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Suprabenthic fauna from the Bellingshausen Sea and western Antarctic Peninsula: spatial distribution and community structure

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SUMMARY: During the austral summers of 2003 and 2006 suprabenthic assemblages were investigated at 35 stations located in the Bellingshausen Sea and off the western Antarctic Peninsula, at depths ranging from 45 to 3280 m. Suprabenthos was collected with a Macer-GIROQ sledge equipped with an automatic opening and closing system. This study presents data on the occurrence and relative abundance of the major suprabenthic taxa collected in the water layer immediately adjacent to the bottom (10-140 cm above bottom). Assemblages were dominated by Peracarida and the most common groups were Amphipoda, Mysida, Isopoda and Cumacea. Among the 66 taxa identified, 40 account for more than 80% of the dissimilarity levels among any of the different combinations between groups of stations. The highest dissimilarity values in the segregation of the pairwise station groups were obtained for Mysidae, Lysianassidae, Gammaridea, Cumacea and Munnopsidae. The recorded faunistic patterns showed dependences in the environmental variables depth and percentage of mud in the sediment, as single and combined variables.

Keywords: suprabenthos, Bellingshausen Sea, Antarctic Peninsula, Southern Ocean.

RESUMEN: FAUNA SUPRABENTÓNICA DEL MAR DE BELLINGSHAUSEN Y DEL OESTE DE LA PENÍNSULA ANTÁRTICA: DISTRIBUCIÓN ESPACIAL Y ESTRUCTURA DE LAS COMUNIDADES. – Durante los veranos australes 2003 y 2006, se investigaron las comunidades suprabentónicas en un total de 35 estaciones localizadas en el mar de Bellingshausen y al oeste de la Península Antártica, en profundidades de 45-3280 m. El suprabentos se muestreó con un trineo tipo Macer-GIROQ equipado con un sistema de abertura-cierre. Este estudio presenta los datos relativos a la abundancia de los principales taxones suprabentónicos recolectados en la capa de agua inmediatamente adyacente al fondo (10-140 cm). Las comunidades estaban dominadas por los peracáridos y los grupos más abundantes fueron Amphipoda, Mysida, Isopoda y Cumacea. De entre los 66 taxones identificados, 40 explican más del 80% de los niveles de disimilaridad entre cualesquiera de las diversas combinaciones entre grupos de estaciones. Los valores más altos de disimilaridad en la segregación de las parejas de grupos de estaciones fueron obtenidos por Mysidae, Lysianassidae, Gammaridea, Cumacea y Munnopsidae. La mejor combinación de variables ambientales con los datos faunísticos registrados es una combinación de la profundidad y del porcentaje del fango en el sedimento. En particular, la profundidad es la variable que muestra el mejor resultado cuando cada variable abiótica se considera por separado.

Palabras clave: suprabentos, mar de Bellingshausen, Península Antártica, Antártida.

INTRODUCTION

Suprabenthic organisms are known to live in the benthic boundary layer and to play an important role in bentho-pelagic food webs (Mauchline, 1980; Brandt, 1995). They are highly consumed by a great diversity of predators such as seals, penguins, demersal fish and shrimps, and contribute to the recycling of particulate organic matter to higher trophic levels of the marine ecosystem (Brandt, 1993, 1995; Svavarsson *et al*., 1993). The contribution of suprabenthos to ecosystem functioning has also been demonstrated for Antarctic waters and is therefore taken into consideration in bentho-pelagic coupling, a new developing area in modern Antarctic research (Arntz *et al*., 2005).

Investigations on Antarctic suprabenthic assemblages are still rare. They have been done using different types of sledges and dredges, and the geographical coverage of the whole Southern Ocean remains only very partially fulfilled (San Vicente *et al*., 1997, 2007: South Shetland Islands and Bransfield Strait; Linse *et al*., 2002; Lörz and Brandt, 2003; Weddell Sea and Northwest Antarctic Peninsula; Rehm *et al*., 2007; Ross Sea; Brökeland *et al*., 2007 and Brandt *et al.,* 2007a,b: deep Weddell Sea and adjacent areas; South Sandwich arc: Kaiser *et al.,* 2008). Thus, the Antarctic sector corresponding to the Bellingshausen Sea and western Antarctic Peninsula have remained virtually unknown until nowadays.

As an integrated study of benthic ecosystems, the BENTART research programme was a good opportunity to fill this gap and bring new insights on poorly known Antarctic suprabenthic assemblages (Ramos, 2003). The BENTART 03 cruise (24 January to 3 March, 2003) and the BENTART 06 cruise (2 January to 17 February, 2006) were carried out on board the RV *Hesperides* in the Bellingshausen Sea and off the southwestern Antarctic Peninsula. The main objectives of the present study were to provide new data on the occurrence and geographical and bathymetrical distribution of their suprabenthic assemblages.

