Adelaide Desalination Plant Intertidal Monitoring

Second Interim Report

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Introduction

Guidelines were implemented in 2008 by the South Australian Water Corporation for the construction of the Adelaide Desalination Plant project which encompasses the implementation of environmental monitoring during the pre construction, construction and full operation phases. Presented here is the second interim report of baseline monitoring for the intertidal reef system adjacent to the construction zone and the subtidal region surrounding the construction zone undertaken during the second year of the desalination project. Environmental monitoring of the rocky intertidal zone involved an assessment of invertebrate and algal communities.

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 of Exxon Mobil 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 recent 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 (1998).

Monitoring a major development like the Port Stanvac desalination plant requires well planned ecological studies that account for the natural spatial and temporal variability in marine communities. 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. BACI experimental designs have been used previously to detect the effects of physical disturbance to marine communities from various anthropogenic activities such as dredging, prawn trawling and boat anchoring (Skilleter *et al*. 2006; Pitcher *et al*. 2009; Montefalcone *et al*. 2008). Therefore, BACI experimental design principals were followed for this monitoring. Suitable control locations should be situated at sites with similar habitat, at varying distances from the impact source. For the intertidal survey the design included sampling at both impacted (Port Stanvac Construction Zone) and un-impacted control (North and South Control Zones) sites repeatedly before, during and after plant construction and operation.

Aims and Objectives

The investigation was conducted to establish a baseline dataset for intertidal communities along the coastline of Gulf St. Vincent. This dataset will allow the evaluation of potential impacts associated with the operation of the Port Stanvac desalination plant with future monitoring. More specifically, this is the second quarterly report during the second year of environmental monitoring before initiation of the desalination plant. This report presents baseline data collected across the Port Stanvac Construction Zone and the North and South Control Zones during Autumn and Winter 2010 for intertidal surveys.

Methods

Sampling locations and sites

Sites along the Fleurieu Peninsula were selected according to comparable strata type and topography. Five locations within the Port Stanvac fenced area were sampled (Figure1) with reference locations located to the North at Marino Rocks and Hallett Cove (Figure 1) and to the South at Carrickalinga, Second Valley and Fisheries Beach (Figure 1). Two 20 x 20 m plots 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 using each of the methods outlined in previous reports (Baring *et al.* 2010) during low tides in May 2010 for the Autumn survey. Surveys were extended over August and September for the Winter 2010 survey and over November and December for the Spring 2010 survey due to extremely bad weather during the Winter and Spring periods in 2010 (Table 1). The Spring 2010 sampling has been completed, yet data are still being analysed and will be reported in the next interim report.

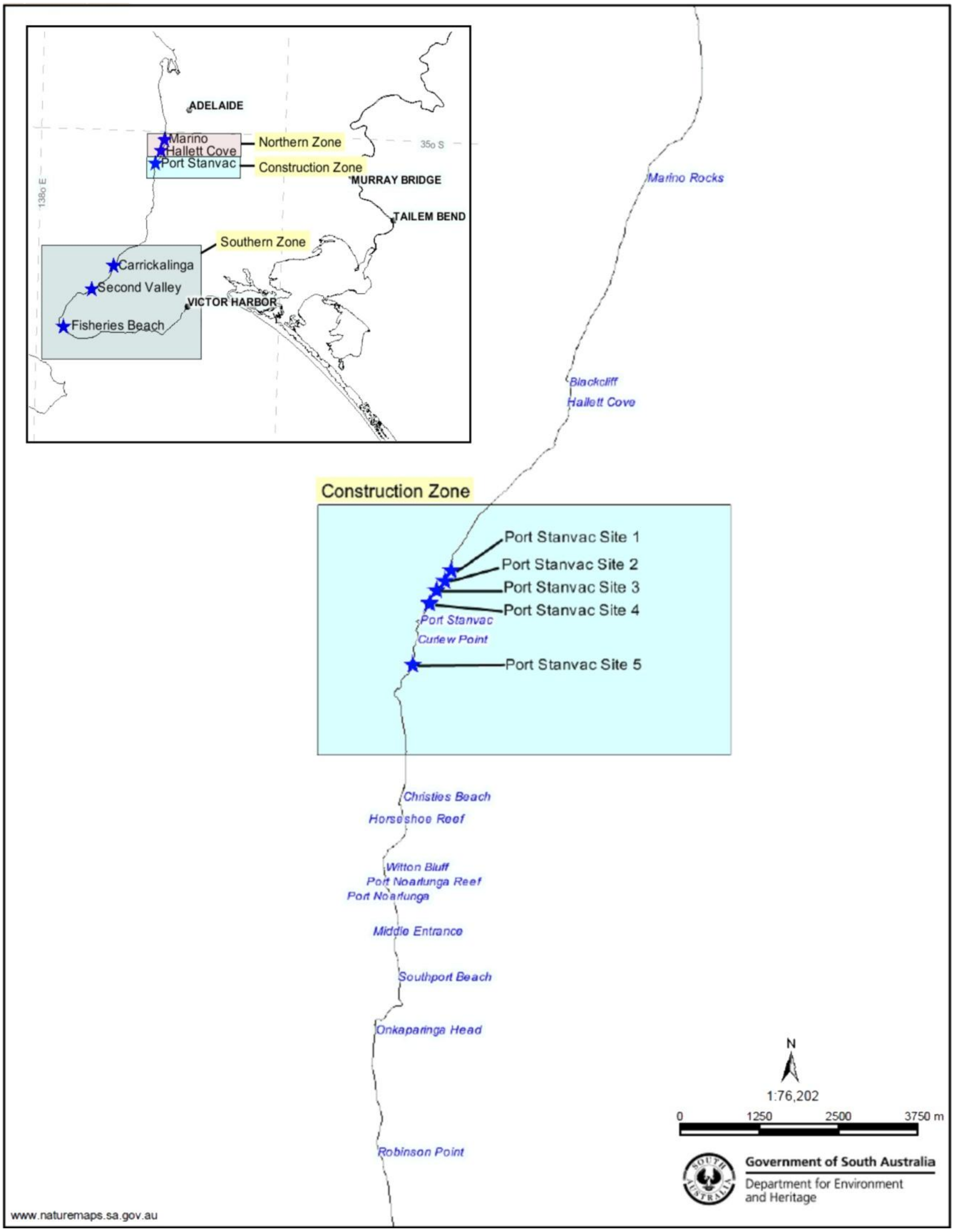


Figure 1: Intertidal sampling sites for the (a) Port Stanvac Construction Zone, Northern Reference Zone and Southern Reference Zone during Autumn/Winter 2010 and (b) magnified snapshot of the five Sites within the Construction Zone for the Autumn, Winter and Spring 2010 survey. Maps adapted from Nature 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 Autumn, Winter and Spring in 2010.

