Adelaide Desalination Plant Intertidal Monitoring

Third Interim Report

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1. 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 third interim report of baseline monitoring for the intertidal reef system adjacent to 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, but 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 high biodiversity 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.

2. 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 third 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 Spring 2010 for intertidal surveys and preliminary observations for the intertidal surveys for Summer 2011.

3. Methods

3.1 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 November and December 2011 for the Spring survey and during February 2011 for the Summer survey. The Summer 2011 sampling has been completed, yet data are still being analysed and will be reported in the final report.

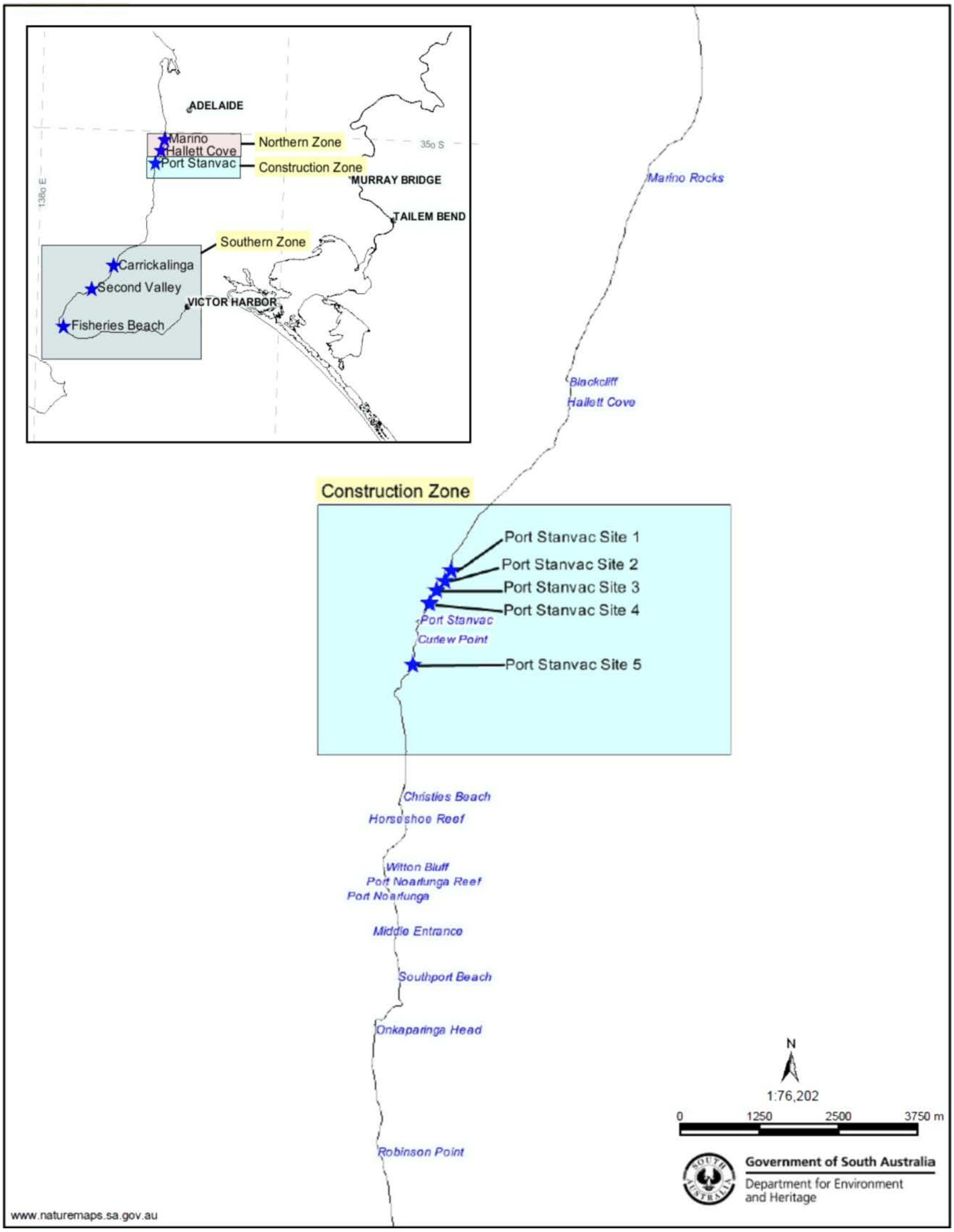


Figure 1: Intertidal sampling sites for the (a) Port Stanvac Construction Zone, Northern Reference Zone and Southern Reference Zone during Spring 2010 and Summer 2011 (b) magnified snapshot of the five Sites within the Construction Zone for the Spring 2010 and Summer 2011 surveys. Maps adapted from Nature 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 (refer to Figure 1 for locations) sampled during Spring 2010 and Summer 2011