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MATERIALS AND METHODS

Field sampling

During the BENTART-03 and BENTART-06 cruises (2003 and 2006 austral summers, respectively), 35 stations (depth range: 45-3280 m) located in the Bellingshausen Sea (from the Antarctic Peninsula to Thurston Island) and off the western Antarctic Peninsula (from Gerlache Strait to Marguerite Bay) were sampled in order to study their benthic communities (Fig. 1, Table 1).

Suprabenthic samples were collected with a modified Macer-GIROQ sledge (Cartes *et al.,* 1994). This sledge is equipped with 3 superimposed nets (0.5 mm

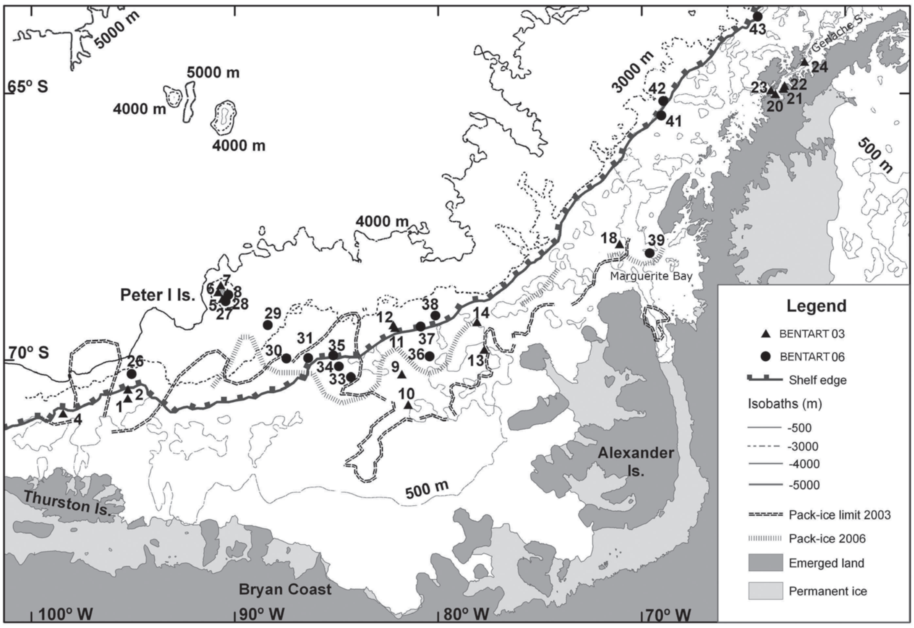

FIG. 1. – Position of the BENTART-03 and BENTART-06 sampling stations in the Bellingshausen Sea and off the western Antarctic Peninsula.

TABLE 1. – Geographical location, depth and environmental bottom characteristics (from Troncoso *et al*., 2007 and Saiz-Salinas *et al*., 2008) of the BENTART-03 and BENTART-06 suprabenthic sampling stations around the Bellingshausen Sea (BS) and off the West Antarctic Peninsula (WAP). Haul lengths calculated from GPS-derived position of the research vessel at the beginning and at the end of each tow (see Brandt and Barthel 1995). nd: not determined.

