

Macrobenthic mollusc assemblages and diversity in the West Antarctica from the South Shetland Islands to the Bellingshausen Sea

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Abstract Although frequent studies have been made on the benthos assemblages living in the Southern Ocean, few studies have dealt with molluscan assemblages and ecology. During the research programmes BENTART carried out in austral summers of 2003 and 2006 in a study area including Low Island, West Antarctic Peninsula, Bellingshausen Sea and Peter I Island, 45 stations were sampled using quantitative box-corer, Agassiz trawl, epibenthic sledge and rock dredge, at depths of 53–3,304 m. These data were used to search and analyse the malacological assemblages. A total of 2,889 living specimens of molluscs belonging to 139 species of shelled Gastropoda, Bivalvia and Scaphopoda were recoded. Gastropods were the best-represented in species richness, but the bivalves accounted the major abundance and *Cyamiocardium denticulatum* (460 individuals) was the most abundant species. Species richness varied from 1 to 37 species and diversity showed great variations at different stations. Four groups of stations of low similarities and some differences in faunistic composition were observed: one that gathers the Antarctic Peninsula and Peter I Island, one that also includes the Low Island, and two composed by stations of Bellingshausen Sea.

Keywords Macrobenthic molluscs · Diversity · Assemblages · West Antarctica

Introduction

The diversity and analysis of macrobenthic molluscs assemblages are likely to contribute to a better understanding of the structure and interactions inside the more complex assemblages in which they live and interact with other bottom organisms, because they have a particularly wide ecological and ethological spectrum.

Although frequent studies have also been made in recent years on the benthos assemblages living in the Southern Ocean (e.g., Sáiz-Salinas et al. 1997; Arnaud et al. 1998; Linse et al. 2002; Bowden 2005; Rehm et al. 2006; San Vicente et al. 2007), few studies have dealt with molluscan assemblages and ecology (Arnaud and Hain 1992; Cattaneo-Vietti et al. 2000; Arnaud et al. 2001; Schiaparelli et al. 2006), and only one work on Bellingshausen Sea (Troncoso et al. 2007) by means of a quantitative approach of soft-bottom molluscs from box-cores samples.

The BENTART research programme were carried out on board the RV *Hespérides* from 24 January to 3 March 2003 (BENTART 03) and from 2 January to 17 February 2006 (BENTART 06) in West Antarctica from Low Island in the South Shetland Islands to Thurston Island in the Bellingshausen Sea, including Peter I Island. As an integrated study of the benthic ecosystem (Sáiz-Salinas et al. 2008), the BENTART programme is a good opportunity for analysing the molluscan assemblages.

All molluscan classes were present in this region, but we will only include the shelled Gastropoda, Bivalvia and Scaphopoda in this study, because Aplousobranchia, Polyplacophora, and some Opisthobranchia have taxonomic gaps in

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their identification. On the basis of the data obtained during this survey, we try to discover how many molluscan assemblages are living in the study area; what are their species diversity; which species characterize those assemblages and which species they have in common; which are the most abundant, more distributed and rare species; and which are the possible ecological and physical causes that characterize those assemblages.

Materials and methods

The research programme of the BENTART cruises aboard RV *Hespérides* was carried out during the austral summers of 2003 and 2006. Forty-five stations were sampled at depths of 53–3,304 m (Table 1), in a study area including Low Island (South Shetlands Islands), West Antarctic Peninsula, Bellingshausen Sea and Peter I Island (Fig. 1). Benthic samples were collected using several sampling gears, including a quantitative box-corer (with an effective surface of sampling of 0.06 m²), an Agassiz trawl (2.01 m wide and 1.12 m high, having a mesh size of 10 mm; duration of tow 8 min), an epibenthic sledge (with an opening-closing system, which is activated by contact with the sea floor and with superimposed nets of 0.5-mm mesh size; rectangular opening, 40 × 80 cm; duration of tow 8 min) and a rock dredge (0.8 m width and 0.3 m height, with a mesh size of 10.0 mm; duration of tow 8 min). Since the total haul of an Agassiz trawl, epibenthic sledge and a rock dredge does not provide an accurate measure of density, the abundance per station was derived from a subsample of 50 l taken at random in each haul (Arnaud et al. 1998). The content of each sample was sieved using three mesh sizes: 5, 1 and 0.5 mm (in the box-cores), and 10, 5 and 1 mm (in the Agassiz, epibenthic sledges and rock dredges). The molluscs retained in the two largest sieves were counted to estimate their relative abundance in the total macrobenthic fauna, then were fixed in borax-buffered 4% formaldehyde in seawater and after 1 day transferred and preserved in 70% ethanol for further taxonomic study. Environmental parameters in stations were measured [depth, redox (Eh) and organic matter] and the bottom type was characterized (Table 1).

Species were identified, quantified and data were organized into station by species matrices. For each sampling station, the total abundance (N) and species richness (S) were calculated, the Shannon–Wiener index (H'), and Pielou's evenness index (J') were used to assess species diversity and evenness, also the density (individuals × m²) was calculated in box-corer samples. For population studies, data were standardized (fourth root), so that the absolute number of individuals were comparable between stations. To identify the main assemblages, non-parametric multivariate techniques as described by Field et al. (1982) were

performed using the PRIMER (Plymouth Routines in Multivariate Ecological Research) version 6.0 programme (Clarke and Gorley 2005). The Bray–Curtis similarity coefficient (Clarke and Warwick 1994) was applied to the transformed grouped data obtaining a similarity matrix. Hierarchical clustering with group-averaged linking and non-metric multidimensional scaling (MDS) was then performed using the similarity matrix. Possible differences in faunistic composition between groups of stations were tested using a one-way ANOSIM test. The SIMPER programme was next used to identify species that greatly contributed to the similarity into each station group. Based on the groups of stations defined using the Bray–Curtis coefficient, the species were classified according to the criteria of constancy C and fidelity F (Dajoz 1971), with formulae and scales according to Arnaud et al. (2001).

Results

A total of 2,889 living specimens of molluscs belonging to three classes, 49 families and 139 species were recorded (Fig. 2). The class Gastropoda was the best-represented in terms of species richness (25 families and 87 species), followed by Bivalvia (20 families and 47 species) and Scaphopoda (4 families and 5 species). The most diverse family was the gastropod Buccinidae (17 species), followed by Trochidae (12 species), Turridae (10 species), Muricidae (6 species), and the bivalves Yoldiidae and Galeommatidae (6 species each). In terms of abundance, the class Bivalvia accounted most of individuals (1,884 specimens) followed by Gastropoda (643 specimens) and Scaphopoda (362 specimens, Fig. 2b). The tiny bivalves *Cyamiocardium denticulatum* (460 individuals), *Thyasira debilis* (430 individuals), *Adacnarca nitens* (228 individuals), *Yoldiella profundorum* (161 individuals), the scaphopod *Dentalium majorinum* (159 individuals) and gastropod *Neobuccinum eatoni* (89 individuals) were the most abundant species.

