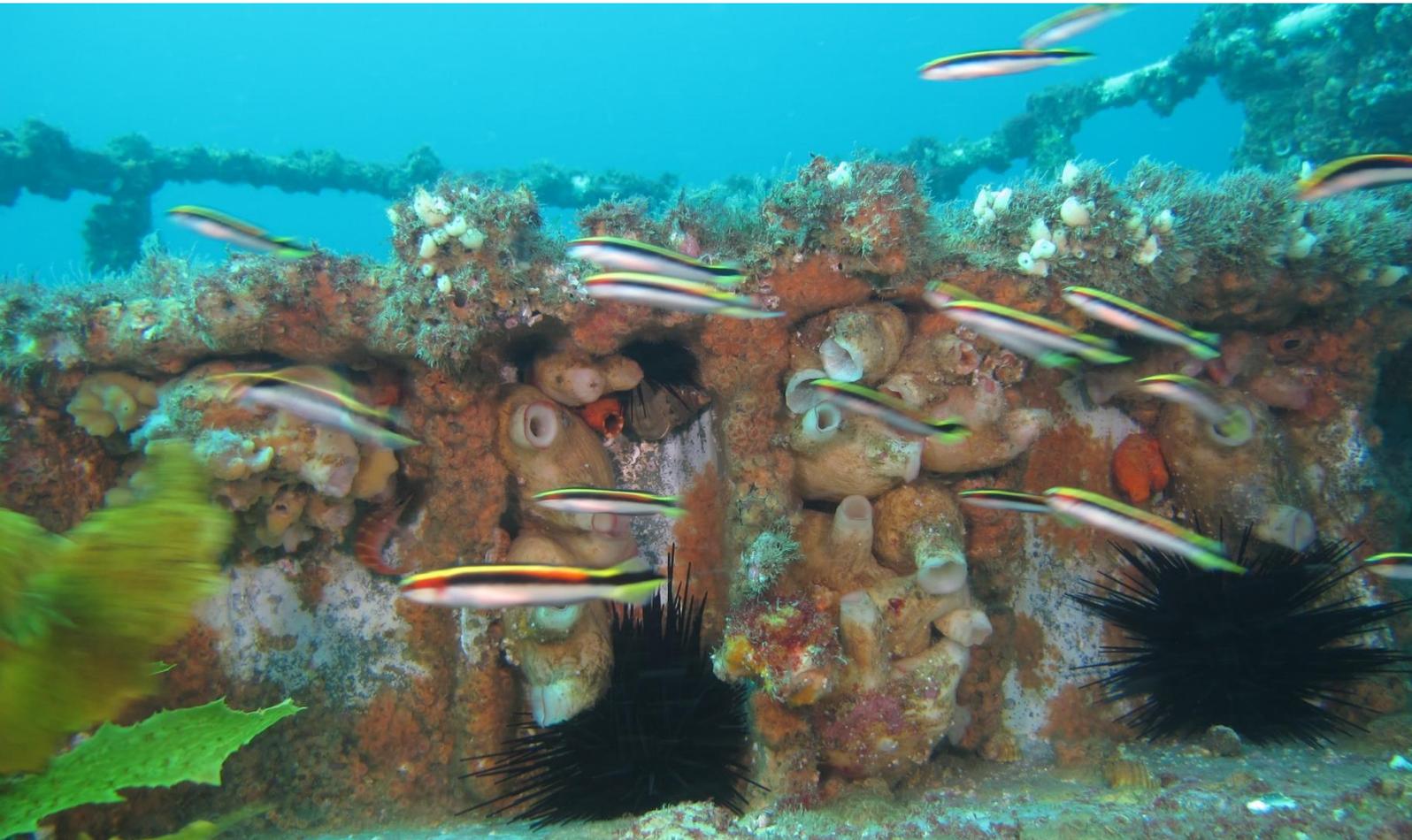




**Cardno  
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**Shaping the Future**

**Marine and Freshwater Studies**



# **Ex-HMAS Adelaide Artificial Reef Reef Community Monitoring Survey 11**

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## Document Control

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## Executive 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 in March 2011.

This Progress Report outlines the methodology and findings of Reef Community Monitoring Survey 11 (**Table ES 1**), as required as part of the LTMMP. Surveys have been carried out approximately on a quarterly basis since the scuttling of the ship in April 2011. The scope of work to be carried out by Cardno Ecology Lab was initially for a two year period post-scuttling (a total of eight reef community surveys), however, as the LTMMP is currently under review, a ninth, tenth and eleventh reef community survey has been completed in the interim. This Progress Report outlines the methodology and findings of Reef Community Survey 11 (Survey 11).

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 done as part of Survey 11 were carried out on 22, 23 and 29 October 2014. Survey methods involved using divers to take photoquadrats and under water video transects on different parts of the ship. Photoquadrats were analysed for percentage cover of encrusting biota using Coral Point Count with Excel extensions (CPCe) and compared with the previous Monitoring Surveys. Underwater video footage was reviewed and also used to describe the encrusting reef assemblage and fish species present.

Results of Survey 11 show marked changes in the composition of the reef assemblage over the past six months following Survey 10 in March 2014. These pronounced differences between surveys may partly be due to the longer timeframe between surveys (usually 3 months), therefore allowing more time for successional changes to become apparent. Over the approximately six month period between Surveys 10 and 11, the total percent cover of serpulid/barnacle and turfing algae matrix and solitary ascidians decreased overall, while there was an increase in the cover of anemones, brown filamentous algae/hydroid, large barnacle matrix and various encrusting sponges. There was also an increase in the cover of bare surface and early colonising matrix in Survey 11 compared to Survey 10.

As reported for the majority of previous surveys, analysis of photoquadrats showed the reef assemblages occurring on horizontally orientated (deck) surfaces (characterised by *Ecklonia radiata* and red encrusting algae) were different in composition from the vertically orientated (hull) reef assemblages (characterised by ascidians, large barnacles and anemones).

Depth was also a significant factor in structuring the reef assemblage with deeper transects characterised by a greater percent cover of large barnacles and anemones and shallow transects characterised by a greater percent cover of early colonising matrix and brown filamentous algae/hydroid. This pattern has been consistent throughout the monitoring program.

Deck position (i.e. bow, mid ship and stern) was a significant factor influencing assemblage composition. As discussed in previous reports, this factor is confounded by depth, as the mid ship deck position is situated on top of the superstructure, whereas the bow and stern deck positions are situated at the level of the flight deck in deeper water. Notwithstanding this, spatial differences on the deck surfaces were evident, as bow and stern reef assemblages were also found to be different despite occurring at similar depths. These differences were mainly

due to a greater percent cover of kelp, red encrusting algae and serpulid/barnacle matrix at the mid ship and a greater cover of brown filamentous algae/hydroid at the stern.

The number of fish species observed by divers and from video and fixed photos has generally increased since scuttling of the ship in April 2011. Twenty eight fish species were recorded during Survey 11 which was marginally higher than the number recorded during Survey 10 (25 species). Species of fish recorded during Survey 11 that have not previously been recorded included the pygmy scorpion fish (*Scorpaenodes scaber*) and banded parma (*Parma polylepis*). Both are found on coastal and estuarine reefs in New South Wales although the banded parma is less common in southern New South Wales.

**Table ES1:** Summary of Reef Community Sampling Carried Out To-Date

Survey	Sampling Dates	Timeframe
Baseline	18 April and 30 May 2011	1 week post-scuttling
Monitoring Survey 1	11 and 13 October 2011	6 months post-scuttling
Monitoring Survey 2	14 and 16 February 2012	10 months post-scuttling
Monitoring Survey 3	03 and 04 May 2012	1 year post scuttling
Monitoring Survey 4	27 July 2012	1 year 3 months post scuttling
Monitoring Survey 5	31 October and 01 November 2012	1 year 6 months post scuttling
Monitoring Survey 6	16 and 17 January 2013	1 year 9 months post scuttling
Monitoring Survey 7	29 and 30 April 2013	2 years post scuttling
Monitoring Survey 8	16 and 17 July 2013	2 years 3 months post-scuttling
Monitoring Survey 9	16 and 21 October 2013	2 years 6 months post-scuttling
Monitoring Survey 10	03 and 04 March 2014	2 years 11 months post-scuttling
Monitoring Survey 11	22, 23 and 29 September 2014	3 years 5 months post-scuttling

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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
Epifauna	Animals that live on the surface of the seabed
Epiphytic	Growing on the surface of.
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.
Macroinvertebrate	Organisms associated with sediment and retained in a sieve of 0.5 to 1.0 mm
LAT	Lowest Astronomical Tide
LTMMMP	Long Term Monitoring and Management Plan
PCoA	Principle Coordinates Analyses
PERMANOVA	Permutational Analysis of Variance. A statistical routine run in Primer-E.
SIMPER	Similarity Percentage Analysis. 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 (DSEWP&C).

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) which was prepared 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 LTMMP and a review of the LTMMP is currently underway. The LTMMP includes the following environmental monitoring components:

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

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, however, during this interim review period, the scope has been extended to include additional surveys.

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 methodology and findings for the eleventh reef community survey which have been carried out on a near quarterly basis since April 2011 (**Table 1**). This progress report (Survey 11) 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 Bulbaring 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) and is embedded 1 m – 2 m into the flat, sandy, seabed.

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 Ex-HMAS Adelaide 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 from the keel 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).

Preparation for scuttling 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. Potential contaminants such as fuels, oils, heavy metals, batteries and electrical items containing polychlorinated biphenols (PCBs) were removed. Diver access holes were 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).

The Ex-HMAS Adelaide was prepared to meet DSEWPaC standards which were specified during the months of preparation prior to scuttling. DSEWPaC had conducted a series of inspections to confirm that its detailed requirements were achieved. The original clean-up process included removing loose or flaking paint in accordance with DSEWPaC's requirements.

## 1.3 Previous Surveys

### 1.3.1 Baseline Survey

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

- 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. The remainder of 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 were therefore made to subsequent monitoring surveys. Additional transects were added to the superstructure to provide a greater vertical range, while some of the deeper horizontal transects were not surveyed. The sampling design was modified to allow for more robust statistical analyses to be undertaken.

