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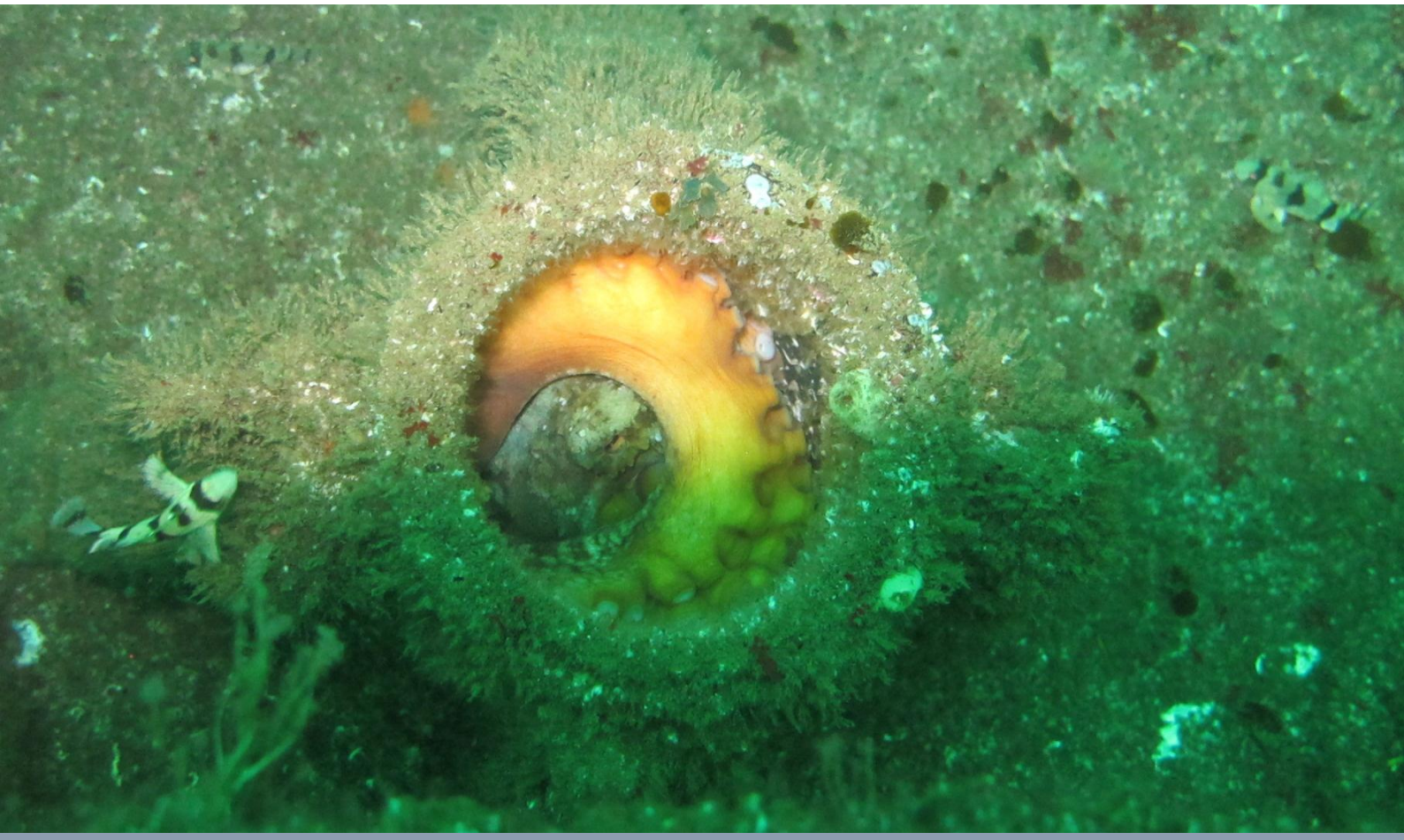

Ex-HMAS Adelaide Artificial Reef

Reef Community Monitoring

Survey 1

Job Number: EL1112024

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Cover Image: Octopus (*Octopus* sp.) and Eastern fortesque (*Centropogon australis*) living on the Ex-HMAS Adelaide, October 2011. Photographer, Yesmin Chikani (Cardno Ecology Lab).

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Summary

Cardno (NSW/ACT) trading as Cardno Ecology Lab Pty Ltd was commissioned by the Department of Primary Industries – Catchments and Lands, to undertake the post-scuttling environmental monitoring for the Ex-HMAS Adelaide artificial reef and dive site.

A comprehensive environmental assessment has been undertaken for the project in accordance with state and federal environmental legislation. This included approval under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) and obtaining an Artificial Reef (or Sea Dumping) Permit issued under the *Environment Protection (Sea Dumping) Act 1981* from the federal Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC). A condition of the Permit is that the Department of Primary Industries – Catchments and Lands must implement the proposed Long Term Monitoring and Management Plan (LTMMP) prepared by Worley Parsons in March 2011.

This Progress Report outlines the methodology and findings of Reef Community Monitoring Survey 1, the first of eight reef community surveys required as part of the LTMMP. These surveys are to be carried out on a quarterly basis. The aims of the reef community survey as outlined in the LTMMP were to gain an understanding of:

- Types of flora and fauna assemblages present;
- Rate of development of fouling assemblages and how they change over time;
- Variation in the rates at which assemblages develop on different surfaces of the vessel; and
- Presence of introduced or pest species.

Field surveys were carried out over a two-day period on 11 and 13 October 2011. Survey methods involved using divers to take photoquadrats and under water video on different parts of the ship. Photoquadrats were statistically analysed for percentage cover of encrusting biota using Coral Point Count with Excel extensions (CPCe). Photoquadrats from the baseline survey (carried out in April/May 2011) were also compared with the current survey (although statistical comparisons were not made between these). Underwater video footage was reviewed and used to describe the encrusting reef community colonising the hull, deck and superstructure.

Analysis of photoquadrats taken from different parts of the ship indicated that even at this relatively early stage of colonisation, spatial differences in community assemblages were evident. This was particularly apparent among transects sampled from the deck (horizontally orientated) and hull (vertically orientated) surfaces, which were significantly different from each other, mainly due to differences in abundance of serpulid and serpulid/barnacle matrices. Visually comparing photoquadrats between the baseline and current survey showed that the majority of the ship's surface had changed from being virtually bare to completely covered in encrusting organisms including serpulid polychaetes, barnacles, ascidians, encrusting algae, bryozoans and hydroids.

Fish abundance and diversity observed around the Ex-HMAS Adelaide have also increased substantially. A total of three species; from three families were initially observed in the baseline survey. These included blackspot goatfish (*Parupeneus spilurus);* bannerfish (*Hemiochus* sp.) and sabretooth blenny (*Petroscirtes lupus*). A total of 19 species from 16 families were observed during the present survey. The assemblage of fish observed in the present study was dominated by eastern fortesque (*Centropogon australis*) and yellowtail scad (*Trachurus novaezelandiae*) and included a mixture of resident reef-associated species and transient visitors which are typical of temperate natural reef habitats. No introduced marine pests or species that are protected under conservation legislation were observed during the survey.

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Glossary

Artificial Reef	A structure or formation placed on the seabed for the purpose of increasing or concentrating populations of marine plants and animals or for the purpose of being used in human recreational activities.
CPCe	Coral Point Count with Excel Extensions. A software package used to analyse cover of encrusting organisms and corals.
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities
EP&A Act	Environmental Planning & Assessment Act 1979
LAT	Lowest Astronomical Tide
Epiphytic	Growing on the surface of.
LTMMP	Long Term Monitoring and Management Plan
Introduced Marine Pest	Introduced marine pests are species moved to an area outside their natural range, generally by human activities, and that threaten the environment, human health or economic values.
PCoA	Principle Coordinates Analyses
PERMANOVA	Permutational Analysis of Variance. A statistical routine run in Primer-E.
SIMPER	Similarity Percentage. A statistical routine run in Primer-E.

1 Introduction

1.1 Background and Aims

Cardno (NSW/ACT) trading as Cardno Ecology Lab Pty Ltd was commissioned by the Department of Primary Industries – Catchments and Lands, to undertake the post-scuttling environmental monitoring for the Ex-HMAS Adelaide artificial reef and dive site.

The Ex-HMAS Adelaide was gifted from the Australian to the NSW Government for the specific purpose of scuttling the ship as an artificial reef off the Central Coast of NSW. A comprehensive environmental assessment was undertaken for the project in accordance with state and federal environmental legislation. This included approval under the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) and obtaining an Artificial Reef (or Sea Dumping) Permit issued under the *Environment Protection (Sea Dumping) Act 1981* from the federal Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC).

Sea Dumping Permits ensure that appropriate sites are selected, materials are suitable and appropriately prepared, that there are no significant adverse impacts on the marine environment and that the reef does not pose a danger to marine users. A condition of the Permit is that the Department of Primary Industries – Catchments and Lands, must implement the proposed Long Term Monitoring and Management Plan (LTMMP) prepared by Worley Parsons in March 2011.

The LTMMP covers environmental and structural monitoring for the first five years post-scuttling and forms the basis for ongoing monitoring and maintenance over the operational life of the vessel as a dive site, which is estimated to be 40 years. The frequency of monitoring and the methodologies used will be reviewed periodically during the life of the Plan. The scope of work to be carried out by Cardno Ecology Lab is for a two year period post-scuttling, which follows on from initial baseline investigations carried out by Worley Parsons in April/May 2011. It includes the following environmental monitoring components:

- Reef communities;
- Sediment quality; and
- Bioaccumulation studies.

This Progress Report follows from a baseline survey following scuttling of the ship. It outlines the methodology and findings for the first of eight reef community surveys. These surveys are to be carried out on a quarterly basis.

The aims of the reef community monitoring survey, as outlined in the LTMMP, is to gain an understanding of:

- Types of flora and fauna assemblages present;
- Rate of development of fouling assemblages and how they change over time;
- Variation in the rates at which assemblages develop on different surfaces of the vessel; and
- Presence of introduced or pest species.

This progress report outlines the following:

- Description of sampling dates, times, weather conditions and tidal height;
- Description of the methods used including the position of the fixed transects and photoquadrats;
- Results including interpretation of video footage, fixed point photographs and CPCe analyses;
- Statistical analyses of photoquadrats over time and spatially.
- Identification of fish, threatened or protected species and any introduced or marine pest species observed during the survey;
- Discussion of findings; and
- Reports of any condition or occurrence that may influence results of the study.

1.2 Study Site and Vessel

The Ex-HMAS Adelaide artificial reef and dive site is located within Bulbararing Bay, approximately 1.87 km offshore from Avoca Beach. The ship lies at a depth of approximately 32 m to 34 m of water at Lowest Astronomical Tide (LAT) on top of a relatively flat, sandy substratum. There is a minimum of 6 m of sand overlying bedrock. The vessel is orientated with the bow facing into the prevailing ESE swell direction (**Figure**

1). Approximate depths to various levels on the ship from Lowest Astronomical Tide (LAT) are shown in **Figure 2**.

The ship is 138.1 m in length, with a beam of 14.3 m and an original displacement of 4,200 tonnes. The hull is made of steel and the superstructure of aluminium alloy. Heights are approximately 12 m to the main deck, 18 m to the bridge, 24 m to the top of the foremast (the mast closest to the bow), and 39 m to the top of the mainmast (NSW Government 2011). The ship was decommissioned and initial works carried out by the Department of Defence at the Royal Australian Navy's (RAN) Fleet Base. The contractor then prepared the ship for scuttling. This involved the removal of the main mast structures for safety and navigation reasons and stripping of machinery, hatches and any items that could pose a risk to divers or the environment. Decontamination included the removal of fuels, oils, heavy metals, batteries and electrical items containing, or that may have contained polychlorinated biphenols (PCBs), were removed. Diver access holes have been cut into the sides of the hull, floors and ceilings to allow extra vertical access between decks and also to allow light to penetrate. Further holes were also made to allow air to escape during the scuttling process (NSW Government 2011).

1.3 Baseline Studies

The Ex-HMAS Adelaide was scuttled on the 13 April 2011. A baseline investigation of reef communities was carried out between the 18 April and 30 May 2011, immediately post-scuttling. In accordance with the methodology outlined in the LTMMP, underwater video and still photography was taken along horizontal and vertical transects of the ship using divers. These were sampled as follows:

- Horizontal Hull = 6 transects in total (3 x 100 m transects along the starboard and port planes).
- Vertical Hull = 4 transects in total (2 x starboard (stern and bow), 2 x port (stern and bow)).
- Horizontal Deck = 6 transects in total (2 x 50 m transects at the bow, mid ship and stern).

Qualitative surveys of the superstructure were also undertaken.

As expected, marine growth on the vessel was minimal, consisting of green foliose algae and calcareous casings of serpulid polychaete worms, although these were thought to have colonised the lower part of the vessel's hull while docked for preparation prior to scuttling. A light covering of algae and bryozoans was noted on the horizontal (deck) surface of the vessel approximately two weeks post-scuttling, otherwise the superstructure was bare. Three species of juvenile fish including blennies (Blenniidae), goatfish (Mullidae) and bannerfish (Chaetodontidae) were recorded around the vessel although their abundance was not reported.

As for the current study, SCUBA divers were limited to working to a maximum depth of 30 m (as per Australian Standard AS 2815: Training and Certification of Occupational Divers) and as the lowest point of the vessel sits at approximately 33.9 m (LAT), samples could not be collected from the bottom section of the hull. Horizontal transects along the hull were within 1 m of each other and did not provide the vertical spread across the hull as intended. Furthermore, in adverse weather conditions, horizontal surveys of the hull proved difficult due to surges and time restrictions. An alternative design to that specified within the LTMMP was therefore recommended whereby six additional transects (50 m length) were taken on the deck of the ship which is at approximately 28 m LAT, and can therefore be sampled at all tides. In summary, the following recommendations were made for future monitoring surveys:

- Horizontal Hull transects be limited to a single 100 m transect along the horizontal plane on either side of the vessel; and
- Additional vertical transects be taken on either side of the super structure.

Adjustments to the sampling methodology from that outlined in the LTMMP have therefore been made to this monitoring survey. This sampling design will allow for a more robust statistical analysis and help identify the nature of the reefs development over time by increasing the number of vertical transects at the bow and stern, allowing comparisons to be made at different depths. The single horizontal transects on each side of the hull provides adequate coverage within the limits of scientific diving as per the LTMMP. Within the safe diving limits, additional horizontal transects along this plane (as initially proposed in the LTMMP) would provide little additional benefit in terms of vertical coverage and are therefore redundant. The sampling design proposed will provide the best coverage and most efficient use of bottom time. The design is also similar to other studies investigating the development of artificial reefs in space and time, such as the Ex-HMAS Brisbane in Queensland (Schlacher-Hoelinger *et al*. 2009), which has proven to be successful.

Boundary of Dive Site	Easting (MGA 94)	Northing (MGA 94)
A	356428.713	6296117.693
B	356538.438	6296341.142
C	356850.615	6296188.618
D	356742.410	6295963.310

Figure 1: Location of Ex-HMAS Adelaide Artificial Reef and Dive Site. The approximate location and orientation of the ship is indicated by the yellow line.

2 Study Methods

2.1 Field Methods

2.1.1 Photoquadrats

Line transects were demarcated along vertical and horizontal planes of the ship on the hull, superstructure and deck. These transects were based on those previously used for the baseline survey, although additional transects were added. Where possible, cable ties used in the baseline survey to mark transects were located to ensure the same transects were sampled. Fluorescent pink flagging tape was also added to help locate the same transects in future surveys where needed. Within each line transect, replicate photoquadrats (50 x 50 cm) were taken to sample reef assemblages colonising different parts of the ship. In total, 82 photoquadrats and 16 line transects were sampled. These included:

Horizontal Hull (23 m LAT)

- x 2 transects in total: (1 x 100 m transects along the starboard and port planes).
- x 12 photoquadrats in total (x 6 photoquadrats along each side).

Vertical Hull (19 – 24 m LAT)

- x 4 transects in total: (portside stern x 1), (portside bow x 1), (starboard stern x 1), (starboard bow x 1),
- x 20 photoquadrats in total (x 5 photoquadrats along each vertical transect).

Vertical Superstructure (22 – 17 m LAT)

- x 4 transects in total: (portside stern x 1), (portside bow x 1), (starboard stern x 1), (starboard bow x 1),
- x 20 photoquadrats in total (x 5 photoquadrats along each vertical transect).

Deck (22 – 19 m LAT)

- x 6 transects in total (2 x 50 m transects at the bow, 2 x mid ship and 2 x stern).
- x 30 photoquadrats in total (x 5 per transect).

The approximate locations of all transects are indicated on **Figure 2**.

Note that depths given are in LAT and actual depths factoring in tides and the ships partial burial into the sediment are several metres deeper.