	GPS Co-ordinates				
Location	South	East	Season	Date	Tidal Height (m)
Marino Rocks	S 35°02'45.6"	E 138°30'27.6"	Spring	23/11/2010	0.14
			Summer	3/02/2011	0.21
Hallett Cove	S 35°05'06.2"	E 138°29'31.5"	Spring	22/11/2010	0.14
			Summer	3/02/2011	0.21
Port Stanvac 1	S 35°06'48.8"	E 138°28'13.5"	Spring	24/11/2010	0.19
			Summer	22/02/2011	0.25
Port Stanvac 2	S 35°06'28.4"	E 138°28'20.0"	Spring	25 & 29/11/10	0.29 & 0.75
			Summer	15/02/2011	0.24
Port Stanvac 3	S 35°06'15.4"	E 138°28'31.8"	Spring	29/11/2010	0.75
			Summer	16/02/2011	0.24
Port Stanvac 4	S 35°06'12.4"	E 138°28'34.4"	Spring	14/12/2010	0.6
			Summer	17/02/2011	0.11
Port Stanvac 5	S 35°06'25.7"	E 138°28'20.7"	Spring	25/11/2010	0.29
			Summer	10/02/2011	0.37
Carrickalinga	S 35°25'09.0"	E 138°19'25.2"	Spring	9/11/2010	0.33
			Summer	9/02/2011	0.22
Second Valley	S 35°30'36.3"	E 138°12'54.2"	Spring	8/11/2010	0.28
			Summer	1/02/2011	0.38
Fisheries Beach	S 35°37'58.5"	E 138°06'49.4"	Spring	8/11/2010	0.28
			Summer	9/02/2011	0.22

3.2 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 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.

3.3 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.

3.4 Data Analyses

Data analyses were completed for the Spring 2010 survey, while the Summer 2011 survey is currently at the final stages of species identification and data entry. 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. 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 Spring 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.

4. Results

4.1 Photoquadrats

4.1.1 Invertebrate Species Diversity

During the Spring survey the largest number of species (predominantly molluscs) were identified within the northern side of the Construction Zone (Site 1a, 3b, 4a; Figure 2)[1]. Several sites within the Southern Reference Zone (Carrickalinga 1 & 2, Second Valley 1, Fisheries Beach 2; Figure 2) had similar numbers of species to sites of the Construction Zone. The lowest number of species across all three zones in Spring were recorded within the Northern Reference Zone (Figure 2). PERMANOVA indicated a significant difference between zones for total species numbers (Pseudo – $F_{2, 1.43}$ = 5.85; P = 0.0078). Pair-wise analysis revealed group differences between the Construction and Northern reference zone (t = 3.23; P = 0. 0085).

In Spring, most sites in the Construction Zone had moderate species diversity and a relatively even occurrence of species. The highest species diversities and eveness were found at Port Stanvac 1 and 3, which was only exceeded at Second Valley in the Southern Reference Zone (Table 2). Some sites in the Northern and Southern Reference Zone were dominated by few species, resulting in low diversity. In particular the Northern Reference Zone had low species diversity compared to sites within the Port Stanvac Construction Zone (Table 2).