Zone	Station	Date	Time		Latitude S		Longitude W		Depth (m)		Haul length (m)	Redox potential mV	Organic matter (%)	Carbonates (%)	Gravel (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Mud (%)
			begin	end	begin	end	begin	end	begin	end									
BENTART-03																			
BS (Thurston Is.)	1	30/01/03	8:01	8:03	70º38.30’	70º38.32’	95º13.78’	95º13.67’	524	524	77	252.2	4.81	n.d.	14.30	7.90	7.50	19.10	51.20
BS (Thurston Is.)	2	31/01/03	21:32	21:34	70º29.60’	70º29.62’	95º14.48’	95º14.33’	743	743	100	289.3	5.02	n.d.	81.40	1.80	1.10	4.20	11.50
BS (Thurston Is.)	4	02/02/03	19:32	19:34	70º53.52’	70º53.52’	98º27.45’	98º27.37’	430	430	49	271.3	4.56	n.d.	31.00	9.60	5.40	16.40	37.60
BS (Peter I Is.)	5	04/02/03	22:04	22:06	68º56.70’	68º56.73’	90º33.37’	90º33.27’	124	123	87	199.3	1.43	n.d.	0.14	0.14	0.32	19.50	79.90
BS (Peter I Is.)	6	05/02/03	19:13	19:15	68º49.95’	68º49.88’	90º49.30’	90º49.18’	192	196	152	122.5	1.35	n.d.	0.00	0.10	0.10	21.00	78.80
BS (Peter I Is.)	7	06/02/03	12:30	12:32	68º42.27’	68º42.27’	90º49.87’	90º49.82’	363	385	34	174.8	1.85	n.d.	0.00	0.20	0.20	6.10	93.50
BS (Peter I Is.)	8	06/02/03	19:45	19:47	68º50.13’	68º50.20’	90º21.28’	90º21.28’	87	85	130	155.8	1.23	n.d.	0.10	0.80	4.90	58.90	35.30
BS	9	11/02/03	12:16	12:18	70º14.70’	70º14.62’	81º46.10’	81º45.93’	540	539	182	261.8	5.96	n.d.	3.90	6.10	4.40	12.40	73.20
BS	10	11/02/03	23:01	23:03	70º44.27’	70º44.23’	81º28.35’	81º28.23’	498	494	104	260	4.05	n.d.	15.80	5.20	7.90	16.40	54.70
BS	11	13/02/03	13:56	13:59	69º27.32’	69º27.27’	82º08.13’	82º07.88’	1288	1290	187	266	3.81	n.d.	22.40	8.50	3.70	10.60	54.80
BS	12	13/02/03	20:34	20:39	69º24.63’	69º24.55’	82º14.12’	82º14.67’	2028	2029	388	261.5	5.29	n.d.	23.00	11.10	5.80	18.06	42.04
BS	13	14/02/03	22:58	23:02	69º49.65’	69º49.70’	77º49.80’	77º49.30’	608	618	332	240.5	4.64	n.d.	10.20	3.60	4.10	17.50	64.60
BS	14	16/02/03	17:36	17:39	69º21.27’	69º21.25’	78º04.65’	78º04.43’	492	491	148	n.d.	3.68	n.d.	34.70	5.10	3.80	11.70	44.70
WAP	18	20/02/03	17:57	17:59	67º57.67’	67º57.62’	71º03.62’	71º03.77’	356	356	139	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
WAP	20	22/02/03	21:28	21:30	65º01.30’	65º01.25’	63º25.33’	63º25.25’	46	45	112	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
WAP	21	23/02/03	19:20	19:22	64º54.07’	64º54.07’	63º01.77’	63º01.63’	106	102	110	133.5	2.49	n.d.	4.40	14.80	17.90	34.80	28.10
WAP	22	24/02/03	23:07	23:10	64º59.65’	64º59.63’	62º57.90’	62º57.75’	286	287	123	137	6.40	n.d.	0.00	0.00	0.30	3.20	96.50
WAP	23	25/02/03	23:10	23:14	64º55.93’	64º56.02’	63º38.42’	63º38.10’	657	646	301	272.5	6.75	n.d.	0.00	0.50	0.50	7.10	91.90
WAP	24	26/02/03	15:55	16:00	64º19.55’	64º19.63’	61º58.83’	61º58.72’	1052	1059	172	170.5	8.32	n.d.	0.00	0.24	0.23	1.53	98.00
BENTART-06																			
BS (Thurston Is.)	26	20/01/06	21:41	21:45	70º14.26’	70º14.24’	95º05.82’	95º06.12’	1870	1869	191	178.9	1.99	5.87	1.33	11.22	29.09	49.43	8.94
BS (Peter I Is.)	27	23/01/06	9:52	9:54	68º59.88’	68º59.89’	90º26.80’	90º26.96’	1892	1895	108	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
BS (Peter I Is.)	28	23/01/06	20:31	20:33	68º52.85’	68º52.96’	90º19.02’	90º19.27’	1347	1342	263	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
BS (Peter I Is.)	29	24/01/06	22:34	22:38	69º24.81’	69º24.72’	88º22.33’	88º22.06’	3280	3219	242	262.1	8.92	1.14	1.54	5.56	2.47	5.25	85.19
BS	30	26/01/06	19:36	19:40	69º58.40’	69º58.34’	87º26.89’	87º26.61’	1799	1798	209	187.7	7.01	2.97	58.38	1.78	1.02	8.88	29.95
BS	31	28/01/06	16:16	16:20	69º57.76’	69º57.82’	86º22.13’	86º22.39’	1395	1395	199	207.8	5.31	2.54	0.00	2.22	4.81	20.74	72.22
BS	33	30/01/06	14:55	15:01	70°16.16’	70°15.99’	84°11.50’	84°11.33’	435	431	332	290.2	4.02	1.38	20.11	12.99	8.86	26.32	31.72
BS	34	31/01/06	1:35	1:48	70°06.03’	70°06.40’	84°52.62’	84°52.24’	620	612	726	326	1.80	1.27	0.00	12.91	14.98	59.89	12.21
BS	35	31/01/06	19:30	19:39	69°55.62’	69°55.52’	85°09.21’	85°08.42’	1136	1137	535	260.7	7.36	2.40	47.65	3.78	1.73	9.13	37.72
BS	36	02/02/06	22:23	22:33	69°55.78’	69°55.51’	80°24.38’	80°24.62’	563	559	523	289	8.51	0.47	33.15	1.08	1.08	3.96	60.72
BS	37	03/02/06	22:12	22:20	69°25.93’	69°25.92’	80°50.50’	80°50.86’	513	516	235	244	5.70	0.64	35.37	17.04	10.27	16.15	21.17
BS	38	04/02/06	22:15	22:17	69º15.18’	69º15.16’	80º12.18’	80º12.00’	1339	1343	124	298.2	5.98	0.83	65.69	3.14	1.26	2.72	27.20
WAP	39	07/02/06	22:58	23:04	68º07.67’	68º07.73’	69º35.68’	69º35.19’	154	146	356	221.9	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
WAP	41	10/02/06	10:43	10:49	65º27.33’	65º27.11’	69º00.49’	69º00.99’	358	358	560	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
WAP	42	10/02/06	20:50	20:55	65º09.97’	65º09.90’	68º56.01’	68º55.79’	1272	1275	215	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
WAP	43	11/02/06	22:08	22:20	63º21.62’	63º21.36’	64º17.48’	64º17.09’	249	246	580	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.