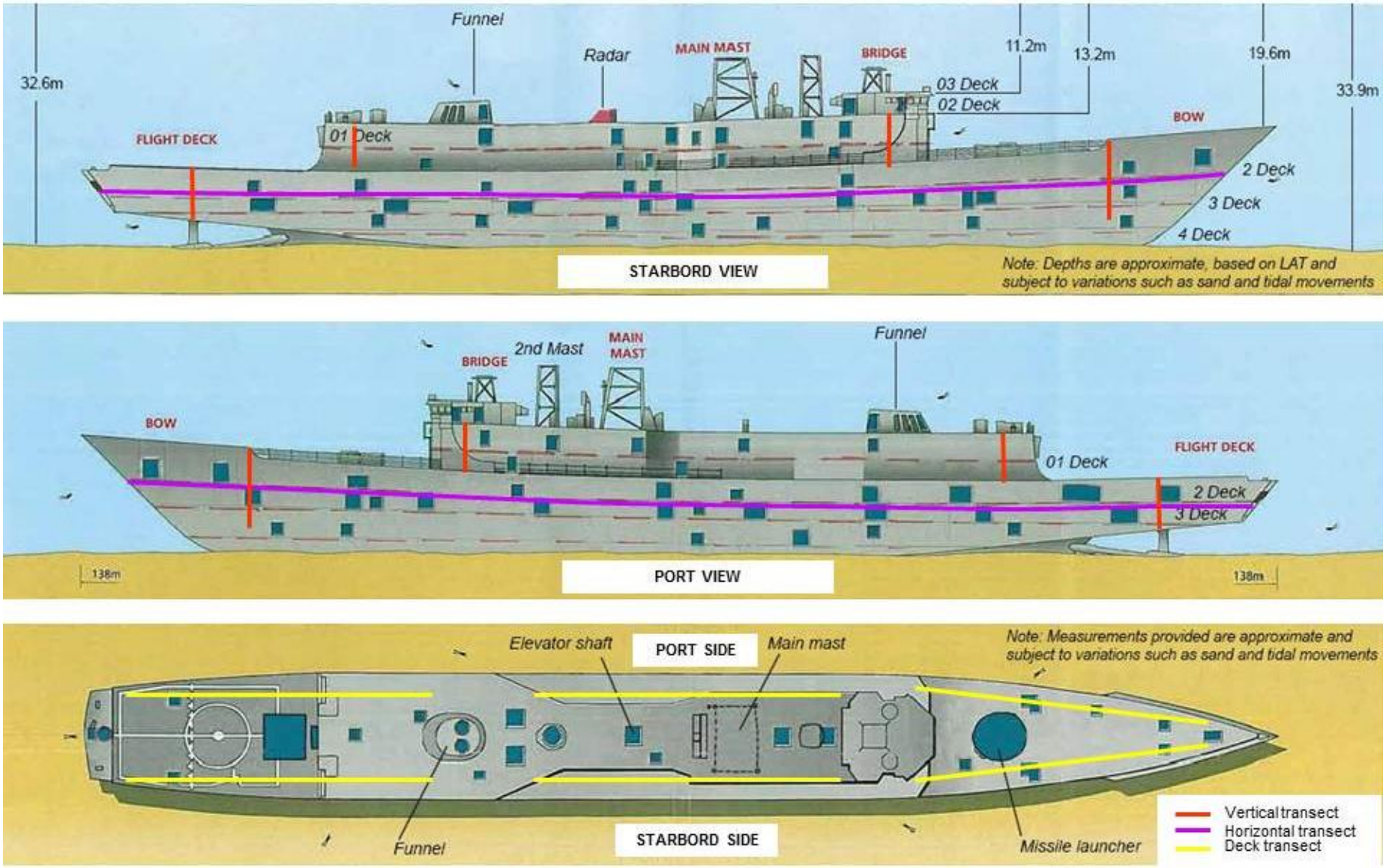

Figure 2: Plans of the Ex-HMAS Adelaide and Positions of the Reef Community Survey Sampling Transects.

Photoquadrats were acquired at regular intervals along each transect. For the vertical transects this was approximately every metre. For horizontal hull transects this was approximately every 6 m and for the deck and superstructure every 10 m (consistent with the baseline survey). Photographs were taken with a Canon G12 digital still camera which provides high quality (10MP) photographs. Photographs of individual taxa were taken to aid in identification and the interpretation the video transects and photoquadrats. Fish species encountered were also photographed where possible.

2.1.2 Fixed Point Photographs

Photographs were taken at 10 fixed point locations. This is to provide a qualitative record of succession over time. These locations were marked with luminous flagging tape and locations noted to assist in identifying these points in future surveys. Notes were taken on the exact location, distance from the structure or reference point and depth at which the photographs were taken (**Appendix A**).

2.1.3 Video Transects

Video footage covered the same transects used for the photoquadrat survey. Divers used underwater scooters, enabling them to maintain a constant slow speed and depth while filming along the proposed transects. Video was taken on Canon G12 still cameras set to HD video mode or a Sony miniDV HD camcorder. The video footage was taken at approximately 1 – 2 m from the vessel and angled at approximately 45° towards the vessel. This allowed the benthic community to be seen clearly in the foreground of the footage, while also capturing fish swimming in the background.

2.2 Analysis

2.2.1 Photoquadrats

Photographs were reviewed immediately after collection to ensure they were of suitable quality to meet the long term outcomes of the study. Where necessary, photographs were colour-corrected using Adobe Photoshop which helped filter out the green light and bring out natural colours.

Photoquadrats were analysed for percentage cover of encrusting biota (algae, bryozoans, sponges, sessile invertebrates, etc.) using Coral Point Count with Excel extensions (CPCe) (Kohler and Gill 2006). A 'virtual' photoquadrat scaled to 50 x 50 cm was digitally overlaid on each of the 82 frames (**Figure 3**). Within each photoquadrat, 100 points were placed on a 10 x 10 grid and the taxon, matrix or substratum under each point was identified visually. The total number of each was used as an estimate of percentage cover. Still photographs of different taxa were then compiled to prepare a project-specific Coral Identification Manual and project coral code file for use with CPCe. Identifications were made to the highest taxonomic level practical, although it should be recognised that at this early stage of colonisation, species level identification of many encrusting organisms such as sponges, bryozoans and ascidians was not feasible without further laboratory identification. In many instances, groups were described as an encrusting 'matrix' or were based on morphological characteristics such as colour or growth form. Examples of the matrix categories assigned included:

Serpulid matrix = serpulid tubes, sediment and fine brown filamentous algae;

Barnacle matrix = *Balanus* spp. sediment and fine brown filamentous algae;

Large barnacle matrix = large barnacles, sediment and brown filamentous algae;

Serpulid/barnacle matrix = Mixture of serpulid tubes and barnacles with a layer of encrusting red algae; and

Early colonising matrix = Indeterminate layer of trapped sediment and fine, filamentous brown algae.

QA/QC checks of CPCe files and identifications were made to minimise the potential for user bias in visual identification and to ensure the accuracy and repeatability of methods.

Analyses carried out included:

1. General findings
2. Analysis of spatial variation in reef communities
3. Analyses of temporal variation in reef communities using a qualitative approach.

General Findings

General findings included a list of species, taxa or groups identified, a description of the groups identified and general trends in total percentage cover.

Spatial Analyses

Variation in reef assemblages on different parts of the ship were analysed using multivariate and univariate statistical techniques as appropriate. Due to the existing design of the sampling program (pre-determined by the LTMMP and the baseline survey) testing of spatial differences was done in separate analyses.

The hypotheses (1-4) were:

1. No significant differences in reef assemblage structure between deep and shallow vertical transects

2. No significant differences in reef assemblage structure between port and starboard vertical transects

The design to test these hypotheses was as follows:

- Depth (shallow/deep): fixed, orthogonal
- Aspect (port/starboard): fixed, orthogonal
- Transect: nested (depth x aspect), random.

This design compared vertical transects among the superstructure (i.e. port bow, port stern, starbord bow and starbord stern) and vertical hull at the same positions.

3. No significant differences in reef assemblage structure between horizontally orientated (i.e. deck) surfaces and vertically orientated (hull) surfaces.

The design to test these hypotheses was as follows:

- Orientation (deck/hull): fixed, orthogonal.
- Aspect: (port/starboard): fixed, orthogonal.

This design compared transects from the deck (stern and mid, port and starbord) with the two horizontal trasects along the ship's hull.

4. No significant differences in reef assemblage structure among positions (deck surface only).

The design to test these hypotheses was as follows:

- Position (bow, mid-ships, stern): fixed, orthogonal.
- Aspect (port/starboard): fixed, orthogonal.

This design compared all transects sampled along the deck surfaces of the ship.

Statistical analysis of photoquadrat data was done using PERMANOVA+ (based on Bray-Curtis similarity matrices) in PRIMER v6. This is a permutational approach to analysis of variance (ANOVA) that is superior to traditional methods (Anderson *et al.* 2008) in that there is no assumption of normality in the data and designs can be unbalanced (e.g. different numbers of replicate samples at different places or times) if necessary. The approach yields exact tests for each level of an experimental design and is robust to differences among variances. As transformation of data to achieve normality was unnecessary, percentage data were not transformed. This also avoids problems with the transformation commonly applied to percentage data that have been recently identified (Warton and Hui 2011).

Multivariate data were represented graphically using Principles Coordinates Analysis (PCoA), a generalised form of Principal Components Analysis which complements the permutational ANOVA procedure (Anderson *et al*. 2008). Similarity Percentage Analysis (SIMPER) was used to identify those taxa, or groups of taxa contributing most to dissimilarities between assemblages.

Where appropriate, further univariate analyses were done using PERMANOVA+ (based on Euclidian distance) to investigate the abundance of species or taxa contributing the most to the spatial variability of samples.

Temporal Analyses

As data from the baseline survey indicated that all surfaces of the ship were bare (with the exception of a layer of green filamentous algae), statistical analysis over time was unnecessary as the percentage cover between the baseline survey and the current survey (survey 1) was clear from photoquadrats and video footage. A qualitative

approach was therefore taken whereby photoquadrats from the baseline survey were compared visually with photoquadrats from survey one from different parts of the ship.

A quantitative comparison of reef assemblages over time will be carried out once data from future surveys are available for comparison.

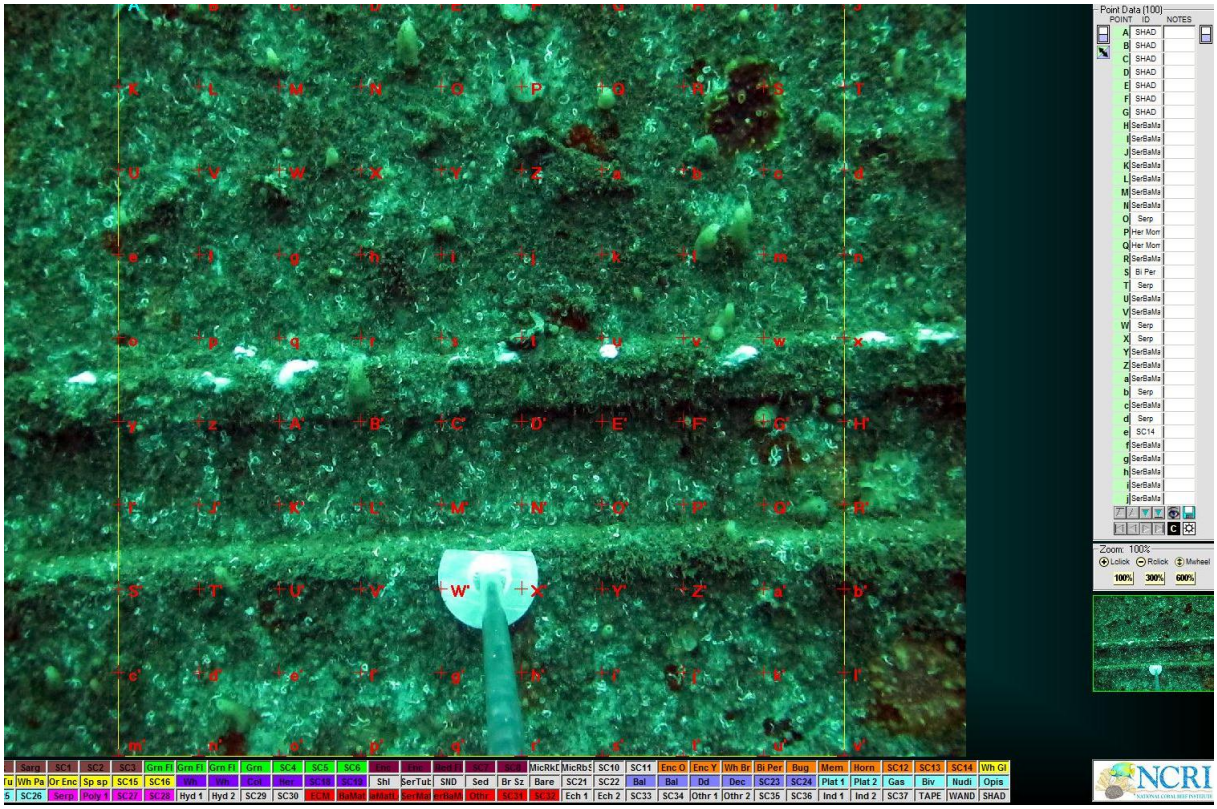

Figure 3: Screenshot of the CPCe Photoquadrat Analyses Frame with a Virtual 10 x 10 Grid Overlayed.

2.2.2 Fixed Point Photographs

Photoquadrats provided a quantitative analysis of encrusting cover. A qualitative appreciation of reef development was provided from fixed point photos. Fixed point photographs were qualitatively evaluated and compared to photos taken in similar locations during the baseline survey. It is noted, however, that due to difficulty in finding many of the original fixed points, direct comparisons were not made. Direct comparisons at the exact fixed points will be used for comparison in future surveys.

2.2.3 Video Transects

Video footage was reviewed and used to describe the encrusting reef community colonising the hull, deck and superstructure. Categories included: sessile invertebrates, mobile invertebrates, aquatic vegetation and fish. Identifications were done to the highest taxonomic level practical.

Fish observed were identified and added to the master species list for all surveys to date. Notes were made on the abundance of fish observed but no quantitative assessment of the fish assemblage associated with the ship was made in this survey.

Species of particular interest, i.e. that were observed in abundance or that were possible pests/introduced species were identified for further investigation. In future reef community surveys specimens will be brought back to the laboratory for identification.

3 Results

3.1 Photoquadrats

3.1.1 General Findings

In total, 28 individual taxa or groups of taxa were identified through the analysis of the 82 quadrats. This included serpulid polychaete worms, barnacles (*Balanus* spp.), encrusting bryozoans, solitary ascidians, sponges and hydroids, among others. Turfing brown and encrusting red algae were abundant and sporophytes of the brown macroalga, *Ecklonia radiate,* were evident in photoquadrats taken from the foredeck. In the majority of photoquadrats, the encrusting layer consisted of a variety of different organisms forming a matrix with trapped fine sediment and filamentous or turfing algae. A scraping of this encrusting layer was taken by divers from the top of the hull between the bow and mid-ship to gain an appreciation of the diversity of benthic macroinvertebrates colonising the encrusting layer. These species would not otherwise be detected from visual analyses of photoquadrats. Several families of polychaete worms (hesionidae, syllidae and serpulidae), amphipod crustaceans (aoridae and icilidae) and bivalve molluscs (hiatellidae and laternulidae) were found living among the serpulid tubes and barnacles which were attached directly to the ships surface.

The most numerically dominant group throughout the survey was the 'serpulid matrix' which consisted of serpulid tubes with a layer of sediment and fine turfing brown algae. The serpulid/barnacle matrix and large barnacle matrix were also dominant. As indicated from the scraping of the hull, many small invertebrates such as polychaetes, amphipod crustaceans and bivalves are likely to inhabit these matrices. In terms of percentage contribution, serpulid tubes, encrusting red algae, barnacle sp.1 (*Balanus* sp.), red encrusting bryozoan and *Membranipora membranacea* respectively, were the next most abundant groups of taxa. Occasional solitary ascidians were present, but in relatively low abundance. A summary of all taxa and groups of taxa identified in the analyses of photoquadrats is given in **Appendix B**.

3.1.2 Spatial Variation in Reef Communities

Analysis of photoquadrats from all transects taken from different parts of the ship (16 in total) indicated that the position of transects was a significant factor in determining community assemblages (**Appendix C1**). PCoA ordination (**Figure 4**) showed that around 52 % of the total variation among samples was due to differences between deck/horizontal transects and vertical transects (regardless of depth or aspect).

Vertically orientated hull surfaces and horizontally orientated deck surfaces were significantly different from each other (P=<0.001)(**Appendix C2**). This was reflected in the PCoA ordination (**Figure 5**) which shows that differences in the data between deck and hull surfaces (at a similar depth) accounted for approximately 26 % of total variation in the data. Although not statistically significant, 54 % of total variation was a result of differences among transects, irrespective of orientation (**Figure 5**). *Post-hoc* t-tests and SIMPER analyses indicated that significant differences among the deck and hull surfaces could be attributed primarily to the percent cover of serpulid matrix (40 % contribution) and serpulid/barnacle matrix (32 % contribution). Serpulid polychaetes alone and encrusting red algae accounted for 4.6 % and 3.5 % of total species/group dissimilarities respectively (**Appendix D**).

Differences in the type of encrusting assemblages between these surfaces can be seen in **Plates 1 – 6** (deck surfaces) and **Plates 7 – 12** (hull surfaces). Deck surfaces showed a more uniform and flat distribution of encrusting serpulid matrix, whereas the hull surfaces appeared to have allowed colonisation of larger barnacles and a more diverse assemblage of ascidians and bryozoans, which in turn, create a more heterogeneous substratum for successive species to colonise. Kelp (*Ecklonia radiata*) sporophytes were only observed on the deck of the ship. As macroalgae require light to grow it is likely that the surface of the deck provided a superior environment with greater light intensity.

Neither depth, (shallow versus deep), nor aspect (port side versus starbord side) appeared to play a significant role in determining the structure of the encrusting reef assemblage (**Figures 6** and **7**, **Appendix C3**).

No significant differences were found among transects from different positions on the deck surface (i.e. bow, mid-ships and stern) (**Figure 7**, **Appendix C4**).

