS project, visual recording of the wreck sites played a major role, with shipwrecks 'inspected and recorded to determine the identity of the wreck, to record surface artefacts and to make a video baseline record for future monitoring' (Illidge *et al.* 2004: 327). Although the wrecks were initially located through the deployment of a magnetometer, subsequent investigations of the wrecks were conducted by divers using Surface Supplied Breathing Apparatus (SSBA) (Illidge *et al.* 2004: 349).

In both these cases, the monitoring and documentation of the wrecks were performed by divers. What must be kept in mind however are the recurring issues of cost, time and efficiency that are associated with the deployment of divers. Cost in particular is a major issue for maritime archaeology in Australia given the decreasing funding base from both State and Federal Government. It was noted in the AHSPP that there has been no increase in funding by the Federal Government for the past 20 years and that 'most jurisdictions in Australia have either remained at funding and staffing levels or decreased with operational money becoming scarcer in successive financial years' (Veth *et al.* 2011: 755).

The deployment of divers for comprehensive wreck inspection is costly. In the management plan for the *Burgzaand Noord,* the total cost to deploy a team of divers in the water for a day when conducting the yearly inspection of the site is EUR €2 230.00 (Manders 2004: 19), or approximately AUD $2 850.00. According to Michael Sparg (2012 pers. comm. 5 June), owner of commercial diving company *Ecomarine Services,* to put a team of divers in the water for an inspection only could cost between AUD $3 500.00 and AUD $4 000.00 per day. This cost is also dependent on there being a decompression chamber within two hours steaming time of the wreck site. If this is not possible, the cost to have a decompression chamber on board the diving vessel must also be factored in, which increases the total cost dramatically (M. Sparg, 2012, pers. comm. 5 June). Given that there are over 7 500 documented shipwrecks in Australian waters (Veth *et al.* 2011: 1), the estimated cost of monitoring even a representative sample of sites by deploying divers is clearly high and beyond current operating budgets.

An example of this can be seen in an article on the management of the Japanese midget submarine M24. It is noted that 'the engagement of commercial dive teams to undertake the archaeological documentation work under supervision has been prohibitive financially' (Smith 2008: 82), with archaeological investigation of the submarine conducted through 'a succession of ROV surveys' (Smith 2008: 82).

ROVs as an alternative

With the issue of prohibitively high costs associated with the deployment of divers in mind, it is argued in this paper that the deployment of small, commercially available ROVs is a more cost efficient and effective alternative. This can also provide a simpler solution to the routine monitoring and inspection of shipwrecks sites in <150 m of water (the maximum depth rating for the ROVs focussed on in this paper) around Australia. Compact, easy to use and equipped with high definition video and still cameras, an ROV can perform a routine inspection of a site in a short period of time and only requires a small team to operate it.

Training and familiarisation with a small ROV is a relatively simple task, achievable in a couple of days. To give an example, in 2010, as a member of the Mazotos wreck project (Demesticha 2010), I was placed in command of the project's ROV. The operational basics were learnt in about a day and a half, merely through appropriate instruction and observing the actions of Markos Garras, the project's Technical Director.

For the purpose of this paper three commercially available ROVs will be focussed upon. These are the SeaOtter-2, produced by JW Fishers; the SYSROV Mini 150C, produced by Sysmarine; and the PRO3XE, produced by VideoRay. All three ROVs are depth-rated to 150 m, and weigh less than 20 kg. Their small size enables them to be launched from a small boat, and operated by a single person. The ROVs are equipped with underwater cameras and lighting, enabling easy video documentation of a wreck site. The SeaOtter-2 retails at AUD $19 985.00 while the SYSROV Mini 150C costs AUD $14 526.00. The PRO3XE is more expensive, retailing at AUD $31 400.00. A full list of the ROVs' specifications is given in Appendix A.

