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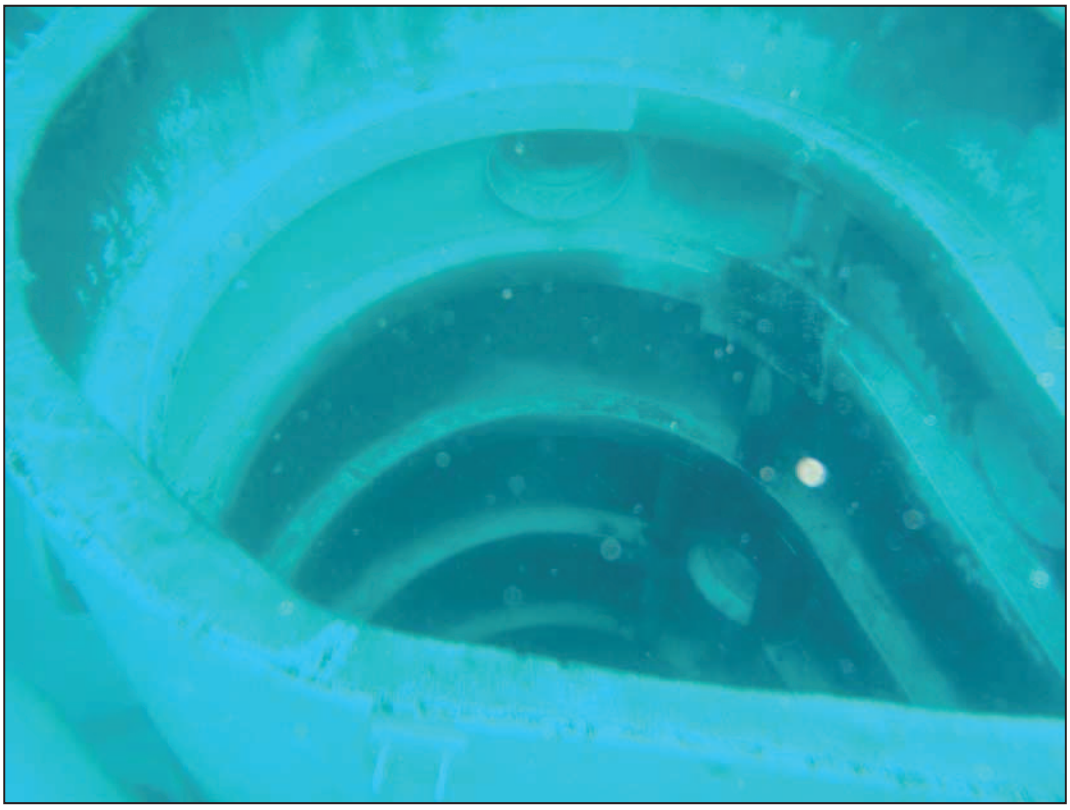
NSW CROWN LANDS
(A DIVISION OF THE NSW DEPARTMENT OF PRIMARY INDUSTRIES)

Ex-HMAS ADELAIDE Artificial Reef

Reef Community and Sediment Movement Surveys



301020-03410 – FINAL

29 June 2011

Infrastructure & Environment
3 Warabrook Blvd
Warabrook, NSW, 2304
Tel: +61 2 4985 0000
Fax: +61 2 4985 0099
www.worleyparsons.com
WorleyParsons Services Pty Ltd
ABN 61 001 279 812

Executive Summary

The Ex-HMAS ADELAIDE was a long-range escort frigate which was scuttled off the coast of Terrigal and Avoca Beach on Wednesday 13 April 2011. The Ex-HMAS ADELAIDE was gifted to the New South Wales (NSW) Government for the purpose of creating an artificial reef and recreational dive site. An Artificial Reef Permit (SD2008/1062) was issued by the Department of Environment, Water, Heritage and the Arts (DEWHA), under the *Environment Protection (Sea Dumping) Act* 1981, in March 2010. In accordance with the Artificial Reef Permit, NSW Crown Lands must implement a *Long Term Management and Monitoring Plan*. The Plan includes monitoring of reef community development on the vessel. The results of the *Reef Community Baseline Survey* are provided in this report.

The *Reef Community Baseline Survey* involved the establishment of horizontal and vertical transects on the hull and superstructure of the vessel immediately post scuttling (i.e. within 1 – 2 weeks) once safety and stability clearance had been provided. Transects were recorded using a combination of underwater video and still photography methods, for the purpose of providing a record of the baseline condition of marine growth on the vessel, to be used as a comparison in all future reef monitoring surveys.

Marine growth was present (green foliose algae and serpulid tube worm casings) on the lowermost extent of the hull in areas which have been submerged during docking while the vessel was prepared for scuttling. This growth was captured in vertical photo transects run down the hull at the bow and stern of the vessel. Transects in the horizontal plane along the hull were undertaken a few weeks post scuttling (due to tidal and weather constraints) and at this early stage, a light covering of marine algae was found over the hull of the vessel, along with a number of stolonate ctenostome (soft) bryozoans. However, no visible marine growth was present on the superstructure of the vessel. Marine fauna observed during the *Reef Community Baseline Survey* included juvenile fish species including brown sabretooth blennies, blackspot goatfish, and bannerfish. No threatened, protected or introduced marine pest species were detected.

There were a number of constraints identified in undertaking surveys on the hull of the vessel which have been identified and these should be taken into account to ensure that future monitoring on the vessel is safe, viable and informing. These constraints and options for alternative survey locations are discussed in the report.

Disclaimer

PROJECT 301020-03410 - EX-HMAS ADELAIDE ARTIFICIAL REEF

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL/ REVIEW	DATE
A	DRAFT Issued for internal review	Dr K Newton	D Hall & Dr A Cohen	N/A	23 May 2011	N/A	
B	DRAFT Issued for client review	Dr K Newton	A Ling		3 June 2011		
B	DRAFT Issued for internal review	Dr K Newton	H Houridis		6 June 2011	N/A	
C	FINAL DRAFT Issued for client review	Dr K Newton	A Ling		14 June 2011		
D	FINAL REPORT	Dr K Newton		P Moses	15 June 2011	A Ling	
E	FINAL REPORT 2	Dr K Newton	A Ling & C Cole		29 June 2011	A Ling	

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1. INTRODUCTION

1.1 Background

The Ex-HMAS ADELAIDE was a long-range escort frigate which was scuttled off the coast of Terrigal and Avoca Beach on Wednesday 13 April 2011 for the purpose of creating an artificial reef and recreational dive site. An Artificial Reef Permit (SD2008/1062) was issued by the Department of Environment, Water, Heritage and the Arts (DEWHA), under the *Environment Protection (Sea Dumping) Act* 1981, in March 2010. In accordance with the Artificial Reef Permit, NSW Crown Lands (a division of the Department of Primary industries) must implement the approved *Long Term Management and Monitoring Plan (LTMMP)*.

The purpose of the LTMMP is to provide for the post-scuttling management and monitoring of the Ex-HMAS ADELAIDE Artificial Reef and covers monitoring for the first five years post-scuttling. The LTMMP contains provision for review, based on the results of the monitoring.

The LTMMP includes requirements to undertake and report changes in the environmental conditions on and around the artificial reef. Specifically, the environmental monitoring includes the following:

- Reef communities survey;
- Sediment movement;
- Sediment quality; and
- Bioaccumulation study.

The results of the initial *Reef Communities Survey* are provided in this report.

1.2 Location of the Dive Site

The Ex-HMAS ADELAIDE is located in Bulbararing Bay, between Avoca Beach and Terrigal Headland, on the NSW Central Coast. The ship is located approximately 1.4 km from Terrigal Headland and 1.9 km from Avoca Beach (**Figure 1.1**). Depth of the vessel on the seabed at the bow of the vessel is 33.9 m below Lowest Astronomical Tide (LAT – which is approximately equal to zero at Fort Denison Tide Gauge) and 32.6 m below LAT on the seabed at the stern of the vessel. The depth of water over the main mast is 8.02 m LAT (personal communication NSW Crown Lands 2011). **Table 1.1** provides the scuttling co-ordinates for the vessel.

Table 1.1 Co-ordinates of the scuttling location for the Ex-HMAS ADELAIDE.

Latitude / Longitude	Northing / Easting (MGA 94)
Latitude (south): 33˚27.91'	Northing (MGA 94): 6,296,076.969
Longitude (east): 151˚27.38'	Easting (MGA 94): 356,551.686

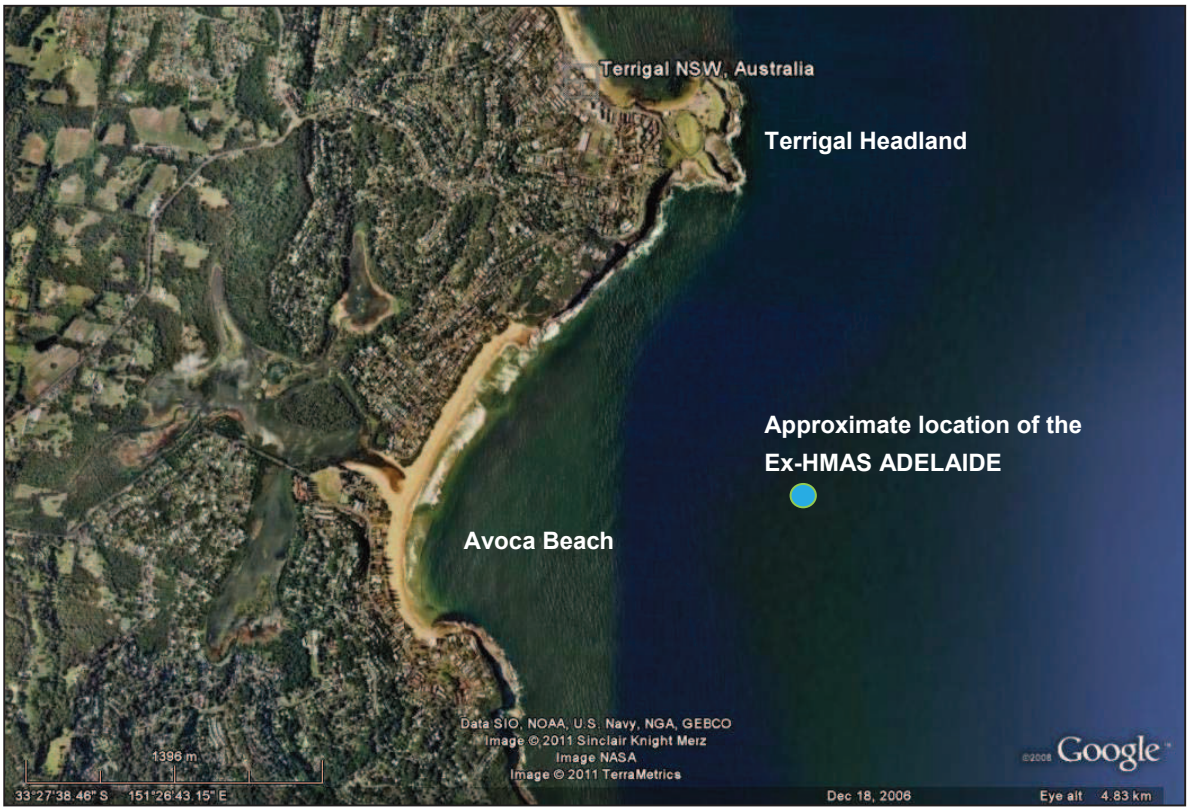


Figure 1.1 Approximate location of the Ex-HMAS ADELAIDE artificial dive reef.

1.3 Project Aims & Scope

The rationale for investigating the reef communities of the Ex-HMAS ADELAIDE Artificial Reef is to gain an understanding of the types of flora and fauna assemblages present, examine the rate of development of fouling assemblages and how they change over time, identify whether there is variation in the rates of development of assemblages on different surfaces of the vessel and identify whether any introduced species are present.

The LTMMP requires the investigation of the reef communities to be achieved through marine ecological surveys undertaken to describe the marine flora and fauna living on the Ex- HMAS

ADELAIDE Artificial Reef on a seasonal basis (i.e. quarterly) for the first two years and then biannually from years three to five, with the first survey to be taken within 1 to 2 weeks of scuttling to try to capture the initial stages of colonisation.

Specifically, the LTMMP requires the following:

"*a total of six video transects (of fixed length, approximately 100 m) will be surveyed along the hull, i.e. three equidistant transects on each of the port and starboard sides in the horizontal plane. The video survey will involve divers swimming down the transect line, whilst remaining within 1 m of the transect line at all times. By necessity, these surveys will be conducted at water depths of less than 30 m, due to diving constraints (see note below). As such transects will be taken at the top of the hull, the mid-point and at maximum divable depth. Photos will be taken at six equidistant points along each transect to illustrate the vertical colonisation of the hull.*

To complement the video surveillance work, a second diver will take incidental photographs of reef communities growing in and around the vessel and on vertical and horizontal surfaces. Fixed photo points will be established along the video transects to provide a record vertically up the hull. Any fish species encountered will be photographed and recorded (any threatened or protected species along with any introduced marine pest species will be documented and described). The location of points for photographs will be determined post-scuttling as colonisation will be affected by microclimates and seasonal changes.

The video footage will be used to describe the subtidal reef community assemblages, including sessile invertebrates (e.g. corals, hydroids, ascidians, sponges, oysters, barnacles, and mussels), motile invertebrates (e.g. crustaceans, gastropods), fish communities and aquatic vegetation. A description of the assemblages including any new growth and the rate of growth of fouling biota will be provided after every survey event".

Section 2 of this report outlines the study methods and **Section 3** provides the results of the Baseline survey. In **Section 4** a discussion of the survey results and the expected future development of sessile communities on the ship is provided. **Section 5** provides recommendations for future monitoring on the Ex-HMAS ADELAIDE.

