Adelaide Desalination Plant
Intertidal Monitoring Summer 2012

June 2012

Stewart T.D.C. & Dittmann S.*
School of Biological Sciences, Flinders University
*Author for correspondence
e-mail: sabine.dittmann@flinders.edu.au

Flinders UNIVERSITY

This report can be cited as: Stewart T.D.C. & Dittmann, S. (2012) *Adelaide Desalination Plant Intertidal Monitoring Summer 2012*, Flinders University, Adelaide

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1. Executive Summary

This report presents data from intertidal rocky shore monitoring undertaken as a requirement for the environmental monitoring program proposed by the South Australian Water Corporation in conjunction with Adelaide Desalination Plant/Adelaide Aqua. This report covers the monitoring period of summer 2012. The objectives of this study were to monitor the invertebrate and algal communities of rocky shore habitats within the Port Stanvac exclusion zone and within two reference zones to the north and south, in order to ascertain baseline data as a reference for future monitoring.

A total of 20 sites were sampled, with four at the northern reference zone, six at the southern reference zone and ten within the construction zone. As in previous intertidal monitoring, photoquadrats and video transect methods were used to assess the structure of flora and fauna communities within the intertidal rocky shores of all three zones.

Overall, the Port Stanvac exclusion zone had higher biodiversity and individual abundances of invertebrates and higher percent cover of algae. A total of 23 species from 4 Phyla were identified across sites in the photoquadrats. Variation in distribution occurred for most of the taxonomic groups and invertebrate community structure. Variation of individual abundances of the barnacle species, *Chthamalus antennatus* and mollusc species *Patelloida latistrigata* accounted for most of the variability observed in the northern reference and Port Stanvac exclusion zones. Polychaete tubeworms and the mussel *Limnoperna pulex* accounted for the greatest percent cover of sessile organisms identified in quadrat surveys, but their distribution was highly variably.

Transect analysis revealed that percent substrate cover was generally low with a high proportion of bare rock at each site, yet the Port Stanvac exclusion zone had the highest percent cover of fauna and sessile invertebrates. Spatial variability of invertebrate and algal communities is common in intertidal reefs and can be attributed, but not limited, to effects such as site topography or human influences.

Recommendations for future monitoring include continuity of sites and methodology used in this survey to allow for a better understanding of the influences as long-term monitoring programmes can help better determine change in highly variable environments.

2. Introduction

2.1 Rocky Shores and the Gulf St. Vincent

The coastline along the Fleurieu Peninsula in South Australia's Gulf St. Vincent, is comprised of rocky intertidal reef habitats that support complex algal and invertebrate communities (Benkendorff and Thomas 2007; Benkendorff *et al.*, 2008). Port Stanvac was once a working petroleum refinery, which has been closed off from public access for the last two decades. The intertidal reefs at Port Stanvac appear to be ecologically significant on a regional scale with large populations of invertebrate predators indicating a healthy reef system (Dutton and Benkendorff, 2008). Preliminary surveys by Dutton and Benkendorff (2008) indicate that the fenced off reefs at Port Stanvac may provide a biodiversity hotspot for intertidal molluscs and red algal species. Further, a review of Southern Australian herbarium collections by Scott *et al*. (2009) indicates that the Port Stanvac area is a hotspot for vulnerable macroalgal species, based primarily on the work of Prof. Brian Womersley (1988).

2.2 Potential desalination effects on marine rocky-shore flora and fauna

Many putative impacts of desalination plants onto the marine environment have been suggested (Winters *et al.*1979; Einav *et al.* 2002; Miri and Chouikhi 2005; Younos 2005); however, few peer reviewed and published studies present empirical data supporting claims for direct or indirect effects, leaving it unclear whether such impacts are really corroborated by science (Roberts *et al.* 2010). The intertidal rocky shores along the Fleurieu Peninsula are heterogeneous environments with a high level of connectivity to other coastal ecosystems (Benkendorff *et al*. 2008); hence shifts in the rocky shore community structure may occur from anthropogenic activities in surrounding marine and terrestrial habitats. Impacts on intertidal rocky shore can also influence other larger scale ecosystem level processes, such as primary productivity, detritus supply and water quality, in other communities (Thompson *et al.* 2002). In the longer term, during the desalination plant operation phase, intertidal reefs could be affected by larval entrainment in the intake pipe reducing local recruitment of species with planktonic larvae (Lattemann and Hopner 2008). Also, there is a possibility for intertidal communities to be subjected to salinity stress if the dense brine plumes do not sufficiently flush from the outlet pipe, particularly in the warmer seasons where minimal flushing by open ocean water occurs (Samarasinghe *et al*. 2003; Kämpf *et al*. 2009).

2.3 Use of rocky shore flora and fauna as indicators of human impacts

An understanding of the spatial and temporal variation of species diversity and composition on intertidal reefs is essential to achieve appropriate management solutions (Underwood 1994). The intertidal zone is characteristically complex, with interactions between oceanographic and ecological processes as well as anthropogenic influences (Castilla and Duran 1985; Ruis et al. 2006). To be able to differentiate natural from anthropogenic influences, the assessment of intertidal biodiversity essentially has to incorporate various measures to understand all interconnecting influences.

Intertidal reefs support a variety of flora and fauna which are found within a mosaic of habitats (Schoch and Dethier 1996) and intertidal communities can vary over different scales of time and space (Underwood 1998; Olabarria and Chapman 2002) and many researchers focused their studies on identifying which processes influence variability. The distribution, abundance and interactions between organisms or with their environment require an understanding of the hierarchy of scales at which processes act. Differences in biodiversity can occur within and across patches of habitat, across habitats and on a biogeographical scale (Whittaker 1975; Gray 1997). Similarly, changes on a temporal scale can occur within days, months or years.

Rocky shore invertebrate communities have been utilised to assess the effects of human disturbances, for example trampling, fishing or collecting, and pollution (Kingsford *et al.* 1991; Underwood, 1993). These disturbances have been shown to reduce species richness and abundance of some species, which has a flow on effect to the entire intertidal community (Keough and Quinn 1998, 2000). A reduction in numbers of key animal and plant species from communities in marine systems is a good indicator of human-induced changes to environmental conditions (Scheltinga *et al*., 2004). Yet, abundances will not only change due to human impacts, but also naturally.

Marine algae are classified into three major groups: Chlorophyta (green algae), Phaephophyta (brown algae) and Rhodophyta (red algae). The southern Australian marine macroalgal flora has the highest species richness (1200 species) and endemism (75% of red algae) of any regional macroalgal flora in the world. Marine algae enhance the heterogeneity of a rocky shore by providing increased surface area for attachment, shelter, sediment traps and a source of food for invertebrate species (Chemello and Milazzo 2002). Additionally, macroalgae are important for the possible utilisation as a food resource and also as pollution indicators (Womersley 1984; Phillips 2001). Algal species assemblages are dynamic, as their structure, composition and abundances vary temporally (Underwood and Chapman 1998). Temporal and spatial differences within algal assemblages have been attributed to biogeographical and seasonal effects, activities of grazers, disturbances and recruitment (Underwood and Chapman 1998). Changes in macroalgal density are a useful indicator as algal beds may change quickly in response to disturbances (Ward *et al*., 1998). The effects of trampling can often be seen through a reduction of algal cover on the shore resulting in the loss of habitats for invertebrates (Keough and Quinn 1998). Additionally, macroalgae respond rapidly and predictably to a wide range of pollutants and as such they are useful in providing early warning signals of deteriorating conditions, such as the influx of pollutants (McCormick and Cairns 1994).