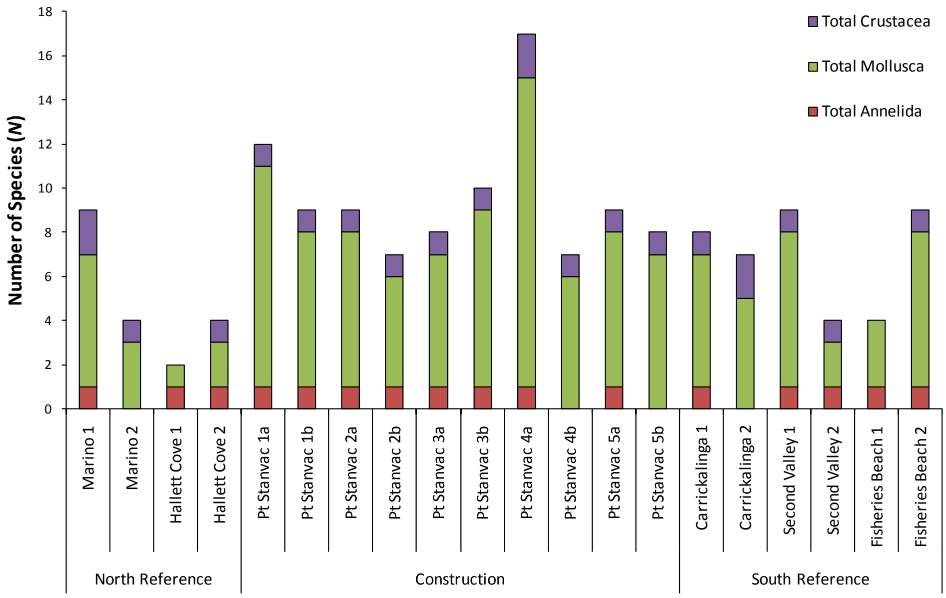


Figure 2: Total species number per phyla identified in quadrats during the Spring survey for the Northern Reference Zone, Construction Zone and Southern Reference Zone in Spring 2010.

[1] *Refer to Appendix 1 for complete presence/absence list of species per site

Table 2: Diversity indices for the Spring 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.

Site	S	N	Shannon-Wiener	Pielou's Evenness	Simpson
Marino Rocks	10	420	0.9096	0.395	0.4131
Hallett Cove	3	624	0.3211	0.2922	0.1718
Port Stanvac 1	11	287	1.721	0.7177	0.7718
Port Stanvac 2	8	722	1.173	0.5639	0.5441
Port Stanvac 3	10	139	1.779	0.7725	0.7718
Port Stanvac 4	17	1313	1.203	0.4245	0.4758
Port Stanvac 5	10	971	1.152	0.5004	0.5135
Carrickalinga	9	1211	0.4991	0.2271	0.2049
Second Valley	9	41	1.816	0.8264	0.8232
Fisheries Beach	10	168	1.168	0.5073	0.4937

4.1.2 Invertebrate Abundances

In Spring, the average invertebrate abundance from the Construction Zone was 351.6 individuals ± SD 314.8, in comparison with 261 ind. ± SD 115.2 in the Northern and 236.7 ind. ± SD 463.3 in the Southern Reference Zones. A two factor (Zone and Site (Zone)) univariate PERMANOVA of total invertebrate abundances revealed a significant difference between Sites (Zones) (Pseudo – $F_{7, 68.06}$ = 5.29; P = 0.0002) but not between Zones (Pseudo –$F_{2, 86.7}$ = 1.27; P = 0.329).

Total abundances of all phyla within the Construction Zone were largest at the southern sites, Port Stanvac 4b and 5b (Figure 3a). The highest abundance of all phyla across all zones was found within the Southern Reference Zone at Carrickalinga 1 (Figure3a). However, some of the lowest abundances of all sites also occurred within the Southern Reference Zone, at Carrickalinga 2, Second Valley 1 and 2, Fisheries Beach 1 (Figure 3a).

Molluscs were most abundant within the Northern Reference Zone at sites Marino 2 as well as Hallett Cove 1 and 2 (Figure3b). Mollusc abundances were significantly different between Zones (PERMANOVA , Pseudo – $F_{2, 53.87}$ = 5.08; P = 0.0437), but not Sites (Zones) (Pseudo – $F_{7, 10.6}$ = 1.88; P = 0.07). Pair-wise analysis for Zone revealed significant differences between the Construction and Southern Reference Zone (t = 2.66; P (MC) = 0.04) as well as between the Northern and Southern Reference Zones (t = 3.38; P (MC) = 0.04).

Large abundances of crustaceans were found at the southern end of the Construction Zone (Sites 4b, 5b) and also at Carrickalinga 1 (Figure 3c.). Abundances of crustaceans were significantly different between Sites(Zones) (PERMANOVA , Pseudo – $F_{7, 69.76}$ = 6.95; P = 0.0001) but not between Zones (Pseudo – $F_{2, 85.35}$ = 1.22; P = 0.32).