NOTE: Under *Australian Standard AS 2815: Training and Certification of Occupational Divers*, commercial divers using self-contained underwater breathing apparatus (SCUBA) are restricted to working underwater to depths of 30 m. While *AS 2815* allows commercial divers to access depths beyond 30 m, commercial divers must use surface-supplied underwater breathing apparatus (SSBA) with surface compression chambers. The use of SSBA for commercial diving around the ex-HMAS ADELAIDE Artificial Reef for the environmental monitoring was not considered safe due to the risk of entanglement with the vessel and mooring lines.

2. METHODS

The *Baseline Survey* study assessed the baseline condition of benthic assemblages on horizontal and vertical surfaces of the Ex-HMAS ADELAIDE using underwater video and still photography methods. Being the initial *Reef Communities Survey* it was necessary to first establish the survey baselines (transects) followed by the required surveys. This work was conducted during the week of 18 - 24 April 2011, one week following scuttling of the Ex-HMAS ADELAIDE. Additional work was undertaken on 30 May 2011 to supplement the initial survey.

The initial *Reef Communities Survey* was undertaken to establish the baseline condition of the benthic assemblages on horizontal and vertical surfaces of the Ex-HMAS ADELAIDE Artificial Reef using underwater video and still photography methods as described below. Photos of sediment characteristics around the hull of the vessel were also taken to provide information about sediment movement during and immediately following scuttling.

During the baseline reef survey, any threatened or protected marine flora and fauna observed on or near to the vessel were identified, as were any introduced marine pest species. All incidental marine fauna observed during the surveys was also photographed.

2.1 Hull Transects

Transects were established on the hull of the Ex-HMAS ADELAIDE in both the horizontal and vertical planes and included six transects in the horizontal plane and four transects in the vertical plane. (refer to **Figure 2.1**)

The following describes the methodology used to establish these transects.

Horizontal Plane

Six permanent video transects were established on the hull of the Ex-HMAS ADELAIDE (i.e. three equidistant transects on each of the port and starboard sides) in the horizontal plane. These transects were established within a period around low tide and favorable climatic conditions to maximise the depth of the lowest transect within the diving limit for commercial divers (30 m below water level).

The two shallowest transects (~28 m depth) commenced at the stern of the vessel immediately below the gunwale and ran for 100 m in the horizontal plane towards the bow of the vessel. The two middle transects (~29 m depth) commenced at the stern of the vessel 1 m below the gunwale and ran for 100 m in the horizontal plane towards the bow of the vessel. The two lowest transects (~30 m depth) commenced at the stern of the vessel 2 m below the gunwale and ran for 100 m in the horizontal

plane towards the bow of the vessel (N.B. the depth of the ship did not allow for greater spacing between transects).

Due to the lack of attachment points on the hull itself, no marking for the start of transects in the horizontal plane on the hull was undertaken. Instead, the start of these transects was determined as the stern of the vessel, with the first transects undertaken immediately below the gunwale, second transects 1 m below the gunwale and the third transects 2 m below the gunwale.

Vertical Plane

Four permanent photographic transects were established on the hull of the Ex-HMAS ADELAIDE (i.e. bow and stern on each of the port and starboard sides) in the vertical plane. These transects were located in the vertical plane down the sides commenced at the gunwale and continued down the hull to a depth of ~30 m below water level. The location of the start of each transect in the vertical plane was delineated using three black cable ties on the deck of the vessel.

Figure 2.1 provides the indicative locations of transects in the vertical and horizontal planes on the hull of the vessel, marking the start points, indicated by the green arrows (N.B. only the port side of the ship is shown and the transects shown are replicated on the starboard side).

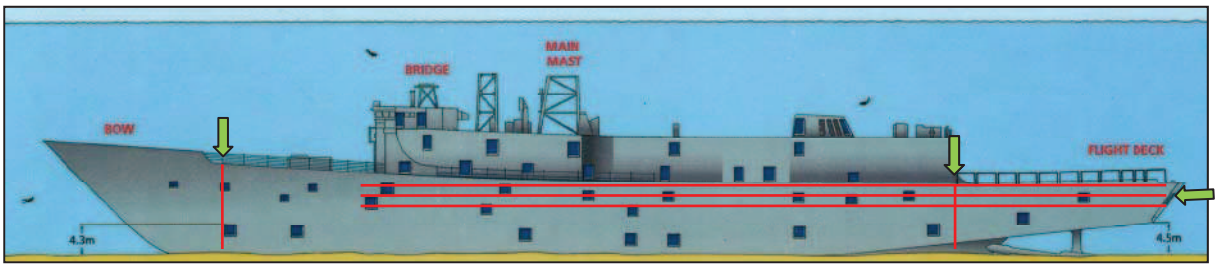


Figure 2.1 Approximate location of transects on the hull of the Ex-HMAS ADELAIDE (N.B. this image is diagrammatical only and is not to scale).

2.2 Hull Surveys

Surveys on the hull of the Ex-HMAS ADELAIDE were undertaken in both the horizontal and vertical planes and included six transects in the horizontal plane and four transects in the vertical plane. The following describes the methodology used for these surveys.

Horizontal Plane

The surveys of the hull in the horizontal plane were undertaken using the following methods:

- Continuous filming of the hull surface using a video camera along each of the six 100 m long transects; and

- still camera imagery captured at six points along each transect (i.e. every 15 m after the start point) using a 25 cm^2 quadrant.

Vertical Plane

The surveys of the hull in the vertical plane were undertaken using still camera imagery down each of the four transects starting at the gunwale to a depth of ~30 m below water level. Photographs down each of these transects were taken at 1 m intervals using 25 cm^2 quadrants.

When taking the 1 m measurements, the measuring tape was held tight against the hull of the ship, rather than in a direct vertical line from the gunwale to the seabed, to increase the area able to be sampled. At the bow of the vessel photographic transects in the vertical plane began at the base of the first rail from the bow (~20 m depth). At the stern of the vessel transects in the vertical plane began at the location where the first rail would have been (i.e. handrail had been removed) from the entrance to the hangar (~27 m depth).

Coral point count (CPC) analysis was used to determine the percentage cover of marine taxa in each photo quadrat captured where marine growth was present.

2.3 Superstructure and Deck Transects

Due to the LTMMP requirement to for *the first reef communities survey to be taken within 1 to 2 weeks of scuttling*, it was necessary for the initial survey to be undertaken around high tide in a period of deteriorating climatic and ocean conditions. Consequently, due to the safe diving limit for commercial divers and the adverse climatic and ocean conditions the initial survey baselines (transects) were established on the vessel superstructure and decks. The following describes the methodology used to establish these transects.

Six permanent horizontal transects were established on the Ex-HMAS ADELAIDE Artificial Reef to monitor the development of reef communities as they established on horizontal surfaces of the ship. Transect establishment took into account depth (3 different depths were sampled) and accessibility (transects were laid along areas of deck which allowed essentially unimpeded diver movement).

Due to the ships overall length of 138 m and the presence of features such as cabins, locked doors, masts etc. there was a lack of deck area which allowed for unimpeded movement for a direct length of 100 m. Therefore, each transect was setup as a 50 m line along which video and still images were able to be captured along both sides, giving a total recorded length of 100 m.

Transect Locations

1. **Bow:** Two horizontal transects were established at the bow of the ship, one transect running along the port side and the other transect on the starboard side of the main deck from the anchor towards the stern, with a maximum depth of ~26 m at high tide.
2. **Stern:** Two horizontal transects were established on the port and starboard sides of the stern, running across the flight deck and into the hanger, with a maximum depth of ~28 m at high tide.
3. **Mid Ship:** Two horizontal transects were established mid ship, one each along the port and starboard sides of the upper deck extending from the bridge back towards the stern, with a maximum depth of ~21 m at high tide.

Figure 2.2 provides the indicative locations of each of the horizontal transects on the superstructure, marking the start point, indicated by the green arrows.

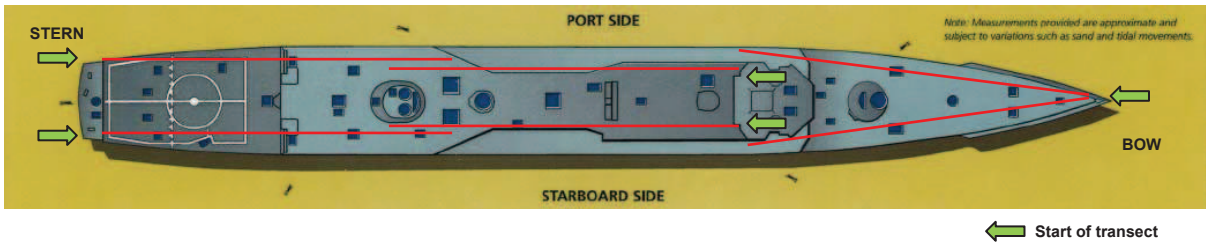


Figure 2.2 Approximate location of horizontal transects on the superstructure of the Ex-HMAS ADELAIDE (N.B. this image is diagrammatical only and is not to scale).

Marking of Transects

The start of each horizontal transect on the superstructure was marked with a single, large, black cable tie. Every 10 m (or as close as possible to this length where an attachment point could be found) another cable tie was attached to mark the transect route and to signify locations for still photographs (see **Figure 2.3** for an example).

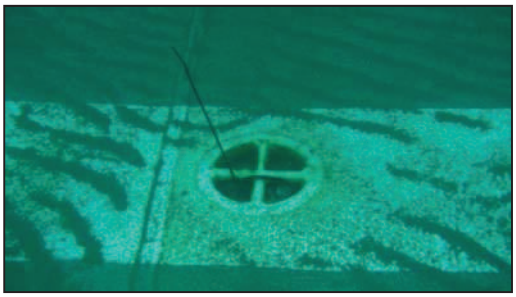


Figure 2.3 Black cable ties were used to delineate the transect route.

2.4 Superstructure and Deck Surveys

When undertaking the horizontal surveys on the superstructure and decks, a 50 m long tape was laid tightly along the transect line. Underwater video footage of each transect was captured while swimming slowly at a height of approximately 1 m above the deck. Divers conducting video swam along one side of the transect line and then back down the other side (each time starting on the inner side of the vessel) to obtain a total length of video of 100 m. Underwater still images of a variety of horizontal and vertical features at every 10 m interval (or marker point) were also captured.

2.5 Marine Sediments around the Ex-HMAS ADELAIDE Artificial Reef

A series of still images of sedimentary features of interest on the seafloor at the bow and stern of the ship were taken during the baseline surveys. In accordance with commercial diving practices these were taken from a depth of 30 m, and taken at low tide as to allow the maximum diving depth possible in relation to the position of the seabed.

2.6 Marine Fauna

Any incidental sightings of marine fauna during the baseline surveys were recorded using still photography.

2.7 Threatened / Protected and Introduced Marine Species

Care was taken to identify any threatened or protected marine species on or around the vessel whilst undertaking the baseline surveys. In addition, any sightings of introduced marine pest species were recorded using still photographs.

3. RESULTS

3.1 Hull

Vertical transects which were run down the hull of the Ex-HMAS ADELAIDE, on both the port and starboard sides of the bow and stern, showed evidence of fouling by marine organisms towards their lowermost extents as described in **Section 3.1.1**. Transects that were run along the hull of the vessel in the horizontal plane were required to be undertaken a few weeks following the initial survey due to the tidal and weather constraints described previously. Only a light covering of marine algae and occasional soft bryozoans were visible along these transects (see **Section 3.1.2**).

Transects in the Vertical Plane

A series of still images taken down the hull (i.e. in the vertical plane) were captured starting at the gunwale and then at 1m intervals to 30 m depth (at low tide). On the bow of the ship the hull of the vessel was free of marine growth until the -7 m and -8 m quadrats (see **Figures 3.1** and **3.2**). On the stern of the ship the hull was free of marine growth until the -5 m quadrats (see **Figures 3.3** and **3.4**). The results of CPC analysis are provided in **Tables 3.1** to **3.4**. The locations of marine growth on these transects are presumably representative of the water level while the vessel was berthed in Sydney Harbour prior to scuttling. Marine growth on the hull observed during the baseline survey consisted of small green foliose algae and serpulid worm casings. The serpulid worm casings on the Ex-HMAS ADELAIDE are most likely to belong to the endemic polychaete species *Galeolaria caespitosa*, which is one of the most common serpulid tubeworm species in marine waters of southern and eastern Australia (Edgar 1997). Some localised areas of bare metal were identified on the hull, immediately above the marine growth, approximately 7 m below the gunwale. These areas may be the result of ship preparation activities or indicative of previous marine growth which has either been sloughed off or removed during routine hull cleaning.

Transects in the Horizontal Plane

Video transects were run along the hull in the horizontal plane on either side of the vessel to a maximum depth of 30 m. Still images were captured every 15 m with a total of six captured along each transect. These horizontal transects showed a light covering of marine algae in all still photographs.

3.1.1 Bow Port Side Vertical Transect

CPC analysis of sessile marine growth on the bow port side showed the hull was free of obvious growth until -8 m below the gunwale. At this point there was a high density of serpulid worm casings (75% total cover) and green algae also occurred with a cover of 25%. By -9 m the density of green

algae was reduced to 10% and the cover of serpulid worm casings was also reduced to 65%. Bare metal occurred between -6 m and -7 m below the gunwale (see **Table 3.1** and **Figure 3.1**).

Table 3.1 Coral point count results from bow port side analysis.

