Adelaide Desalination Plant Final Intertidal Monitoring Report 2009/2010

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[This document contains the final report for the seasonal Adelaide Desalination Plant Intertidal Monitoring Program undertaken by Flinders University in 2009/2010.]

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Executive Summary

The intertidal rocky shore survey herein was undertaken as a requirement for the Adelaide Desalination Project environmental monitoring program proposed by the South Australian Water Corporation in conjunction with Adelaide Aqua. During 2009/2010 ten sites were selected within the desalination plants major project declaration area (Construction Zone) at Port Stanvac. A further four sites North of Port Stanvac were identified as the Northern Reference Zone, while eight sites were selected along the Fleurieu Peninsula as the Southern Reference Zone. Four surveys were conducted from Autumn 2009 through to the Summer of 2010 using photoquadrat and video transect methods to assess the structure of fauna and flora communities within the intertidal rocky shores of all three Zones. Overall, the Construction Zone had higher invertebrate biodiversity and larger abundances compared to both of the Reference Zones. Significant differences in photo quadrat invertebrate abundances frequently arose between the Construction Zone and Northern Reference Zone, and between the Construction Zone and Southern Reference Zone. Species richness, diversity and abundances of invertebrates in photo quadrats generally increased from Autumn to Winter and declined during Spring and Summer, with less dominant species contributing to dissimilarities between Zones in Summer. Large site to site variation was observed within all three Zones, across all four seasons. Video transects identified a general pattern of low percent cover of flora and fauna in the Construction Zone during Autumn which increased from Winter to Spring and declined during Summer, while the percent cover in both Reference Zones was relatively low and mainly consisted of bare substrate (particularly in Autumn and Winter).

There were some constraints with the intertidal surveys, particularly in the cooler months (Autumn and Winter) due to decreased availability of access to the lowest intertidal zone caused by higher tides and increased wave exposure. Future surveys will also have the same intertidal access restrictions and therefore recommendations have been made for comparisons of flora and fauna communities between surveys on a season to season basis. Access to the low intertidal zone was also consistently restricted at Kings Beach. Therefore a decision was made to exclude this site from further surveys. The 2009/2010 intertidal survey has provided a complete annual baseline dataset of flora and fauna community structure along the rocky shoreline adjacent to the Adelaide Desalination Plant site at the ‘pre construction phase’, which allows for consistent comparisons to be made at the next two environmental monitoring phases of ‘construction’ and ‘full operation’.

Introduction

In 2008 the South Australian Water Corporation established guidelines for construction of the Adelaide Desalination Plant project which encompasses the implementation of environmental monitoring during the pre construction, construction and full operation phases. Herein is the first year of baseline monitoring during the pre construction phase of the desalination project for invertebrate and algal communities of the intertidal reef system adjacent to the construction zone.

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). Along this coastline lies Port Stanvac, once a working petroleum refinery of Exxon Mobil which has been closed off from public access for the last two decades. The intertidal reefs at Port Stanvac appear to be biologically 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).

The intertidal shores along Fleurieu Peninsula are heterogeneous environments with a high level of connectivity to other coastal ecosystems; hence there is the potential for shifts in the community structure to occur as a result of anthropogenic impacts in surrounding marine and terrestrial habitats. Impacts on intertidal communities 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). The development of a desalination plant at Port Stanvac has the potential to impact local intertidal reefs during the construction phase due to increased vehicles and human activities in the area and from possible silt plumes from the tunnelling process which could temporarily smother intertidal communities, thus causing anoxia and species die-off (Marshall and McQuaid 1989; Schiel *et al*. 2006). In the longer term, during the desalination plant operation phase, intertidal reefs could be impacted 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 from open ocean waters occur (Samarasinghe *et al*. 2003; Kampf *et al*. 2009).

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, in order to follow the BACI experimental design principals, suitable control locations should be situated at sites with similar intertidal habitat, at varying distances from the desalination plant.

A series of marine biology surveys have been previously undertaken at two sites in Port Stanvac and several control locations in 1978-1981 by Womersely (1988). In addition, Piller (1998) undertook baseline surveys at Port Stanvac and a number of other sites in the Adelaide metropolitan region to develop an intertidal monitoring program for Mobil, Port Stanvac. However, in both of these studies, control locations to the south of Port Stanvac were limestone reefs, whereas the reefs at Port Stanvac are composed of hard igneous rock with complex boulder fields, rock platforms, crevices and rock pools (Dutton and Benkendorff, 2008). Comparisons of intertidal communities along the Fleurieu Peninsula have revealed significant differences between limestone and hard rock reefs (Benkendorff and Thomas, 2007; Benkendorff *et al*., 2008), thus requiring careful selection of control locations for environmental monitoring.

Aims and Objectives

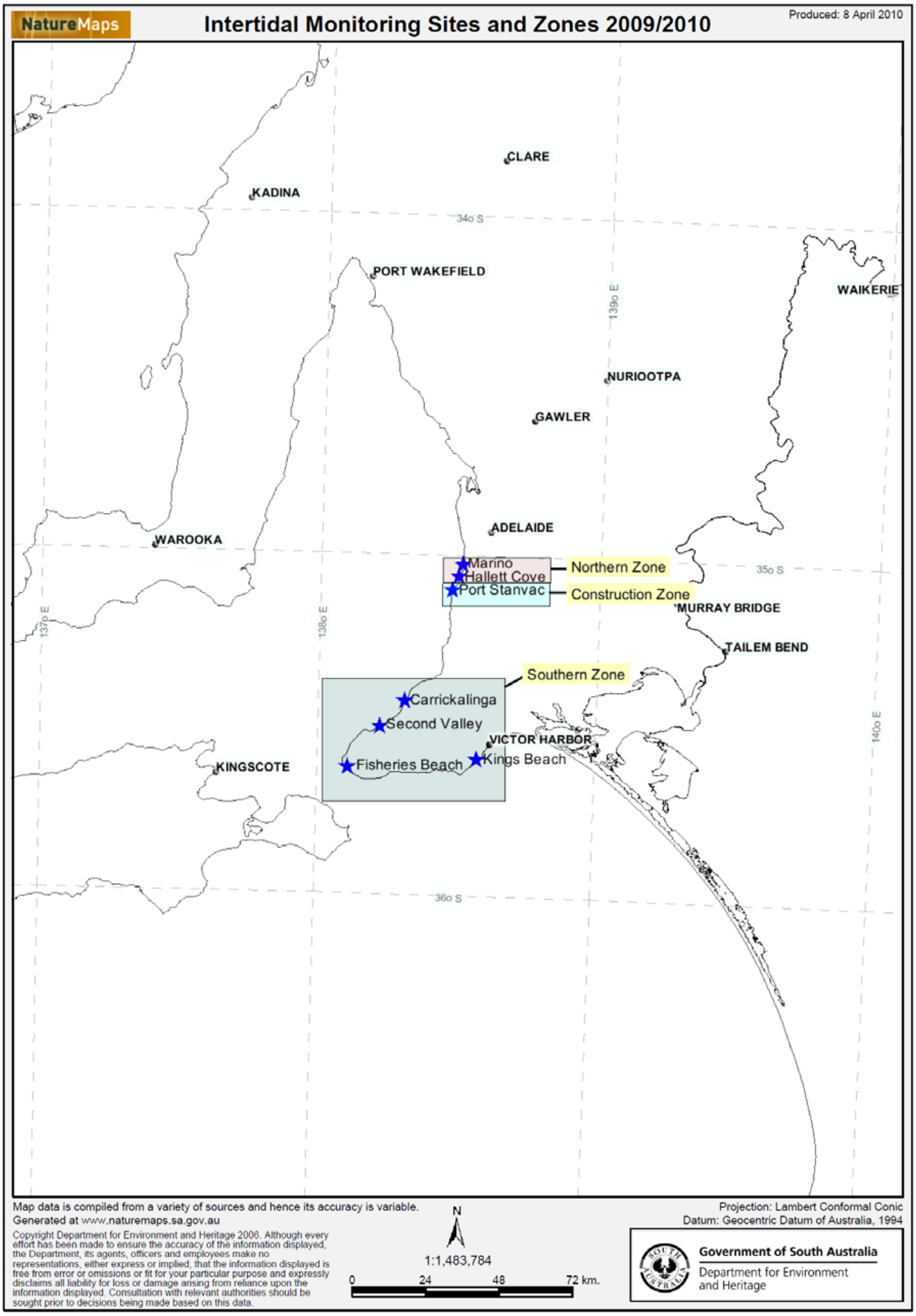
The intertidal assessment herein was undertaken as an initial sampling effort to obtain a 'before impact' dataset of the intertidal communities within the Port Stanvac Construction zone, as well as at northern and southern reference zones.

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 (Figure 1a and 1b) with reference locations located to the North at Marino Rocks and Hallett Cove (Figure 1a) and to the South at Carrickalinga, Second Valley, Fisheries Beach and Kings Beach (Figures 1a). Two 20 x 20 m plots were surveyed within the intertidal zone at each location, thus generating data from 22 specific sites. GPS coordinates were taken from the middle of each plot. All sites were surveyed during low tides in May (Autumn), August (Winter), November (Spring) and January (Summer) 2009/2010 (Table 1), using each of the methods outlined below.

(1a)



NatureMaps
Intertidal Monitoring Sites and Zones 2009/2010
Produced: 8 April 2010
CLARE
KADINA
34o S
PORT WAKEFIELD
WAIKERIE
139o E
NURIOOTPA
GAWLER
ADELAIDE
WAROOKA
Marino
Hallett Cove
Port Stanvac
Northern Zone
Construction Zone
35o S
MURRAY BRIDGE
TAILEM BEND
137o E
138o E
Southern Zone
Carrickalinga
Second Valley
VICTOR HARBOR
Fisheries Beach
Kings Beach
KINGSCOTE
140o E
36o S
Map data is compiled from a variety of sources and hence its accuracy is variable.
Generated at www.naturemaps.sa.gov.au
Copyright Department for Environment and Heritage 2006. Although every effort has been made to ensure the accuracy of the information displayed, the Department, its agents, officers and employees make no representations, either express or implied, that the information displayed is free from error or omissions or fit for your particular purpose and expressly disclaims all liability for loss or damage arising from reliance upon the information displayed. Consultation with relevant authorities should be sought prior to decisions being made based on this data.
N
1:1,483,784
0
24
48
72 km.
Projection: Lambert Conformal Conic
Datum: Geocentric Datum of Australia, 1994
Government of South Australia
Department for Environment and Heritage

(1b)

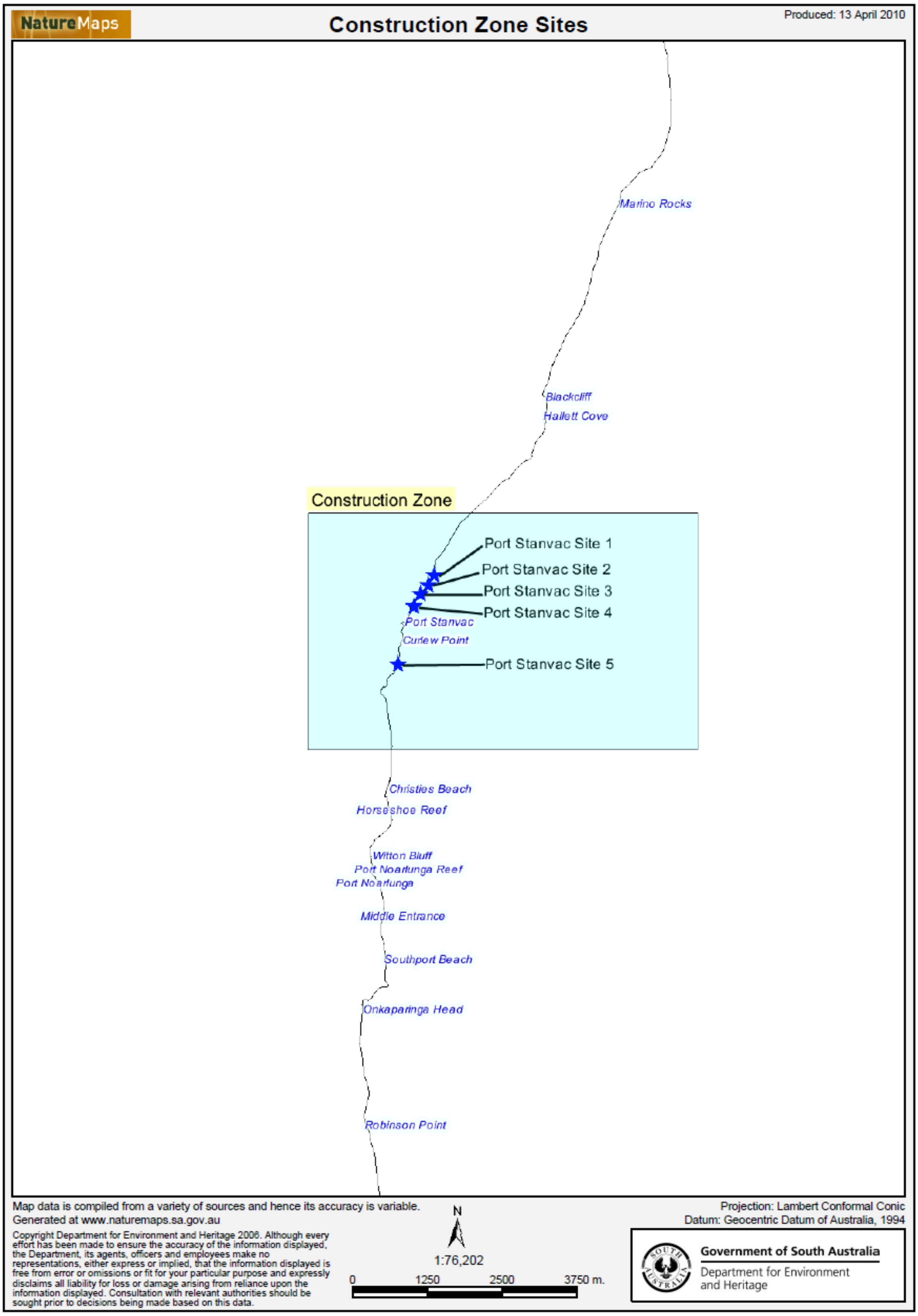


Figure 1: Intertidal sampling sites for the (a) Port Stanvac Construction Zone, Northern Reference Zone and Southern Reference Zone during 2009/2010 and (b) magnified snapshot of the five Sites within the Construction Zone for the 2009/2010 survey. Maps adapted from Nature Maps, Department of Environment 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 all four seasons in 2009/2010.

Location	GPS Co-ordinates South	East	Season	Date	Tidal Height (m)
Marino Rocks	S 35°02'45.6"	E 138°30'27.6"	Autumn	13/5/09	0.41
			Winter	11/8/09	0.56
			Spring	6/11/09	0.32
			Summer	19/1/10	0.16
Hallett Cove	S 35°05'06.2"	E 138°29'31.5"	Autumn	13/5/09	0.41
			Winter	11/8/09	0.56
			Spring	6/11/09	0.32
			Summer	22/1/10	0.26
Port Stanvac 1	S 35°06'48.8"	E 138°28'13.5"	Autumn	15/5/09	0.74
			Winter	12/8/09	0.61
			Spring	4/11/09	0.15
			Summer	14/1/10	0.30
Port Stanvac 2	S 35°06'28.4"	E 138°28'20.0"	Autumn	15/5/09	0.74
			Winter	10/8/09	0.53
			Spring	4/11/09	0.15
			Summer	20/1/10	0.18
Port Stanvac 3	S 35°06'15.4"	E 138°28'31.8"	Autumn	26/5/09	0.77
			Winter	10/8/09	0.53
			Spring	4/11/09	0.15
			Summer	20/1/10	0.18
Port Stanvac 4	S 35°06'12.4"	E 138°28'34.4"	Autumn	14/5/09	0.67
			Winter	12/8/09	0.61
			Spring	5/11/09	0.21
			Summer	15/1/10	0.22
Port Stanvac 5	S 35°06'25.7"	E 138°28'20.7"	Autumn	14/5/09	0.67
			Winter	07/8/09	0.60
			Spring	5/11/09	0.21
			Summer	15/1/10	0.22
Carrickalinga	S 35°25'09.0"	E 138°19'25.2"	Autumn	27/5/09	0.38
			Winter	27/8/09	0.69
			Spring	3/11/09	0.16
			Summer	12/1/10	0.69
Second Valley	S 35°30'36.3"	E 138°12'54.2"	Autumn	27/5/09	0.38
			Winter	26/8/09	0.61
			Spring	3/11/09	0.16
			Summer	12/1/10	0.69
Fisheries Beach	S 35°37'58.5"	E 138°06'49.4"	Autumn	28/5/09	0.50
			Winter	27/8/09	0.69
			Spring	3/11/09	0.16
			Summer	18/1/10	0.15
Kings Beach	S 35°36'13.6"	E 138°34'56.1"	Autumn	25/5/09	0.77
			Winter	26/8/09	0.61
			Spring	2/11/09	0.33
			Summer	18/1/10	0.36

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 0.25m^2 quadrats were randomly placed within each 20mx20m 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 1030SW / Tough8000 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*), 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 videoed 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 10cm 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 recorded 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 recorded and then transition from one type of organism cover to another was recorded along each transect to a resolution of 1cm. Total percent cover for each category, organism or substrate was subsequently calculated from the summed total distance covered, divided by the total length (20m). 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 20m were not always able to be obtained (in particular at Kings Beach 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

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 an index number closer to one. Pielou's index identifies the equitability of species presence at each site where a larger number indicates less evenness and Simpson's index is a measure of ecological diversity with infinite diversity decreasing from zero to one, indicating dominance of single species (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 and between Seasons. 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 for all four seasons were undertaken on quadrat abundance data to determine if there were similarities between Sites, Zones and Season. 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 levels, with a vector length set at 0.5 on Spearman Rank correlations. In order to distinguish the dissimilarities between invertebrate communities a PERMANOVA design was used, incorporating the factors of Zone, Sites nested within Zone, and Season. 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

Invertebrate Species Richness

In total, 45 species were recorded in the quadrat surveys across all sites and seasons (Appendix 1). There were some differences in the number of species recorded for each season with the highest number of species recorded in Winter and the lowest number recorded in Summer (Appendix 1). During Autumn, species richness was highest at the southern end of the Construction Zone at Port Stanvac (Sites 5a and 5b), due to a greater number of mollusc species compared to all other sites (Figure 2a). The lowest number of species was recorded at Marino (site 1) and Kings Beach (site 1) (Figure 2a). Crustaceans were solely represented by barnacles at most sites and only one species of annelid (*Galeolaria caespitosa*) was recorded at eight sites.

Species richness in Winter was greatest at four of the Construction Zone sites (Sites 1a, 1b, 4a and 5b) due to a higher number of mollusc species compared to all other sites (Figure 2b). Crustacea were represented by barnacles at all sites across the three Zones with the highest species richness recorded at Hallett Cove (site 1). The annelid species *G. caespitosa* was recorded at most sites in the Northern Reference and Construction Zones, yet completely absent from all sites in the Southern Reference Zone (Figure 2b).

In Spring, species richness was highest at Port Stanvac (Site 2c) due to a large number of mollusc species and the representation of four separate taxonomic groups (i.e. Crustacea, Mollusca, Annelida and Cnidaria; Figure 2c). In addition, another species of Annelida (*Pomatoceros taenita*) was recorded at some of the Port Stanvac sites (Sites 1a, 5a and 5b), which had not been identified in the two previous seasons. Low species richness (< 5 species) was recorded at most of the sites in the Southern Reference Zone with the exception of Second Valley (Site 1), Fisheries Beach (Site 2) and Kings Beach (Site 2). All sites in the Northern Zone had similar species richness with only a small range between the lowest and highest numbers recorded (6 to 10 species; Figure 2c).

During Summer, species richness was highest at Port Stanvac (Sites 2a and 2b) with molluscs contributing most to the total species recorded (Figure 2d). All other sites within the Construction and The Northern Reference Zones had similar species richness (11-13 species) with the exception of Port Stanvac Site 5b. In comparison species richness at sites in the Southern Reference Zone was generally low, except Second Valley Site1 and both of the Kings Beach sites (Figure 2d).

Invertebrate Species Diversity

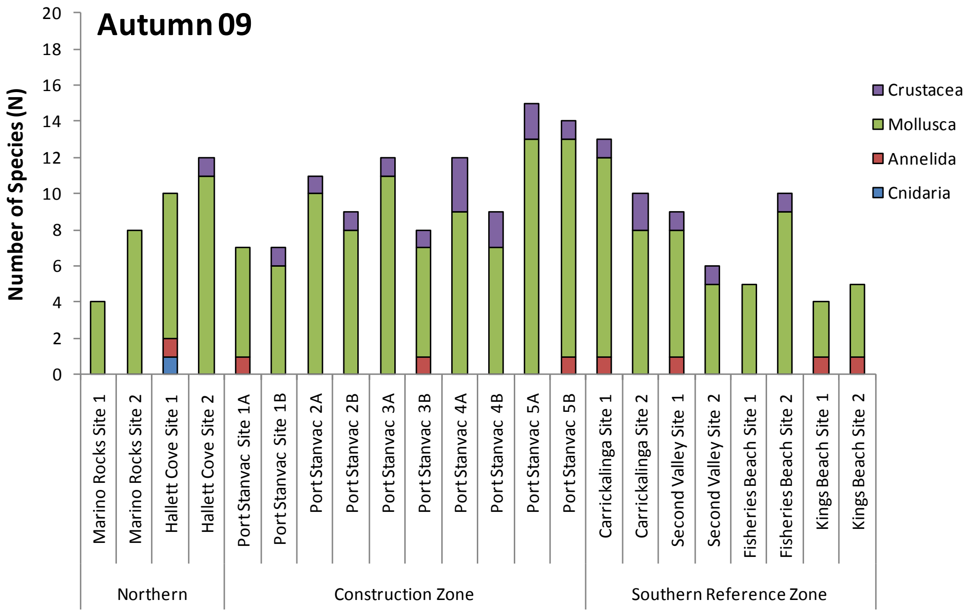
The diversity indices calculated for Autumn indicated that most sites in the Construction Zone (except Port Stanvac 5) had high Shannon-Wiener diversity values and uneven distribution according to Pielou's Index (Table 2a). Simpson's Index was high for two sites in the Construction Zone (Port Stanvac Sites 2 and 3), indicating species dominance (*Chthalamus antennatus* and *Nerita atramentosa*; Site 2, *C. antennatus* and *Austrolittorina unifasciata*; site 3, Appendix 1a) at both sites. In comparison, the Northern Reference Zone sites had high diversity with an even distribution of species (Table 2a). The Southern Reference Zone also showed a similar pattern of high diversity with an even species distribution at Carrickalinga, Second Valley and Fisheries Beach. However, low species diversity was recorded at Kings Beach (Table 2a).