Location	GPS Co-ordinates South	East	Season	Date	Predicted Tidal Height (m)
Marino Rocks	S 35°02'45.6"	E 138°30'27.6"	Autumn	30/4/10	0.57
			Winter	30/8/10	0.52
			Spring	23/11/10	0.14
Hallett Cove	S 35°05'06.2''	E 138°29'31.5"	Autumn	30/4/10	0.57
			Winter	30/8/10	0.52
			Spring	22/11/10	0.14
Port Stanvac 1	S 35°06'48.8"	E 138°28'13.5"	Autumn	3/5/10	0.54
			Winter	1/9/10	0.69
			Spring	24/11/10	0.19
Port Stanvac 2	S 35°06'28.4"	E 138°28'20.0"	Autumn	3/5/10	0.54
			Winter	1/9/10	0.69
			Spring	25 & 29/11/10	0.29 & 0.75
Port Stanvac 3	S 35°06'15.4"	E 138°28'31.8"	Autumn	14/5/10	0.67
			Winter	13/9/10	0.55
			Spring	29/11/10	0.75
Port Stanvac 4	S 35°06'12.4"	E 138°28'34.4"	Autumn	17/5/10	0.69
			Winter	13/8/10	0.52
			Spring	14/12/10	0.60
Port Stanvac 5	S 35°06'25.7"	E 138°28'20.7"	Autumn	13/5/10	0.69
			Winter	13/9/10	0.55
			Spring	25/11/10	0.29
Carrickalinga	S 35°25'09.0"	E 138°19'25.2"	Autumn	29/4/10	0.62
			Winter	27/8/10	0.42
			Spring	9/11/10	0.33
Second Valley	S 35°30'36.3"	E 138°12'54.2"	Autumn	28/4/10	0.65
			Winter	24/8/10	0.61
			Spring	8/11/10	0.28
Fisheries Beach	S 35°37'58.5"	E 138°06'49.4"	Autumn	29/4/10	0.62
			Winter	27/8/10	0.42
			Spring	8/11/10	0.28

Invertebrate abundance

Photoquadrats were used to assess invertebrate abundance, species diversity and species richness as 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 randomly placed within each 20 m x 20 m plot. Each quadrat was divided into quarters, with one photograph taken of each quarter, as well as one encompassing the whole quadrat, using an Olympus Model µ 1030 SW / Tough 8000 digital camera (see Dutton and Benkendorff, 2008). Photographs were later downloaded onto a computer and analysed using Paint.NET v3.36 image analysis 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.

Percent cover of sessile organisms

The 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 tube worms (*Galeolaria caespitosa* and *Pomatoceros taenita*), as well as percent algal cover from the low to high tide zones. Video footage was taken of each replicate transect using an Olympus Model Tough8000 digital camera to ensure that transects were completed within the short time frame between low and high 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. Due to the difficulties in reliably identifying algae, these were grouped into broad morphological categories (e.g. foliose green, encrusting brown/red/green, brown turfing, red foliose etc.) such as those used in Reef Watch surveys (Reef Watch, 2007). In regions where there was an overlap of sessile communities, 'mixed community' categories (e.g. mixed algal, mixed invertebrate) were established to represent and identify the presence of multiple species. Bare substrate and sediment cover was also noted along these transects.

The video transects were downloaded and analysed using VLC Media software, with regular pausing along transects to identify sessile organisms and allow accurate recording of distance intervals. At the start of each transect, the type of organism cover was noted and then transition from one type of organism cover to another was noted 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 (20 m). Means and standard deviation were generated from 5 replicate transects in each plot. However, due to the seasonal influence of wind, swell and wave exposure, transects of 20 m were not always able to be obtained (in particular at Second Valley during Autumn and Winter surveys). In these cases percent cover was calculated by dividing the summed distance of organisms by the total distance covered by the transect, thus giving a proportional cover comparable to that of other shoreline transects.

Data analyses

Data analyses were completed for the Autumn and Winter surveys, while the Spring survey is currently at the species identification and data entry stage. To determine the diversity and evenness of invertebrate species composition at all sites, three different diversity indices were calculated (Shannon-Wiener index, Pielou's evenness and Simpson's index) based on the total number of individuals (*N*) from the number of each taxa (*S*). The Shannon-Wiener index identifies greater species diversity with a higher index number. Pielou's index identifies the equitability of species presence at each site where a larger number indicates higher evenness and Simpson's index of diversity is a measure of ecological diversity with higher diversity increasing from zero to one (Clarke and Warwick 2001).

Abundances of each taxonomic group was statistically analysed using PERMANOVA to determine if there were significant differences between Zones and Sites nested within Zones, for each Season. 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) to get a decent test (Anderson *et al*. 2008).

Analyses of invertebrate community composition of quadrat data and substrate structure of video transects for Autumn and Winter were undertaken to determine if there were similarities between Sites and Zones. A square root transformation was performed on both the invertebrate community and substrate structure datasets for Sites and Zones. Principle Co-ordinates Analysis (PCO) was employed to provide a visual pattern of invertebrate community structure and substrate structure, as it preserves original dissimilarities between points (Anderson *et al*. 2008). In order to distinguish the dissimilarities between invertebrate communities and substrate structure 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.

Results

Photoquadrats

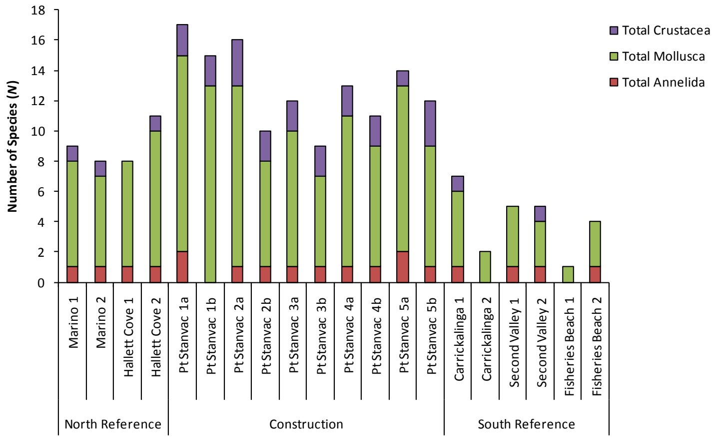
Invertebrate Species Diversity

During the Autumn survey the largest number of species (mainly molluscs) was identified within the northern side of the Construction Zone (Site 1a, 1b, 2a; Figure 2a). In comparison, the Northern Reference Zone had similar numbers of species to the most southern sites of the Construction Zone (Sites 5a and 5b; Figure 2a). The lowest number of species across all three zones in Autumn were recorded within the Southern Reference Zone (Figure 2a). PERMANOVA indicated a significant difference between zones for total species numbers (Pseudo – F = 27.35; P = 0.0001). Pair-wise analysis revealed group differences between the Construction and Northern reference zone (t = 2.93; P = 0. 01) as well as the Construction and Southern reference zone (t = 6.88; P = 0.0003). A significant difference was also detected between the Northern and Southern reference zone (t = 3.32; P = 0.0145).

In Winter, the largest number of species (mainly molluscs) occurred at the most southern sites of the Construction Zone (Sites 5a, 5b; Figure 2b). Species numbers at most sites in the Northern Reference Zone were similar to numbers found in the Construction Zone. The lowest numbers of species were found at most sites in the Southern Reference Zone, except one site at Fisheries Beach (Figure 2b). PERMANOVA indicated a significant difference between zones for total species numbers (Pseudo – F = 18.06; P = 0.0001). Pair-wise analysis revealed group differences between the Construction and Northern reference zone (t = 2.97; P = 0. 01) as well as the Construction and Southern reference zone (t = 5.64; P = 0.0005).

In Autumn, most sites in the Construction Zone had moderate species diversity and a relatively even distribution between species. The Northern Reference Zone also had moderate species diversity with similar abundances between species (Table 2a). Diversity was low in the Southern Reference Zone and uneven at Fisheries Beach due to the dominance of the gastropod *Austrolittorina unifasciata* (Table 2a).

(a)



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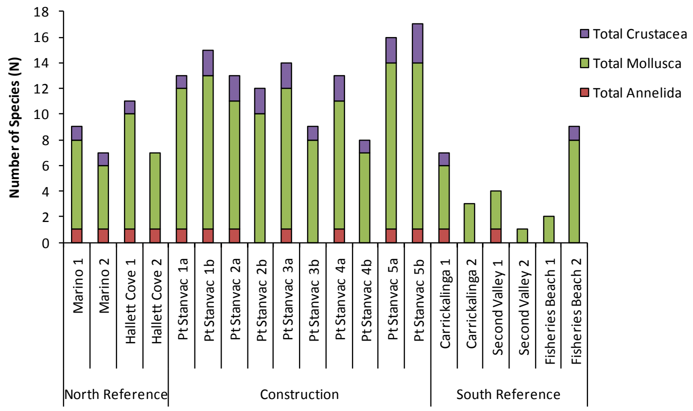


Figure 2: Total species number per phyla identified in quadrats during the (a) Autumn and (b) Winter survey for the Northern Reference Zone, Construction Zone and Southern Reference Zone in 2010.