Image	Total growth (%)	Serpulid casings (%)	Green algae (%)	No growth (%)	Comments
Gunwale	0	0	0	100	No growth
-1 m	0	0	0	100	No growth
-2 m	0	0	0	100	No growth
-3 m	0	0	0	100	No growth
-4 m	0	0	0	100	No growth
-5 m	0	0	0	100	Weld line
-6 m	0	0	0	100	Bare metal
-7 m	0	0	0	100	Bare metal
-8 m	100	75	25	0	Highest density of green algae, high density of serpulid casings
-9 m	75	65	10	35	Lower density of green algae, high density of serpulid burrows


Gunwale

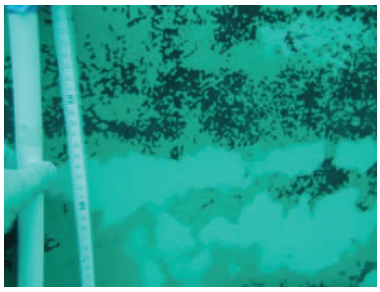

-1 m


-2 m

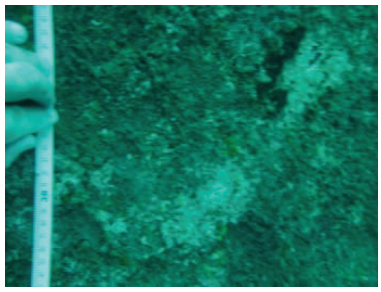

-3 m


-4 m


-5 m


-6 m


-7 m


-8 m

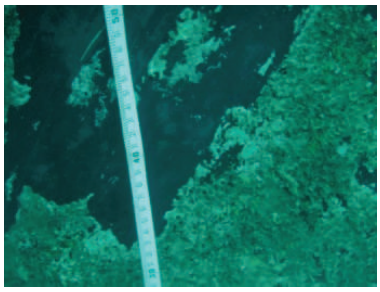

-9 m

Figure 3.1 Vertical photo quadrats down the hull of the bow port side (showing depth relative to uppermost quadrat at the gunwale).

3.1.2 Bow Starboard Side Vertical Transect

CPC analysis of photo quadrats down the hull on the bow starboard side showed no obvious marine growth until the -7 m quadrat, where serpulid worm casings covered 40% of the hull. At -8 m, serpulid casings covered a slightly smaller proportion, with green algae also covering 30%. At -9 m below the gunwale, the cover of serpulid casings increased to 80% and green algae covered 20% of the hull. Bare metal was found at -6 m from the gunwale (see **Table 3.2** and **Figure 3.2**).

Table 3.2 Coral point count results from bow starboard side analysis.

Image	Total growth (%)	Serpulid casings (%)	Green algae (%)	No growth (%)	Comments
Gunwale	0	0	0	100	No growth
-1 m	0	0	0	100	No growth
-2 m	0	0	0	100	No growth
-3 m	0	0	0	100	No growth
-4 m	0	0	0	100	No growth
-5 m	0	0	0	100	Rust spots
-6 m	0	0	0	100	Bare metal
-7 m	40	40	0	60	Serpulid casings
-8 m	60	30	30	40	Serpulid casings and green algae
-9 m	100	80	20	0	High proportion of serpulid casings with green algae

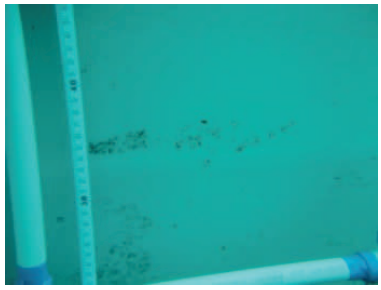

Gunwale

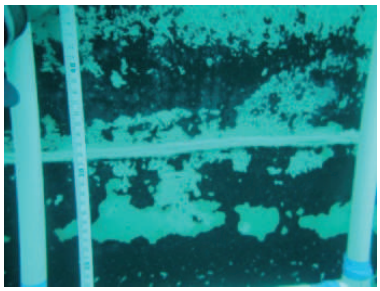

-1 m

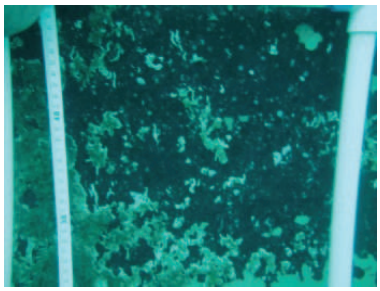

-2 m

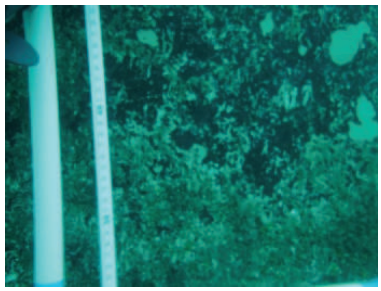

-3 m


-4 m


-5 m


-6 m


-7 m


-8 m

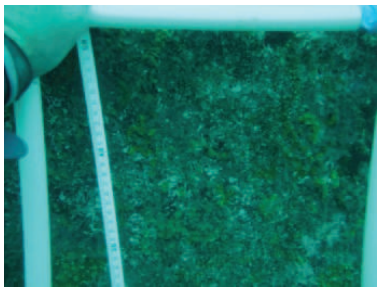

-9 m

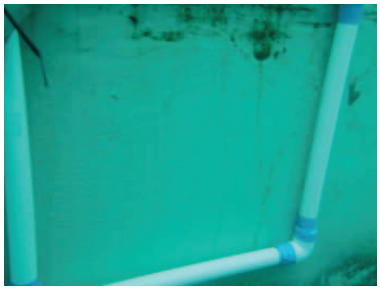
Figure 3.2 Vertical photo quadrats down the hull of the bow starboard side (showing depth relative to uppermost quadrat at the gunwale).

3.1.3 Stern Port Side Vertical Transect

CPC analysis showed that no marine growth was present down the hull on the vertical stern port side until the -5 m quadrat where serpulid casings covered 80% and green algae 10%. At -6 m, marine growth covered 100% of the hull and consisted of 85% serpulid casings and 15% green algae (see **Table 3.3** and **Figure 3.3**).

Table 3.3 Coral point count results from stern port side analysis.

Image	Total growth (%)	Serpulid casings (%)	Green algae (%)	No growth (%)	Comments
Gunwale	0	0	0	100	Rust spots
-1 m	0	0	0	100	No growth
-2 m	0	0	0	100	No growth
-3 m	0	0	0	100	No growth
-4 m	0	0	0	100	No growth
-5 m	90	80	10	10	High proportion of serpulid burrows and small proportion of green algae
-6 m	100	85	15	0	High proportion of serpulid burrows and small proportion of green algae


Gunwale


-1 m


-2 m


-3 m


-4 m


-5 m

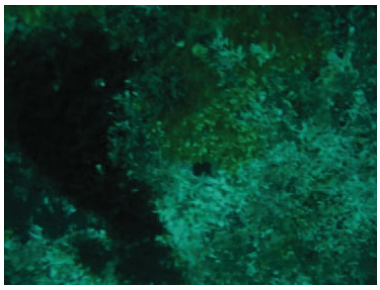

-6 m

Figure 3.3 Vertical photo quadrats down the hull of the stern port side (showing depth relative to uppermost quadrat at the gunwale).

3.1.4 Stern Starboard Side Vertical Transect

CPC analysis on the vertical transect of the stern starboard side of the hull showed no marine growth until 5 m from the gunwale. There was 50% cover of serpulid worm casings at -5 m, after which serpulid casings dominated the hull (85% at -6 m and 80% at -7 m) with smaller proportions of green algae (15% at -6 m and 20% at -7 m). Bare metal was observed at 4 m from the gunwale (**Figure 3.4** and **Table 3.4**).

Table 3.4 Coral point count results from stern starboard side analysis.

Image	Total growth (%)	Serpulid casings (%)	Green algae (%)	No growth (%)	Comments
Gunwale	0	0	0	100	No growth
-1 m	0	0	0	100	No growth
-2 m	0	0	0	100	No growth
-3 m	0	0	0	100	No growth
-4 m	0	0	0	100	Bare metal
-5 m	50	50	0	50	Serpulid casings
-6 m	100	85	15	0	High proportion of serpulid casings and lower proportion of green algae
-7 m	100	80	20	0	High proportion of serpulid casings and lower proportion of green algae

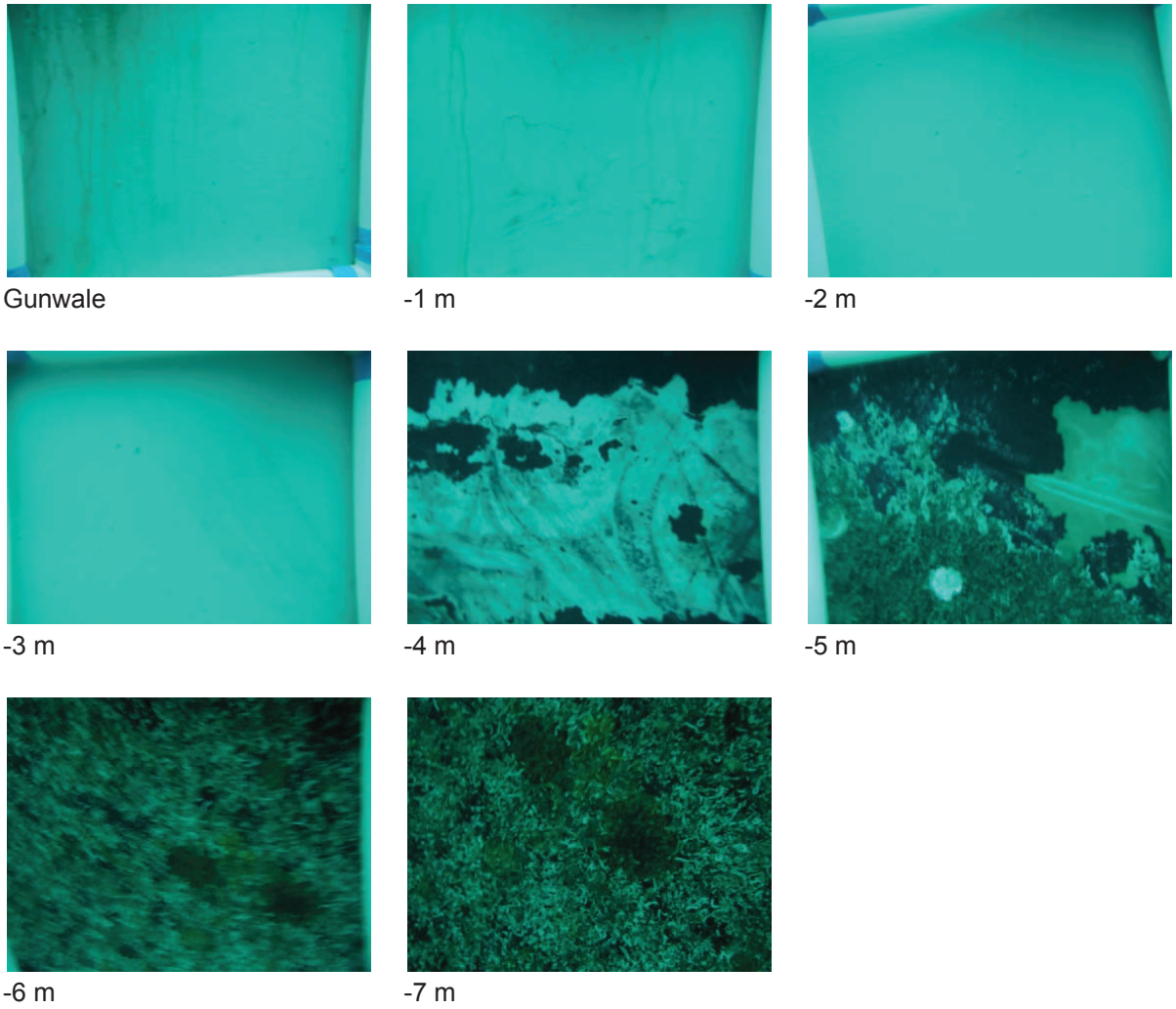
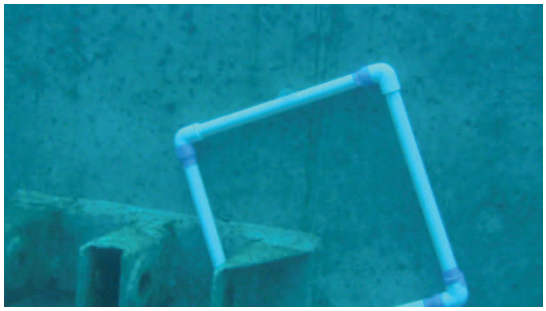


Figure 3.4 Vertical photo quadrats down the hull of the stern starboard side (showing depth relative to uppermost quadrat at the gunwale).

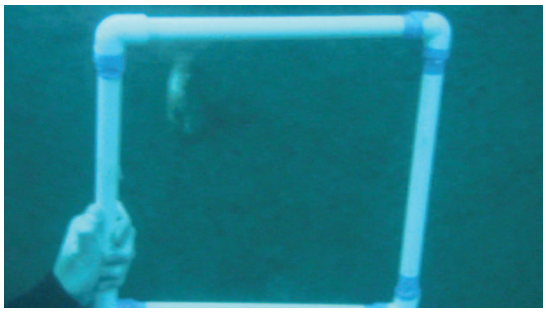
3.1.5 Port Side Horizontal Plane - Transect 1

The port side transect taken along the hull in the horizontal plane, taken immediately below the gunwale, was undertaken along a depth gradient of 28 m. A light coating of marine algae all over the vessel at this depth was observed in all still images taken on the hull as shown in **Figure 3.5**.