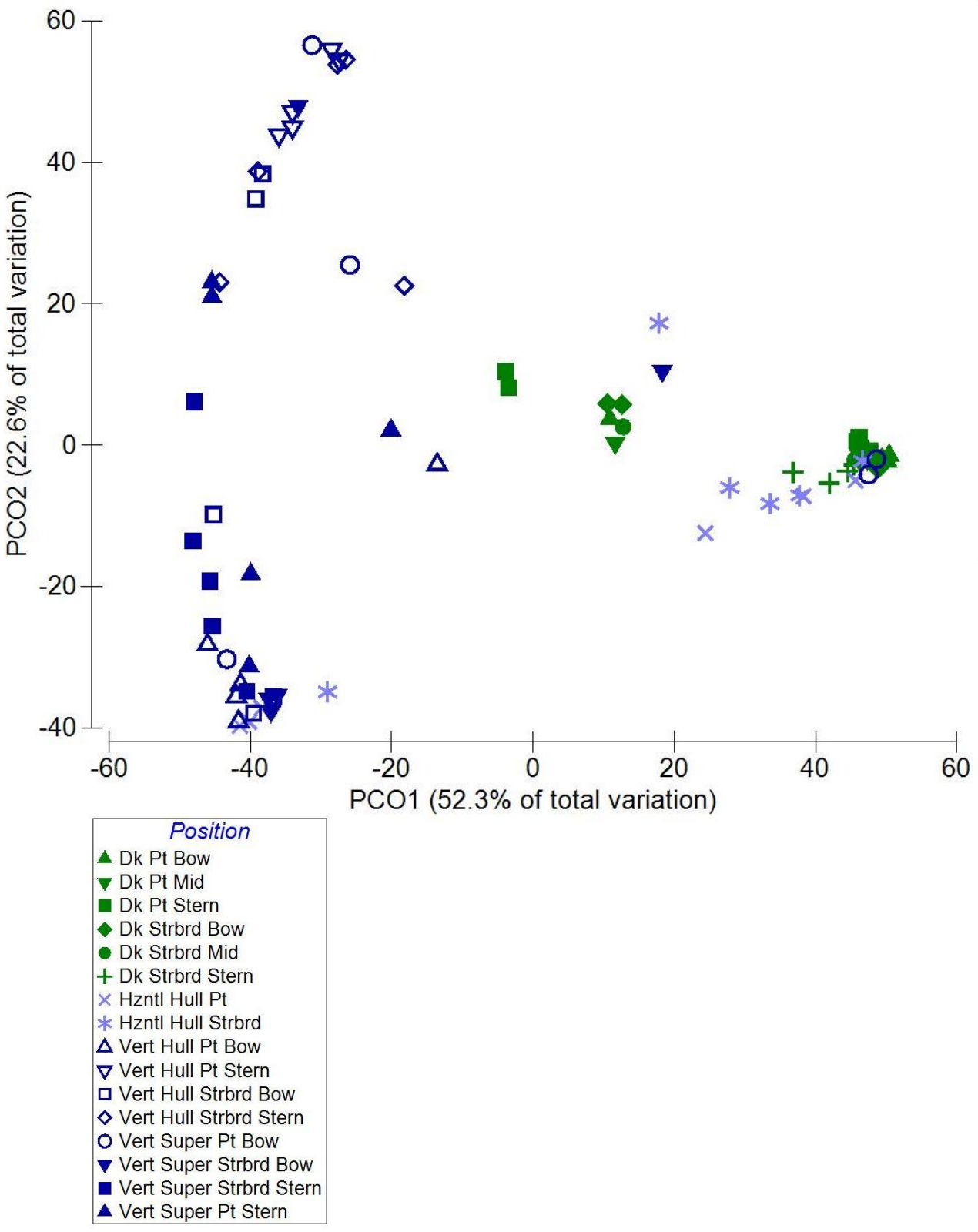

Figure 4: Principal Coordinates Analyses (PCoA) of Percent Cover of Encrusting Assemblages from Transects Taken at all Positions on the Ex-HMAS Adelaide.

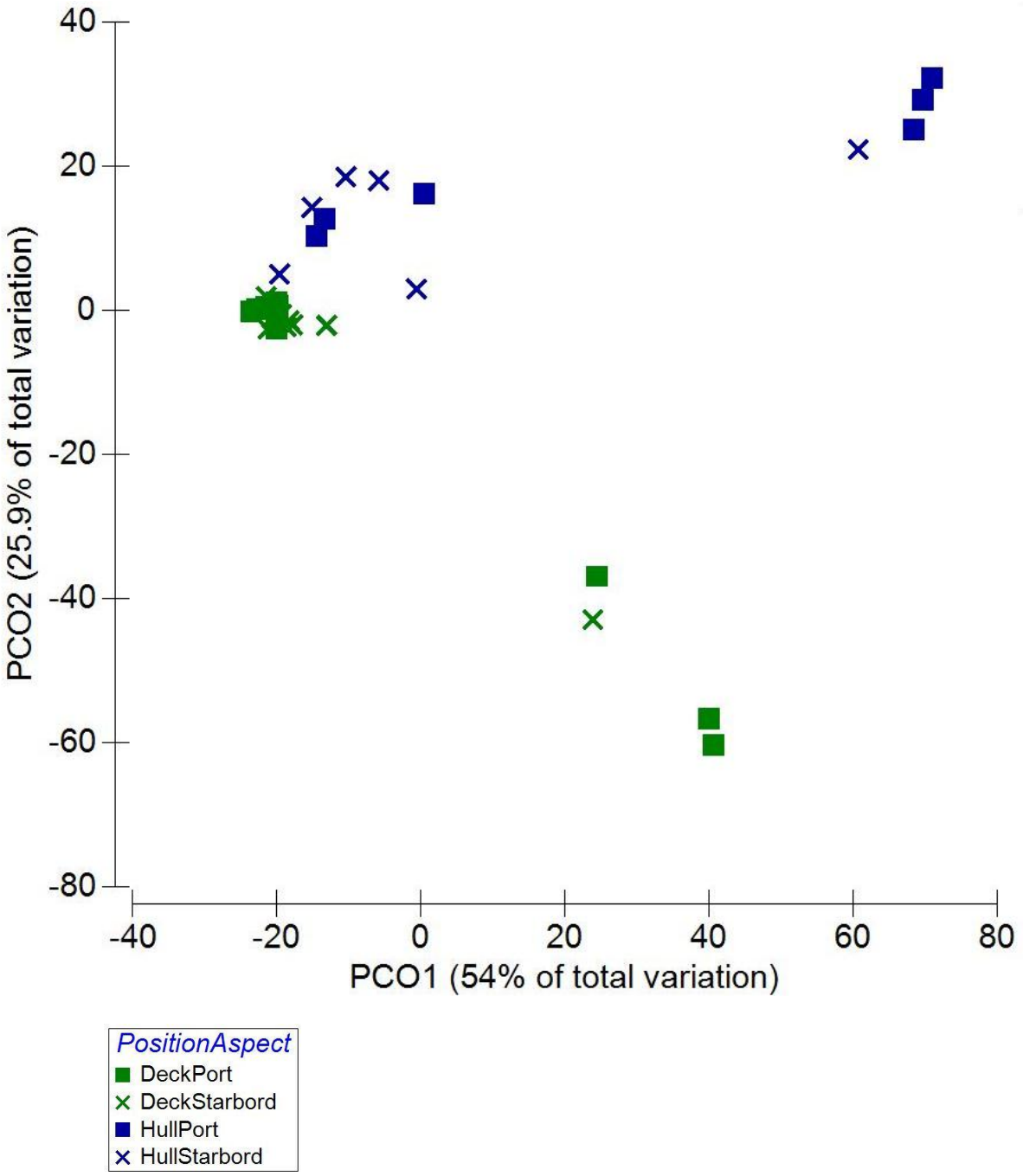

Figure 5: Principal Coordinates Analyses (PCoA) of Percent Cover of Encrusting Assemblages from Transects Taken on Hull and Deck Surfaces of the Ex-HMAS Adelaide.

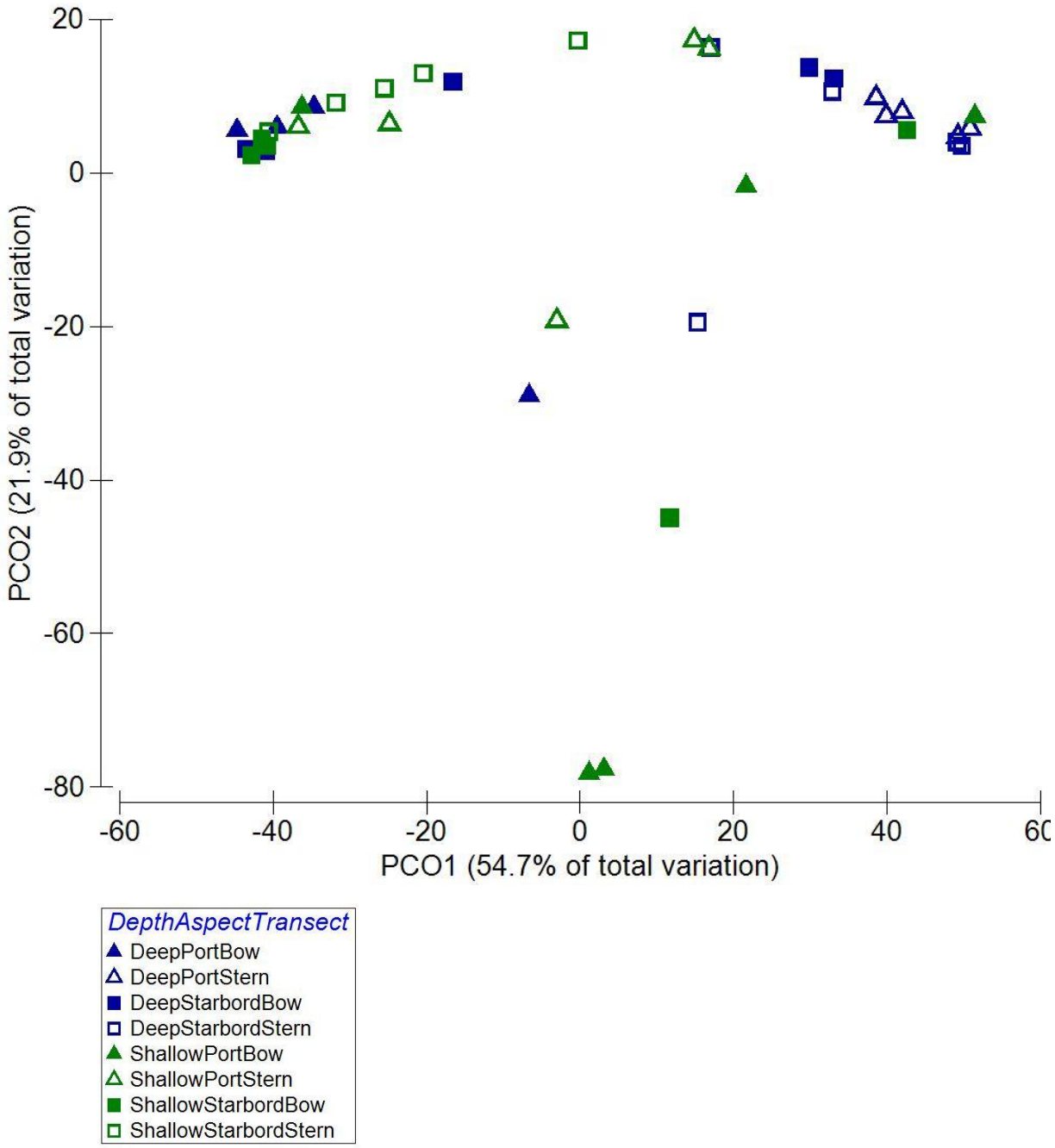

Figure 6: Principal Coordinates Analyses (PCoA) of Percent Cover of Encrusting Assemblages from Transects at Different Depths and Aspect on the Ex-HMAS Adelaide.

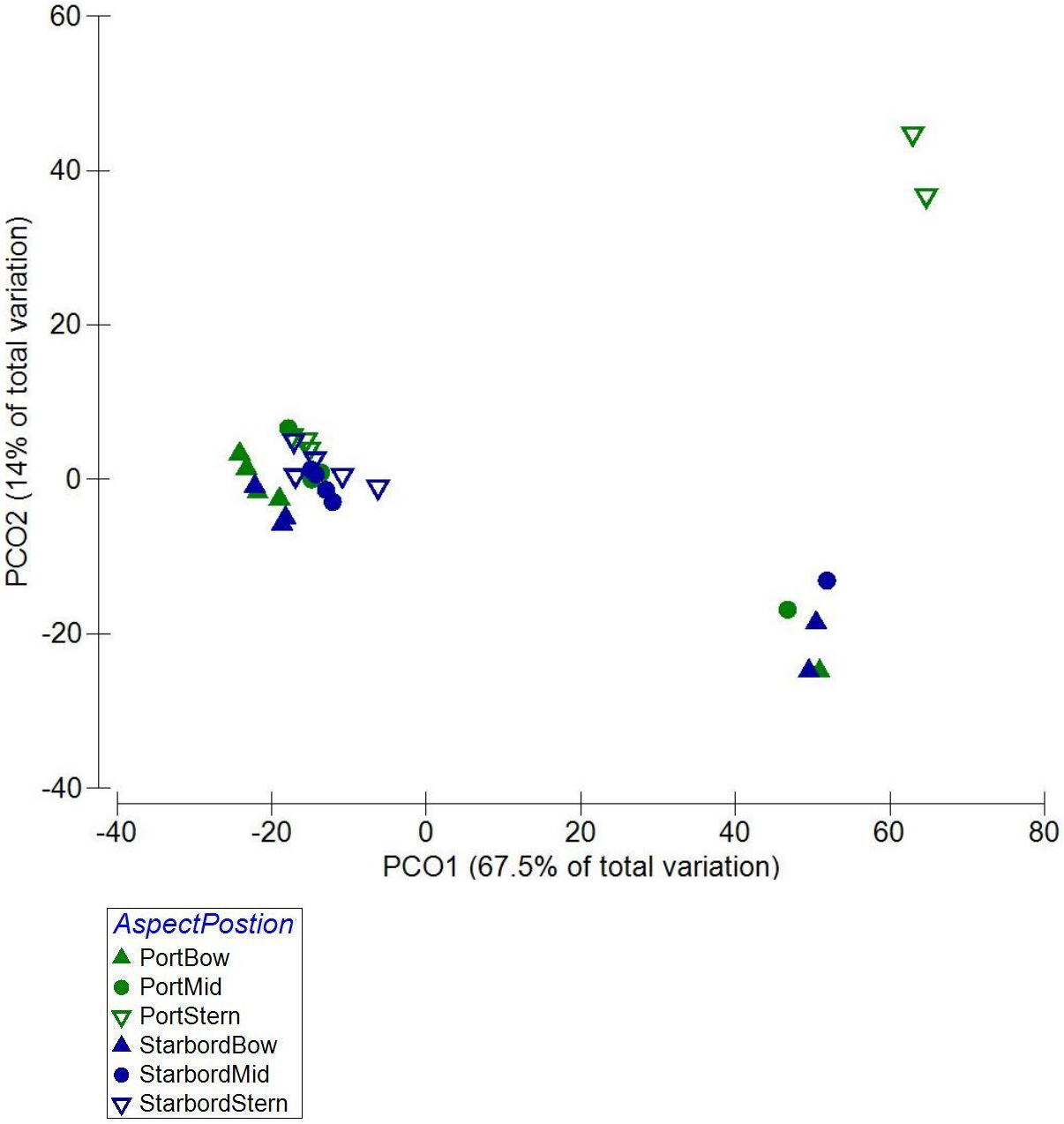

Figure 7: Principal Coordinates Analyses (PCoA) of Percent Cover of Encrusting Assemblages from Transects Taken at Different Positions on the Deck Ex-HMAS Adelaide.

3.1.3 Temporal Variation in Reef Communities

Representative photographs of each section of the ship surveyed (with the exception of the superstructure) are given in **Plates 1 -12**. Photographs of various parts of the superstructure, such as compartments and fixtures were taken in the baseline survey, but were not comparable with the superstructure photos taken in the present survey (which focused on the flat vertical surfaces to allow comparison in the statistical analyses). Parts of the ship that were compared between the baseline study and the first monitoring survey showed obvious differences between sampling times. The majority of photos taken in the baseline survey showed the surface of the ship was generally bare apart from a very fine layer of algae evident in some photos e.g. **Plate 5**. As described in **Section 1.3**, the obvious layer of algae and dead serpulid tubes evident in lower vertical transects of the baseline survey (**Plates 9 – 12**) were a result of the ships' time spent at dock prior to scuttling. A substantial layer of encrusting growth has since colonised the previously bare surfaces of the entire ship over the past six months.

3.2 Fixed Photographs

Photograhs taken from fixed locations are presented in **Appendix A.** All surfaces were covered with an encrusting layer of early colonisers as identified in the photoquadrat analyses. Of note, were large barnacles covered in a layer of brown filamentous algae and sediment that were conspicuous along the top edge of the hull (Fixed photograph 1) and on structures associated with the superstructure such as ladders and railings (fixed photographs 2 and 3) but not on the deck surfaces. Fish including fortescue (*Centropogon australis*), mado (*Atypicthys strigatus*) and silver sweep (*Scorpis lineolata*) were clearly seen in several frames. Fortescue in particular, can be seen motionless on the encrusting matrix in many of the photographs.

3.3 Video Transects

The results of observations made from video transects are summarised in **Table 1** below. A list of all fish observed during the baseline survey and the current monitoring survey (Survey 1) are listed in **Table 2**. Species of recreational, commercial or conservation value are indicated.

Table 1: Summary of observations of attached encrusting and fish assemblages observed from video footage of the Ex-HMAS Adelaide on the 11 and 13 October 2011.

