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SPECIES COMPOSITION AND SPATIAL DISTRIBUTION OF ECHINODERMS IN THE SHALLOW COAST OF ADMIRALTY BAY, KING GEORGE ISLAND, ANTARCTICA

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Abstract: *The echinoderm species composition from the shallow coast of Admiralty Bay was assessed from specimens collected during the austral summers of 2008/9 and 2010/11. Their density, diversity and community structure at four sampling stations in two bathymetric zones [shallow (20 – 30 m) and deep (50 – 60 m)] were compared. We tested the following hypotheses based on previous environmental and biological data: 1) echinoderm density is lower in the shallowest zones; 2) diversity from the deepest zone is higher; 3) community structure differs among stations and bathymetric zones. The hypothesis that the total density is lowest in the shallowest zone was rejected, and density differed only among stations. Diversity differed only between stations, but lowest values occurred mainly in the shallowest zones. PERMANOVA analysis showed that assemblages differed between depths, there being an interaction with stations. Environmental condition differences (e.g., sediment texture) between areas and depths probably induced the highest abundance of the sea star Odontaster validus and the sea urchin Sterechinus neumayeri in the shallowest zone, and that of the brittle stars Ophionotus victorae and Amphioplus acutus in the deepest zone. These results will support future investigations that should also incorporate multiple spatial and temporal scales.*

Keywords: Megafauna, Echinodermata, South Shetlands, Species Composition, Diversity.

Introduction

Admiralty Bay at the King George Island, South Shetlands, became an Antarctic Specially Managed Area (ASMA #1) in 1996. Brazil has systematically monitored the bay since the Austral summer of 2002/03 (Montone *et al.,* 2013). Three research stations - the Brazilian Comandante Ferraz, the Polish Henryk Arctowski, and the Peruvian Machu Picchu – are located in this bay and therefore the area is subject to fairly high human scientific activities.

Echinoderms represent one of the most conspicuous groups of marine invertebrates in Antarctica (e.g., Clarke *et al.* 2004; Barnes, 2005; Arntz *et al.*, 2006), and this is also the case for Admiralty Bay (Sicinski *et al.,* 2011). They are particularly diverse in Antarctica, representing about 10% of the 4.100 known benthic species (Clarke & Johnston, 2003). In Admiralty Bay they represent about 6% of the 1.300 known species of the benthic fauna (Sicinski *et al.*, 2011). Echinoderms play an important role in Antarctic marine ecosystems as they are abundant and usually show patchy, but fairly high biomass (Clarke & Johnston, 2003). Corbisier *et al.* (2004) recorded a wide range of feeding habits in Admiralty Bay, for instance, the sea star *Odontaster validus* as carnivore, the brittle star *Ophionotus victoriae* as omnivore, and the sea urchin *Sterechinus neumayeri* as herbivore (these animals represented in Figure 2).

Nonato *et al.* (2000) and Sicinski *et al.* (2011) showed that benthic depth zonation in Admiralty Bay is essentially influenced by the sediment texture and by the action of the ice. The latter reduces the occurrence of sessile forms in shallowest zones, and generally a low diversity of organisms is dominated by wandering animals (Sicinski *et al.*, 2011). At depths more than 20-25 m, conditions are more stable and these authors suggest that a more diverse benthic community occurs.

Taking into account the relevance of echinoderms for the Antarctic benthic communities and also the different conditions existent at different depths in the Admiralty Bay coastal marine environment, the following hypotheses were raised: 1) the density of echinoderms is lowest in the shallowest zone of the bay (20-30 m) in relation to the deepest zone (50-60 m), and it differs between distinct sampling stations; 2) the diversity in the shallowest zone is lower than the deepest zone and differs between sampling stations; 3) the echinoderm assemblages differ between stations and depths.

Materials and Methods

Study site main features

Admiralty Bay is the largest bay of King George Island with a maritime area of 144 km^2. It is very heterogeneous and characterized as a fjord system with a 550 m deep central basin (Pruszak, 1980; Campos *et al.*, 2013). The presence of blocks of ice resulting from melting icebergs and glaciers in the seawater and on beaches are common. According to Sicinski (2004), the sediment of Admiralty Bay is very heterogeneous, with several grain size fractions originated from the coastal erosion and melting of icebergs.