Faunistic parameters

Species richness (S), abundance (per sample gear), density, diversity (H') and evenness (J') varied widely (Table 2).

Highest species richness was recorded in the Antarctic Peninsula (station PA39, 37 species), followed by two stations of Peter I Island (PI 8 and PI 5, with 23 and 22 species, respectively), while the lowest values corresponded to stations with one species, two of Bellingshausen Sea (MB10 and MB12) and two of Antarctic Peninsula (PA18 and PA40).

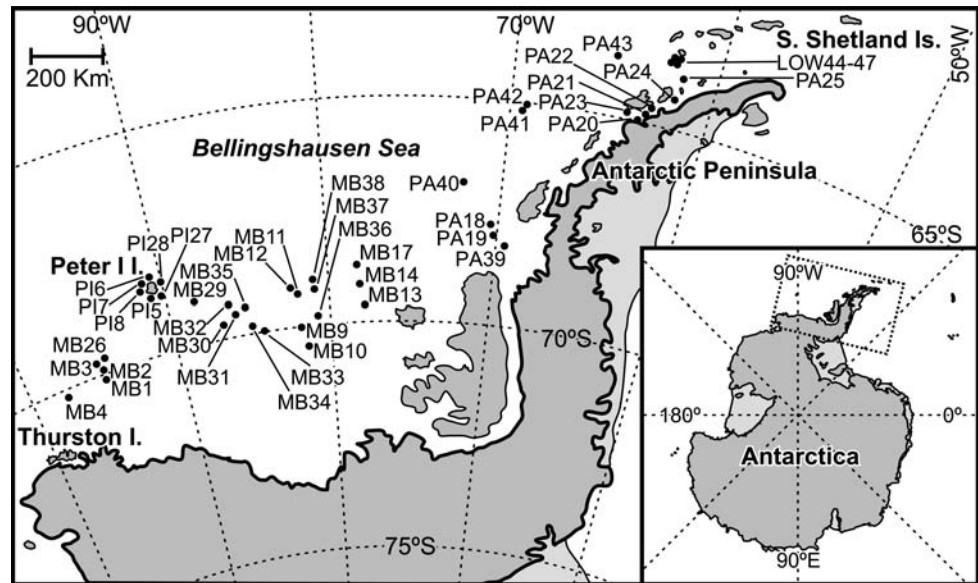
Maximal abundances were found at stations of Peter I Island preferably, being PI 5, PI 8 and PI 6 the stations with highest values (705, 344 and 211 specimens, respectively),

Table 1 Location, depth and environmental parameters on the surface of sediments from the survey stations: redox potential (mV), organic matter (OM, %) and bottom type

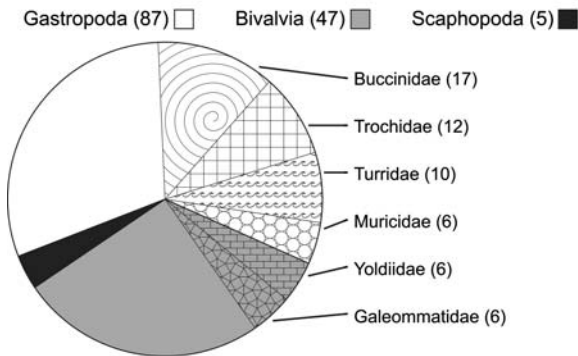
Station	Latitude S	Longitude W	Depth (m)	Redox	OM	Bottom type
MB1	70°38.22'	95°15.36'	534	252.2	4.81	Mud
MB2	70°29.25'	95°14.83'	780	289.3	5.02	Gravel
MB3	70°17.58'	95°11.86'	1,431	259.8	5.42	Mud with gravel
MB4	70°52.86'	98°26.12'	425	271.3	4.56	Mud with gravel
PI 5	68°56.70'	90°35.70'	126	199.3	1.43	Mud
PI 6	68°49.61'	90°48.78'	210	122.5	1.35	Mud
PI 7	68°42.20'	90°40.80'	410	174.8	1.85	Mud
PI 8	68°50.18'	90°51.08'	90	155.8	1.23	Fine sand
MB9	70°14.40'	81°47.03'	532	261.8	5.96	Mud
MB10	70°44.31'	81°27.85'	497	260	4.05	Mud
MB11	69°27.07'	82°06.76'	1,289	266	3.81	Mud
MB12	69°24.27'	82°11.88'	2,032	261.5	5.29	Mud with gravel
MB13	69°49.56'	77°43.68'	605	240.5	4.64	Mud
MB14	69°21.12'	78°04.91'	498	n.d.	3.68	Mud with gravel
MB17	68°54.88'	78°14.16'	2,044	224.7	1.98	Gravel
PA18	67°57.31'	71°04.70'	354	n.d.	n.d.	Stones and gravel
PA19	68°04.13'	70°52.38'	513	n.d.	n.d.	Stones
PA20	65°01.03'	63°25.25'	53	n.d.	n.d.	Gravel
PA21	64°54.01'	63°01.11'	107	133.5	2.49	Fine sand with mud
PA22	64°50.58'	62°57.91'	294	137	6.40	Mud
PA23	64°55.95'	63°38.40'	655	272.5	6.75	Mud
PA24	64°20.11'	61°58.82'	1,056	170.5	8.32	Mud
PA25	63°52.85'	61°48.52'	110	n.d.	1.16	Fine sand with gravel
MB26	70°14.62'	95°02.20'	1,920	178.9	1.99	Fine sand
PI 27	68°59.20'	90°26.60'	1,873	n.d.	n.d.	Mud
PI 28	68°52.31'	90°18.80'	1,191	n.d.	n.d.	Mud
MB29	69°26.08'	88°26.17'	3,304	262.1	8.92	Mud
MB30	69°58.98'	87°31.08'	1,814	187.7	7.01	Gravel with mud
MB31	69°56.98'	86°19.27'	1,426	207.8	5.31	Mud
MB32	69°47.60'	86°27.33'	1,847	n.d.	n.d.	Mud
MB33	70°15.90'	84°11.45'	438	290.2	4.02	Fine sand with mud
MB34	70°08.20'	84°51.68'	603	326	1.80	Fine sand
MB35	69°56.03'	85°11.30'	1,117	260.7	7.36	Gravel with mud
MB36	69°56.28'	80°24.55'	560	289	8.51	Mud with gravel
MB37	69°26.38'	80°51.62'	495	244	5.70	Gravel with mud
MB38	69°14.08'	80°61.20'	1,324	298.2	5.98	Gravel with mud
PA39	68°07.62'	69°36.20'	157	n.d.	n.d.	Mud with small stones
PA40	66°57.55'	72°34.97'	402	n.d.	n.d.	Mud with gravel
PA41	65°28.29'	69°01.71'	350	n.d.	n.d.	Mud with gravel
PA42	65°09.99'	68°56.18'	1,272	n.d.	n.d.	Mud with gravel
PA43	63°21.71'	64°17.68'	254	n.d.	n.d.	Mud with gravel
LOW44	63°25.81'	62°12.23'	82	n.d.	n.d.	Sessile epifaunal communities
LOW45	63°25.90'	62°12.69'	86	n.d.	n.d.	Sessile epifaunal communities
LOW46	63°26.22'	62°14.70'	97	n.d.	n.d.	Sessile epifaunal communities
LOW47	63°28.01'	62°12.91'	115	n.d.	n.d.	Sessile epifaunal communities