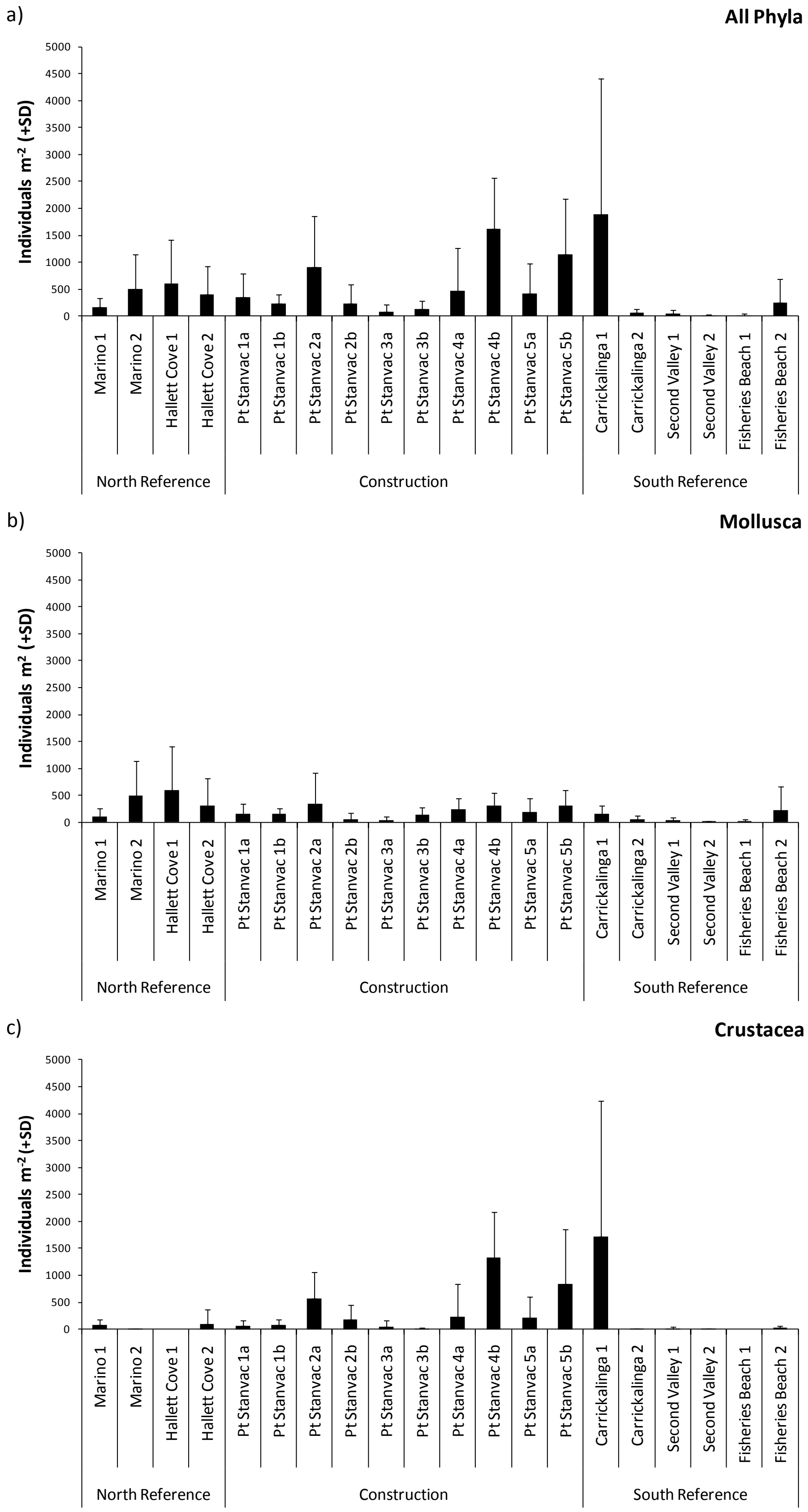
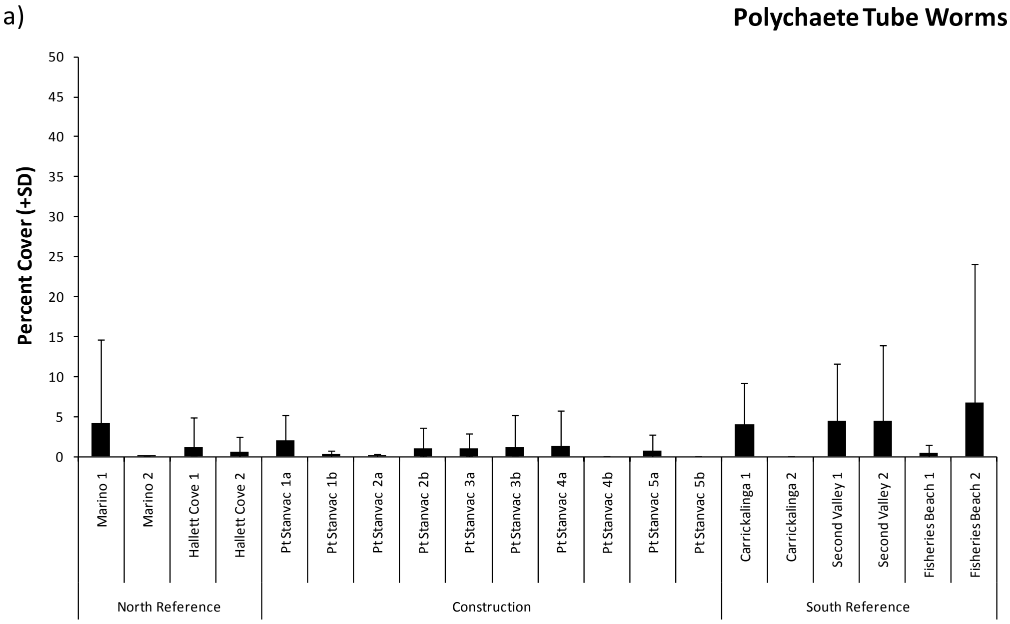