Sampling

Samples were taken using an “Agassiz Trawl” dredge with an opening of 56 x 36 cm, a bottom sack of 60 cm long and a 4 mm mesh size at four monitoring stations: Refuge II (R2), Ferraz Station (FS), Ullman Point (UP) and Botany Point (BP) (Figure 1), in two bathymetric zones during

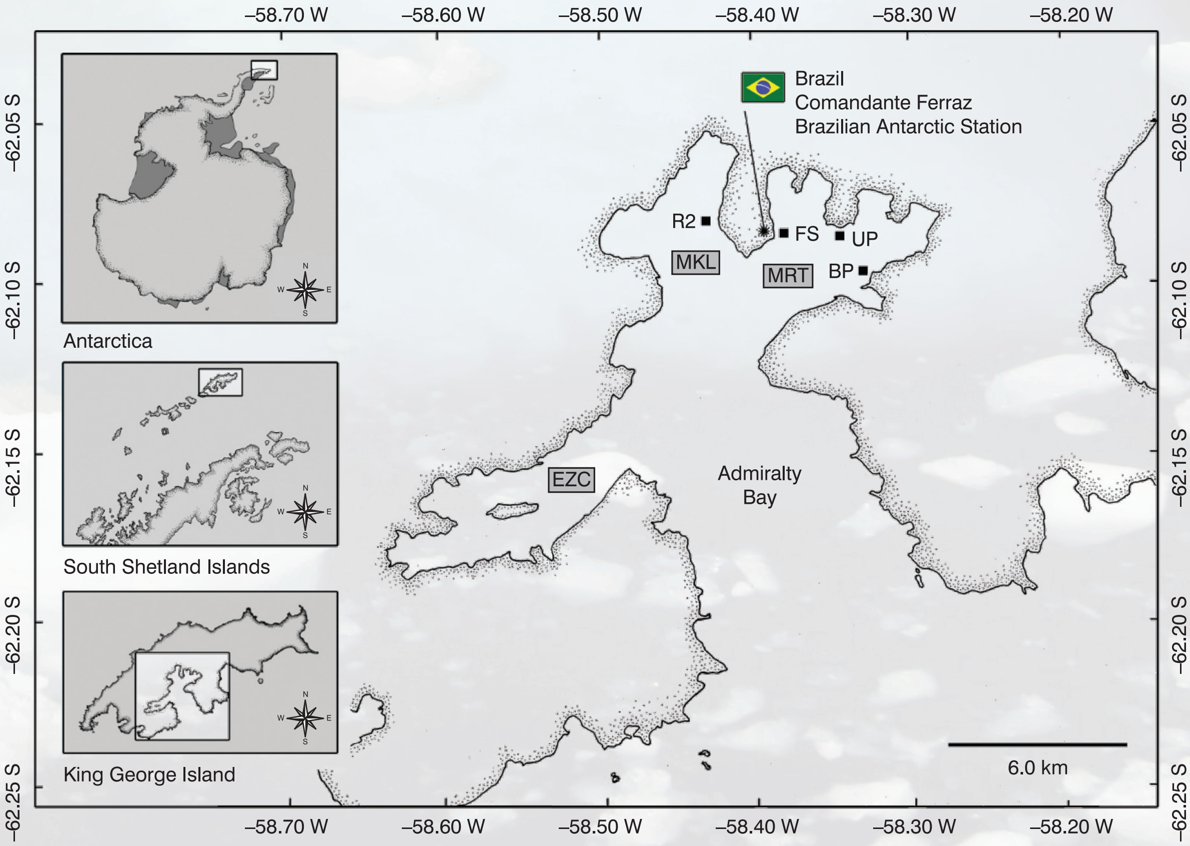

Figure 1. Study area, in highlight Admiralty Bay with three inlets (Ezcurra (EZC), Mackellar (MKL) and Martel (MRT)) and the four sampling stations. R2 = Refuge II; FS = Ferraz Station; UP = Ullman Point; BP = Botany Point. Modified from Moura (2009).