MB Bellingshausen Sea, *PI* Peter I Is., *PA* Antarctic Peninsula, *LOW* Low Island (South Shetland Islands), *n.d.* no data

Fig. 1 Position of the benthic stations sampled on the BENTART 03 and BENTART 06 cruises. *Inset* shows the location of the study area in Antarctica



Species number N=139



Specimens N=2889

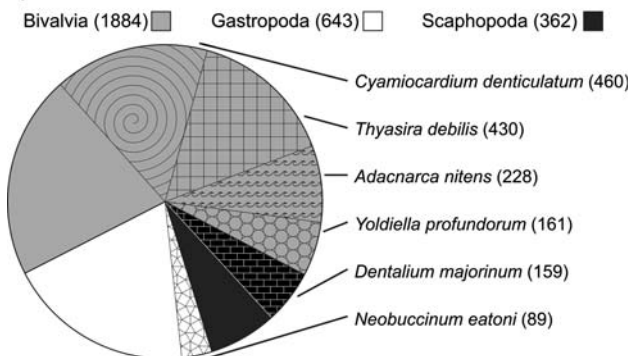


Fig. 2 Number of species and specimens of each molluscan class, indicating the best-represented families and most abundant species

the lowest were found at two sites of Antarctic Peninsula (PA18 and PA40) and one of the Bellingshausen Sea (MB10), each with one specimen only, agreeing with stations of lowest richness. The highest densities in box-cores samples agreed with sites of maximal abundances (PI 5, PI 8 and PI6).

Diversity (H') varied between 2.93 (station PA39) and 0 (stations with one species: MB10, MB12, PA18 and PA40), with high values at stations close to Antarctic Peninsula and several stations in the middle of Bellingshausen Sea (e.g., stations MB38 and MB34). Evenness (J') was usually high in most sampling sites, except in stations of Peter I Island and some of Bellingshausen Sea (e.g., MB9).

Most of the stations close to Peter I Island (PI 5, PI 6, PI 7 and PI 8) had the greatest number of molluscs (119–705 specimens) but simultaneously had the low values of diversity and evenness as a consequence of the presence of extremely abundant species, the tiny bivalves *C. denticulatum*, *T. debilis* and *A. nitens*; for example, among the three species added of about 600 specimens at station PI 5.

Molluscan assemblages and community structure

The cluster analysis revealed the presence of four groups of stations in two main clusters (Fig. 3) with low similarities levels of about 5%, each group is separated into two sub-groups. The group A includes the stations of the northern Antarctic Peninsula and shallower stations of Peter I Island (Subgroup A1) and the majority of the stations of Bellingshausen Sea (Subgroup A2). Group B splits the stations of the southern Antarctic Peninsula, Low Island and deeper stations of Peter I Island (Subgroup B1) from some stations of Bellingshausen Sea (Subgroup B2). MDS ordination (Fig. 4) showed similar results to those of the dendrogram, with an acceptable stress value of 0.16. Two major groups (A and B) are segregated from top to bottom MDS graphic, and a gradient depth from the deeper stations of Bellingshausen Sea to Peter I Island, Antarctic Peninsula and Low Island can be identified from left to right. The ANOSIM test showed the highest significant differences on the

Table 2 Faunistic parameters at each station: species richness (S), abundance (N), density (D) (ind. m⁻² in box-cores), Shannon–Wiener diversity index (H') and Pielou's evenness index (J')

Station	Richness (S)	Abundance (N)					Density (D)	Diversity (H')	Evenness (J')
		Box-corer	Agassiz trawl	Epibenthic sledge	Rock dredge	Total			
MB1	3	1	3	–	–	4	16	1.04	0.95
MB2	6	2	6	–	–	8	16	1.73	0.97
MB3	4	5	5	–	–	10	27	1.09	0.79
MB4	6	3	5	–	–	8	16	1.67	0.93
PI 5	22	446	208	22	29	705	1,019	1.67	0.54
PI 6	7	145	66	–	–	211	331	0.95	0.49
PI 7	12	67	52	–	–	119	134	1.56	0.63
PI 8	23	244	100	–	–	344	558	1.96	0.62
MB9	3	13	40	–	–	53	52	0.19	0.17
MB10	1	1	–	–	–	1	16	0.00	n.d.
MB11	4	2	6	–	–	8	6	1.21	0.88
MB12	1	2	–	–	–	2	16	0.00	n.d.
MB13	6	3	17	3	–	23	24	0.87	0.49
MB14	8	5	–	9	–	14	80	1.87	0.90
MB17	2	–	13	–	–	13	–	0.43	0.62
PA18	1	–	1	–	–	1	–	0.00	n.d.
PA19	3	–	6	–	–	6	–	1.01	0.92
PA20	13	–	50	–	–	50	–	2.15	0.84
PA21	18	22	6	–	–	28	117	2.71	0.94
PA22	15	55	76	–	–	131	147	1.73	0.64
PA23	4	2	29	–	–	31	16	0.96	0.69
PA24	5	2	8	–	2	12	32	1.35	0.84
PA25	7	7	4	–	–	11	56	1.85	0.95
MB26	5	–	14	–	–	14	–	1.27	0.79
PI 27	5	–	–	100	–	100	–	0.89	0.55
PI 28	4	–	2	90	–	92	–	0.31	0.22
MB29	2	–	5	–	–	5	–	0.50	0.72
MB30	12	8	44	–	–	52	21	2.11	0.85
MB31	12	7	77	9	–	93	37	1.76	0.71
MB32	4	–	25	–	–	25	–	0.50	0.36
MB33	7	3	–	47	–	50	48	1.05	0.54
MB34	19	–	40	17	–	57	–	2.26	0.77
MB35	10	4	12	16	–	32	64	2.10	0.91
MB36	16	7	6	86	–	99	112	2.10	0.76
MB37	11	7	28	–	–	35	112	2.04	0.85
MB38	17	6	4	57	–	67	48	2.42	0.85
PA39	37	–	98	45	–	143	–	2.93	0.81
PA40	1	–	1	–	–	1	–	0.00	n.d.
PA41	15	–	–	56	–	56	–	2.30	0.85
PA42	8	–	–	46	–	46	–	1.64	0.79
PA43	6	–	–	12	–	12	–	1.68	0.94
LOW44	5	–	13	–	–	13	–	1.18	0.73
LOW45	7	–	9	–	–	9	–	1.89	0.97
LOW46	8	–	59	–	–	59	–	0.77	0.37
LOW47	18	–	33	3	–	36	–	2.68	0.93