Figure 3: Mean abundances and standard deviations (SD) for (a) all phyla, (b) mollusca and (c) crustacea identified in photoquadrats (n=10) from the 2010 Spring survey at all sites encompassing three zones; Northern Reference Zone, Construction Zone and Southern Reference Zone.

4.1.3 Percent Cover of Sessile Invertebrates

In Spring, the percent cover of sessile fauna was under 15% for all species across the three separate zones. The percent cover was high at most sites of the Southern Reference Zone due to polychaete tubeworms (Figures 5a). There was a greater presence of the mussel *Limnoperna pulex* at the sites Hallett Cove 2 and Port Stanvac 4b in comparison to other sites across all zones (Figure 5b). Mean percent cover of *L. pulex* was low across the Southern Reference Zone and the northern end of the Port Stanvac Construction Zone (Figure 5b).



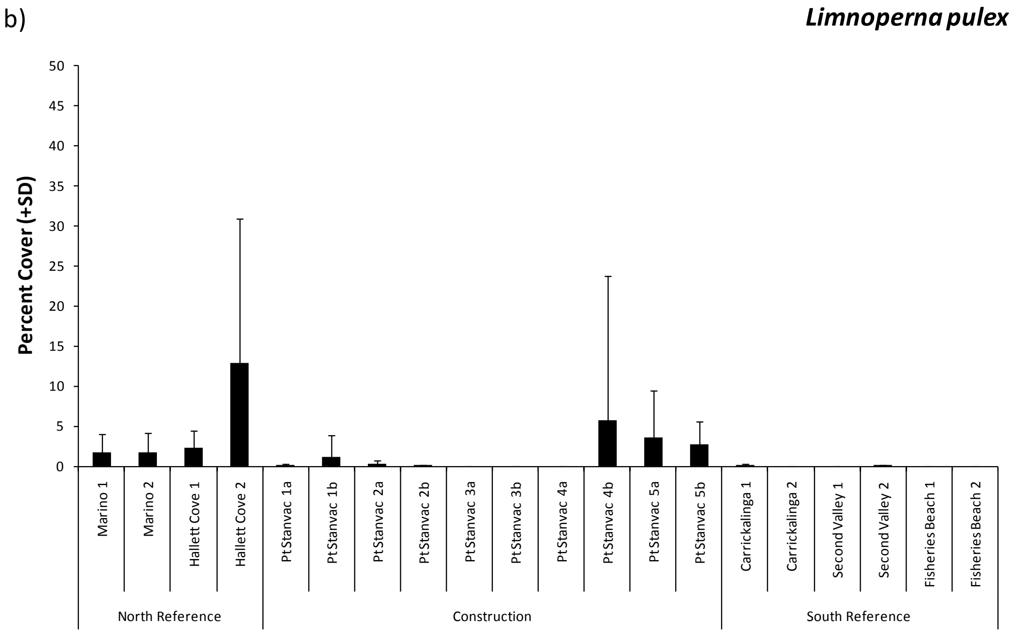


Figure 5: Mean percent cover and standard deviations (SD) for (a) polychaete tubeworms (*Galeolaria caespitosa* and *Pomatoceros taenita*) (b) the mollusc *Limnoperna pulex* identified from photo quadrats (n=10) in the Spring 2010 survey at all sites encompassing three zones; Northern Reference Zone,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

4.1.4 Community Structure of Rocky Shore Invertebrates

The rocky shore invertebrate community was different in each zone (Figure 7). Two factor PERMANOVA for Zones and Sites (Zone) revealed a significant difference between Zones (Pseudo – $F_{2, 7760.8}$ = 3.40; P = 0.0055) but not for Sites (Zone) (Pseudo – $F_{7, 22.84}$ = 1.43; P = 0.06). The Northern Reference Zone had a more distinct community structure compared to the more variable assemblages occurring in the Southern and Construction Zones. Pair-wise tests indicated group differences between the Construction and Northern Reference Zone (t = 1.98; P (MC) = 0.0194) and between the Northern and Southern Reference Zones (t = 4.50; P (MC) = 0.0001). No significant difference was found between the Construction and Southern Reference Zone (t = 1.37; P = 0.1125), also indicated by partial overlap of points in the PCO plot (Figure 7).