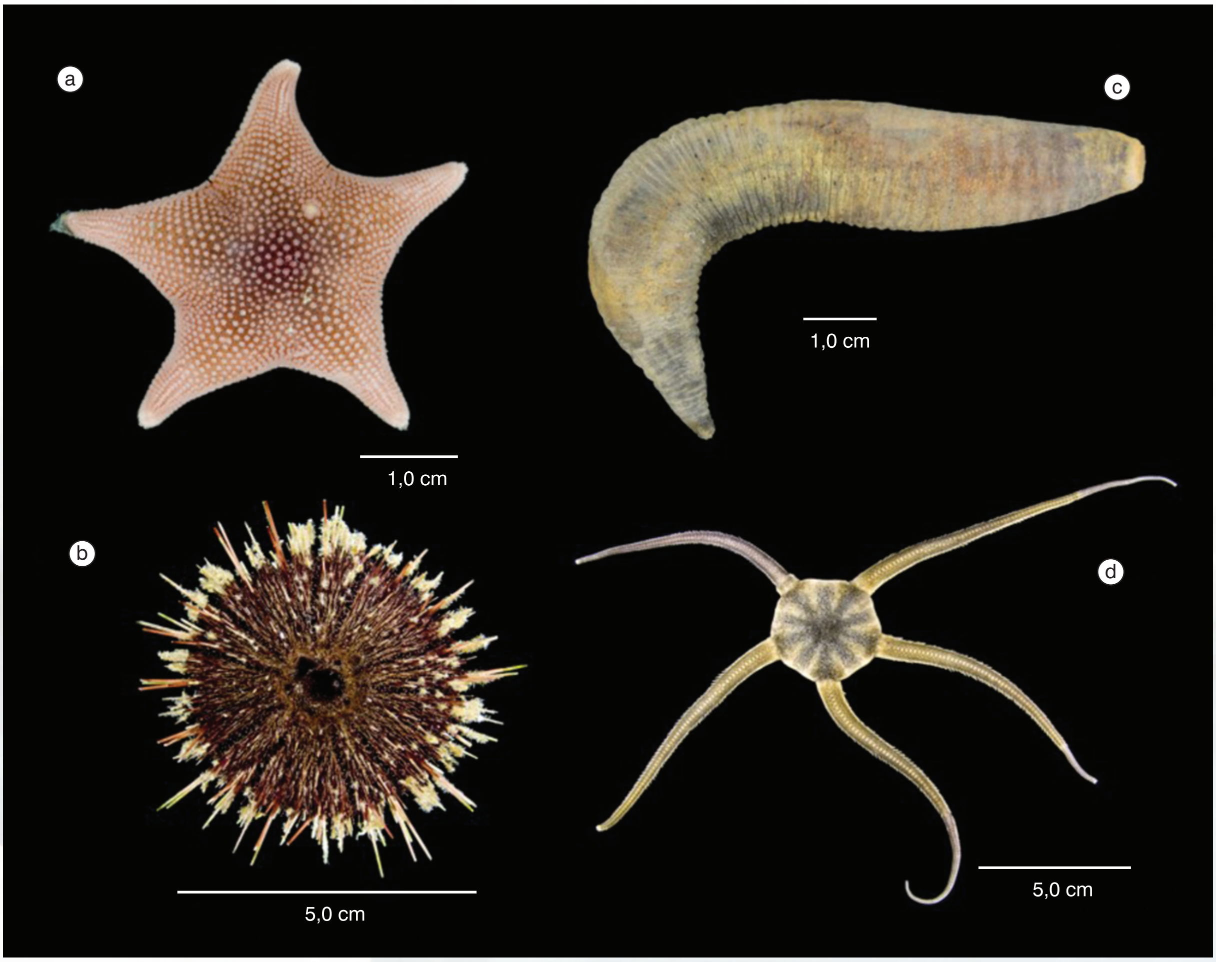

Figure 2. Echinoderms from Admiralty Bay, King George Island, Antarctica. A) *Odontaster validus*; B) *Sterechinus neumayeri*; C) *Molpadia musculus*; D) *Ophionotus victoriae*. Photos A, B and D by Gabriel S.C. Monteiro (IO-USP); Photo C by Andre M. Lanna.

the Austral summers as follows: 50-60 m depth in 2008/09 (deepest zone); and 20-30 m in 2010/11 (shallowest zone).