Fig. 3 Mollusc assemblages in the study area determined by cluster analysis based on the Bray–Curtis coefficient. Two main clusters are indicated and subgroups are delineated

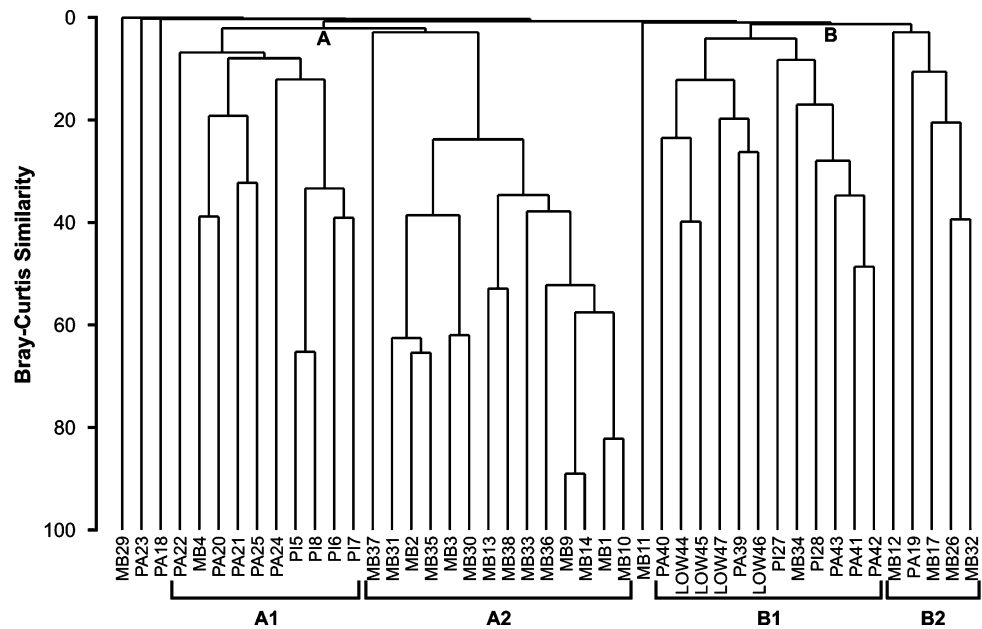
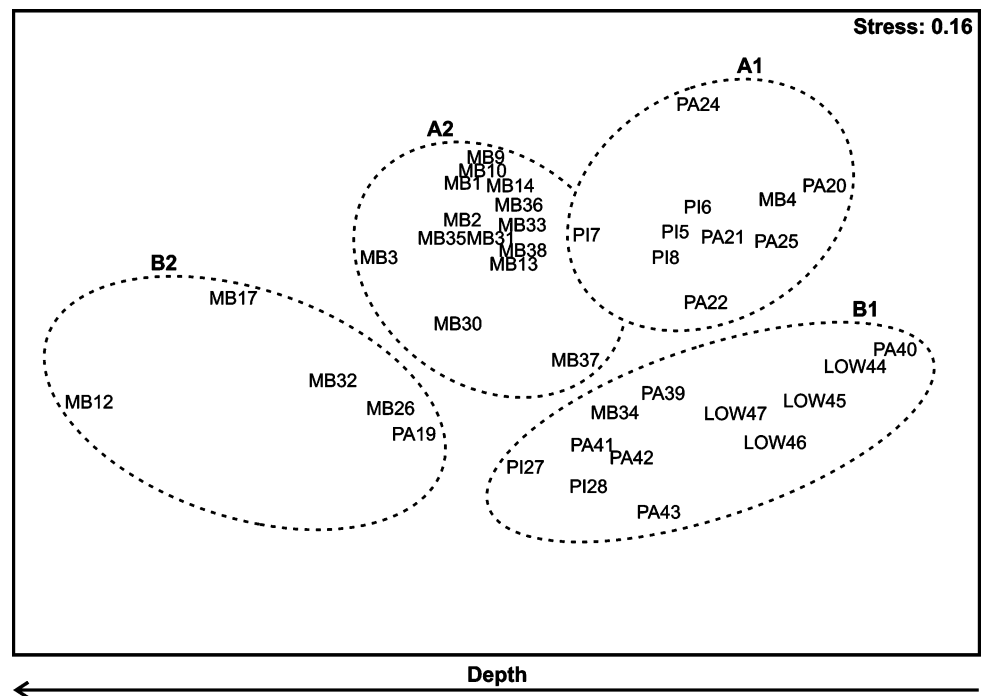


Fig. 4 MDS plot of assemblages illustrating a deep-shallow water gradient across the study area. The subgroups delineated are derivative of cluster analysis



faunistic composition between subgroups A1 and B2, and between A2 and A1 (Table 3).

The results of the SIMPER analysis for the similarity into the several subgroups and the species that more contributed to similarity are shown in Table 4. The subgroup A2 is the most similar with an average similarity of 30.11. On the other hand, B1 is the less similar subgroup, with only a value of 10.91 of average similarity. Dissimilarity between the subgroups was high (above 0.98), being contributed mainly by *T. debilis*, *Cyclocardia astartoides* and *C. denticulatum* (for the pairs of subgroups A1 vs. B2 and

A1 vs. B1), *D. majorinum*, *Adamussium colbecki* and *Bathyarca sinuata* (for the pairs of subgroups A2 vs. B1 and A2 vs. B2), *Rhabdus cf. perceptus*, *Y. profundorum* and *T. debilis* (B1 vs. B2), and *T. debilis*, *D. majorinum* and *C. denticulatum* (A2 vs. A1).