### 1.3.2 Monitoring Survey 1

Following the baseline survey, the first monitoring survey was carried out over a two-day period on 11 and 13 October 2011. Analysis of photoquadrats taken from different parts of the ship indicated that at approximately six months post-scuttling, 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. Visual comparison of photoquadrats between the baseline and monitoring survey 1 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 had also increased substantially. A total of three species; from three families were initially observed in the baseline survey. A total of 19 species from 16 families were observed during the first monitoring survey. The most common species of fish were eastern fortesque (*Centropogon australis*) and yellowtail scad (*Trachurus novaezelandiae*), but also observed were 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 first survey.

### 1.3.3 Monitoring Survey 2

Approximately 10 months post-scuttling, there was a small increase in the number of individual taxa or groups of taxa, including red and brown algae, anemones and sponges not previously recorded. Throughout the ship a matrix of barnacles, sediment and brown filamentous algae provided the greatest cover, followed by a matrix of serpulid tubes covered with trapped sediment and turfing brown algae. Large barnacles, sediment, brown filamentous algae and the brown macroalgae *Ecklonia radiata*, had the next greatest percentage cover. Analysis of spatial differences and comparison through time indicated that the assemblage recorded on the ship in February 2012 was significantly different to that in October 2011, although the effect of time was not consistent among parts on the ship. Fish abundance and species richness observed around the Ex-HMAS Adelaide did not appear to have increased since the previous survey, although several new species including tarwhine (*Rhabosargus sarba*), girdled scalyfin (*Parma unifasciata*) and yellowtail kingfish (*Seriola lalandi*) were recorded, some of which were likely to be seasonally abundant at the time of survey.

### 1.3.4 Monitoring Survey 3

The colonisation of the Ex-HMAS Adelaide, approximately one year post- scuttling, was substantial and the assemblage that had formed was consistent with observations on similar artificial structures on the east coast of Australia and abroad. Analysis of photoquadrats taken from different parts of the ship showed that the number of individual taxa or groups of taxa (32 recorded) was similar to that of previous surveys, although several taxa not previously recorded were observed in the current survey. The most abundant group throughout the survey was the serpulid polychaete, barnacle and encrusting algal matrix. Several new taxa/groups were also recorded. Analysis of spatial differences and comparison through time indicated that the assemblage recorded on the ship was significantly different to that in previous surveys, although the effect of time was not consistent among parts of the ship. The encrusting layer had become notably thicker on certain parts of the ship since the previous survey. Kelp (*Ecklonia radiata*) and red branching algae had continued to grow substantially on parts of the ship (particularly the mid deck) since the previous survey. Fish abundance and species richness observed around the Ex-HMAS Adelaide had not increased substantially since the previous survey, although several new species were recorded.

### 1.3.5 Monitoring Survey 4

Fifteen months post-scuttling the entire ship was covered with an encrusting layer of serpulid polychaete tubes, barnacles, encrusting bryozoans, sponges and ascidians among other groups. Taxa/groupings that were well represented during the fourth survey included the ascidian *Herdmania momus*, large barnacle, sediment and brown filamentous algae matrix and turfing brown algae, sediment and serpulid matrix. New taxa included an orange colonial ascidian (likely to be *Botryloides leachi*) and a purple sponge, although these groups were present in low abundances. Overall, there appeared to be a transition from an assemblage numerically dominated by an encrusting serpulid matrix to that dominated by barnacles and ascidians. Analysis of spatial differences and temporal comparison indicated that the assemblage recorded on the ship was significantly different to that in previous surveys, although there were similarities in some of the spatial patterns with orientation continuing to be an important factor in structuring the reef assemblage. Inspection of the fixed photos indicated that the encrusting layer had become marginally thicker on certain parts of the ship such as ladders and railings, but not on others. Fish abundance and species richness decreased in comparison with the earlier monitoring surveys although two new species (batfish (*Platax* sp.) and dusky flathead (*Platycephalus fuscus*)) were recorded in survey 4.

### 1.3.6 Monitoring Survey 5

Survey 5 showed that the number of individual taxa or groups of taxa of sessile benthic biota had increased since previous surveys, although the assemblage was becoming less variable and more uniform over the ship as a whole. Similar taxa to those observed in the previous survey were recorded, with the serpulid, barnacle and encrusting algal matrix being numerically abundant, although there appeared to have been an increase in the percent cover of *Ecklonia radiata*, large barnacles and the bryozoan *Biflustra perfragilis*. Several taxa/groupings not previously documented on the ship included two new categories of colonial ascidians and a polyplacophoran (chiton). Analysis of spatial differences and comparison through time indicated that the assemblage recorded on the ship 18 months post-scuttling was significantly different to that in previous surveys, although there were similarities in some of the spatial patterns. Orientation continued to be an important factor in structuring the reef assemblage, with deck and hull surfaces being consistently different. Reef assemblages on the deck surfaces of the ship also varied consistently through time, with position (bow, mid ship or stern) being an important factor, although this was also dependent on whether transects were on the port or starboard side of the ship. Fish abundance and species richness had generally increased during Survey 5 compared to previous surveys and several new species were observed. These included eastern hula fish (*Trachinops taeniatus*), schooling bannerfish (*Heniochus diphreutes*), blotched hawkfish (*Cirritichthys aprinus*), eastern kelpfish (*Chironemus marmoratus*), rock cale, (*Crinodus lophodon*), comb wrasse (*Coris picta*) and six spined leatherjacket (*Meuschenia freycineti*). A pair of eastern blue groper (*Archoerodus viridis*) was also observed during this survey.

### 1.3.7 Monitoring Survey 6

Although the number of epibenthic taxa, or groupings of taxa recorded during survey 6 (approx. 21 months post scuttling) had decreased slightly since the previous survey, the general pattern of assemblages becoming less variable throughout time was still apparent. Again, the serpulid, barnacle and encrusting algal matrix was numerically dominant, although a noticeable increase in cover of encrusting bryozoans and sponges was apparent. As for previous surveys, the ascidian, *Herdmania momus* and the common kelp, *Ecklonia radiata* were well represented on the ships surface. A number of taxa not previously recorded in other surveys were observed, including white tubular sponges, unidentified globular ascidians and numerous dead barnacles. In terms of spatial and temporal patterns, orientation (i.e. deck vs hull surfaces), depth (i.e. superstructure vs hull) and position (i.e. bow vs mid-ships vs stern) were again key factors in structuring the reef assemblage associated with the ship. Fish abundance and species richness was similar between surveys 5 and 6, although a new species of leatherjacket (*Eubalichthys mosaicus*) was observed.

### 1.3.8 Monitoring Survey 7

The assemblage sampled in Survey 7 was similar to that observed in the previous survey with the serpulid, barnacle and encrusting algal matrix being numerically abundant, but with notable increases in the percent cover of bare surface, large barnacle/sediment and brown filamentous algae matrix, and serpulid matrix. Other taxa/groupings that were well represented during the survey (and have been abundant in previous surveys) included the ascidian *Herdmania momus*, and the common kelp *Ecklonia radiata*. Categories that decreased

between Monitoring Surveys 6 and 7 were encrusting red algae, white papillate sponge, the laced bryozoan *Biflustra perfragilis* and encrusting orange bryozoan. New taxa recorded in Survey 7 included a small orange anemone and two unidentified solitary ascidians. Orientation continued to be an important factor in structuring the reef assemblage on the ship, although differences were not consistent for both Surveys 6 and 7. Depth was not found to be a significant factor in structuring assemblages associated with the vertical surfaces of the superstructure and the hull. Reef assemblages on different sections of the deck (i.e. bow mid ship and stern) also varied from one another, although differences were not consistent through time. A total of 26 species of fish, including six new species (Gunther's butterflyfish (*Chaetodon guentheri*), magpie morwong (*Cheilodactylus vestitus*), southern fusilier (*Paracaesio xanthurus*), Gunther's wrasse (*Pseudolabrus guntheri*), luculentus wrasse (*Pseudolabrus luculentus*), and the black-banded sea perch (*Hypoplectrodes nigroruber*), were recorded during Survey 7.

### 1.3.9 Monitoring Survey 8

In general, similar taxa to those observed in the previous survey were recorded in Survey 8, with the serpulid, barnacle and encrusting algal matrix being numerically most abundant, followed by the conglomeration of large barnacles, sediment and brown filamentous algae and the solitary ascidian *Herdmania momus*. As for previous surveys, analysis of photoquadrats showed a strong and recurrent pattern of assemblages occurring on horizontally orientated (deck) surfaces being different in composition from the vertically orientated (hull) assemblage. Deck position (i.e. bow, mid ship and stern) also appeared to be a significant factor whereas depth was not. Some less abundant taxa of soft corals, hydroids and other unidentified algae were observed growing on the deck and superstructure, but were not captured within the photoquadrat survey as they were sparsely distributed. This highlights the importance of using a variety of sampling techniques to gain a better understanding of the overall species diversity rather than reliance upon a single method. In total, 26 species of fish, including several species not previously observed, were recorded during Survey 8. New species identified included a Port Jackson shark (*Heterodontus portusjacksoni*), samson fish (*Seriola hippos*), moon wrasse (*Thalassoma lunare*), eastern wirrah (*Acanthistius ocellatus*), rainbow runner (*Elagatis bipinnulata*) and one spot puller (*Chromis hypsilepis*). Several migrating whales and a pod of dolphins were also observed by divers during the field survey.