Winter diversity indices showed high Shannon-Wiener values for all sites within the Construction Zone (except Port Stanvac 5), however the sites of Port Stanvac 1 and 3 had uneven species distributions and high Simpson's Indices (Table 2b) indicating species dominance (*Siphonaria diemenensis* and *Phasianellidae* spp.; site 1, *C. antennatus*; site 3, Appendix 1b). In the Northern Reference Zone both sites had high species diversity with uneven distribution, which was due to the dominance of multiple species at both sites (Table 2b). For the Southern Reference Zone, both Carrickalinga and Second Valley had high species diversity with an even distribution of species, whereas the species diversity at Fisheries Beach and Kings Beach was very low in comparison (Table 2b).

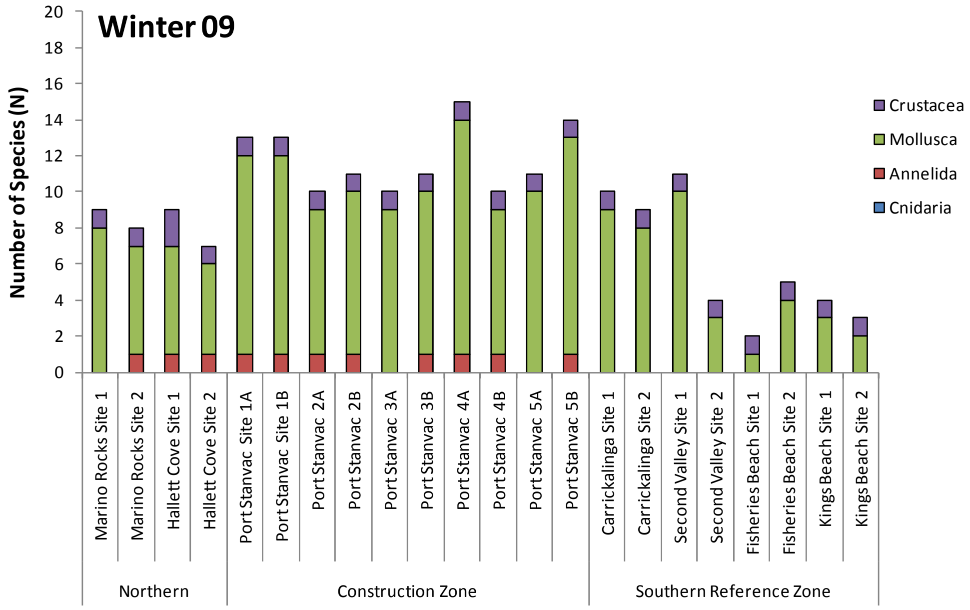
In Spring, three of the Construction Zone sites (Port Stanvac 2, 3 and 5) had high Shannon-Wiener diversity indices with slightly uneven species distribution indicating some species dominance (*C. antennatus* and *S. diemenensis* at all three sites; Appendix 1c) (Table 2c). For the Northern Reference Zone, Hallett Cove had high species diversity with a relatively even distribution, whereas the species diversity at Marino was very low (Table 2c). In the Southern Reference Zone, Second Valley had the highest Shannon-Wiener diversity index with an uneven Pielou's value and a relatively high Simpson's Index indicated that there was some species dominance at this site (*A. unifasciata*; Appendix 1c) (Table 2c).

During the Summer survey, the highest Shannon-Wiener index for the Construction Zone sites was identified at Port Stanvac 4, which had an uneven species distribution (Table 2d) due to the dominance of the barnacle species *Chamaesipho tasmanica* (Appendix 1d). In comparison, the Port Stanvac 2 site also had high species diversity, however there was an even species distribution throughout this site. Hallett Cove had the highest species diversity index within the Northern Reference Zone, with an uneven distribution and high Simpson's Index (Table 2d) due to the dominance of *N. atramentosa* (Appendix 1d). In the Southern Reference Zone, the high species diversity and uneven species distribution at Fisheries Beach (Table 2d) was due to the dominance of *S. diemenensis* across this site (Appendix 1d). Diversity at all other sites within the Southern Reference Zone was low in comparison.

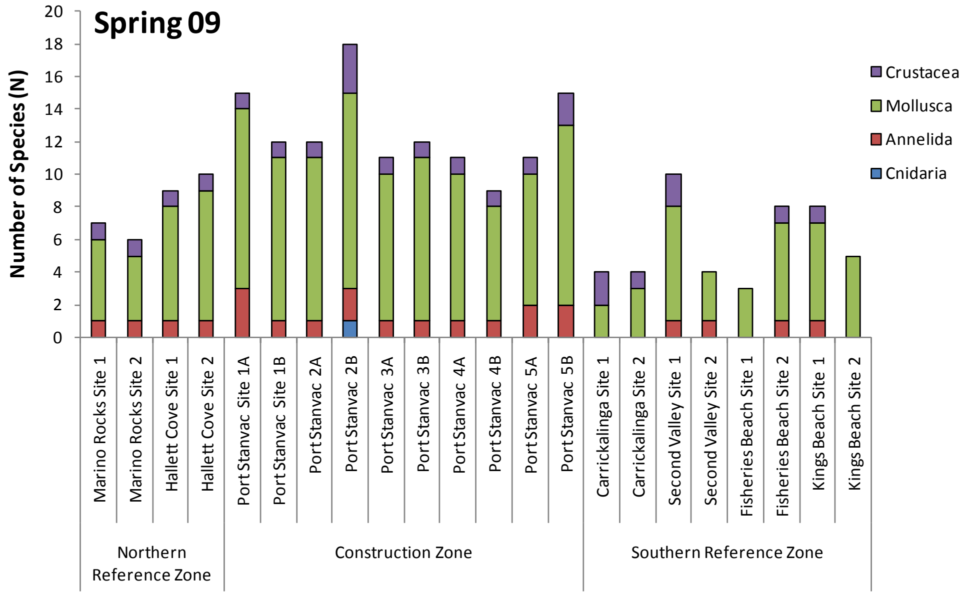
(a)


Autumn 09
Number of Species (N)
20
18
16
14
12
10
8
6
4
2
0
Crustacea
Mollusca
Annelida
Cnidaria
Marino Rocks Site 1
Marino Rocks Site 2
Hallett Cove Site 1
Hallett Cove Site 2
Port Stanvac Site 1A
Port Stanvac Site 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 Site 1
Carrickalinga Site 2
Second Valley Site 1
Second Valley Site 2
Fisheries Beach Site 1
Fisheries Beach Site 2
Kings Beach Site 1
Kings Beach Site 2
Northern
Construction Zone
Southern Reference Zone

(b)


Winter 09
Number of Species (N)
20
18
16
14
12
10
8
6
4
2
0
Crustacea
Mollusca
Annelida
Cnidaria
Marino Rocks Site 1
Marino Rocks Site 2
Hallett Cove Site 1
Hallett Cove Site 2
Port Stanvac Site 1A
Port Stanvac Site 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 Site 1
Carrickalinga Site 2
Second Valley Site 1
Second Valley Site 2
Fisheries Beach Site 1
Fisheries Beach Site 2
Kings Beach Site 1
Kings Beach Site 2
Northern
Construction Zone
Southern Reference Zone

(c)



(d)

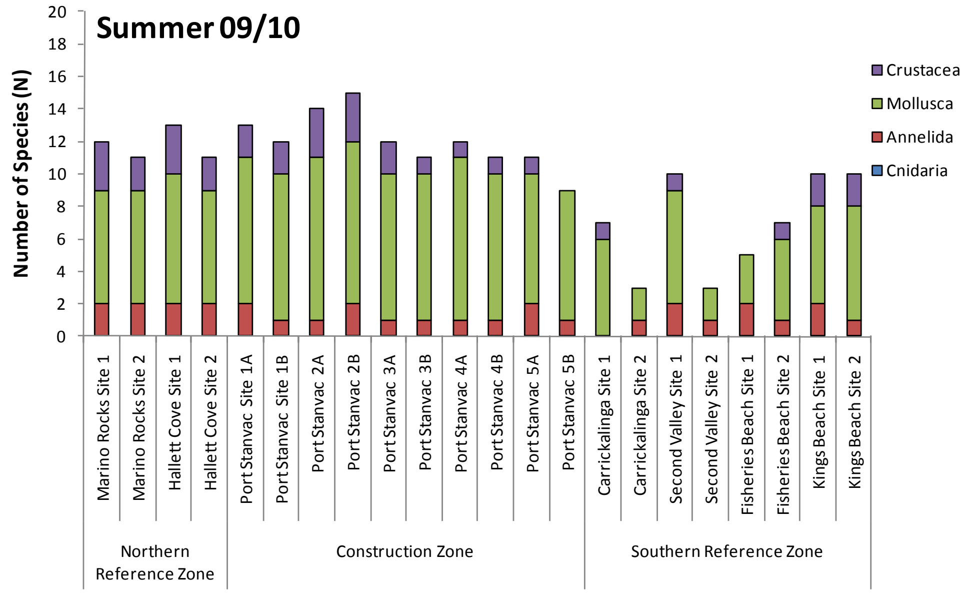


Figure 2: Total species number per phyla identified in quadrats during the (a) 2009 Autumn, (b) 2009 Winter, (c) 2009 Spring and (d) 2009/2010 Summer intertidal survey for all sites encompassing three Zones; Northern Reference Zone, Construction Zone and Southern Reference Zone.

Table 2: Diversity indices for the (a) Autumn, (b) Winter, (c) Spring and (d) Summer intertidal survey during 2009. *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	6 (2.8)	61.5 (30.4)	1.06 (0.39)	0.61 (0.06)	0.53 (0.16)
Hallett Cove	10.5 (2.1)	122 (72.1)	1.36 (0.14)	0.58 (0.01)	0.65 (0.05)
Port Stanvac 1	6.5 (0.7)	53.5 (7.8)	1.14 (0.08)	0.61 (0.01)	0.60 (0.00)
Port Stanvac 2	10 (1.4)	136 (52.3)	1.78 (0.05)	0.77 (0.03)	0.79 (0.00)
Port Stanvac 3	9.5 (3.5)	163 (89.1)	1.64 (0.02)	0.75 (0.14)	0.77 (0.04)
Port Stanvac 4	10.5 (2.1)	979 (1176.6)	1.25 (0.61)	0.55 (0.31)	0.59 (0.25)
Port Stanvac 5	13.5 (2.1)	1791.5 (878.9)	0.57 (0.11)	0.22 (0.06)	0.25 (0.03)
Carrickalinga	10.5 (0.7)	190.5 (72.8)	1.28 (0.28)	0.54 (0.10)	0.59 (0.12)
Second Valley	7 (1.4)	139 (151.3)	0.90 (0.50)	0.48 (0.31)	0.42 (0.31)
Fisheries Beach	7 (2.8)	71 (58)	1.29 (0.24)	0.68 (0.02)	0.66 (0.04)
Kings Beach	3.5 (0.7)	93 (14.1)	0.22 (0.10)	0.17 (0.05)	0.09 (0.04)

(b)

Site	S	N	Shannon-Weiner	Pielou's evenness	Simpson
Marino	12 (1.4)	125 (5.7)	1.93 (0.14)	0.82 (0.02)	0.84 (0.03)
Hallett Cove	11 (0)	124.5 (9.1)	1.99 (0.30)	0.74 (0.12)	0.78 (0.07)
Port Stanvac 1	18 (1.4)	321 (22.6)	2.13 (0.05)	0.74 (0.00)	0.82 (0.00)
Port Stanvac 2	13 (0)	353 (2.8)	1.34 (0.17)	0.52 (0.07)	0.56 (0.09)
Port Stanvac 3	15.5 (3.5)	147.5 (40.3)	2.07 (0.28)	0.76 (0.04)	0.82 (0.05)
Port Stanvac 4	16 (1.4)	914.5 (115.3)	1.27 (0.22)	0.46 (0.06)	0.62 (0.09)
Port Stanvac 5	13.5 (2.1)	2097.5 (1539.4)	0.82 (0.16)	0.31 (0.04)	0.37 (0.03)
Carrickalinga	8 (0)	191.5 (186)	1.06 (0.19)	0.51 (0.09)	0.51 (0.11)
Second Valley	8.5 (6.4)	162 (162.6)	0.96 (0.08)	0.52 (0.18)	0.47 (0.07)
Fisheries Beach	3.5 (2.1)	86 (118.8)	0.50 (0.27)	0.60 (0.57)	0.56 (0.62)
Kings Beach	2 (1.4)	356 (123)	0.02 (0.03)	0.02 (0.03)	0.01 (0.01)

(c)

Site	S	N	Shannon-Wiener	Pielou's evenness	Simpson
Marino	4.5 (0.7)	235.5 (178.9)	0.60 (0.00)	0.40 (0.04)	0.30 (0.01)
Hallett Cove	7.5 (0.7)	300 (196.6)	1.13 (0.33)	0.56 (0.19)	0.56 (0.19)
Port Stanvac 1	11 (1.4)	913.5 (344.4)	0.66 (0.16)	0.27 (0.05)	0.30 (0.05)
Port Stanvac 2	12.5 (3.5)	784.5 (48.8)	1.38 (0.37)	0.55 (0.08)	0.67 (0.12)
Port Stanvac 3	9.5 (0.7)	1010 (75.0)	1.51 (0.18)	0.67 (0.06)	0.71 (0.05)
Port Stanvac 4	8 (1.4)	1359.5 (384.0)	0.98 (0.22)	0.47 (0.07)	0.50 (0.16)
Port Stanvac 5	10 (2.8)	1603.5 (283.5)	1.34 (0.01)	0.59 (0.07)	0.65 (0.00)
Carrickalinga	4 (0.0)	238.5 (17.7)	0.86 (0.18)	0.62 (0.13)	0.50 (0.12)
Second Valley	6 (4.2)	68 (63.6)	1.19 (0.36)	0.76 (0.14)	0.63 (0.07)
Fisheries Beach	5 (2.8)	104.5 (95.5)	0.76 (0.07)	0.53 (0.16)	0.38 (0.04)
Kings Beach	5 (1.4)	324.5 (81.3)	0.43 (0.36)	0.25 (0.18)	0.21 (0.20)

(d)

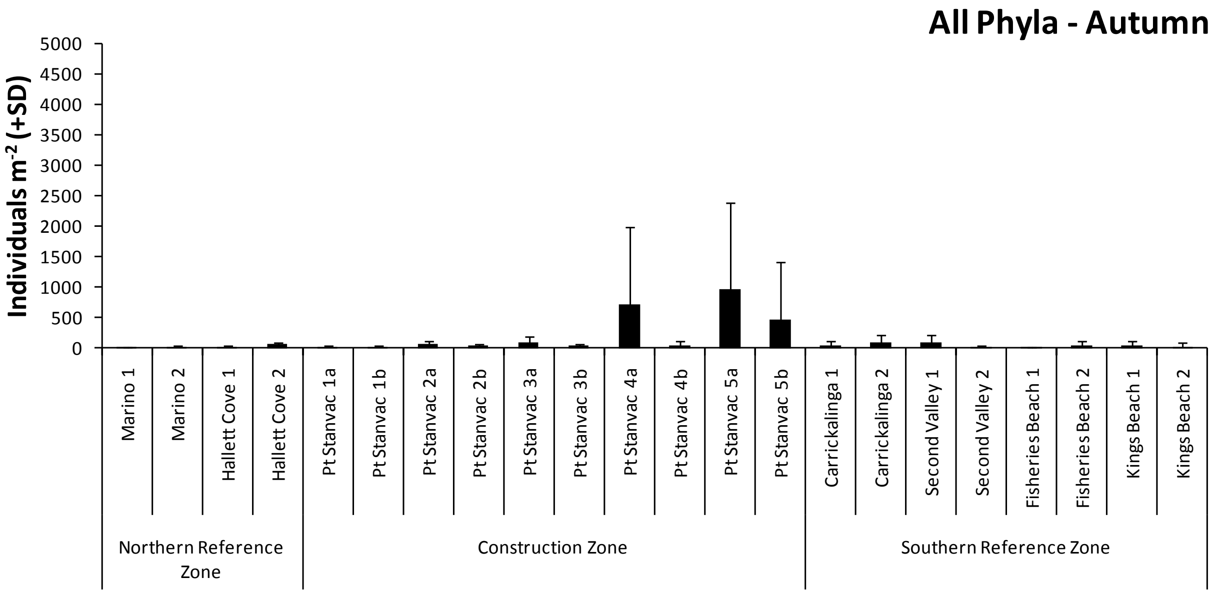
Site	S	N	Shannon-Wiener	Pielou's evenness	Simpson
Marino	7.5 (0.7)	328.5 (251)	0.70 (0.36)	0.34 (0.16)	0.32 (0.19)
Hallett Cove	9 (1.4)	46 (0.0)	1.63 (0.03)	0.74 (0.04)	0.73 (0.02)
Port Stanvac 1	11 (1.4)	1295 (401.6)	0.75 (0.13)	0.31 (0.07)	0.35 (0.08)
Port Stanvac 2	12 (0.0)	635 (314)	1.24 (0.17)	0.50 (0.07)	0.57 (0.11)
Port Stanvac 3	12.5 (0.7)	771 (374.8)	0.62 (0.03)	0.25 (0.02)	0.24 (0.02)
Port Stanvac 4	9.5 (3.5)	2767 (2996.7)	1.40 (0.19)	0.65 (0.20)	0.68 (0.12)
Port Stanvac 5	10 (0.0)	1184.5 (832.3)	0.51 (0.02)	0.22 (0.01)	0.20 (0.01)
Carrickalinga	3.5 (2.1)	24 (17)	0.87 (0.33)	0.80 (0.16)	0.54 (0.08)
Second Valley	3.5 (3.5)	11 (14.1)	0.78 (1.10)	0.87 (0.00)	0.80 (0.00)
Fisheries Beach	6.5 (0.7)	52 (7.1)	1.33 (0.10)	0.72 (0.09)	0.68 (0.07)
Kings Beach	7 (2.8)	413 (17)	0.55 (0.53)	0.27 (0.22)	0.24 (0.25)

Photo Quadrat Invertebrate Abundance

All Phyla

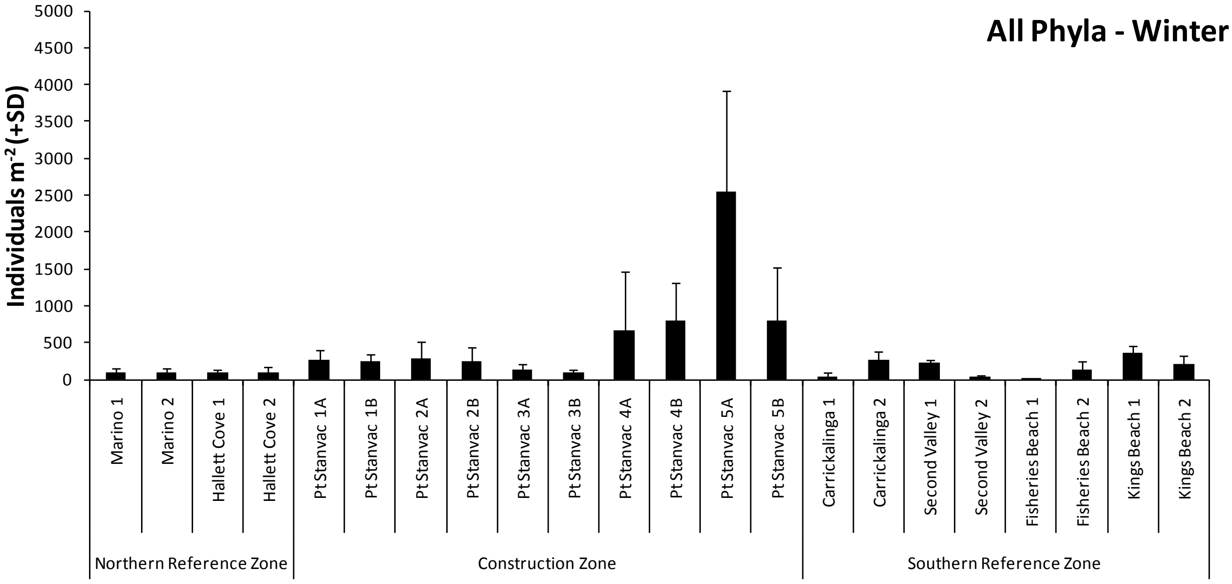
During Autumn, the highest number of individuals per m^2 for all phyla occurred in the southern most sites of Port Stanvac, (Sites 4a, 5a and 5b; Figure 3a) with no significant difference occurring between Zones (Pseudo - *F* = 2.1649; *P* (perm) = 0.1635). Although no significant difference was detected (Pseudo - *F* = 3.8236; *P* (perm) = 0.06), individual abundance generally increased at most sites during Winter, with the highest amount of individuals per m^2 recorded at the southern Sites of Port Stanvac (Figure 3b). During Spring, a reduction in the number of individuals per m^2 was observed at sites within the southern end of the Construction Zone, with less variation occurring between sites (Figure 3c). Significant differences were detected between Zones (Pseudo - *F* = 39.052; *P* (perm) = 0.0013) with a pair-wise test revealing significant differences between the Northern Reference Zone and Construction Zone (t = 6.2239; *P* (MC) = 0.0015), as well as between the Construction Zone and the Southern Reference Zone (t = 8.4224; *P* (MC) = 0.0001). Abundances throughout Summer were similar to those observed during Spring, with slightly higher variation within the Construction Zone (Figure 3d). Similar to the Spring data, significant differences between Zones were also detected (Pseudo - *F* = 17.071; *P* (perm) = 0.0023). A pair-wise test revealed that significant differences occurred between the Northern Reference and Construction Zones (t = 2.6152; *P* (MC) = 0.0415), as well as the Construction Zone and the Southern Reference Zone (t = 5.8297; *P* (MC) = 0.0006).