During Winter, the Construction Zone had moderate species diversity and an even distribution between species at three sites (Sites 1, 3 and 5). In comparison, two of the Construction Zone sites (Sites 2 and 4; Table 2b) had low species diversity with an uneven distribution. Species diversity in the Northern Reference Zone was moderate with an even distribution between species. Species diversity was low in the Southern Zone with an uneven species distribution at Second Valley and Fisheries Beach due to the dominance of *Austrolittorina unifasciata* and *Nerita atramentosa* respectively (Table 2b).

Table 2: Diversity indices for the (a) Autumn and (b) Winter intertidal survey during 2010. *S* = number of taxa; *N* = total number of individuals. All values are means and include Standard Deviation (SD) from the two replicate plots per site.

(a)

Site	*S*	*N*	Shannon-Wiener	Pielou's evenness	Simpson
Marino	7.5 (0.7)	97.5 (60.1)	1.62 (0.00)	0.81 (0.04)	0.77 (0.01)
Hallett Cove	8.5 (2.1)	85.5 (20.51)	1.52 (0.15)	0.72 (0.01)	0.73 (0.04)
Port Stanvac 1	14 (0.0)	359.5 (116.7)	1.65 (0.22)	0.62 (0.08)	0.72 (0.05)
Port Stanvac 2	12 (4.2)	432.5 (419.3)	1.73 (0.71)	0.69 (0.19)	0.75 (0.17)
Port Stanvac 3	9.5 (2.1)	322.5 (132.2)	1.45 (0.13)	0.66 (0.12)	0.65 (0.12)
Port Stanvac 4	10 (1.4)	1061.5 (963.8)	1.36 (0.23)	0.59 (0.06)	0.63 (0.04)
Port Stanvac 5	10.5 (0.7)	1457.5 (1832.1)	1.64 (0.58)	0.69 (0.23)	0.74 (0.15)
Carrickalinga	4 (2.8)	71.5 (62.9)	0.49 (0.11)	0.53 (0.42)	0.28 (0.17)
Second Valley	4 (0.0)	25 (19.8)	1.01 (0.21)	0.73 (0.15)	0.59 (0.17)
Fisheries Beach	2 (1.4)	92.5 (6.4)	0.11 (0.16)	0.21 (0.00)	0.05 (0.07)

(b)

Site	*S*	*N*	Shannon-Wiener	Pielou's evenness	Simpson
Marino	7 (1.4)	93 (56.5)	1.37 (0.35)	0.70 (0.11)	0.69 (0.12)
Hallett Cove	7 (2.8)	86 (8.5)	1.60 (0.20)	0.85 (0.08)	0.77 (0.02)
Port Stanvac 1	13 (1.4)	276 (145.7)	1.80 (0.23)	0.70 (0.06)	0.76 (0.01)
Port Stanvac 2	12 (0.0)	1095 (260.2)	0.87 (0.01)	0.35 (0.01)	0.38 (0.00)
Port Stanvac 3	11 (2.8)	182.5 (3.5)	1.69 (0.75)	0.70 (0.24)	0.70 (0.24)
Port Stanvac 4	10 (2.8)	738 (118.8)	1.03 (0.19)	0.46 (0.14)	0.46 (0.13)
Port Stanvac 5	14.5 (0.7)	1226.5 (1144.8)	1.51 (0.31)	0.57 (0.13)	0.68 (0.04)
Carrickalinga	4 (1.4)	60.5 (12.0)	0.89 (0.78)	0.60 (0.42)	0.47 (0.43)
Second Valley	2 (1.4)	30 (41.0)	0.12 (0.17)	0.21 (0.00)	0.10 (0.00)
Fisheries Beach	5.5 (4.9)	60 (59.4)	0.74 (0.74)	0.44 (0.19)	0.37 (0.37)

Invertebrate Abundances

In Autumn, the total abundances of all phyla were largest at the southern end of the Construction Zone at two sites (Sites 4b, 5b: Figure 3a). The North and South Reference Zones had low abundances of all phyla compared to sites in the Construction Zone (Figure 3a). Across all sites and zones, the abundances of molluscs were low, but the largest abundances were identified within the Construction Zone (Sites 1a, 4b, 5b; Figure3c). Large abundances of crustaceans (mainly barnacles) contributed most to the total abundances at the southern end of the Construction Zone (Sites 4b, 5b; Figures 3a and 3b).

Two factor (Zone and Site (Zone)) univariate PERMANOVA of total invertebrate abundances revealed a significant difference between Zones (Pseudo – F = 10.72; P = 0.01) but not Sites (Zones). Further pair-wise tests indicated that the comparisons between the Construction Zone and the Southern Reference Zones (t = 4.03; P (MC) = 0.007) influenced the significant differences at the Zone level. Analysis of mollusc abundances with PERMANOVA indicated a

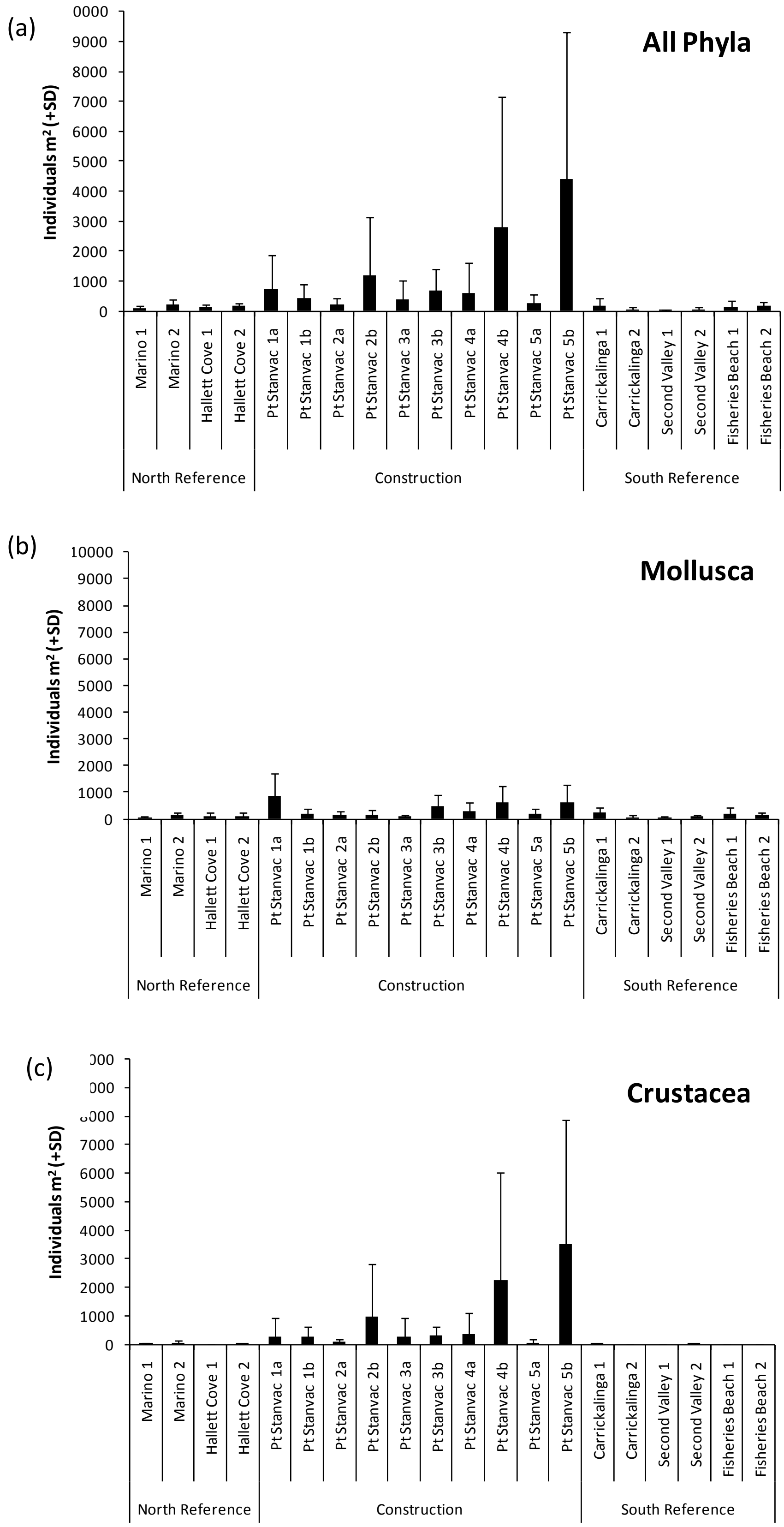


Figure 3: Mean abundances and standard deviations (SD) for (a) all phyla, (b) mollusca and (c) crustacea identified in photo quadrats (n=10) from the 2010 Autumn survey at all sites encompassing three zones; Northern Reference Zone, Construction Zone and Southern Reference Zone.