### 1.3.10 Monitoring Survey 9

Analysis of photoquadrats showed that the number of individual taxa or groups of taxa (33 recorded in total) was similar to Survey 8 and that the assemblages sampled in the two surveys were not significantly different. Similar taxa to those observed in the previous survey were recorded in Survey 9, with the serpulid, barnacle and encrusting algal matrix being numerically most abundant, followed by an early colonising matrix, the conglomeration of large barnacles, sediment and brown filamentous algae and solitary ascidians. Two new species (an echinoderm and colonial ascidian) were also recorded by divers in Survey 9, but were not captured in any photoquadrats. As for previous surveys, analysis of photoquadrats showed that assemblages occurring on horizontally orientated (deck) surfaces were very different in composition from the vertically orientated (hull) assemblage. Deck position (i.e. bow, mid ship and stern) also appeared to be a significant factor in determining epibenthic assemblage composition, whereas depth was not. The number of fish species observed has remained the same (26 species in total) from Surveys 8 and 9. No new species of fish were observed, however, a pair of cuttlefish (*Sepia* sp.) was filmed near the wheelhouse of the ship camouflaged against the deck.

### 1.3.11 Monitoring Survey 10

Analysis of photoquadrats taken from different parts of the ship showed that the number of individual taxa or groups of taxa (32 recorded in total) was similar to Survey 9 and that the assemblages sampled in the two surveys were not significantly different. Similar to previous surveys, the most abundant category identified in Survey 10 in terms of total percentage cover was an encrusting matrix of serpulid polychaete worms, barnacles and turfing algae (serpulid/barnacle matrix). Other numerically abundant categories included solitary ascidians, the conglomeration of large barnacles, sediment and brown filamentous algae, tiny orange anemones (*Corynactis* sp.), 'early colonising matrix', red encrusting algae and brown filamentous algae/hydroid.

Assemblages occurring on horizontally orientated (deck) surfaces were again different in composition from the vertically orientated (hull) assemblage mainly due to a greater percent cover of serpulid, barnacle and encrusting algal matrix, red encrusting algae and *Ecklonia radiata* on the deck than on the hull and a greater percent cover

of large barnacle, sediment and brown filamentous algae matrix, solitary ascidians, tiny orange anemones and early colonising matrix on the vertically orientated hull surfaces. No obvious patterns relating to depth or deck position were evident, although in general, the assemblage associated with the mid deck was characterised by *Ecklonia radiata* and red encrusting algae. The number of fish species observed remained similar for the past four surveys (between 25 and 26 species recorded in total). A wobbegong shark (*Orectolobus* sp.) and black reef leatherjacket (*Eubalichthys bucephalus*) were both recorded for the first time during Survey 10. Both are commonly found on coastal reefs along the New South Wales Coast.

**Table 1: Summary of Reef Community Sampling Carried Out To-Date**

Survey	Sampling Dates	Timeframe
Baseline	18 April and 30 May 2011	1 week post-scuttling
Monitoring Survey 1	11 and 13 October 2011	6 months post-scuttling
Monitoring Survey 2	14 and 16 February 2012	10 months post-scuttling
Monitoring Survey 3	03 and 04 May 2012	1 year post scuttling
Monitoring Survey 4	27 July 2012	1 year 3 months post scuttling
Monitoring Survey 5	31 October and 01 November 2012	1 year 6 months post scuttling
Monitoring Survey 6	16 and 17 January 2013	1 year 9 months post scuttling
Monitoring Survey 7	29 and 30 April 2013	2 years post scuttling
Monitoring Survey 8	16 and 17 July 2013	2 years 3 months post-scuttling
Monitoring Survey 9	16 and 21 October 2013	2 years 6 months post-scuttling
Monitoring Survey 10	03 and 04 March 2014	2 years 11 months post-scuttling
Monitoring Survey 11	22, 23 and 29 September 2014	3 years 5 months post-scuttling



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. The approximate locations of all transects are indicated on **Figure 2**. These transects were based on those used for the previous monitoring survey. Along 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

- 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

- 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

- 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

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

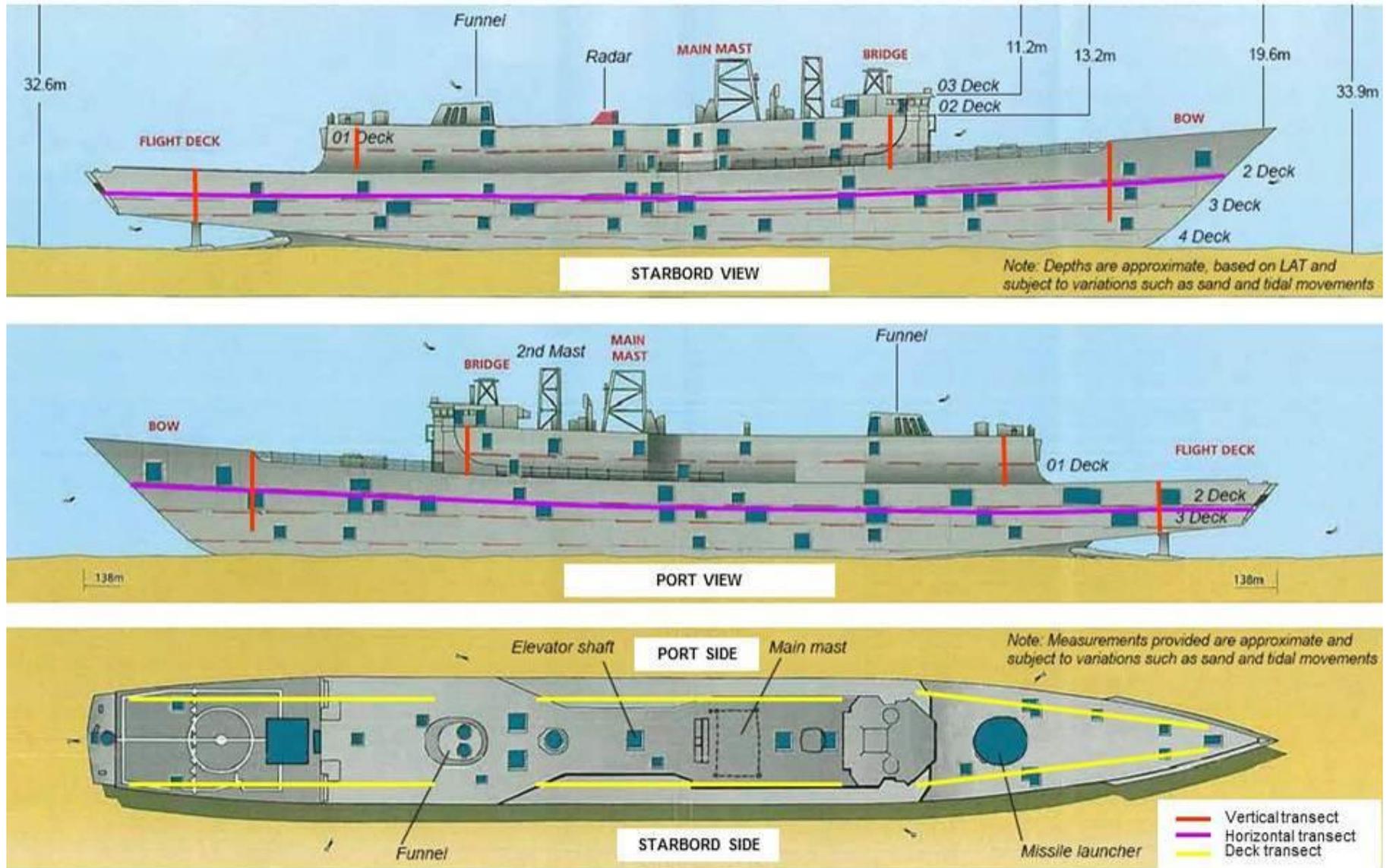


Figure 2: Plans of the Ex-HMAS Adelaide and positions of the Reef assemblage Community Survey survey Sampling sampling Transects.

Photoquadrats were acquired at regular intervals along each transect. For the vertical transects this was approximately every 0.5 m. This was originally every metre, however, the 30 m depth limit for divers meant the number of replicate photoquadrats was restricted, therefore photoquadrats were taken every 0.5 m.

For horizontal hull transects this was approximately every 6 m and for the deck and superstructure every 10 m (consistent with earlier surveys). 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 of the video transects and photoquadrats. Dive lights were attached to the camera for better resolution of colours and clarity. Fish species encountered were also photographed where possible.

### 2.1.2 Fixed Point Photographs

Photographs were taken at 10 fixed point locations. This was to provide a qualitative record of changes to reef assemblages over time. 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 swim at a constant slow speed and depth while filming along the proposed transects. Video was taken with 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. The total number of each taxon/group was used as an estimate of percentage cover. Still photographs of different taxa were then compiled to prepare a project-specific Biota Identification Manual and project coral code file for use with CPCe. Identifications were made to the highest taxonomic resolution practical, although it should be recognised that species level identification of many encrusting organisms such as sponges, bryozoans and ascidians may not be 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; and
- Serpulid/barnacle matrix = Mixture of serpulid tubes and barnacles with a layer of encrusting red 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 assemblage; and
3. Analyses of temporal variation in reef assemblage using a qualitative approach.