Transect	Encrusting Assemblages	Fish Assemblages
Deck, Vertical Hull and Vertical Superstructure Port Bow	A matrix of serpulid worm tubes, sediment and algal-based epiphytic growth covered the majority of the deck, hull and superstructure along with scattered, encrusting bryozoans.	Fortesque (*Centropogon australis)* were abundant (> 100 observations). Individual observations were also made of chinaman leather jacket (*Nelusetta ayraudi*), silver sweep (*Scorpis lineolata*) and Australian mado (*Atypicthys strigatus*).
Deck, Port Mid	A matrix of serpulid worm tubes, sediment and algal-based epiphytic growth covered the majority of the deck with scattered encrusting bryozoans. A number of small bright white patches (a few centimetres in diameter) of an unknown substance also scattered the deck.	Fortesque (*Centropogon australis*), yellowtail scad (*Trachurus novaezelandiae*) and Australian mado (*Atypicthys strigatus*) were abundant (> 100 observations). Three observations were made of banner fish (*Hemiochus* sp.) and one observation was made of snapper (*Pagrus auratus*).
Deck, Vertical Hull and Superstructure Port Stern	Surfaces were covered in a matrix of serpulid worm tubes, sediment and algal-based epiphytic growth over the majority of the deck, hull and superstructure along with scattered inconspicuous encrusting bryozoans.	Fortesque (*Centropogon australis*) were abundant (> 100 observations).
Deck, Vertical Hull and Superstructure Starboard Bow	Surfaces were covered in a matrix of serpulid worm tubes, sediment and algal-based epiphytic growth over the majority of the deck, hull and superstructure along with scattered inconspicuous encrusting bryozoans.	Fortesque (*Centropogon australis)* were abundant (> 100 observations). Observations were also made of two white ear (*Parma microlepis*) and one bastard trumpeter (*Latridopsis forsteri*).
Deck Starboard Mid	Surfaces were covered in a matrix of serpulid worm tubes, sediment and algal-based epiphytic growth which covered the majority of the deck along with scattered inconspicuous encrusting bryozoans.	Fortesque (*Centropogon australis*) and Australian mado *(Atypicthys strigatus)* were abundant (> 100 observations). Yellowtail scad *(Trachurus novaezelandiae)* were common (> 10 observations).
Deck, Vertical Superstructure and Starboard Stern	Surfaces were covered in a matrix of serpulid worm tubes, sediment and algal-based epiphytic growth over the majority of the deck, hull and superstructure along with scattered inconspicuous encrusting bryozoans. Numerous large round hydroid colonies were also observed.	Fortesque (*Centropogon australis),* yellowtail scad *(Trachurus novaezelandiae)* and Australian mado *(Atypicthys strigatus)* were abundant (>100 observations). One observation was made of a three-bar porcupinefish (*Dicotlichtys punctulatus*) and stripey (*Microcanthus strigatus*)

Transect	Encrusting Assemblages	Fish Assemblages
Horizontal Hull Port	Surfaces were covered in a matrix of serpulid worm tubes, sediment and algal-based epiphytic growth covering majority of the hull along with obvious large barnacles, also covered in epiphytic growth. Hydroids and solitary ascidians were also present on occasion.	Fortesque (*Centropogon australis*) were abundant (> 100 observations). Australian mado (*Atypicthys strigatus*) were common (>10 observations). Single observations were also made of chinaman leather jacket (*Nelusetta ayraudi*), red morwong (*Cheilodactylus fuscus*), silver sweep (*Scorpis lineolata*) and Eastern blue groper (*Achoerodus viridis*).
Horizontal Hull Starboard	Surfaces were covered in a matrix of serpulid worm tubes, sediment and algal epiphytic growth over the majority of the hull with obvious large barnacles covered in epiphytic growth.	Fortesque (*Centropogon australis*) were abundant (> 100 observations). Three observations were also made of mado (*Atypicthys strigatus*) and one of silver sweep (S*corpis lineolata*).

Table 2: Species of Fish Observed in Association with the Ex-HMAS Adelaide Artificial Reef between April/May 2011 and October 2011. (*) = recreationally important species, (+) = commercially important species, (#) = species of conservation significance.

Family	Species Name	Common Name	Baseline Survey (April/May 2011)	Survey 1 (October 2011)
Aulopidae	*Aulopus purpurrissatus*	Sergeant baker		●
Scorpaenidae	*Centropogon australis*	Eastern Fortesque		●
Scorpaenidae	*Scorpaena cardinalis*	Red rock cod		●
Dinolestidae	*Dinolestes leweni*	Longfin pike		●
Carangidae	*Trachurus novaezelandiae*	Yellowtail scad+		●
Sparidae	*Pagrus auratus*	Snapper (juv)*+		●
Mullidae	*Parupeneus spilurus*	Blackspot goatfish	●	
Chaetodontidae	*Hemiochus* sp.	Bannerfish	●	●
Scorpididae	*Scorpis lineolata*	Silver sweep*		●
Microcanthidae	*Atypicthys strigatus*	Mado		●
Microcanthidae	*Microcanthus strigatus*	Stripey		●
Cheilodactylidae	*Nemadactylus douglasii*	Blue morwong*		●
Cheilodactylidae	*Cheilodactylus fuscus*	Red morwong		●
Latrididae	*Latridopsis forsteri*	Bastard trumpeter		●
Pomacentridae	*Parma microlepis*	White ear		●
Labridae	*Achoerodus viridis*	Eastern blue groper#		●
Blenniidae	*Petroscirtes lupus*	Sabretooth blenny	●	
Monacanthidae	*Nelusetta ayraudi*	Chinaman leather jacket*+		●
Tetraodonitdae	*Dicotlichthys punctulatus*	Three-bar porcupinefish		●

4 Discussion

4.1 Encrusting Biota

Assemblages in space

Analysis of photoquadrats taken from different parts of the ship indicated that at this relatively early stage of colonisation spatial differences in community assemblages were evident. This was particularly apparent among transects on the deck (horizontally orientated) and hull (vertically orientated) surfaces, which were significantly different from each other. This was attributed mainly to differences in abundance of serpulid and serpulid/barnacle matrices.

Several other studies have shown that surface orientation can influence the development of epibiotic assemblages (Glasby 2000, Irving and Connell 2002, Knott *et al*.2004) and many researchers have shown that different assemblages develop on surfaces of different orientations (e.g. Glasby and Connell 2002, Harris and Irons 1982, Todd and Turner 1986, Hurlbut 1991). The reasons for differences are not clear, but may involve factors such as light (Kennelly 1989, Baynes 1999, Glasby 1999), predation/grazing (Keough and Downes 1982, Osman *et al*. 1992), larval behaviour (Raimondi and Keough 1990, Hurlbut 1991) and water flow at micro- or meso-scales (Breitburg *et al*. 1995, Guichard and Bourget 1998).

Sedimentation may also be greater on horizontal surfaces (Baynes and Szmant 1989, Irving and Connell 2002). Increased sediment loads can smother many plants and filter feeding invertebrates, resulting in considerable differences in benthic assemblages between vertical and horizontal surfaces (Glasby 2000 in Walker *et al.* 2007).

Orientation is likely to be just one of several factors affecting the structure of benthic reef assemblages (whether natural or artificial). Other factors include depth (Rule and Smith 2007, Moura *et al*. 2007), habitat complexity (Edwards and Smith 2005, Moura *et al.* 2007) and processes such as recruitment (Perko-Finkel and Benayahu 2007) and succession (Nicoletti *et al*. 2007).

Assemblages through time

Colonisation of the Ex-HMAS Adelaide, six months post- scuttling, has been substantial and the early colonising assemblage that has formed is consistent with observations on similar artificial structures on the east coast of Australia and abroad. Pioneer species, such as barnacles, serpulid polychaetes, hydroids and bryozoans, often occupy a large proportion of available space on newly created artificial reefs (Ardizzone *et al.* 1989, Boaventura *et al*. 2006) although the sequence of macrobenthic colonisation appears to vary among seasons and locations. Colonisation of other sunken vessels by sessile invertebrates has also proven to be relatively rapid. For example, the Ex-HMAS Brisbane (Queensland) became colonised within three months of deployment by red, brown and blue/green algae, limpets and goose barnacles (Queensland EPA 2007). Mobile invertebrates such as crabs, shrimps, crayfish and octopus, were recorded within nine months.

The HMAS Swan (Dunsborough, Western Australia) was initially colonised by hydroids, which covered approximately 70 % – 90 % of the area surveyed (Morrison 2001). Algal growth also dominated the encrusting marine life during the summer months, particularly on the upper surfaces. Other sessile groups, such as sponges, ascidians, anemones and soft corals, were shown to proliferate on shaded portions of the vessel.

4.2 Fish and Mobile Macroinvertebrates

The initial colonisation of artificial reefs by fish is due to the behavioural response of fish to objects, in which certain species move towards structure rather than bare, featureless habitat (Brickhill *et al.* 2005). Six months after being scuttled in April 2011, fish abundance and diversity observed around the Ex-HMAS Adelaide have increased substantially. A total of three species; (blackspot goatfish, (*Parupeneus spilurus;* bannerfish, *Hemiochus* sp. and sabretooth blenny, *Petroscirtes lupus*) from three families, were initially observed in the baseline survey. A total of 19 species from 16 families were observed during the present survey. Only one of the three species initially observed (bannerfish, *Hemiochus* sp.) was observed during both surveys. Eastern fortesque (*Centropogon australis*), were present in large numbers in close association with the ships surface. Eastern fortesque, which are a type of scorpionfish, are extremely well camouflaged (Kuiter 1996) and on close inspection, could be seen in photoquadrats lying motionless on the ships surface. It is likely that these fish were lying in wait to ambush their prey which generally consists of invertebrates or small fish. Eastern fortesque are

generally associated with sheltered bays or estuaries although they can also be found on inshore reefs to a depth 30 m (Neira *et al*. 1998). They are very common in the reproductive season (spring time) which may account for the large numbers observed in the October Survey. Mado (*Atypicthys strigatus*) and yellowtail scad *(Trachurus novaezelandiae*) were also observed in large schools and are commonly found in association with natural rocky reef habitat. Fish were generally observed around the superstructure at shallower depths.

Fish occurring on the wreck of the Ex-HMAS Brisbane (Queensland) were monitored during the first year after deployment. Within weeks, common hardyhead, yellowtail scad and baitfish (transient visitors) were observed on the wreck. After three to six months a number species including batfish, blennies and emporer fish (residents), slimy mackerel, yellowtail kingfish, whiting, sweetlips, amberjack, flounder, flathead, rays, dolphinfish, trevally, leatherjacket and pilchards (transient species) were observed. Within six to nine months, greasy cod, red firefish, scorpion fish, damsel fish guitarfish and spotted wobbegongs were found to be resident on the wreck. Anglerfish, lionfish, garfish, triggerfish, snapper and bonito (among others) were also observed. Monitoring of the Ex- HMAS Swan over a two year period showed an increase in average species richness from two to 32 species. The fish community showed a gradual increase in abundance over the monitoring period with a rapid increase in mean diversity within the first two months of deployment. The assemblage on the wreck showed a rapid shift from omnivorous weed/sand fishes to one dominated by planktivorous and carnivorous reef fishes.

Fish observed in the present study are commonly found on natural rocky reefs in the greater Sydney region. This is consistent with other studies which show that over time, fish assemblages colonising artificial reefs may become similar in species composition to neighbouring natural reefs (Clynick *et al*. 2008, Santos and Monteiro 2007, Relini *et al*. 2002). Similarities between natural and artificial reefs are considered to be largely dependent on the similarity of structural properties of the artificial reefs (Perkol-Finkel *et al*. 2006, Edwards and Smith 2005).

Species of fish colonising an artificial reef may live permanently on the structure (resident) or be transient visitors. The species observed in the present study were a mixture of both reef-associated residents, such as bannerfish (*Hemiochus* sp.), mado (*Atypicthys strigatus*), stripey (*Microcanthus strigatus*) and white ear (*Parma microlepis*) and transient species such as sergeant baker (*Aulopus purpurrisatus*), and longfin pike (*Dinolestes leweni*). Several of these species may also move among different reefs from time to time, using the artificial reef as a temporary refuge, but not feeding there continually.

The season of deployment may be a factor in determining the type and abundance of species that colonise an artificial reef. For example, Markevich (2005) found that artificial reefs deployed in spring or early summer were more rapidly colonised than those deployed in autumn due to patterns of plankton settlement.]

The extent and nature of the marine colonisation of the Ex-HMAS Adelaide is consistent with the findings of surveys of other scuttled vessels and artificial reefs in Australia and elsewhere.

5 Acknowledgements

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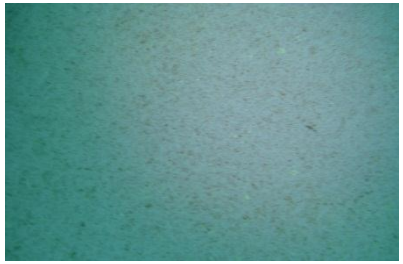
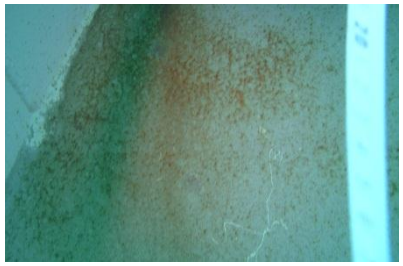
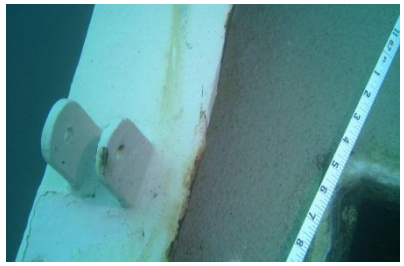
7 Plates

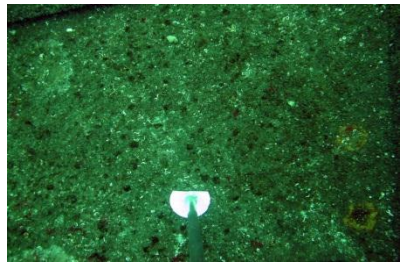
Deck, Port Bow

Baseline Survey (April/May 2011)



Monitoring Survey 1 (October 2011)



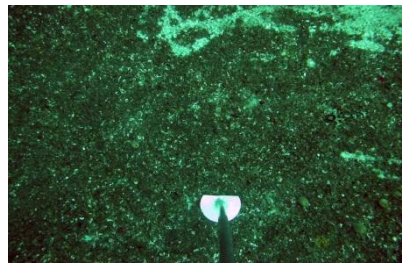
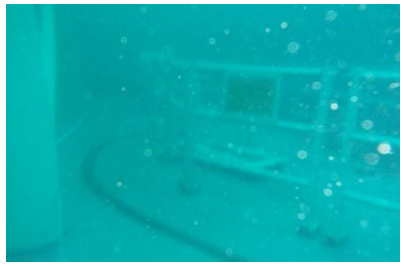
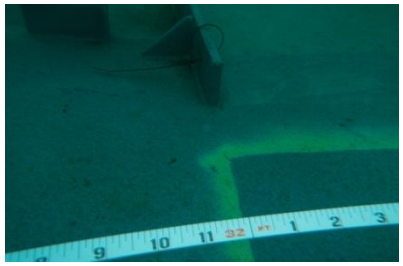
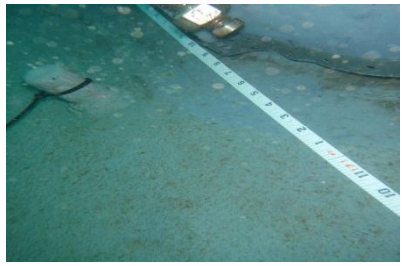



Plate 1: Deck port bow

Deck, Port Mid

Baseline Survey (April/May 2011)

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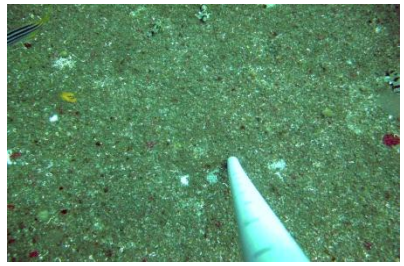
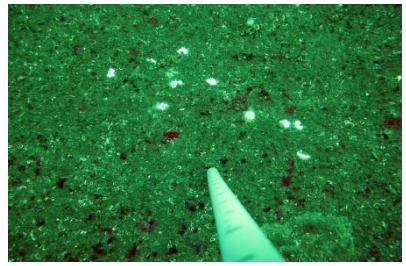
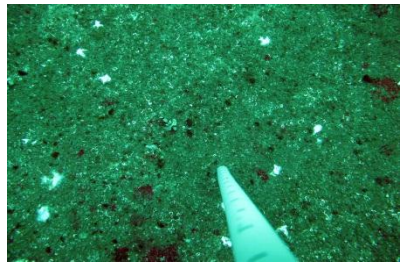
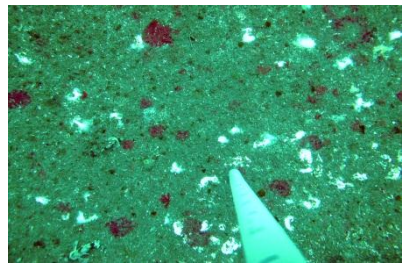
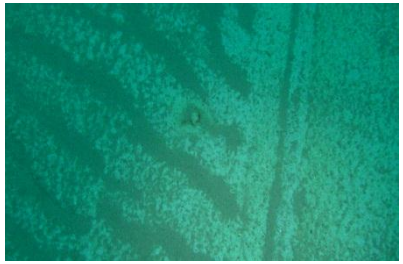





Plate 2: Deck port mid

Deck, Port Stern

Baseline Survey (April/May 2011)

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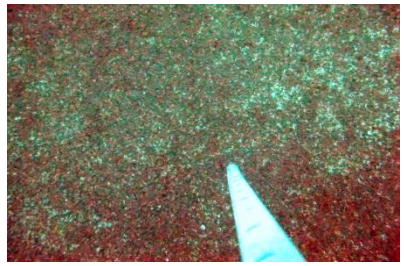
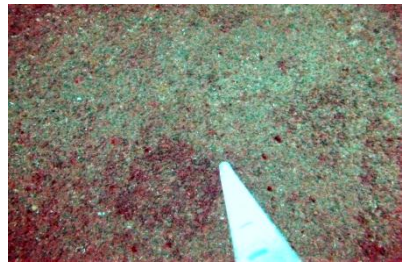
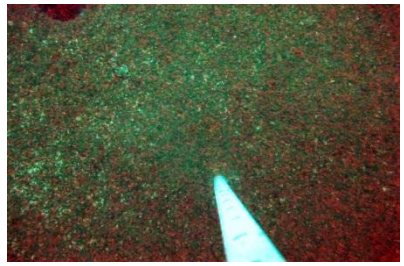
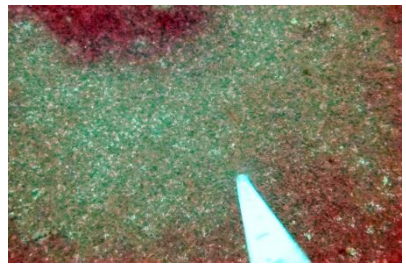
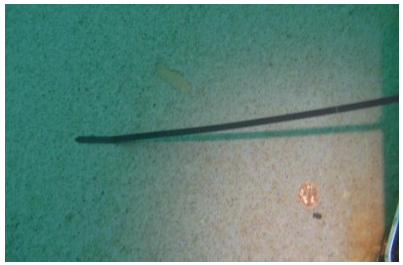





Plate 3: Deck port stern

Deck, Starbord Bow

Baseline Survey (April/May 2011)






Monitoring Survey 1 (October 2011)