(a)



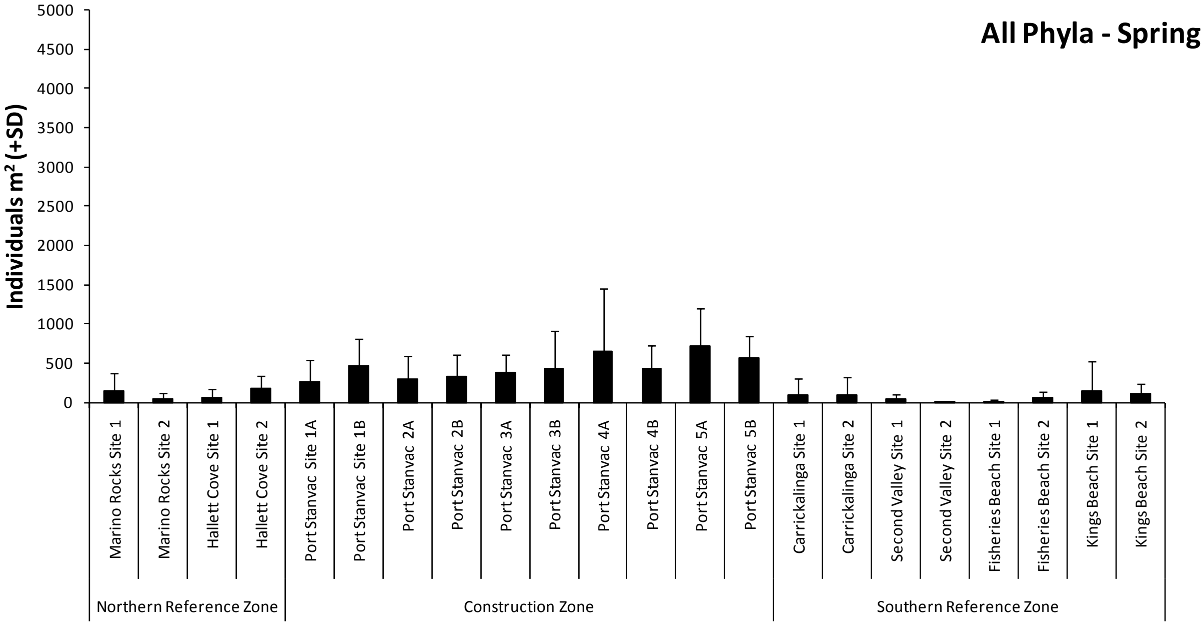
All Phyla - Autumn
Individuals m-2 (+SD)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Marino 1
Marino 2
Hallett Cove 1
Hallett Cove 2
Pt Stanvac 1a
Pt Stanvac 1b
Pt Stanvac 2a
Pt Stanvac 2b
Pt Stanvac 3a
Pt Stanvac 3b
Pt Stanvac 4a
Pt Stanvac 4b
Pt Stanvac 5a
Pt Stanvac 5b
Carrickalinga 1
Carrickalinga 2
Second Valley 1
Second Valley 2
Fisheries Beach 1
Fisheries Beach 2
Kings Beach 1
Kings Beach 2
Northern Reference Zone
Construction Zone
Southern Reference Zone

(b)



All Phyla - Winter
Individuals m-2 (+SD)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Marino 1
Marino 2
Hallett Cove 1
Hallett Cove 2
Pt Stanvac 1A
Pt Stanvac 1B
Pt Stanvac 2A
Pt Stanvac 2B
Pt Stanvac 3A
Pt Stanvac 3B
Pt Stanvac 4A
Pt Stanvac 4B
Pt Stanvac 5A
Pt Stanvac 5B
Carrickalinga 1
Carrickalinga 2
Second Valley 1
Second Valley 2
Fisheries Beach 1
Fisheries Beach 2
Kings Beach 1
Kings Beach 2
Northern Reference Zone
Construction Zone
Southern Reference Zone

(c)



(d)

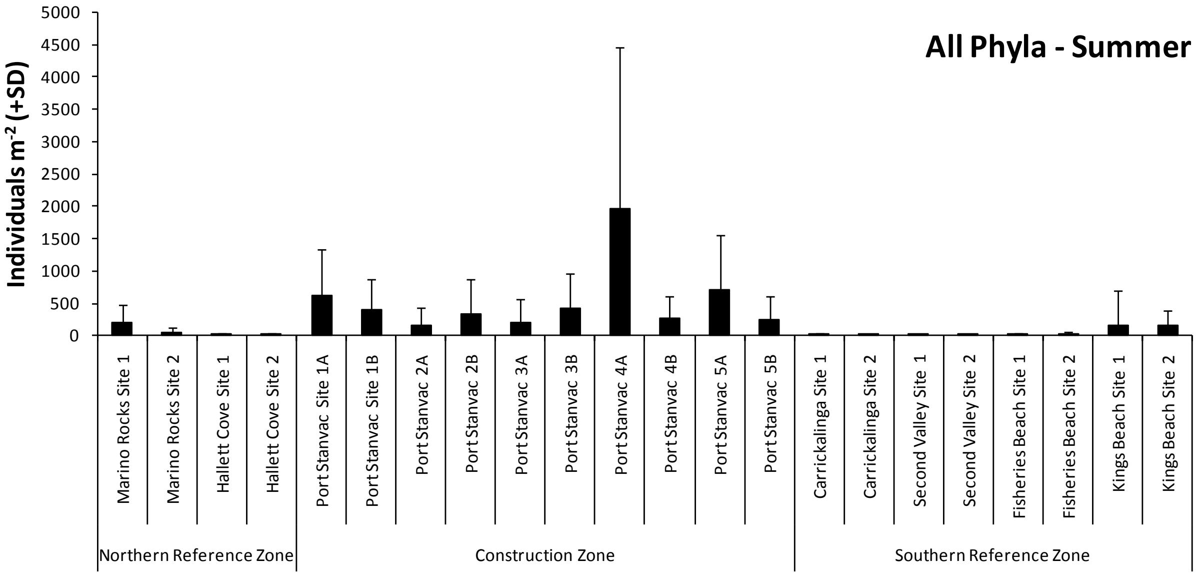
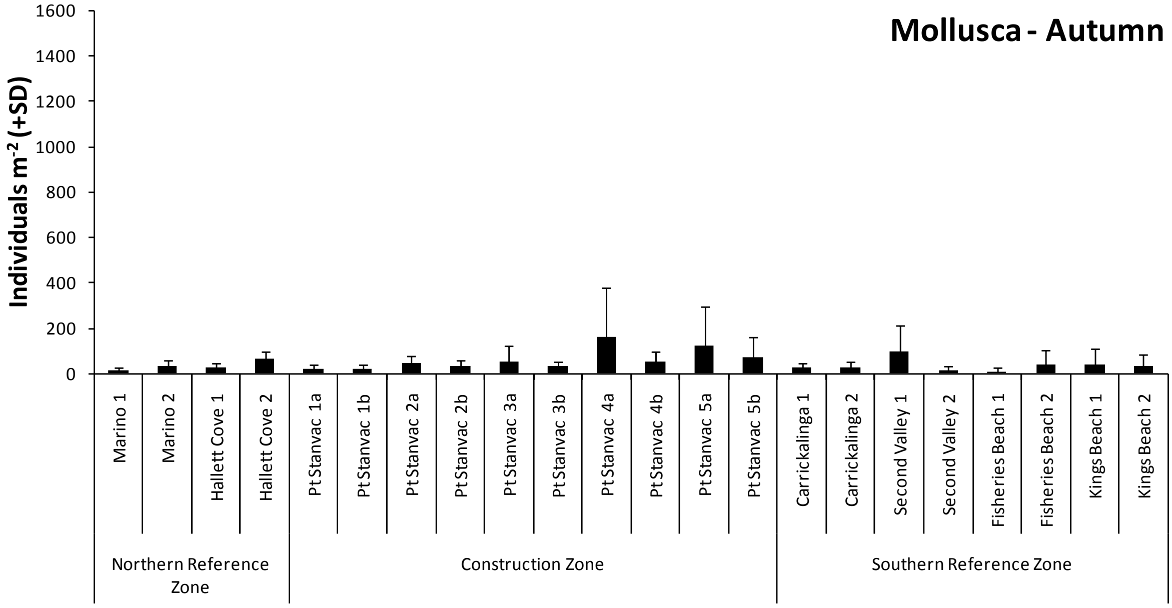


Figure 3: Mean abundances and standard deviations (SD) for all phyla identified in photo quadrats (n=10) from the (a) Autumn, (b) Winter, (c) Spring and (d) Summer surveys at all sites encompassing three zones; Northern Reference Zone, Construction Zone and Southern Reference Zone during 2009/2010.

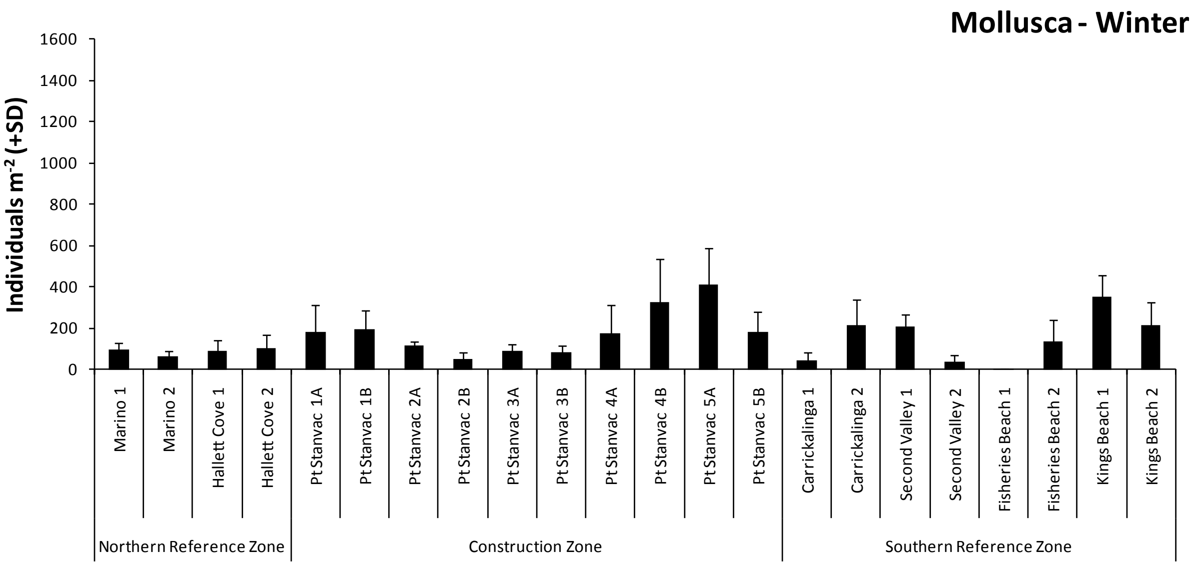
Mollusca

During Autumn there was little variation in the number of molluscs per m^2 between sites and zones, with no significant difference occurring between Zones (Pseudo-*F* = 3.0389; *P* (perm) = 0.0999). Individual abundances were low in comparison to other seasons, with the highest density of Mollusca occurring at Port Stanvac Sites 4a, 5a, 5b and Second Valley Site 1 (Figure 4a). Throughout Winter higher individual abundances were detected at every site, with the exception of two sites (Port Stanvac 4a and Fisheries Beach 1) where individuals per m^2 were lower than the previous Autumn survey (Figure 4b). However, despite changes in individual abundances at all sites, no significant difference was detected between Zones (Pseudo-*F* = 1.2731; *P* (perm) = 0.3321). Mollusc densities were greatest during Spring and Summer, with an increase in the mean number of individuals per m^2 occurring during these seasons for both the Northern reference and Construction zones (Figures 4c and 4d). A significant difference was detected between Zones during Spring (Pseudo-*F* = 30.516; *P* (perm) = 0.0009), with a pair-wise test further revealing significant differences between the Northern Reference and Construction Zones (t =4.8086; *P* (MC) = 0.0044), as well as the Construction and Southern Reference Zones (t =7.603; *P* (MC) = 0.0002). An overall reduction in the mean number of individuals at sites within the Southern Reference Zone occurred throughout Summer and a significant difference was detected between Zones (Pseudo-*F* = 26.549; *P* (perm) = 0.0005), with a pair-wise test revealing a significant difference between the Construction and Southern Reference Zone (t =7.3058; *P* (MC) = 0.0002). The Port Stanvac sites contained the greatest number of molluscs per m^2 throughout all seasons and also the greatest variation in abundance between seasons. The lowest variation in individual abundance occurred in the Southern reference zone, with no noticeable increases in individuals per m^2 throughout the Spring and Summer seasons, inconsistent with the trend at other sites.

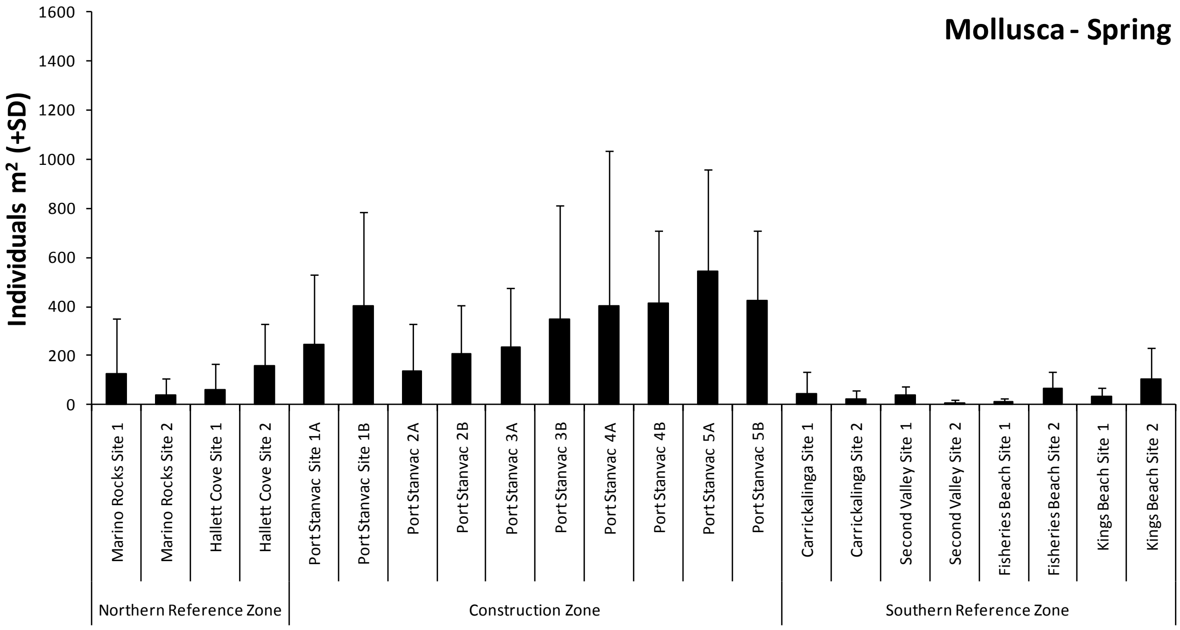
(a)


Mollusca - Autumn
Individuals m-2 (+SD)
1600
1400
1200
1000
800
600
400
200
0
Marino 1
Marino 2
Hallett Cove 1
Hallett Cove 2
Pt Stanvac 1a
Pt Stanvac 1b
Pt Stanvac 2a
Pt Stanvac 2b
Pt Stanvac 3a
Pt Stanvac 3b
Pt Stanvac 4a
Pt Stanvac 4b
Pt Stanvac 5a
Pt Stanvac 5b
Carrickalinga 1
Carrickalinga 2
Second Valley 1
Second Valley 2
Fisheries Beach 1
Fisheries Beach 2
Kings Beach 1
Kings Beach 2
Northern Reference Zone
Construction Zone
Southern Reference Zone

(b)


Mollusca - Winter
Individuals m-2 (+SD)
1600
1400
1200
1000
800
600
400
200
0
Marino 1
Marino 2
Hallett Cove 1
Hallett Cove 2
Pt Stanvac 1A
Pt Stanvac 1B
Pt Stanvac 2A
Pt Stanvac 2B
Pt Stanvac 3A
Pt Stanvac 3B
Pt Stanvac 4A
Pt Stanvac 4B
Pt Stanvac 5A
Pt Stanvac 5B
Carrickalinga 1
Carrickalinga 2
Second Valley 1
Second Valley 2
Fisheries Beach 1
Fisheries Beach 2
Kings Beach 1
Kings Beach 2
Northern Reference Zone
Construction Zone
Southern Reference Zone

(c)



(d)

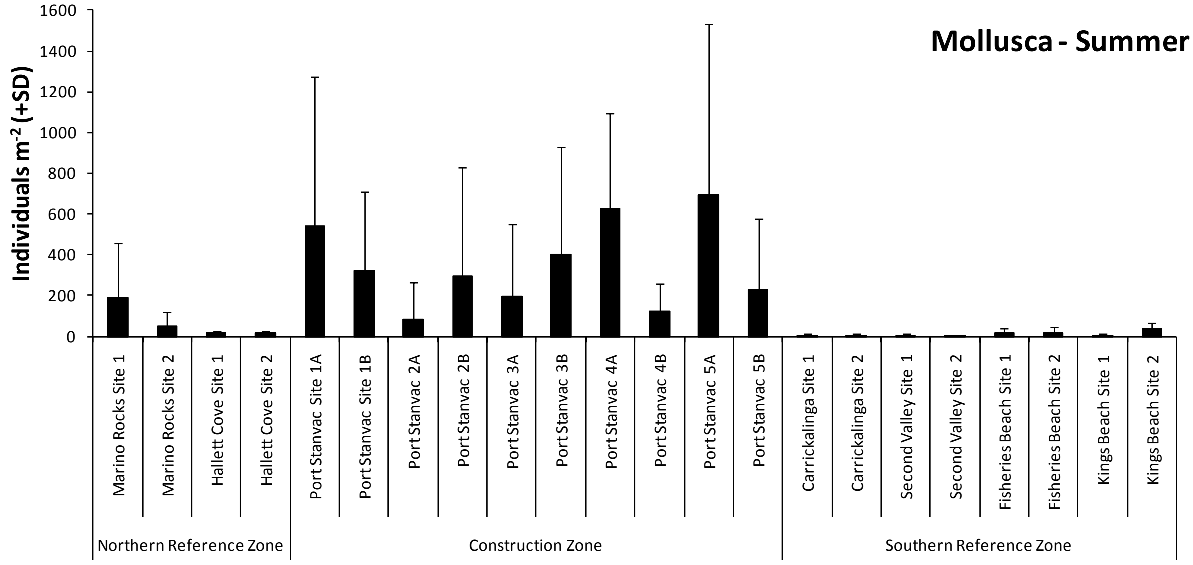
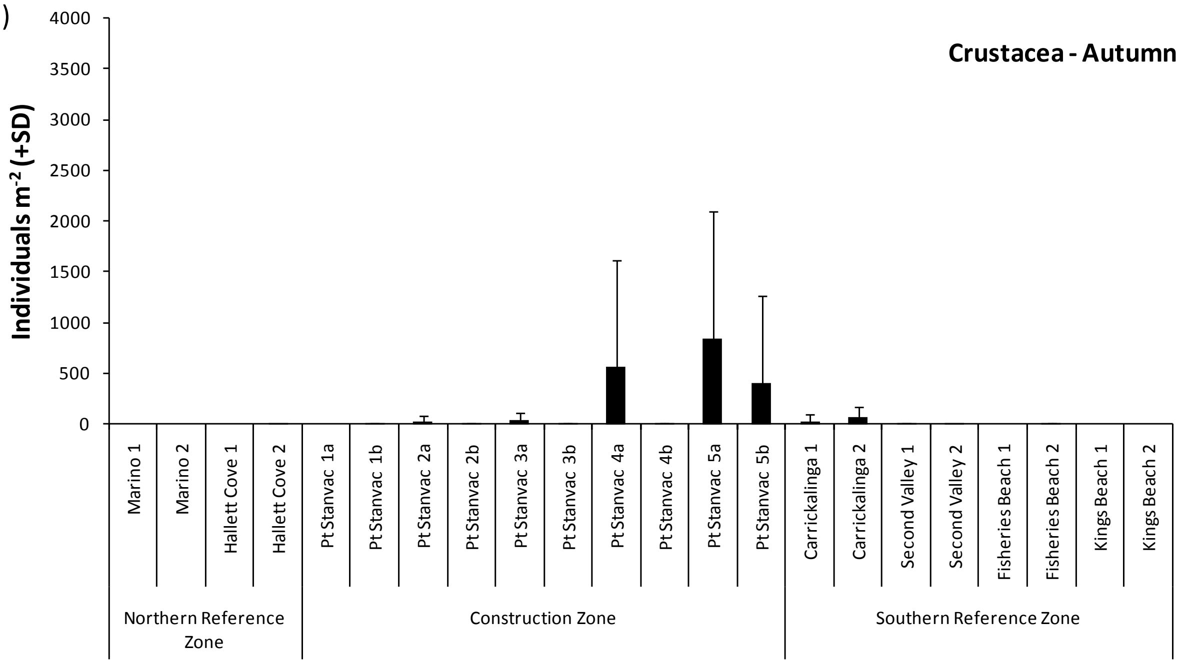


Figure 4: Mean abundances and standard deviations (SD) for Mollusca identified from photo quadrats (n=10) in the (a) Autumn, (b) Winter, (c) Spring and (d) Summer surveys at all sites encompassing three zones; Northern Reference Zone, Construction Zone and Southern Reference Zone during 2009/2010.