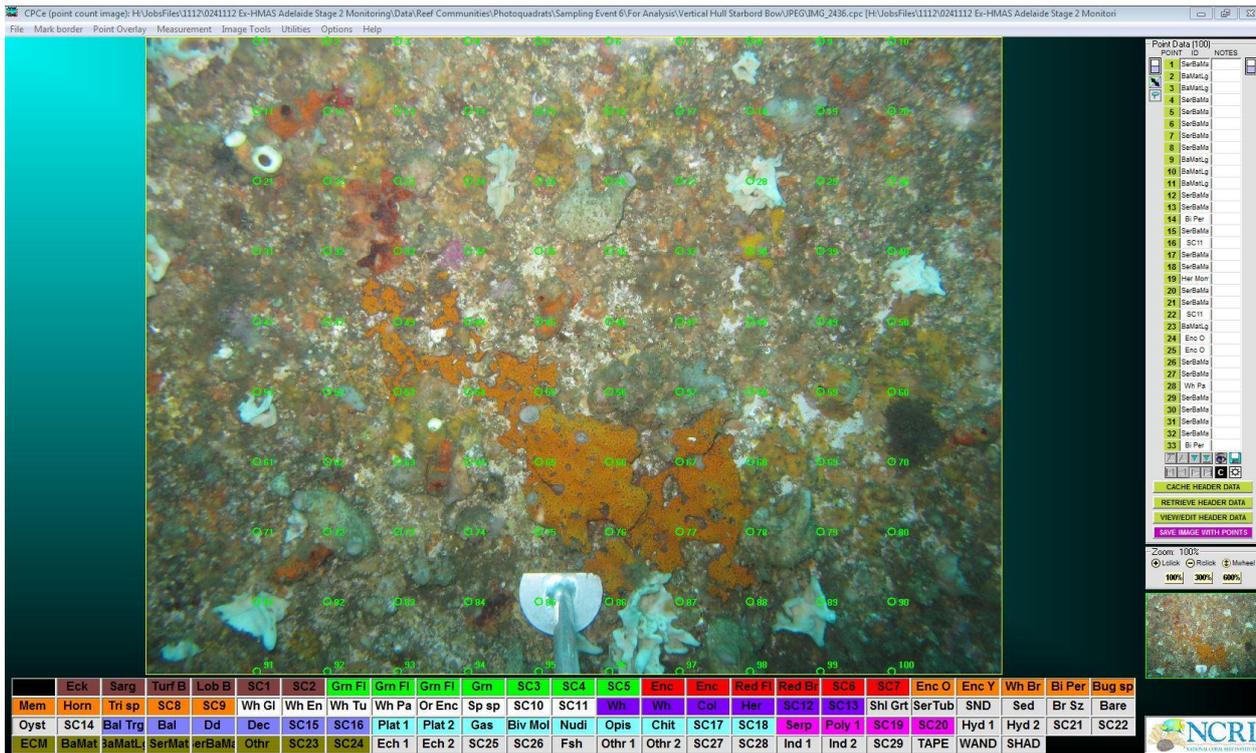


Figure 3: Screenshot of the CPCe Photoquadrat Analyses Frame with a Virtual 10 x 10 Grid Overlaid.

### 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 and Temporal Analyses

Variation in reef assemblages on different parts of the ship and over time were analysed using multivariate statistical techniques. Due to the existing design of the sampling program (pre-determined by the LTMMMP and the baseline survey) this was separated into different analyses. As data for the baseline survey was limited, no time comparisons were made between the baseline and Monitoring Survey 1. Time was added as a factor in the subsequent analyses to investigate both spatial and temporal trends between the current and preceding surveys, in this case, Surveys 9 and 10. The four null hypotheses tested were:

#### 1. No significant differences in reef assemblage structure among all monitoring survey times.

The design to test this hypothesis was as follows:

- Time (Surveys 1 - 11): fixed, orthogonal;

This design compared reef assemblage structure among the 11 sampling surveys to date (regardless of their spatial positioning on the ship). Note that for this eleventh survey, mean percentage cover per survey was used due to the large data set.

#### 2. No significant differences in reef assemblage structure between horizontally orientated (i.e. deck) surfaces and vertically orientated (i.e. hull) surfaces on both the port and starboard sides of the ship between consecutive monitoring survey times.

The design to test these hypotheses was as follows:

- Time (Survey 10/Survey 11): fixed, orthogonal;
- Orientation (deck/hull): fixed, orthogonal;
- Aspect: (port/starboard): fixed, orthogonal.

This design compared transects from the deck (bow, mid ship and stern from port and starboard sides) with the two horizontal transects along the ship's hull at two monitoring survey times.

### **3. No significant differences in reef assemblage structure between deep and shallow vertical transects on both the port and starboard sides of the ship between consecutive monitoring survey times.**

The design to test these hypotheses was as follows:

- Time (Survey 10/Survey 11): fixed, orthogonal;
- Depth (shallow/deep): fixed, orthogonal;
- Aspect (port/starboard): fixed, orthogonal;
- Transect: nested (depth x aspect), random.

This design compared vertical transects on the superstructure (i.e. port bow, port stern, starboard bow and starboard stern) and vertical transects on the hull at the same positions at two monitoring survey times.

### **4. No significant differences in reef assemblage structure among positions (deck surface only) on both the port and starboard sides of the ship between consecutive monitoring survey times.**

The design to test these hypotheses was as follows:

- Time (Survey 10/Survey 11): fixed, orthogonal;
- 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 at two monitoring survey times.

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). Although the CPCe coral code file used in Survey 11 was the same as for previous surveys, categories were grouped into broader classifications for purpose of the statistical analysis to reduce the chance of inconsistencies and subjectivity in identifications due to variability in photographic quality or colour across surveys.

Multivariate data were represented graphically using Principle 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.

Differences in the dispersion of data between surveys were examined using the PERMDISP routine in Permanova+. This routine is used to separate the effects of differences in dispersion of points within clusters from differences in the relative positions of the clusters (Anderson *et al.* 2008).

#### **2.2.2 Fixed Point Photographs**

Photographs were taken at 10 fixed point locations. This was to provide a qualitative record of changes to reef assemblages over time. Notes were taken on the exact location, distance from the structure or reference point, and depth at which the photographs were taken.

#### **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 resolution 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 during 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.

## **2.3 Limitations**

- Photographic quality and hence the ability to accurately identify taxa was dependent on the conditions at the time of sampling. Good quality photoquadrats may therefore result in the identification of a greater number of taxa than would be the case for photoquadrats where visibility was poor;
- Certain taxa were harder to distinguish and identify than others, potentially resulting in a bias towards more conspicuous species. Sponges, bryozoans and colonial ascidians were often difficult to distinguish from one another;
- Only organisms visible on the surface of the encrusting layer were recorded in photoquadrats. Organisms living embedded within or beneath the encrusting layer may therefore be under represented;
- Fish observations carried out as part of these surveys were not quantitative and should be treated as indicative only.

## 3 Results

### 3.1 Photoquadrats

#### 3.1.1 General Findings

In total, 28 categories/groups of taxa were identified from the 82 quadrats that were sampled during Survey 11 (**Appendix B**). The most abundant category identified during Survey 11 in terms of total percentage cover was an encrusting matrix of serpulid polychaete worms, barnacles and turfing algae (serpulid/barnacle matrix), which was also the most abundant category in the previous survey and contributed to over 50% of cover of the total area sampled. Brown filamentous algae/hydroids, tiny orange anemone (*Corynactis* sp.), solitary ascidians and large barnacles, sediment and brown filamentous algae (large barnacle matrix) also contributed to 13.4%, 7.9%, 6.4%, and 5.7% of total percentage cover respectively.

Over the approximately six month period between Surveys 10 and 11, the total percent cover of serpulid/barnacle and turfing algae matrix and solitary ascidians decreased overall, while there was an increase in the cover of anemones, brown filamentous algae/hydroid, large barnacle matrix and various encrusting sponges. There was also an increase in the cover of bare surface and early colonising matrix.

A summary of all taxa and groups of taxa identified in the analyses of photoquadrats for Survey 11 is given in **Appendix B**.

Comparisons of photoquadrats from the Baseline and Monitoring Surveys 1-11 are presented in **Plates 1 – 16**.

#### 3.1.2 Spatial and Temporal Variation in Reef Communities

##### *All Times (Surveys 1-11)*

Overall, time was a significant factor in terms of explaining variability in reef assemblages associated with the ship (**Appendix C**). Pair-wise tests indicated that the reef assemblage recorded during Survey 11 was significantly different to all other survey periods. Similarly, reef assemblages differed among previous surveys with the exceptions of S2 and 3, 4 and 6, 4 and 7, 4 and 8, 5 and 6, 7 and 8 and Surveys 9 and 10 (**Appendix D**). **Figure 4** also shows that approximately 65.8% of the total variation among samples was explained by the two axes within the PCoA. Differences in assemblages recorded during Surveys 10 and 11 were mainly explained by a decrease in mean percent cover of serpulid/barnacle matrix and solitary ascidians in Survey 11 coupled with increases in the percent cover of brown filamentous algae/hydroid, large barnacle matrix and tiny orange anemones compared to Survey 11 (**Appendix E**).

Differences observed were further explained by the significant PERMDISP result for the factor 'Time' which shows greater variability (or dispersion) among transects in Surveys 1-3 and less variability (i.e. greater clustering of points) in Surveys 4-10, although Survey 11 was more variable than Survey 10 (**Figure 4, Appendix F**).

##### *Time, Orientation (deck and hull) and Aspect (port and starboard)*

The assemblage of sessile invertebrates found on horizontal deck surfaces was significantly different from that of the vertical hull surfaces in both Surveys 10 and 11 regardless of aspect, however, both the deck and hull assemblages observed during Survey 10 were different from that during Survey 11 (**Appendix C, Appendix D**). This difference is clear from the grouping of points in the PCoA which explains 70.4% of the total variation among samples (**Figure 5**).

SIMPER analyses indicated that differences between the hull and deck assemblages in Survey 11 were mainly due to a greater percent cover of serpulid/barnacle matrix and red encrusting algae on the deck than on the hull surface and a greater percent cover of solitary ascidians, anemones, large barnacle matrix and early colonising matrix on the hull than the deck. This was similar to Survey 10, apart from there being a greater influence of brown filamentous algae/hydroid which was more abundant on the deck than on the hull.

Differences between Surveys 10 and 11 on horizontal deck surfaces were due to a decrease in percent cover of serpulid/barnacle matrix and brown filamentous algae/hydroids, but an increase in percent cover of anemones, large barnacles and solitary ascidians between survey periods. Differences on the vertical hull surfaces between Surveys 10 and 11 on the vertical hull surfaces were also due to a decrease in percent cover of serpulid/barnacle

matrix and an increase in percent cover of anemones, large barnacles and solitary ascidians, as well as an increase in early colonising matrix between survey periods (**Appendix E**).

PERMDISP for the factor Time and Orientation was significant, indicating that the differences in orientation (between hull and deck) and time were partly due to differences in dispersion as well as locational differences among samples, with greater variability among photoquadrats sampled during Survey 11 compared to Survey 10 (**Appendix F**). This is also evident in the PCoA plot (**Figure 5**) which shows greater distances between sample points during Survey 11 and more clustering of points during Survey 10.