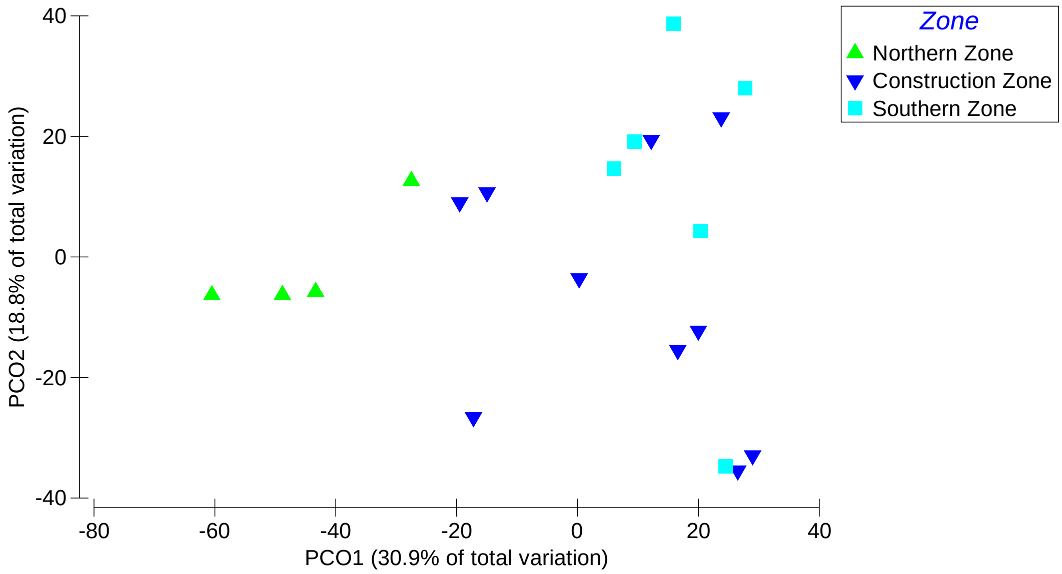


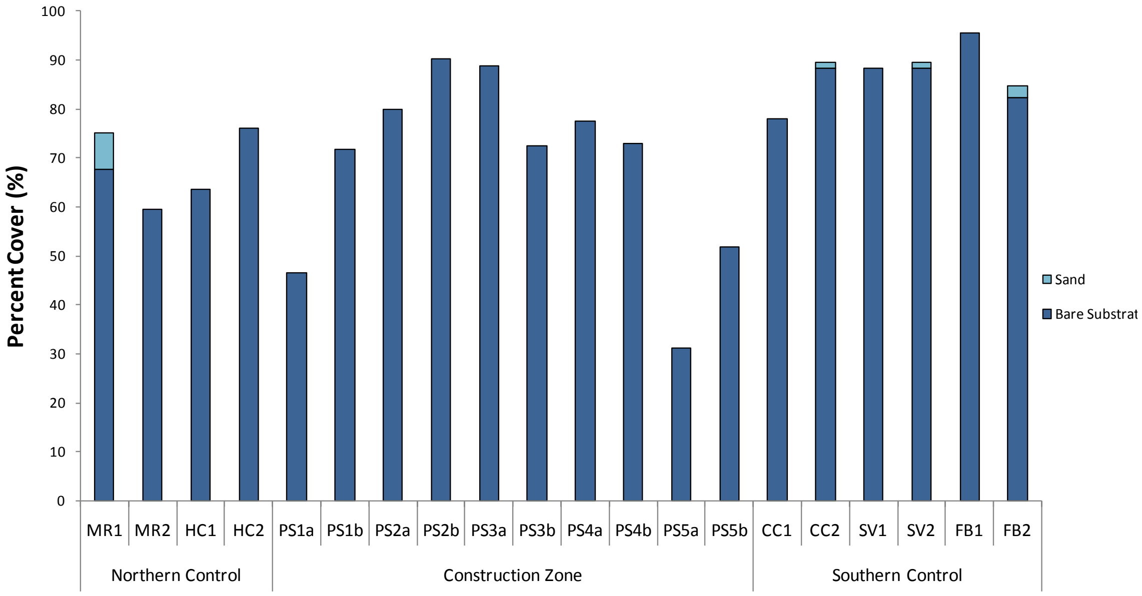
Figure 7: Principle Co-Ordinates (PCO) plot of invertebrate communities for the Spring 2010 survey for the sampling Zones using Bray-Curtis resemblance matrices.