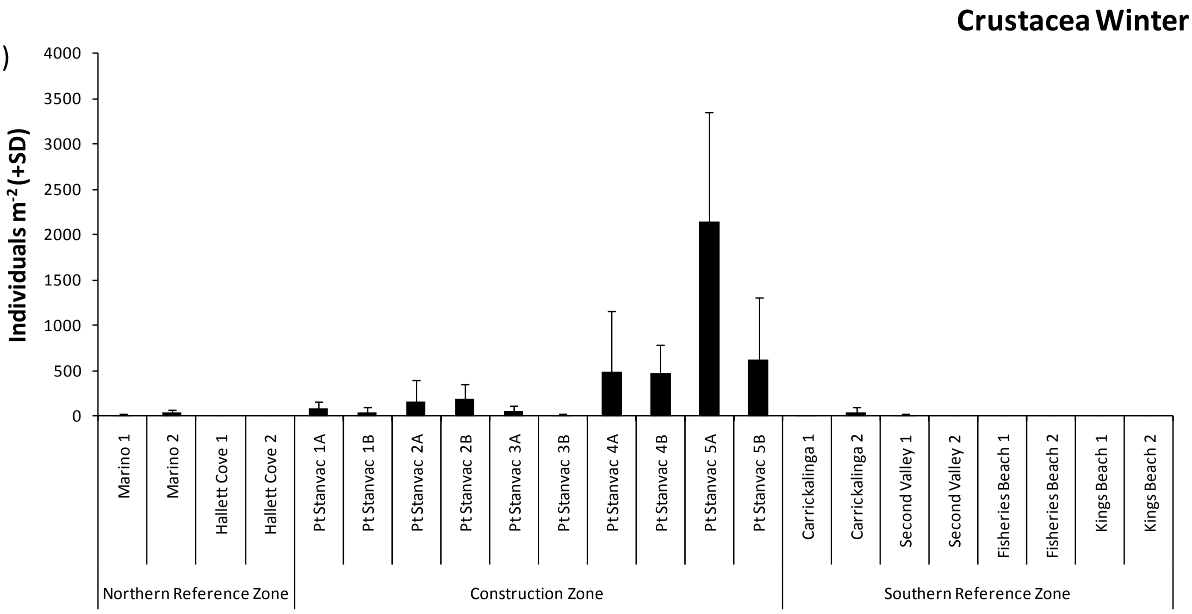
Crustacea

During Autumn, the highest abundance of Crustacea occurred at the most southern sites in the Construction Zone, Port Stanvac sites 4a, 5a and 5b, while Crustacea were absent from the Northern Reference Zone (Figure 5a). No significant difference was detected between Zones during Autumn (Pseudo-F = 1.7763; P (perm) = 0.1967). Throughout Winter, Crustacea were recorded at more sites and in higher densities than during the Autumn survey with a significant difference occurring between Zones (Pseudo-F = 6.0798; P (perm) = 0.0212). The highest abundances occurred at the most Southern sites of the Construction zone (Figure 5b) with pair-wise test revealing a significant difference between the Construction and Southern reference Zone (t =3.0725; P (MC) = 0.0197). During Spring, Crustacea were more prevalent than the previous seasons, being recorded at all but 3 sites. However, when compared to previous surveys a decrease in individuals per m^2 was observed within the Construction Zone with less variability between sites and zones (Figure 5c). PERMANOVA revealed a difference between Zones (Pseudo-F = 24.153; P (perm) = 0.0007) with a pair-wise test confirming a significant differences occurring between the Northern and Construction Zone (t = 3.7609; P (MC) = 0.0129) and the Construction and Southern Zone (t = 6.2563; P (MC) = 0.0002). During Summer there was greater variability in the abundance of Crustacea between sites (Figure 5d). However, no significant difference was observed in the distribution within zones throughout Summer (t = 6.2563; P (MC) = 0.0002).

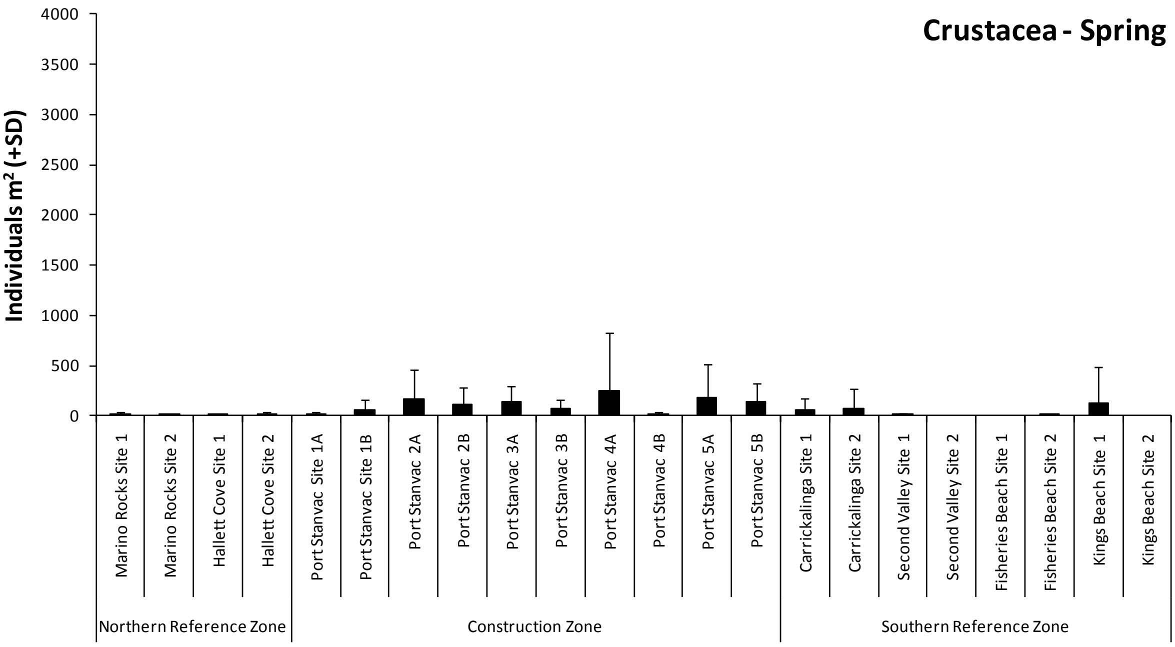
(a)


Crustacea - Autumn
Individuals m-2 (+SD)
4000
3500
3000
2500
2000
1500
1000
500
0
Marino 1
Marino 2
Hallett Cove 1
Hallett Cove 2
Pt Stanvac 1a
Pt Stanvac 1b
Pt Stanvac 2a
Pt Stanvac 2b
Pt Stanvac 3a
Pt Stanvac 3b
Pt Stanvac 4a
Pt Stanvac 4b
Pt Stanvac 5a
Pt Stanvac 5b
Carrickalinga 1
Carrickalinga 2
Second Valley 1
Second Valley 2
Fisheries Beach 1
Fisheries Beach 2
Kings Beach 1
Kings Beach 2
Northern Reference Zone
Construction Zone
Southern Reference Zone

(b)


Crustacea Winter
Individuals m-2 (+SD)
4000
3500
3000
2500
2000
1500
1000
500
0
Marino 1
Marino 2
Hallett Cove 1
Hallett Cove 2
Pt Stanvac 1A
Pt Stanvac 1B
Pt Stanvac 2A
Pt Stanvac 2B
Pt Stanvac 3A
Pt Stanvac 3B
Pt Stanvac 4A
Pt Stanvac 4B
Pt Stanvac 5A
Pt Stanvac 5B
Carrickalinga 1
Carrickalinga 2
Second Valley 1
Second Valley 2
Fisheries Beach 1
Fisheries Beach 2
Kings Beach 1
Kings Beach 2
Northern Reference Zone
Construction Zone
Southern Reference Zone

(c)



(d)

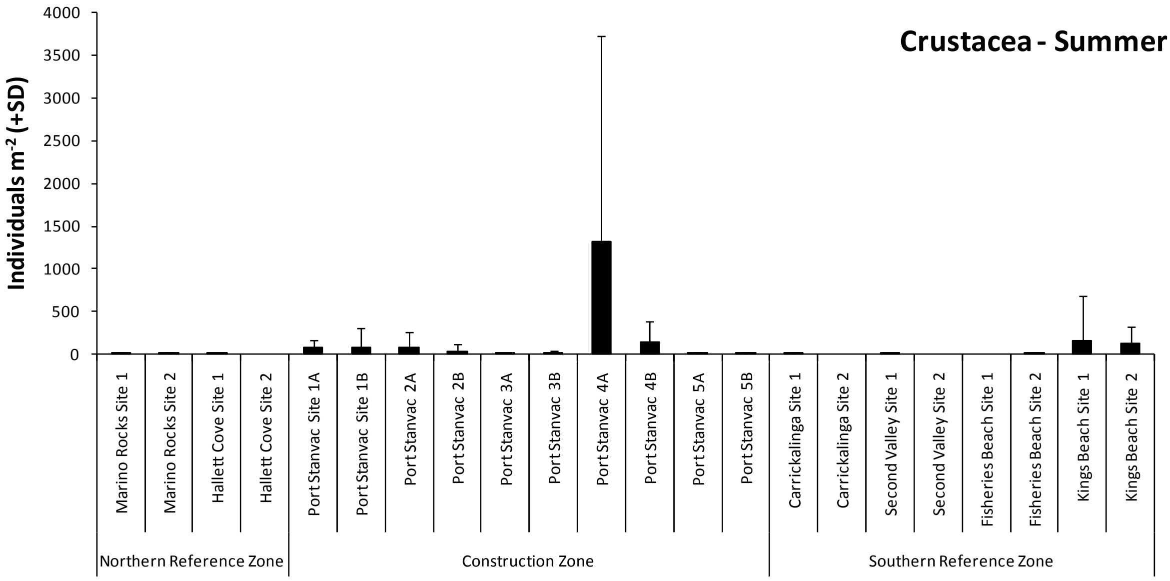


Figure 5: Mean abundances and standard deviations (SD) for Crustacea identified from photo quadrats (n=10) in the (a) Autumn, (b) Winter, (c) Spring and (d) Summer surveys at all sites encompassing three zones; Northern Reference Zone, Construction Zone and Southern Reference Zone during 2009/2010.

Photo Quadrat Percent Cover

Galeolaria caespitosa

The highest percent cover *G. caespitosa* occurred during Autumn at Port Stanvac 5b, Carrickalinga 1 and Second Valley 1 (Figure 6a). However, percent cover was highly variable within sites, as indicated by large standard deviations. The lowest prevalence of *G. caespitosa* occurred during Winter, being recorded in only 7 sites and not recorded within the Southern Reference Zone (Figure 6b). The smallest percent cover of *G. caespitosa* occurred during Spring (Figure 6c) and Summer (Figure 6d), with little variation and smaller percent cover between sites.

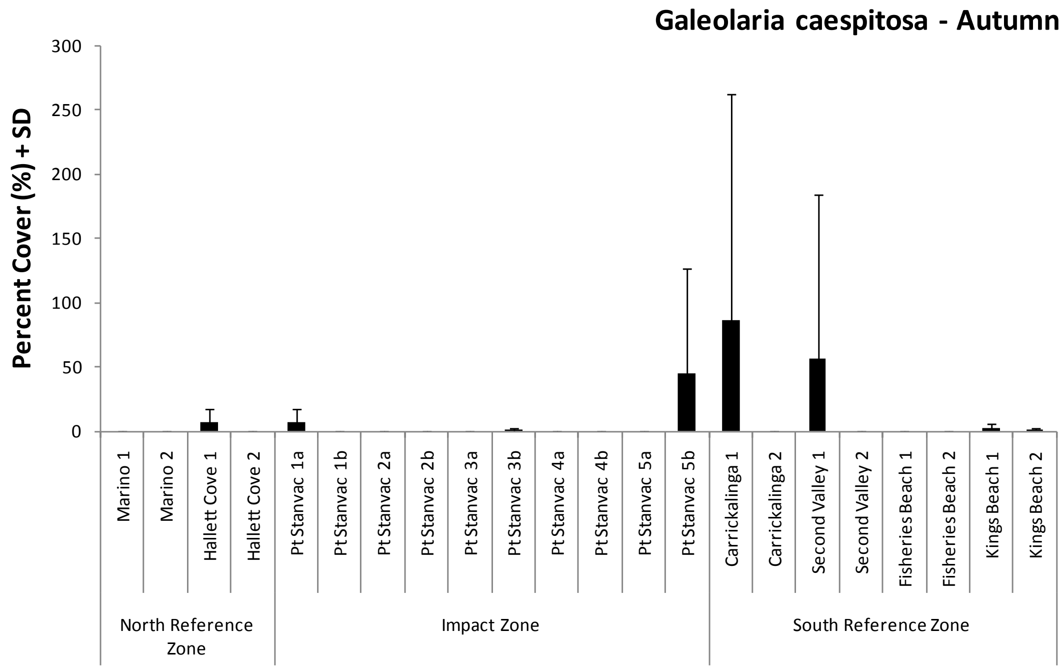
Pomatoceros taenita

Pomatoceros taenita was first detected during Spring, occurring at sites within the Construction and Southern Reference Zone, while not being observed at any site within the Northern Reference Zone (Figure 7a). *P. taenita* was more prevalent during Summer, being recorded in all zones at higher densities than the previous season (Figure 7b).

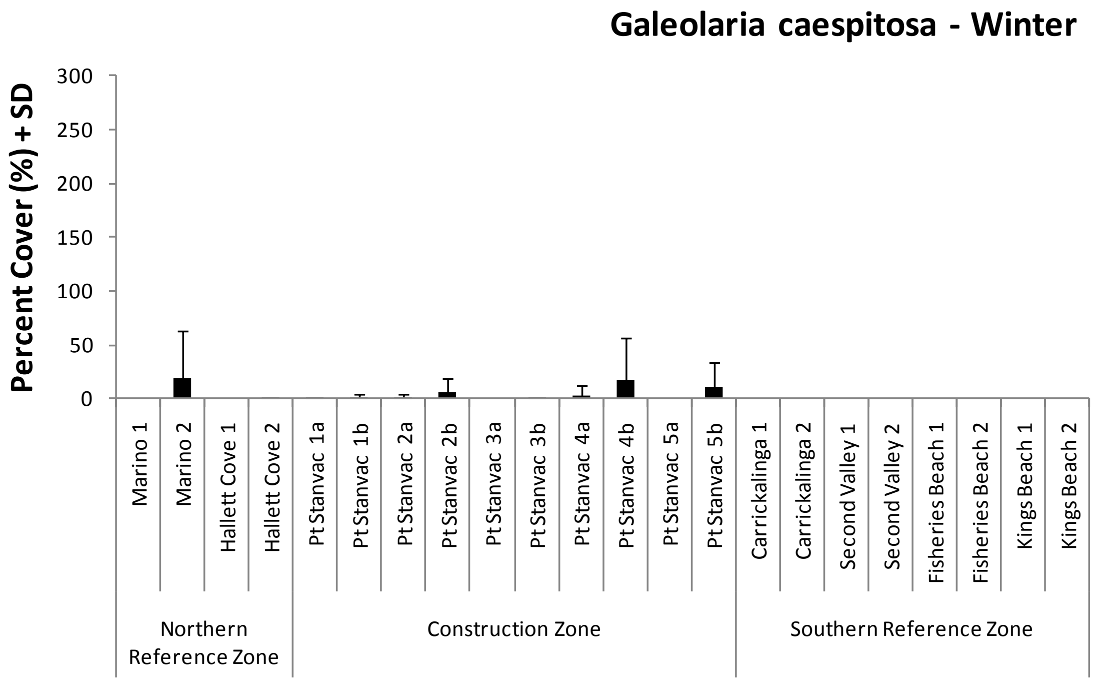
Limnoperna pulex

In Autumn, *Limnoperna pulex* was recorded at one site in the Southern Reference Zone (Carrickalinga 1), while being unobserved at all sites within the Northern Reference and Construction zones (Figure 8a). In Winter, *L. pulex* was recorded at 4 sites within the Construction Zone, Port Stanvac 2b, 4a, 5a and 5b (Figure 8b). *L. pulex* was most dominant during Spring, with the species being recorded at all sites within the Northern and Construction Zones, as well as Kings Beach 1 and 2 in the Southern Reference Zone (Figure 8c). During Summer, *L. pulex* was absent from all sites within the Southern Reference Zone and overall percent cover was lower than the previous season (Figure 8d).

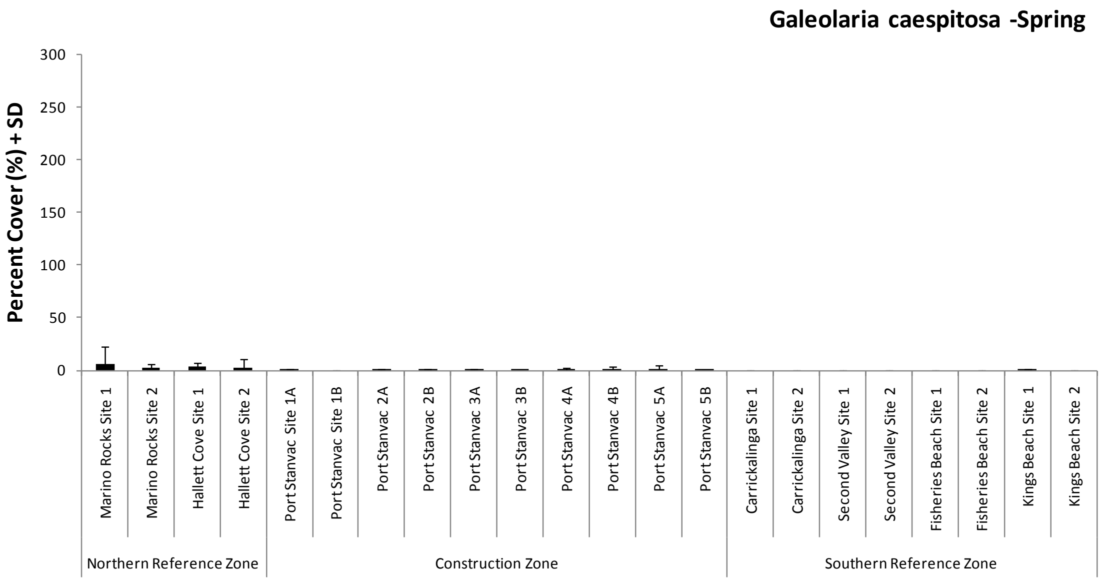
(a)


Galeolaria caespitosa - Autumn
Percent Cover (%) + SD
300
250
200
150
100
50
0
Marino 1
Marino 2
Hallett Cove 1
Hallett Cove 2
Pt Stanvac 1a
Pt Stanvac 1b
Pt Stanvac 2a
Pt Stanvac 2b
Pt Stanvac 3a
Pt Stanvac 3b
Pt Stanvac 4a
Pt Stanvac 4b
Pt Stanvac 5a
Pt Stanvac 5b
Carrickalinga 1
Carrickalinga 2
Second Valley 1
Second Valley 2
Fisheries Beach 1
Fisheries Beach 2
Kings Beach 1
Kings Beach 2
North Reference Zone
Impact Zone
South Reference Zone

(b)


Galeolaria caespitosa - Winter
Percent Cover (%) + SD
300
250
200
150
100
50
0
Marino 1
Marino 2
Hallett Cove 1
Hallett Cove 2
Pt Stanvac 1a
Pt Stanvac 1b
Pt Stanvac 2a
Pt Stanvac 2b
Pt Stanvac 3a
Pt Stanvac 3b
Pt Stanvac 4a
Pt Stanvac 4b
Pt Stanvac 5a
Pt Stanvac 5b
Carrickalinga 1
Carrickalinga 2
Second Valley 1
Second Valley 2
Fisheries Beach 1
Fisheries Beach 2
Kings Beach 1
Kings Beach 2
Northern Reference Zone
Construction Zone
Southern Reference Zone

(c)



(d)