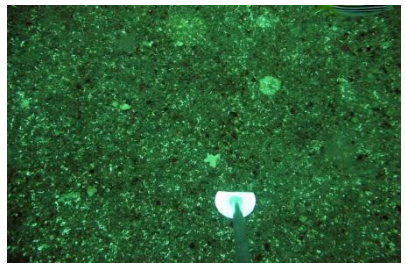
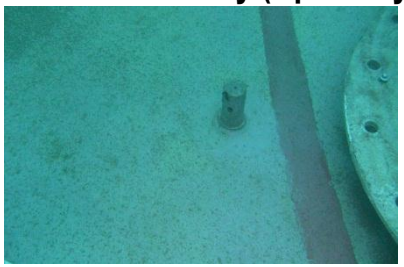
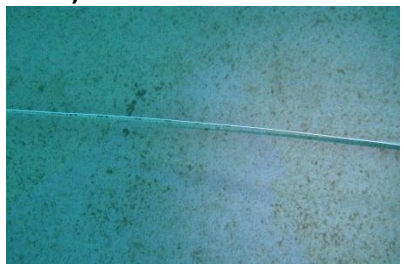
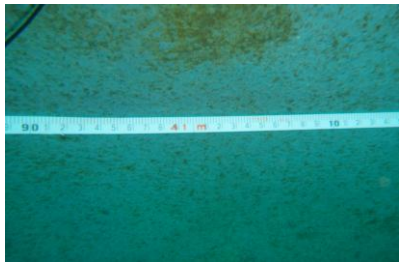
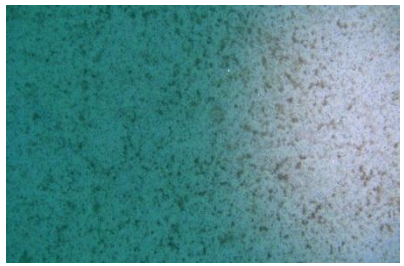



Plate 4: Deck starbord bow

Deck, Starbord Mid

Baseline Survey (April/May 2011)

Monitoring Survey 1 (October 2011)

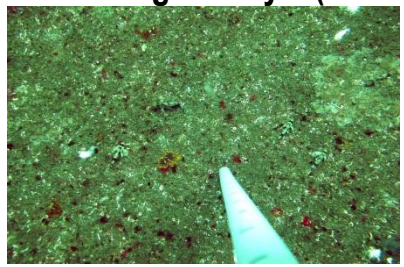
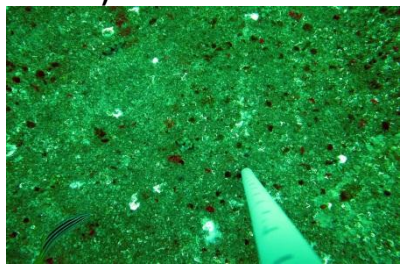
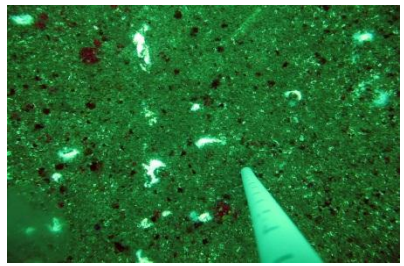
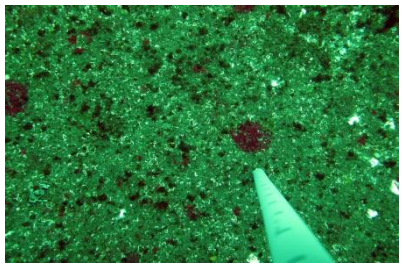
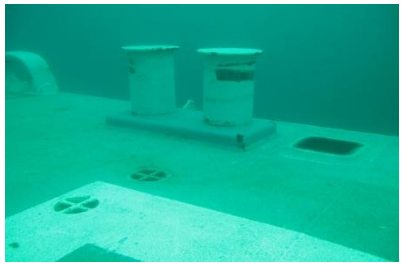
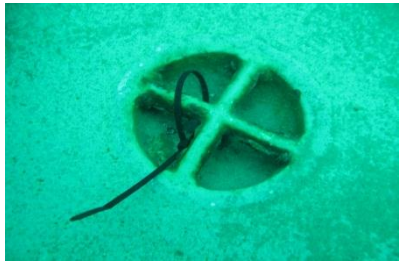
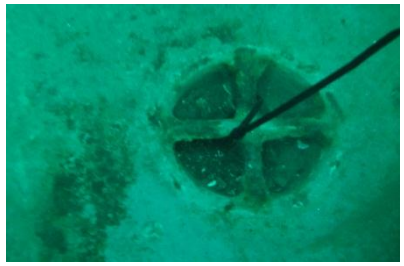





Plate 5: Deck starbord mid

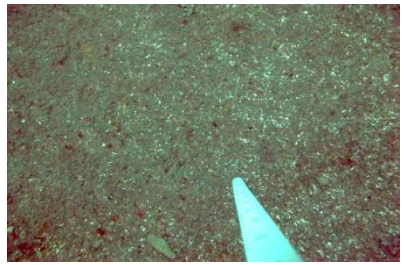
Deck, Starbord Stern

Baseline Survey (April/May 2011)



Monitoring Survey 1 (October 2011)



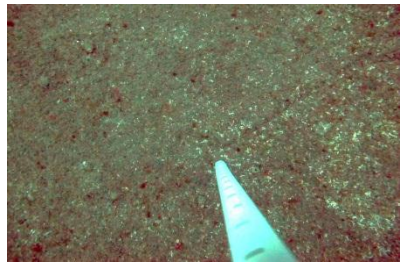
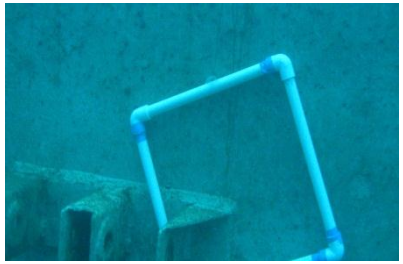
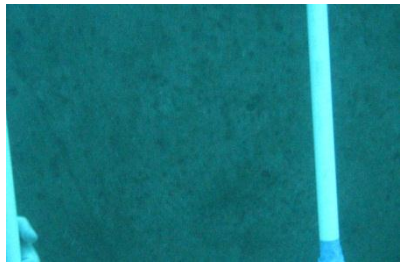
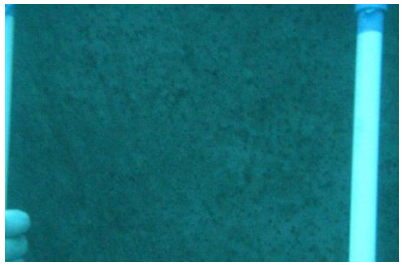
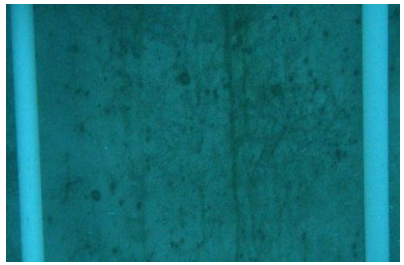



Plate 6: Deck starbord stern

Horizontal Hull, Port

Baseline Survey (April/May 2011)



Monitoring Survey 1 (October 2011)

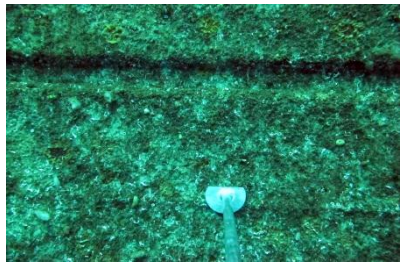
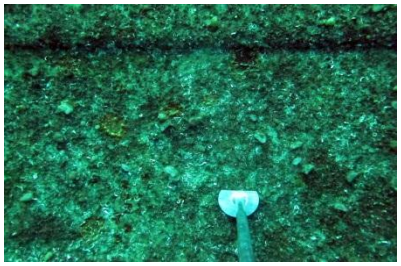
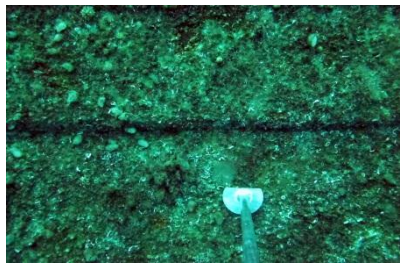
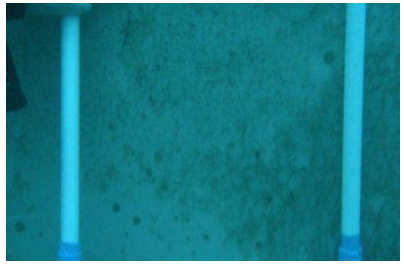
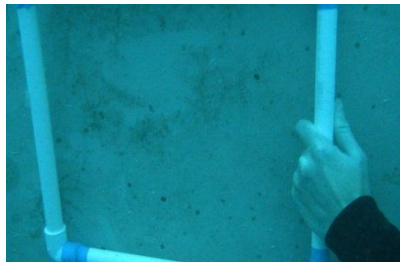
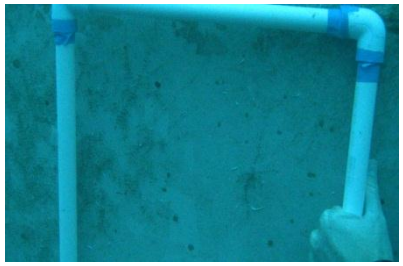
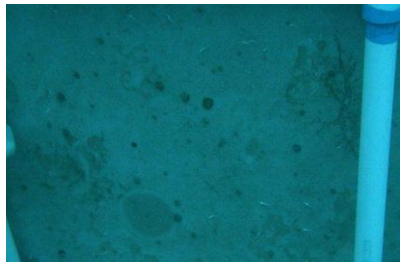
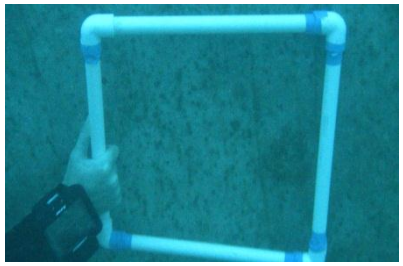





Plate 7: Horizontal hull port

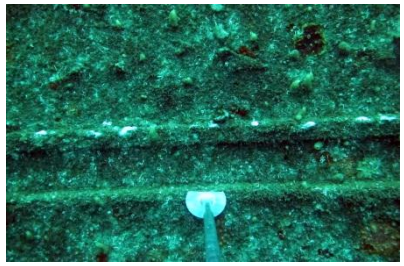
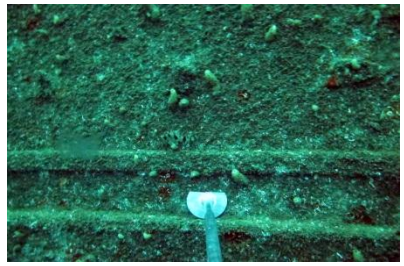
Horizontal Hull, Starbord

Baseline Survey (April/May 2011)



Monitoring Survey 1 (October 2011)

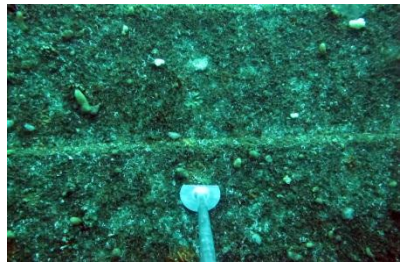
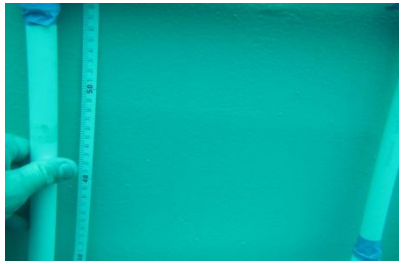
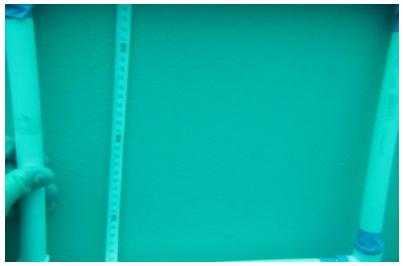


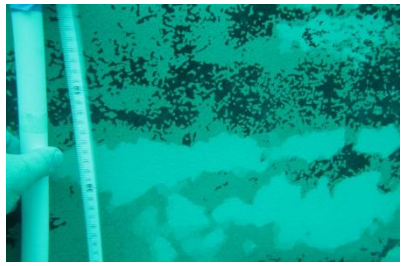

Plate 8: Horizontal hull starbord

Vertical Hull, Port Bow

Baseline Survey (April/May 2011)





Monitoring Survey 1 (October 2011)



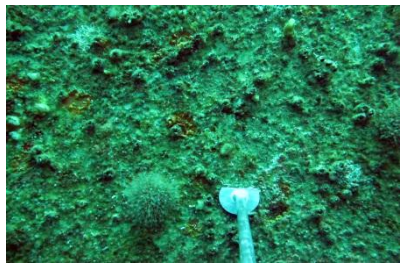
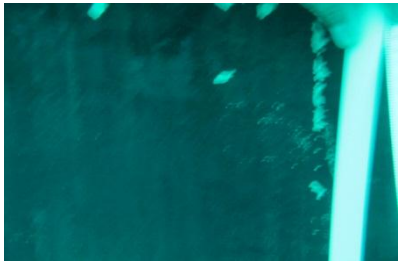



Plate 9: Vertical hull port bow

Vertical Hull Port Stern

Baseline Survey (April/May 2011)



Monitoring Survey 1 (October 2011)

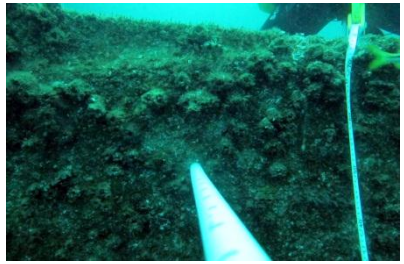
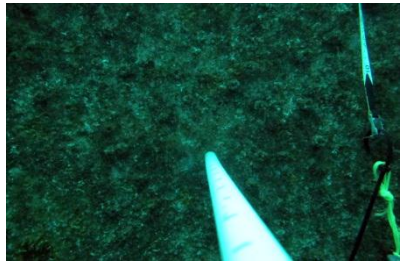
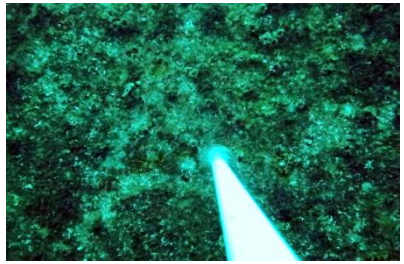
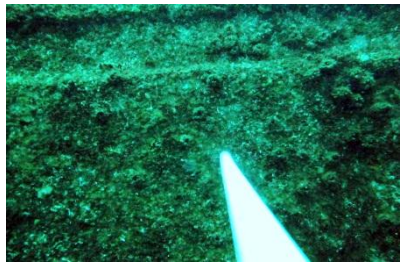
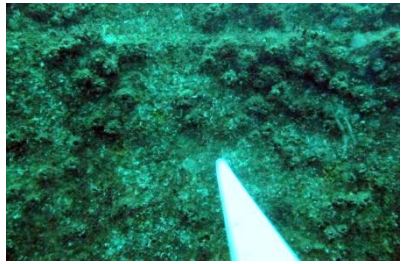






Plate 10: Vertical hull port stern

Vertical Hull, Starbord Bow

Baseline Survey (April/May 2011)

Monitoring Survey 1 (October 2011)

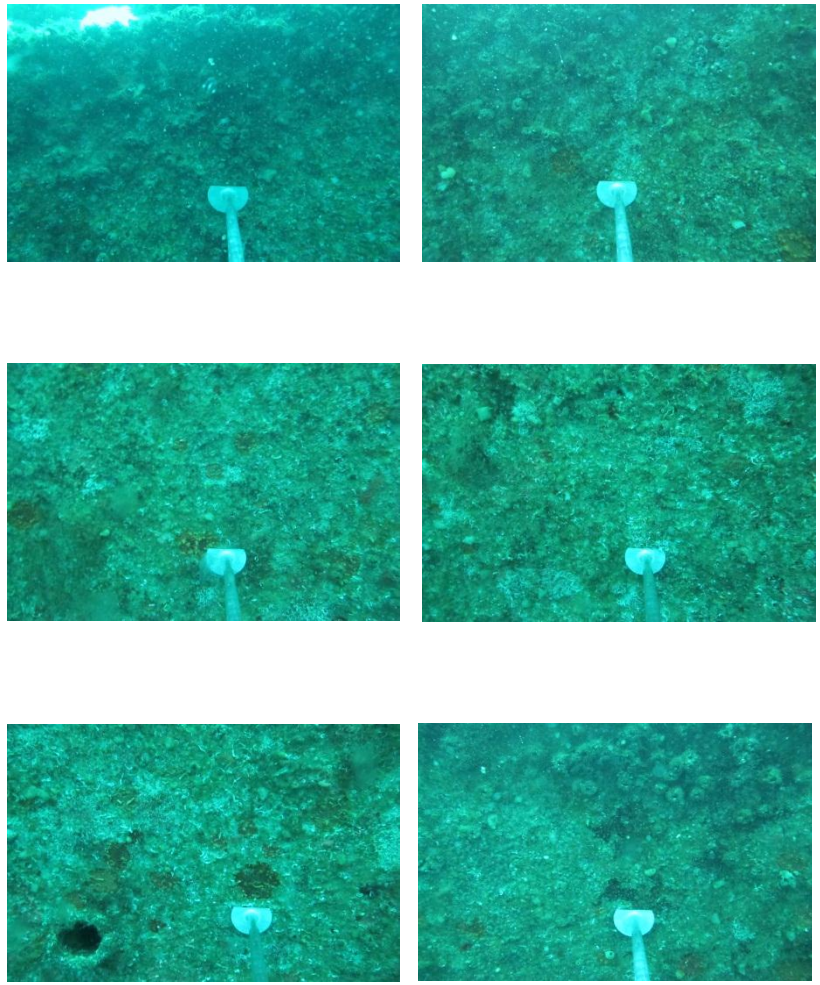
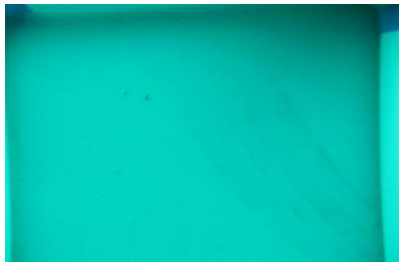
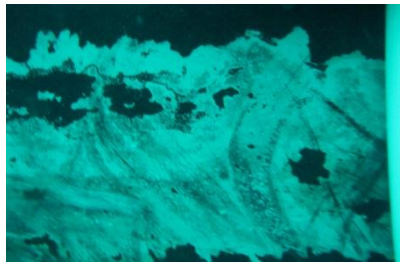
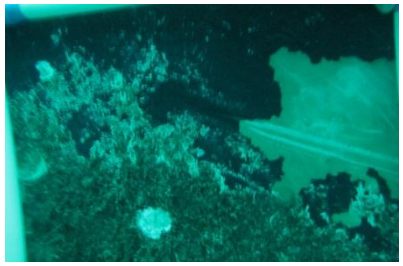