significant difference between Zones (Pseudo – *F* = 7.63; *P* = 0.01) and Sites (Zones) (Pseudo – *F* = 2.21; *P* = 0.03). Pair-wise analysis for Zone differences were only significant between the Construction and Southern Reference Zone (t = 3.57; *P* (MC) = 0.01). PERMANOVA of crustacean abundances indicated that there was a significant differences between Zones (Pseudo – *F* = 11.91; *P* = 0.01) but not Sites (Zones). Pair-wise tests revealed that the significant difference for Zones was between the Construction Zone and both the Northern (t = 2.90; *P* (MC) = 0.03) and Southern Reference Zones (t = 4.12; *P* (MC) = 0.007).

During Winter, total abundances of all phyla were largest at the southern most site of the Construction Zone (Site 5b; Figure 4). In comparison, all sites of the Northern and Southern Reference Zones had much smaller total abundances than the Construction zone (Figure 4). Abundances of molluscs at the Construction zone and North reference zone were similar to each other except for a large abundance at Site 5b in the southern end of the Construction Zone (Figure 4). In comparison, abundances of molluscs in the Southern Reference Zone were smaller than the Construction Zone at most sites (Figure 4). The largest abundances of crustaceans (entirely barnacles) were found at the southern end of the Construction Zone (Site 5b) which included a large proportion of recently settled juveniles. In the Northern Reference Zone, abundances of crustaceans were very low and completely absent at four sites of the Southern Reference Zone (Figure 4).

Two factor (Zone and Site (Zone)) PERMANOVA analyses of total abundances for Winter revealed a significant difference between Zones (Pseudo – *F* = 10.28; *P* = 0.01) and Sites (Zones) (Pseudo – *F* = 2.08; *P* = 0.04). Pair-wise analyses of Zones indicated that the only contributing group differences were between the Construction and Southern Reference Zone (t = 3.96; *P* (MC) = 0.006). Abundances of molluscs were significantly different between Zones (Pseudo – *F* = 10.94; *P* = 0.004) and Sites (Zones) (Pseudo – *F* = 2.60; *P* = 0.01) from PERMANOVA analyses. Further pair-wise tests for Zones indicated that the grouping differences were between the Construction and Southern Reference Zones (t = 4.32; *P* (MC) = 0.004). PERMANOVA of crustacean abundances revealed a significant difference between Zones (Pseudo – *F* = 9.16; *P* = 0.01) with group differences between the Construction and Southern Reference Zone (t = 3.56; *P* (MC) = 0.01) from pair-wise tests.

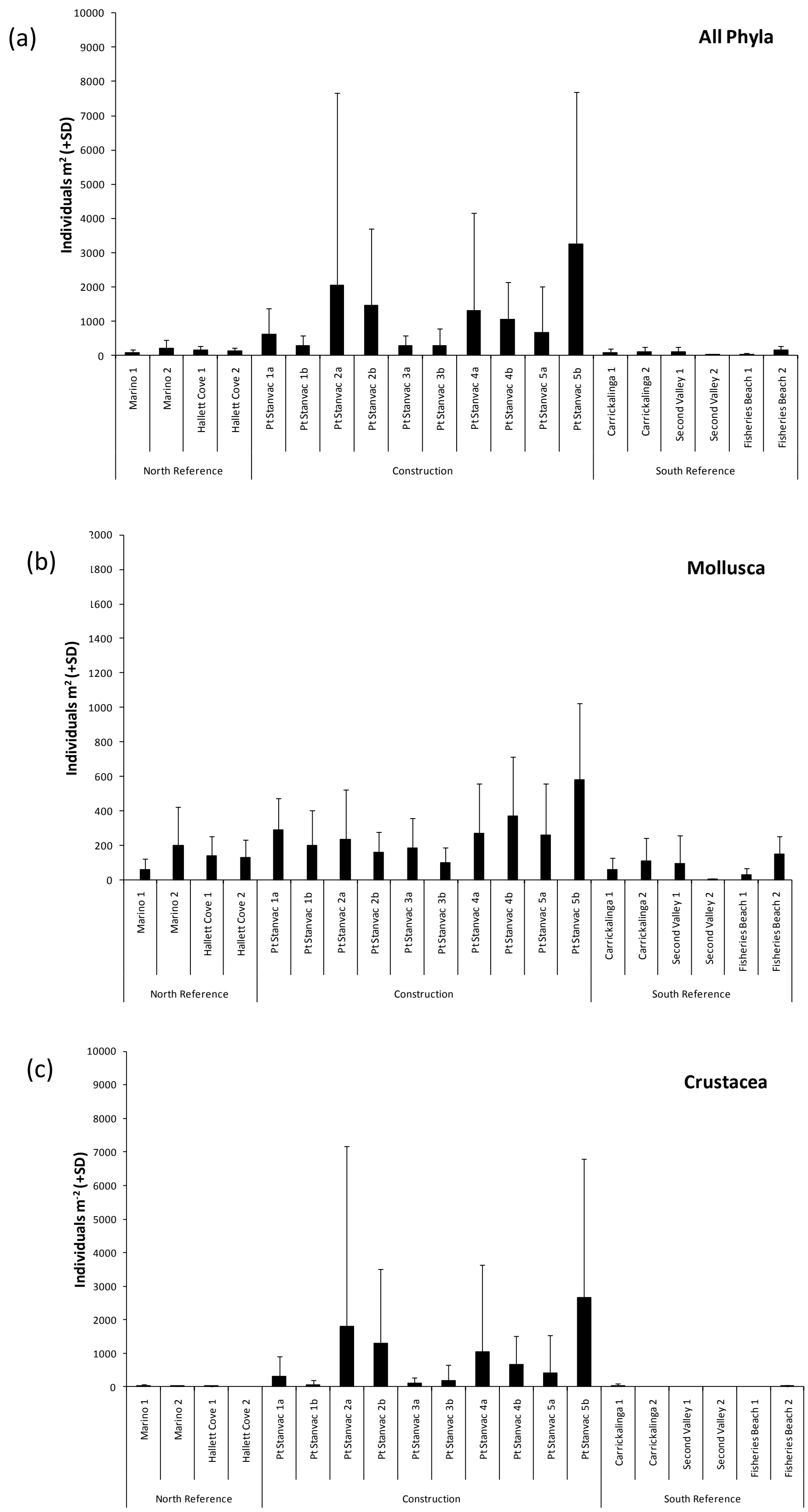
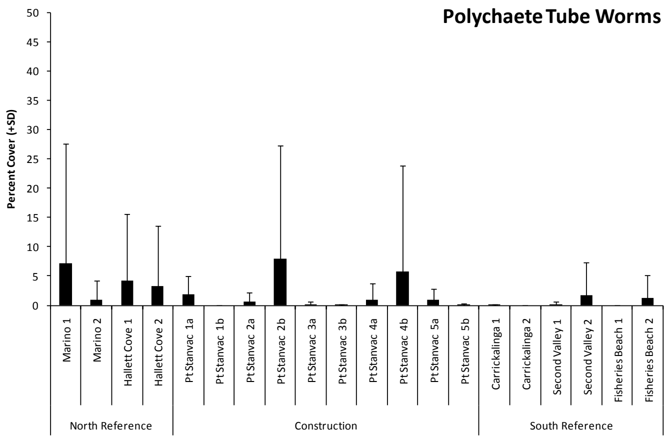


Figure 4: Mean abundances and standard deviations (SD) for (a) all phyla, (b) mollusca and (c) crustacea identified in photo quadrats (n=10) from the 2010 Winter survey at all sites encompassing three zones; Northern Reference Zone, Construction Zone and Southern Reference Zone.