Once the initial capital outlay is made for the ROV, the cost of deploying it in the water to routinely perform an inspection of a wreck is far less than it would be to do the same task with a team of divers. To give an example of these costs, a number of elements must be considered. The first major cost associated with deployment would be the cost of the boat use. According to prices listed on the website for Boab Boat Hire, the cost associated with hiring a 20-ft boat with a 150 hp engine and an offshore range of 15 nautical miles, is AUD $445.00 per day (<http://www.boabboathire.com.au/rates.php?boat=CentreCab>). Such a boat would be easily large enough for the deployment of one of the ROVs considered in this paper. The ROV would also require use of a small 800 Watt/240 Volt generator to power it. A generator fitting these specifications, the Homelite HGN 1200B, was found on the website for Australian hardware retailer Bunnings for AUD $325.00 (<http://www.bunnings.com.au/products_product_generator-petrol-homelite-1100w-portable-1xac-hgn1200b_P6210240.aspx?page=2>).

In contrast, a much larger boat would be required to deploy a team of divers to inspect a wreck site. The Australian/New Zealand Standard for Occupational Diving Operations states in Section 6.3.3 that for dive depths between 1.5 and 30 m, a minimum of four personnel are required to be present: one supervisor, one diver, one diver's attendant and one standby diver. Even if the dive supervisor acts as the diver's attendant (which is dependent on the results of a risk assessment performed prior to the dive), the space taken up by three divers and their gear will still require a larger boat than would be necessary for two personnel and a small ROV. The cost to hire a boat suitable to deploy a team of three divers can be as much as AUD $1 200.00 per day (M. Sparg 2013, pers. comm. 6 March). This is before considering the aforementioned cost of AUD $3 500.00 to AUD $4 000.00 for the divers themselves.

Of course *in-situ* conservation and allied measurement tasks cannot be carried out by an ROV. Overall, however, an ROV could be considered to pay for itself within a small number of deployments. Additionally, an ROV is capable of many more hours at depth than even SSBA divers, allowing for more data capture over the same span of time on a site.

As early as 1989, Michael McCarthy of the Western Australian Museum's Department of Maritime Archaeology made use of a small ROV to help with investigations of the Japanese submarine *I-124* and a wreck thought to be the SS *Koombana*. In his investigation of the *Koombana*, McCarthy (1991: 77) notes that following deployment of the ROV with an attached wide angle lens the 'photographic results were outstanding and attested to the quality of the record possible'. Although some difficulties arose when using the ROV to investigate the wreck of the *I-124*, it still played an integral role in the positive identification of the submarine (McCarthy 1990: 25).

In the investigation of the wreck of the Australian submarine *AE2*, a small ROV was used by the research team, composed of members of the *AE2* Commemorative Foundation (AE2CF) and the Turkish Institute of Nautical Archaeology (TINA). It was to conduct 'a comprehensive visual survey of the submarine and its surroundings' and 'to deploy an ultrasonic thickness gauge, allowing assessments to be made of the residual condition of *AE2*' (Neill & Graham 2008: 98). The ROV was of similar size to the SeaOtter and the Mini 150C, and it is noted that 'because of the light weight and relative simplicity of the vehicle, a two-person team was able to operate it throughout the expedition' (Neill & Graham 2008: 98).

The ROV proved to be a valuable recording tool, collecting over 12 hours of video footage, deployed almost every day of the expedition (Neill & Graham 2008: 99) and provided 'a comprehensive video survey of the submarine's entire visible area...including clear images of marine flora growing on the submarine and corrosion effects' (Smith 2008: 6). This same video survey provided the major data set available for subsequent methodical analysis of the wreck (Smith 2008: 6).

The ROV also undertook survey of the seabed surrounding the submarine for associated debris. This was achieved through establishing survey lines parallel to the submarine's hull at 3-m intervals, determined through use of the ROV's scanning sonar (Neill & Graham 2008: 112). It was also noted that due to the ROV pilot maintaining a consistent altitude during the runs, it would 'be possible to build a reasonable seabed profile from the ROV depth records' (Neill & Graham 2008: 112).

Unfortunately, the readings taken with the ultrasonic thickness gauge were all too high, appearing to include concretions on the hull of the submarine in their measurements, rather than just the hull plating (Smith 2008: 26). Despite these issues, the actual measurements taken with the ROV were comparable to those taken by the divers (Rikard-Bell 2008: 148), indicating that with proper calibration of the equipment the ROV remained a viable method of deployment for the thickness gauge. It was also noted that the divers 'found it extremely difficult to get steady readings' when using the thickness gauge (Rikard-Bell 2008: 147), a difficulty that was not experienced by the ROV pilot.