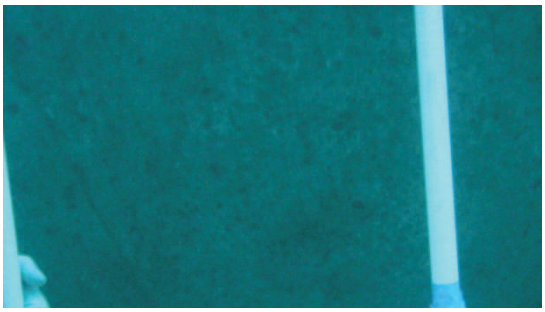


Quadrat 1

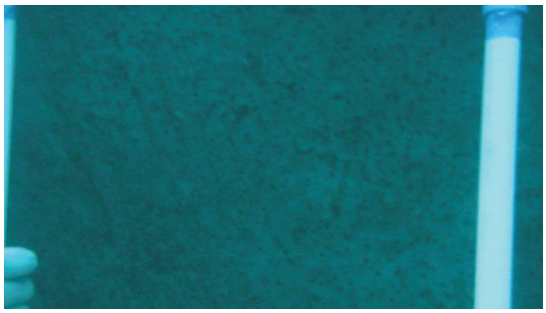
Quadrat 2



Quadrat 3



Quadrat 4



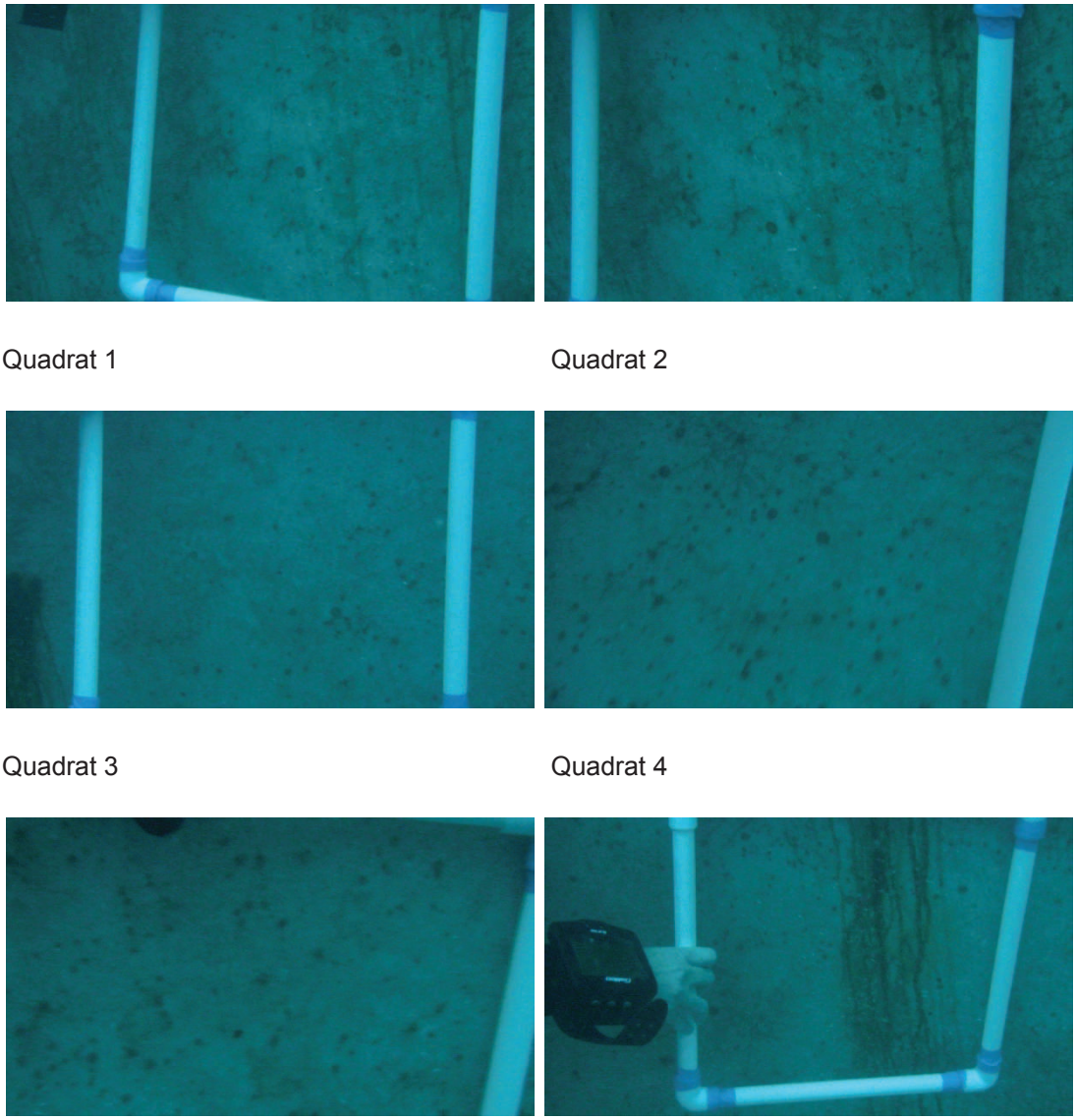
Quadrat 5

Quadrat 6

Figure 3.5 Still images taken along the port side horizontal plane under the gunwale.

3.1.6 Port Side Horizontal Plane - Transect 2

The port side transect taken along the hull in the horizontal plane, taken 1 m below the gunwale, was undertaken along a depth gradient of 29 m. A light coating of marine algae was observed on the hull in all still images taken as shown in **Figure 3.6**.



Quadrat 1 Quadrat 2

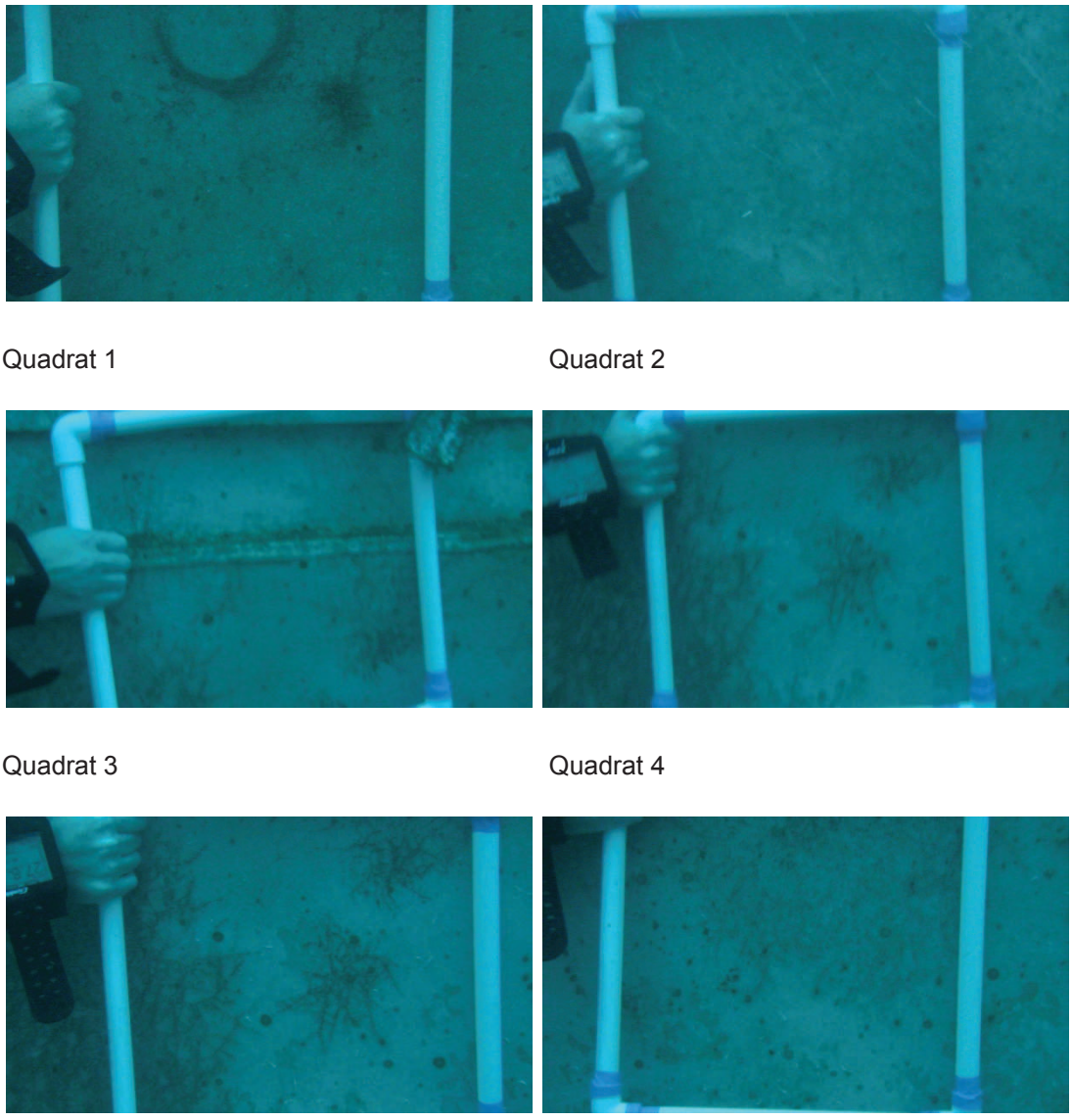
Quadrat 3 Quadrat 4

Quadrat 5 Quadrat 6

Figure 3.6 Still images taken along the port side horizontal plane 1 m below the gunwale.

3.1.7 Port Side Horizontal Plane - Transect 3

The port side transect taken along the hull in the horizontal plane, taken 2 m below the gunwale, was undertaken along a depth gradient of 30 m. A light coating of algae was observed on the hull in all still images. Stolonate ctenostome (soft) bryozoans were also recorded in quadrats 3, 4 and 5 (see **Figure 3.7**).



Quadrat 1 Quadrat 2

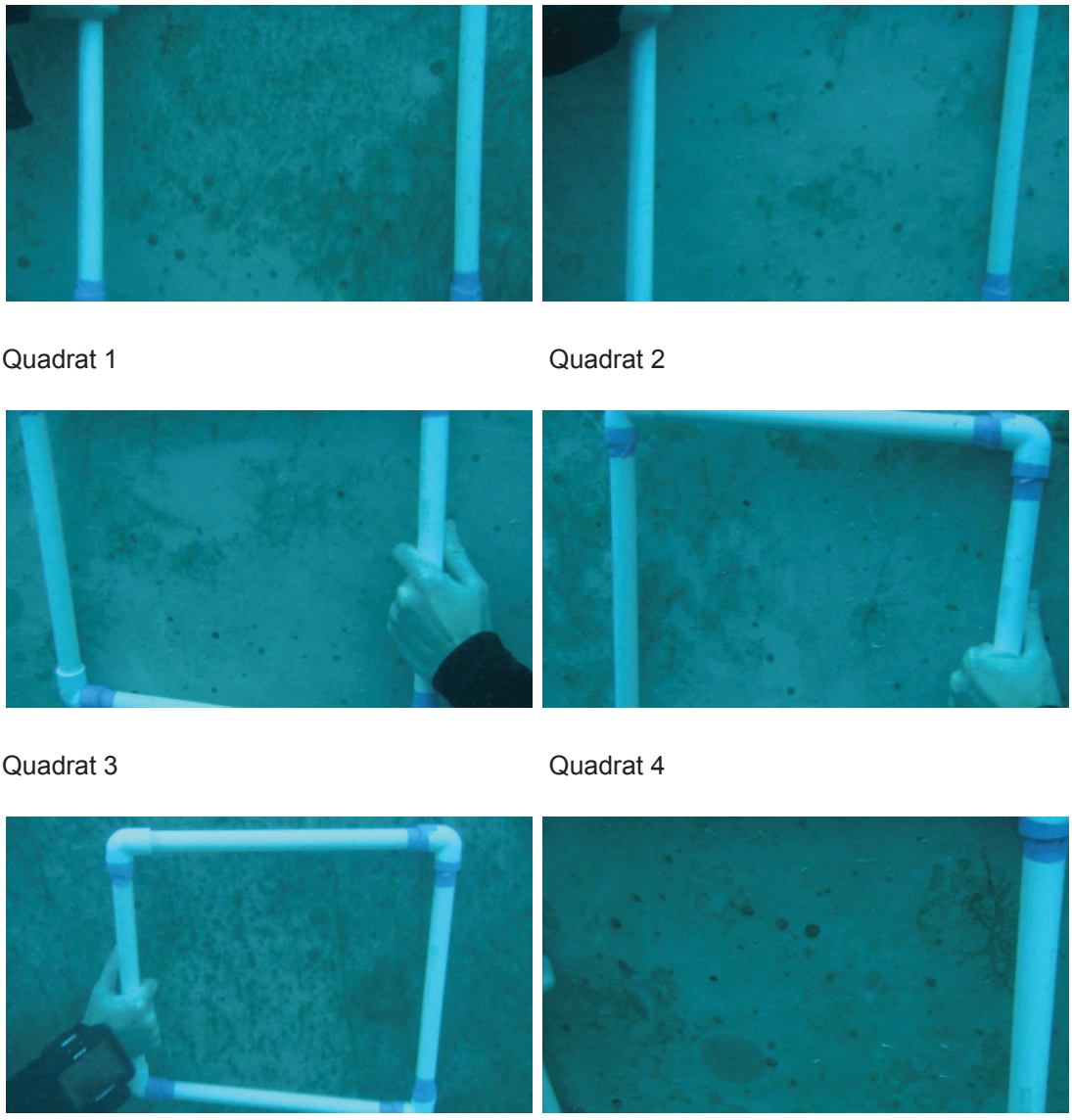
Quadrat 3 Quadrat 4

Quadrat 5 Quadrat 6

Figure 3.7 Still images taken along the port side horizontal plane 2 m below the gunwale.

3.1.8 Starboard Side Horizontal Plane - Transect 1

The starboard side transect taken along the hull in the horizontal plane, taken immediately below the gunwale, was undertaken along a depth gradient of 28 m. A light coating of marine algae was present on the hull in all still images taken as shown in **Figure 3.8**. Stolonate ctenostome bryozoans were also observed in a number of quadrats (i.e. 2, 4 and 6).