Percent Cover of Sessile Invertebrates

In Autumn, the percent cover of sessile fauna was under 10% for all species across the three separate zones. The percent cover was high at most sites of the Northern Reference Zone and two sites of the Construction Zone (Port Stanvac Sites 2b and 4b) due to polychaete tubeworms (*Galeolaria caespitosa* and *Pomatoceros taenita*; Figures 5a). Percent cover of the mussel *Limnoperna pulex* was very low across all three zones (Figure 5b).

(a)



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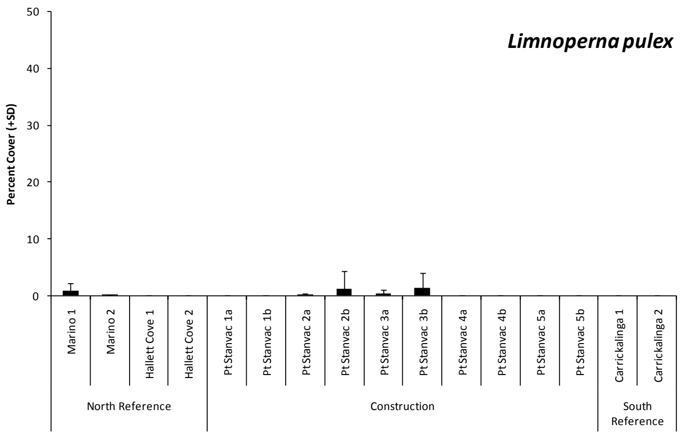
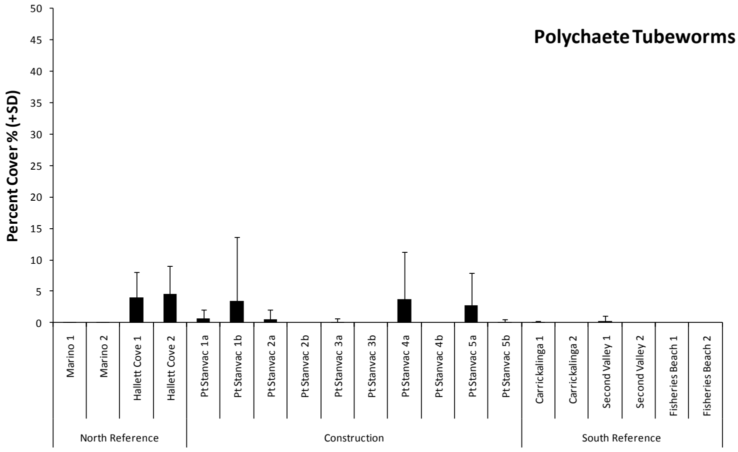


Figure 5: Mean percent cover and standard deviations (SD) for (a) polychaete tubeworms (*Galeolaria caespitosa* and *Pomatoceros taenita*) (b) the mollusc *Limnoperna pulex* identified from photo quadrats (n=10) in the Autumn 2010 survey at all sites encompassing three zones; Northern Reference Zone, Construction Zone and Southern Reference Zone.

During Winter, the percent cover of polychaete tubeworms was below 10% across all three zones but highest at Hallett Cove in the Northern Reference Zone (Figure 6). The percent cover of the mussel *L. pulex* was very low and absent at most sites across the three zones (Figure 6).

(a)



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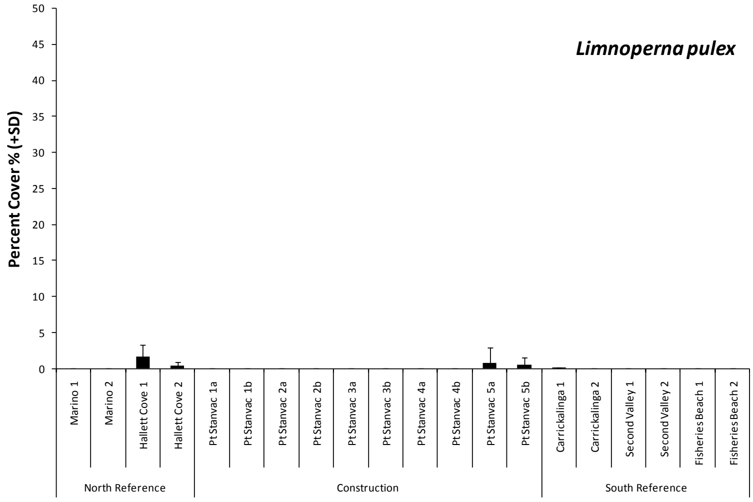
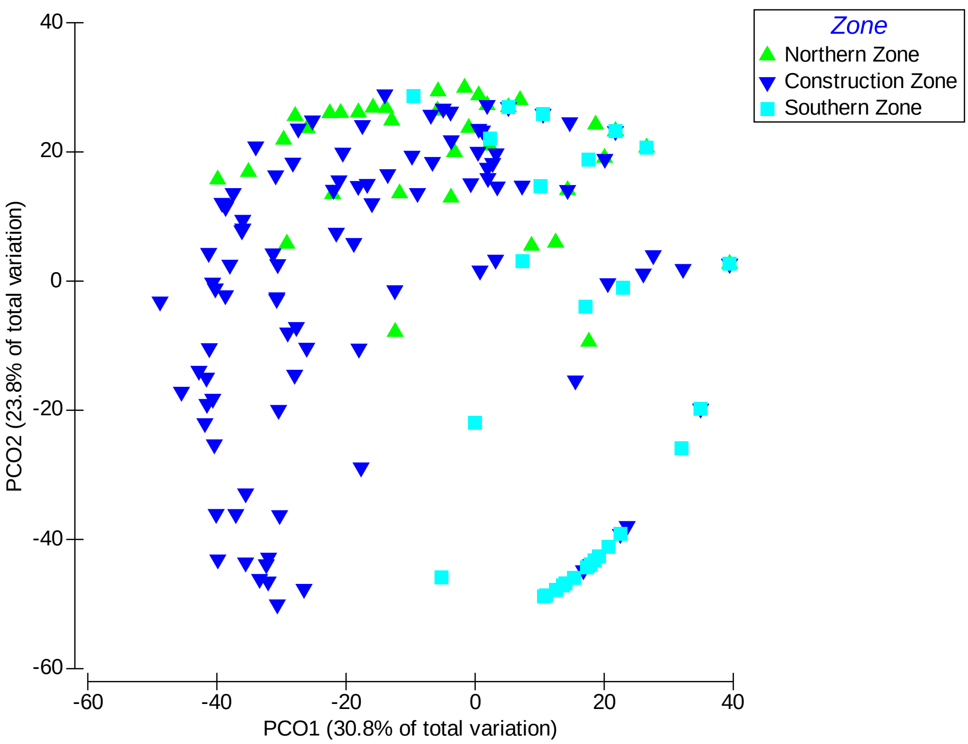


Figure 6: Mean percent cover and standard deviations (SD) for (a) polychaete tubeworms (*Galeolaria caespitosa* and *Pomatoceros taenita*) and (b) the mollusc *Limnoperna pulex* identified from photo quadrats (n=10) in the Winter 2010 survey at all sites encompassing three zones; Northern Reference Zone, Construction Zone and Southern Reference Zone.