Data analyses

Density (ind.100 m^{-2}) was calculated by dividing the number of organisms by the total area dredged (about one minute long for each dredging). Species diversity was calculated using Shannon-Wiener Index. The analysis of variance (ANOVA) was used to test the significance of the difference between the values of total density of *Ophionotus victoriae*, *Sterechinus neumayeri*, *Amphioplus acutus* and *Odontaster validus*. Sampling station was considered a fixed factor with four levels and orthogonal to depth a random factor with two levels, replicated three times. The same model was used to test the difference between the species diversity using the Shannon index. Normality and heteroscedasticity were tested using the Shapiro-Wilk and Cochran tests, respectively. When these premises were not satisfied, the values were transformed to log x+1. Principal Components Analysis (PCA) was performed to describe spatial and temporal variations in community assemblages. The Hellinger transformation was applied to the biological matrix, which preserves the Euclidian distance, and is considered a robust procedure for ordination of biological data using principal components (Legendre & Gallagher, 2001). All the analyses were done using the R program (R Development Core Team, 2007), with the assistance of GAD (Sandrini-Neto & Camargo, 2011) and the vegan (Oksanen *et al.*, 2011) packages, and PERMANOVA program (Anderson, 2005).

Results

A total of 2.473 echinoderms were collected, represented by 18 species in seven families of sea stars, three of sea urchins, three of sea cucumbers and two of brittle stars (Table 1).

The total density and that of *O. victoriae* differed only between stations, being lowest at Refuge II. A difference occurred between depths, where the density of *A. acutus* was highest in the deepest zone, and that for *O. validus* in the shallowest zone. The density of *S. neumayeri* was highest in the shallowest zones of the bay, there being a significant interaction between station-depth (Figure 3; Table 2).

The diversity of echinoderms differed between stations. The lowest values occurred at Botany Point, especially in the shallowest zone. But generally, the diversity did not differ between the shallowest and deepest zones (Figure 3; Table 2).

The principal components analysis explained 60% of the biological variability and the diagram divided the stations into two main groups, shallowest and deepest zones (Figure 4.). *S. neumayeri* and *O. validus* were associated with the shallowest zone, whilst *A. acutus* and *O. victoriae* were associated with the deepest zone. PERMANOVA analysis corroborated the results found using the PCA, showing that echinoderm assemblages differed between bathymetric zones, but there was a significant interaction within stations (Table 3).

Discussion

In this study, 18 species of echinoderms were registered. This is equivalent to 22% of the total echinoderm species (81 species) known for Admiralty Bay (Sicinski *et al.*, 2011). Ice scouring along the seabed (Nonato *et al.*, 2000), as well as anthropogenic disturbances (Martins *et al.*, 2012) have been mentioned as the main drivers for benthic bathymetric variability in the shallow coastal zones of Admiralty Bay. Even though these may influence communities' structure (Sicinski *et al.*, 2011), we rejected the hypothesis that the total echinoderm density decreases in the shallowest zones here sampled.

Conversely, the density of the echinoderms differed among sampling stations, and was lowest in Refuge II, where during the studied Austral summers (2008/09 and 2010/11) a considerable amount of blocks of ice was observed, even though not recorded. This ice was probably derived from the Domeiko Glacier, which occupies an extensive area of Mackellar Inlet. The effect of anchor ice and ice scour could be the main causes for the low community density at the Refuge II sampling station. And this might have been true for both bathymetric zones analysed here, as the echinoderms showed low densities in both the shallowest and deepest zones. In high latitudes, processes such as anchor ice and ice scour are common in the bottom of bays, and are known to cause disturbances in benthic