mesh size) that simultaneously sample the motile fauna in the 10-50 cm (N_1), 55-95 cm (N_2) and 100-140 cm (N_3) near-bottom water layers. Each net is fixed to an anterior rectangular box (width 80 cm; height 40 cm) and equipped with an opening-closing system activated by contact with the sea floor (to prevent contamination of suprabenthic samples by organisms from the water column).

The sledge was towed over the sea bottom for 2-12 minutes at 1.5-2 knots. Sledge haul length was estimated from GPS-derived position of the research vessel at the beginning and at the end of each tow by means of the following formula (Brandt and Barthel, 1995; Linse *et al.,* 2002; Lörz and Brandt, 2003):

$$\text{Haul length (m)} = 1852 \sqrt{} ((\Delta\text{lat'})^2 + \cos \text{lat'}\ \Delta\text{long'})^2$$

where Δ lat' and Δlong' are the difference in latitude and longitude between starting and ending points, respectively. Distance trawled was determined using the remote acoustic SCANMAR HC4 trawl system attached to the sledge which can monitor in real time the bottom contact of the sledge at station depths <1200 m. At deeper stations (>1200 m), the sledge was lowered at 1 m/sec until the cable length to water depth ratio reached 1.0, then 0.5 m/sec was applied until the sledge contacted bottom at a mean cable length to water depth ratio of 1.5 (as indicated by the winch tension meter). Total distances across the seafloor varied from 34 to 726 m. Thus, depending on the sampled depth, the calculation of the trawl distances was considered as accurate in shallow water samples (<1200 m) and was approximately exact enough for the deeper samples (Brenke, 2005). Density values were calculated from areas swept by the sledge on the bottom (haul length x net box width) and standardised to individuals /100 m^2. In total, 8193 m^2 of ocean bottom were sampled with the suprabenthic sledge. It must be reported that the erratic presence of large drop stones over the sea floor (resulting from iceberg rafting) greatly perturbed sledge samplings, particularly at stations 11, 12, 28 and 29 in the Bellingshausen Sea.

The material collected from the 35 sampling stations was sorted on board to family level, where possible, for the 9 major taxonomic groups (pycnogonids, leptostracans, mysids, amphipods, cumaceans, isopods, tanaidaceans, euphausiids and decapods), and then preserved with 10% neutral formalin before laboratory examination for further accurate identifications. Small zooplankton components (copepods, ostracods, chaetognaths) and demersal fishes were excluded from this study.

Environmental characteristics (Table 1) related to surface sediments (redox potential, organic content, carbonates and granulometric composition) were taken from Troncoso *et al.* (2007) and Saiz-Salinas *et al*. (2008).