Community Structure of Rocky Shore Invertebrates

In Autumn, the PCO plot for zones showed a large variability in community structure within the Construction Zone (Figure 7a). The Northern Reference Zone had similar community structure to the Construction Zone as identified by partial overlap of cluster points. A proportion of the Southern Reference Zone showed heterogenous clustering of data points in the PCO plot with some overlap to the other two zones (Figure 7a). Two factor PERMANOVA for Zones and Sites (Zone) of invertebrate communities revealed a significant difference between Zones (Pseudo – F = 14.18; P = 0.0006) and Sites (Zone) (Pseudo – F = 1.62; P = 0.009). Pair-wise tests indicated group differences between the Construction Zone and both the North Reference (t = 2.57; P (MC) = 0.0006) and South Reference Zones (t = 4.50; P (MC) = 0.0001). Also, pairwise tests

(a)



(b)

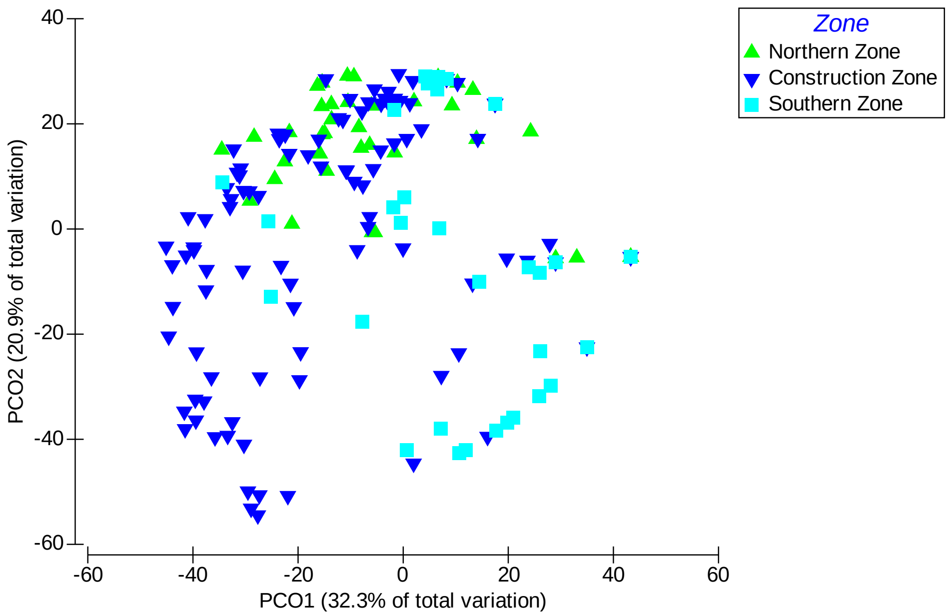


Figure 7: Principle Co-ordinates (PCO) plot of invertebrate communities in (a) Autumn and (b) Winter for Zones using Bray-Curtis resemblance matrices.

showed a significant difference between communities of the Northern Reference and Southern Reference Zone (t = 3.84; *P* (MC) = 0.0003).

Invertebrate communities in the Construction Zone during Winter were similar to the Autumn data with no distinct clustering on the PCO plot (Figure 7b). The Northern Reference Zone community data clustered more closely during Winter, while the Southern Reference was more homogenous (Figure 7b). PERMANOVA of Zones and Sites (Zone) indicated a significant difference between Zones (Pseudo – $F = 6.59$; $P = 0.0007$) and Sites (Zones) (Pseudo – $F = 3.37$; $P = 0.0001$). Pair-wise tests revealed group differences between the Construction Zone and both the Northern (t = 1.82; *P* (MC) = 0.01) and Southern Reference Zones (t = 3.13; *P* (MC) = 0.0001). In addition, pair-wise comparisons of the Northern and Southern Reference Zones had significantly different community structure (t = 2.41; *P* (MC) = 0.008).

Video Transects

Percent of Substrate Cover

During Autumn, most sites had >75% cover of bare substrate across the three Zones (Figure 8a). In the Southern Reference Zone, Fishery Beach had a large amount of wrack and sand (38% cover) (Figure 8a). Three sites in the Construction Zone had ≥ 30% cover of flora and sessile fauna (mainly mixed algae at sites 1a and 3b, barnacles and mixed algae at site 5b; Figure 8b).

In Winter, the percent cover of bare substrate was > 70% at most sites across all three zones with a small percentage of sand cover at some sites in the Northern and Southern Reference Zones. In the Northern Reference Zone a high percentage cover of wrack dominated one site at Second Valley (Figure 9a). The Construction Zone had three sites with > 30% flora and fauna cover (Site 1a, 5a and 5b; Figure 9b) and most sites within the Construction Zone consisted of high percentages of mixed algae and barnacles.

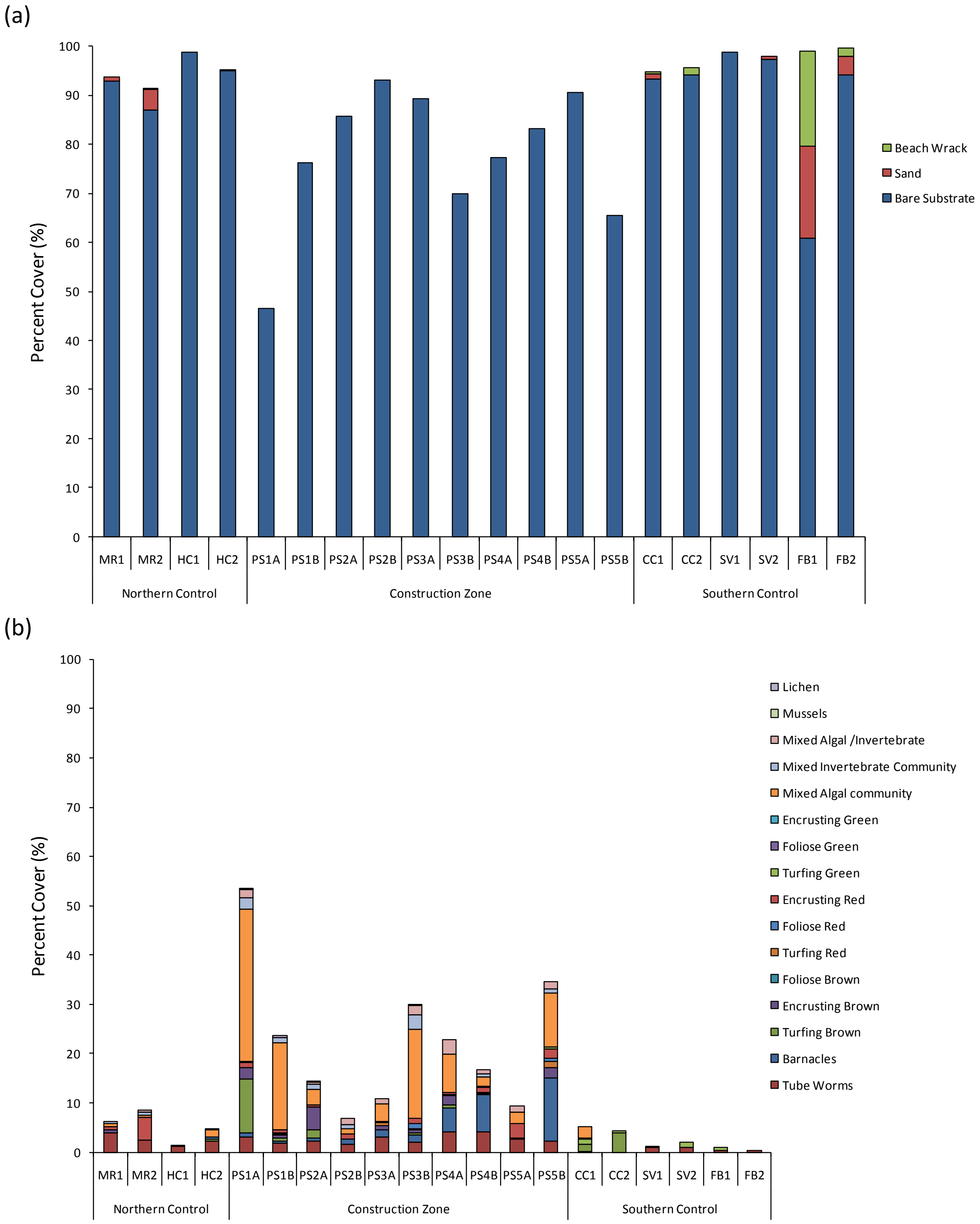


Figure 8: Mean percent cover intertidal reefs, split into (a) bare substrate, sand and beach wrack, and (b) flora and fauna as quantified from video transects. Based on intertidal reefs at all sites, across three Zones; Northern Reference Zone, Construction Zone and Southern Reference Zone during the Autumn survey in 2010.