#### ***Time, Depth (shallow and deep) and Aspect (port and starboard)***

The assemblages sampled in deep transects were consistently different from those sampled in shallow transects, regardless of Time or Aspect (**Appendix C, Figure 6**).

SIMPER analyses indicated that these differences were mainly due to a greater percent cover of large barnacle matrix and anemones in the deeper transects in comparison with the shallow transects and a greater percent cover of early colonising matrix in shallower transects compared to the deep transects (**Appendix E**).

No significant difference in the dispersion of samples was evident for the significant factor Depth, therefore the differences observed were due to locational factors (**Appendix F**).

#### ***Time, Position (bow, mid ship, stern) and Aspect (port and starboard)***

Significant differences in sessile reef assemblages among the three positions on the ship's deck surface (i.e. bow, mid ship or stern) were detected, although these were not consistent with Time (**Appendix C, Figure 7**). Pair-wise tests indicated that differences between Surveys 10 and 11 were generally a result of a decrease in the percent cover of serpulid/barnacle matrix and encrusting algae and an increase in brown filamentous algae/hydroids at the bow and stern positions between surveys. Differences at the mid ship position were also due to a decrease in the percent cover of serpulid/barnacle matrix, an increase in brown filamentous algae/hydroids, as well as an increase in percent cover of kelp (*Ecklonia radiata*) between surveys. Pair wise tests indicated that during Survey 10 the bow, mid ship and stern assemblages were all significantly different from each other, however during Survey 11 only the mid ship and stern differed significantly from one another. These differences were mainly due to a greater percent cover of kelp, red encrusting algae and serpulid/barnacle matrix at the mid ship and a greater cover of brown filamentous algae/hydroid at the stern (**Appendix D, Appendix E**).

Results are illustrated in the corresponding PCoA plot which shows that approximately 84.9% of the total variation among samples could be explained by the two axes in the ordination (**Figure 7**). The PCoA result also shows that the variability among replicate samples was greatest for the mid-ship position during Survey 11 and least variable at the bow position during Survey 10. This pattern was further highlighted within the PERMDISP results, with highly significant differences in the dispersion of samples detected for the interaction term (**Appendix F**).

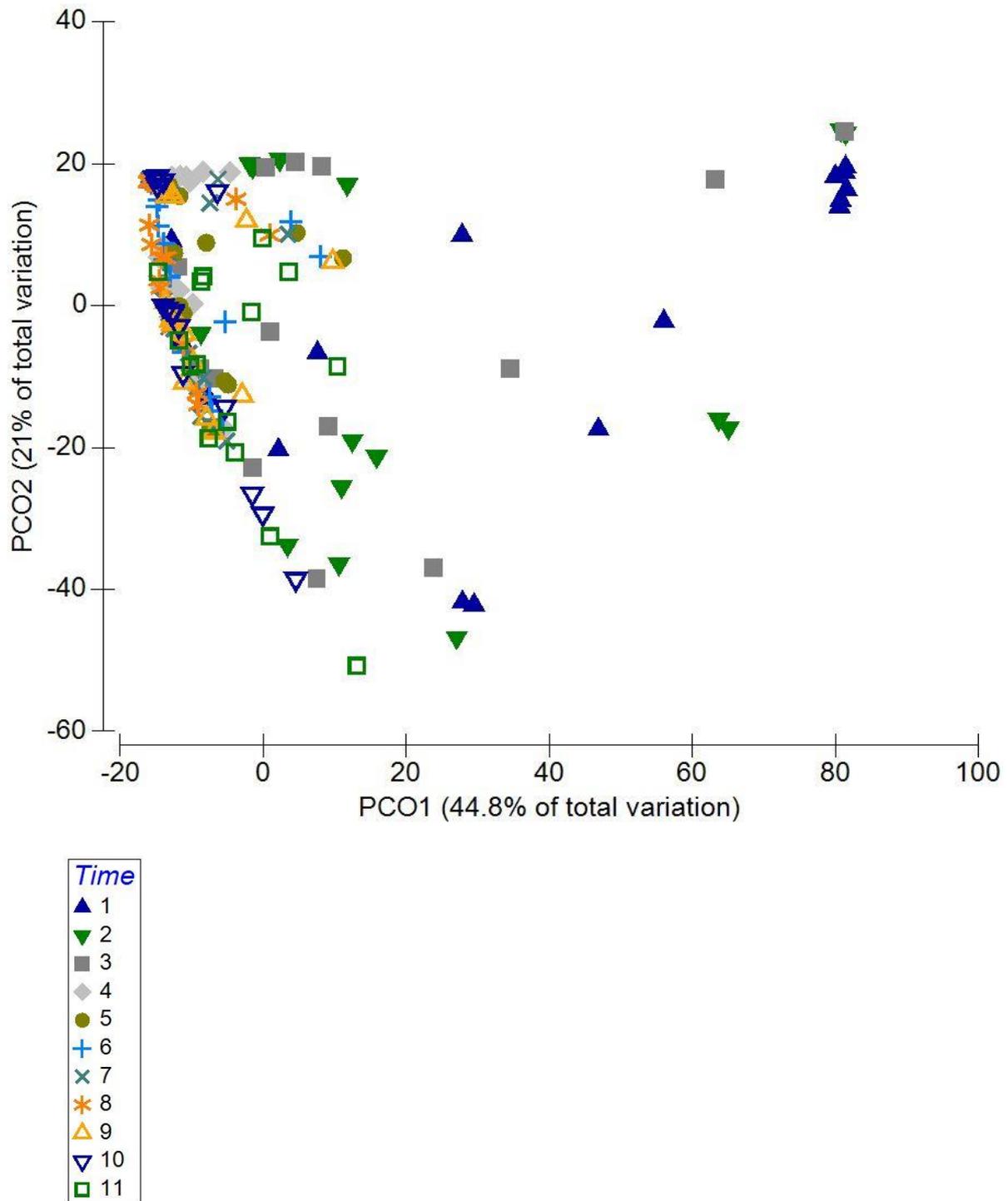


Figure 4: Principal Coordinates Analyses (PCoA) of Percent Cover of Encrusting Assemblages from Transects Taken at all Positions on the Ex-HMAS Adelaide for Surveys 1 to 11.