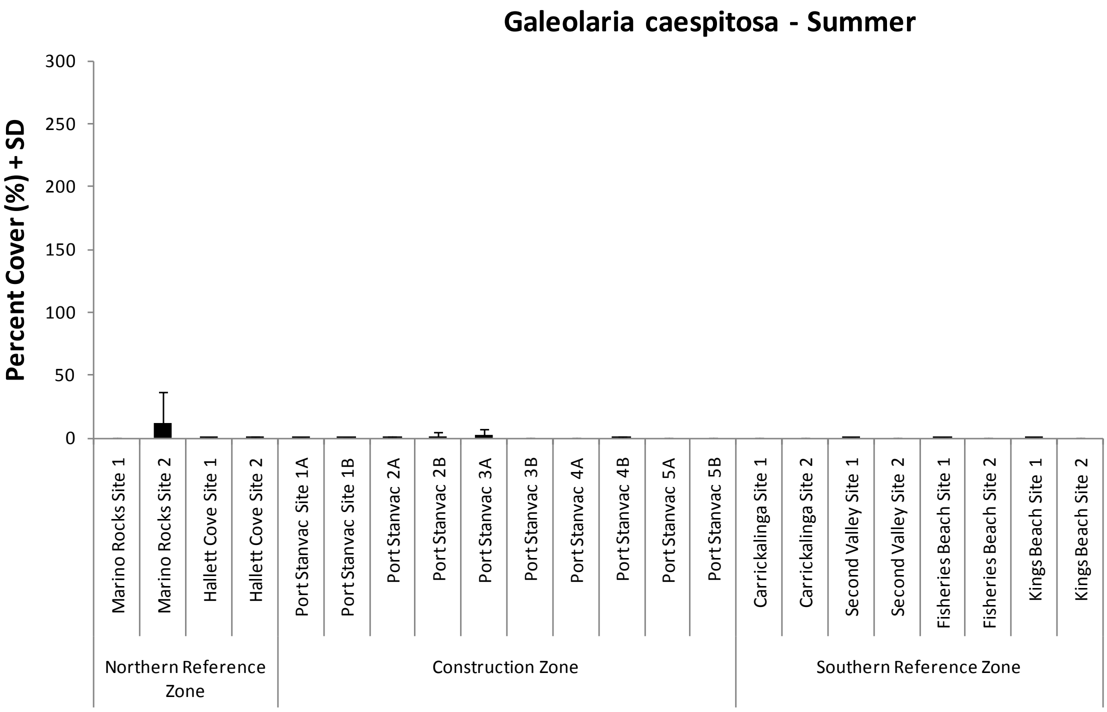
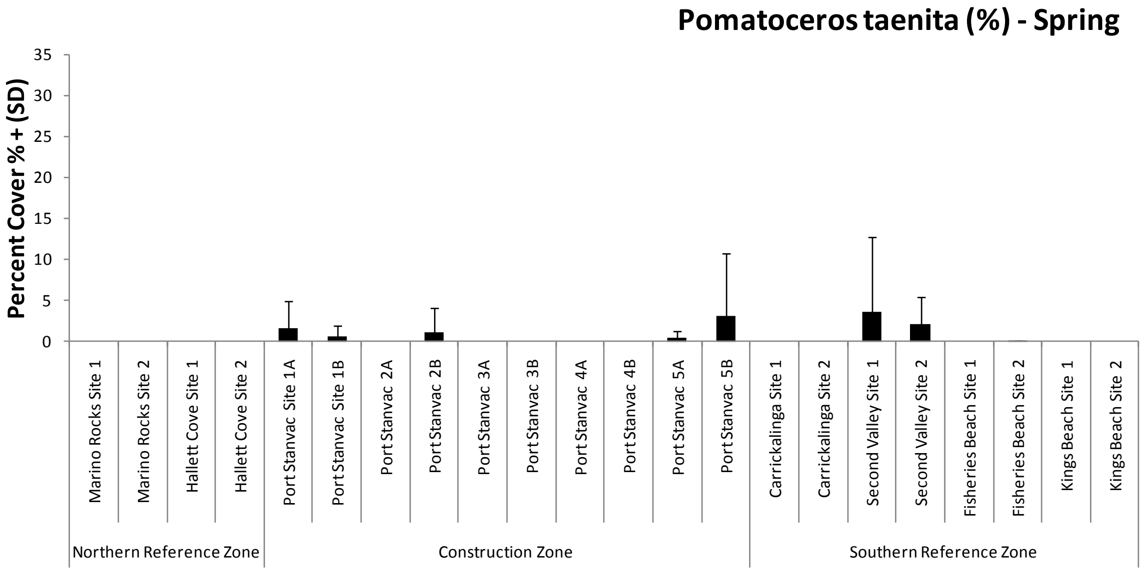


Figure 6: Mean percent cover and standard deviations (SD) for the polychaete tubeworm *Galeolaria caespitosa* identified from photo quadrats (n=10) in the (a) Autumn, (b) Winter, (c) Spring and (d) Summer surveys at all sites encompassing three zones; Northern Reference Zone, Construction Zone and Southern Reference Zone during 2009/2010.

(a)



(b)

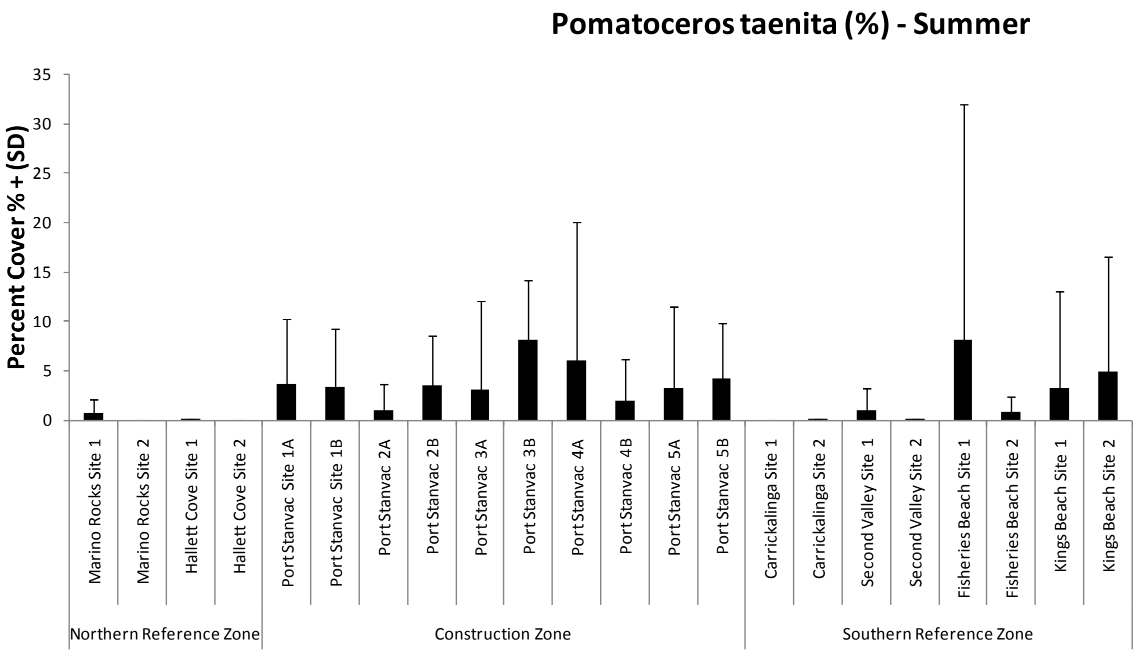
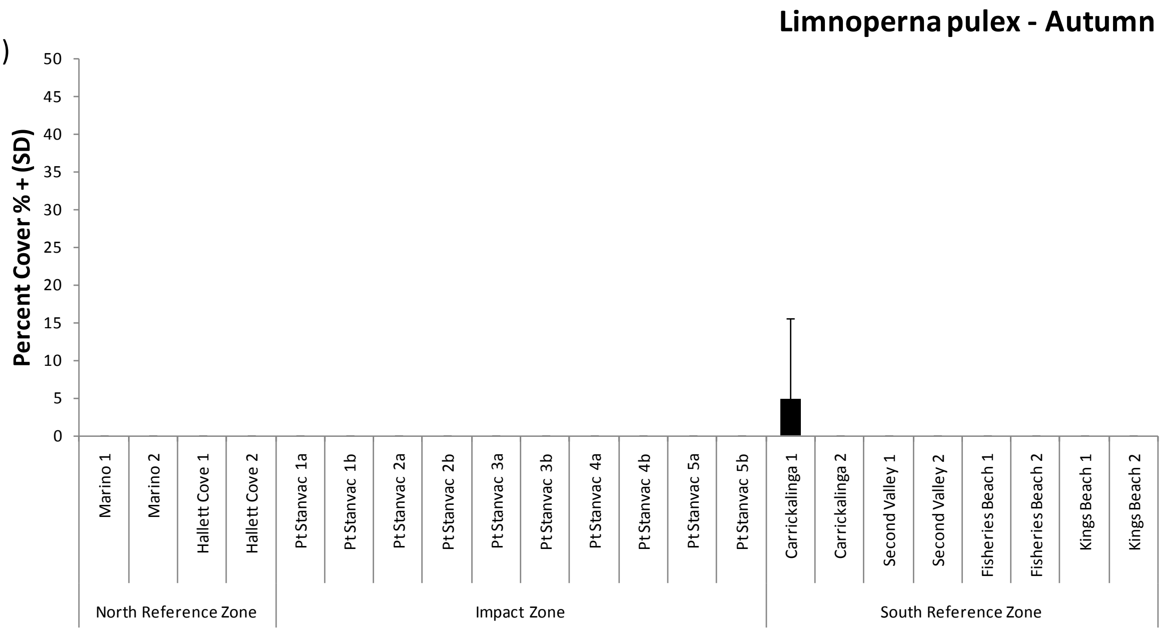
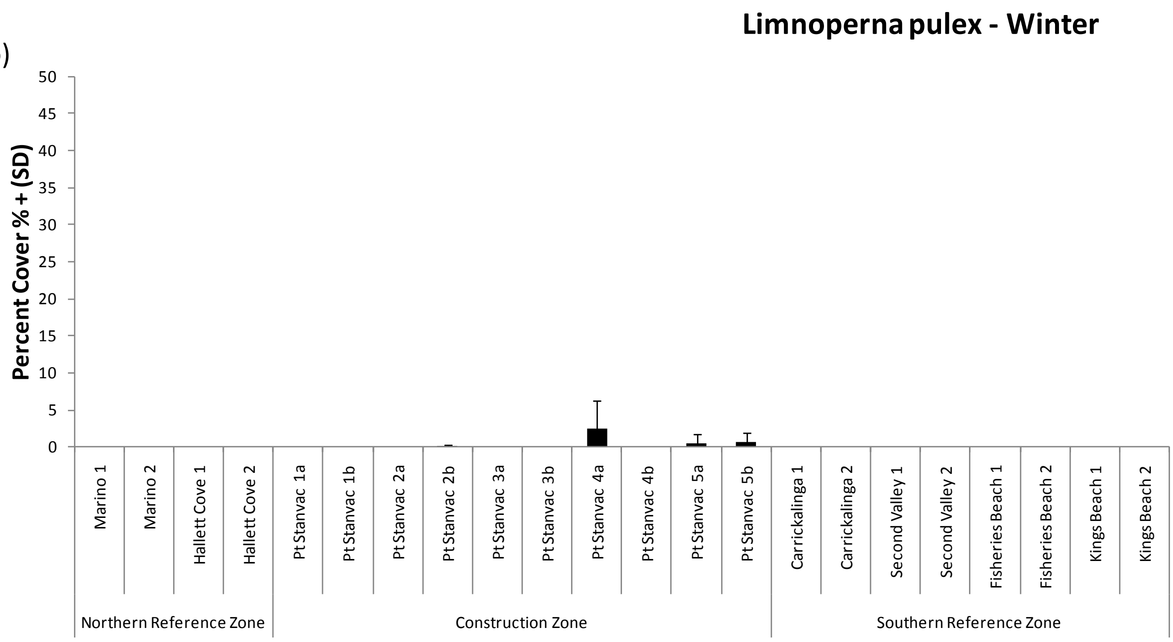


Figure 7: Mean percent cover and standard deviations (SD) for the polychaete tubeworm *Pomatoceros taenita* identified from photo quadrats (n=10) in the (a) Spring and (b) Summer surveys at all sites encompassing three zones; Northern Reference Zone, Construction Zone and Southern Reference Zone during 2009/2010.

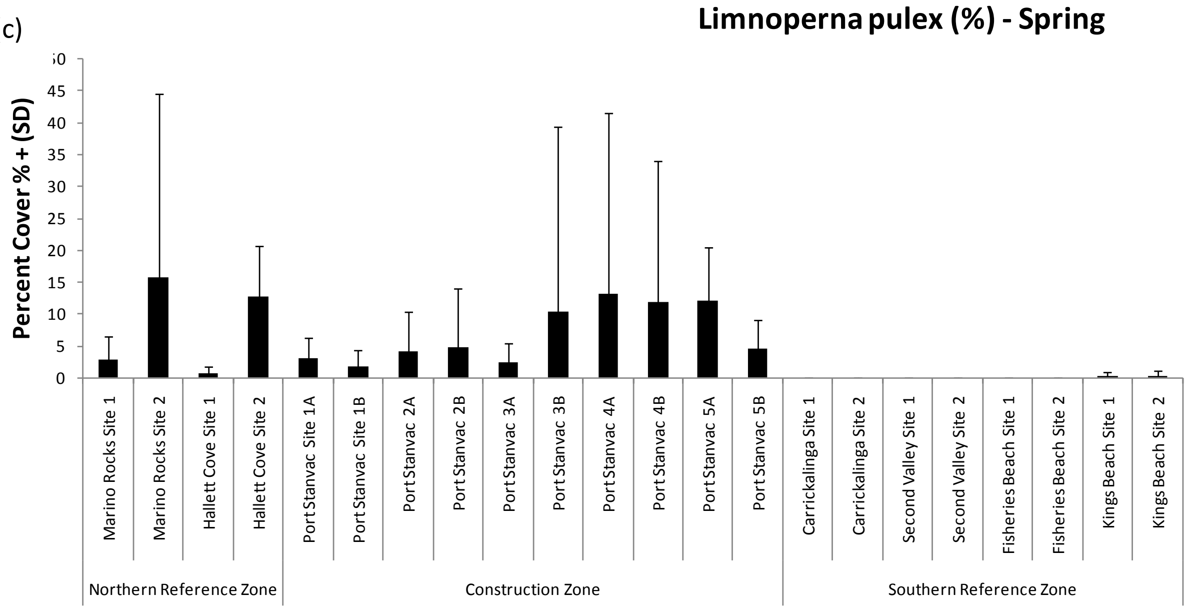
(a)


Limnoperna pulex - Autumn
Percent Cover % + (SD)
50
45
40
35
30
25
20
15
10
5
0
Marino 1
Marino 2
Hallett Cove 1
Hallett Cove 2
Pt Stanvac 1a
Pt Stanvac 1b
Pt Stanvac 2a
Pt Stanvac 2b
Pt Stanvac 3a
Pt Stanvac 3b
Pt Stanvac 4a
Pt Stanvac 4b
Pt Stanvac 5a
Pt Stanvac 5b
Carrickalinga 1
Carrickalinga 2
Second Valley 1
Second Valley 2
Fisheries Beach 1
Fisheries Beach 2
Kings Beach 1
Kings Beach 2
North Reference Zone
Impact Zone
South Reference Zone

(b)


Limnoperna pulex - Winter
Percent Cover % + (SD)
50
45
40
35
30
25
20
15
10
5
0
Marino 1
Marino 2
Hallett Cove 1
Hallett Cove 2
Pt Stanvac 1a
Pt Stanvac 1b
Pt Stanvac 2a
Pt Stanvac 2b
Pt Stanvac 3a
Pt Stanvac 3b
Pt Stanvac 4a
Pt Stanvac 4b
Pt Stanvac 5a
Pt Stanvac 5b
Carrickalinga 1
Carrickalinga 2
Second Valley 1
Second Valley 2
Fisheries Beach 1
Fisheries Beach 2
Kings Beach 1
Kings Beach 2
Northern Reference Zone
Construction Zone
Southern Reference Zone

(c)



(d)

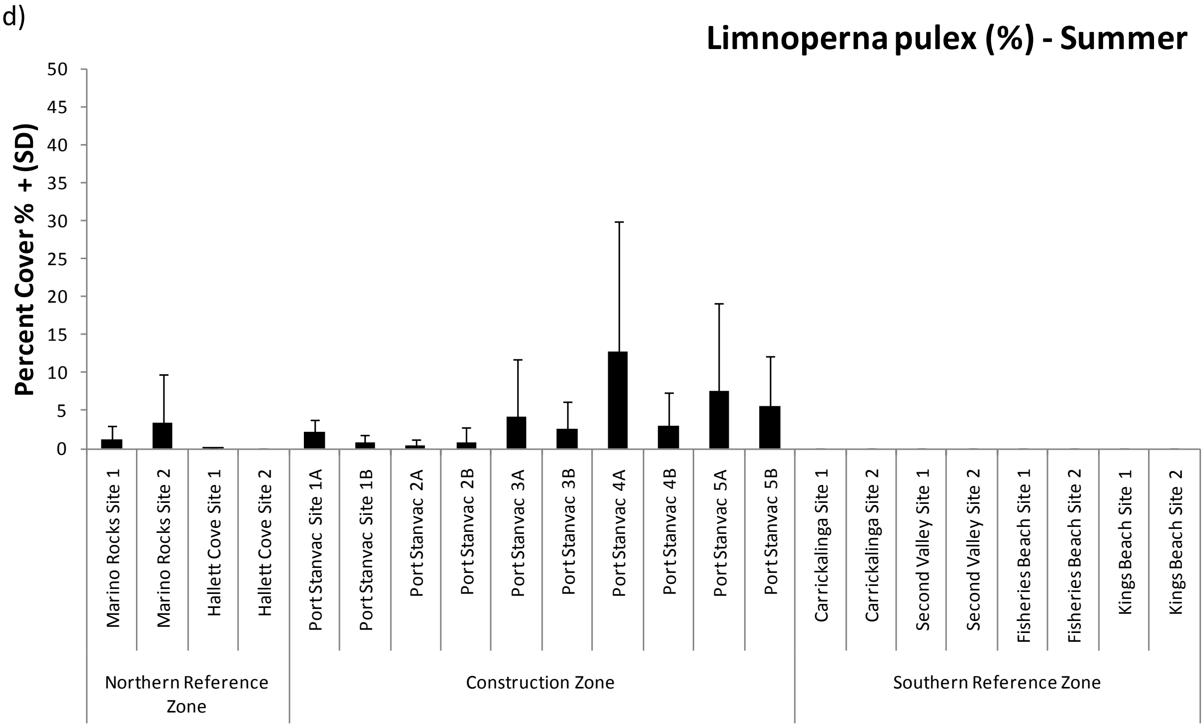


Figure 8: Mean percent cover and standard deviations (SD) for the mussel *Limnoperna pulex* identified from photo quadrats (n=10) in the (a) Autumn, (b) Winter, (c) Spring and (d) Summer surveys at all sites encompassing three zones; Northern Reference Zone, Construction Zone and Southern Reference Zone during 2009/2010.

Invertebrate Communities

In Autumn, the PCO plot of all three zones indicated that invertebrate communities in the Northern Reference Zone were more homogeneous between Sites in comparison to the other Zones (Figure 9a). The Construction Zone also had a proportion of the invertebrate community similar to the Northern Reference Zone (Figure 9a), but with more variability between Sites (Figure 9b). The Southern Reference Zone showed similar variability to the Construction Zone (Figure 9a), with sites such as Carrickalinga and Second Valley showing some overlap with the more outlying sites at Port Stanvac (Figure 9b). The vector overlay on the PCO plot indicated that the mollusc species *Nerita atramentosa* was positively correlated to some sites in the Construction Zone and Carrickalinga in the South Reference Zone, while *Austrolittorina unifasciata* and *Chthalamus antennatus* were negatively correlated with multiple sites of the Construction and Southern Zones (Figure 9b). PERMANOVA results indicated that there was a significant difference between Zones (Pseudo-F = 2.403; P (perm) = 0.0415) and Sites nested within Zones (Pseudo-F = 4.173; P (perm) = 0.0001). Pair-wise tests to determine which groups contributed to the significant difference between Zones indicated that only the North Reference and South Reference Zones had dissimilar invertebrate communities (t = 1.714; P (MC) = 0.0368).

The PCO plot of invertebrate communities in Winter indicated high variability in all three Zones with no distinct clustering (Figure 10a). A vector overlay on the PCO plot indicated that two mollusc (*Bembicium vittatum* and *A. unifasciata*) and one barnacle species (*C. antennatus*) had a positive correlation with various sites of the Construction Zone (Figure 10b). Further analyses with PERMANOVA revealed that there were significant differences between Zones (Pseudo-F = 4.2954; P (perm) = 0.0012) and Sites nested within Zones (Pseudo-F = 4.2289; P (perm) = 0.0001). Pair-wise tests for Zones identified that there were significantly different invertebrate communities between the Construction and Southern Reference Zones (t = 2.5034; P (MC) = 0.0002), and the North and South Reference Zones (t = 2.0765; P (MC) = 0.0148).

During Spring, the PCO plot of invertebrate communities in all Zones indicated that there was some loose clustering for each of the three Zones (Figure 11a), but with a large amount of variability between Sites (Figure 11b). The vector overlay on the PCO plot indicated that three species of molluscs (*S. diemenensis*, *C. solida* and *Patelloida latistrigata*) and one barnacle (*C. antennatus*) had a positive correlation with multiple sites in the Construction Zone, while a negative correlation was identified for

Austrolittorina unifasciata with some of the Southern Reference Zone sites (Figure 11). PERMANOVA results indicated that there was a significant difference between Zones (Pseudo-*F* = 11.092; *P* (perm) = 0.0004) and Sites nested within Zones (Pseudo-*F* = 3.5035; *P* (perm) = 0.0001). Further analyses using pair-wise tests revealed that all three Zones had significantly different invertebrate communities (North v. Construction; (t = 2.15; *P* (MC) = 0.0038), North v. South; (t = 2.6111; *P* (MC) = 0.001), Construction v. South; (t = 4.3366; *P* (MC) = 0.0001).