2.4 Design of environmental monitoring studies

Monitoring plays an important role in a major development, like the Port Stanvac desalination plant, and requires well planned ecological studies that can provide an assessment of the variability in natural communities at two spatial scales; 1) within the development site and 2) between different sites of similar environmental conditions inside and outside the development zone, to provide a reference for benchmarking any changes detected in subsequent monitoring surveys. Underwood (1991, 1992) recommends replicated before/after, control/impact (beyond BACI) studies in order to detect anthropogenic effects over and above the natural variability in local communities. Such designs are beneficial in assessment of environmental impacts on marine systems, in order to detect anthropogenic effects exceeding the natural variability in local communities (Underwood 1991; 1992; Morrisey *et al.* 1992). Therefore, BACI experimental design principals were followed for this monitoring. Suitable reference locations should be situated at sites with similar habitat, at varying distances from the impact source.

The marine environment off Port Stanvac contains numerous habitat types including rocky reefs, soft sediment, shell grit habitat, macroalgae and seagrass (Benkendorff *et al*. 2008; Bryars *et al.* 2008; Edyvane 2008; Fotheringham and Coleman 2008; Loo and Drabsch 2008; Loo *et al.* 2008; Turner and Collings 2008). Suitable reference locations with a similar range of habitat are situated to the north (Marino Rocks and Hallett Cove) and south (Carrickalinga, Second Valley and Fisheries Beach) of the Port Stanvac desalination plant exclusion zone. For the intertidal survey the design included sampling at sites within the Port Stanvac exclusion zone and the northern and south reference zones.

2.5 Study rational and scope

An EIS prepared by SA Water identified a potential for a negative effect of the construction and operation of a desalination plant at Port Stanvac on the rocky intertidal flora and fauna (SA Water 2008). As a condition of licence to construct and operate the desalination plant, the Environment Protection Authority ordered that the company in charge of construction of the plant, Adelaide Aqua, must meet strict ecological monitoring requirements including surveying intertidal macrofauna and algae, at 20 sites, including 10 reference locations (EPA Licence; available at URL: http://www.epa.sa.gov.au/xstd_files/Water/Other/desal_licence.pdf; accessed 18/08/2011).

Communities on intertidal reefs have been shown to be variable between reefs and also over time (Creese and Kingsford, 1998; Chapman, 2002). Sampling design for monitoring needs to be optimised across all sites and standardised in both time and space to facilitate comparison of data sets (Benkendorff, 2003). In addition, samples must have sufficient replication in order to reduce the amount of intrinsic variation, and increase the ability to detect changes in the data (Underwood and Chapman, 2002).

Here we report on a seasonal rocky intertidal survey programme that commenced in May 2009 along 100 transects (representing the sites required by the EPA licence), 50 line intercept transects carried out within the Port Stanvac exclusion zone and a further 50 transects from two reference zones, consisting of a total of five reference sites. This report presents the results of the summer 2012 survey as part of an ongoing intertidal flora and fauna monitoring programme, commenced mid-2009, during the establishment of a desalination plant at Port Stanvac. To obtain an indication of the spatial variation in flora and fauna communities, sites were selected from Marino Rocks and south to Fisheries Beach on the tip of the Fleurieu Peninsula.

2.6 Study aims and design

This investigation was strictly monitoring, with scope to test for potential mechanisms for disturbance of the desalination plant on the marine benthos by way of spatial comparisons.

The goal was to determine any impact of construction on the rocky intertidal habitat at Port Stanvac relative to natural levels of background spatial and temporal variation in these habitats along the Fleurieu Peninsula. Thus, this montoring programme aimed to:

- determine the spatial and temporal pattern of distribution and abundance of rocky intertidal communities to be used as a baseline data set for future monitoring programmes on potential disturbances resulting from the desalination plant operations at Port Stanvac, relative to background spatial and temporal variation, measured at nearby reference locations.

To achieve these aims, the monitoring programme included sampling of rocky intertidal communities at Port Stanvac and at nearby reference sites using photoquadrats and video transects. Sampling on multiple spatial and temporal scales allowed quantification of the natural variation of the rocky intertidal communities. This design allowed to detect disturbance of construction at Port Stanvac, if any, over natural background levels of variation, in a beyond-BACI type design (Underwood 1992). This report details the results obtained for the spatial variation of flora and fauna communities across five reference sites and five sites within thePort Stanvac exclusion zone for summer 2012.

3. Methods

3.1 Sampling locations, sites and dates

Sites along the Fleurieu Peninsula were selected according to comparable rock strata type and topography. Five locations within the Port Stanvac fenced area were sampled (Figure 1b) with reference locations located to the North at Marino Rocks and Hallett Cove (Figure 1a) and to the South at Carrickalinga, Second Valley and Fisheries Beach (Figures 1a). These sites have been surveyed for this monitoring since autumn 2009. Please note; as the establishment of the desalination plant has moved to an operational phase, the construction zone, as per previous reports, is now referred to as the Port Stanvac exclusion zone.

Two 20 x 20 m plots, placed roughly 100 m apart, were surveyed within the intertidal zone at each location, thus generating data from 20 specific sites. GPS coordinates were taken from the middle of each plot. All sites were surveyed during low tides throughout January 2012 (Table 1), using the methods outlined below.

3.2 Invertebrate abundance

Photoquadrats were used to assess invertebrate abundance, species diversity and species richness. This method can be rapidly applied in the field and provides a permanent record for future reference. Ten replicate 0.25 m^2 quadrats were haphazardly placed within each 20 m x 20 m plot. Each quadrat was divided into quarters, with one high resolution photograph taken of each quarter, as well as one encompassing the whole quadrat, using an Olympus Model µ 1030SW digital camera (see Dutton and Benkendorff, 2008), generating a total of 1,200 high resolution photos. Photographs were later downloaded onto a computer and analysed using Paint.NET v3.36 imaging software. All visible mobile fauna was identified and counted to a minimum of family level, with identification to species level where possible. Organisms which were unable to be identified to the family level (due to heavy erosion of the shell or algal/invertebrate encrustation etc.) were marked as unidentified species. All field work was conducted during tides below 0.7 m.