Data analysis

Data were organised at each station by taxa matrices constructed with the family level for almost all the major taxonomic groups (66 families and 9 orders). Univariate measurements such as total abundance (N_1, N_2, N_3 and N_t), number of taxa (T), the Shannon-Wiener diversity index (H', $\log_e$) and Pielou's evenness (J') were calculated for each sampling station. The composition of suprabenthic assemblages was analysed by means of non-parametric multivariate techniques as described by Field *et al.* (1982) using the PRIMER v 5.0 (Plymouth Routines in Multivariate Ecological Research) software package (Clarke and Gorley, 2001). A matrix of similarity between samples was constructed by means of the Bray-Curtis coefficient applied to fourth-root transformed abundances (N_t, ind./ 100 m^2) to down-weight the contribution of the most abundant taxa. From this matrix the 35 suprabenthic samples were classified by cluster analysis based on the complete linkage sorting algorithm. An ordination analysis was performed by means of non-metric multidimensional scaling. The SIMPER routine was then used to identify taxa that mostly contributed to distinctions between station groups.

The BIO-ENV procedure of the PRIMER package was used to characterise the possible relationship between suprabenthic distributions in the study area and the measured environmental variables. Specifically, depth (m) and the following abiotic variables were considered in the analyses: redox potential (Eh) of sediments, organic matter content (%) and all granulometric fractions (%; gravel: >2 mm, coarse sand: >0.5 mm, medium sand: >0.25 mm, fine sand: >0.0625 mm, mud: <0.0625 mm). Carbonates as well as stations 18, 20 (from BENTART-03), 27, 28, 39, 41, 42 and 43 (from BENTART-06) were discarded from the analysis due to the lack of such sediment data. All variables were previously transformed by log (x+1).

RESULTS

Abundance, near-bottom vertical distribution, taxa richness and diversity

The overall material collected in the 10-140 cm water layer of the 35 sampling stations contained a total of 12 613 individuals sorted into 9 major zoological groups (amphipods: 50.4% of total individuals; mysids: 28.6%; isopods: 12.4%; cumaceans: 4.4%; pycnogonids: 1.5%; euphausiids: 1.3%; tanaids: 0.9%; decapods: 0.5%; leptostracans: 0.1%) and 66 taxa (amphipods: 24 taxa; isopods: 21; cumaceans: 6; pycnogonids: 5; decapods: 4; mysids: 3; euphausiids: 1; tanaids: 1 and leptostracans: 1) (Table 2).

TABLE 2. – Total abundance (number of individuals) and total taxon richness (T_{Nt}, total number of families) of the major suprabenthic groups in the 10-50 cm (N_1), 55-95 cm (N_2), 100-140 cm (N_3) and combined 10-140 cm (N_t) near-bottom water layers sampled.

Taxonomic group	N_1	N_2	N_3	N_t	T_{Nt}
Pycnogonida	154	29	6	189	5
Leptostraca	7	1	0	8	1
Mysida and Lophogastrida	2632	754	217	3603	3
Amphipoda	5416	617	325	6358	24
Cumacea	511	29	11	551	6
Isopoda	1433	111	19	1563	21
Tanaidacea	98	12	1	111	1
Euphausiacea	49	85	35	169	1
Decapoda	50	7	4	61	4
Total BENTART 03-06	10350	1645	618	12613	66

In most major taxonomic groups, the fauna showed a clear vertical distribution gradient with a decrease in abundance between the 10-50 cm, the 55-95 cm and the 100-140 cm water layers above the bottom (82.1%, 13.0% and 4.9% of total abundance, respectively). Only the euphausiids were less abundant in the lowermost sampling level (Table 2).

Considering the whole 10-140 cm water layer by combining the abundances of the three nets

TABLE 3. – Abundance (ind./100 m^2) of the major taxonomical groups, taxa richness (T), Shannon-Wiener diversity (H', log$_e$) and Pielou evenness index (J') of the suprabenthic fauna sampled in the 10-140 cm near-bottom water layer. PYC, Pycnogonida; LEP, Leptostraca, MYS, Mysida and Lophogastrida; AMP, Amphipoda; CUM, Cumacea; ISO, Isopoda; TAN, Tanaidacea; EUP, Euphausiacea; DEC, Decapoda.