These two examples illustrate the successful use of small, commercially available ROVs in the Australian context. They exemplify the identification, recording and indeed analytical tasks that are envisaged for ROVs. Through the deployment of a small ROV, equipped with video and still cameras, maritime archaeologists will be able to gather a large corpus of information about wreck sites such as the wreck's condition, level of degradation, and any external factors such as scouring or damage by anchors, which may affect its degradation. This can be done for a fraction of the cost and time that it would take to achieve the same results with deploying diver teams—and these likely capped at <50 m depth for routine surveys. In turn, this information will facilitate more detailed cultural heritage management plans for these sites. An example might be the deployment of an ROV to inspect the effects on a wreck site of an extreme weather event, known to lead to scouring and the sudden exposure of buried elements (Veth *et al.* 2011: 2), in order to help determine future management strategies. The end result is an expanded and effective methodology to safely manage, monitor and protect Australia's underwater cultural heritage.

Underwater imaging

There is also a great potential for the application of ROVs in site mapping and underwater imaging. An excellent example of the capabilities of this technology can be seen in the work undertaken by Mahon and colleagues at the submerged ancient town of Pavlopetri (Mahon *et al.* 2011). The town is located 4 m beneath the surface in the Bay of Vatika, in south-eastern Greece (Harding *et al.* 1969), covering an area of approximately 50 000 m^2 (Mahon *et al.* 2011: 2315). In the 2010 season, a diver-held stereo-vision system was used with corresponding Simultaneous Localisation and Mapping (SLAM) software to create three-dimensional visual reconstructions of areas in the site. Although the equipment was used by divers during the 2010 season, it was noted that it could be easily fitted to an ROV or autonomous underwater vehicle (AUV) which, in turn, is also able to power the system (Mahon *et al.* 2011: 2316). Oscar Pizarro (2012, pers. comm. 11 June) from the Australian Centre for Field Robotics indicated that the same system was also mounted to an AUV in the 2011 season in order to map a larger area.

Similar work has been performed at Chios (Foley *et al.* 2009). A detailed and comprehensive photomosaic of the wreck Chios A was produced, with the data required collected in a little over nine hours bottom time (Foley *et al.* 2009: 278). The AUV was able to travel along a set of track lines 2.5 m above the wreck taking photographs every three seconds (Foley *et al.* 2009: 278). Once the photographs had been collected, they were combined with data relating to the AUV's position in order to create a photomosaic of the wreck. Although the work was performed by an AUV, the techniques used can easily be applied to an ROV, as can be seen in the photomosaics produced of the wrecks at Ashkelon and Skerki Bank (Ballard *et al.* 2002; McCann & Oleson 2004).

Determining the actual positioning of the ROV or AUV once it is in the water however is one of the major shortcomings of this smaller ROV and AUV technology. For routine inspections of heritage sites, this does not pose a serious problem since the primary purpose of the ROV's deployment would be to visually inspect the condition of the wreck and surrounding area, rather than to accurately map it. If the full capabilities of ROV technology are to be realised however, particularly as they relate to underwater imaging, accurate methods of underwater positioning must be implemented. In the case of the Chios expedition, the AUV was positioned in the water through the use of Long Baseline (LBL) transponders. These transponders are placed on buoys, which must then be moored around the wreck. The buoys communicate with the ROV or AUV through sonar. The position of the ROV is then calculated relative to the fixed GPS coordinates of the transponders. Typically, three or more transponders must be deployed for the system to be effective (Zielinski & Zhou 2005: 256).

There are two main problems with this system, however. Firstly, the extra space that would be taken up by the transponders may, in some cases, negate the advantages provided by the small size of the ROV. Secondly, the set-up time for the transponders is significant. Another option that can be considered is a Super Short Baseline (SSBL) positioning system. These systems operate through the deployment of a small, tightly integrated transducer array that can either be mounted on a pole to be placed over the side of a vessel, or in some cases on the bottom of the vessel itself. The advantage here is the ease of deployment that the system provides, allowing for accurate ROV positioning with minimal impact in terms of time and space.