3.3 Percent cover of sessile organisms

A line intercept transect method (e.g. Benkendorff and Thomas, 2007; Dutton and Benkendorff, 2008) was used to assess the percent cover of sessile invertebrates (e.g. black mussels *Limnoperna pulex* (formerly *Xenostrobus pulex*) and polychaete tube worms (*Galeolaria caespitosa and Pomatoceros taeniata*), as well as percent algal cover from the low to high tide zones. The method was adapted to include the use of video recording in which footage was taken of each replicate transect using an Olympus Model Tough8000 digital camera. This ensured that transects were completed during low tides on the same day at each location. Transects were filmed by walking slowly along a tape measure, showing distance covered in centimetres. The camera was set at a rate of 30 frames per second and held approximately 10 cm from the substrate to ensure that the footage was captured at a high resolution. Taxa identified along video transects were classified into functional groups to minimise the time taken for the survey analysis and also due to the complexity of identifying certain algae species. Functional groups were chosen according to morphology or broad taxonomic group (e.g. foliose green, encrusting brown/red/green, brown turfing, red foliose etc.) such as those used in Reef Watch surveys (Reef Watch, 2007). Using a functional grouping approach is useful for understanding broader generalizations on the ecology of rocky shores as well as predicting changes in community structure. In regions where there was an overlap of sessile and algal communities, 'mixed community' categories were established to represent and identify the presence of multiple species. The percent of bare substrate and sediment cover was also recorded along these transects.

Video transects were analysed using VLC Media software, with regular pausing along transects to identify sessile organisms and to allow accurate recording of distance intervals. At the start of each transect, the type of organism cover was recorded and then transition from one type of organism cover to another recorded along each transect to a resolution of 1 cm. Total percent cover for each category, organism or substrate was subsequently calculated from the summed total distance covered, divided by the total length of the transect (20 m). Means and standard deviation were generated from 5 replicate transects in each plot. However, transects of 20 m were not always obtained (at Second Valley during high swirl). In these cases, percent cover was calculated by dividing the summed distance of organisms by the total transect distance, thus giving a proportional cover comparable to that of other shoreline transects.

3.4 Data analyses

To determine the diversity and evenness of invertebrate species composition at all sites, three different diversity indices were calculated (Shannon-Wiener index and Pielou's evenness) based on the total number of individuals (*N*) from the number of each taxa (*S*). The Shannon-Wiener index identifies greater species diversity the higher the index value. Pielou's index identifies the equitability of species presence at each site where a larger number indicates higher evenness (Clarke and Warwick 2001).

Abundances of each taxonomic group were statistically analysed using PERMANOVA to determine if there were significant differences between Zones and Sites nested within Zones. PERMANOVA utilises permutations based on dissimilarities and does not assume a normal distribution for the original variables, making it a useful tool for analysing ecological community datasets (Anderson *et al*. 2008). Further pair-wise tests were also conducted to detect which group differences contributed to any significant result using PERMANOVA. Monte Carlo tests were undertaken in the pair-wise test function in PERMANOVA if low permutations were obtained. The Monte Carlo (*P)* value is better suited and more reliable when there are not enough possible permutations (i.e. < 100) (Anderson *et al*. 2008).

Analyses of invertebrate community composition for each of the seasons were undertaken on quadrat abundance data to determine if there were similarities between sites and zones. A square root transformation was performed on the abundance data for sites and zones. Principle Co-ordinates Analysis (PCO) was employed to provide a visual pattern of invertebrate community structure, as it preserves original dissimilarities between points (Anderson *et al*. 2008). In addition, vector overlays were superimposed onto PCO plots to determine the strongest associations of variables (species) at both the site and zone level using Spearman Rank correlations. In order to distinguish the dissimilarities between invertebrate communities a PERMANOVA design was used, incorporating the factors of zone and sites nested within zone. To detect which group differences contributed to any significant result, further pair-wise permutation tests were carried out using PERMANOVA, with a Monte Carlo test if low permutations resulted. All univariate and multivariate analyses were performed using the PRIMER version 6.0 with PERMANOVA + add on programme.

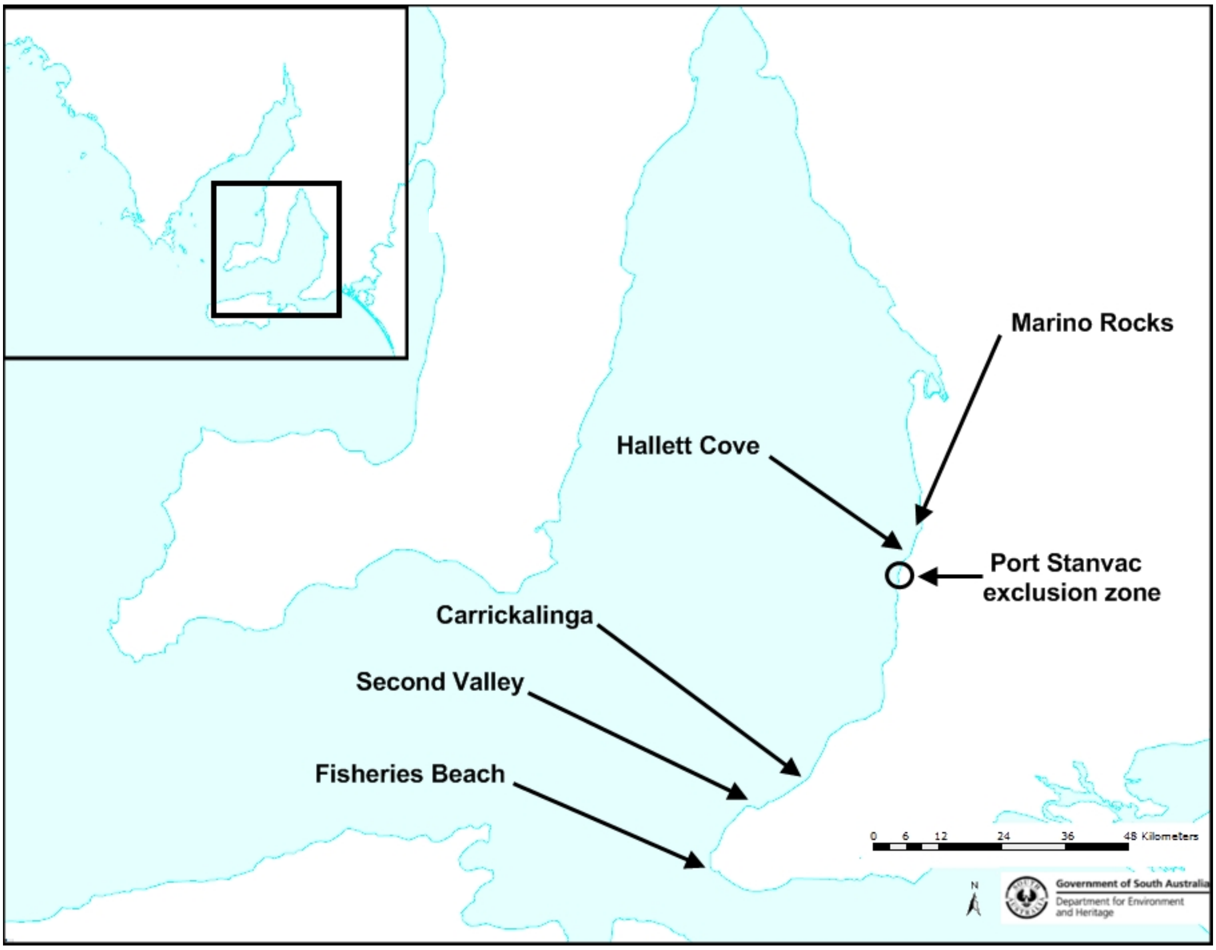


Figure 1: Intertidal sampling sites; Port Stanvac exclusion zone; Northern Reference Zone (Marino Rocks and Hallett Cover); and the Southern Reference Zone (Carrickalinga, Second Valley and Fisheries Beach), during summer 2012. Maps adapted from Nature Maps, Department of Environment and Heritage, Government of South Australia, www.naturemaps.sa.gov.au

Table 1: Sampling dates and GPS co-ordinates for the intertidal study sites sampled during summer, January 2012.