Zone/Station	PYC	LEP	MYS	AMP	CUM	ISO	TAN	EUP	DEC	ind./100 m^2	T	H'	J'
Bellingshausen Sea													
1	2	2	58	138	8	76	6	2	5	297	15	1.71	0.63
2	3	0	10	18	4	9	1	1	1	47	13	2.26	0.88
4	0	0	10	15	0	3	0	0	3	31	6	1.63	0.91
5	7	0	3	513	4	27	3	0	1	558	9	0.44	0.20
6	3	0	62	35	3	14	3	3	0	123	11	1.44	0.60
7	4	0	7	805	70	48	4	0	0	938	9	1.11	0.51
8	4	0	1	470	17	75	32	1	0	600	15	1.00	0.37
9	1	0	10	47	1	5	0	1	0	65	9	1.07	0.49
10	0	0	49	32	1	4	1	0	1	88	10	1.17	0.51
11	0	0	1	8	0	1	0	1	0	11	4	0.92	0.66
12	0	0	0	1	0	0	0	1	0	2	2	0.68	1.00
13	0	0	24	64	7	11	2	0	0	108	12	1.33	0.53
14	1	0	5	25	4	7	0	0	0	42	8	1.36	0.66
26	1	0	10	139	6	24	0	5	4	189	30	2.37	0.70
27	1	0	218	127	0	69	2	7	0	424	15	1.63	0.60
28	0	0	1	1	0	2	0	6	0	10	7	1.42	0.73
29	1	0	1	4	0	3	1	6	0	16	14	2.17	0.82
30	1	1	22	121	56	114	0	1	1	317	33	3.08	0.88
31	3	2	28	161	35	84	1	0	0	314	28	2.80	0.84
33	2	0	18	40	7	3	0	0	0	70	22	2.29	0.74
34	7	0	40	377	24	92	5	0	0	545	37	2.45	0.68
35	1	0	3	20	5	9	0	2	0	40	27	2.94	0.89
36	0	0	16	19	2	7	2	1	0	47	24	2.55	0.80
37	1	0	27	33	2	7	0	5	0	75	20	2.14	0.72
38	0	2	39	90	15	37	7	1	2	193	32	2.90	0.84
Antarctic Peninsula													
18	0	0	0	6	2	1	0	0	0	9	3	0.80	0.73
20	0	0	15	26	0	1	0	0	2	44	4	0.92	0.67
21	0	0	0	11	0	0	0	0	0	11	1		
22	1	0	1234	12	0	0	0	1	43	1291	6	0.22	0.12
23	0	0	8	10	0	0	0	10	0	28	6	1.27	0.71
24	0	0	31	26	13	8	6	20	0	104	9	1.76	0.80
39	1	0	1	16	5	6	0	4	0	33	22	2.56	0.83
41	1	0	8	27	6	7	0	2	0	51	29	2.79	0.83
42	57	0	6	194	12	13	0	1	0	283	34	1.68	0.48
43	1	0	275	177	4	33	0	3	0	493	37	1.93	0.53

TABLE 4. – Total abundance (number of individuals) of the families and/or major taxa identified in the combined 10-140 cm (N_t) near-bottom water layer sampled.

Station	1	2	4	5	6	7	8	9	10	11	12	13	14	26	27	28	29	30	31	33	34	35	36	37	38	18	20	21	22	23	24	39	41	42	43	TOTAL
PYCNOGONIDA																																				
Nymphonidae		2			3	1						1			1		1			3	29	5	1										1	97	2	147
Ammotheidae					1		2																													3
Austrodecidae	1						2	1					1	1				2	4	1	3			1					1			2	4	1		25
Callipallenidae				5																	7														1	13
Pycnogonidae																																	1			1
LEPTOSTRACA																																				
Nebaliidae	1																	1	3						2								1			8
LOPHOGASTRIDA																																				
Eucopiidae																1																		1		2
MYSIDA																																				
Petalophthalmidae								2	1					4	13			19	13	1	2	2	1											4	90	152
Mysidae	36	8	4	2	75	2	1	13	40	2		65	6	11	175	1	1	17	32	48	228	10	66	50	39		13		1214	20	42	3	36	5	1184	3449
AMPHIPODA																																				
Ampeliscidae																					36											3	5		57	101
Amphilochidae																				3	39											2			4	48
Dexaminidae																					32														1	33
Epimeriidae									1			1		3							10	1												3	13	32
Eusiridae														1	66	2		8	13	13	80	1	12	8	3						2		2	3	103	317
Iphimediidae																		2							4								1	2	5	14
Isaeidae														23																					16	39
Ischyroceridae																				3													15			18
Leucothoidae																																1				1
Lysianassidae														116	2		1	44	81	21	953	22	13	31	14							7	2	281	284	1872
Melitidae														2																				1		3
Melphidippiidae														2							548													2		552
Oedicerotidae			1											3			1	8	10		32	4	9	1	5							8	32	5	41	160
Pardaliscidae																	1	10	12	1	3	4	1	4	3							2	10	1	1	53
Phoxocephalidae														2							3	2	8	4	3							1	7	4	5	39
Podoceridae															2				25			3														30
Stegocephalidae														3	27		1	21	50	3	2	13	5	1	15									9	3	153
Stenothoidae		1												8					3	3	54				1								2	1	8	81
Stilipediidae																																		1		1
Synopiidae														32	1			24	12	41	266	9	2	8	4							1	14	10	157	581
Urothoidae																		23	10			19	8		13										4	77
Gammaridea unid.	81	9	3	357	43	159	475	68	26	12	3	169	30	13	7		2	59	25	17	111	2	11	4	11	7	23	10	12	24	34	21	28	9	113	1978
Caprellidea	2	2				59	14							3	3						6			1	1									1	3	95
Hyperiidea	2	2	2			1								1	2	1	1	4	16		13	7	12		12					1			1	1	1	80
CUMACEA																																				
Bodotriidae														3				13		2	31	1											8	4	4	66
Nannastacidae														4				33	34	11	42	9	5		4							15	19	5	6	187
Lampropidae														2				12	18	5	16	6		1	5								1	3		69
Leuconidae																		3				3	3	2	1											12
Diastylidae																		6		1	34		2		2									4	5	54
Cumacea unid.	5	3		3	4	19	18	2	1			19	5					27	4		17	4			3	2				1	18		1	5	2	163
ISOPODA																																				
Anthuridea				8								10									21	15	10	2	2							1		1	19	89
Acanthaspidiidae													1																							1
Desmosomatidae		3			1		2		1			4						11	6		17	3		1	1						2		1		1	54
Haploniscidae														6			1	14		1														1		23
Ischnomesidae																		3																		3