Plate 11: Vertical hull starbord bow

Vertical Hull, Starbord Stern

Baseline Survey (April/May 2011)




Monitoring Survey 1 (October 2011)

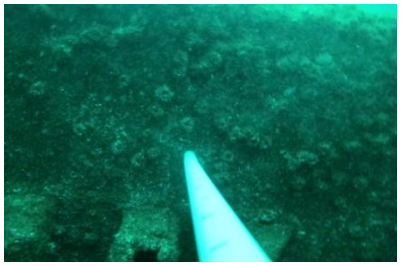
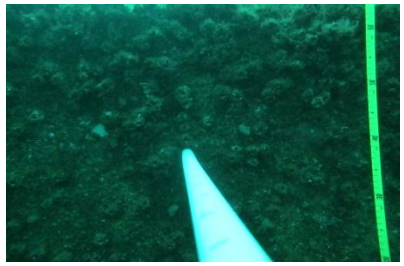
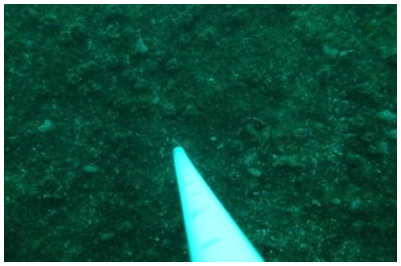
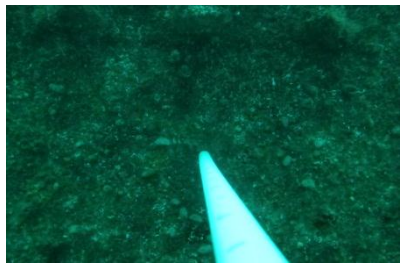
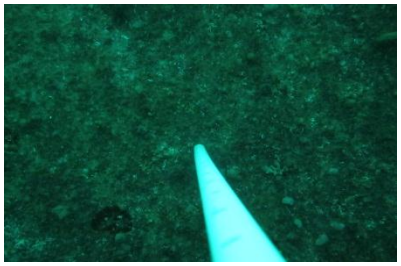
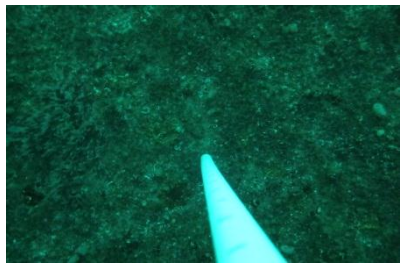







Plate 12: Vertical hull starbord stern

8 Appendices

Appendix A: Fixed Photograph Locations.
Appendix B: Mean Percentage Cover (± Standard Error) of Reef Communities.
Appendix C: PERMANOVA of Reef Assemblages.
Appendix D: Pair-wise t-tests and SIMPER Analyses.

Appendix A: Fixed Photo Locations and Descriptions

Fixed Photo: 1

Location: Flight deck port side between the hanger and hull. Photo taken standing 2 m towards the stern from the pipe.

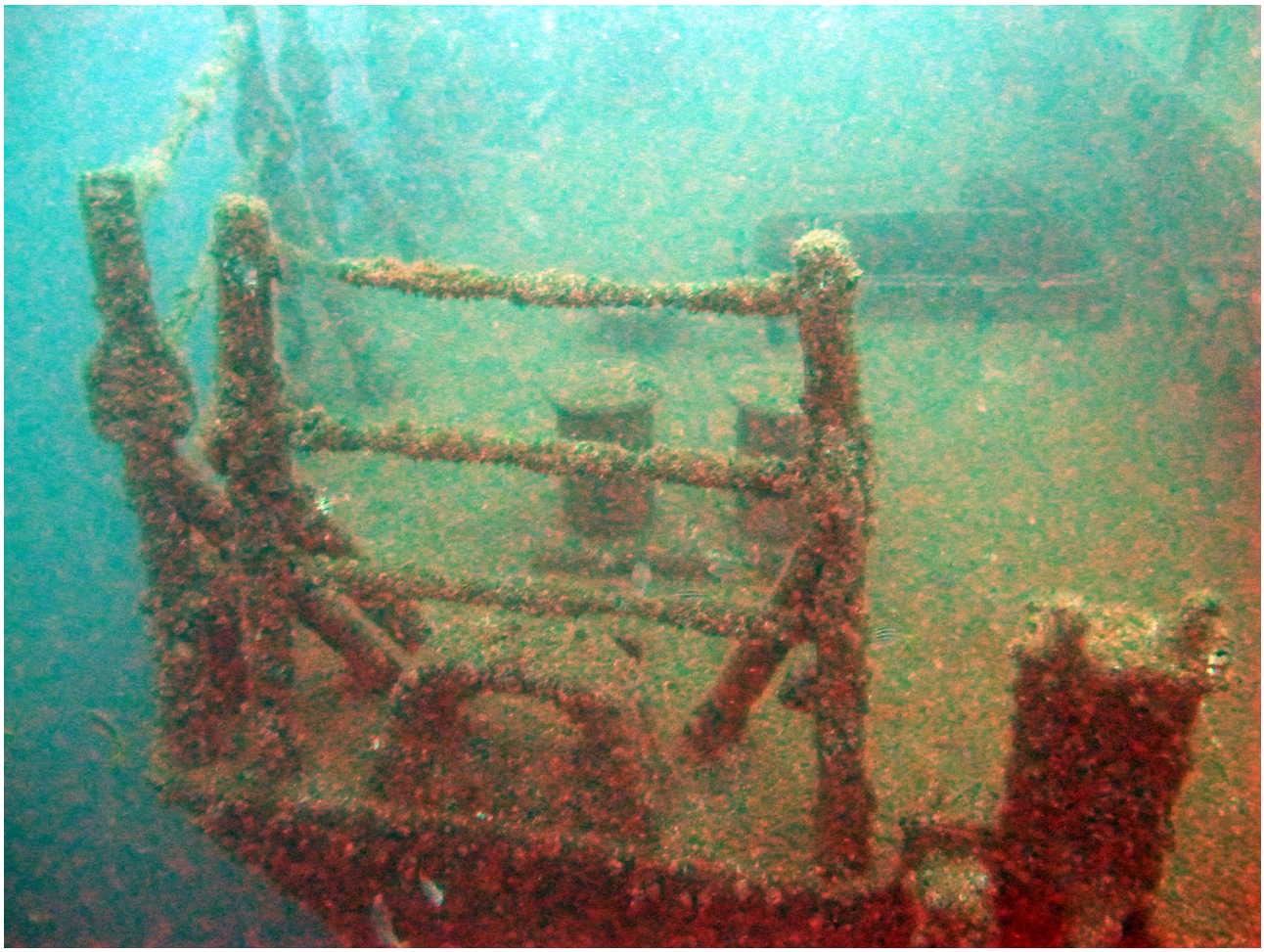
Depth: Approximately 27 m

Appendix A: (Continued).

Fixed Photo: 2

Location: Back of the flight deck, starbord side. Photo taken swimming 2 m off and above the deck.

Depth: Approximately 27 m

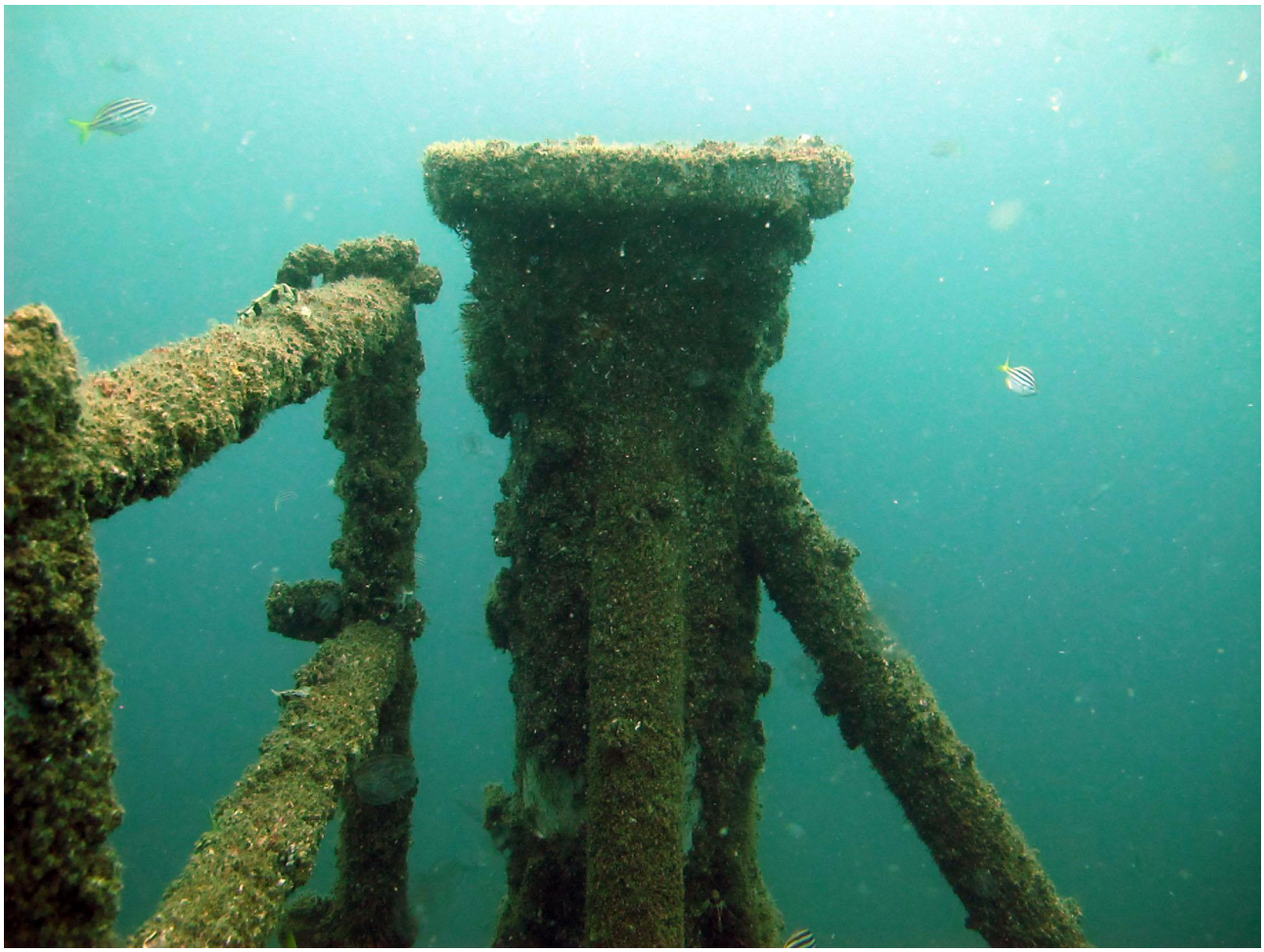


Appendix A: (Continued).

Fixed Photo: 3

Location: Middle of the stern end of the top deck. Photo taken standing 2 m towards the bow from the pillar.

Depth: Approximately 23 m

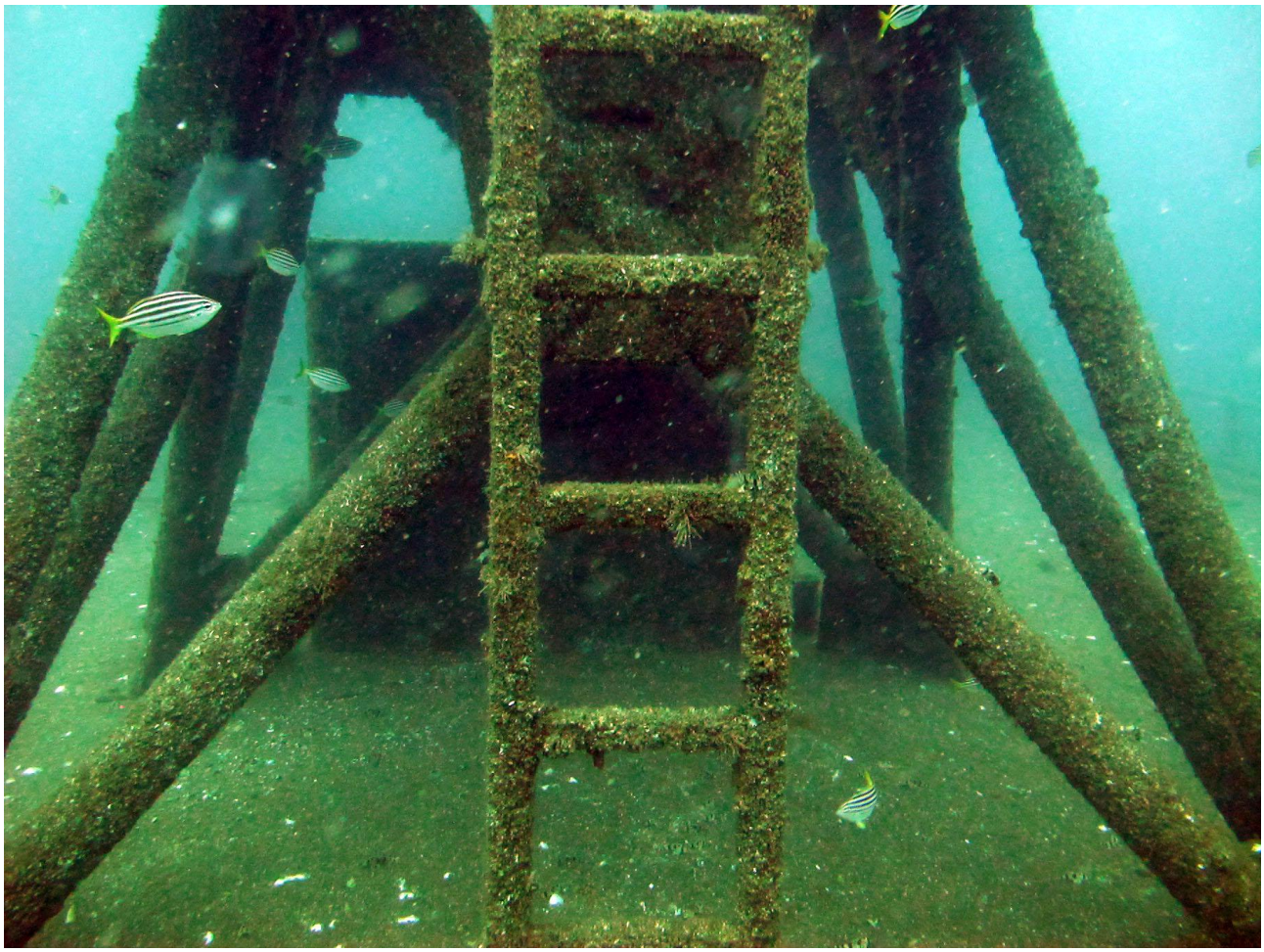


Appendix A: (Continued).

Fixed Photo: 4

Location: Middle of the the top deck. Photo taken standing 2 m towards the stern from the main mast.

Depth: Approximately 23 m



Appendix A: (Continued).

Fixed Photo: 5

Location: Front of the main mast. Photo taken standing on top of the bridge facing the main mast.

Depth: Approximately 18 m

Appendix A: (Continued).

Fixed Photo: 6

Location: Port bollard between the bow and mid-ship on the front deck. Photo taken standing 2 m towards bridge facing the bow.

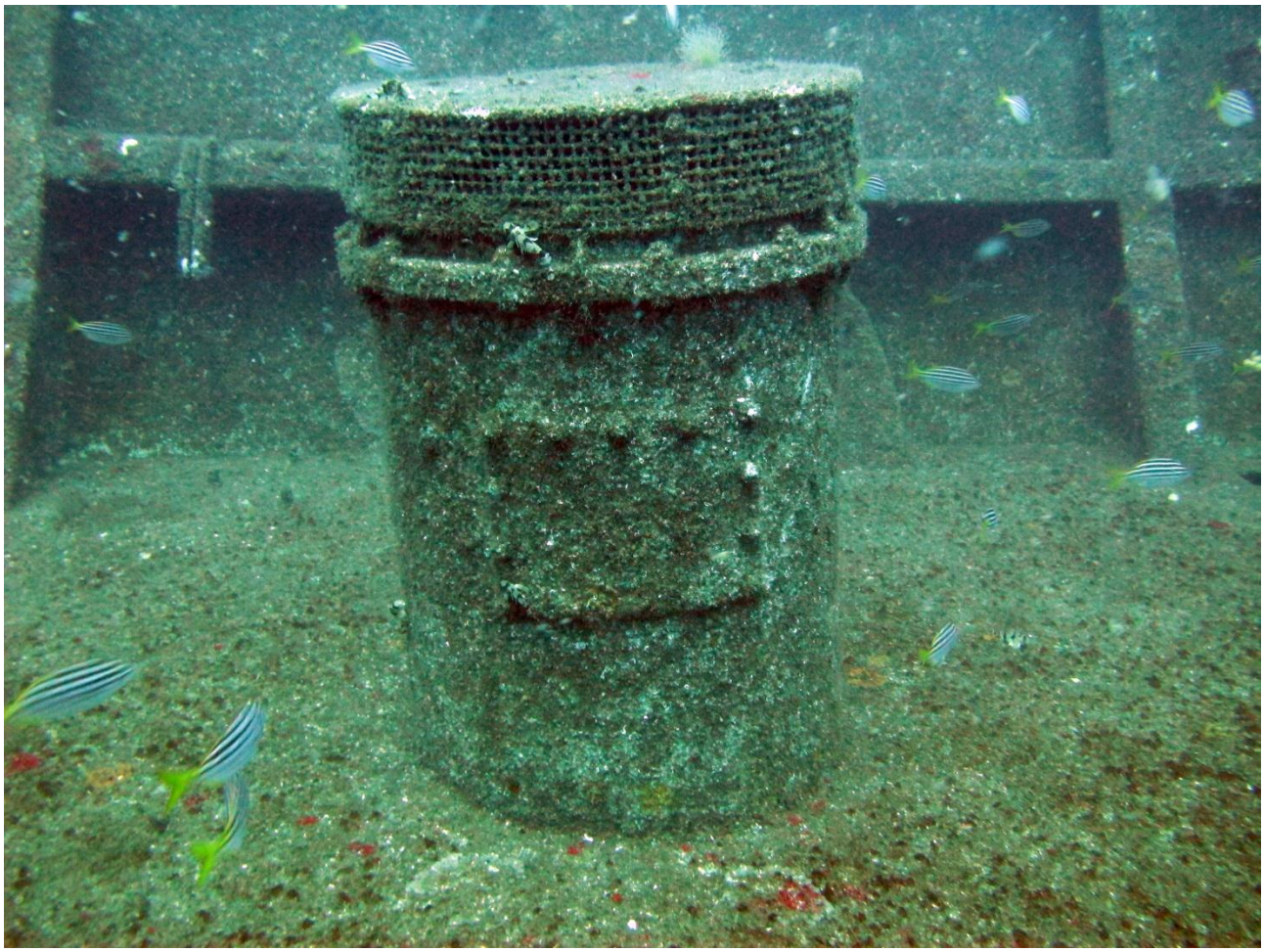
Depth: Approximately 26 m

Appendix A: (Continued).