The values of the constancy index (*C*) and fidelity index (*F*) for species in each group are listed in Table 5. The subgroup A1 (69 species) is located in the northern Antarctic Peninsula and western Peter I Island, except for MB4, which is off Thurston Island in Bellingshausen Sea. In all stations the sediment is muddy or fine sandy, except in

PA20, the shallowest station, where is gravelly. Shallow depths from 53 to 425 m characterized this subgroup, but PA24 was the only deeper station. Of the commonest

Table 3 ANOSIM, pairwise test comparing groups (global $R = 0.619$); R values and significance levels are presented

Groups	R value	Significance level (%)
A2, A1	0.729	0.1
A2, B2	0.662	0.1
A2, B1	0.630	0.1
A1, B2	0.774	0.1
A1, B1	0.424	0.1
B2, B1	0.536	0.1

species in this subgroup, no species were constant, 1 very common (*T. debilis*, preferential) and 12 common (*Pseudamauroopsis anderssoni*, and *Falsilunatia delicatula*, exclusive; *N. eatoni*, *Philobrya sublaevis*, *C. denticulatum*, and *Siphonodentalium dalli* f. *antarcticus*, elective; *Margarella refulgens*, *A. nitens*, *C. astartoides*, and *Cuspidaria infelix*, preferential; and *Onoba gelida*, and *Chlanidota signeyana*, accessory).

The subgroup A2 (54 species) gathers the shallowest 14 stations of Bellingshausen Sea from 438 to 1,814 m. The predominant sediment is muddy with gravel. This subgroup has one constant species (*D. majorinum*, accessory) and six common (*B. sinuata*, and *Limopsis longipilosa*, elective; *Anatoma euglypta*, and *Striopulsellum* cf. *minimum*, preferential; *A. colbecki*, accessory; and *C. infelix*, occasional). The other species are not very common.

Table 4 Results of the SIMPER analysis

Species by group	Av. abund.	Av. sim.	Sim./SD	Contrib. (%)	Cum. (%)
Group A2		30.11			
<i>Dentalium majorinum</i> Mabilite and Rochebrune 1889	2.74	22.74	1.07	75.53	75.53
<i>Adamussium colbecki</i> (Smith 1902)	0.94	3.36	0.35	11.15	86.68
<i>Bathyarca sinuata</i> Pelseneer 1903	0.73	2.78	0.35	9.24	95.92
Group A1		14.53			
<i>Thyasira debilis</i> (Thiele 1912)	5.50	6.76	0.76	46.51	46.51
<i>Cyclocardia astartoides</i> (Martens 1878)	0.98	2.61	0.34	17.97	64.49
<i>Cyamiocardium denticulatum</i> (Smith 1907)	4.40	1.91	0.39	13.17	77.65
<i>Siphonodentalium dalli</i> f. <i>antarcticus</i> (Odhner 1931)	1.50	1.13	0.34	7.79	85.45
<i>Cuspidaria infelix</i> Thiele 1912	1.44	0.72	0.38	4.96	90.40
Group B2		12.35			
<i>Rhabdus</i> cf. <i>perceptus</i> (Mabilite and Rochebrune 1889)	0.85	8.10	0.74	65.58	65.58
<i>Dentalium majorinum</i> Mabilite and Rochebrune 1889	0.02	4.25	0.61	34.42	100
Group B1		10.91			
<i>Yoldiella profundorum</i> (Melvill and Standen 1912)	0.07	2.27	0.38	20.79	20.79
<i>Chlanidota signeyana</i> Powell 1951	0.02	2.05	0.41	18.78	39.58
<i>Thyasira debilis</i> (Thiele 1912)	0.06	1.13	0.49	10.37	49.95
<i>Pseudamauroopsis aureolutea</i> (Strebel 1908)	0.02	0.97	0.35	8.86	58.81
<i>Onoba gelida</i> (Smith 1907)	0.03	0.71	0.39	6.51	65.32
<i>Marseniopsis conica</i> (Smith 1902)	0.01	0.45	0.26	4.11	69.43
<i>Striopulsellum</i> cf. <i>minimum</i> (Plate 1908)	0.03	0.38	0.21	3.48	72.91
<i>Cuspidaria minima</i> (Egorova 1993)	0.02	0.35	0.20	3.23	76.15
<i>Cyamiocardium denticulatum</i> (Smith 1907)	0.02	0.35	0.21	3.20	79.34
<i>Philobrya sublaevis</i> Pelseneer 1903	0.01	0.29	0.21	2.61	81.96
<i>Anatoma euglypta</i> (Pelseneer 1903)	0.01	0.27	0.30	2.44	84.40
<i>Antimargarita</i> sp.	0.01	0.20	0.12	1.84	86.25
<i>Brookula</i> sp. 2	0.02	0.20	0.21	1.84	88.08
<i>Lissarca notorcadensis</i> Melvill and Standen 1907	0.03	0.17	0.12	1.59	89.68
<i>Brookula</i> sp. 1	0.02	0.17	0.12	1.56	91.23

Groups were ranked according to its average similarities (*Av. sim.*) and species according to their average contribution (*Contrib.*, %) to similarity in each group; average abundance (*Av. abund.*), similarity/standard deviation (*Sim./SD*) and cumulative percentage to similarity (*Cum.*, %) are indicated

Table 5 Constancy index (*C*, %) and fidelity index (*F*, %) in the subgroups A1 (Stations of Northern Antarctic Peninsula and Peter I Island), A2 (Stations of Bellingshausen Sea), B1 (Station of Low Island, Southern Antarctic Peninsula and Peter I Island) and B2 (Stations of Bellingshausen Sea)