In the Summer survey, invertebrate communities showed some distinct clustering within the Construction Zone (Figure 12a), but generally the communities were highly variable between Sites (Figure 12b). In comparison, invertebrate communities of the North and South Reference Zones had no distinct clustering indicating high variability within both Zones. The vector overlay on the PCO plot identified four mollusc and two barnacle species which had a strong positive correlation with multiple sites in the Construction Zone (Figure 12). The mollusc species *N. atramentosa* was identified to have a slight positive correlation to particular sites from all three Zones. PERMANOVA results identified a significant difference between Zones (Pseudo-*F* = 7.1987; *P* (perm) = 0.0006) and Sites nested within Zones (Pseudo-*F* = 4.0603; *P* (perm) = 0.0001). Pair-wise tests identified that there was a significant difference between the invertebrate communities of all three Zones (North v. Construction; (t = 1.7791; *P* (MC) = 0.0286), North v. South; (t = 1.7884; *P* (MC) = 0.0339), Construction v. South; (t = 3.8927; *P* (MC) = 0.0001).

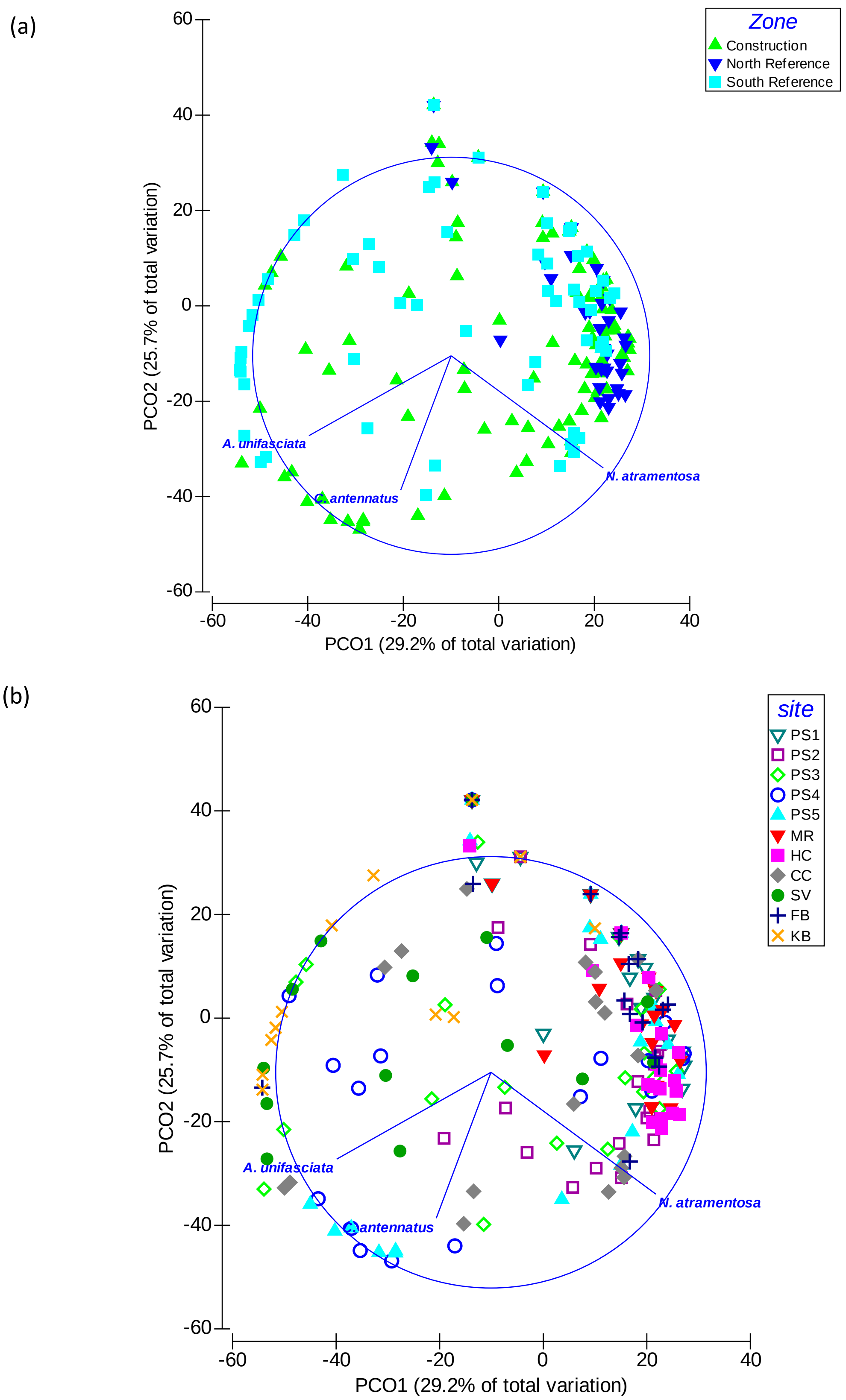
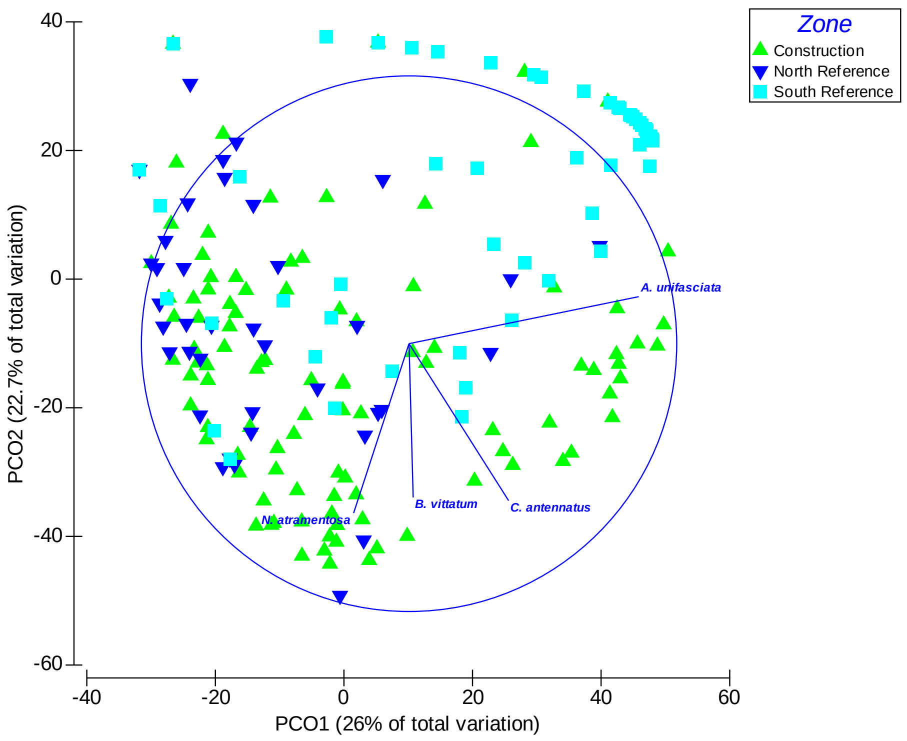


Figure 9: Principle Co-ordinates (PCO) plot of invertebrate communities in Autumn for (a) Zones and (b) Sites with vector overlay displaying the strongest species correlations using Spearman Ranks. Abbreviations; PS, Port Stanvac; MR, Marino Rocks; HC, Hallett Cove; CC, Carrickalinga; SV, Second Valley; FB, Fisheries Beach; KB, Kings Beach.

(a)



(b)

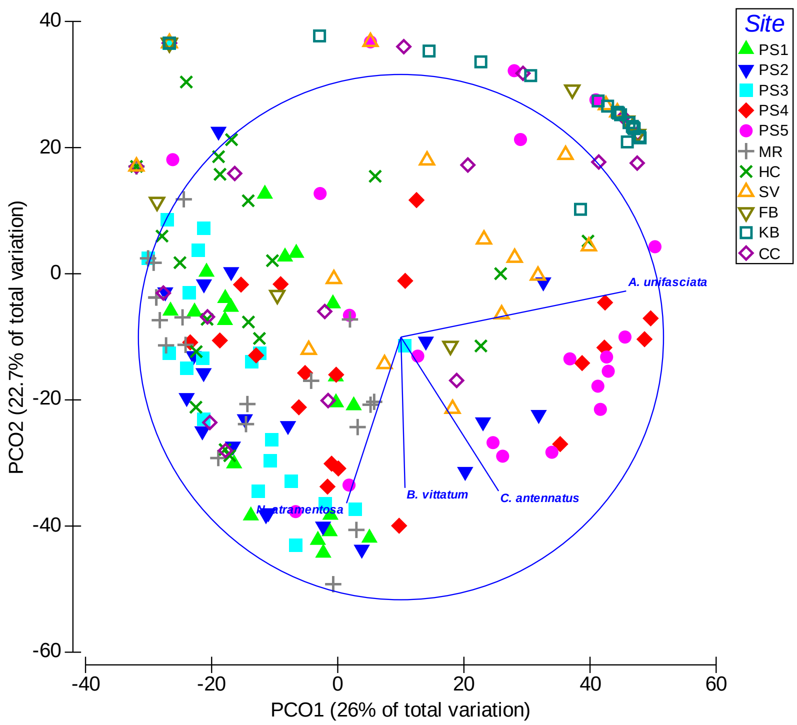


Figure 10: Principle Co-ordinates (PCO) plot of invertebrate communities in Winter for (a) Zones and (b) Sites with vector overlay displaying the strongest species correlations using Spearman Ranks. Abbreviations; PS, Port Stanvac; MR, Marino Rocks; HC, Hallett Cove; CC, Carrickalinga; SV, Second Valley; FB, Fisheries Beach; KB, Kings Beach.

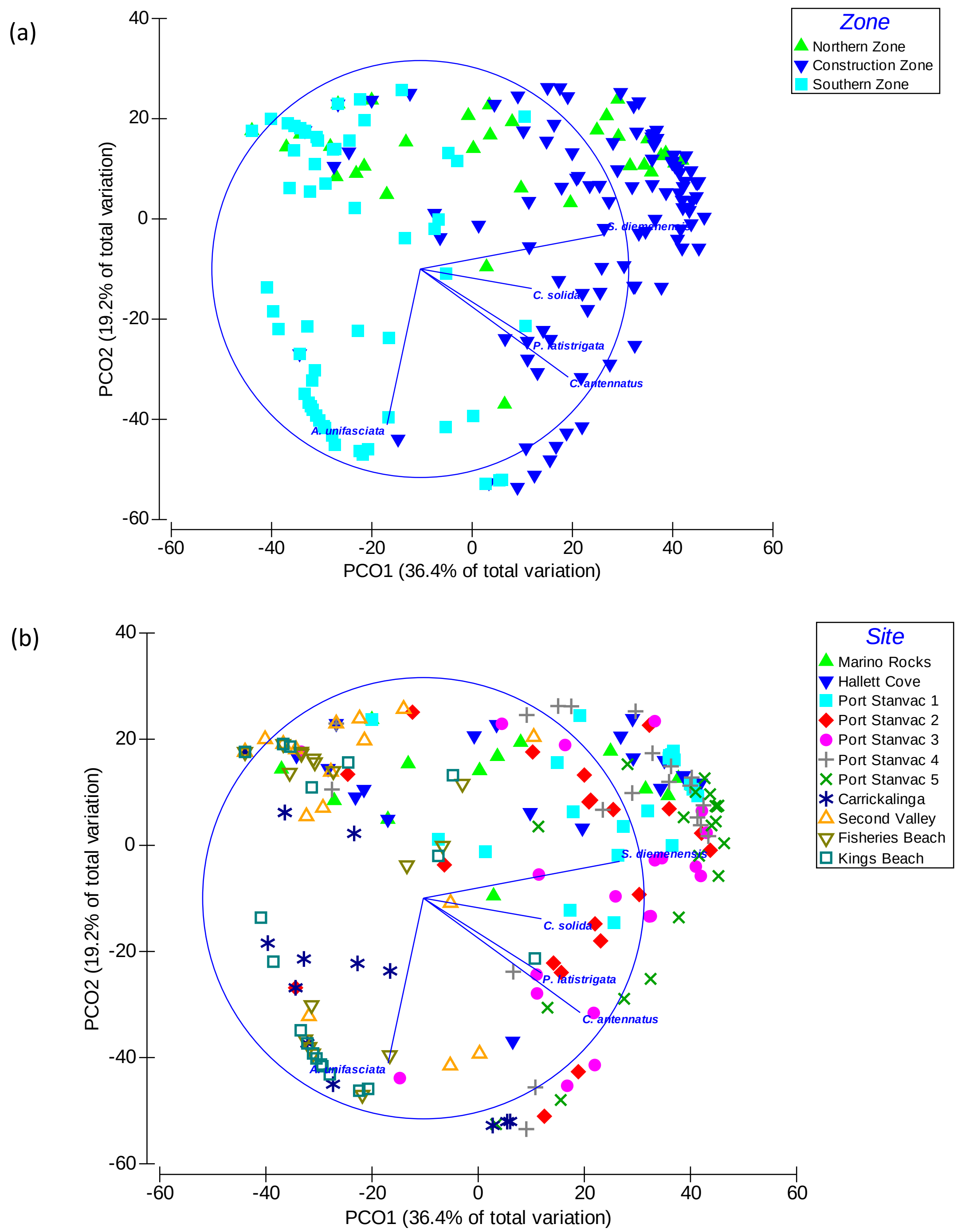


Figure 11: Principle Co-ordinates (PCO) plot of invertebrate communities in Spring for (a) Zones and (b) Sites with vector overlay displaying the strongest species correlations using Spearman Ranks. Abbreviations; PS, Port Stanvac; MR, Marino Rocks; HC, Hallett Cove; CC, Carrickalinga; SV, Second Valley; FB, Fisheries Beach; KB, Kings Beach.

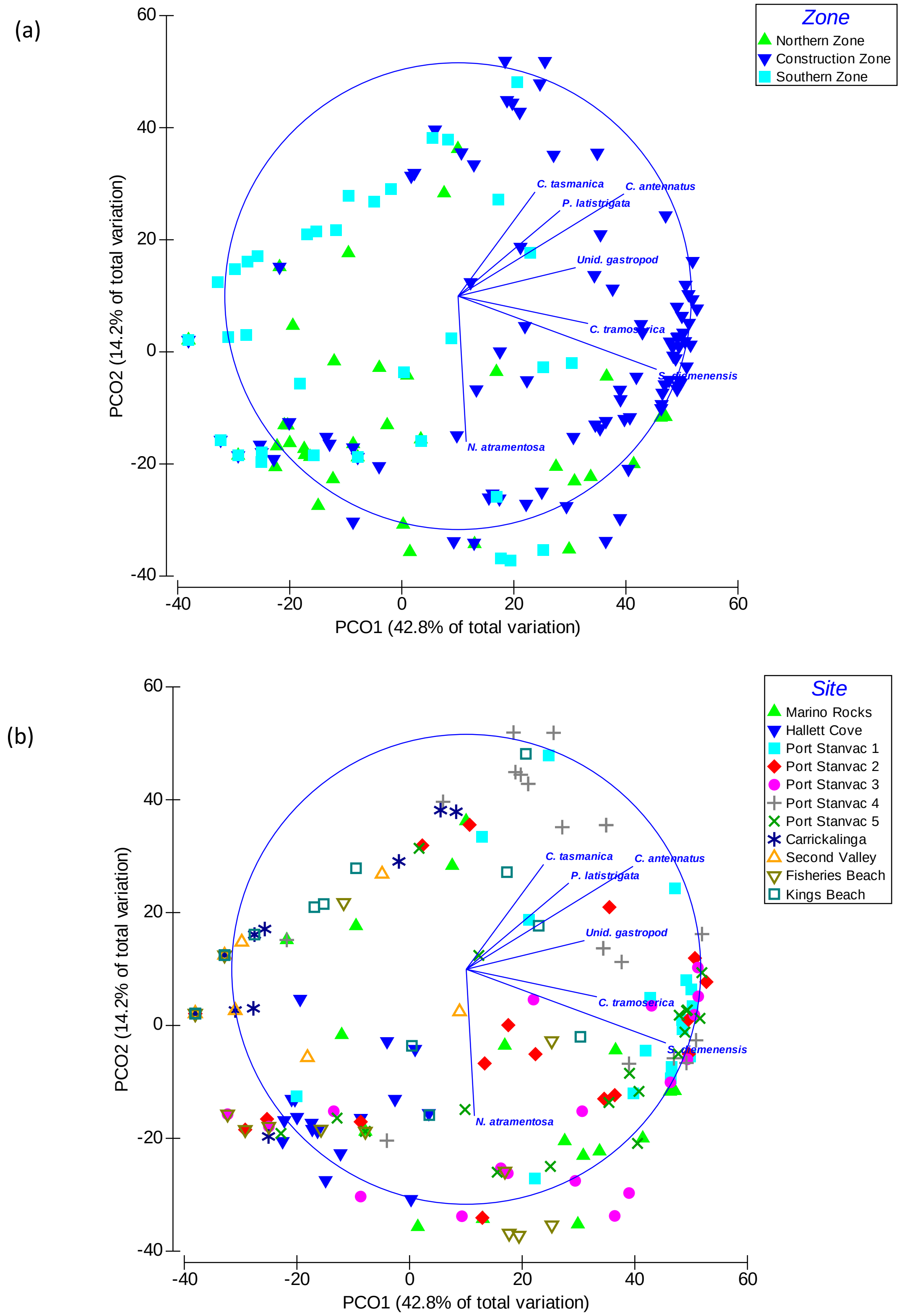


Figure 12: Principle Co-ordinates (PCO) plot of invertebrate communities in Summer for (a) Zones and (b) Sites with vector overlay displaying the strongest species correlations using Spearman Ranks. Abbreviations; PS, Port Stanvac; MR, Marino Rocks; HC, Hallett Cove; CC, Carrickalinga; SV, Second Valley; FB, Fisheries Beach; KB, Kings Beach.

The PCO plot of all Seasons (Figure 13) showed large variability in the invertebrate community structure with no distinct clustering for any of the four Seasons. A three way, mixed model PERMANOVA for Seasons, Zones and Sites nested within Zones identified that there were significant interactions and differences between all factors, across all Seasons (Table 3). The main factor of interest from this test was the difference between Seasons, which was further analysed using pair-wise tests. Results from the pair-wise tests indicated that the invertebrate communities differed significantly between all pairs of Seasons (Table 4).

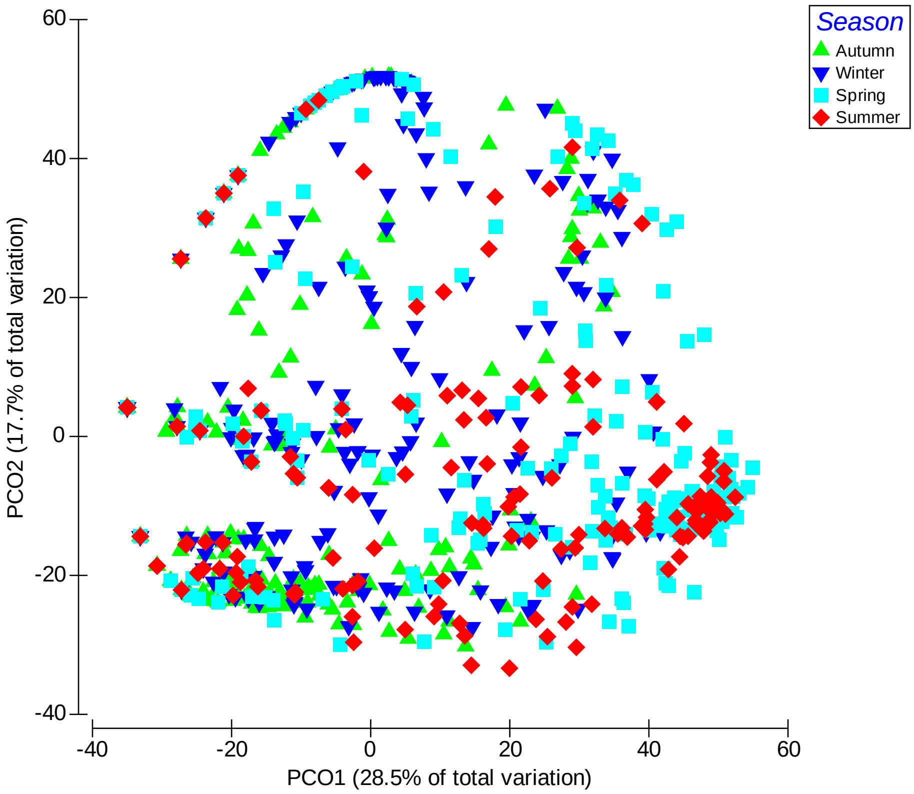


Figure 13: Principle Co-ordinates (PCO) plot of invertebrate communities for all Seasons during 2009/2010.

Table 3: PERMANOVA results of invertebrate community composition of intertidal reefs surveyed during 2009/2010. Test based on a 3 way mixed model design using permutations with significant *P* value identified in bold.

Source	d.f.	SS	MS	Pseudo-F	*P* (perm)
Zone	2	244930	122470	11.153	**0.0002**
Season	3	173200	57733	9.5092	**0.0001**
Site (Zone)	8	87842	10980	6.0095	**0.0001**
Zone x Season	6	108210	18035	2.9706	**0.0001**
Site (Zone) x Season	24	145710	6071.2	3.3228	**0.0001**
Residual	836	1527500	1827.2		

Table 4: Results of pair-wise tests for differences between Seasons from the 2009/2010 survey.