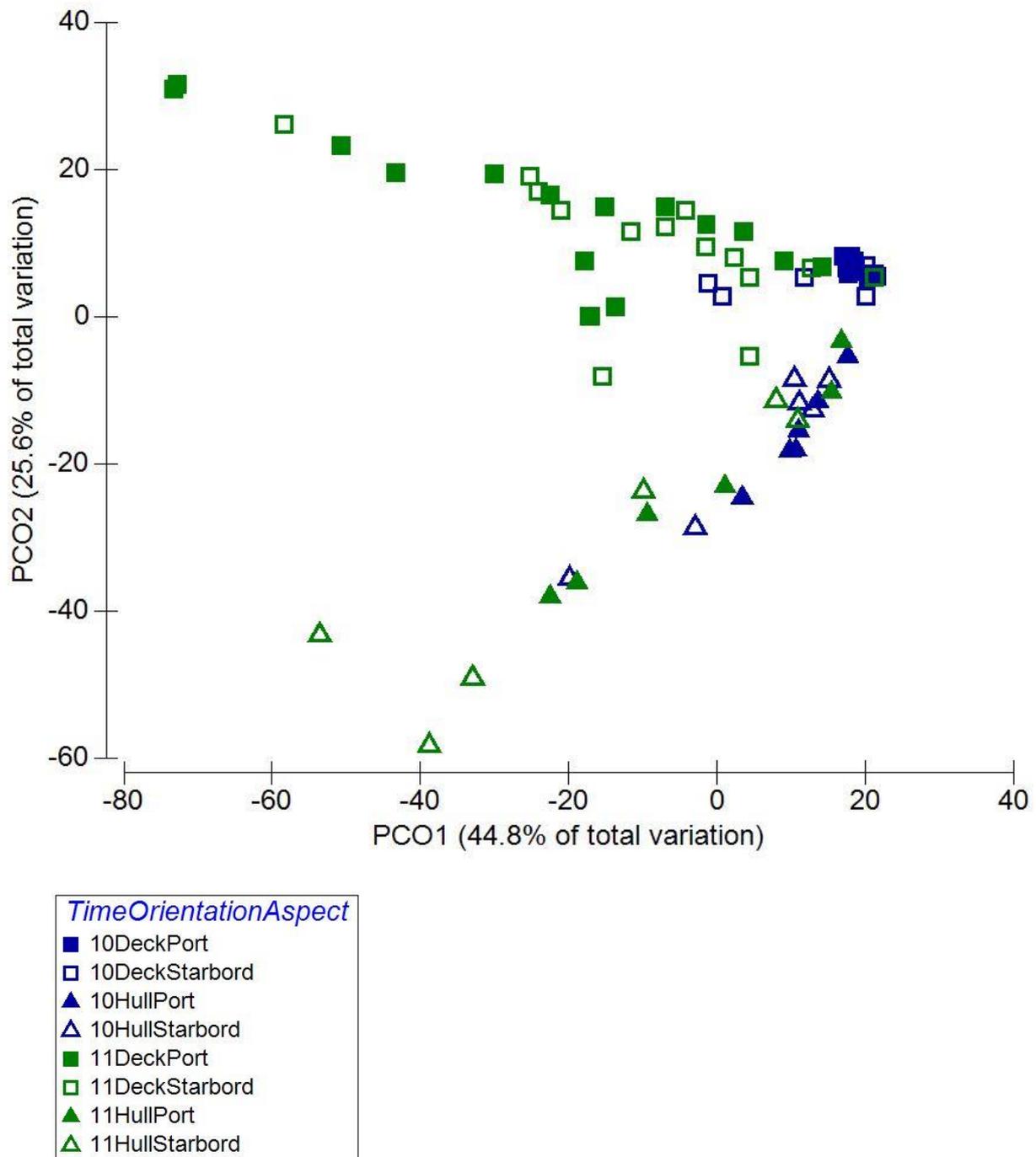
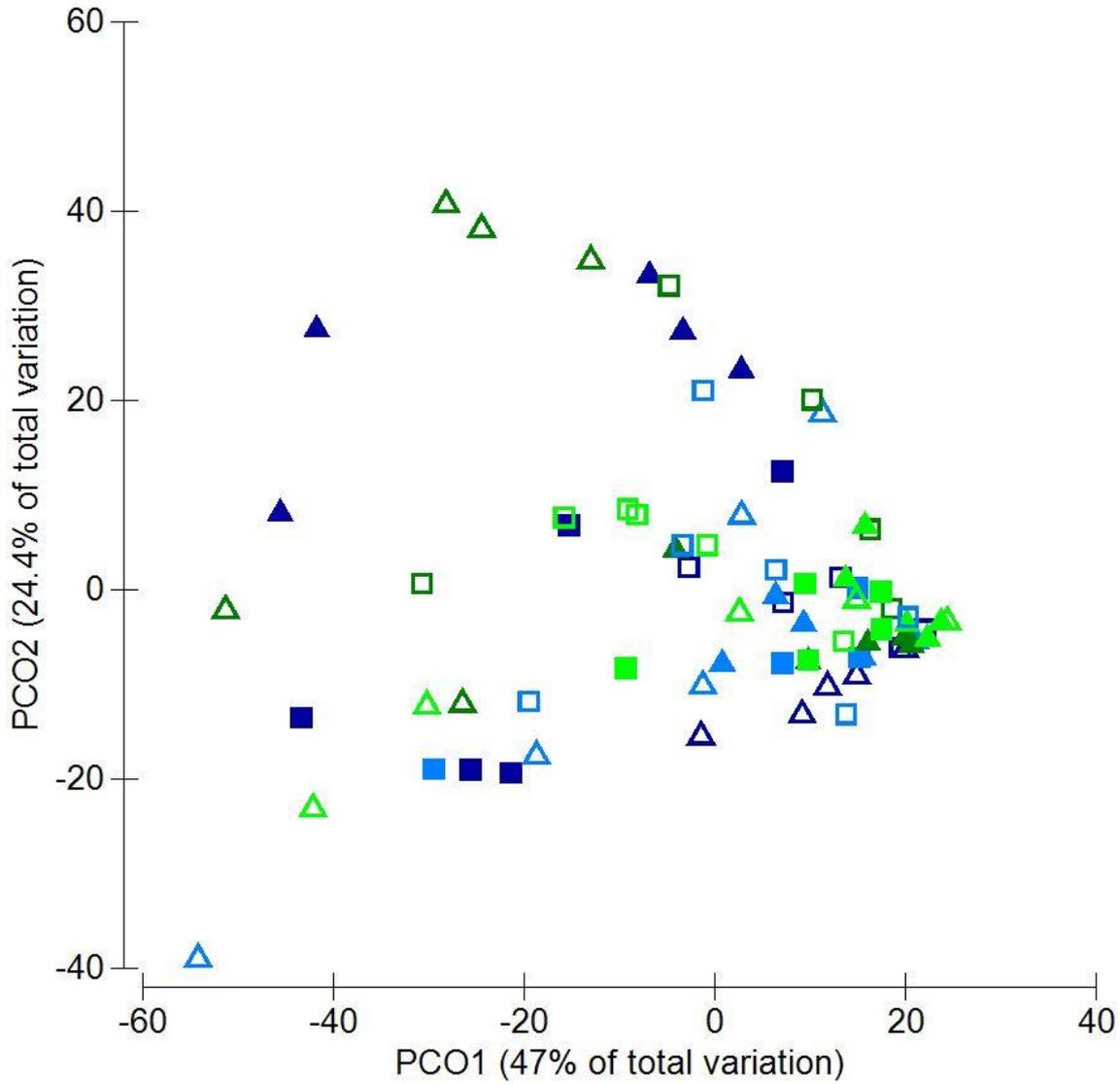


Figure 5: Principal Coordinates Analyses (PCoA) of Percent Cover of Encrusting Assemblages from Transects Taken on Hull and Deck Surfaces of the Ex-HMAS Adelaide for Surveys 10 and 11.



- TimeDepthAspectTransect*
- ▲ 10DeepPortBow
  - △ 10DeepPortStern
  - 10DeepStarboardBow
  - 10DeepStarboardStern
  - ▲ 10ShallowPortBow
  - △ 10ShallowPortStern
  - 10ShallowStarboardBow
  - 11ShallowStarboardBow
  - ▲ 10ShallowStarboardStern
  - △ 11DeepPortBow
  - 11DeepPortStern
  - 11DeepStarboardBow
  - ▲ 11DeepStarboardStern
  - △ 11ShallowPortBow
  - 11ShallowPortStern
  - 11ShallowStarboardStern

Figure 6: Principal Coordinates Analyses (PCoA) of Percent Cover of Encrusting Assemblages from Transects at Different Depths and Aspect on the Ex-HMAS Adelaide for Surveys 10 and 11.

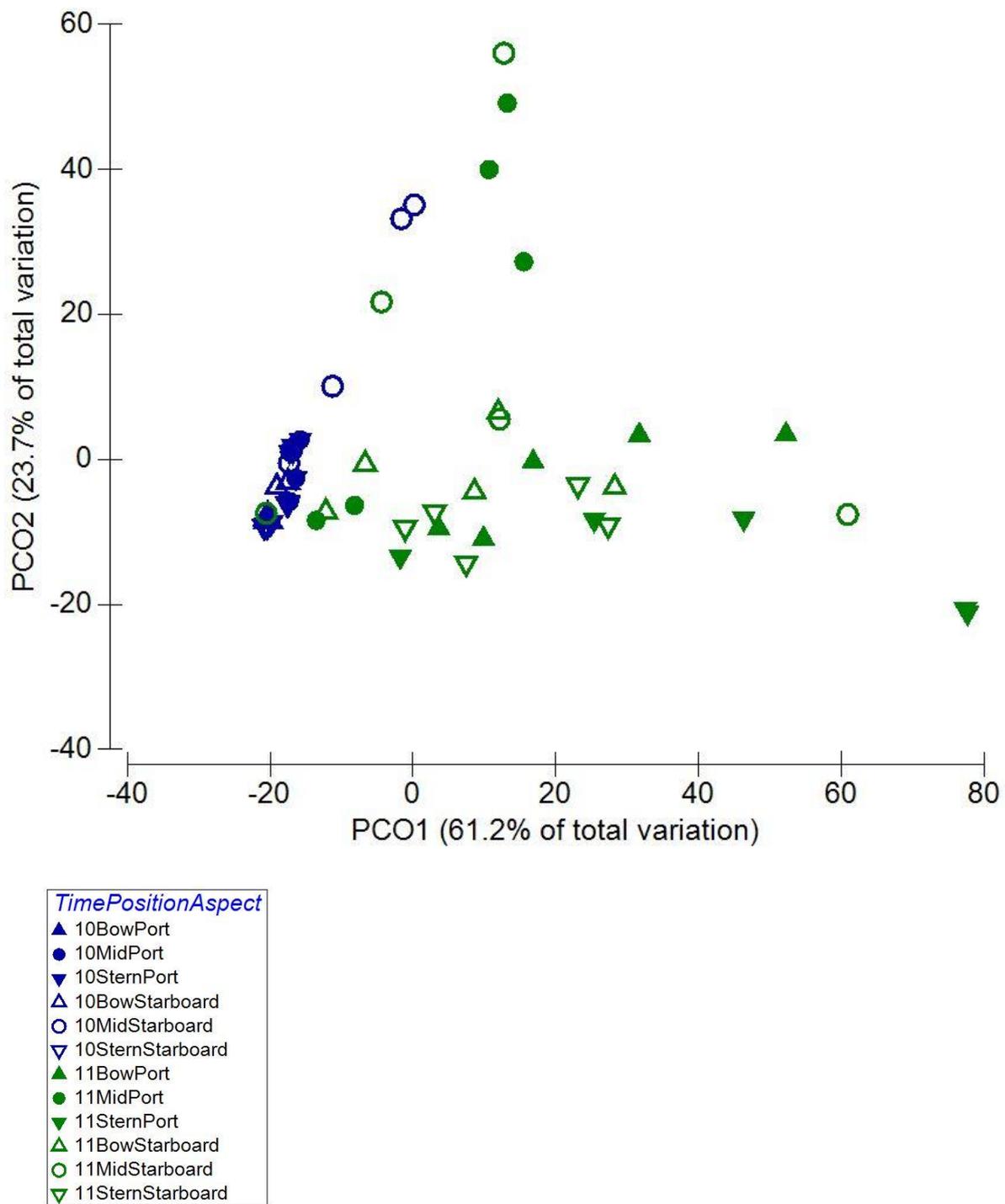


Figure 7: Principal Coordinates Analyses (PCoA) of Percent Cover of Encrusting Assemblages from Transects Taken at Different Positions on the Deck Ex-HMAS Adelaide for Surveys 10 and 11.

## 3.2 Fixed Photographs

Photographs taken from fixed locations are presented in **Appendix A**. Overall the encrusting assemblage does not appear to have changed significantly over the past four months between Surveys 10 and 11 and remains to primarily consist of a thick encrusting layer over more complex structures such as ladders, railings and masts and to a lesser extent on deck surfaces. Quality of fixed point photographs was generally low due to poor visibility.

## 3.3 Video Transects

The results of observations made from video transects are summarised in **Table 2** below. All fish species observed during previous surveys and the current monitoring survey (Survey 11) are listed in **Table 3**. Species of recreational, commercial or conservation value are also indicated. A total of 28 species of fish including two not previously recorded during the monitoring program (pygmy scorpion fish (*Scorpaenodes scaber*) and banded parma (*Parma polylepis*) were identified during survey 11.