Species	A1		A2		B1		B2	
	<i>C</i>	<i>F</i>	<i>C</i>	<i>F</i>	<i>C</i>	<i>F</i>	<i>C</i>	<i>F</i>
Gastropoda								
<i>Nacella polaris concinna</i> (Strebel 1908)	20.00	100						
<i>Iothia coppingeri</i> (Smith 1881)	10.00	33.33					20.00	66.67
<i>Anatoma euglypta</i> (Pelseneer 1903)			35.71	51.72	33.33	48.28		
<i>Cornisepta antarctica</i> (Egorova 1972)			7.14	100				
<i>Puncturella spirigera</i> Thiele 1912					8.33	100		
<i>Zeidora</i> sp.					8.33	100		
Trochidae sp. 1			7.14	100				
Trochidae sp. 2			7.14	46.15	8.33	53.85		
<i>Antimargarita dulcis</i> (Smith 1907)			14.29	100				
<i>Antimargarita smithiana</i> (Hedley 1916)			7.14	100				
<i>Antimargarita</i> sp.					16.67	100		
<i>Calliotropis antarctica</i> Dell 1990			14.29	63.16	8.33	36.84		
<i>Calliotropis pelseneeri</i> Cernohorsky 1977	10.00	31.82	21.43	68.18				
<i>Calliotropis</i> sp.			7.14	100				
<i>Margarella refulgens</i> (Smith 1907)	30.00	64.29			16.67	35.71		
<i>Solariella antarctica</i> Powell 1958		n.g.		n.g.		n.g.		n.g.
<i>Submargarita</i> sp.	10.00	28.57			25.00	71.43		
<i>Tropidomarga biangulata</i> Powell 1951					8.33	100		
<i>Brookula</i> sp. 1					16.67	100		
<i>Brookula</i> sp. 2					25.00	100		
<i>Cirsonella extrema</i> Thiele 1912					8.33	100		
<i>Liotella endeavourensis</i> Dell 1990			7.14	100				
<i>Lissotesta</i> sp.			7.14	46.15	8.33	53.85		
<i>Leptocollonia innocens</i> (Thiele 1912)			7.14	100				
<i>Dickdellia labioflecta</i> (Dell 1990)	10.00	100						
<i>Eatoniella glacialis</i> (Smith 1907)	10.00	54.55			8.33	45.45		
<i>Eatoniella kerguelenensis regularis</i> (Smith 1915)	10.00	100						
<i>Eatoniella</i> cf. <i>kerguelenensis kerguelenensis</i> (Smith 1875)					16.67	100		
<i>Onoba gelida</i> (Smith 1907)	30.00	38.07	7.14	9.06	41.67	52.87		
<i>Onoba kergueleni</i> (Smith 1875)	10.00	100						
<i>Onoba turqueti</i> (Lamy 1905)	10.00	100						
<i>Powellisetia deserta</i> (Smith 1907)					8.33	100		
<i>Torellia insignis</i> (Smith 1915)					8.33	100		
<i>Torellia mirabilis</i> (Smith 1907)					8.33	100		
<i>Torellia planispira</i> (Smith 1915)	20.00	100						
<i>Marseniopsis conica</i> (Smith 1902)	10.00	23.08			33.33	76.92		
<i>Marseniopsis mollis</i> (Smith 1902)	20.00	54.55			16.67	45.45		
<i>Marseniopsis syowaensis</i> Numanami and Okutani 1991	10.00	100						
<i>Pseudamauropsis anderssoni</i> (Strebel 1906)	30.00	100						
<i>Pseudamauropsis aureolutea</i> (Strebel 1908)	20.00	26.33	14.29	18.81	41.67	54.86		
<i>Falsilunatia delicatula</i> (Smith 1902)	30.00	100						
<i>Acirsa antarctica</i> (Smith 1907)							20.00	100
<i>Hemiaclis incolorata</i> (Thiele 1912)					8.33	100		
<i>Melanella antarctica</i> (Strebel 1908)	20.00	58.33	14.29	41.67				

Table 5 continued

Species	A1		A2		B1		B2	
	C	F	C	F	C	F	C	F
<i>Cerithiopsis antarctica</i> (Smith 1907)	10.00	100						
<i>Trophon coulmanensis coulmanensis</i> Smith 1907	10.00	100						
<i>Trophon cuspidarioides</i> Powell 1951	10.00	100						
<i>Trophon drygalskii</i> Thiele 1912			14.29	100				
<i>Trophon echinolamellatus</i> Powell 1951					8.33	100		
<i>Trophon longstaffi</i> Smith 1907	20.00	100						
<i>Trophon minutus</i> Strebel 1907	10.00	100						
Buccinidae sp. 1					8.33	100		
Buccinidae sp. 2	20.00	70.59			8.33	29.41		
Buccinidae sp. juv.					8.33	100		
<i>Antarctodonus thielei</i> (Powell 1958)					8.33	100		
<i>Chlanidota signeyana</i> Powell 1951	50.00	46.67	7.14	6.67	50.00	46.67		
<i>Lusitromina abyssorum</i> (Lus 1993)							20.00	100
<i>Neobuccinum eatoni</i> (Smith 1875)	40.00	73.68	14.29	26.32				
<i>Notoficula bouveti</i> (Thiele 1912)					8.33	100		
<i>Pareuthria regulus</i> (Watson 1882)	10.00	54.55			8.33	45.45		
<i>Probuccinum tenerum</i> (Smith 1907)	10.00	100						
<i>Prosipho chordatus</i> (Strebel 1908)	10.00	100						
<i>Prosipho hedleyi</i> Powell 1958	10.00	100						
<i>Prosipho hunteri</i> Hedley 1916					8.33	100		
<i>Prosipho pellitus</i> Thiele 1912	10.00	100						
<i>Prosipho pusillus</i> Thiele 1912	10.00	100						
<i>Prosipho reversa</i> Powell 1958					8.33	100		
<i>Prosipho turruta</i> Oliver & Picken 1984					8.33	100		
<i>Harpovoluta charcoti</i> (Lamy 1910)	10.00	21.43			16.67	35.71	20.00	42.86
<i>Nothoadmete</i> sp. 1					8.33	100		
<i>Nothoadmete</i> sp. 2	10.00	100						
<i>Belaturricula ergata</i> (Hedley 1916)			7.14	100				
<i>Belaturricula gaini</i> (Lamy 1910)					8.33	100		
<i>Aforia magnifica</i> (Strebel 1908)	10.00	54.55			8.33	45.45		
<i>Aforia multispiralis</i> Dell 1990	20.00	100						
<i>Conorbela antarctica</i> (Strebel 1908)					16.67	100		
<i>Leucosyrinx paratenoceras</i> Powell 1951	10.00	41.18	14.29	58.82				
<i>Lorabela</i> sp. 1	20.00	100						
<i>Lorabela</i> sp. 2			7.14	100				
<i>Lorabela</i> sp. juv.					8.33	100		
<i>Pleurotomella</i> sp. juv.					8.33	100		
<i>Typhlodaphne innocentia</i> Dell 1990	20.00	100						
<i>Typhlomangelia principalis</i> Thiele 1912			21.43	100				
<i>Acteon antarcticus</i> Thiele 1912			7.14	100				
<i>Neactaeonina</i> cf. <i>edentula</i> (Watson 1883)	10.00	37.50			16.67	62.50		
<i>Newnesia antarctica</i> Smith 1902					8.33	100		
<i>Philina alata</i> Thiele 1912	20.00	70.59			8.33	29.41		
Bivalvia								
<i>Nucula austrobenthalis</i> Dell 1990		n.g.		n.g.		n.g.		n.g.
<i>Propeleda longicaudata</i> (Thiele 1912)	10.00	30.66	14.29	43.80	8.33	25.55		