Groups	**t**	***P* (perm)**
Autumn, Winter	2.4152	**0.0043**
Autumn, Spring	4.451	**0.0001**
Autumn, Summer	3.3008	**0.0006**
Winter, Spring	3.1053	**0.0002**
Winter, Summer	2.789	**0.0009**
Spring, Summer	1.8219	**0.0333**

Video Transect Substrate Cover

During Autumn, the percent cover of flora and fauna along video transects had the highest diversity in the Construction Zone with barnacles, encrusting algae and mixed algae well represented at some sites (Figure 14a). In comparison, sites of the Northern and Southern Reference Zones had low percent cover in any functional group (< 10%) and instead both Zones consisted of mainly bare substrate (Figure 14b). PERMANOVA revealed a significant difference between Zones (Pseudo-F = 2.5374; P = 0.0479) and pair-wise tests identified a significant difference between the Northern and Construction Zones (t = 1.9637; P (MC) = 0.0342). A small amount of sand was detected at Port Stanvac Site 5 and several sites in the Southern Zone during the Autumn surveys (Figure 14b).

In Winter, the percent cover of flora and fauna found along video transects was diverse in the Construction Zone and generally quite low (<20%) with the exception of Site 1 which had a large percentage contribution of mixed algae (Figure 15a). The Northern and Southern Reference Zones consisted mainly of bare substrate, and beach wrack in the case of Fisheries Beach in the Southern Zone (Figure 15a, 15b). PERMANOVA revealed a significant difference between Zones (Pseudo-F = 6.4865; P = 0.0007) and pair-wise tests identified significant differences between the Northern and Construction Zones (t = 2.2349; P (MC) = 0.0132) and the Southern and Construction Zones (t = 3.3943; P (MC) = 0.0004). Similar to Autumn, a small amount of sand was detected at Port Stanvac Site 5 in Winter, although more sand was detected at several sites in the Northern and Southern Zones (Figure 15b).

The Spring survey revealed a general increase compared to previous seasons in the percent cover of flora and fauna in video transects at all Zones (Figure 16a). Seven out of ten sites in the Construction Zone had high percentages of flora and fauna cover (60-70%), with large percentage contributions of mixed algae and mixed invertebrates (Figure 16a). The Northern Reference Zone had a high percent cover of flora and fauna at Hallett Cove 2, which was due to the large percent contribution of mixed algae. In comparison, to the other two Zones, the Southern Reference Zone had very low percent cover (< 10%) and mainly consisted of bare substrate (Figure 16b). PERMANOVA revealed a significant difference between Zones (Pseudo-F = 22.082; $P = 0.0005$) and pair-wise tests identified significant differences between the Northern and Southern Zones ($t = 3.8385$; P (MC) = 0.0005) and the Construction and Southern Zone ($t = 6.418$; P (MC) = 0.0001). No sand was detected in Port Stanvac during Spring, although sand persisted at some sites in the Northern and Southern Zones (Figure 16b).

In Summer, the percent cover of flora and fauna in the Construction Zone decreased at most sites (except PS3a and PS4a increased; Figure 17a). Overall, mixed algae and mixed invertebrates contributed the most to the total percent cover in the Construction Zone. Compared to Spring, the Northern Reference Zone had an increase in the percent cover of flora and fauna at Marino, while the percent cover at Hallett Cove decreased. The percent cover in the Southern Reference Zone increased at both sites at Fisheries Beach and Kings Beach, but was relatively low overall due to the high percentage of bare substrate in this Zone (Figure 17b). PERMANOVA revealed a significant difference between Zones (Pseudo-F = 9.148; $P = 0.0041$) and pair-wise tests identified significant differences between the Northern and Construction Zones ($t = 2.0531$; P (MC) = 0.0249) and the Construction and Southern Zones ($t = 4.5675$; P (MC) = 0.0001). Similar to Spring, no sand was detected in Port Stanvac during Summer, although a small percent cover of sand was recorded at several sites in the Northern and Southern Zones (Figure 17b).

PERMANOVA for Seasons, Zones and Sites nested within Zones identified that there were significant interactions and differences between percent cover across all Seasons (Table 4). The difference between Seasons was further analysed using pair-wise tests. Results from the pair-wise tests indicated that the only non-significant group differences in percent cover of flora and fauna was between Autumn and Winter ($t = 1.1912$; $P = 0.2434$) and Spring and Summer ($t = 1.1925$; $P = 0.2671$) (Table 6).

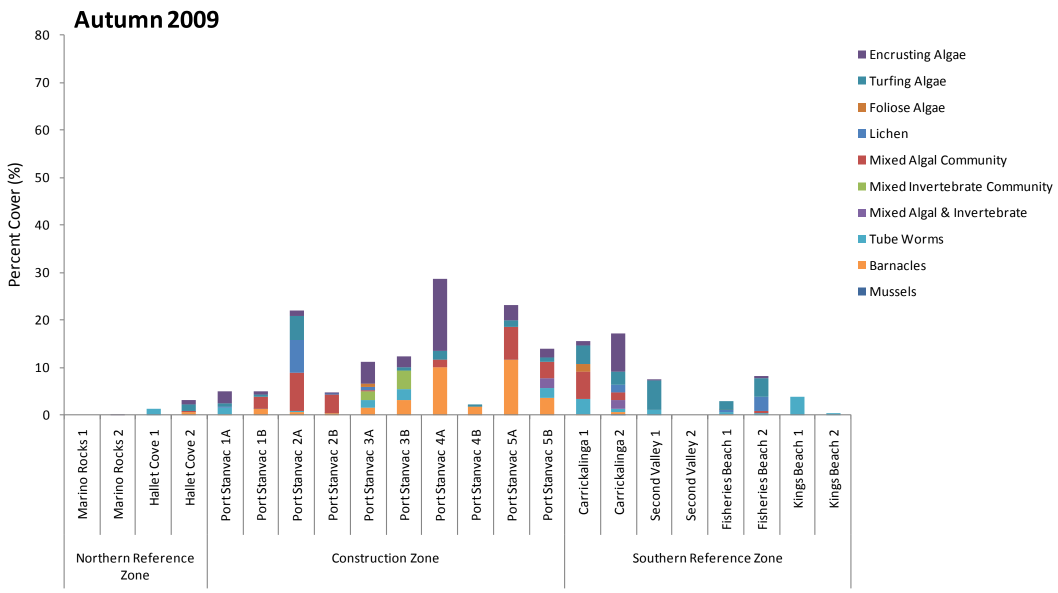
Table 5: PERMANOVA results of percent cover of intertidal reefs surveyed during 2009/2010. Test based on a 3 way mixed model design using permutations with significant *P* value identified in bold.

Source	d.f.	SS	MS	Pseudo-F	*P* (perm)
Zone	2	65998	32999	16.327	**0.0002**
Season	3	41964	13988	13.732	**0.0001**
Site (Zone)	8	16164	2020.5	10.108	**0.0001**
Zone x Season	6	23733	3.8845	3.8845	**0.0002**
Site (Zone) x Season	24	24433	1018	5.093	**0.0001**
Residual	395	78955	199.89		

Table 6: Results of pair-wise tests for differences between percent cover for all Seasons from the 2009/2010 survey, with significant *P* value identified in bold..

Groups	t	*P* (perm)
Autumn, Winter	1.1912	0.2434
Autumn, Spring	5.6012	**0.0001**
Autumn, Summer	3.6769	**0.0009**
Winter, Spring	5.1899	**0.0001**
Winter, Summer	3.679	**0.0017**
Spring, Summer	1.1925	0.2671

(a)



(b)

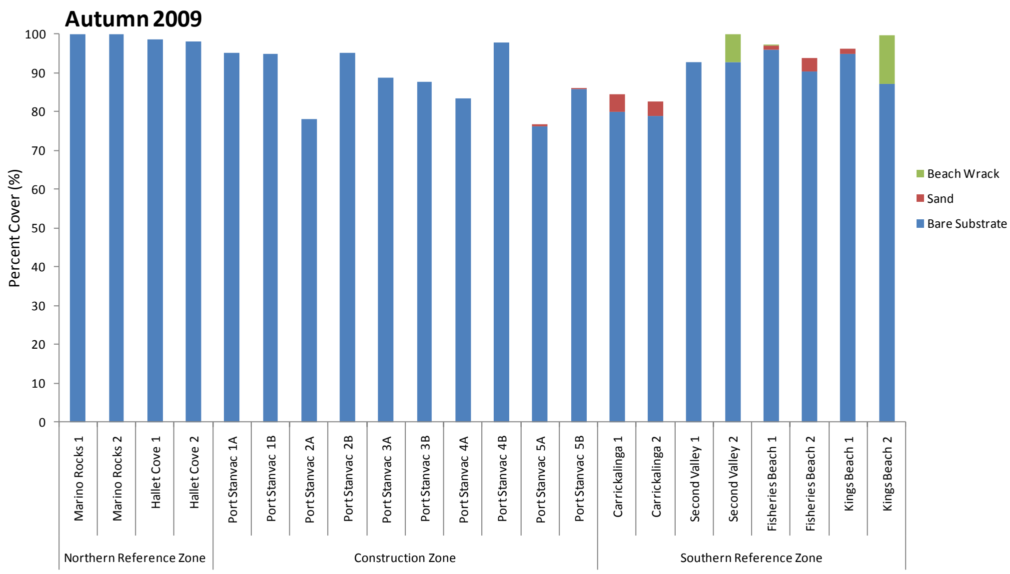
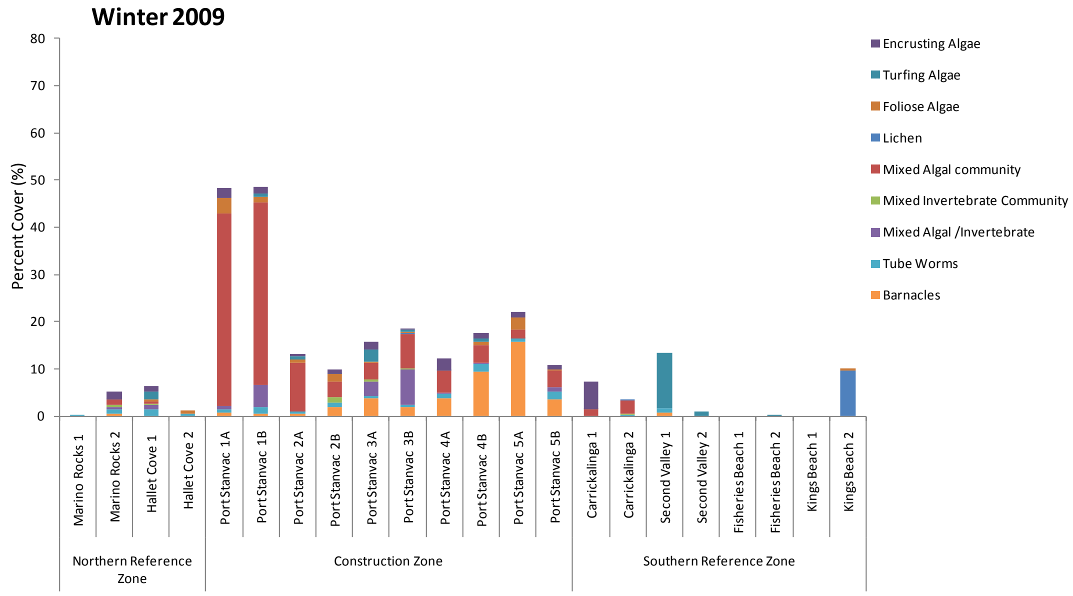


Figure 14: Mean percent cover of (a) bare substrate, sand and beach wrack, and (b) flora and fauna quantified from video transects of intertidal reefs at all sites, across three Zones; Northern Reference Zone, Construction Zone and Southern Reference Zone during the Autumn survey in 2009.

(a)



(b)

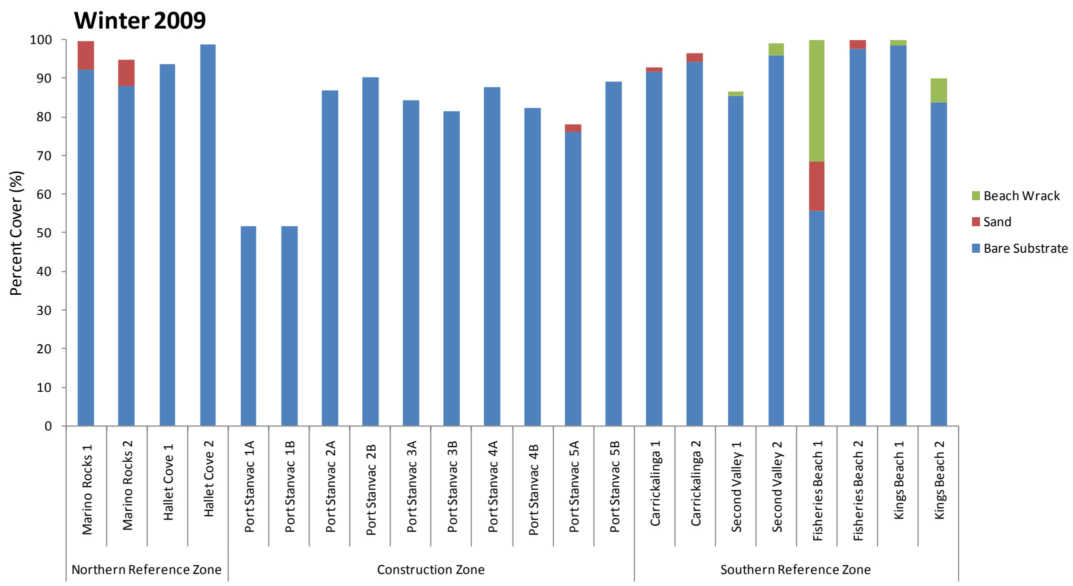
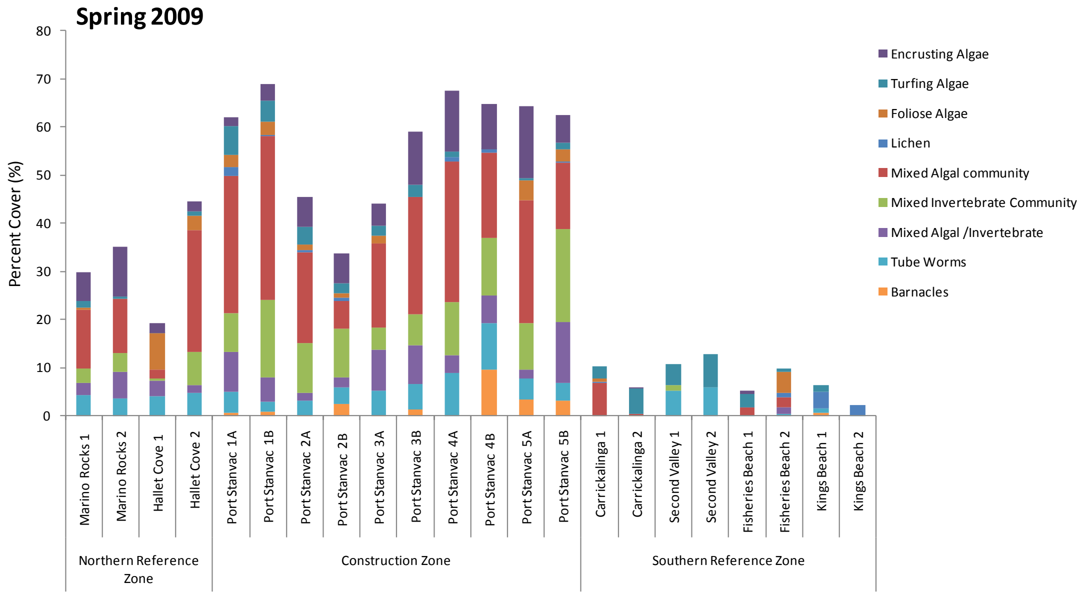


Figure 15: Mean percent cover of (a) bare substrate, sand and beach wrack, and (b) flora and fauna quantified from video transects of intertidal reefs at all sites, across three Zones; Northern Reference Zone, Construction Zone and Southern Reference Zone during the Winter survey in 2009.

(a)



(b)

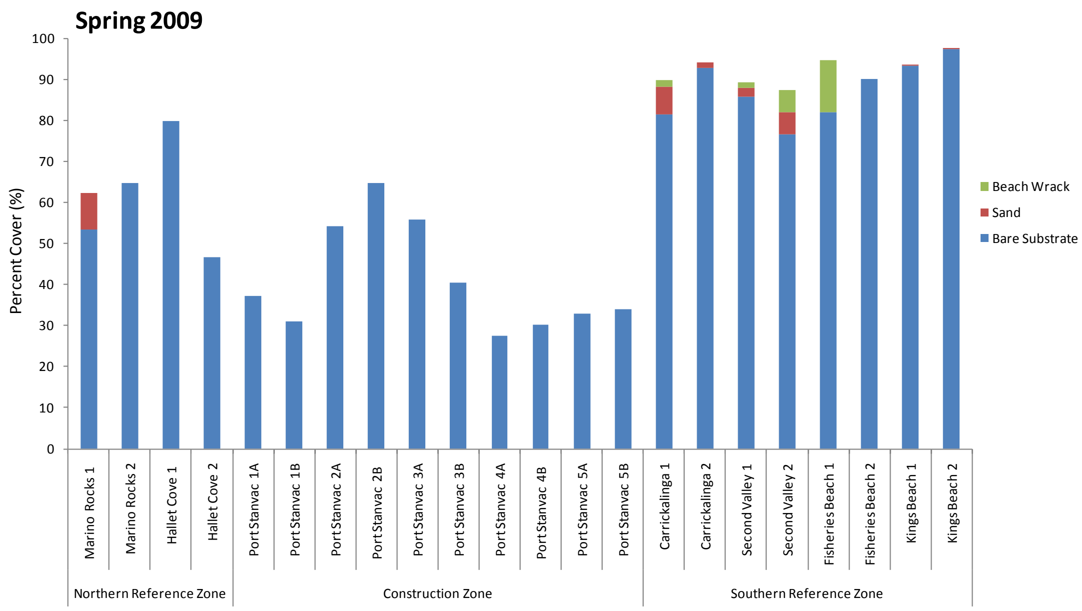


Figure 16: Mean percent cover of (a) bare substrate, sand and beach wrack, and (b) flora and fauna quantified from video transects of intertidal reefs at all sites, across three Zones; Northern Reference Zone, Construction Zone and Southern Reference Zone during the Spring survey in 2009.

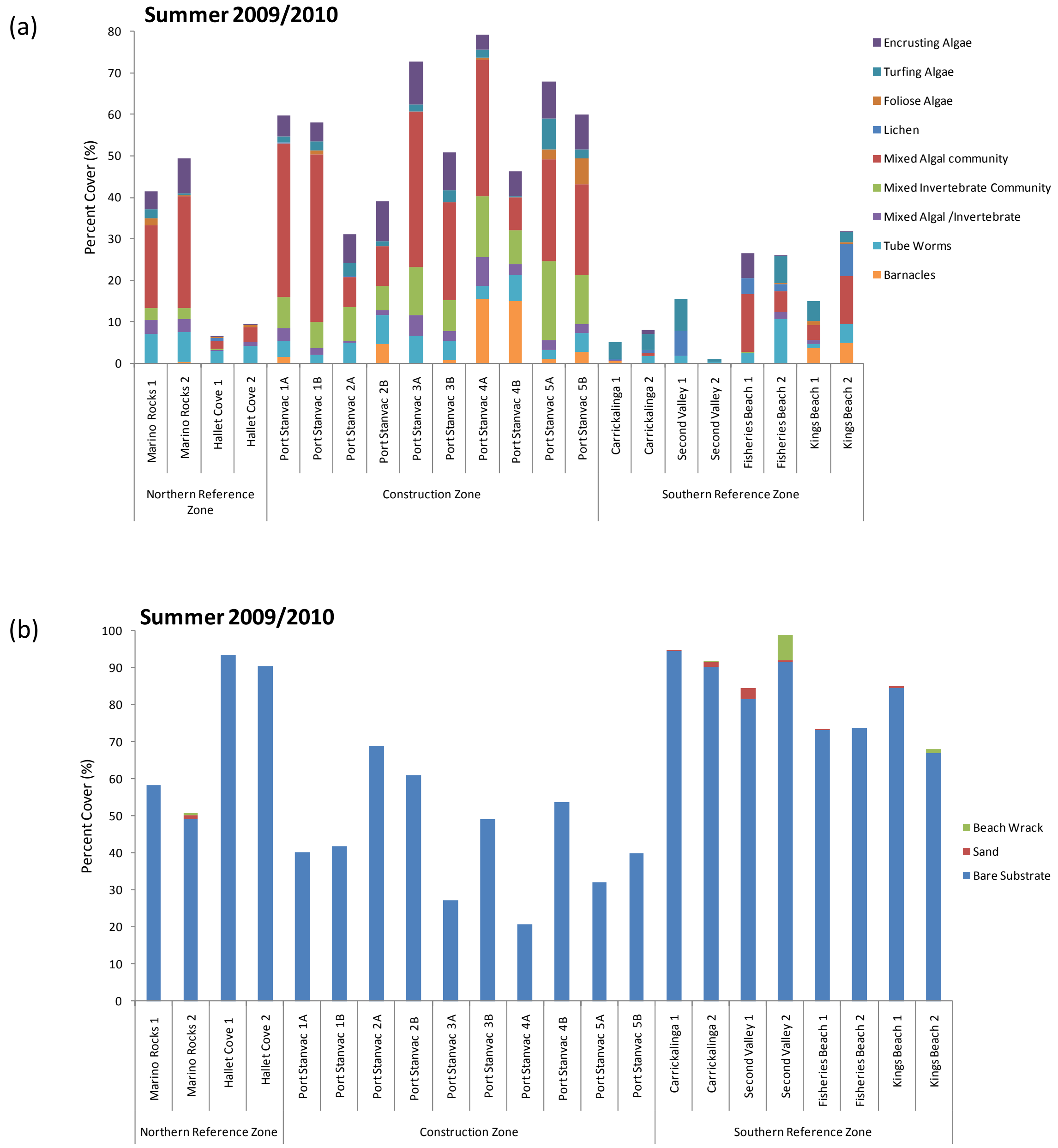


Figure 17: Mean percent cover of (a) bare substrate, sand and beach wrack, and (b) flora and fauna quantified from video transects of intertidal reefs at all sites, across three Zones; Northern Reference Zone, Construction Zone and Southern Reference Zone during the Summer survey in 2009/2010.