Quadrat 1 Quadrat 2

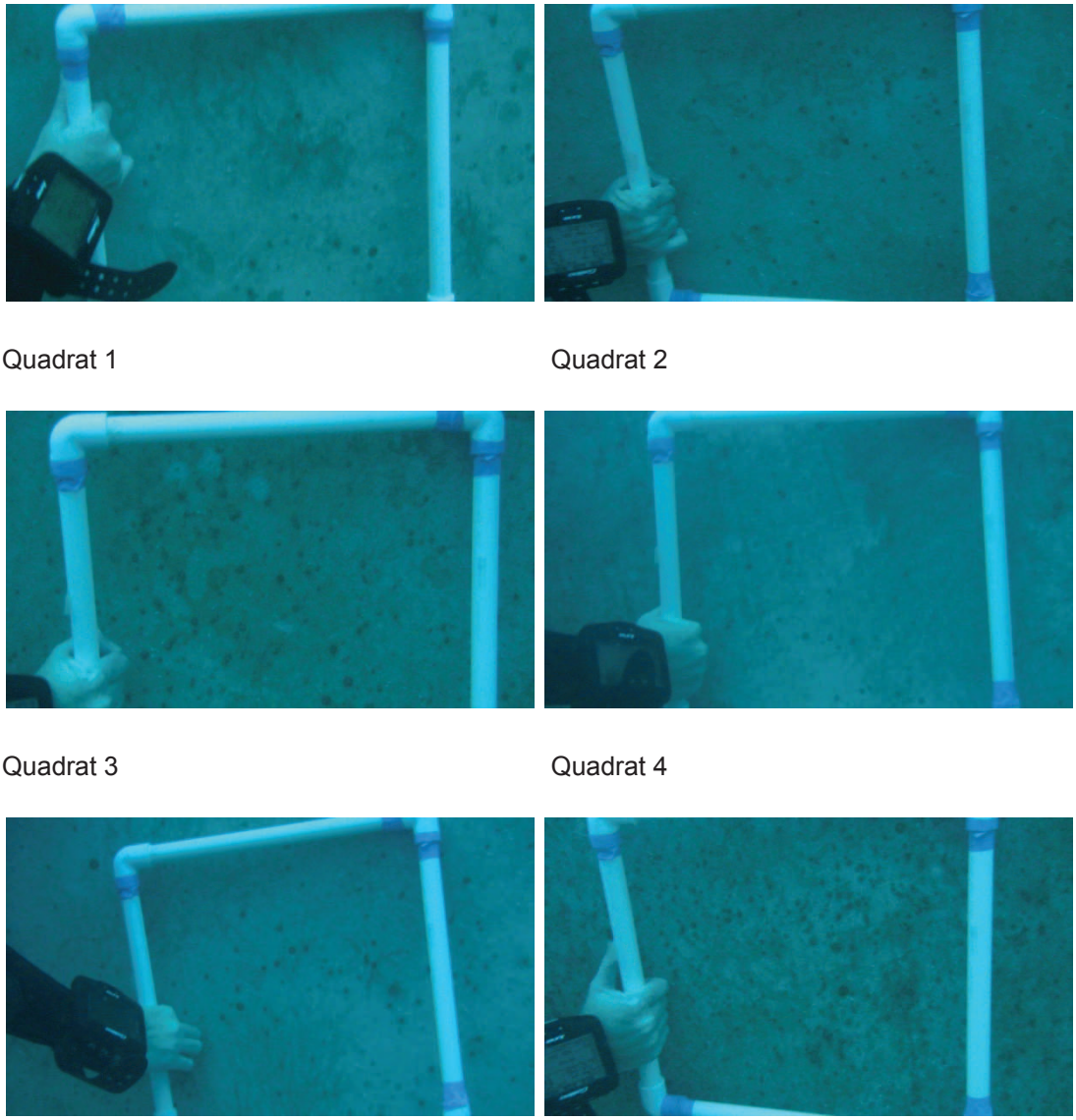
Quadrat 3 Quadrat 4

Quadrat 5 Quadrat 6

Figure 3.8 Still images taken along the starboard side horizontal plane below the gunwale.

3.1.9 Starboard Side Horizontal Plane - Transect 2

The starboard side transect taken along the hull in the horizontal plane, taken 1 m below the gunwale, was undertaken along a depth gradient of 29 m. As with all other quadrats a light coating of algae was present over the hull in all still images taken (see **Figure 3.9**).



Quadrat 1 Quadrat 2

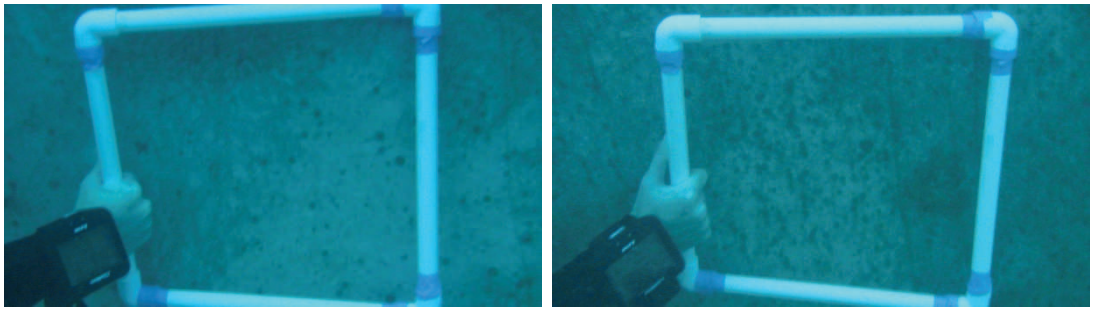
Quadrat 3 Quadrat 4

Quadrat 5 Quadrat 6

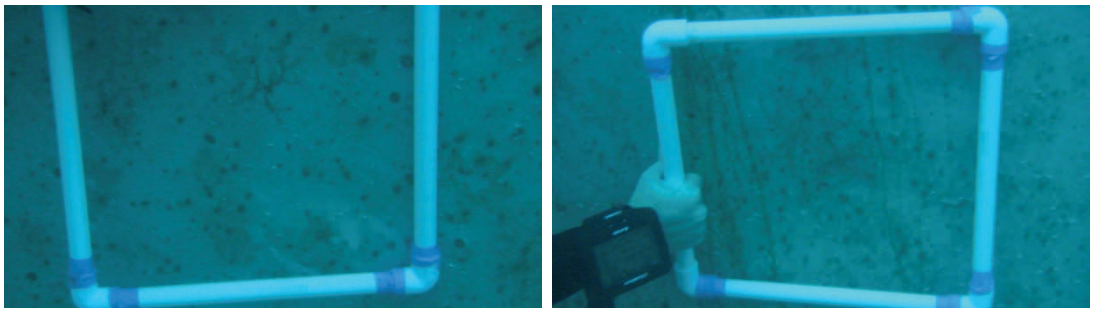
Figure 3.9 Still images taken along the starboard side horizontal plane 1 m below the gunwale.

3.1.10 Starboard Side Horizontal Plane - Transect 3

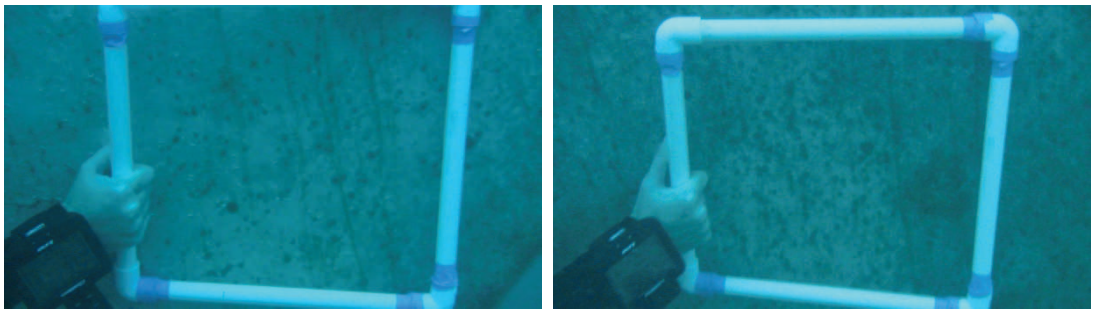
The starboard side transect taken along the hull in the horizontal plane, taken 2 m below the gunwale, was undertaken along a depth gradient of 30 m. A light covering of algae was found to cover the hull in all quadrats as shown in **Figure 3.10**.



Quadrat 1 Quadrat 2



Quadrat 3 Quadrat 4



Quadrat 5 Quadrat 6

Figure 3.10 Still images taken along the starboard side horizontal plane 2 m below the gunwale.

3.2 Superstructure and Deck

Qualitative video and still imagery was collected along each of the permanent horizontal transects on the superstructure of Ex-HMAS ADELAIDE. Video footage was collected to provide a permanent record of the baseline condition of the ship in regard to sessile benthic reef communities. Future reef community surveys would be conducted along the same permanent transects to enable comparison over time to assess the development of sessile marine communities on the vessel. A series of still images of horizontal and vertical features on the ship were also captured every 10 m along these horizontal transects. These images are provided below and may be used for comparisons with future surveys. During the baseline survey no obvious marine growth was present on the horizontal or vertical surfaces or features of the superstructure.

3.2.1 Bow Port Side

No obvious marine growth was present on the bow port side horizontal transect (see **Figure 3.11**).

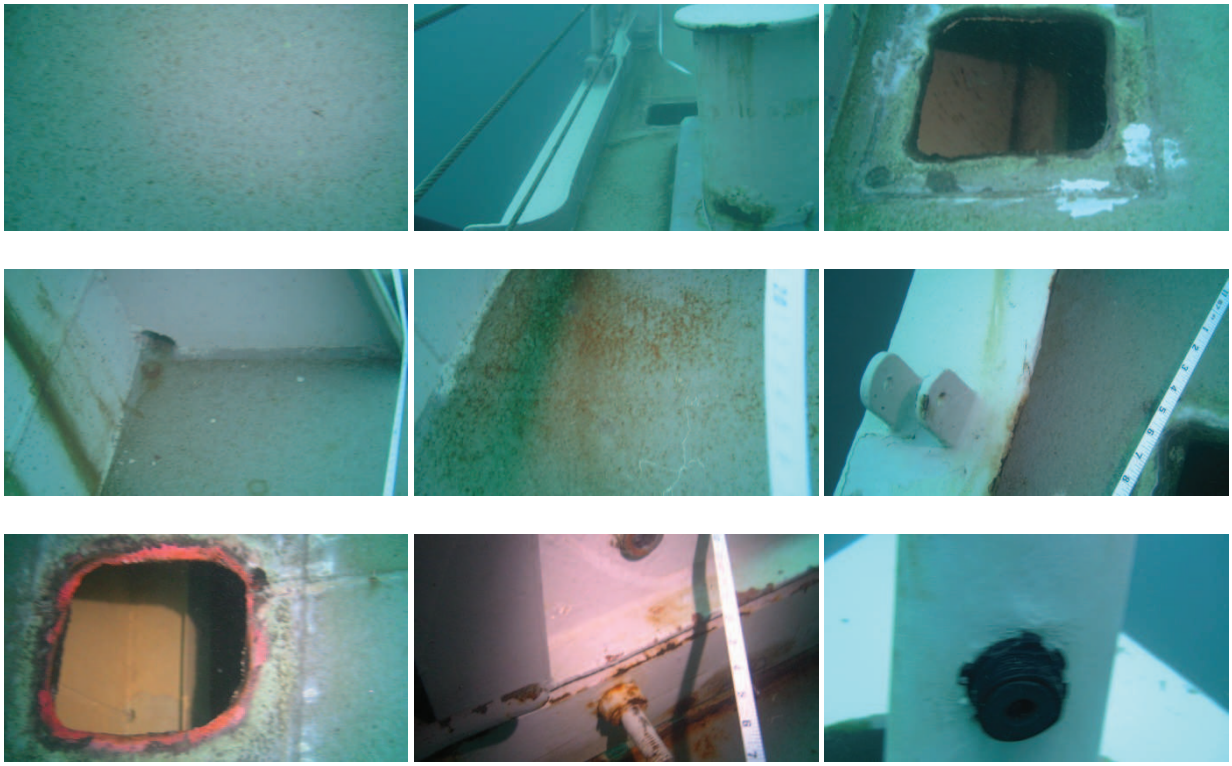


Figure 3.11 Still images captured on the bow port side transect.

3.2.2 Bow Starboard Side

No obvious marine growth was present on the bow starboard side transect as shown in **Figure 3.12** below.

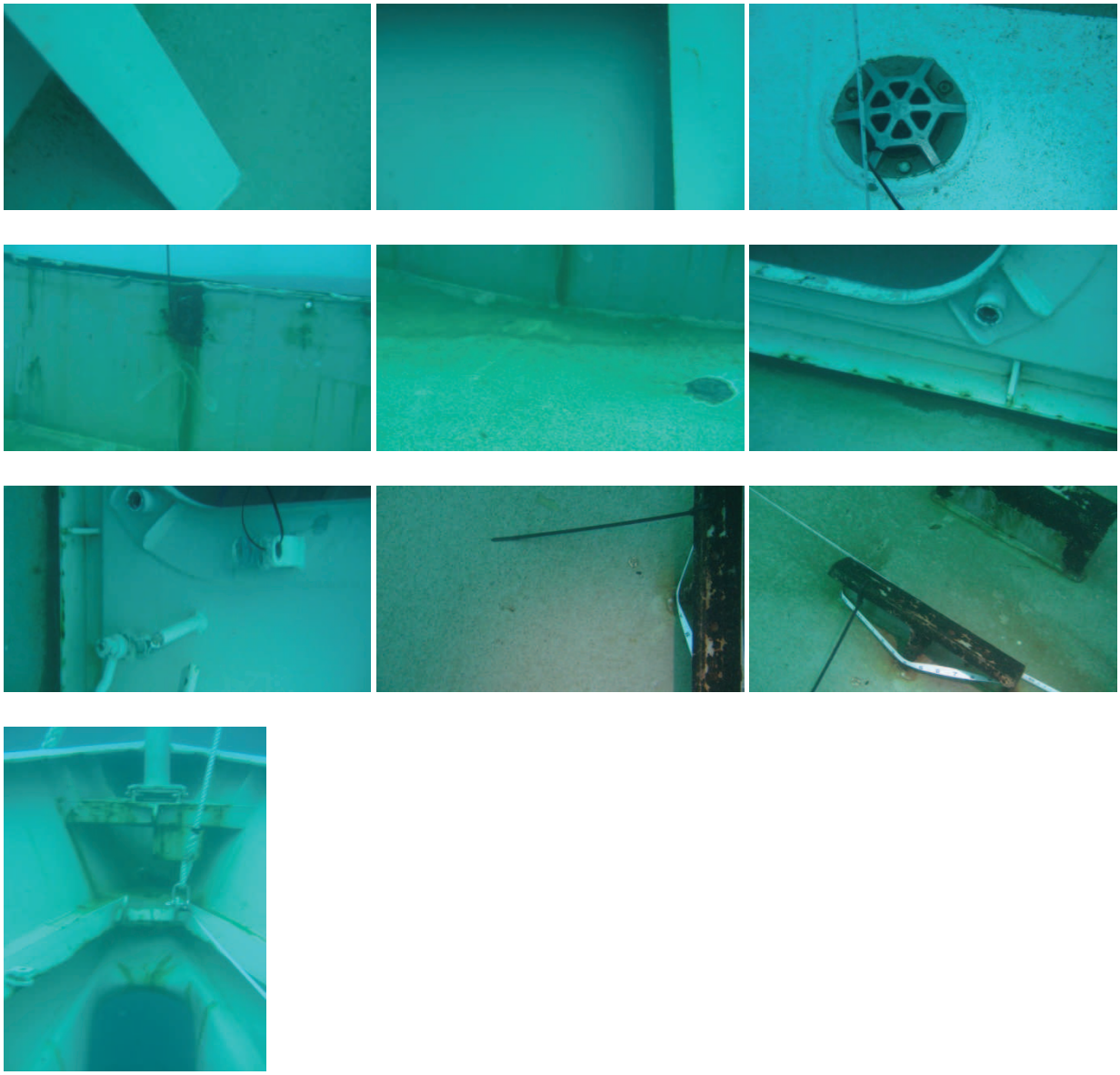


Figure 3.12 Still images captured on the bow starboard side transect.