Table 5 continued

Species	A1		A2		B1		B2	
	C	F	C	F	C	F	C	F
<i>Yoldia eightsi</i> (Couthouy in Jay 1839)	10.00	100						
<i>Yoldiella antarctica</i> (Thiele 1912)	10.00	30.66	14.29	43.80	8.33	25.55		
<i>Yoldiella ecaudata</i> (Pelseneer 1903)			14.29	63.16	8.33	36.84		
<i>Yoldiella oblonga</i> (Pelseneer 1903)			21.43	100				
<i>Yoldiella profundorum</i> (Melvill & Standen 1912)	10.00	10.61	14.29	15.15	50.00	53.03	20.00	21.21
<i>Yoldiella sabrina</i> (Hedley 1916)			7.14	100				
<i>Malletia pellucida</i> Thiele 1912			21.43	51.72			20.00	48.28
<i>Bathyarca sinuata</i> Pelseneer 1903			42.86	68.18			20.00	31.82
<i>Limopsis knudseni</i> Dell 1990			7.14	100				
<i>Limopsis lilliei</i> Smith 1915	20.00	70.59			8.33	29.41		
<i>Limopsis longipilosa</i> Pelseneer 1903	10.00	25.93	28.57	74.07				
<i>Limopsis marionensis</i> Smith 1885			7.14	100				
<i>Limopsis tenella dalli</i> Lamy 1912					8.33	100		
<i>Adacnarca nitens</i> Pelseneer 1903	50.00	61.76	14.29	17.65	16.67	20.59		
<i>Lissarca notorcadensis</i> Melvill and Standen 1907	10.00	37.50			16.67	62.50		
<i>Philobrya sublaevis</i> Pelseneer 1903	50.00	66.67			25.00	33.33		
<i>Philobrya wandelensis</i> Lamy 1906	10.00	100						
<i>Dacrydium albidum</i> Pelseneer 1903			14.29	46.15	16.67	53.85		
<i>Limatula hodgsoni</i> (Smith 1907)	10.00	20.29	14.29	28.99	25.00	50.72		
<i>Limatula pygmaea</i> (Philippi 1845)	10.00	54.55			8.33	45.45		
<i>Limatula simillima</i> Thiele 1912			14.29	100				
<i>Pectinidae</i> sp.			14.29	63.16	8.33	36.84		
<i>Adamussium colbecki</i> (Smith 1902)	20.00	21.93	42.86	47.00	8.33	9.14	20.00	21.93
<i>Hyalopecten pudicus</i> (Smith 1885)			7.14	100				
<i>Cycloclamys gaussianus</i> (Thiele 1912)					8.33	100		
<i>Cycloclamys notalis</i> (Thiele 1912)			7.14	46.15	8.33	53.85		
<i>Cycloclamys pteriola</i> (Melvill and Standen 1907)			7.14	100				
<i>Thyasira bongraini</i> (Lamy 1910)	20.00	100						
<i>Thyasira debilis</i> (Thiele 1912)	70.00	52.13	14.29	10.64	50.00	37.23		
<i>Cyclocardia astartoides</i> (Martens 1878)	40.00	62.69	7.14	11.19	16.67	26.12		
<i>Galeommatoidea</i> sp.			21.43	100				
<i>Mysella antarctica</i> (Smith 1907)					16.67	100		
<i>Mysella gibbosa</i> (Thiele 1912)			7.14	100				
<i>Mysella</i> sp.	10.00	100						
<i>Mysella</i> sp. juv.					8.33	100		
<i>Pseudokellya cardiformis</i> (Smith 1885)	10.00	100						
<i>Cyamiocardium denticulatum</i> (Smith 1907)	50.00	66.67			25.00	33.33		
<i>Cyamiomactra laminifera</i> (Lamy 1906)	20.00	100						
<i>Lyonsia arcaeformis</i> Martens 1885					8.33	100		
<i>Poromya adelaidis</i> (Hedley 1916)					16.67	100		
<i>Laternula elliptica</i> (King and Broderip 1831)	10.00	54.55			8.33	45.45		
<i>Thracia meridionalis</i> Smith 1885	10.00	54.55			8.33	45.45		
<i>Cuspidaria infelix</i> Thiele 1912	50.00	57.53	28.57	32.88	8.33	9.59		
<i>Cuspidaria minima</i> (Egorova 1993)	10.00	28.57			25.00	71.43		
<i>Myonera fragilissima</i> (Smith 1885)			7.14	46.15	8.33	53.85		

Table 5 continued

Species	A1		A2		B1		B2	
	C	F	C	F	C	F	C	F
Scaphopoda								
<i>Dentalium majorinum</i> Mabilie and Rochebrune 1889	20.00	10.55	92.86	48.99	16.67	8.79	60.00	31.66
<i>Rhabdus cf. perceptus</i> (Mabilie and Rochebrune 1889)	10.00	10.29	7.14	7.35			80.00	82.35
<i>Striopulsellum cf. minimum</i> (Plate 1908)			28.57	53.33	25.00	46.67		
<i>Cadulus thielei</i> Plate 1908			7.14	46.15	8.33	53.85		
<i>Siphonodentalium dalli f. antarcticus</i> (Odhner 1931)	40.00	84.85	7.14	15.15				

$C \leq 12$, rare; $C = 13\text{--}25$, not very common; $C = 26\text{--}50$, common; $C = 51\text{--}75$, very common; $C = 76\text{--}100$, constant; $F \leq 10$, accidental; $F = 11\text{--}33$, occasional; $F = 34\text{--}50$, accessory; $F = 51\text{--}66$, preferential; $F = 67\text{--}90$, elective; $F = 91\text{--}100$, exclusive; *n.g.*, species no grouped

The subgroup B1 (75 species, the highest record of richness) consists of the stations of Low Island, the southern Antarctic Peninsula and eastern Peter I Island, except MB34, of Bellingshausen Sea. The predominant sediment is muddy with gravel or small stones, except Low Island, whose bottoms are composed by sessile epifaunal communities. The majority of the stations presented low depths (<402 m), although some stations were located at very deep waters (PI 27, PI28 and PA42). The most noteworthy species are not constant and very common, only seven common species were recorded (*Marseniopsis conica*, elective; *O. gelida*, *Pseudamauroopsis aureolutea*, and *Y. profundorum*, preferential; and *A. euglypta*, *C. signeyana*, and *T. debilis*, accessory).