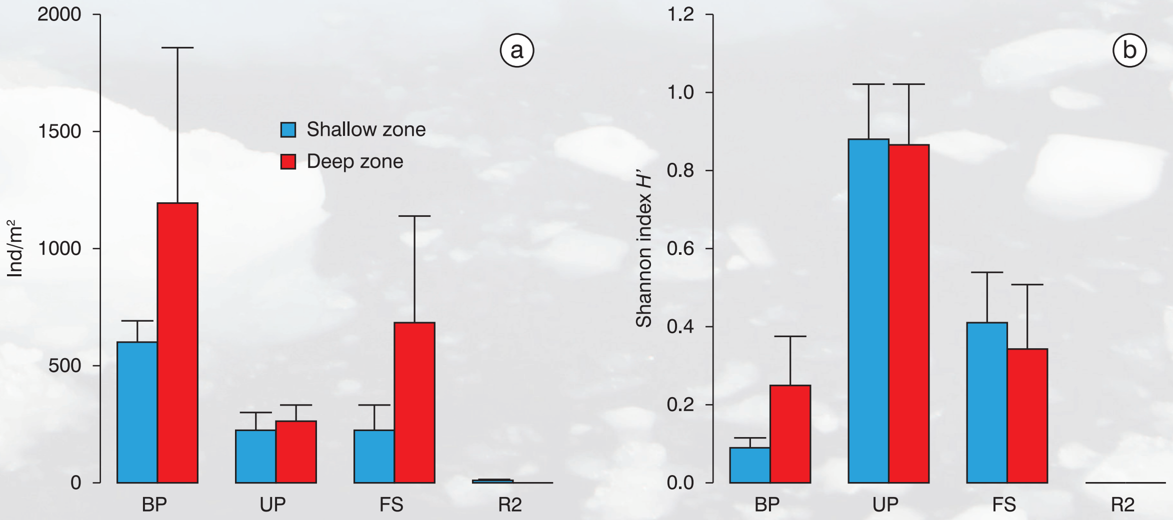

Figure 3. a) Density (±SD) and b) Diversity (±SD) of the echinoderms in the four sampling stations, in the shallow and deep zones in Admiralty Bay. BP = Botany Point; UP = Ullman Point; FS = Ferraz Station; R2 = Refuge II.

communities, as well as freezing or even crushing the organisms, and therefore reducing diversity (Gutt, 2001). The slower speed of the tidal currents in the Mackellar Inlet (~0.02 m.s^{-1}) in comparison to Martel (~0.10 m.s^{-1}) (Weber & Montone, 2006) could reduce salinity condition and increase turbidity during the summer, accentuated by the melting ice. As echinoderms are typically marine organisms with low tolerance for salinity changes, these processes should be considered important regulatory sources for their distribution within Admiralty Bay.

Differences between depths were found when the species densities were investigated separately. For example, the density of the amphiurid brittle star *A. acutus* was always highest in the deepest zone of the bay. In general, amphiurids are infaunal deposit feeders, and characteristically live in muddy sediments (Rosenberg, 1995). The Admiralty Bay

Table 1. Echinoderms species collected in Admiralty Bay, King George Island, Antarctica.

Class Asteroidea		
	Family Odontasteridae	
		Acodontaster conspicuus (Koehler, 1920)
		Odontaster validus Koehler, 1906
	Family Ganeriidae	
		Perknaster charcoti (Koehler, 1912)
	Family Poraniidae	
		Porania antarctica (Smith, 1876)
	Family Korethrasteridae	
		Remaster gourdoni Koehler, 1912
	Family Solasteridae	
		Cuenotaster involutus (Koehler, 1912)
	Family Asteriidae	
		Diplasterias brucei (Koehler, 1908)
	Family Astropectinidae	
		Psilaster charcoti (Koehler, 1906)
Class Echinoidea		
	Family Echinidae	
		Sterechinus neumayeri (Meissner, 1900)
	Family Schizasteridae	
		Abatus sp.
	Family Ctenocidaridae	
		Ctenocidaris rugosa (Koehler, 1926)
Class Holothuroidea		
	Family Psolidae	
		Psolus charcoti Vaney, 1906
	Family Cucumariidae	
		Cucumaria georgiana (Lampert, 1886)
		Trachythyone bouvetensis (Ludwig & Heding, 1935)
	Family Molpadiidae	
		Molpadia musculus Risso, 1826
Class Ophiuroidea		
	Family Ophiuridae	
		Ophionotus victoriae Bell, 1902
		Ophiura rouchi (Koehler, 1902)
	Family Amphiuridae	
		Amphioplus acutus Mortensen, 1936