3.2.3 Stern Port Side

No obvious marine growth was present on the stern port side horizontal transect as shown in **Figure 3.13**.

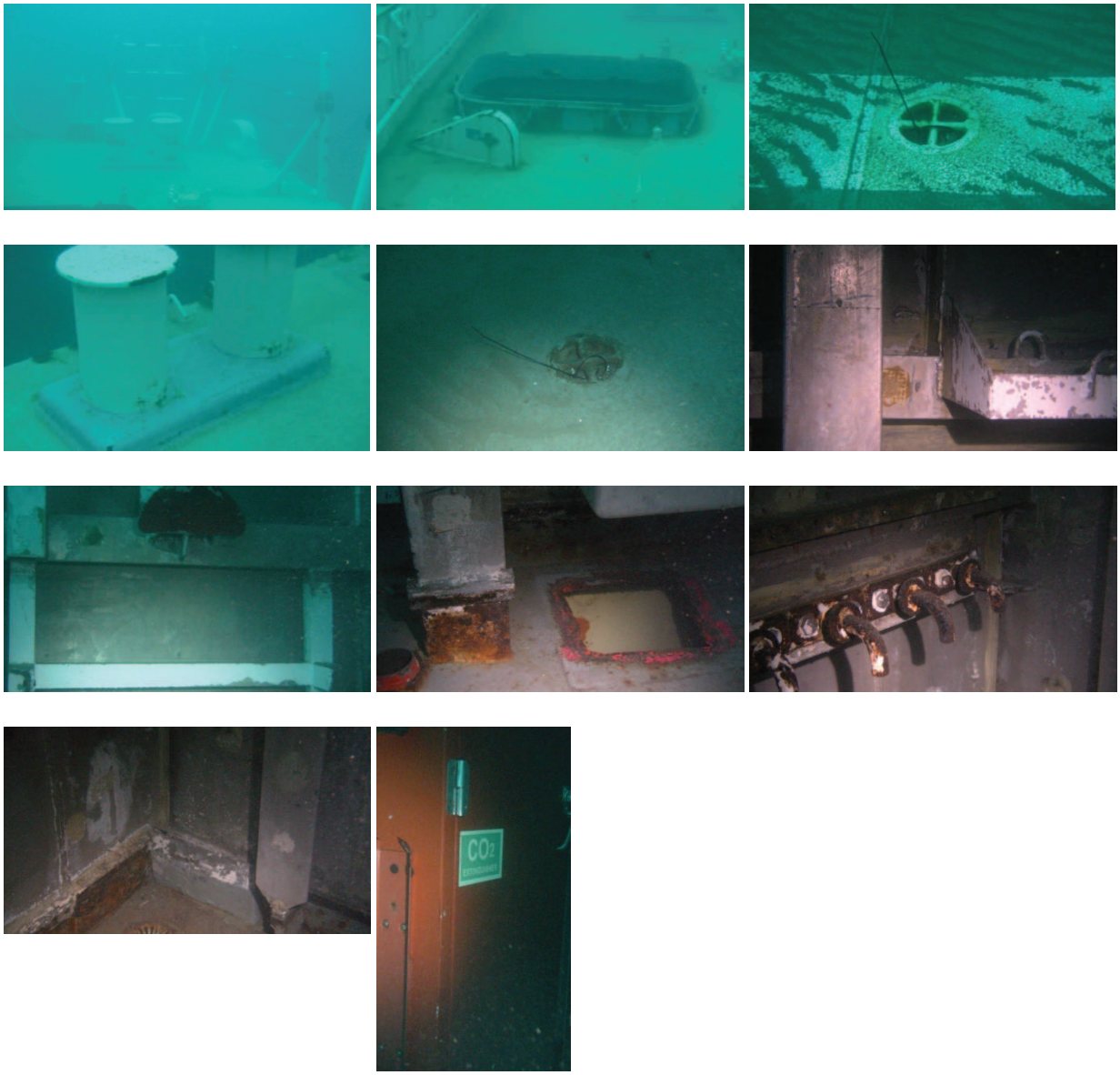


Figure 3.13 Still images captured on the stern port side transect.

3.2.4 Stern Starboard Side

No obvious marine growth was present on the stern starboard side transect as shown in **Figure 3.14** below.

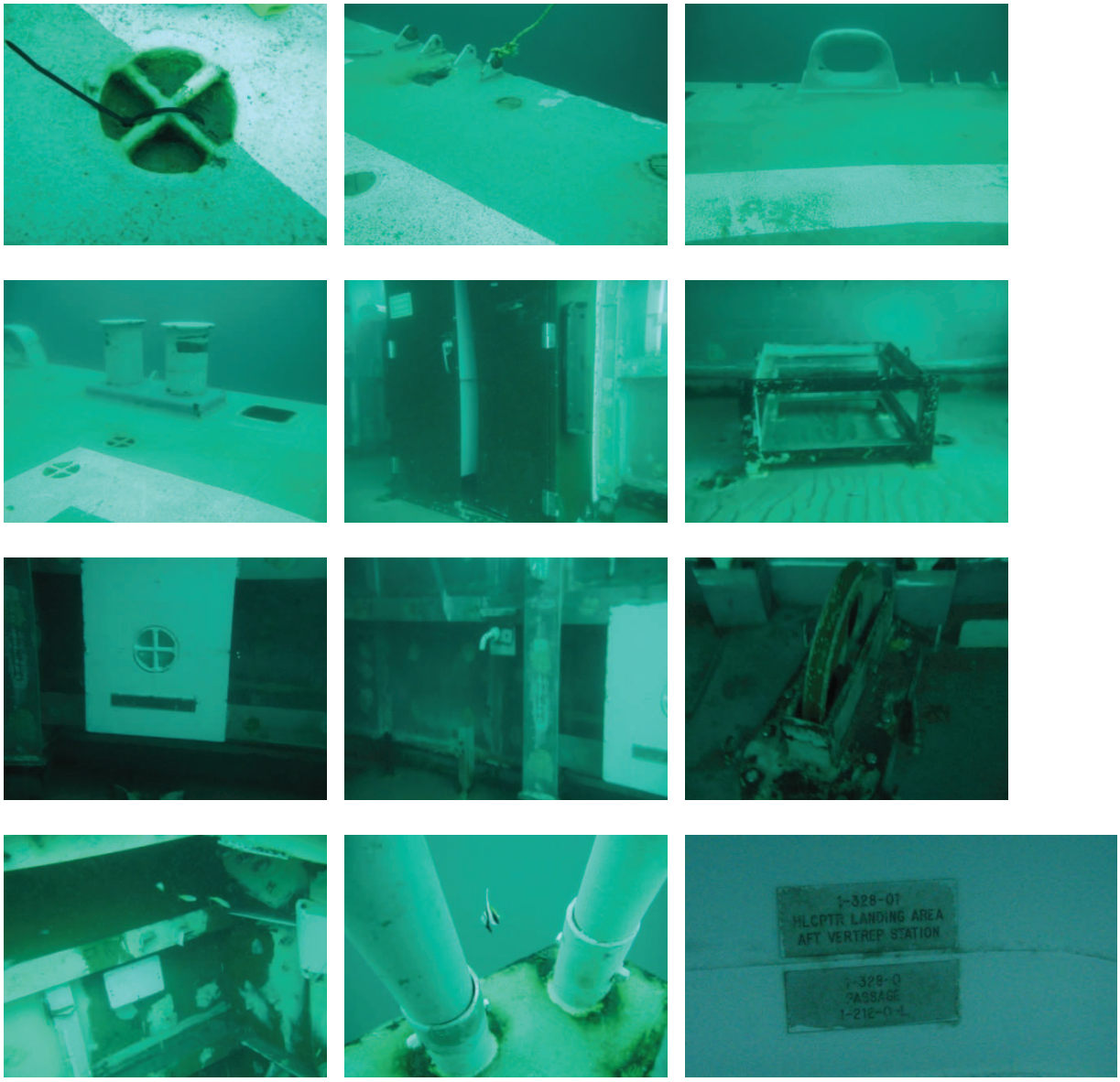


Figure 3.14 Still images captured on the stern starboard side transect.

3.2.5 Mid Ship Port Side

No obvious marine growth was present on the mid ship port side transect as shown in **Figure 3.15**.

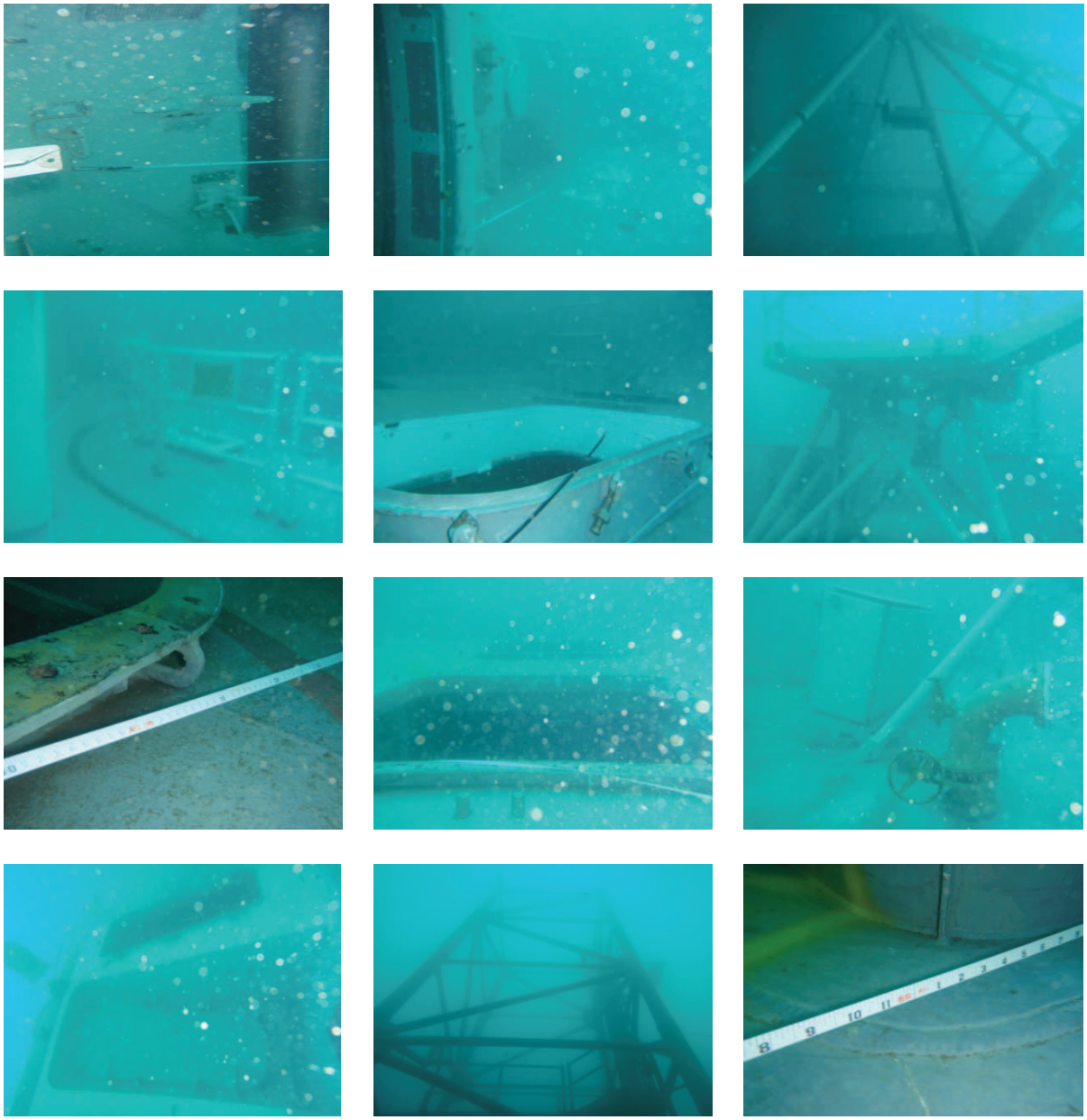


Figure 3.15 Still images captured on the mid ship port side transect.

3.2.6 Mid Ship Starboard Side

No obvious marine growth was present on the mid ship starboard side transect as shown in **Figure 3.16**.