4.2 Video Transects

4.2.1 Percent of Substrate Cover

During Spring, the highest percent of bare rock occurred within the Southern Reference Zone, with an average of 86% across the 4 sites. In comparison, an average of 67% and 68% bare rock cover was recorded at the Northern Reference Zone and Construction Zone respectively. The site with the least amount of bare rock was Port Stanvac 5a, while Fisheries Beach 1 had almost totally bare rock. Overall, sand cover was very low, and detected at only four sites (MR1, CC2, SV2 and FB2), with none of them located within the Construction Zone (Figure 8a). Algal and sessile fauna was highest at Port Stanvac site 5a, 5b and 1a where the sites had greater than 45% cover. Tube worms were present at all sites in all zones (Figure 8b).

(a)



(b)

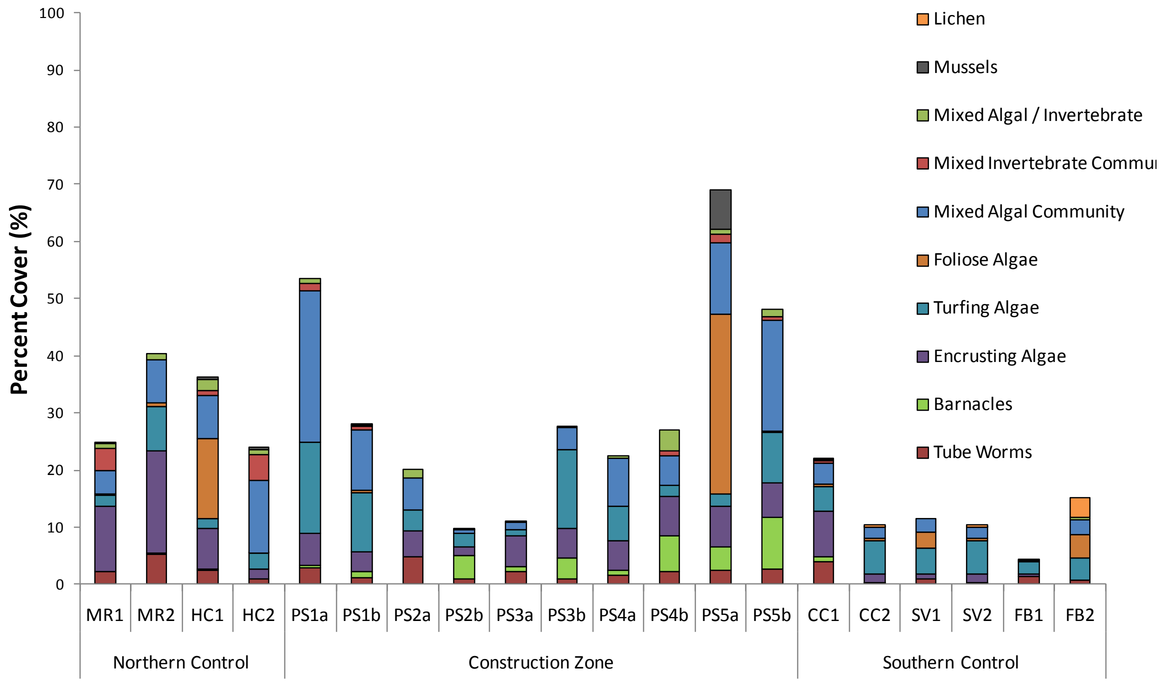


Figure 8: Mean percent cover of intertidal reefs, split into (a) bare substrate and sand and (b) algal and fauna as quantified from video transects. Based on intertidal reefs at all sites, across three Zones; Northern Reference Zone, Construction Zone and Southern Reference Zone during the Spring survey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

4.2.2 Video Transects – Community Structure

Based on the video transects, the assessment for rocky shores revealed significantly different communities between zones (PERMANOVA , Pseudo-$F_{2,\ 2902.5}$ = 3.0868; P = 0.0015). Pair-wise tests indicated significant differences between the Northern Reference Zone and the Construction Zone (P (MC) = 0.0316), and the Southern Reference Zone and Construction Zone (P (MC) = 0.0066). However, no significant difference was detected between the Northern and Southern Reference Zones (t =1.4216 ; P = 0.1059) (Figure 9).