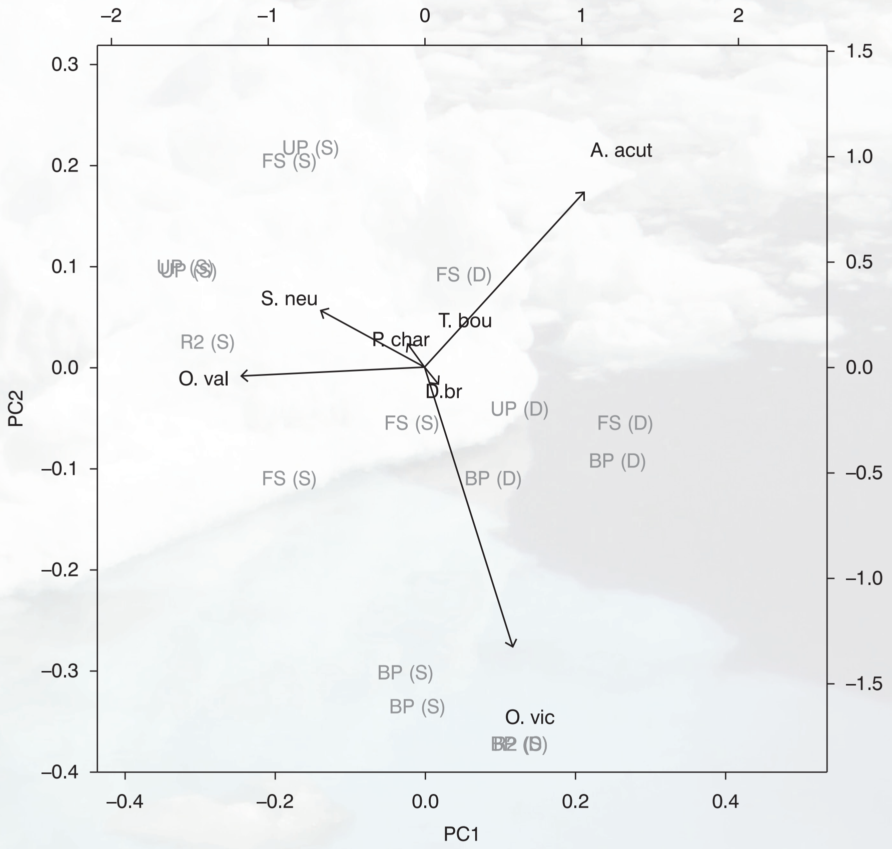

Figure 4. PCA diagram of echinoderm species. (O.val) *O. validus*, (S.neu) *S. neumayeri*, (A.acut) *A. acutus*, (O.vic) *O. victoriae*, (P.char) *P. charcoti*, (D.br) *D. brucei*, (T.bou) *T. bouvetensis*. R2(S) = Refuge II Shallow; FS(S) = Ferraz Station Shallow; UP(S) = Ullman Point Shallow; BP(S) = Botany Point Shallow; R2(D) = Refuge II Deep; FS(D) = Ferraz Station Deep; UP(D) = Ullman Point Deep; BP(D) = Botany Point Deep.

shallowest zones consist of predominantly thick sediment with a significant presence of pebbles, while the deepest zone is characterised by muddy sediment (Schaefer *et al.*, 2004), and this would possibly explain the highest density of *A. Acutus* at this zone. *S. neumayeri*, a macroalgae consumer (Corbisier *et al.*, 2004), was more abundant in the shallowest zones. We expected that this could be positively related to the macroalgae biomass found in these zones. And a regression of the density of *S. neumayeri* against the biomass of macroalgae showed a significant positive relationship ($n = 12$, $p < 0.05$) between them. Large quantities of macroalgae were found in Ferraz and Ullman Point, creating suitable conditions for the dominance of *S. neumayeri*. The lack of macroalgae from the Botany Point samples could be related to the intake of melting water with terrigenous material originated from the Krak Glacier. This would cause high turbidity and reduce the photic layer, being less suitable for the algae growth. *S. neumayeri* was not recorded from this sampling station. This was the reason of the interaction between the station-depth found in the ANOVA analysis.

The hypothesis that the diversity is highest in the deepest zones was not corroborated. The evidence suggested that regulatory processes controlling diversity do not have an effect on the bathymetric scale sampled. Although the values of diversity found were similar, the PCA diagram and the PERMANOVA analysis showed that the assemblages differed between depths. The sea star *Odontaster validus* and sea urchin *S. neumayeri* were more abundant in shallowest zones, the latter absent in deepest zones, while the brittle stars *A. acutus* and *O. victorae* were abundant in deepest zones, and rare in shallowest zones. Also, diversity was different between stations. Ullman Point showed the highest

Table 2. Summary of ANOVA analysis of the total density, density of *Ophionotus victoriae*, *Amphioplus acutus, Sterechinus neumayeri, Odontaster validus* and diversity. DF = Degrees of Freedom; SS = Sum of Squares; MS = Mean of Squares. Values of p in bold <0.05.