Janirellidae																			1																	1
Janiridae		2					3											6	19		235	1	1	4								1		4	29	305
Joeropsidae							3																													3
Macrostylidae																	1	3	5																	9
Munnidae							3							1						1	14											1	7		34	61
Munnopsidae	4	2		9	13	6	1	3	1			14		16	57	4	3	66	83	3	224	14	14	2	22					1	8	4	10	3	27	614
Nannoniscidae	1													8				24	1						1										2	37
Paramunnidae				2	1	7	13																									1				24
Thambematidae																									1											1
Asellota unid.														2				17														1				20
Aegidae																1																				1
Cymothoida Bopyridae													1	1				5			3				2	1										13
Cirolanidae	9												3	2				14	7		8	3	4	1	3							2	1	2	27	86
Gnathiidae	32		1					1				1						28	9	1	3	1	1	3	1		1					5	2	8	1	99
Serolidae	1									1		1	3		3		1		3	1			1		4								6	3	6	34
Valvifera					2		53	3	1												12										1		4		9	85
TANAIDACEA																																				
Tanaidacea unid.	4	1		2	4	1	33		1			6			2		2		1		30		9		7						8					111
EUPHAUSIACEA																																				
Euphausiidae	1	1			4		1	2		2	4	1		8	6	12	11	2			2	10	4	10	1				1	23	28	10	10	1	14	169
DECAPODA																																				
Lithodidae														1																						1
Nematocarcinidae		1												5											2											8
Hippolytidae				1														1									2		38			1				43
Crangonidae	3		1						1																				4							9
Nt	183	37	12	389	151	255	624	95	74	17	7	292	50	287	367	22	28	530	500	184	3166	174	203	139	192	10	39	10	1270	70	143	93	232	486	2282	12613

sampled by the sledge, the lowest abundance value was recorded at station 12 (2 ind./100 m^2) at 2029 m depth in the central part of the Bellingshausen Sea, whereas the highest was recorded at station 22 (1291 ind/100 m^2) at 287 m depth in the Gerlache Strait, Antarctic Peninsula. The high number of mysids was the reason for the high abundance at station 22 (Table 3).

At the family level adopted in this study, taxon richness ranged from 1 (station 21, Antarctic Peninsula) to 37 families (station 34, Bellingshausen Sea; station 43, Antarctic Peninsula) (Table 4). The six most abundant taxa were Mysidae, Lysianassidae, Melphidippiidae, Synopiidae, Gammaridea unid. and Munnopsidae (76.7% of the collected material). According to their occurrence at the 35 sampling stations, the most frequent groups were amphipods (35 stations), mysids (32), isopods (32), cumaceans (25), euphausiids (23) and pycnogonids (22). The highest Shannon-Wiener diversity value was recorded at station 30 in the Bellingshausen Sea (H' =3.08), whereas the lowest was found at station 21 of the Antarctic Peninsula (H' =0.00). Evenness ranged from 1.00 (station 12) to 0.12 (station 22) (Table 3).