A number of SSBL systems are available (Zielinski & Zhou 2005). Some ROV production companies including Seabotix and VideoRay also offer fully integrated SSBL systems as options for their ROVs. For example, two positioning systems are available from VideoRay that are compatible with the PRO3XE, a SmartTether produced by VideoRay, and an SSBL system manufactured by Tritech. An important factor that must be considered though is the price of these units, with some SSBL systems available costing almost as much as the ROVs themselves. In the case of the VideoRay systems, the SmartTether costs AUD $24 000.00 while the SSBL system costs AUD $26 000.00. As with the ROVs, the cost must be weighed up against the potential benefits provided by the equipment. Often, an entire wreck site can be surveyed in just a few hours by the ROV (Ballard *et al.* 2000; Singh *et al.* 2000; Webster *et al.* 2001). This is without the need to deploy divers or, alternatively, leaves them free to focus on tasks that the ROV is unable to perform.

In-situ preservation

As mentioned previously, since the introduction of the CPUCH, there has been a strong move in the archaeological community towards *in-situ* preservation, considered as the first though not the only priority. For iron shipwrecks, the use of sacrificial anodes as a means of halting corrosion and beginning the conservation process *in situ* has been pioneered in Australia (MacLeod 1989; 1990 & 1995). The technique, in which a reactive metal such as a zinc or aluminium alloy is electrically connected to the less reactive iron artefact, has proven very effective. The placement of the anodes however, which usually need to be affixed with a clamp or other mechanism (Gregory 1999), is a task that is best performed by a diver. Although it is suggested by Smith (2008: 10) that an ROV could be used for the annual replacement and affixing of anodes to the wreck of the *AE2*, such a task would require the use of an ROV far more advanced than those covered in this paper.

Reburial of a ship's structure is another method of *in-situ* preservation that has gained more prominence in recent years, particularly wooden shipwrecks (Ortmann *et al.* 2010; Richards 2012). Reburial stabilizes a wreck site and aims to decrease its overall deterioration rate with minimal continuing maintenance costs (Veth *et al.* 2011: 7). There are a number of methods that can be used. They range from dumping vast quantities of sediment onto the wreck site from a hopper barge (Oxley 1996) to the utilization of geotextiles that assist the collection of sediment from the water column (Palma 2005; Curci 2006; Bjordal & Nilsson *c.* 2008). It goes without saying that these tasks necessitate putting divers in the water, as the equipment and techniques required for these methods are far beyond the capabilities of current ROVs.

Of course, the *in-situ* preservation of a shipwreck is an ideal scenario. Natural processes of degradation coupled with the enormous pressure that is being placed on the seabed by human activities, such as aggregate extraction and offshore construction, will lead to situations where the only option for the continued preservation of some sites will be excavation. To date, there have been no ROVs designed that are capable of performing this task to the levels of precision that can be achieved by human divers.

Despite these limitations, however, there still remains the potential for the archaeological application of ROVs towards the *in-situ* preservation of wrecks. Overall there has been a lack of subsequent monitoring to determine the effectiveness of the reburial of cultural materials (Gregory 1998), with Veth *et al.* (2011: 7) noting that it is imperative that pre- and post-burial studies take place in order 'to gain a full understanding of the changes occurring in the local environment and the associated deterioration of archaeological material'.

Much like the deployment of an ROV for visual survey, the deployment of an ROV to perform environmental analysis presents an efficient, low cost alternative to putting divers in the water for the same task. For example, part of Brendan Foley's (2009: 284) work at Chios also involved the use of onboard chemical sensors to determine 'the levels of biological and anthropogenic activity'. The past several years have seen significant advances in the development of *in-situ* sensor technologies, which allow for a broad spectrum of chemical analyses to be undertaken by ROVs (Camilli *et al.* 2004). These analyses will then allow for an accurate assessment to be made of the success of the reburial strategy in ensuring the long-term preservation of the site (Nyström Godfrey *et al.* 2007; Richards *et al.* 2007).