Density *(Echinoderms)*					
Factor	DF	SS	MS	F	p
Station	3	82.844	27.614	13.233	**0.031**
Depth	1	0.326	0.3259	0.237	0.633
Depth x Station	3	6.26	2.086	1.517	0.248
Residuals	16	22.003	1.3752		
Ophionotus victoriae					
Station	3	106.117	35.372	13.1637	**0.031**
Depth	1	0.045	0.045	0.0094	0.924
Depth x Station	3	8.061	2.687	0.5568	0.651
Residuals	16	77.216	4.826		
Amphioplus acutus					
Station	3	33.969	11.323	1.6865	0.339
Depth	1	47.314	47.314	21.9432	**0.000**
Depth x Station	3	20.142	6.714	3.1138	0.056
Residuals	16	34.499	2.156		
Sterechinus neumayeri					
Station	3	32.638	10.879	1	0.500
Depth	1	31.384	31.384	86.465	**0.000**
Depth x Station	3	32.638	10.879	29.973	**0.000**
Residuals	16	5.808	0.363		
Odontaster validus					
Station	3	1.5362	0.5121	0.2883	0.833
Depth	1	22.231	22.231	27.6415	**0.000**
Depth x Station	3	5.3284	1.7761	2.2084	0.127
Residuals	16	12.8682	0.8043		
Diversity					
Station	3	2.54815	0.84938	57.8906	**0.000**
Depth	1	0.00282	0.00282	0.0706	0.790
Depth x Station	3	0.04402	0.01467	0.3678	0.780
Residuals	16	0.63827	0.03989		

Table 3. Summary of PERMANOVA analysis. DF = Degrees of freedom; SS = Sum of squares; MS = Mean of squares. *p*(MC) probability of Monte Carlo permutation.

Factor	**DF**	**SS**	**MS**	**F**	***P*(perm)**	***p*(MC)**
Station	3	3.3631	1.1210	1.1060	0.3942	0.4281
Depth	1	3.3033	3.3033	10.4893	**0.0001**	**0.0001**
Depth x Station	3	3.0408	1.0136	3.2186	**0.0002**	**0.0009**
Residuals	16	5.0388	0.3186			

diversity followed by Ferraz and Botany. Despite the fact that the highest density and species richness occurred in Botany, diversity there was depressed by the dominance of *O. victoriae*.

Conlan *et al.* (2004) reported that marine benthos is affected by sewage discharges from McMurdo Station. These authors showed declined diversity and changes of the dominant species in that area. Previous studies (*e.g.* Schaefer *et al.*, 2004, Santos *et al.*, 2005) pointed out high values of total organic matter in the vicinity of Ferraz in comparison with those obtained in other reference areas (Botany, Hennequin and Arctowski) from Admiralty Bay. Montone *et al.* (2010) reported high values of faecal steroids in front of Ferraz. Also, the Ferraz sewage appear to influence an area up to approximately 200 m distant from its effluent (Montone *et al.,* 2013), which includes the 60 m isobath sampled here. However, our results showed that possible disturbances caused by sewage discharges not necessarily could be considered as a primary source for the variability in echinoderms distribution. They were fairly dense and diverse in front of Ferraz Station compared to other stations.

Conclusion

The total echinoderm density and diversity were investigated here against two different depth ranges (20-30 m and 50-60 m) and sampling stations within Admiralty Bay. Differences occurred when the species were analysed separately, probably because of their different biological characteristics, such as the preference for certain sedimentary textures (e.g., *A. acutus*), or feeding habits (e.g., *S. neumayeri*). Future studies should adopt multiple spatial and temporal scales, as the region is characterised by large temporal and spatial variability (Sicinski *et al.,* 2011). Also, it would be relevant to study the echinoderms in relation to other biotic factors, as well as the abiotic ones, taking into account that they may play different roles in the benthic communities according to their niche and feeding habits.

Although previous studies indicated a possible anthropogenic impact in front the Ferraz Station, our results did not corroborate this evidence. The differences found in density, diversity and in the echinoderm assemblages were probably caused by distinct environmental features between the sampling stations, and biological factors related to the community structure in each area. Further studies on echinoderms' distribution in relation to biotic and abiotic factors, including other areas and bathymetric zones from Admiralty Bay (besides the ones shown here) would be relevant to better understand their role in the benthic communities in this ASMA.

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