	GPS Co-ordinates				
Location	**South**	**East**	**Season**	**Date**	**Tidal Height (m)**
Marino Rocks	S 35^{o}02'45.6"	E 138^{o}30'27.6"	Summer	MR1: 27/01/2012	0.17
				MR2: 12/01/2012	0.13
Hallett Cove	S 35^{o}05'06.2''	E 138^{o}29'31.5"	Summer	12/01/2012	0.13
Port Stanvac 1	S 35^{o}06'48.8"	E 138^{o}28'13.5"	Summer	24/01/2012	0.23
Port Stanvac 2	S 35^{o}06'28.4"	E 138^{o}28'20.0"	Summer	25/01/2012	0.22
Port Stanvac 3	S 35^{o}06'15.4"	E 138^{o}28'31.8"	Summer	25/01/2012	0.22
Port Stanvac 4	S 35^{o}06'12.4"	E 138^{o}28'34.4"	Summer	23/01/2012	0.22
Port Stanvac 5	S 35^{o}06'25.7"	E 138^{o}28'20.7"	Summer	13/01/2012	0.18
Carrickalinga	S 35^{o}25'09.0"	E 138^{o}19'25.2"	Summer	11/01/2012	0.12
Second Valley	S 35^{o}30'36.3"	E 138^{o}12'54.2"	Summer	9/01/2012	0.18
Fisheries Beach	S 35^{o}37'58.5"	E 138^{o}06'49.4"	Summer	11/01/2012	0.12

4. Results

4.1 Photoquadrats

4.1.1 Invertebrate Species Diversity

A total of 23 species were recorded on the rocky intertidal shore across all sites during the 2012 summer survey, the majority of which were molluscs, the dominant phylum within the intertidal zone (Figure 2). Twenty taxa were recorded within the Port Stanvac exclusion zone, compared to 15 species found in both the northern and southern reference zones (Appendix 1). A total of 16 molluscs, 5 crustaceans and only one taxa each of annelids and bivalves were recorded in the survey. Consistent with previous baseline recordings, the greatest number of macroinvertebrate species found were located within the Port Stanvac exclusion zone, with the highest species numbers recorded at site Port Stanvac 2A (n=16). Lower species numbers were recorded across the southern reference zone, with the lowest species numbers at site Carrickalinga 2 (n=4) (Figure 2).

The number of species were spatially variable within the intertidal zone, with significant differences in species numbers between zones ($F_{2,180}$= 25.543, P < 0.05), and site(zone) ($F_{17,180}$= 2.038, P < 0.05). A *post hoc* pair-wise analysis revealed significant differences in the number of species between the Port Stanvac exclusion zone and southern reference zone (P = 0.001), as well as between the northern and southern reference zone (P = 0.001), but species numbers were the same between the northern reference and Port Stanvac exclusion zone (P>0.05).

Species diversity was variable between sites and within each zone (Figure 3(b)), with a significant differences in diversity between zone and ($F_{2, 180}$, 14.711, P < 0.05) and site(zone) ($F_{17, 180}$, 1.8297, P < 0.05). Low species diversity was found at sites Carrickalinga site 1 (CC1) and Carrickalinga site 2 (CC2) while sites Second Valley 1 (SV1) and Second Valley 2 (SV2) in the southern reference zone were the most diverse (Figure 3b). However, these higher diversity values are likely due to the relatively low abundance of individuals at both Second Valley sites compared to the number of species identified. A PERMANOVA analysis on the Shannon-Wiener diversity index revealed significant differences in species diversity between zones and sites. Post hoc analysis revealed that the southern reference zone was significantly different in diversity compared to the northern reference zone and the Port Stanvac exclusion zone.

Pielou's index of evenness revealed a relatively even species distribution throughout the northern reference zone and Port Stanvac exclusion zone. Compared to other sites within the exclusion zone, evenness was comparatively low at Port Stanvac site 3B, which was predominantly due to the dominance of the barnacle, *Chthamalus antennatus*. The greatest variation in evenness occurred in the southern reference zone, particularly due to a lower evenness value observed at Carrickalinga (CC1) compared to the relatively higher evenness values seen at Second Valley 1 (SV1) and Second Valley 2 (SV2) (Figure 3a).

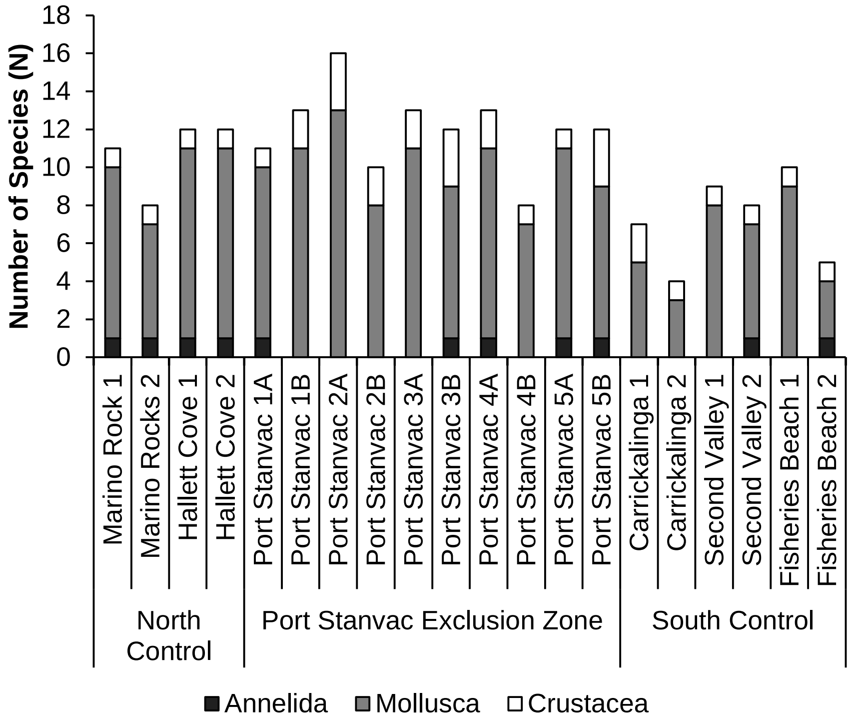


Figure 2: Total species number per phyla identified in quadrats during the Summer 2012 intertidal surveys for all sites encompassing three Zones; Northern Reference Zone, Construction Zone and Southern Reference Zone.