Historically, the archaeological investigation of wreck sites containing human remains has not followed structured guidance (Smith 2004) although there has been discussion on the topic and the ethical issues it presents (McCarthy 2004; Mays 2008). The issue is of relevance to Australian maritime archaeology, as there are a number of sites in the waters off Australia's coast where those entombed in the wreck have known identities and surviving family members and descendants.

This issue was highlighted in the archaeological investigation of the Japanese submarine *I-124* (McCarthy 1990 & 1991). Owing to a large number of submarine losses (Alden 1985) containing human remains, the Japanese government requested that diving be restricted on the wreck site for fear that divers might disturb the human remains onboard (McCarthy 1990: 5). With these restrictions in place, the team was nevertheless able to deploy an ROV to positively identify the submarine as well as undertake an investigation of the wreck. This is not to suggest that professionally trained and qualified maritime archaeologists could be expected to disturb human remains, since it is assumed that members of the profession would treat them with due respect. Nevertheless, in a case like that outlined above, where explicit instruction forbids diving on a wreck, the archaeological application of an ROV could be considered to provide a suitable compromise between the need to investigate a site and a desire to avoid the perception of human intervention.

Summary

To conclude, the application of ROV technology holds great potential for Australian archaeology. When compared to the current practice of deploying divers in the water for routine site inspections, the use of ROVs provides a low cost alternative that offers greater operational depth and allows for more time spent in the water with a marked increase in safety. Lower cost and higher efficiency will also allow for a broader knowledge base of Australia's underwater heritage, as well as more effective and widespread implementation of management plans.

It must be stressed that an increased use of ROV technology is not intended to replace divers and their skill sets. Rather the deployment of ROVs is worth serious consideration as a complement to maritime archaeologists. The ability of an ROV (or AUV) to survey and record sites in a short span of time will enable maritime archaeologists in the water to focus on tasks that require a high degree of specialisation. Even in areas where ROV deployment first appears unsuitable, such as the *in-situ* preservation of wrecks, there still remain tasks that can easily and efficiently be performed by an ROV such as imaging, monitoring the condition of the seabed off the wreck and metals testing.

Acknowledgements

This paper would not have been possible without the support of Archae-Aus who funded part of my research. Thanks must also go to Peter Veth for his invaluable support throughout the writing of this paper as well as Michael Sparg, Oscar Pizarro, Andrew Viduka and Michael McCarthy for their input and for answering a number of questions that I had.

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Appendix A: ROV Specifications

	SYSROV 150C	**JW Fishers Sea Otter 2**	**VideoRay Pro 3XE**
Power Requirements	800 Watts, 200–240 VAC	600 Watts, 120–220 VAC	800 Watts, 100–240 VAC
Total System Weight	45 kg	40 kg	45 kg
Vehicle Dimensions	410 mm x 295 mm 280 mm	580 mm x 400 mm x 300 mm	350 mm x 230 mm x 210 mm
Vehicle Weight	10 kg	19.5 kg	3.8 kg
Operating depth	150 m	150 m	150 m
Speed	1.5 m/sec (3 knots)	1.5 m/sec (3 knots)	1.3 m/sec (2.6 knots)
Sensors	Depth sensor, altitude transducer, electronic compass, water temperature, water pressure	—	Depth sensor, electronic compass
Camera	140° tilt, PAL, 530 TV lines resolution	140° tilt, PAL, 700 TV lines resolution	160° tilt, PAL, 570 TV lines resolution
Rear Camera	Fixed, black and white, 420 TV lines resolution	140° tilt, PAL, 700 TV lines resolution	Fixed, black and white, 430 TV lines resolution
Lighting	2 x forward facing 35 W halogen lights, rear LED lights	2 x forward facing 50 W halogen lights, rear LED lights	2 x forward facing 20 W halogen lights, rear LED lights
Control System	15' LCD screen, digital video out	15' LCD screen, digital video out	15' LCD screen, digital out
Tether	100 m length, 10 mm diameter	100 m length, 19 mm diameter	150 m length, 12 mm diameter