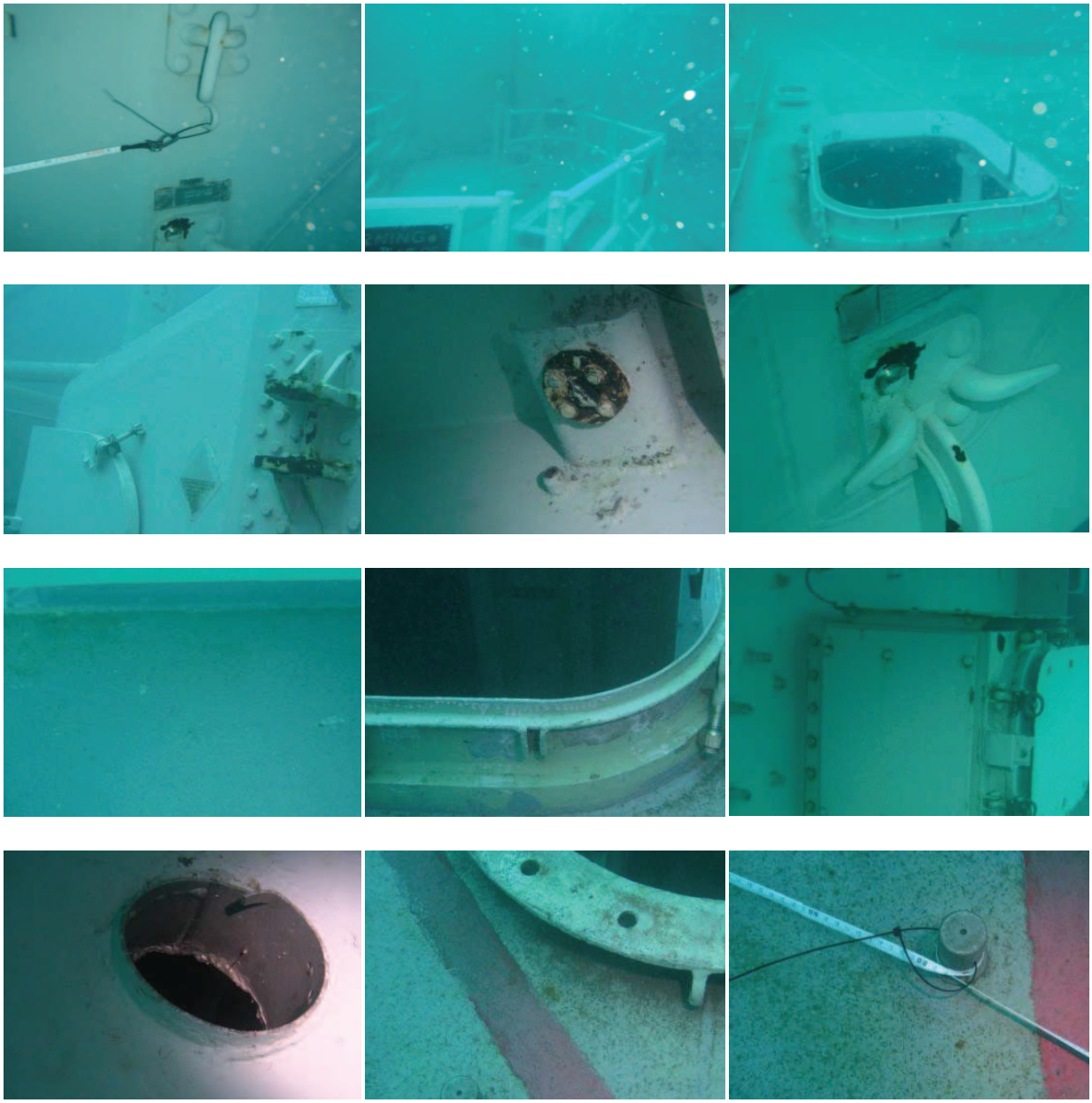


Figure 3.16 Still images captured on the mid ship starboard side transect.

3.3 Seafloor Sediments and Ship Hull

3.3.1 Bow

The seafloor sediments around the bow of the ship consisted of fine sands with a high degree of shell rubble in some areas. Sand ripples were evident with increasing distance from the ship's hull and there was also evidence of sand displacement / scouring where the ship has settled on the seabed. Dense marine growth was present underneath the hull of the ship, but for safety reasons this growth was not assessed (**Figure 3.17**).

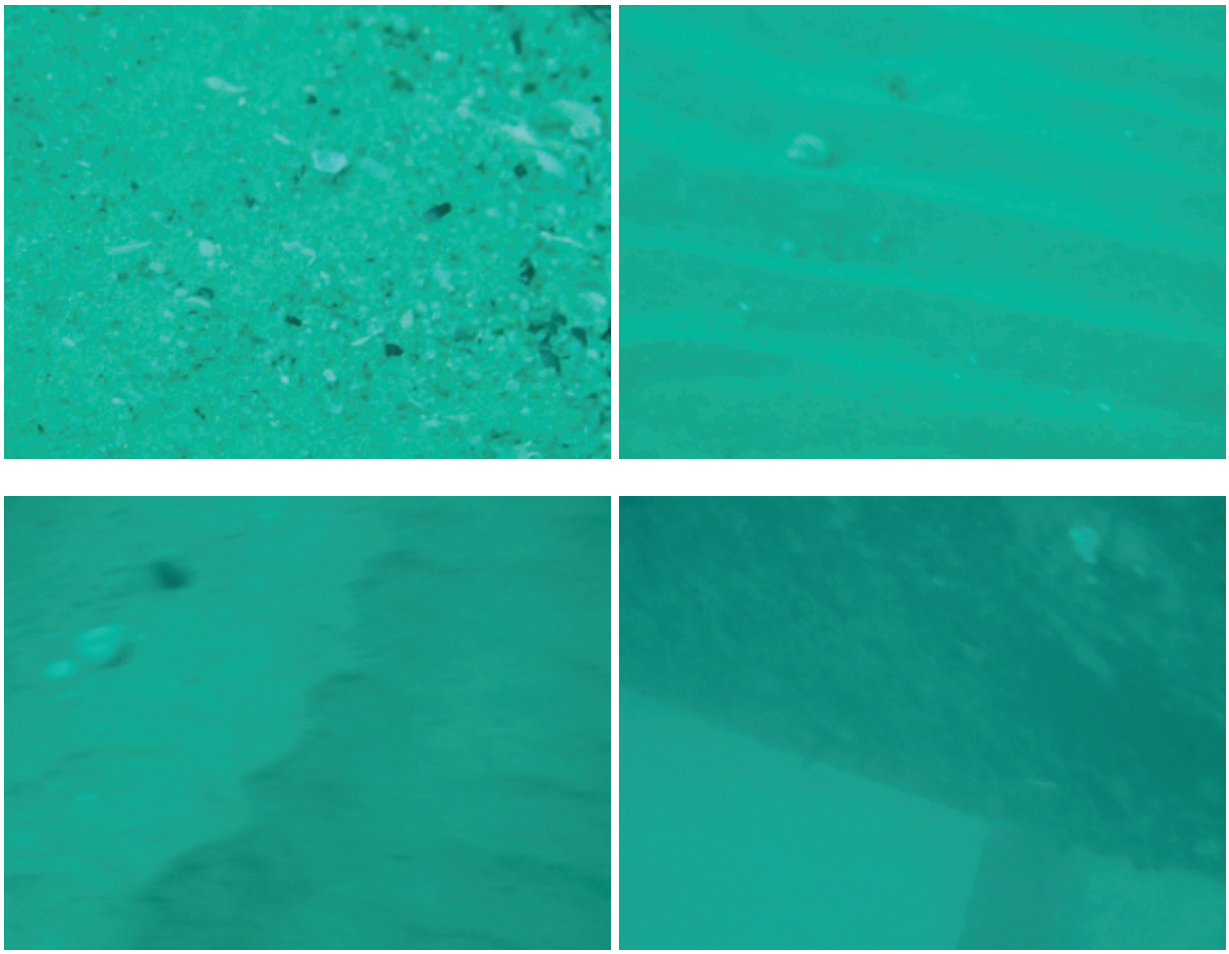


Figure 3.17 Images of the seabed and hull at the bow of the ship.

3.3.2 Stern Port Side

Seafloor sediments at the port side of the stern of the ship consisted of fine sands with a high degree of shell rubble. A significant area of sand displacement / scouring was present approximately 3 m from the vessel. This was around 1.5 m deep and 6 m in diameter. Marine growth was present underneath the hull of the vessel at the stern however this was not assessed due to safety reasons (see **Figure 3.18**).

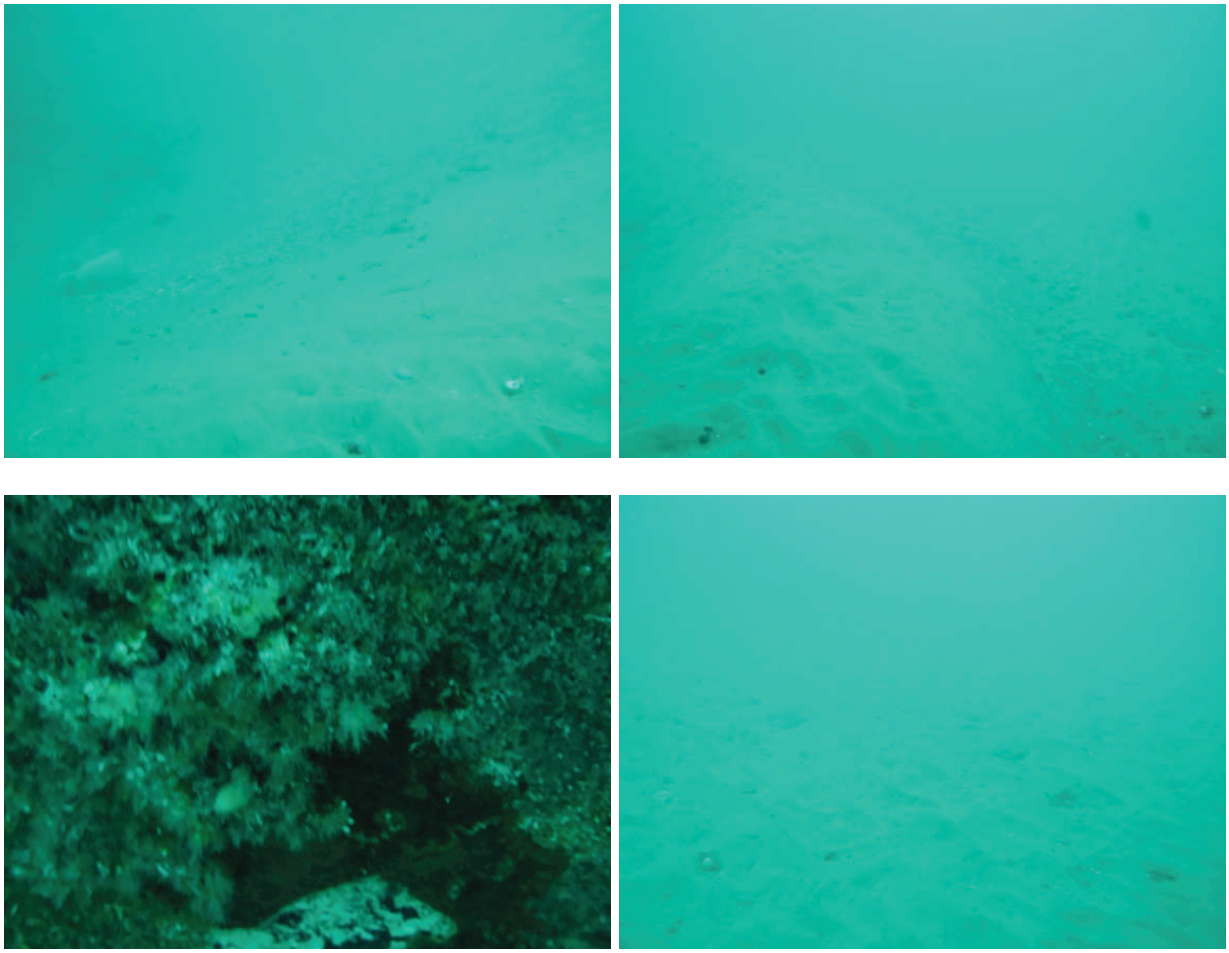


Figure 3.18 Images of the seafloor and hull at the stern of the ship port side.

3.3.3 Stern Starboard Side

Seafloor sediments at the starboard side of the stern of the ship also consisted of fine sands with a high degree of shell rubble. As with the port side of the vessel a significant area of sand displacement / scouring was present approximately 3 m from the vessel, approximately 1.5 m deep and 6 m in diameter. Marine growth was present underneath the hull of the vessel at the stern however this was not assessed due to safety reasons (see **Figure 3.19**).