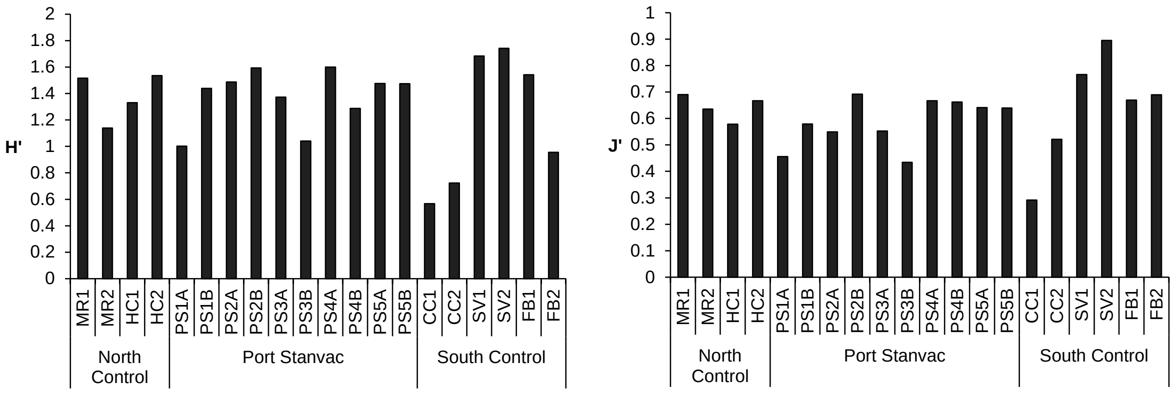


Figure 3: Diversity of invertebrates during summer 2012 survey; based on (a) Pielou's index of evenness, (b) Shannon-Wiener diversity index.

4.1.2 Invertebrate Abundance

Invertebrate abundance and species distribution varied between zones and sites within each zone, with highest abundances recorded within the Port Stanvac exclusion zone and lowest abundances in the southern reference zone (Figure 4a). Mollusca was the dominant phylum recorded across survey sites, with high abundances in both the northern reference and Port Stanvac exclusion zones (Figure 4b). Crustacea were most prevalent within the Port Stanvac exclusion zone, however, large standard deviation bars indicate patchy distribution of Crustacea within this zone (Figure 4c). Both molluscs and crustaceans were present at each site within the three zones.

Percent cover of polychaete tube worms and *Limnoperna pulex*, the only annelid and bivalve recorded in this survey, was highly variable, while they were found within all three zones, they did not occur at every individual site (Figure 4d). The polychaete tube worms were recorded mostly within the northern reference zone, whereas *Limnoperna pulex* was found exclusively within the northern reference and Port Stanvac exclusion zone (Figure 3e).

PERMANOVA test results indicated significant differences between zones and sites nested within zones for total benthic abundances as well as for molluscs and crustaceans (Table 2). Subsequent *post hoc* pairwise analyses showed higher abundances of total benthos and crustaceans at the Port Stanvac exclusion zone in comparison to the two reference zones, while both reference zones did not differ to each other (Table 3). *Posthoc* pairwise tests for mollusc abundances detected similar abundances between the northern reference and Port Stanvac exclusion zone, with significantly lower mollusc abundances in the southern reference zone (Table 3).

Table 2: Results from PERMANOVA showing differences between zone and sites nested within each zone for all phyla, Mollusca and Crustacea; Significant *P*-values are highlighted in bold.

Source	**df**	**All phyla *P* (perm)**	**Mollusca *P* (perm)**	**Crustacea *P* (perm)**
Zone	2	**0.0001**	**0.0001**	**0.0001**
Site(Zone)	7	**0.0003**	**0.0108**	**0.0015**
Residual	190			

Table 3: PERMANOVA Pair-wise test results for term ‘Zone’ for all phyla, Mollusca and Crustacea; Significant *P*-values are highlighted in bold.

Term 'Zone'	**All phyla *P* (perm)**	**Mollusca *P* (perm)**	**Crustacea *P* (perm)**
Northern Reference, Port Stanvac	**0.0006**	0.2278	**0.0001**
Northern Reference, Southern Reference	**0.0369**	**0.0096**	0.3056
Port Stanvac, Southern Reference	**0.0001**	**0.0001**	**0.0001**

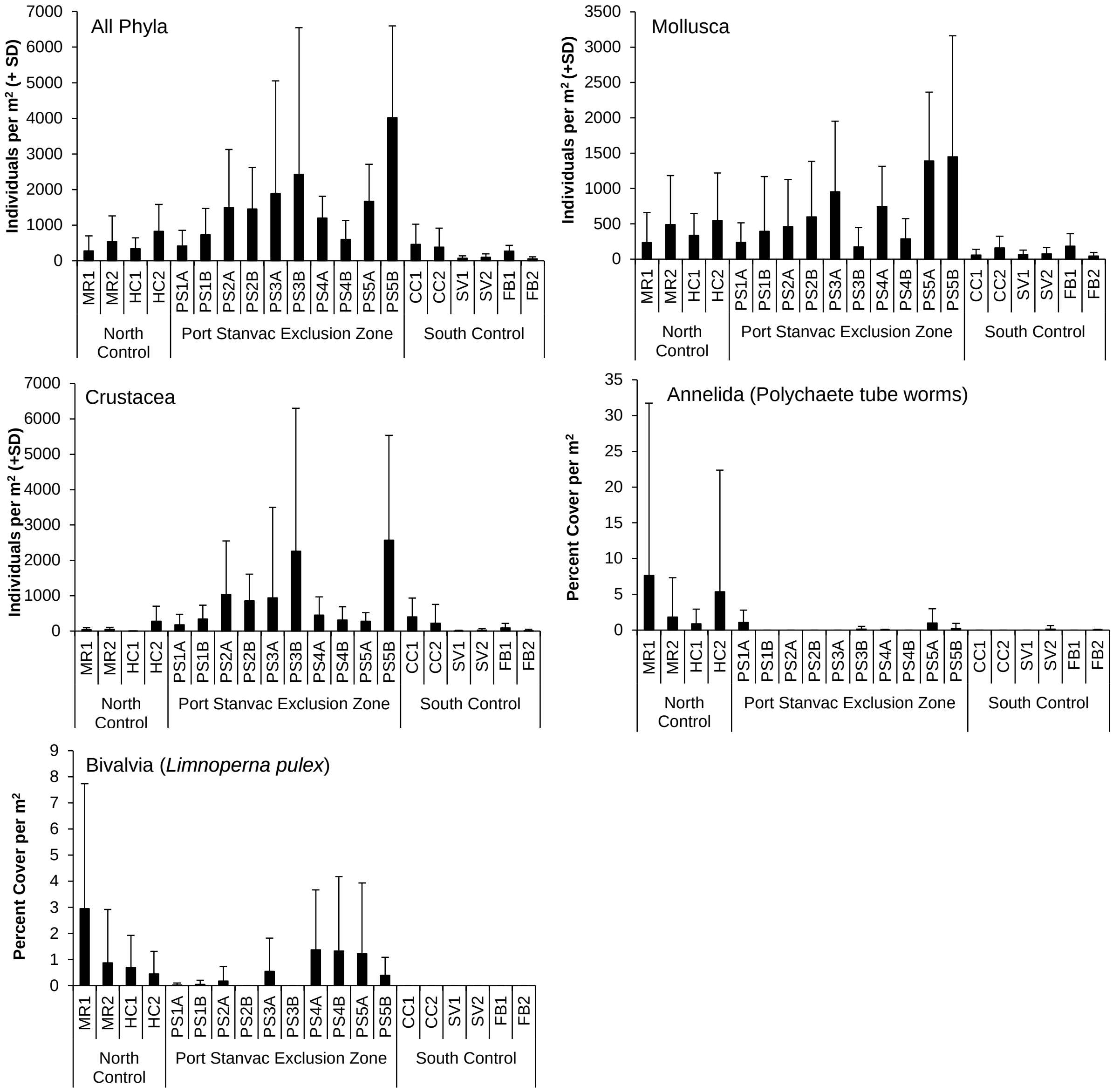
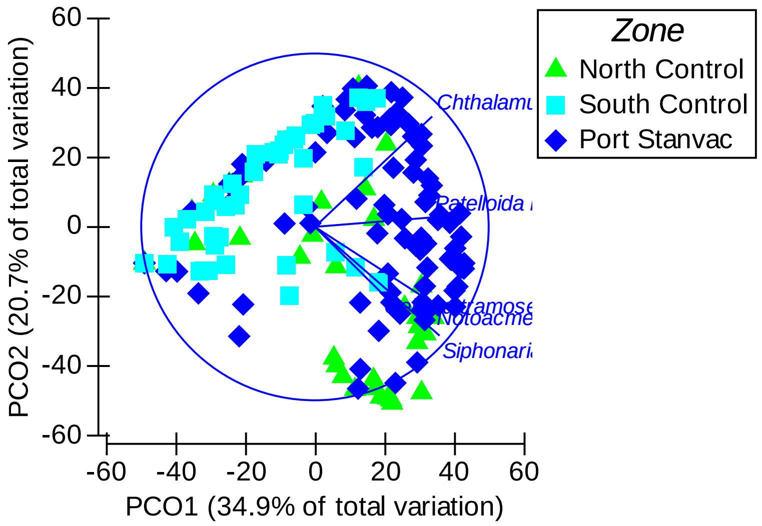