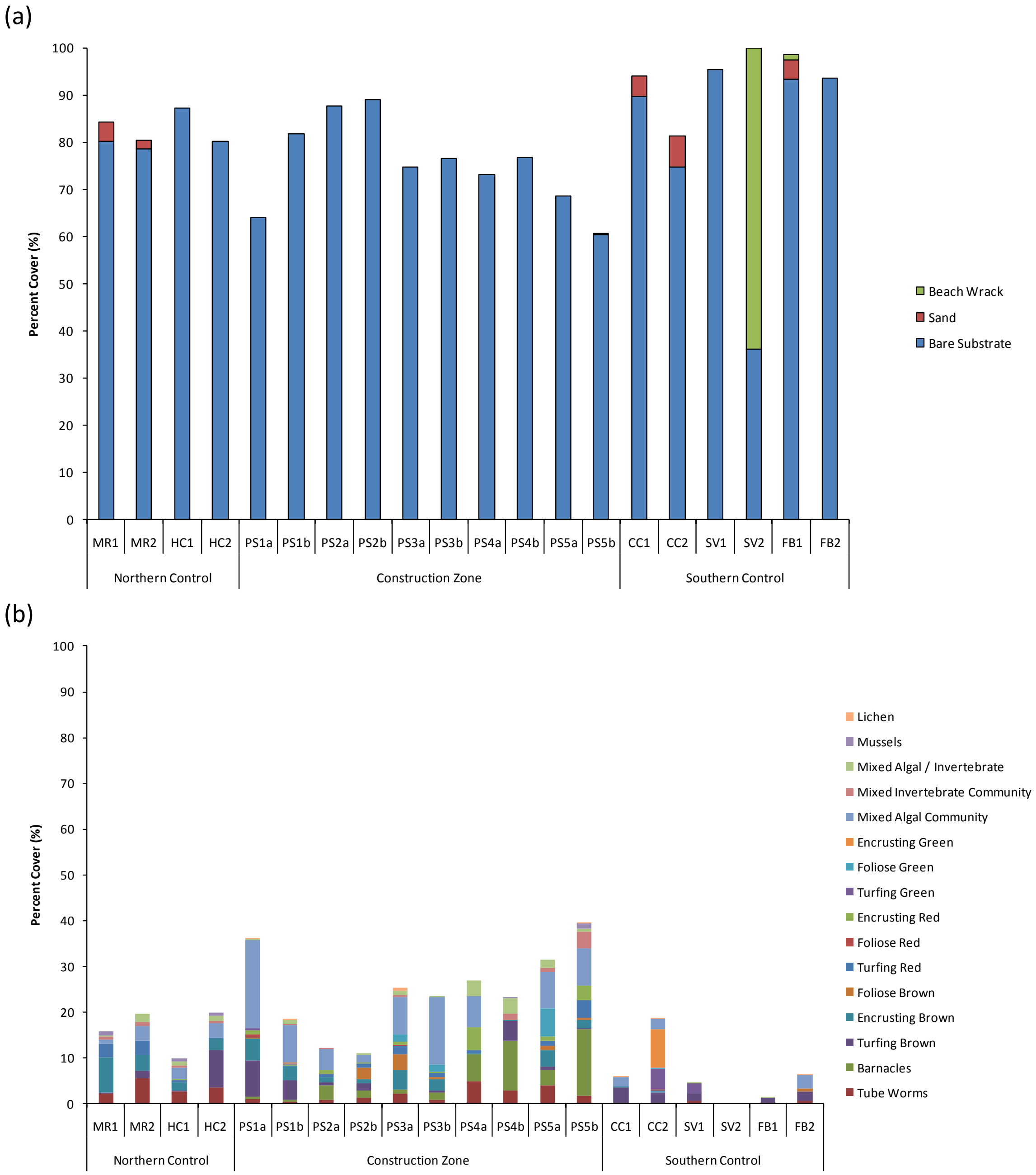


Figure 9: Mean percent cover of (a) bare substrate, sand and beach wrack, and (b) flora and fauna quantified from video transects of intertidal reefs at all sites, across three Zones; Northern Reference Zone, Construction Zone and Southern Reference Zone during the Winter survey in 2010.

Video Transects – Community Structure

In Autumn, the substrate structure in each of the three zones was specific to each zone with little overlap on the PCO plot (Figure 10a). PERMANOVA analyses revealed a significant difference between Zones (Pseudo – *F* = 11.71; *P* = 0.0001) and Sites (Zones) (Pseudo – *F* = 4.31; *P* = 0.0001). Pair-wise tests indicated that the Construction Zone flora and fauna was significantly different to both the Northern (t = 2.60; *P* = 0.0006) and Southern Reference Zones