Discussion

The intertidal surveys undertaken in the Northern Reference, Construction and Southern Reference Zones in each season during 2009/2010 provided an initial baseline dataset of invertebrate and flora communities as a 'before construction' reference for the Adelaide Desalination Plant. Across all seasons, the Construction Zone had higher invertebrate biodiversity and larger abundances of individuals compared to both of the reference Zones. This pattern is consistent with previous research, which also identified the intertidal reefs within the Construction Zone at Port Stanvac as a rich biodiverse region (Dutton and Benkendorff 2008). The higher diversity and abundance of invertebrates on the intertidal reefs in Port Stanvac may be related to the limited access for human recreational activities. Human collection and overturning of boulders can negatively impact intertidal invertebrate populations, with previous studies conducted close to other metropolitan centres around the world showing differences in abundance and size distributions based on accessibility to the intertidal reefs (Castilla and Duran, 1985; Keough *et al*., 1993; Roy *et al*., 2003; Rius *et al.*, 2006). This implies that the fences around Port Stanvac may serve to protect intertidal populations from anthropogenic pressure and thus it would be beneficial to maintain this area as a general public exclusion zone into the future. The relatively high biodiversity and abundance at Port Stanvac also provides a general indicator of reef health and thus any future drop in these parameters approaching baseline levels currently found in the metropolitan Northern Reference Zone should trigger an investigation into the potential causes.

Overall, significant differences in photo quadrat abundances frequently arose from PERMANOVA pair-wise tests between the Northern reference and Construction Zone, as well as between the Construction and Southern reference zones. However, no significant differences were identified between Northern and Southern reference zones (all phyla, Mollusca and Crustacea) throughout any season. This implies that natural changes in reference zones may not perfectly control for potential impacts on the intertidal macrofaunal communities at Port Stanvac. However, there is also substantial site variation within each zone, including the construction zone, with some reference sites showing similar patterns to specific sites within the construction zone. The enormous spatial variability in invertebrate communities is best demonstrated by the PCO plots, which show a broad spread of sites within the construction zone, which is overlapped in some areas by sites in the Northern Reference Zone and in other cases by sites in the Southern Reference Zone. Generally, the high level of spatial variability observed in these baseline surveys is to be expected, with macrofauna often displaying variable patterns of distribution and abundance on intertidal shores (Chapman & Underwood 1996, Chapman 2005). The scale of observation can also influence how community patterns and processes are interpreted (Levin 1992, Blanchard & Bourget 1999). Consequently, intertidal monitoring programs should incorporate sufficient replication several spatial scales. These baseline studies of the Port Stanvac Construction Zone imply that a high level of replication is required to account for the spatial variability both within sites and between sites within zones. Ultimately, the range of Northern and Southern Reference sites used in this baseline study should be sufficient to account for most of the variability in invertebrate communities within the Construction Zone.

A substantial level of temporal variability was also observed in these baseline intertidal surveys. Results of the Autumn survey revealed that invertebrate species diversity, species richness and abundances in quadrats were much higher in the Construction Zone, with dominant species of molluscs and one barnacle contributing most to community differences between Zones. In Winter, the species diversity, species richness and abundances of invertebrates found in quadrats within the Construction Zone were higher than Autumn. The species diversity, species richness and abundances of invertebrates changed in Spring with a decline in overall invertebrate numbers at the southern end of the Construction Zone and a slight increase at the northern end. In Summer a similar pattern in species diversity and abundance was identified compared to Spring, but there were less dominant species and a higher number of species contributing to dissimilarities between Zones. At the Northern and Southern Reference Zones there was a general increase in species diversity, species richness and abundances from Autumn to Winter, which declined during Spring through to Summer. Overall, the high level of temporal variation observed in the patterns of intertidal community structure along the Fleurieu Peninsula in these baseline surveys is consistent with previous studies on intertidal reefs (Dye 1998; Menconi *et al*. 1999; Underwood and Chapman 2000). It implies that it is important to continue monitoring across all four seasons rather than attempting to draw conclusions without accounting for the natural seasonal variation in intertidal community structure.

Video transects also showed strong temporal variability, with low percent cover of flora and sessile fauna within the Construction Zone in Autumn, which increased through Winter to Spring and began to decline in Summer. The Reference Zones mainly consisted of bare substrate throughout Autumn and Winter. In Spring the percent cover of flora and fauna increased in the Northern Reference Zone, while percent cover of flora and fauna did not increase in the Southern Reference Zone until Summer. Overall, the Construction Zone had high percent cover of flora and fauna along video transects during Spring and Summer. The low percent cover of sand in the Construction Zone during Autumn and

Winter and complete absence of sand in Spring and Summer provides a good baseline to detect significant increases in sand cover in future surveys during the construction phase of the desalination plant.

The high abundance, species richness and species diversity of flora and fauna in both quadrats and video transects in Spring and Summer (with the exception of barnacles and the tubeworm *Galeolaria caespitosa*) may be explained by a number of abiotic and biotic factors (Connell 1985; Forde and Raimondi 2004). One major determining factor influencing abundance on intertidal zones is wave exposure (Benkendorff *et al*. 2008). Sampling in Autumn and Winter for the 2009/2010 survey was undertaken during higher tides with increased wave exposure, which provided limited access to the low intertidal zone where the highest diversities are generally found on intertidal rocky shores (Benkendorff *et al*. 2008). A shift in sampling to the mid-littoral zone during the cooler seasons may also account for the higher abundances of barnacles and *G. caespitosa* present at the most southern sites of the Construction Zone (Figures 5 and 6) in Autumn and Winter. The topography of the southern sites in the Construction Zone (particularly sites 4 and 5) consists of multiple large rock ledges in the mid-littoral zone which may provide a preferred habitat for sessile invertebrates such as barnacles. For example, Sutherland (1990) found that the barnacle *Chthlamaus fissus* was relatively constant in the driest microhabitats, which became increasingly variable over time as microhabitats were rehydrated.

The high spatial and temporal variation in abundances and species richness identified across the four seasonal surveys in 2009/2010 follows a common pattern observed within intertidal rocky shores (Schiel 2004). Previous research has identified that high variation of post settlement stages of sessile invertebrates within the rocky intertidal zone is due to complex community dynamics (i.e. competition and predation) and the shore level sampled (Menge 1991), which provides some explanation for the seasonal variation observed in the 2009/2010 intertidal surveys. Identifying the patterns in spatial and temporal variation from abundances and frequencies of flora and fauna is important to evaluate the natural variability on rocky shores particularly in regions that are subject to potential impacts on local biodiversity (Underwood *et al*. 2008), such as the Construction Zone at Port Stanvac. Comparisons can then be made with variances from future datasets of flora and fauna communities with a change in variability (higher or lower) indicating possible effects of stress from potential impacts (Petraitis and Methratta 2006; Anderson *et al*. 2008). In addition, the identification of an increase in the abundances of dominant species (i.e. stress tolerant species) will also indicate the presence of stress on flora and fauna communities (Pinedo *et al*. 2007). Therefore, results from the 2009/2010 survey have provided a spatial and temporal baseline of flora and fauna communities 'before any potential impact' from the Adelaide Desalination Plant.

Recommendations for future monitoring

As this is the preliminary year of intertidal monitoring there is no previous dataset of similar methodologies within the same sites in which to make reliable comparisons of biological data, hence this report has analysed the differences between all zones and identified the general trends across four seasons. Future analysis should be conducted within each season to compare communities before, during and after construction (e.g. Autumn 09, Autumn 10 and Autumn 11) in order to detect changes in biological diversity and limit the effects of seasonal variation. The removal of Kings Beach as a site in the Southern Reference Zone has been recommended for any future monitoring efforts due to problems associated with accessing a sufficient area of the intertidal zone in order to conduct a line-intercept transect. The rocky intertidal area at Kings Beach was relatively steep in slope and appeared to offer adequate width of intertidal rocky shore in which to conduct line-intercept transects when initially selected as a reference location during Summer 2009. However, a significantly reduced area of the intertidal zone was available during Autumn and Winter, with accessibility to the shoreline being heavily dependent on weather conditions, making for inconsistent and unreliable sampling conditions during these months. The position of the low tide mark on the shoreline is dependent on a combination of factors such as seasonal variation in tidal patterns and weather conditions (Benkendorff *et al.* 2008). Consequently, this led to difficulties in positioning a consistent starting point for the line-intercept transect method at all sites and seasons. In efforts to reduce any bias caused by this seasonal variation, a minimum of 0.8m tide height was selected as criteria for year round sampling. However, a consistent 'level' for positioning the start of the line-intercept transects was not always achievable which further highlights the importance of making comparisons between same seasons events when tidal heights are more comparable. Since baseline surveys were conducted at three other rocky reefs (6 sites) in the Southern reference zone, the removal of Kings Beach is unlikely to affect the ability to detect any future impacts on the intertidal communities at Port Stanvac.

In conclusion, this study provides useful baseline data for future monitoring to assess intertidal impacts associated with on-going activities in the Port Stanvac area. In order to gain a better understanding of changes in the intertidal zone, replicated surveys should continue to occur during and post construction of the desalination plant. The same set of survey sites should be maintained (with the exception of Kings Beach in the Southern Reference Zone). Each site should be sampled with the same level of replication (spatial and temporal), using the same methodology as reported here.

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Appendix 1

Table 1: Species list of summed total of individuals for each location according to zone for (a) Autumn (b) Winter (c) Spring 2009 and (d) Summer 2010.

(a)

		Northern Reference Zone		Construction Zone					Southern Reference Zone			
Phylum	**Species**	**Marino**	**Hallett Cove**	**Port Stanvac 1**	**Port Stanvac 2**	**Port Stanvac 3**	**Port Stanvac 4**	**Port Stanvac 5**	**Carrickalinga**	**Second Valley**	**Fisheries Beach**	**Kings Beach**
Cnidaria	*Epiactis sp.*	0	1	0	0	0	0	0	0	0	0	0
Annelida	*Galeolaria caespitosa**	-	+	+	+	+	+	+	+	+	+	+
Mollusca	*Notoacmea flammea*	6	22	0	2	0	5	17	1	3	1	0
	Notoacmea petterdi	0	3	0	0	0	0	1	0	0	0	0
	Patelloida latistrigata	0	0	0	0	0	5	1	0	0	0	0
	Cellana tramoserica	1	2	0	0	0	2	0	4	0	2	0
	Cellana solida	0	0	0	0	0	2	5	1	7	3	0
	Nerita atramentosa	76	125	60	77	53	62	80	73	12	43	3
	Montfortula rugosa	0	1	0	0	3	4	0	0	0	0	0
	Diloma concamerata	9	45	32	24	30	8	6	2	0	16	3
	Austrocochlea rudis	0	1	0	2	0	0	0	0	0	0	0
	Austrocochlea constricta	0	18	0	2	2	0	0	0	0	8	0
	Austrocochlea porcata	7	7	1	0	1	1	1	0	0	0	1
	Herpetopoma aspersa	0	0	0	0	0	0	1	0	0	0	0
	Turbo undulatus	0	0	1	0	0	0	0	0	0	0	0
	Afrolittorina praetermissa	1	0	0	0	0	0	0	0	0	0	0
	Austrolittorina unifasciata	2	0	2	35	102	385	339	28	237	55	178
	Bembicium nanum	0	0	0	1	0	5	8	8	0	0	1
	Bembicium vittatum	19	5	3	31	21	59	11	18	9	1	0
	Neogastropoda sp.	0	0	0	0	0	0	2	0	0	0	0
	Dicathais orbita	0	0	0	0	0	0	0	0	2	0	0
	Onchidella nigricans	0	0	0	0	1	0	0	0	0	0	0
	Siphonaria diemenensis	0	10	1	17	9	2	3	1	1	0	0
	Siphonaria zelandica	0	1	0	3	1	0	3	1	0	1	0
	*Limnoperna pulex**	-	-	-	-	-	-	-	+	-	-	-
	Unidentified gastrodpod	2	2	3	8	5	1	3	5	2	2	0
Arthropoda	*Chtalamus antennatus*	0	1	4	70	98	1349	3097	237	5	10	0
	Chamaesipho tasmanica	0	0	0	0	0	62	0	0	0	0	0
	Eliminus modestus	0	0	0	0	0	6	5	0	0	0	0
	Balanus trigonus	0	0	0	0	0	0	0	2	0	0	0

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

NB: Unidentified gastropod refers to organisms which could not be identified to family level due to shell erosion/encrustation etc.

(b)

		Northern Reference Zone		Construction Zone					Southern Reference Zone			
Phylum	**Species**	**Marino**	**Hallett Cove**	**Port Stanvac 1**	**Port Stanvac 2**	**Port Stanvac 3**	**Port Stanvac 4**	**Port Stanvac 5**	**Carrickalinga**	**Second Valley**	**Fisheries Beach**	**Kings Beach**
Annelida	*Eulalia* sp.	0	2	0	0	0	0	0	0	0	0	0
	*Galeolaria caespitosa**	+	+	+	+	+	+	+	-	+	-	-
Mollusca	*Notoacmea flammea*	43	18	4	21	10	3	3	0	2	0	0
	Notacmea sp.	20	14	6	2	6	8	3	0	0	0	0
	Patelloida alticostata	9	0	41	1	12	18	10	0	1	1	0
	Patelloida latistrigata	0	2	2	19	7	8	11	0	0	0	0
	Patelloida sp.	0	0	3	0	2	0	0	0	0	0	0
	Cellana tramoserica	7	3	14	10	1	6	0	0	0	0	0
	Cellana solida	20	0	19	4	4	23	16	1	0	0	0
	Nerita atramentosa	47	49	40	82	59	20	105	46	31	8	1
	Montfortula rugosa	3	1	0	0	0	0	0	0	0	0	0
	Chlorodiloma adelaidae	0	0	0	0	1	0	0	0	0	0	0
	Diloma concamerata	1	10	6	9	6	1	0	0	5	0	0
	Austrocochlea rudis	0	12	14	15	11	22	0	0	1	1	0
	Austrocochlea constricta	0	6	1	0	14	1	0	1	0	0	0
	Austrocochlea porcata	1	1	12	0	0	1	2	0	1	0	0
	Herpetopoma aspersa	0	0	1	0	0	0	0	2	0	0	0
	Phasianellidae sp.	0	0	124	0	0	0	0	0	0	0	0
	Rissoina fasciata	0	1	6	0	0	0	0	0	0	0	0
	Austrolittorina unifasciata	7	80	0	31	2	460	543	254	239	159	709
	Bembicium auratum	0	0	1	0	0	0	0	0	1	0	0
	Bembicium nanum	0	0	1	6	4	1	1	6	0	0	0
	Bembicium vittatum	29	50	31	39	48	33	23	12	21	2	0
	Onchidella nigricans	0	0	2	0	0	1	0	0	0	0	0
	Siphonaria diemenensis	7	0	130	8	22	18	7	1	0	1	0
	Siphonaria zelandica	0	0	0	1	1	0	0	0	1	0	0
	*Limnoperna pulex**	-	-	-	+	-	+	+	-	-	-	-
	Unidentified gastrodpod	3	0	16	3	2	8	10	1	3	0	2
Arthropoda	*Tetraclitella purpurascens*	0	0	0	0	5	0	157	0	0	0	0
	Chtalamus antennatus	50	0	74	455	78	970	3297	50	3	0	0
	Eliminus modestus	0	0	94	0	0	226	7	9	15	0	0
	Catomerus polymerus	3	0	0	0	0	1	0	0	0	0	0

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

NB: Unidentified gastropod refers to organisms which could not be identified to family level due to shell erosion/encrustation etc.

(c)

Phylum	Species	Northern Reference Zone Marino	Hallett Cove	Construction Zone Port Stanvac 1	Port Stanvac 2	Port Stanvac 3	Port Stanvac 4	Port Stanvac 5	Southern Reference Zone Carrickalinga	Second Valley	Fisheries Beach	Kings Beach
Cnidaria	*Actinia tenebrosa*	0	0	0	2	0	0	0	0	0	0	0
Annelida	*Galeolaria caespitosa**	+	+	+	+	+	+	+	-	-	-	+
	*Pomatoceros taenita**	-	-	+	+	-	-	+	-	+	+	-
	Unidentified polychaete	0	0	1	0	0	0	0	0	0	0	0
Mollusca	*Notoacmea flammea*	3	33	5	23	0	154	52	0	0	0	1
	Notacmea sp.	0	0	0	0	0	0	0	0	1	0	0
	Patelloida latistrigata	0	4	3	102	186	133	268	0	0	0	0
	Cellana tramoserica	0	0	49	57	0	0	21	0	0	1	0
	Cellana solida	6	109	3	1	127	12	272	0	0	0	0
	Nerita atramentosa	0	6	10	25	20	4	11	0	21	41	21
	Montfortula rugosa	0	0	1	0	0	0	0	0	0	0	0
	Diloma concamerata	0	0	0	0	0	1	6	0	2	3	0
	Austrocochlea rudis	0	0	0	0	7	1	0	0	0	0	0
	Austrocochlea constricta	0	0	2	6	0	0	0	0	0	8	5
	Austrocochlea porcata	0	2	0	4	1	0	0	0	0	0	0
	Austrolittorina unifasciata	0	10	2	112	157	104	97	163	58	138	317
	Bembicium auratum	0	1	3	2	0	0	0	0	0	0	0
	Bembicium nanum	0	4	1	1	1	0	3	0	0	0	1
	Bembicium vittatum	0	0	12	9	110	0	4	13	8	6	0
	Siphonaria diemenensis	391	390	1527	509	844	1640	1692	0	25	7	1
	Siphonaria zelandica	3	0	0	0	3	1	0	0	0	0	0
	*Limnoperna pulex**	+	+	+	+	+	+	+	-	-	-	+
	Unidentified gastrodpod	14	0	8	12	1	2	0	3	1	0	1
Arthropoda	*Tetraclitella purpurascens*	0	0	0	5	0	0	0	0	0	0	0
	Chtalamus antennatus	54	41	200	696	563	667	780	280	18	5	302
	Chamaesipho tasmanica	0	0	0	3	0	0	0	18	0	0	0
	Catomerus polymerus	0	0	0	0	0	0	1	0	0	0	0
	Grapsidae sp.	0	0	0	0	0	0	0	0	2	0	0

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

NB: Unidentified gastropod refers to organisms which could not be identified to family level due to shell erosion/encrustation etc.

(d)

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	Kings Beach
Annelida	*Galeolaria caespitosa**	+	+	+	+	+	+	-	-	+	+	+
	*Pomatoceros taenita**	+	+	+	+	+	+	+	+	+	+	+
Mollusca	*Notoacmea flammea*	0	1	8	0	5	0	4	0	0	3	4
	Notacmea sp.	0	0	1	0	0	2	0	0	0	0	0
	Patelloida alticostata	0	0	0	0	12	16	2	1	0	0	0
	Patelloida latistrigata	1	0	3	33	11	441	7	0	0	1	0
	Cellana tramoserica	5	7	26	36	11	10	50	0	0	8	12
	Cellana solida	4	0	7	22	41	14	28	0	0	0	1
	Nerita atramentosa	13	44	1	9	11	0	3	4	4	26	6
	Chlorodiloma adelaidae	0	1	0	0	0	0	0	0	0	0	0
	Diloma concamerata	0	0	0	0	0	0	1	0	0	0	0
	Austrocochlea constricta	0	4	0	7	4	0	0	0	0	1	0
	Austrocochlea porcata	0	3	0	4	1	0	1	0	0	0	0
	Turbo undulatus	0	0	0	1	0	0	0	0	0	1	0
	Austrolittorina unifasciata	0	0	1	4	0	397	0	17	6	1	61
	Bembicium nanum	0	1	0	0	0	0	0	0	0	0	0
	Bembicium vittatum	11	16	13	6	1	2	2	4	1	0	0
	Siphonaria diemenensis	567	3	2074	773	1351	972	2123	0	1	45	14
	Siphonaria zelandica	0	2	0	0	2	0	1	0	1	0	0
	*Limnoperna pulex**	+	+	+	+	+	+	+	-	-	-	-
	Unidentified gastrodpod	7	7	30	70	45	14	78	1	2	0	8
Arthropoda	*Tetraclitella purpurascens*	0	0	1	1	0	18	0	0	0	0	0
	Chtalamus antennatus	49	3	238	184	33	608	60	21	7	18	7
	Chamaesipho tasmanica	0	0	187	120	14	3039	9	0	0	0	713
	Catomerus polymerus	0	0	0	0	0	1	0	0	0	0	0

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

NB: Unidentified gastropod refers to organisms which could not be identified to family level due to shell erosion/encrustation etc.