Figure 4: Mean abundances (+SD) for all phyla, Mollusca, Crustacea, Annelida, and Bivalvia from the summer 2012 intertidal survey encompassing three zones; Northern Reference Zone, Port Stanvac Exclusion Zone and Southern Reference Zone.

4.1.3 Community Analysis

The Principle Coordinate Ordination (PCO plot) of the summer intertidal data illustrates the there is a difference between zones based on community assemblages, with both axes explaining 55.6 % of the observed total variation (Figure 5a). A vector overlay of species identified the dominant species influencing variation in assemblages between sites, including *C. antennatus, Patelloida latistrigata,* S*iphonaria diemenensis*, *Cellana tramoserica* and *Notoacmea* spp (Figure 5a). Distinct clustering of sites within each zone are apparent, with PERMANOVA identifying significant differences between zones ($F_{2,180}$= 7.3413, P < 0.05). The barnacle species *C. antennatus* and the limpet *P. latistrigata* appear to be influencing the separation between the sites within the Port Stanvac exclusion zone and in both the north and south reference zones, whereas *S. diemenensis*, *C. tramoserica* and *Notoacmea* spp. appear to be contributing to the differences between both the sites within the northern reference and Port Stanvac exclusion zones and sites located within the southern reference zone (Figure 5a).The absence of a trajectory line towards the left of Figure 5a also indicates the possible lack of a dominant species in the southern reference zone which could contribute to the spatial variation observed between sites and zones.

a)



b)

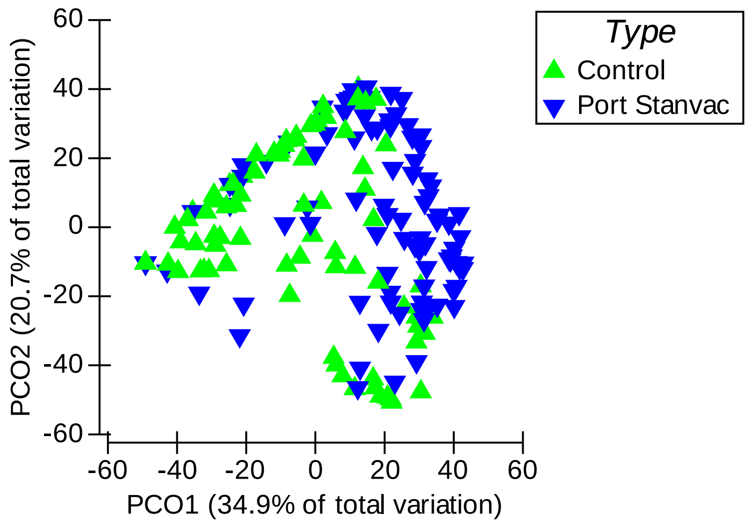


Figure 5: Principle Coordinate Plots (PCO) of invertebrate communities from quadrat surveys using Bray-Curtis resemblance matrices. Data is presented two ways by; (a) Zone, with vector overlay displaying strongest species correlations using Spearman Ranks (0.5); and (b) Type, displaying sites within the Port Stanvac exclusion zone and a common grouping of sites from the northern and southern reference zones.

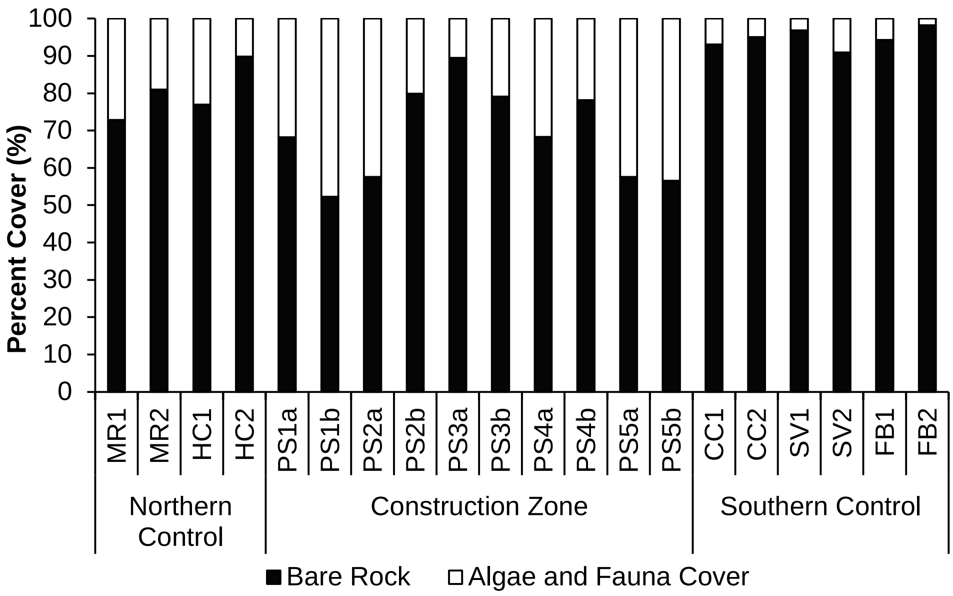
Data were also analysed as type, which was the grouping of sites located in either reference zone to a common group, to further examine the spread and clustering of sites within the Port Stanvac exclusion zone (Figure 5b). PERMANOVA analysis revealed a significant difference between the Port Stanvac exclusion zone and the two reference zones ($F_{1,180}$= 23.248, P < 0.05). The PCO plot further highlights the differences between sites located within the Port Stanvac exclusion zone and sites located outside the exclusion zone on rocky intertidal communities (Figure 5b).