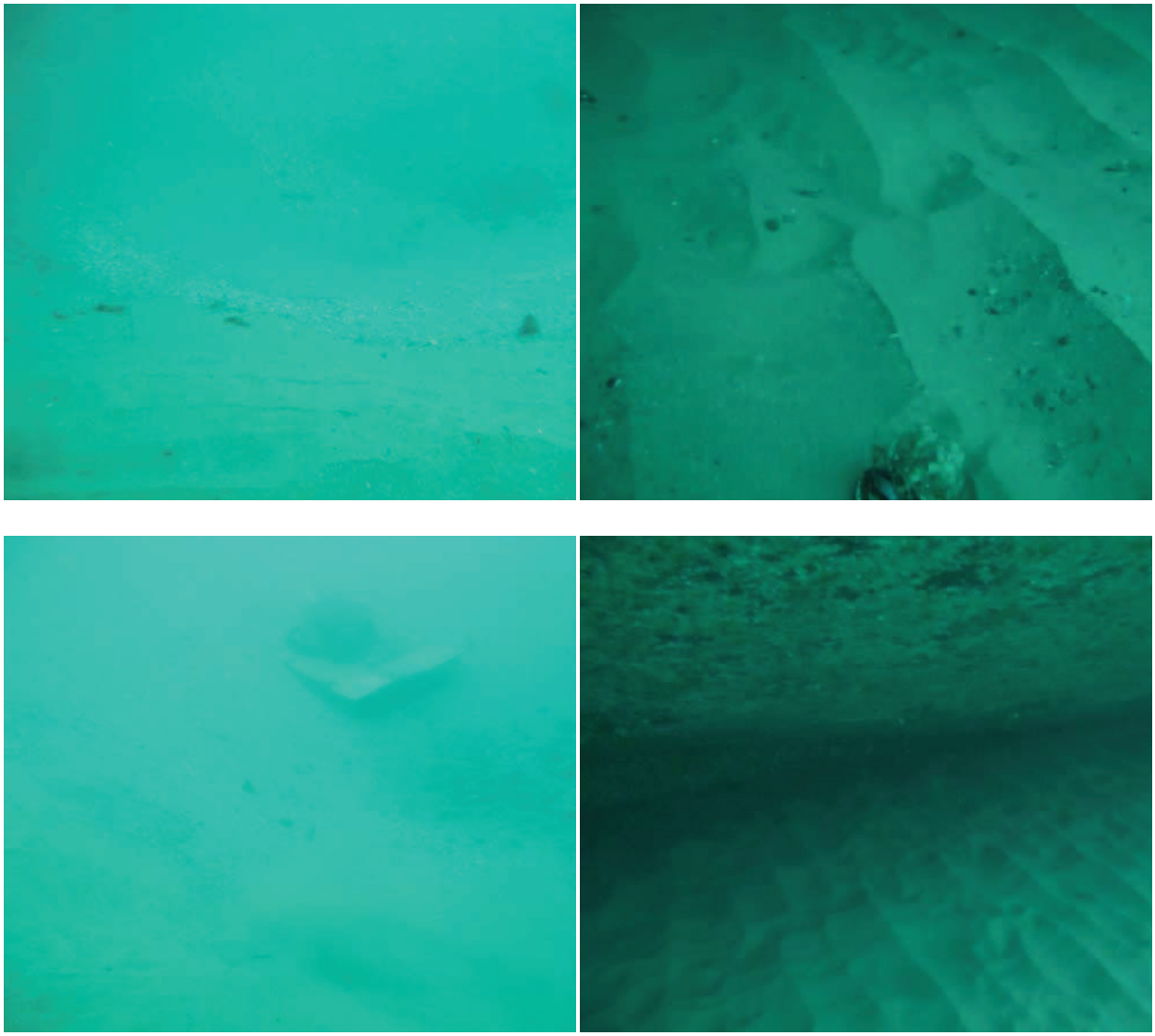


Figure 3.19 Images of the seafloor and hull at the stern of the ship starboard side.

3.4 Marine Fauna

During the baseline reef surveys a number of juvenile fish including brown sabretooth blennies, *Petroscirtes lupus*, blackspot goatfish, *Parupeneus spilurus* and bannerfish, *Hemiochus sp.* were seen to have taken up residence on the vessel, as seen in **Figure 3.20**.

Figure 3.20 Images of marine fish fauna observed during the horizontal transect surveys on the superstructure.

3.5 Threatened / Protected and Introduced Marine Species

No threatened or protected marine flora or fauna were observed on or near to the ship during the baseline surveys, nor were any introduced marine pest species present.

4. DISCUSSION

4.1 Epibenthic Assemblages on the Vessel

Foliose green algae and serpulid worm casings were present on the lowermost extent of the hull of the vessel, in the area which had been submerged during docking prior to scuttling. Transects taken on the horizontal plane of the hull just weeks after the ship was scuttled showed a fine layer of marine algae had formed over the hull of the vessel, and soft bryozoans had also colonized sections of the hull. However, horizontal and vertical surfaces and features on the superstructure were free of any obvious marine growth immediately post scuttling. A number of juvenile fish species were also seen to have taken up in various locations around the ship such as blennies, goatfish and bannerfish immediately after the ship was scuttled.

Algae

Foliose green algae was present on the lower vertical surfaces of the ship's hull, which would have been just below the approximate water level while docked in Sydney Harbour, in high light conditions. It is expected that over time the green algae present on the lower hull will be replaced with assemblages of sessile marine invertebrate taxa which are more common at depth, and in lower light conditions including ascidians, bryozoans and sponges. The growth and survival of marine algae is strongly influenced by incident light levels, and algae have been shown to have greater recruitment to unshaded habitats (Glasby 1999a, b; Goldberg and Foster 2002; Clark *et al.* 2004; Blockey 2007). One explanation for this may be that marine invertebrates, which compete with algae for space, have greater levels of recruitment and survival in shaded areas (Harper and Williams 2001).

Serpulid worms

Serpulid worms are one of the most significant groups of marine fouling polychaetes (Wisely 1959). The serpulid worm casings on the Ex-HMAS ADELAIDE are most likely to belong to the common and endemic polychaete species *G. caespitosa* (Edgar 1997). This filter feeding species is extremely common on exposed rocky shores and artificial substrates in eastern Australia, including Sydney Harbour, and is referred to as "Sydney Coral". This species can occur in such dense aggregations that the casings (or tubes) form a distinct band in mid intertidal zones (Beesley and Ross 2000). The figures below show dense aggregations of these worm casings. While long term survival of *G. caespitosa* is unlikely at the depth that the ship has been scuttled, the serpulid casings form a complex heterogeneous surface, which will likely facilitate the attachment of other marine fouling organisms on the Ex-HMAS ADELAIDE (Svane and Peterson 2001). It will be of interest during future reef surveys to determine whether these areas of biogenically engineered habitat created by serpulid worms are inhabited more quickly than other more homogeneous vertical surfaces of the hull.

4.2 Development of Epibenthic Assemblages

Factors influencing development of benthic assemblages

A high diversity of sessile marine taxa will likely colonise the Ex-HMAS ADELAIDE over time. There have been numerous studies of the development of epibenthic assemblages on subtidal artificial structures in NSW. However, these have often focused on maritime structures such as seawalls and wharfs, which have not been constructed purposely as artificial reefs (e.g. Glasby 1999a; Glasby and Connell 1999; Chapman and Clynick 2006; Clynick *et al.* 2007). A wide range of environmental variables have been found to influence the development of epibenthic subtidal assemblages on natural and artificial substrates including water depth (Moura *et al.* 2007; Rule and Smith 2007), surface orientation (Glasby and Connell 2001; Knott *et al.* 2004), orientation in relation to prevailing currents (Abelson 1994; Abelson and Denny 1997) and surface complexity and structure (Edwards and Smith 2005; Moura *et al.* 2007). The development of epibenthic subtidal assemblages has also been related to the establishment of migratory and stationary fish communities (Aburto-Oropeza and Balart 2001; Clynick *et al.* 2007; Redman and Szedlmayer 2009).

In the early stages of epibenthic assemblage development, the proximity of artificial structures to natural reef habitats and the speed and direction of currents can play an important role. Nearby natural habitats and other artificial structures act as a supply source for juvenile larvae and spores, and artificial structures which are isolated are considered to be closed or semi-closed systems (Connell and Slatyer 1977; Bombace *et al.* 1994). The distance over which larvae can travel and thus can settle and develop on artificial reefs is largely dependent on flow rates (Hurd 2000; England *et al.* 2008). Similarly, water movement around artificial structures will influence the development of assemblages, with increased water movement enhancing the rate at which inorganic nutrient and carbon dioxide are consumed by benthic species, and thus the rates at which important growth enhancing metabolic processes can occur (Denny 1985; Judge and Craig 1997). It is noted that during the period since scuttling of the Ex-HMAS ADELAIDE, weather and metocean conditions on the NSW Central Coast have been extremely unsettled. The area has been subjected to strong and gale force winds at times, heavy rainfall, strong currents and extremely large seas with significant wave action affecting the coastline. A number of sea spouts also formed off the coast and were sighted around the dive site in late May.

Many studies of the early stages of artificial reef colonisation have shown that development follows the ‘inhibition model of succession’ which was first suggested by Connell and Slatyer (1977) (e.g. Cummings 1994; Palmer-Zwahlen and Aseltine 1994). The ‘inhibition model of succession’ is one in which initial settlers dominate the substratum and delay the appearance of secondary ones. Once a shift in community structure has occurred, additional species are then able to settle. Succession progresses to a point where earlier settlers may change the existing habitat in such a way that it becomes suitable for later settlers to attach (Connell and Slatyer 1977). Typical initial fouling organisms on artificial reefs include hydrozoans, polychaetes, molluscs, bryozoans, tunicates and sponges (Schumacher 1988; Palmer-Zwahlen and Aseltine 1994; Perkol-Finkel and Benayahu 2005).

These organisms have been found to play an important role in enhancing structural complexity to allow for settlement of species such as corals in tropical and sub-tropical regions (Schumacher 1988).

Surface orientation, surface complexity and structure may all influence the development of epibenthic community assemblages on artificial reefs. Species composition and abundance may be influenced by the relief of an artificial reef or structure (Baynes and Szmant 1989; Glasby and Connell 2001).

Lower levels of sedimentation and increased water circulation around vertical or inclined surfaces generally lead to higher levels of recruitment on these surfaces than on horizontal surfaces of artificial reefs (Wendt *et al.* 1989). For example, on shipwrecks in South Carolina, Baynes and Szmant (1989) reported a higher abundance of octocorals on vertical compared to horizontal surfaces. In addition, more complex and heterogeneous reef structures and surfaces can affect species diversity, density and size distribution by offering a greater array of habitat niches (Svane and Peterson 2001). Guichard *et al*. (2001) have shown that marine invertebrates preferentially settle on complex rather than simple substrata. Taking into account the above, it is expected that vertical and more complex surfaces of the Ex-HMAS ADELAIDE will provide habitat for a greater array of marine sessile taxa than flat or horizontal surfaces.

4.3 Fish Assemblages

Juvenile fish species were seen to have inhabited the vessel just one week post scuttling. Numerous studies have shown that recruitment of fish species to artificial reefs is rapid over the first year post-deployment, followed by a period of moderate decline before recruitment levels off (e.g. Bohnsack and Talbot 1980; Cummings 1994; Manderson and Able 2003; Markevich 2005; Lowry *et al.* 2010). The theory of island biogeography (MacArthur and Wilson 1967) has been used to define the colonisation and subsequent development of fish communities on artificial reefs, suggesting that the rate of movement of colonising species, distance from the source of recruits and the size of the area being colonised all influence the pattern of succession of fish communities (Walsh 1985). It has also been suggested that rapid colonization of artificial reefs by fish is the result of individuals being attracted from nearby natural habitats (Alevizon and Gorham 1989; Golani and Diamant 1999). The proximity and degree of connectivity among suitable habitats and the artificial reef may play an important role in influencing rates of colonisation and post settlement success (Fernandez *et al.* 2007).

In addition, behavioural factors including ability to cross areas of bare sand between isolated reefs will also influence initial colonisation rates (Fernandez *et al.* 2007). Once initial colonisation has occurred, a number of post settlement processes including predation will act to influence fish species assemblage structure over time, and recent studies have shown that there are significantly higher visitation rates of large predators, resulting in higher rates of juvenile mortality on artificial reefs than natural reefs (Overholtzer and Karen 2004). In the short term (i.e. year), reef fish assemblages on the Ex-HMAS ADELAIDE are likely to rapidly increase in diversity and abundance, with species likely to occur being those which are locally abundant on nearby natural reefs. Over time, a more stable

equilibrium will be reached, with locally abundant predators playing an important role in the resulting community structure.

5. RECOMMENDATIONS FOR FUTURE MONITORING

A number of constraints were identified during the baseline survey and these should be taken into account to ensure that future monitoring on the vessel is safe, viable and informing. These are outlined below together with recommendations for ongoing surveys.

5.1.1 Depth of Vessel

Actual depths encountered during the baseline surveys placed limitations on the work which could be undertaken on the hull of the vessel in accordance with the safe diving limit for commercial divers (see Note – page 3). Consequently, the establishment of the baseline surveys in the horizontal plane along the hull of the vessel, which was undertaken around mean low water, resulted in the 3 horizontal transects (with the shallowest commencing at the stern of the vessel, just below the gunwale at a depth of ~28 m) to be located extremely close to each other (i.e. within 1 m), which is not particularly useful in informing differences in marine growth along a depth gradient.

5.1.2 Transects in the Horizontal Plane on the Hull

A number of other constraints were encountered when endeavoring to undertake transects in the horizontal plane along the hull of the vessel. These included the limitation in dive time when working near the safe diving limit for commercial divers, strong currents and surges around the hull (making it difficult to maintain a stable depth while filming) and a lack of attachment points to mark the survey route and fixed photo points. If a horizontal transect on the hull is deemed to be required it is recommended that only a single transect be undertaken on the hull along the horizontal plane at just below the gunwhale.

5.1.3 Additional Horizontal Transects

Six horizontal transects were set up on the superstructure at a range of depths and with clearly marked routes. Along these transects a wide range of vertical and horizontal surfaces and features are available for the attachment of marine organisms and for monitoring of marine growth over time. These surfaces are likely to attract a high diversity and abundance of marine taxa compared to the hull of the vessel. All horizontal transects would be able to be undertaken by commercial divers in either high or low tide conditions as they are all located in less than 28 m of water at high tide.

5.1.4 Additional Vertical Transects

The vertical photographic transects which were set up and marked at the bow and stern of the vessel would allow for assessment of marine growth on the vertical surface of the hull over time at varied depths. As the quadrats start in as little as 20 m of water (at the bow), a number of quadrats at a

variety of depths are able to be captured. In addition, during low tide conditions it is possible to take still photographs down the hull at bow and the stern in much less time required than taking six 100 m video transects along the hull which would then be used to infer vertical growth (i.e. through comparison of the three transects each side). It suggested that similar vertical photo transects as were set up on the hull could also be set up on either side of the superstructure in shallower waters.

6. REFERENCES

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Aburto-Oropeza O. and Balart E.F. (2001). Community structure of reef fish in several habitats of a rocky reef in the Gulf of California. *Marine Ecology* **22**, 283-305.

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