Fixed Photo: 7

Location: Starbord vent on the bow deck. Photo was taken standing 2 m towards the centre of the deck.

Depth: Approximately 25 m.



Appendix A: (Continued).

Fixed Photo: 8

Location: Inside of bow. Photo was taken standing behind the cut out in the deck.

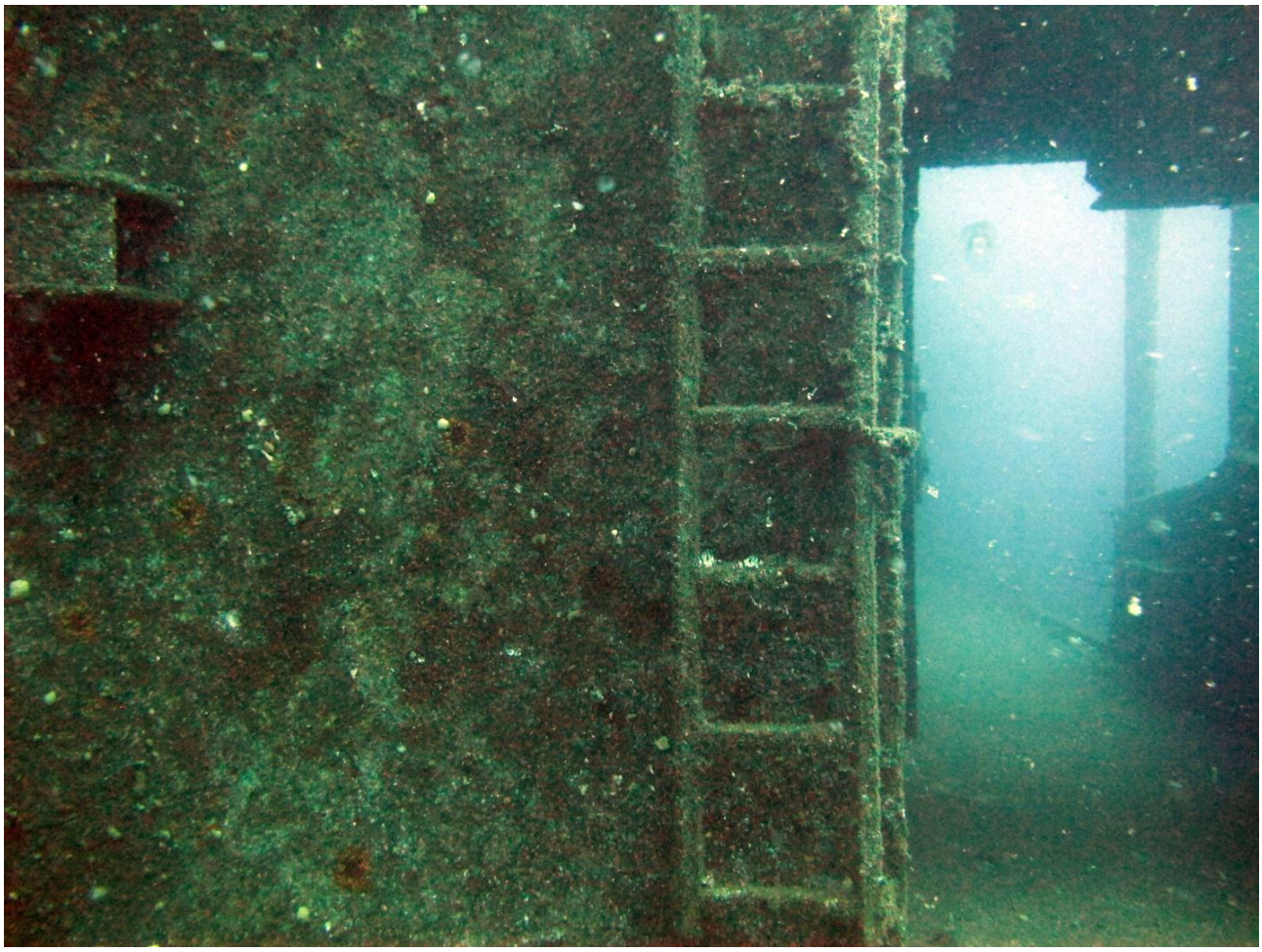
Depth: Approximately 25 m.

Appendix A: (Continued).

Fixed Photo: 9

Location: Wall below the bridge on the starboard side. Photo was taken standing on the front deck 2 m in front of the ladder.

Depth: Approximately 26 m.

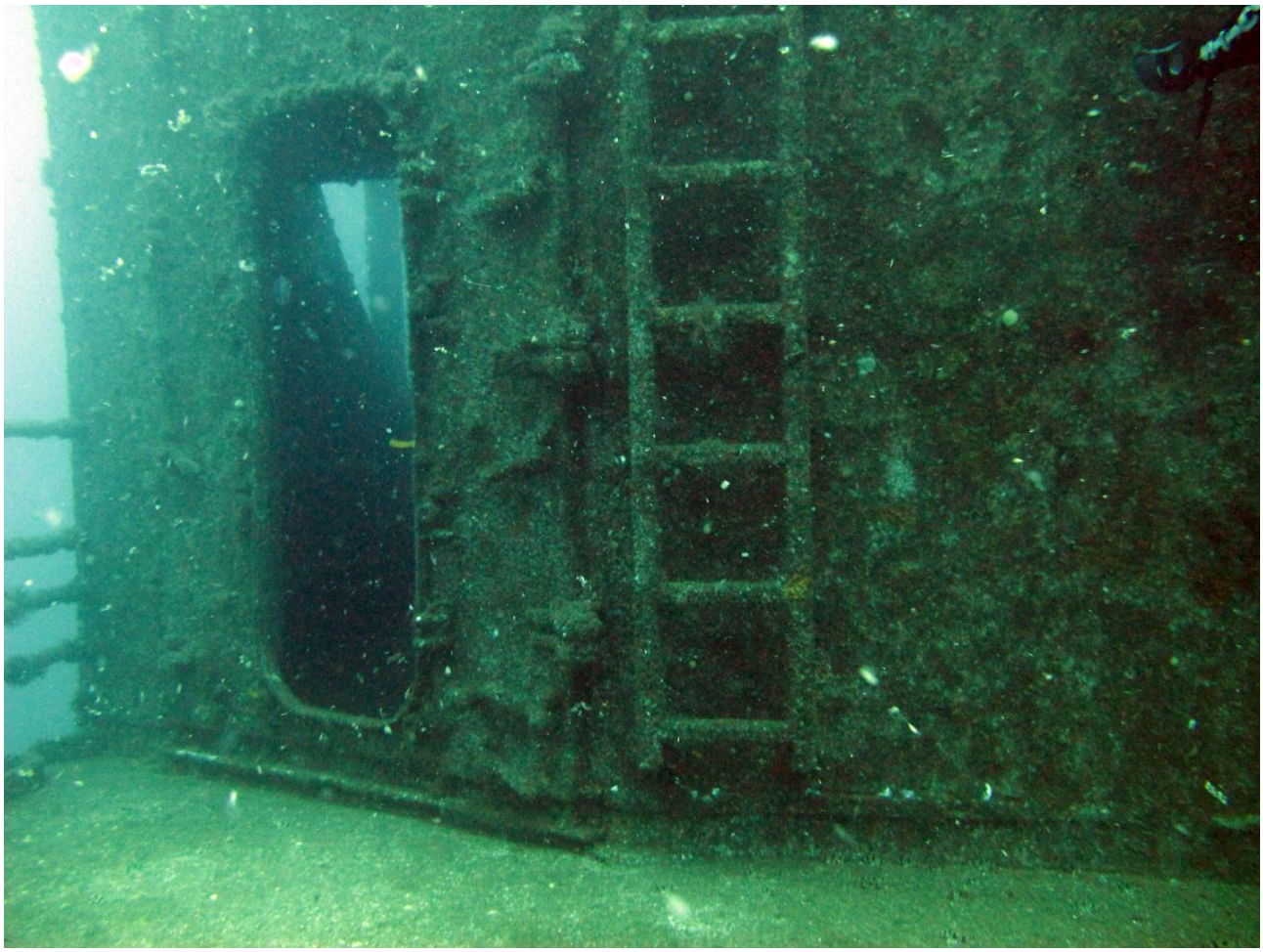


Appendix A: (Continued).

Fixed Photo: 10

Location: Wall below the bridge on the port side. Photo was taken standing on the front deck 2 m in front of the ladder.

Depth: Approximately 26 m.



Appendix B: Mean percentage cover (± standard error) of reef communities for each transect analysed during survey 1.

Categories	Deck Port Bow		Deck Port Mid		Deck Port Stern	
	Mean	S.E.	Mean	S.E.	Mean	S.E.
PHAEOPHYTA						
Ecklonia radiata	0.00	0.00	2.74	1.03	0.00	0.00
Turfing brown algae	1.45	0.79	0.00	0.00	0.00	0.00
TOTAL PHAEOPHYTA	1.45	0.79	2.74	1.03	0.00	0.00
RHODOPHYTA						
Encrusting red algae	0.00	0.00	1.47	1.23	0.00	0.00
TOTAL RHODOPHYTA	0.00	0.00	1.47	1.23	0.00	0.00
BRYOZOA						
Biflustra perfragilis	0.42	0.42	0.00	0.00	0.00	0.00
Encrusting orange bryozoan	0.00	0.00	0.21	0.21	0.00	0.00
Encrusting yellow bryozoan	0.00	0.00	0.00	0.00	0.00	0.00
Encrusting red bryozoan	0.00	0.00	1.06	0.58	0.00	0.00
Hornea foliacea	0.00	0.00	0.00	0.00	0.00	0.00
Menbranipora membranacea	1.24	0.76	0.63	0.26	0.00	0.00
Tryphyllozoan sp.	0.00	0.00	0.00	0.00	0.00	0.00
White branching bryozoan	0.00	0.00	0.21	0.21	0.00	0.00
TOTAL BRYOZOA	1.66	1.18	2.11	1.26	0.00	0.00
PORIFERA						
Spongia sp.	0.00	0.00	1.68	0.98	0.00	0.00
White encrusting sponge	0.00	0.00	0.00	0.00	0.00	0.00
White globular sponge	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL PORIFERA	0.00	0.00	1.68	0.98	0.00	0.00
ASCIDIA						
Herdmania momus	0.00	0.00	0.00	0.00	0.00	0.00
White encrusting solitary ascidian	0.00	0.00	0.00	0.00	0.00	0.00
White tubular solitary ascidian	0.20	0.20	0.00	0.00	0.00	0.00
TOTAL ASCIDIAN	0.20	0.20	0.00	0.00	0.00	0.00
ABIOTIC						
Bare ships surface	0.00	0.00	0.00	0.00	0.00	0.00
Juv oyster shells	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL ABIOTIC	0.00	0.00	0.00	0.00	0.00	0.00
CRUSTACEA						
Balanus sp. 1	0.21	0.21	0.00	0.00	0.00	0.00
TOTAL CRUSTACEA	0.21	0.21	0.00	0.00	0.00	0.00
MOLLUSCA						
Bivalve mollusc	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL MOLLUSCA	0.00	0.00	0.00	0.00	0.00	0.00
POLYCHAETA						
Serpulid polychaete	4.42	2.11	4.01	1.07	1.13	0.51
TOTAL POLYCHAETA	4.42	2.11	4.01	1.07	1.13	0.51
CNIDARIA						
Hydroid sp. 1	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL CNIDARIA	0.00	0.00	0.00	0.00	0.00	0.00
MATRIX						
Barnacle matrix	0.00	0.00	0.00	0.00	0.00	0.00
Early colonising matrix	0.00	0.00	0.00	0.00	0.00	0.00
Large barnacle matrix	0.00	0.00	0.00	0.00	0.00	0.00
Serpulid and barnacle matrix	0.22	0.22	0.00	0.00	0.00	0.00
Serpulid matrix	91.43	2.36	86.29	1.59	98.87	0.51
TOTAL MATRIX	91.66	2.58	86.29	1.59	98.87	0.51
INDETERMINATE						
Fish in frame	0.40	0.25	0.84	0.61	0.00	0.00
Unknown white material	0.00	0.00	0.63	0.42	0.00	0.00
TOTAL INDETERMINATE	0.40	0.25	1.47	1.03	0.00	0.00
TAPE, WAND, SHADOW						
Shadow	2.20	1.43	0.21	0.21	4.60	2.36
Tape measure in frame	0.00	0.00	0.00	0.00	0.00	0.00
Camera Pole in frame	1.40	0.40	5.01	0.01	5.00	0.00
TOTAL TAPE, WAND, SHADOW	3.60	1.83	5.22	0.22	9.60	2.36

Appendix B: (Continued).

Categories	Deck Starbord Bow Mean	Deck Starbord Bow S.E.	Deck Starbord Mid Mean	Deck Starbord Mid S.E.	Deck Starbord Stern Mean	Deck Starbord Stern S.E.
PHAEOPHYTA						
Ecklonia radiata	0.00	0.00	4.67	1.28	0.00	0.00
Turfing brown algae	1.02	0.55	0.00	0.00	0.00	0.00
TOTAL PHAEOPHYTA	1.02	0.55	4.67	1.28	0.00	0.00
RHODOPHYTA						
Encrusting red algae	0.00	0.00	0.00	0.00	13.22	4.49
TOTAL RHODOPHYTA	0.00	0.00	0.00	0.00	13.22	4.49
BRYOZOA						
Biflustra perfragilis	0.00	0.00	0.00	0.00	0.00	0.00
Encrusting orange bryozoan	0.00	0.00	0.00	0.00	0.00	0.00
Encrusting yellow bryozoan	0.00	0.00	0.00	0.00	0.00	0.00
Encrusting red bryozoan	0.20	0.20	2.33	0.84	1.92	0.62
Hornea foliacea	0.00	0.00	0.00	0.00	0.00	0.00
Menbranipora membranacea	2.11	1.65	0.00	0.00	0.00	0.00
Tryphyllozoan sp.	0.00	0.00	0.21	0.21	0.00	0.00
White branching bryozoan	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL BRYOZOA	2.31	1.85	2.54	1.05	1.92	0.62
PORIFERA						
Spongia sp.	0.20	0.20	2.54	1.56	0.00	0.00
White encrusting sponge	0.00	0.00	0.00	0.00	0.21	0.21
White globular sponge	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL PORIFERA	0.20	0.20	2.54	1.56	0.21	0.21
ASCIDIA						
Herdmania momus	0.00	0.00	0.00	0.00	0.00	0.00
White encrusting solitary ascidian	0.41	0.25	0.00	0.00	0.22	0.22
White tubular solitary ascidian	0.41	0.25	0.00	0.00	0.21	0.21
TOTAL ASCIDIAN	0.82	0.50	0.00	0.00	0.43	0.43
ABIOTIC						
Bare ships surface	0.00	0.00	0.00	0.00	0.00	0.00
Juv oyster shells	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL ABIOTIC	0.00	0.00	0.00	0.00	0.00	0.00
CRUSTACEA						
Balanus sp. 1	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL CRUSTACEA	0.00	0.00	0.00	0.00	0.00	0.00
MOLLUSCA						
Bivalve mollusc	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL MOLLUSCA	0.00	0.00	0.00	0.00	0.00	0.00
POLYCHAETA						
Serpulid polychaete	3.49	1.68	4.67	0.56	3.60	0.71
TOTAL POLYCHAETA	3.49	1.68	4.67	0.56	3.60	0.71
CNIDARIA						
Hydroid sp. 1	1.85	1.61	0.00	0.00	0.00	0.00
TOTAL CNIDARIA	1.85	1.61	0.00	0.00	0.00	0.00
MATRIX						
Barnacle matrix	0.00	0.00	0.00	0.00	0.00	0.00
Early colonising matrix	0.00	0.00	0.00	0.00	0.00	0.00
Large barnacle matrix	0.00	0.00	0.00	0.00	0.00	0.00
Serpulid and barnacle matrix	0.00	0.00	0.00	0.00	0.43	0.43
Serpulid matrix	89.69	0.85	84.73	1.91	78.68	5.91
TOTAL MATRIX	89.69	0.85	84.73	1.91	79.12	6.34
INDETERMINATE						
Fish in frame	0.61	0.41	0.42	0.26	1.07	0.60
Unknown white material	0.00	0.00	0.43	0.26	0.43	0.43
TOTAL INDETERMINATE	0.61	0.41	0.85	0.52	1.51	1.03
TAPE, WAND, SHADOW						
Shadow	1.00	0.77	0.40	0.40	0.80	0.58
Tape measure in frame	0.00	0.00	0.00	0.00	0.00	0.00
Camera Pole in frame	1.80	0.37	4.82	0.19	4.80	0.20
TOTAL TAPE, WAND, SHADOW	2.80	1.15	5.22	0.60	5.60	0.78

Appendix B: (Continued).