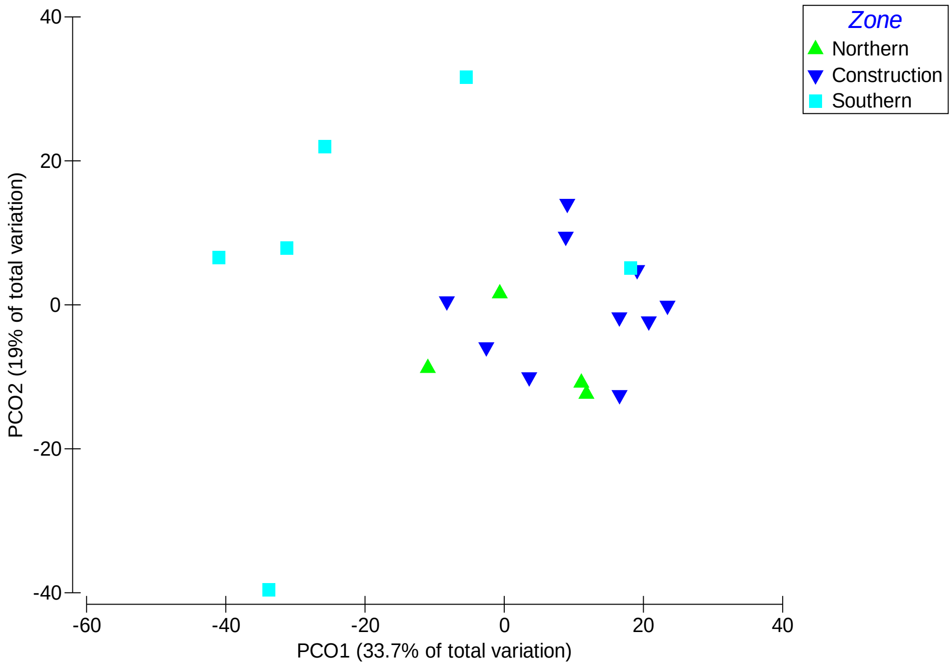


Figure 9: Principle Co-ordinates (PCO) plot of substrate structure obtained via video transect in Spring 2010 for Zones using Bray-Curtis resemblance matrices.

5. Summary of Key Results

- Sites in the Construction Zone had higher invertebrate abundances in Spring 2010, than sites in the Northern and Southern Reference Zones, apart from Carrickalinga 1.
- Diversity indices calculated for invertebrate species at all sites in Spring 2010 revealed that Second Valley had the highest species diversity, with the lowest found at Hallett Cove.
- Crustacea were the dominant phyla within the photo quadrats with highest abundances occurring at the Construction Zone and at Carrickalinga 1.
- Abundances of molluscs were on average similar to crustacean, yet highest abundances obtained from the Northern reference Zone.
- Sessile invertebrates were dominated by polychaete tube worms and were mainly found at the Southern Reference Zone.

- Community structure of rocky shores was distinctively different between the Construction Zone and the North Reference Zone as well as between the Northern and Southern Reference Zones.
- Algal and sessile fauna cover was similar between the Northern and Southern Reference Zones. However, the percent cover of algal and sessile fauna within the Construction Zone was significantly different from both Reference Zones.

6. Preliminary Observations for Summer 2011

A brief analysis of Summer 2011 photoquadrat data indicate that the patterns in invertebrate abundances have remained similar to the Spring 2010. A slight increase in species diversity was detected in the Northern Reference Zone in comparison to the previous season (Spring 2010). Preliminary observations of video transects revealed similar patterns in the percent cover of algal and sessile invertebrates across the Northern, Construction and Southern Zones in comparison to the previous season. A more detailed analysis of Summer 2011 data will further determine variability in community structure across the Construction and Reference Zones.

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8. Appendix 1

Presence of invertebrate species at each location according to zone for Spring 2010.

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			✓	✓		✓	✓			
	Cellana tramoserica	✓		✓		✓	✓	✓	✓		✓
	Cellana solida									✓	
	Nerita atramentosa	✓		✓	✓	✓	✓	✓	✓	✓	✓
	Fissurellidae spp.										✓
	Diloma concamerata					✓		✓			
	Austrocochlea constricta			✓			✓	✓		✓	✓
	Austrocochlea porcata						✓				
	Austrolittorina unifasciata	✓	✓		✓	✓	✓	✓	✓	✓	✓
	Bembicium auratum						✓		✓		
	Bembicium nanum			✓	✓	✓	✓				
	Bembicium vittatum			✓	✓	✓	✓	✓	✓	✓	✓
	Siphonaria diemenensis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Siphonaria zelandica	✓			✓	✓	✓				
	Unidentified gastropod	✓		✓			✓			✓	✓
Crustacea	*Tetraclitella purpurascens*								✓		
	Chtalamus antennatus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Chamaesipho tasmanica						✓				