**Table 2: Summary of Observations of Attached Encrusting and Fish Assemblages Observed from Video Footage of the Ex-HMAS Adelaide in September 2014 (Survey 11)**

Position	Description of Assemblage
Deck Port Bow	The deck surface was encrusted with a uniform assemblage of small barnacles, encrusting algae, hydroids and fine filamentous algae. Tubular solitary sponges, white papillate encrusting sponges and orange encrusting sponge were also conspicuous. Comb jellies (ctenophores) were observed in the water column. Eastern hulafish ( <i>Trachinops taeniatus</i> ), schools of tarwhine ( <i>Rhabdosargus sarba</i> ), rock cale ( <i>Crinodus lophodon</i> ), Kelpfish ( <i>Chironemidae</i> ), eastern blue groper ( <i>Achoerodus viridis</i> ) were all observed.
Deck Port Mid	As per previous surveys, kelp ( <i>Ecklonia radiata</i> ) remained present in this area. The majority of the deck was otherwise heavily encrusted with barnacles, encrusting red algae, hydroids and fine filamentous algae, with patches of white encrusting sponge. Patches of encrusting orange sponges were observed on the rail structures and on the deck. Comb jellies were observed in the water column. Yellowtail kingfish ( <i>Seriola lalandi</i> ), tarwhine, rock cale ( <i>Crinodus lophodon</i> ), blue morwong ( <i>Nemadactylus douglasi</i> ) were observed.
Deck Port Stern	The deck was predominantly covered in serpulid tubes, barnacles, encrusting algae, fine filamentous algae and a fine layer of sediment. Tubular solitary sponges, white and orange papillate encrusting sponges were conspicuous on the deck surface. Comb jellies were observed in the water column. Red morwong ( <i>Cheilodactylus fuscus</i> ), tarwhine, Kelpfish and six-spined leatherjacket ( <i>Meuschenia freycineti</i> ) were observed close to the deck.
Deck Starboard Bow	As with previous surveys, encrusting growth included barnacles, algae and hydroids with patches of encrusting sponges. Solitary, tubular, red, pink and white sponges were observed on the deck. Comb jellies were observed in the water column. Schools of eastern hulafish, bastard trumpeter ( <i>Latridopsis forsteri</i> ) and eastern blue groper were observed.
Deck Starboard Mid	As per previous surveys, the majority of the deck was encrusted with barnacles, encrusting algae, hydroids, fine red filamentous algae. Of note were small branching coralline algae which had not been previously recorded. Tubular solitary sponges, white papillate encrusting sponges, ascidians ( <i>Botrylloides magnicoecum</i> ) and sea urchins ( <i>Centrostephanus rogersii</i> ) were conspicuous on the deck surface. There were also large amounts of kelp ( <i>Ecklonia radiata</i> ). Rock cale, a kelp associated species, was present in this area. Schools of tarwhine, eastern hulafish, yellowtail kingfish and silver trevally ( <i>Pseudocaranx dentex</i> ) were observed as well as solitary crimson banded wrasse ( <i>Notolabrus gymnogenis</i> ), brown spotted wrasse ( <i>Notolabrus parilus</i> ), dusky morwong ( <i>Dactylophora nigricans</i> ), six-spined leatherjacket, yellowfin leatherjacket, eastern blue groper, girdled scalyfin ( <i>Parma unifasciata</i> ), black reef

leatherjacket (*Eubalichthys bucephalus*) and black spot goatfish (*Parupeneus spilurus*).

Deck Starboard Stern	Small barnacles, encrusting algae, hydroids, fine filamentous algae and white encrusting sponges were abundant on flat areas of the deck. A fine layer of sediment was noted on the surface. Comb jellies were observed in the water column. Schools of tarwhine and an eastern blue groper were also recorded.
Horizontal Hull Port and Starboard	The hull remains colonised by sessile invertebrates, particularly ascidians, on both the port and starboard sides of the ship. As with previous surveys, these included various ascidians such as <i>Herdmania momus</i> , large barnacles and encrusting sponges and bryozoans. Tiny orange and pink jewel anemones ( <i>Corynactis</i> sp.) have also become conspicuous forming a thin layer over barnacles. Growth still appeared thickest around the gunwale and around the edges of holes in the hull. Otherwise, the hull remained heavily encrusted with serpulid worm tubes covered with small barnacles, encrusting algae, hydroids and fine filamentous algae. Comb jellies were observed in the water column. The white papillate bryozoan ( <i>Triphyllozoan</i> sp.) was conspicuous in distinct colonies. White ear ( <i>Parma microlepis</i> ) eastern hulafish, trevally, six-spined leatherjacket, yellowfin leatherjacket, tarwhine, red morwong, half banded sea perch ( <i>Hypoplectrodes maccullochi</i> ), eastern blue groper, magpie perch ( <i>Cheilodactylus nigripes</i> ), snapper ( <i>Pagrus auratus</i> ) and tarwhine were observed swimming alongside the hull.
Vertical Hull Bow	Similar to previous surveys, large globular ascidians and barnacles were the most prevalent encrusting biota on the hull of the ship. Various encrusting and papillate sponges and bryozoans remained. Tiny orange anemones ( <i>Corynactis</i> sp.) have also become conspicuous on this part of the ship. Growth appeared thickest around edges of holes in the hull. Jellyfish was observed in the water column. Half banded sea perch ( <i>Hypoplectrodes maccullochi</i> ) was observed.
Vertical Hull Stern	As with previous surveys, ascidians and large barnacles were more prevalent on the hull of the ship, in comparison to the deck surfaces, while bryozoans, sponges and occasional clumps of bryozoans were also observed. The vertical plane of the hull was otherwise encrusted with a layer of barnacles, encrusting algae, hydroids, a fine, filamentous or turfing algae and tiny orange jewel anemones. Comb jellies were observed in the water column. White ear, six-spined leatherjacket, half banded sea perch and schools tarwhine were observed alongside the hull.
Vertical Hull Superstructure	The superstructure surface was covered with ascidians, bryozoans, barnacles, encrusting algae, hydroids, fine filamentous algae and sheets of tiny orange jewel anemones. Comb jellies were observed in the water column. Schools tarwhine, and eastern hulafish were observed as well as girdled scalyfin, eastern blue groper, red morwong, brown spotted wrasse and eastern red scorpioncod ( <i>Scorpaena cardinalis</i> ).

**Table 3: Species of Fish Observed in Association with the Ex-HMAS Adelaide Artificial Reef between April/May 2011 and September 2014.** (\*) = recreationally important species, (+) = commercially important species, (#) = species of conservation significance.  
(x) = No Code in Hutchins and Swainston (2006).

Family	Species Name	Common Name	Species Number (Hutchins & Swainston)	Baseline Survey (April/May 2011)	Survey 1 (October 2011)	Survey 2 (February 2012)	Survey 3 (May 2012)	Survey 4 (August 2012)	Survey 5 (October 2012)	Survey 6 (January 2013)	Survey 7 (April 2013)	Survey 8 (July 2013)	Survey 9 (October 2013)	Survey 10 (March 2014)	Survey 11 (September 2014)
Heterodontidae	<i>Heterodontus portusjacksoni</i>	Port Jackson shark	4									•			
Orectolobidae	<i>Orectolobus</i> sp.	Wobbegong shark	x											•	
Aulopodidae	<i>Aulopus purpurissatus</i>	Sergeant baker	83		•	•	•		•	•		•	•	•	•
Scorpaenidae	<i>Centropogon australis</i>	Eastern fortesque	166		•	•	•								
Scorpaenidae	<i>Scorpaena cardinalis</i>	Eastern red scorpioncod	176		•	•			•		•	•	•	•	•
Scorpaenidae	<i>Scorpaenodes scaber</i>	Pygmy scorpionfish	179												•
Platycephalidae	<i>Platycephalus fuscus</i>	Dusky flathead*+	203					•							
Serranidae	<i>Acanthistius ocellatus</i>	Eastern wirrah	211									•			
Serranidae	<i>Hypoplectrodes maccullochi</i>	Half-banded sea perch	225				•	•			•	•			•
Serranidae	<i>Hypoplectrodes nigroruber</i>	Black-banded sea perch	227								•	•	•		
Plesiopidae	<i>Trachinops taeniatus</i>	Eastern hulafish	246						•	•	•	•	•	•	•
Dinolestidae	<i>Dinolestes leweni</i>	Longfinned pike	263		•			•					•		
Carangidae	<i>Pseudocaranx dentex</i>	Silver trevally	292				•	•	•		•	•	•	•	•
Carangidae	<i>Trachurus novaezelandiae</i>	Yellowtail scad+	294		•			•				•			
Carangidae	<i>Seriola lalandi</i>	Yellowtail kingfish*#	298			•	•		•	•	•	•	•	•	•
Carangidae	<i>Seriola hippos</i>	Samson Fish*	300									•			
Carangidae	<i>Elagatis bipinnulata</i>	Rainbow runner	303									•			
Sparidae	<i>Pagrus auratus</i>	Snapper (juv)*+	310		•	•	•		•	•	•				•
Sparidae	<i>Rhabdosargus sarba</i>	Tarwhine*	311			•	•	•	•	•	•	•	•	•	•
Lutjanidae	<i>Paracaesio xanthurus</i>	Southern fusilier	320								•				
Mullidae	<i>Parupeneus spilurus</i>	Blackspot goatfish	323	•					•	•	•	•	•		•
Kyphosidae	<i>Kyphosus sydneyanus</i>	Silver drummer*	346				•						•	•	
Scorpididae	<i>Atypichthys strigatus</i>	Mado	349		•	•	•	•			•				
Scorpididae	<i>Microcanthus strigatus</i>	Stripey	350		•	•	•							•	
Scorpididae	<i>Scorpis lineolatus</i>	Silver sweep*	353		•	•	•			•	•	•	•	•	•
Ephippidae	<i>Platax</i> sp.	Batfish	355					•					•	•	
Chaetodontidae	<i>Heniochus diphreutes</i>	Schooling bannerfish	372	•	•				•			•			
Chaetodontidae	<i>Chaetodon guentheri</i>	Gunther's butterflyfish	358								•				
Enoplosidae	<i>Enoplosus armatus</i>	Old wife	376				•	•			•		•	•	•
Pomacentridae	<i>Parma microlepis</i>	White ear	388		•			•	•	•	•	•	•	•	•
Pomacentridae	<i>Parma unifasciata</i>	Girdled scalyfin	393			•			•	•	•	•	•	•	•
Pomacentridae	<i>Parma polylepis</i>	Banded Parma	394							•	•	•	•	•	•
Pomacentridae	<i>Chromis hypsilepis</i>	One-Spot Puller	396									•			
Cirritidae	<i>Cirritichthys aprinus</i>	Blotched hawkfish	406						•	•	•	•	•	•	
Chironemidae	<i>Chironemus marmoratus</i>	Eastern kelpfish	411						•						•
Aplodactylidae	<i>Crinodus lophodon</i>	Rock cale	415						•		•	•	•	•	•
Cheilodactylidae	<i>Cheilodactylus fuscus</i>	Red morwong*	416		•	•	•	•	•	•	•	•	•	•	•
Cheilodactylidae	<i>Nemadactylus douglasii</i>	Blue morwong*	424		•	•			•	•	•	•	•	•	•
Cheilodactylidae	<i>Cheilodactylus vestitus</i>	Magpie morwong	421								•	•	•	•	•
Latrididae	<i>Latridopsis forsteri</i>	Bastard trumpeter	427		•				•	•	•	•	•	•	•
Labridae	<i>Achoerodus viridis</i>	Eastern blue groper	438		•	•	•	•	•	•	•	•	•	•	•
Labridae	<i>Coris picta</i>	Comb wrasse	446						•						
Labridae	<i>Notolabrus gymnogenis</i>	Crimson banded wrasse	481				•		•	•			•	•	•
Labridae	<i>Notolabrus parilus</i>	Brown spotted wrasse	483				•							•	•
Labridae	<i>Psuedolabrus luculentus</i>	Luculentus wrasse	487								•	•		•	
Labridae	<i>Thalassoma lunare</i>	Moon wrasse	505									•			
Blenniidae	<i>Petroscirtes lupus</i>	Brown sabretooth blenny	532	•						•					
Blenniidae	<i>Parablennius intermedius</i>	Horned blenny	x												
Monacanthidae	<i>Monacanthus chinensis</i>	Fan belly leatherjacket*	636						•						
Monacanthidae	<i>Meuschenia freycineti</i>	Six-spined leatherjacket*	643						•		•	•	•	•	•
Monacanthidae	<i>Meuschenia trachylepis</i>	Yellow-finned leatherjacket*	646				•		•	•	•	•	•	•	•
Monacanthidae	<i>Nelusetta ayraudi</i>	Chinaman leather jacket*+	648		•	•	•			•				•	•
Monacanthidae	<i>Eubalichthys mosaicus</i>	Mosaic leatherjacket*	652							•					
Monacanthidae	<i>Eubalichthys bucephalus</i>	Black reef leatherjacket	649											•	•
Monacanthidae	<i>Meuschenia</i> spp.	Unidentified leatherjackets	x				•	•	•						
Tetraodontidae	<i>Dicotilichthys punctulatus</i>	Three-bar porcupinefish	682		•				•	•				•	•
Sepiidae	<i>Sepia</i> sp.	Cuttlefish	x										•		
<b>Total Number of Taxa</b>				<b>3</b>	<b>17</b>	<b>14</b>	<b>19</b>	<b>13</b>	<b>23</b>	<b>19</b>	<b>26</b>	<b>26</b>	<b>26</b>	<b>25</b>	<b>28</b>