Categories	Horinzontal Hull Port Mean	Horinzontal Hull Port S.E.	Horinzontal Hull Starbord Mean	Horinzontal Hull Starbord S.E.	Vertical Hull Port Bow Mean	Vertical Hull Port Bow S.E.
PHAEOPHYTA						
Ecklonia radiata	0.00	0.00	0.00	0.00	0.00	0.00
Turfing brown algae	0.00	0.00	0.20	0.20	0.00	0.00
TOTAL PHAEOPHYTA	0.00	0.00	0.20	0.20	0.00	0.00
RHODOPHYTA						
Encrusting red algae	1.04	0.85	0.52	0.35	0.00	0.00
TOTAL RHODOPHYTA	1.04	0.85	0.52	0.35	0.00	0.00
BRYOZOA						
Biflustra perfragilis	1.36	0.63	1.07	0.47	0.17	0.17
Encrusting orange bryozoan	0.00	0.00	0.00	0.00	2.26	0.68
Encrusting yellow bryozoan	0.00	0.00	0.00	0.00	0.00	0.00
Encrusting red bryozoan	0.00	0.00	0.37	0.24	0.35	0.35
Hornea foliacea	0.17	0.17	0.00	0.00	0.00	0.00
Menbranipora membranacea	1.90	1.21	1.60	0.51	0.00	0.00
Tryphyllozoan sp.	0.00	0.00	0.00	0.00	0.00	0.00
White branching bryozoan	0.00	0.00	0.17	0.17	1.39	0.52
TOTAL BRYOZOA	3.43	2.01	3.21	1.39	4.17	1.71
PORIFERA						
Spongia sp.	1.88	0.94	0.37	0.24	0.00	0.00
White encrusting sponge	0.00	0.00	0.00	0.00	0.00	0.00
White globular sponge	0.00	0.00	0.18	0.18	0.00	0.00
TOTAL PORIFERA	1.88	0.94	0.55	0.41	0.00	0.00
ASCIDIA						
Herdmania momus	0.86	0.41	0.57	0.40	1.05	0.54
White encrusting solitary ascidian	0.00	0.00	0.00	0.00	0.00	0.00
White tubular solitary ascidian	0.34	0.22	2.19	0.70	1.25	0.64
TOTAL ASCIDIAN	1.20	0.63	2.76	1.10	2.30	1.19
ABIOTIC						
Bare ships surface	0.00	0.00	0.00	0.00	0.00	0.00
Juv oyster shells	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL ABIOTIC	0.00	0.00	0.00	0.00	0.00	0.00
CRUSTACEA						
Balanus sp. 1	1.36	0.63	0.00	0.00	1.58	0.60
TOTAL CRUSTACEA	1.36	0.63	0.00	0.00	1.58	0.60
MOLLUSCA						
Bivalve mollusc	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL MOLLUSCA	0.00	0.00	0.00	0.00	0.00	0.00
POLYCHAETA						
Serpulid polychaete	6.66	2.55	6.58	2.58	1.05	0.86
TOTAL POLYCHAETA	6.66	2.55	6.58	2.58	1.05	0.86
CNIDARIA						
Hydroid sp. 1	0.35	0.35	1.61	1.21	2.97	1.53
TOTAL CNIDARIA	0.35	0.35	1.61	1.21	2.97	1.53
MATRIX						
Barnacle matrix	0.00	0.00	0.00	0.00	0.00	0.00
Early colonising matrix	0.00	0.00	0.00	0.00	0.00	0.00
Large barnacle matrix	0.00	0.00	6.21	3.96	9.84	7.52
Serpulid and barnacle matrix	50.38	17.08	21.38	9.93	77.92	6.77
Serpulid matrix	33.71	15.34	56.97	12.68	0.00	0.00
TOTAL MATRIX	84.09	32.42	84.57	26.57	87.76	14.29
INDETERMINATE						
Fish in frame	0.00	0.00	0.00	0.00	0.00	0.00
Unknown white material	0.00	0.00	0.00	0.00	0.17	0.17
TOTAL INDETERMINATE	0.00	0.00	0.00	0.00	0.17	0.17
TAPE, WAND, SHADOW						
Shadow	0.17	0.17	6.51	1.71	1.01	0.37
Tape measure in frame	0.00	0.00	0.00	0.00	0.00	0.00
Camera Pole in frame	2.01	0.45	1.67	0.42	2.37	0.21
TOTAL TAPE, WAND, SHADOW	2.17	0.62	8.18	2.13	3.38	0.58

Appendix B: (Continued).

Categories	Vertical Hull Port Stern Mean	Vertical Hull Port Stern S.E.	Vertical Hull Starbord Bow Mean	Vertical Hull Starbord Bow S.E.	Vertical Hull Starbord Stern Mean	Vertical Hull Starbord Stern S.E.
PHAEOPHYTA						
Ecklonia radiata	0.00	0.00	0.00	0.00	0.00	0.00
Turfing brown algae	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL PHAEOPHYTA	0.00	0.00	0.00	0.00	0.00	0.00
RHODOPHYTA						
Encrusting red algae	0.00	0.00	2.67	1.69	0.00	0.00
TOTAL RHODOPHYTA	0.00	0.00	2.67	1.69	0.00	0.00
BRYOZOA						
Biflustra perfragilis	0.00	0.00	0.00	0.00	0.00	0.00
Encrusting orange bryozoan	0.22	0.22	3.09	0.98	0.00	0.00
Encrusting yellow bryozoan	0.00	0.00	0.21	0.21	0.00	0.00
Encrusting red bryozoan	0.00	0.00	3.73	1.65	0.00	0.00
Hornea foliacea	0.00	0.00	0.00	0.00	0.00	0.00
Menbranipora membranacea	0.00	0.00	0.41	0.41	0.00	0.00
Tryphyllozoan sp.	0.00	0.00	0.00	0.00	0.00	0.00
White branching bryozoan	0.00	0.00	5.17	2.15	0.00	0.00
TOTAL BRYOZOA	0.22	0.22	12.61	5.39	0.00	0.00
PORIFERA						
Spongia sp.	0.00	0.00	0.00	0.00	0.00	0.00
White encrusting sponge	0.00	0.00	0.00	0.00	0.00	0.00
White globular sponge	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL PORIFERA	0.00	0.00	0.00	0.00	0.00	0.00
ASCIDIA						
Herdmania momus	0.00	0.00	0.20	0.20	0.00	0.00
White encrusting solitary ascidian	0.00	0.00	0.00	0.00	0.00	0.00
White tubular solitary ascidian	0.00	0.00	0.00	0.00	0.44	0.27
TOTAL ASCIDIAN	0.00	0.00	0.20	0.20	0.44	0.27
ABIOTIC						
Bare ships surface	0.00	0.00	0.00	0.00	0.00	0.00
Juv oyster shells	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL ABIOTIC	0.00	0.00	0.00	0.00	0.00	0.00
CRUSTACEA						
Balanus sp. 1	1.36	0.56	1.64	0.68	2.38	0.90
TOTAL CRUSTACEA	1.36	0.56	1.64	0.68	2.38	0.90
MOLLUSCA						
Bivalve mollusc	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL MOLLUSCA	0.00	0.00	0.00	0.00	0.00	0.00
POLYCHAETA						
Serpulid polychaete	0.22	0.22	2.08	0.87	0.66	0.44
TOTAL POLYCHAETA	0.22	0.22	2.08	0.87	0.66	0.44
CNIDARIA						
Hydroid sp. 1	0.00	0.00	0.00	0.00	2.16	1.22
TOTAL CNIDARIA	0.00	0.00	0.00	0.00	2.16	1.22
MATRIX						
Barnacle matrix	1.48	1.48	0.00	0.00	0.00	0.00
Early colonising matrix	0.00	0.00	0.00	0.00	0.00	0.00
Large barnacle matrix	89.49	3.51	33.33	15.90	82.99	6.81
Serpulid and barnacle matrix	7.00	2.95	47.27	12.53	10.95	7.30
Serpulid matrix	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL MATRIX	97.98	7.94	80.60	28.43	93.94	14.10
INDETERMINATE						
Fish in frame	0.22	0.22	0.00	0.00	0.43	0.26
Unknown white material	0.00	0.00	0.21	0.21	0.00	0.00
TOTAL INDETERMINATE	0.22	0.22	0.21	0.21	0.43	0.26
TAPE, WAND, SHADOW						
Shadow	3.20	1.02	1.01	0.55	2.60	1.47
Tape measure in frame	0.80	0.80	0.00	0.00	0.00	0.00
Camera Pole in frame	6.40	0.60	1.40	0.51	6.40	0.40
TOTAL TAPE, WAND, SHADOW	10.40	2.42	2.41	1.06	9.00	1.87

Appendix B: (Continued).

Categories	Vertical Super Port Bow Mean	Vertical Super Port Bow S.E.	Vertical Super Port Stern Mean	Vertical Super Port Stern S.E.	Vertical Super Starbord Bow Mean	Vertical Super Starbord Bow S.E.
PHAEOPHYTA						
Ecklonia radiata	0.00	0.00	0.00	0.00	0.00	0.00
Turfing brown algae	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL PHAEOPHYTA	0.00	0.00	0.00	0.00	0.00	0.00
RHODOPHYTA						
Encrusting red algae	1.65	1.41	0.00	0.00	13.19	6.23
TOTAL	1.65	1.41	0.00	0.00	13.19	6.23
BRYOZOA						
Biflustra perfragilis	0.21	0.21	0.00	0.00	0.00	0.00
Encrusting orange	0.00	0.00	0.00	0.00	0.21	0.21
Encrusting yellow	0.00	0.00	0.00	0.00	0.00	0.00
Encrusting red	0.41	0.41	0.22	0.22	3.19	2.93
Hornea foliacea	0.00	0.00	0.00	0.00	0.00	0.00
Menbranipora	0.00	0.00	1.31	0.88	0.00	0.00
Tryphyllozoan sp.	0.00	0.00	0.00	0.00	0.00	0.00
White branching	0.21	0.21	0.00	0.00	0.00	0.00
TOTAL BRYOZOA	0.82	0.82	1.52	1.09	3.40	3.14
PORIFERA						
Spongia sp.	0.00	0.00	0.43	0.43	0.00	0.00
White encrusting	0.82	0.82	0.00	0.00	0.43	0.26
White globular sponge	0.21	0.21	0.00	0.00	0.00	0.00
TOTAL PORIFERA	1.03	1.03	0.43	0.43	0.43	0.26
ASCIDIA						
Herdmania momus	0.00	0.00	0.00	0.00	0.00	0.00
White encrusting	0.00	0.00	0.00	0.00	0.00	0.00
White tubular solitary	0.21	0.21	0.00	0.00	0.65	0.26
TOTAL ASCIDIAN	0.21	0.21	0.00	0.00	0.65	0.26
ABIOTIC						
Bare ships surface	0.00	0.00	1.76	1.76	1.91	1.18
Juv oyster shells	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL ABIOTIC	0.00	0.00	1.76	1.76	1.91	1.18
CRUSTACEA						
Balanus sp. 1	1.86	0.94	2.15	1.13	0.67	0.67
TOTAL CRUSTACEA	1.86	0.94	2.15	1.13	0.67	0.67
MOLLUSCA						
Bivalve mollusc	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL MOLLUSCA	0.00	0.00	0.00	0.00	0.00	0.00
POLYCHAETA						
Serpulid polychaete	1.45	0.96	0.65	0.65	0.42	0.26
TOTAL POLYCHAETA	1.45	0.96	0.65	0.65	0.42	0.26
CNIDARIA						
Hydroid sp. 1	0.84	0.61	0.85	0.62	0.66	0.44
TOTAL CNIDARIA	0.84	0.61	0.85	0.62	0.66	0.44
MATRIX						
Barnacle matrix	0.00	0.00	0.00	0.00	0.00	0.00
Early colonising matrix	0.00	0.00	4.62	4.62	0.00	0.00
Large barnacle matrix	26.70	15.38	26.36	13.33	14.47	10.31
Serpulid and barnacle	24.62	14.35	61.02	11.97	52.03	11.00
Serpulid matrix	39.58	21.69	0.00	0.00	11.74	11.74
TOTAL MATRIX	90.90	51.42	91.99	29.91	78.25	33.05
INDETERMINATE						
Fish in frame	1.04	0.80	0.65	0.43	0.43	0.27
Unknown white	0.21	0.21	0.00	0.00	0.00	0.00
TOTAL	1.24	1.01	0.65	0.43	0.43	0.27
TAPE, WAND,						
Shadow	1.00	1.00	0.40	0.40	4.00	1.92
Tape measure in frame	0.20	0.20	0.00	0.00	0.00	0.00
Camera Pole in frame	2.40	0.60	6.80	0.20	2.41	0.60
TOTAL TAPE, WAND,	3.60	1.80	7.20	0.60	6.41	2.53

Appendix B: (Continued).

Categories	Vertical Super Starbord Stern Mean	S.E.
PHAEOPHYTA		
Ecklonia radiata	0.00	0.00
Turfing brown algae	0.00	0.00
TOTAL PHAEOPHYTA		
RHODOPHYTA		
Encrusting red algae	0.86	0.63
TOTAL RHODOPHYTA		
BRYOZOA		
Biflustra perfragilis	0.43	0.26
Encrusting orange bryozoan	1.72	1.00
Encrusting yellow bryozoan	0.00	0.00
Encrusting red bryozoan	0.00	0.00
Homea foliacea	0.00	0.00
Menbranipora membranacea	0.00	0.00
Tryphyllozoan sp.	0.00	0.00
White branching bryozoan	0.00	0.00
TOTAL BRYOZOA		
PORIFERA		
Spongia sp.	0.00	0.00
White encrusting sponge	0.00	0.00
White globular sponge	0.00	0.00
TOTAL PORIFERA	0.00	0.00
ASCIDIA		
Herdmania momus	0.22	0.22
White encrusting solitary ascidian	0.00	0.00
White tubular solitary ascidian	0.65	0.26
TOTAL ASCIDIAN	0.86	0.48
ABIOTIC		
Bare ships surface	0.43	0.43
Juv oyster shells	0.22	0.22
TOTAL ABIOTIC	0.65	0.65
CRUSTACEA		
Balanus sp. 1	2.82	0.88
TOTAL CRUSTACEA	2.82	0.88
MOLLUSCA		
Bivalve mollusc	0.44	0.44
TOTAL MOLLUSCA	0.44	0.44
POLYCHAETA		
Serpulid polychaete	0.00	0.00
TOTAL POLYCHAETA	0.00	0.00
CNIDARIA		
Hydroid sp. 1	0.00	0.00
TOTAL CNIDARIA	0.00	0.00
MATRIX		
Barnacle matrix	0.00	0.00
Early colonising matrix	1.08	1.08
Large barnacle matrix	18.27	6.96
Serpulid and barnacle matrix	72.02	5.78
Serpulid matrix	0.00	0.00
TOTAL MATRIX	91.36	13.81
INDETERMINATE		
Fish in frame	0.86	0.86
Unknown white material	0.00	0.00
TOTAL INDETERMINATE	0.86	0.86
TAPE, WAND, SHADOW		
Shadow	1.20	0.97
Tape measure in frame	0.00	0.00
Camera Pole in frame	6.40	0.68
TOTAL TAPE, WAND, SHADOW	7.60	1.65

Appendix C: Permutational Analysis of Variance of Percent Cover of Reef Assemblages Sampled in Reef Monitoring Survey 1 (11 and 13 October 2011). *P*-values highlighted in bold are significant.

1. All Positions

Source	df	SS	MS	F	*P*
Position	15	1.3892E5	9261.2	6.2145	**0.0001**
Residual	66	98357	1490.3		
Total	81	2.3728E5			

2. Orientation (Vertical vs Horizontal)

Source	df	SS	MS	F	*P*
Orientation	1	11163	11163	7.8073	**0.0005**
Aspect	1	3270.6	3270.6	2.2875	0.0801
Orientation x Aspect	1	2099.2	2099.2	1.4682	0.2112
Res	28	40035	1429.8		
Total	31	56173			

3. Depth and Aspect

Source	df	SS	MS	F	*P*
Depth (Shallow, Deep)	1	5124.5	5124.5	0.74616	0.4682
Aspect (Port, Starbord)	1	1541.2	1541.2	0.22441	0.9322
Depth x Aspect	1	2594.7	2594.7	0.37781	0.7184
Transect (Depth x Aspect)	4	27471	6867.8	4.5456	**0.0001**
Residual	32	48348	1510.9		
Total	39	85080			

4. Position on Deck (Bow, mid-ship, stern)

Source	df	SS	MS	F	P
Position	2	4256	2128	1.6016	0.1567
Aspect	1	771.69	771.69	0.58081	0.6032
Position x Aspect	2	3301.5	1650.7	1.2424	0.2775
Res	24	31887	1328.6		
Total	29	40216			

Appendix D: Pair-Wise *Post-Hoc* t-tests for the Factor 'Orientation' in the Analysis of Percent Cover of Reef Assemblages (11 to 13 October 2011) and SIMPER Analyses of Assemblages Identified as Significantly Different.. (Significant comparisons in bold). Variables are ranked according to their contribution to dissimilarity (up to 90 %).

Groups	t	P(perm)
Deck vsHull	2.7942	0.0007

	Group Deck	Group Hull			
Group/Taxa	Av.Abund	Av.Abund	Av.Diss	Contrib%	Cum.%
Serpulid matrix	69.6	45.39	23.37	39.88	39.88
Serpulid/Barnacle/Encrusting Algae Matrix	0.11	33.71	18.22	31.09	70.97
Serpulid polychaete	3.39	6.09	2.68	4.58	75.55
Encrusting red algae	3.7	0.88	2.04	3.48	79.03
Wand	4.98	1.87	1.74	2.97	81.99
Shadow	1.54	2.62	1.69	2.89	84.88
Menbranipora membranacea	0.23	1.92	1.05	1.79	86.67
Large Barnacle,sediment,brown fil	0	1.61	1.01	1.73	88.4
Ecklonia radiata	1.86	0	0.98	1.67	90.06