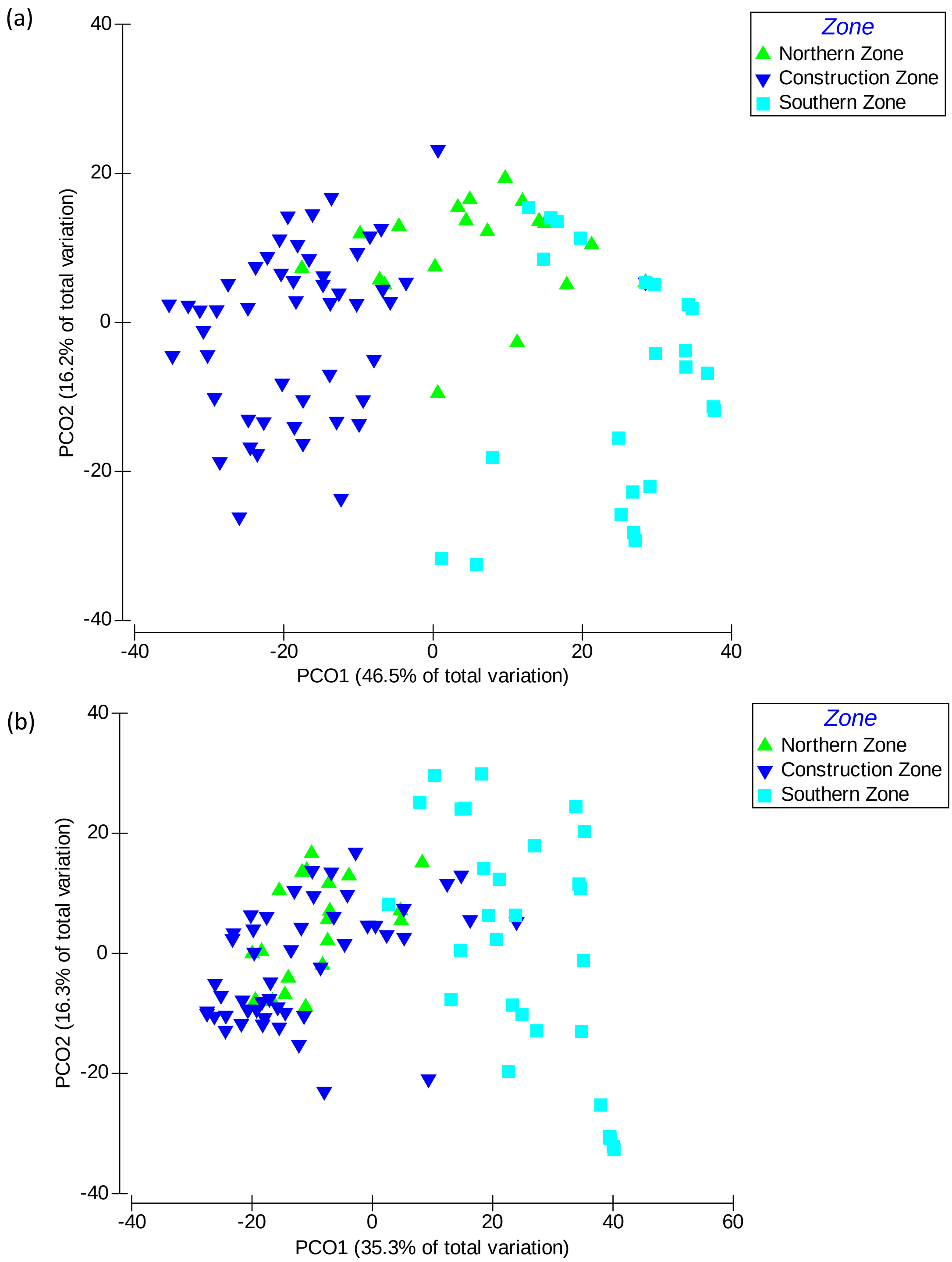


Figure 10: Principle Co-ordinates (PCO) plot of substrate structure in (a) Autumn and (b) Winter for Zones using Bray-Curtis resemblance matrices.

(t = 4.49; *P* = 0.0001). In addition, pair-wise tests between the Northern and Southern Reference Zone (t = 2.14; *P* = 0.004) were also significantly different.

During Winter, the flora and fauna of the Construction Zone and Northern Zone were more similar while the Southern Reference Zone had only a small overlap with the Construction Zone and Northern Reference Zone (Figure 10b). PERMANOVA revealed a significant difference between Zones (Pseudo – F = 6.67; P = 0.0001) and Sites (Zones) (Pseudo – F = 6.28; P = 0.0001). Pair-wise tests indicated significant differences between the Construction Zone and both the Northern (t = 1.80; P = 0.004) and Southern Reference Zones (t = 3.07; P = 0.0004) as well as significant difference between the Northern and Southern Reference Zones (t = 2.35; P = 0.004).

Summary of key results

The Construction Zone at Port Stanvac had similar species richness and diversity during both the Autumn and Winter sampling periods. Molluscs contributed most to species richness in the Construction Zone during both the Autumn and Winter surveys. Only the Northern Reference Zone had comparable species richness to the Construction Zone in both the Autumn and Winter surveys, while the Southern Reference Zone had much lower species richness.

Total abundances in the Construction Zone generally increased during Winter, and in both Autumn and Winter surveys crustaceans contributed most to abundances. The abundances of all phyla and of crustaceans at both the Northern and Southern Reference Zone were lower than at the Construction Zone in both seasons. In comparison, between Autumn and Winter the abundance of molluscs remained consistent in the Construction Zone. Mollusc abundances in the Northern Reference Zone were comparable to values from the Construction Zone, while abundances in the Southern Reference Zone were much lower.

Community structure of rocky shores remained distinctly different for each zone in Autumn and Winter based on both photo quadrats and video transects. In the Construction Zone, mixed algae and barnacles contributed most to the community structure in Autumn and Winter.

The high species richness and large abundances of invertebrate fauna identified in the rocky shores of the Construction Zone is comparable with previous surveys undertaken in 2009/2010. The distinctly different community structure of rocky shores at all three zones and in particular the Construction Zone, provides similar results to surveys undertaken in the previous year (Baring *et al*. 2010).

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Appendix 1

Presence of invertebrate species at each location according to zone for (a) Autumn and (b) Winter 2010.

(a)

Photoquadrat Winter 2010		North Reference		Construction					South Reference		
Species		Marino	Hallett Cove	Port Stanvac 1	Port Stanvac 2	Port Stanvac 3	Port Stanvac 4	Port Stanvac 5	Carrickalinga	Second Valley	Fisheries Beach
Annelida	*Galeolaria/Pomatoceros %*	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Mollusca	*Limnoperna pulex %*		✓					✓	✓		
	Notoacmea flammea	✓	✓	✓	✓	✓	✓	✓			✓
	Notoacmea spp.			✓	✓			✓			
	Patelloida alticostata							✓			
	Patelloida latistrigata			✓	✓		✓	✓			
	Patelloida spp.			✓							✓
	Cellana tramoserica	✓	✓	✓	✓			✓			
	Cellana solida		✓			✓		✓			
	Nerita atramentosa	✓	✓	✓	✓	✓	✓	✓	✓		✓
	Diloma concamerata			✓	✓		✓	✓			✓
	Austrocochlea constricta	✓	✓	✓	✓	✓	✓	✓			✓
	Austrocochlea porcata					✓	✓	✓			
	Afrolittorina praetermissa				✓						
	Austrolittorina unifasciata		✓		✓	✓	✓	✓	✓	✓	✓
	Bembicium nanum	✓		✓			✓	✓		✓	✓
	Bembicium vittatum	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Siphonaria diemenensis	✓	✓	✓	✓	✓	✓	✓	✓		✓
	Siphonaria zelandica	✓		✓			✓		✓		
	Unidentified gastropod		✓	✓	✓	✓		✓			
Crustacea	*Tetraclitella purpurascens*						✓				
	Chthamalus antennatus	✓	✓	✓	✓	✓	✓	✓	✓		✓
	Chamaesipho tasmanica			✓	✓	✓		✓			
	Catomerus polymerus							✓			

(b)

Phylum	Species	Northern Reference Zone		Construction Zone					Southern Reference Zone		
		Marino	Hallett Cove	Port Stanvac 1	Port Stanvac 2	Port Stanvac 3	Port Stanvac 4	Port Stanvac 5	Carrickalinga	Second Valley	Fisheries Beach
Annelida	*Galeolaria caespitosa (%)*	✓	✓	✓	✓	✓		✓			
	Pomatoceros taenita (%)			✓	✓	✓	✓	✓	✓	✓	✓
Mollusca	*Limnoperna pulex (%)*			✓			✓	✓			
	Notoacmea flammea	✓	✓	✓	✓	✓	✓			✓	
	Notoacmea spp.	✓		✓	✓	✓		✓			
	Patelloida latistrigata		✓	✓	✓	✓	✓	✓			
	Cellana tramoserica	✓	✓	✓	✓	✓	✓	✓			
	Cellana solida	✓	✓	✓	✓		✓	✓			
	Nerita atramentosa	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Diloma concamerata			✓	✓			✓	✓		
	Austrocochlea rudis			✓							
	Austrocochlea constricta			✓	✓	✓		✓	✓		
	Austrocochlea porcata	✓		✓							
	Austrolittorina unifasciata		✓	✓	✓	✓	✓	✓	✓	✓	✓
	Bembicium auratum	✓		✓							
	Bembicium nanum			✓							
	Bembicium vittatum	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Siphonaria diemenensis	✓	✓	✓	✓	✓	✓	✓	✓		✓
	Siphonaria zelandica		✓		✓						
	Unidentified gastropod		✓	✓	✓	✓	✓				
	Tetraclitella purpurascens				✓						
Crustacea	*Chthamalus antennatus*	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Chamaesipho tasmanica			✓	✓	✓	✓	✓			
	Catomerus polymerus							✓			

*Data for *G. Caespitosa, P. taenita* and *L. pulex* calculated to percent, therefore +/- denotes presence or absence of species at specific site