## 4 Discussion

### 4.1 Encrusting Biota

Results of Survey 11 (September 2014) showed marked changes in the composition of the sessile reef assemblage over the past six months following Survey 10 (March 2014), whereas previous consecutive surveys have remained similar in the overall composition of the reef assemblage. The pronounced differences between surveys may partly be due to the longer timeframe between surveys (usually 3 months), therefore allowing more time for successional changes to occur. This may also be related to seasonal differences.

In particular, there was a distinct decrease in the cover of serpulid/barnacle matrix as other encrusting groups, mainly brown filamentous algae/hydroids and orange jewel anemones have overgrown the layer of calcareous tubes and barnacles. There has also been a notable increase in larger barnacles and different types of encrusting sponges. Large red tubular sponges have grown and become notably more conspicuous in the deck of the ship. Sea urchins (*Centrostephanus rodgersii*) were also observed for the first time in crevices between the deck and gunwale. This species is commonly found on NSW coastal reefs and feeds on algae (including kelp) and invertebrates, they in turn provide food for larger predators such as fish and large decapods, although in rocky subtidal reefs they can also graze large areas of macroalgae reducing the overall biodiversity, creating areas known as 'barrens' habitat (Underwood *et al.* 2006). An ascidian (*Pseudodiazona claviformis*) and gastropod mollusc (*Dicathais orbita*) were also recorded in photoquadrats during this survey for the first time, although they had been observed previously from general photographs. Ongoing successional changes through time would be expected as new species create secondary habitat and increased habitat complexity for other benthic invertebrates to occupy. The cover of bare surface also increased overall, which may be a result of mature reef detaching due to storms or disturbance. These new patches also create an attachment surface for early colonisers such as algae, small barnacles and serpulids which have been outcompeted or overgrown on other parts of the ship.

As for previous surveys, analysis of photoquadrats showed a recurrent pattern of assemblages occurring on horizontally orientated (deck) surfaces being different in composition from the vertically orientated (hull) assemblage. The pattern of assemblage composition during Survey 11, was similar to that observed during Survey 10 with a greater percent cover of serpulid/barnacle matrix and red encrusting algae on the deck than on the hull surface and a greater percent cover of solitary ascidians, anemones, large barnacle matrix and early colonising matrix on the hull, although the abundance of brown filamentous algae/hydroid had a greater influence during Survey 11 with a greater percent cover on the deck than on the hull. As discussed in previous monitoring survey reports, it is likely that suspension/filter feeders such as ascidians, anemones and large barnacles tend to proliferate on more shaded portions of the ship or possibly where there is more current to improve feeding efficiency (i.e. vertical surfaces), whereas algae occur where light availability is optimal on the upper horizontal surfaces.

Depth was also a significant factor in structuring the reef assemblage with deeper transects characterised by a greater percent cover of large barnacles and anemones and shallow transects characterised by a greater percent cover of early colonising matrix and brown filamentous algae/hydroid. The main effects of increasing depth are the reduction in wave energy and a reduction in the quality and intensity of light available to photosynthetic organisms (Reefwatch SA). It is therefore possible that anemones and larger barnacles are better adapted to potentially more sheltered conditions on the hull of the ship whereas early colonising matrix (likely to be comprised of microalgae) and brown filamentous algae can take advantage of the light availability on the superstructure.

Deck position (i.e. bow, mid ship and stern) was a significant factor influencing assemblage composition. As discussed in previous reports, this factor is confounded by depth, as the mid ship deck position is situated on top of the superstructure, whereas the bow and stern deck positions are situated at the level of the flight deck in deeper water. Notwithstanding this, spatial differences on the deck surfaces were evident, as bow and stern reef assemblages were also found to be different despite occurring at similar depths. These differences were mainly due to a greater percent cover of kelp, red encrusting algae and serpulid/barnacle matrix at the mid ship and a greater cover of brown filamentous algae/hydroid at the stern.

By nature of the ships design and its partial burial within the seabed, there may be subtle depth differences on various sections of the deck that may influence shading on these parts of the ship, ultimately affecting the benthic assemblages in these areas.

## **4.2 Fish and Macroinvertebrates**

The number of fish species observed by divers and from video and fixed photos has generally increased since scuttling of the ship in April 2011. Twenty eight fish species were recorded during Survey 11 which was marginally higher than the number recorded during Survey 10 (25 species). Species of fish recorded during Survey 11 that have not previously been recorded included the pygmy scorpion fish (*Scorpaenodes scaber*) and banded parma (*Parma polylepis*). Both are found on coastal and estuarine reefs in New South Wales although the banded parma is less common in southern New South Wales.

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## **7 Plates**

- Plate 1: Comparison of Photoquadrats Over Time (Deck Port Bow)**
- Plate 2: Comparison of Photoquadrats Over Time (Deck Port Mid)**
- Plate 3: Comparison of Photoquadrats Over Time (Deck Port Stern)**
- Plate 4: Comparison of Photoquadrats Over Time (Deck Starboard Bow)**
- Plate 5: Comparison of Photoquadrats Over Time (Deck Starboard Mid)**
- Plate 6: Comparison of Photoquadrats Over Time (Deck Starboard Stern)**
- Plate 7: Comparison of Photoquadrats Over Time (Horizontal Hull Port)**
- Plate 8: Comparison of Photoquadrats Over Time (Horizontal Hull Starboard)**
- Plate 9: Comparison of Photoquadrats Over Time (Vertical Hull Port Bow)**
- Plate 10: Comparison of Photoquadrats Over Time (Vertical Hull Port Stern)**
- Plate 11: Comparison of Photoquadrats Over Time (Vertical Hull Starboard Bow)**
- Plate 12: Comparison of Photoquadrats Over Time (Vertical Hull Starboard Stern)**
- Plate 13: Comparison of Photoquadrats Over Time (Vertical Superstructure Port Bow)**
- Plate 14: Comparison of Photoquadrats Over Time (Vertical Superstructure Port Stern)**
- Plate 15: Comparison of Photoquadrats Over Time (Vertical Superstructure Starboard Bow)**
- Plate 16: Comparison of Photoquadrats Over Time (Vertical Superstructure Starboard Stern)**

## **8 Appendices**

**Appendix A: Fixed Photograph Locations.**

**Appendix B: Mean Percentage Cover ( $\pm$  Standard Error) of Reef Communities.**

**Appendix C: PERMANOVA of Reef Assemblages.**

**Appendix D: Pair-wise t-tests.**

**Appendix E: SIMPER Analyses**

**Appendix F: PERMDISP Analyses**