4.2 Transect Data

4.2.1 Percent of Substrate Cover

During summer 2012, the highest proportion of bare rock occurred within the southern reference zone, with an average of 95 % bare rock across all sites, while the Port Stanvac exclusion zone had an average of less than 66 % bare rock cover across all at sites. Sand cover was very low, occurring at only 6 sites across all three zones and accounting for just 5 % of total substrate cover (Figure 6a). Algal and sessile fauna cover was highest within the Port Stanvac exclusion zone, particularly at sites PS5a and PS5b where there was more than 30 % sessile fauna cover (Figure 6b).

a)



b)

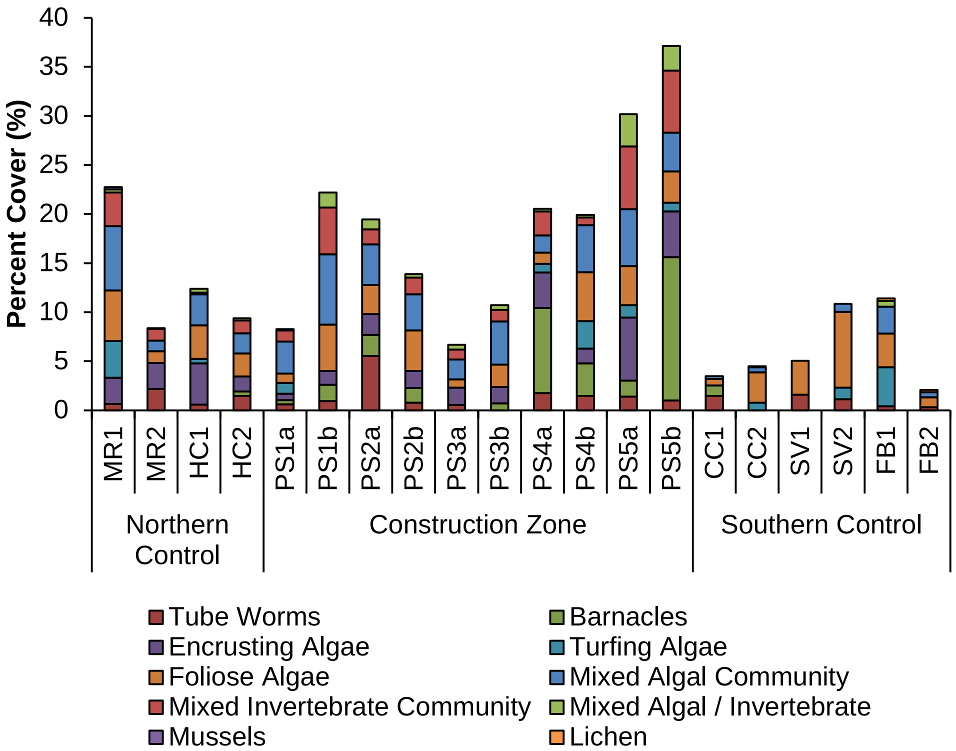
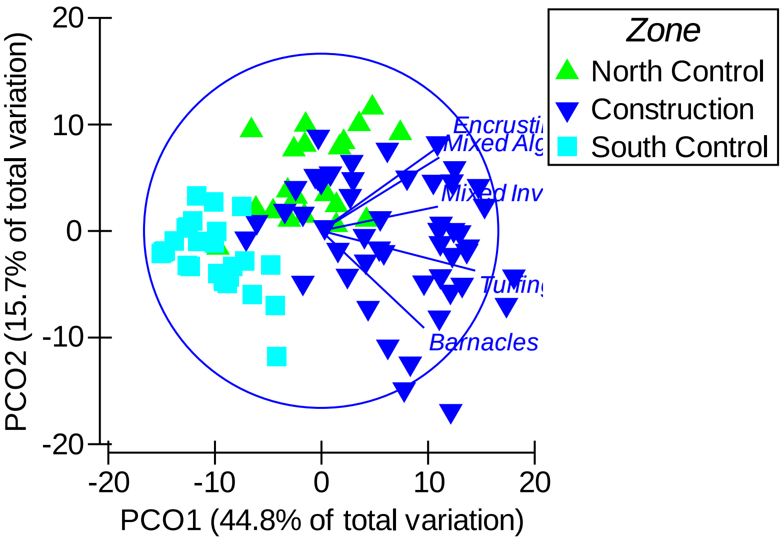


Figure 6: Mean percent cover of intertidal reefs, split into (a) bare substrate and sand and (b) algal and fauna quantified from transects. Based on intertidal reefs at all sites, across three Zones; Northern Reference Zone, Construction Zone and Southern Reference Zone during the Summer 2012 survey.

4.2.2 Community Analysis of Substrate Cover

A PCO plot of substrate cover identified a distinct grouping of all sites within each zone, with most sites in the southern reference zone clustering towards the left of the PCO plot and the majority of those found within the Port Stanvac exclusion zone to the right (Figure 7a). There is distinct overlapping of sites within the northern reference zone with sites in the southern reference zone and Port Stanvac exclusion zone. A vector overlay of substrate cover identified the dominant substrate that was driving variation between sites, including the influence of barnacles and turfing algae at sites within the Port Stanvac exclusion zone and the contribution of algal and invertebrate cover driving differences in the northern reference zone and Port Stanvac exclusion zone. A PERMANOVA analysis on substrate cover revealed significant differences occurring between both zone ($F_{2,\ 90}$, 33.108, P < 0.05) and site(zone) ($F_{7,\ 90}$, 4.4132, P < 0.05). Further *post hoc* pair-wise analysis revealed significant differences occurring between all zones and sites nested within zones indicating high variability within the dataset.

a)



b)