The subgroup B2 (10 species, the lowest record of richness) includes the deepest stations from the Bellingshausen Sea (>1,847 m), which muddy and gravely sediments, except the station PA19, with comparatively low depth (513 m) and bottom of stones. The commonest species only are composed by one constant (*R. cf. perceptus*, elective) and one very common (*D. majorinum*, occasional).

Three species, the bivalves *Y. profundorum* and *A. colbecki*, and the scaphopod *D. majorinum*, are present in all these groups (Table 5). On the other hand, two species do not belong in any group, the gastropod *Solariella antarctica* and the bivalve *Nucula austrobenthalis*. The subgroup B1 had the highest number of exclusive species (32), followed by A1 (29), A2 (21) and B2 (2).

The scaphopod *D. majorinum* was the most abundant and widely distributed species throughout the Bellingshausen Sea. In Peter I Island the most abundant species were the tiny bivalves *C. denticulatum*, *T. debilis* and *A. nitens*, with the highest abundances observed in the whole study area. In the Antarctic Peninsula, the bivalve *Yoldia eightsi* was the most abundant, although it was followed by *Y. profundorum*, which was the widely distributed species throughout this area. In Low Island, the bivalve *Lissarca notorcadensis* was the most abundant, followed distantly by *P. aureolutea*, the most widely distributed.

Discussion and conclusions

This study is a semiquantitative approach of the entire study area of BENTART 03 and 06 cruises considering all samples gears for the analysis. Therefore, these results agree with the comparison with neighbouring areas made in the specific works of quantitative analyses of soft-bottom molluscs from box-cores samples (Troncoso et al. 2007) and bathymetric zonation and diversity gradient of gastropods and bivalves (Aldea et al. 2008). However, this work extends the number of species and analyses of molluscan assemblages from 62 species (Troncoso et al. 2007) and 134 species (Aldea et al. 2008) to 139 species.

Gastropods occurred in smaller abundances than bivalves, but with higher species richness, agreeing with other studies in neighbour areas (Arnaud and Hain 1992; Arnaud et al. 2001). At families' level, the most diverse family of gastropods was the Buccinidae, which has a high diversity in Antarctic waters (Dell 1990), in the bivalves was the Yoldiidae that coincidentally is the most diverse family in the Scotia Arc Islands (Linse 2004). At species' level, the most abundant species in Antarctic Peninsula and Peter I Island were *C. denticulatum* and *A. nitens*, which agree with those found in the South Shetland Islands (Arnaud et al. 2001), while *T. debilis* and *N. eatoni* were abundant in the Ross Sea (Cattaneo-Vietti et al. 2000).

Molluscan assemblages exhibit a bathymetric pattern, which was previously detailed and explained in this area (Aldea et al. 2008) and some trends were reported in soft-bottom molluscs (Troncoso et al. 2007). Furthermore, a depth gradient from deeper stations of the western sector of the Bellingshausen Sea to the eastern shallow water stations closer to the Antarctic Peninsula was identified in benthic assemblages (Sáiz-Salinas et al. 2008). Shallow bottoms of muddy or fine sandy sediments are dominated by *T. debilis* and *D. majorinum*, and deeper bottom of muddy and gravely sediments are dominated by *R. cf. perceptus* and *D. majorinum*.

In continental shelf zone there are two factors (i.e., bottom type and depth) that group the northern Antarctic

Peninsula with Peter I Island (subgroup A1), of low depths (53–425 m) and muddy or fine sandy sediments, although the values of O.M. and redox do not indicate any trend. On the other hand, southern Antarctic Peninsula with Low Island and eastern Peter I Island (subgroup B1) were grouped. The blackish colour of the sediment revealing a medium-high values of O.M. (Troncoso, pers. obs.), and muddy sediments with gravel or small stones indicate the grouping of the stations of these distant areas with predominantly low depths (<402 m).

Deeper bottoms are composed principally of muddy and gravely sediments and are disperse in subgroups A1, A2 and B1. The subgroup B2 gathers four deepest stations of Bellingshausen Sea. In fact, the distribution of assemblages of macrobenthos are improved by a synergy of depth, redox values and O.M. content of the sediment (Sáiz-Salinas et al. 2008), the qualitative and quantitative differences between molluscs assemblages follow the same tendency.

Knox (1994) and Arntz et al. (1994) considered that the decreases in the supply of organic matter as depth increases are the main limiting factor for the Antarctic benthos. The benthic assemblages are controlled by three major factors too: food supply, temperature and sediment regime (Mühlenhardt-Siegel 1988, 1989; Brey and Clarke 1993; Sáiz-Salinas et al. 1997; Piepenburg et al. 2002; Skowronski and Corbisier 2002; Lovell and Trego 2003). Temperature and food and their seasonal oscillations influence metabolism and growth of Antarctic marine invertebrates and hence are important factors structuring benthic assemblages (Clarke 1988; Brey and Clarke 1993; Brêthes et al. 1994).

High rates of sedimentation may inhibit suspension-feeding organisms (Lovell and Trego 2003). In this sense in the molluscs' distribution in the Bellingshausen Sea, two trophic strategies appear: filter feeders like *C. denticulatum*, and deposit-feeders like *Y. eightsi* are present in the shallow waters, and scavengers with broad bathymetric distribution, like *C. signeyana*, and carnivorous, like *Trophon drygalskii* in deep waters, this pattern was previously reported with similar assemblages of molluscs in neighbour areas by Arnaud et al. (2001).

Interactions with other organisms and biological factors such as developmental mode, fecundity, egg size or mobility could play an important role in shaping patterns of species and molluscs assemblages distribution (Aldea et al. 2008).

Finally, ice or iceberg impacts can also have a very considerable influence on the structure of benthic assemblages (Peck et al. 1999; Gutt 2001). Disturbance from ice in Antarctic benthic marine systems varies at different spatial and temporal scales (Peck et al. 1999; Gerdes et al. 2003). This heterogeneity may enhance the diversity of benthic assemblages (Gutt et al. 1999, 2001; Peck et al. 1999; Gerdes et al. 2003). Sáiz-Salinas et al. (2008) confirm this fact in

the Bellingshausen Sea, by mean of the intense iceberg traffic from the mainland (such as iceberg scouring over the sea-floor, high sedimentation rates and intense fall of drop-stones onto the sea floor).

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