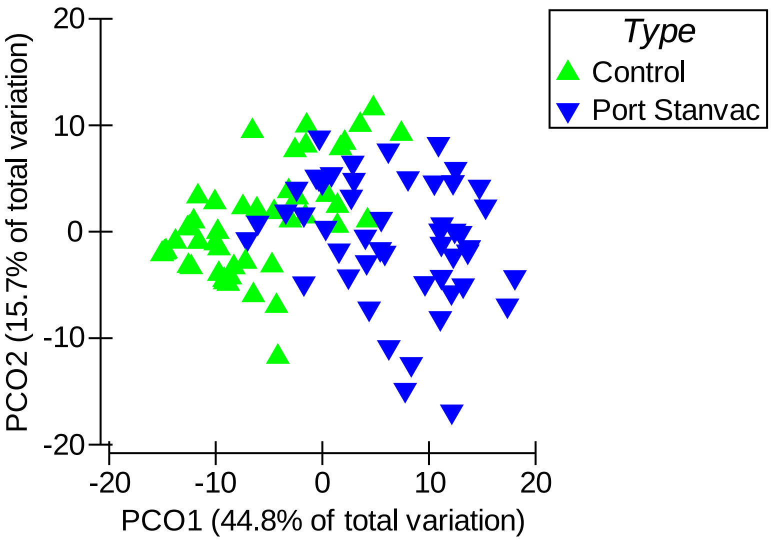


Figure 7: Principle Coordinate Plot (PCO) of flora and fauna cover from video transect surveys, presented two ways for interpretation by (a) Zone, and (b) Type, using Euclidean resemblance matrices.

5. Discussion

The intertidal survey undertaken in summer 2012 is a continuation of previous research as part of an ongoing environmental monitoring program during the establishment of the Adelaide Desalination Plant. The general observations and patterns observed within this report are consistent with those seen in previous intertidal reports for the Port Stanvac exclusion zone and the northern and southern reference zones (Dutton and Benkendorff 2008).

The greatest numbers of species were found to occur within the Port Stanvac exclusion zone, as were the highest individual abundances of species across all phyla. Previously Port Stanvac has been identified as a region rich in biodiversity (Womersley 1988; Dutton and Benkendorff 2008, Cantin et al. 2011). The Port Stanvac intertidal zone is characterised by a variety of different sized boulders and rock pools. Higher numbers of intertidal species can be attributed to complex habitats such as boulder zones as they provide protection from predation, shelter and habitats for egg mass deposition (Chapman 2002; Benkendorff and Davis 2004). In addition, the coastline adjacent to the Port Stanvac Exxon Mobil oil refinery, running between Marino Rocks to the north and O'Sullivans beach to the south, has been publically inaccessible for the past two decades. Previous studies on the intertidal coastline have highlighted the negative impact that human recreational activities have on intertidal species (Castilla and Duran 1985; Ruis et al. 2006) and also the role that an exclusion area plays in determining population sizes and dynamics when in effect (Moreno et al. 1986).

Species diversity between the Port Stanvac exclusion zone and the northern reference zone was more similar compared to the southern reference zone. This is likely due to the similar abundance of mollusc species, the dominant phyla throughout all three zones, between the northern reference and Port Stanvac exclusion zone. According to the Shannon-Wiener index, species diversity appeared to be highest at the two Second Valley sites despite the greatest number of species and highest individual abundance being found at sites located within the Port Stanvac exclusion zone. However, a diversity index value alone may not necessarily best represent a region of high biodiversity. Closer examination of raw individual abundance data needs to be considered together with diversity indices in order to generate a more realistic account of biodiversity at a specific region. In this case, the Second Valley sites had higher than expected diversity values due to the low individual abundance of species when compared with the total number of species identified. While the Second Valley sites are important as rocky intertidal reference locations in this monitoring program, caution should be exercised when using sites with low individual abundances of species as a measure of diversity for the Fleurieu intertidal coastline as sites may be a misrepresentation of biodiversity in that region.

High and variable densities of Crustacea and Mollusca from quadrat data indicated a patchy distribution of individuals across all sites. Variability of intertidal data can originate from the interaction between organisms and various environmental parameters such as tide, exposure, habitat (Underwood and Chapman 1995) and as a result, a high level of spatial variability can be expected, with macrofauna often displaying variable patterns of distribution and abundance along intertidal shores (Chapman and Underwood 1996; Chapman 2005). Highly variable distribution of substrate cover was also evident across all sites and zones with the greatest percent of substrate cover occurring within the Port Stanvac exclusion zone. This may be attributed to the restricted access of the public to the Port Stanvac coastline as previous studies have shown that algae are susceptible to human trampling (Keough and Quinn 1998) and notable increases in percent cover have been recorded at sites which are protected in a refuge free from physical disturbance such as human activity (Moreno et al. 1984).

Due to the nature of baseline monitoring and the high variability that exists in environmental datasets, consistency in maintaining a balanced experimental design, including high level of replication, will allow for more accurate temporal and spatial comparisons. Regular monitoring is recommended to ensure that sufficient data is collected in order to better asses any environmental impact that may result from the ongoing operation of a desalination plant at Port Stanvac.

6. Acknowledgements

We would like to extend our thanks to Eli Brown for assisting his expertise in the collection of data and Dr Justine Keuning for her editing and formatting skills. Lastly, thank you to the staff at the Port Stanvac Exxon Mobil oil refinery for allowing Flinders University access to the intertidal study sites.

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Appendix 1

Taxa	Species	Marino Rocks 1	Marino Rocks 2	Hallett Cove 1	Hallett Cove 2	Port Stanvac 1A	Port Stanvac 1B	Port Stanvac 2A	Port Stanvac 2B	Port Stanvac 3A	Port Stanvac 3B	Port Stanvac 4A	Port Stanvac 4B	Port Stanvac 5A	Port Stanvac 5B	Carrickalinga 1	Carrickalinga 2	Second Valley 1	Second Valley 2	Fisheries Beach 1	Fisheries Beach 2
Annelida	*Galeolaria/Pomatoceros* (%)	✓	✓	✓	✓	✓					✓	✓		✓	✓				✓		✓
Mollusca	*Limnoperna pulex* (%)	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓						
	Notoacmea flammea	✓			✓	✓	✓	✓		✓				✓				✓			
	Notacmea spp.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓					✓	
	Patelloida alticostata					✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		✓	✓
	Patelloida latistrigata	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓		
	Scutellastra peronii									✓	✓			✓							
	Cellana tramoserica	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓		✓	
	Cellana solida	✓		✓	✓	✓	✓	✓	✓	✓		✓									
	Nerita atramentosa																				
	Diloma concamerata			✓																	
	Austrocochlea constricta																				✓
	Austrocochlea porcata			✓				✓													
	Austrolittorina unifasciata				✓		✓	✓		✓	✓	✓			✓	✓	✓		✓	✓	
	Bembicium nanum			✓				✓					✓	✓				✓	✓	✓	
	Bembicium vittatum	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	
	Siphonaria diemenensis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	
	Siphonaria zelandica																	✓		✓	
Crustacea	*Chtalamus antennatus*	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Chamaesipho tasmanica						✓	✓	✓	✓	✓	✓			✓	✓					
	Eliminus modestus										✓										
	Elminius flindersi							✓													
	Catomerus polymerus														✓						