Suprabenthic assemblages

Based on taxa abundances in the 10-140 cm near-bottom water layer, five main groups (A, B, C, D and E) were discriminated by the cluster analysis of the 35 sampling stations, with a similarity level of about 30% (Fig. 2). All groups were significantly different (ANOSIM Global R = 0.926, *P*<0. 1, all pairwise *P*<0.5) in terms of community structure. The MDS ordination plot (Fig. 3) shows similar results to those

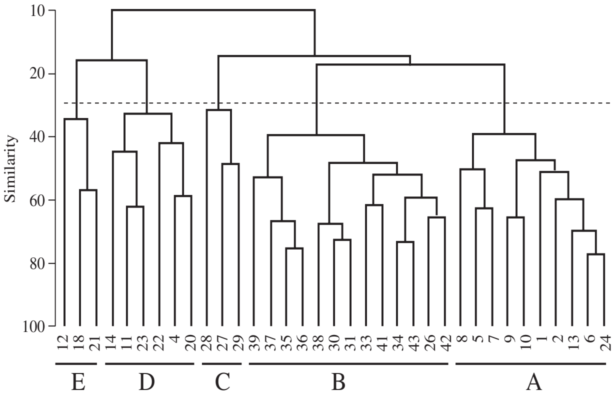

FIG. 2. – Hierarchical cluster analysis (square root-transformed abundances, Bray-Curtis similarity coefficient) of the 35 sampling stations.

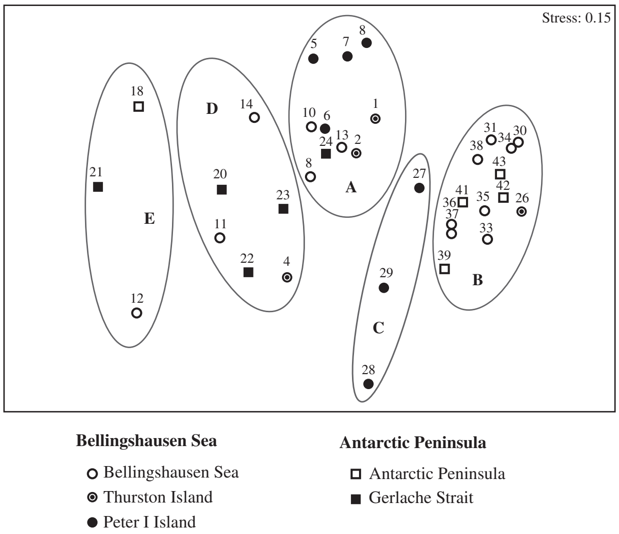

FIG. 3. – Non-metric multidimensional scaling (MDS) ordination plot of adjusted Bray-Curtis similarities between BENTART-03 and BENTART-06 samples.

of the dendogram, with an acceptable stress value (0.15). Sampling sites are segregated along the first dimension, which cannot be easily identified as an environmental and/or geographical gradient but can be identified as a biodiversity (number of taxa) gradient.

The results of the SIMPER analysis on groups A, B, C, D and E are shown in Table 5. Average within-group similarities ranged from 41.02% for group C to 56.37% for group B. Group A includes 9 stations from the Bellingshausen Sea (85-743 m depth, Antarctic continental shelf) and 1 station from the Antarctic Peninsula (1052-1059 m depth) with a moderate taxa richness (9-15 taxa) and dominated by Amphipoda (Gammaridea), Mysidae, Cumacea and Isopoda (Munnopsidae); these taxa account for 71.09% of the average within-group similarity.

Group B includes 9 stations from the Bellingshausen Sea (431-1870 m depth) and 4 stations from the Antarctic Peninsula (146-1275 m depth) with the highest taxa richness (20-37 taxa) of all the studied assemblages; 9 taxa account for 53.23% of the average within-group similarity (decreasing order): Lysianassidae, Mysidae, Gammaridea, Synopiidae, Munnopsidae, Nannastacidae, Oedicerotidae, Eusiridae and Cirolanidae.

Group C includes 3 stations located off Peter I Island (1342-3219 m depth) characterised by a moderate taxa richness (7-15 taxa) and dominated by Euphausiidae, Munnopsidae, Hyperiidea and Mysidae (account for 73.37% of the average within-group similarity).

TABLE 5. – Results of SIMPER analysis. Average similarity within groups. Families are ranked according to their average contribution to similarity within the five stations groups A-E discriminated by the multivariate analysis of the 35 sampling stations. A cut-off at a cumulative similarity of 80% was applied to the data analysis. Unid: unidentified; Av.Ab.: average abundance; Av.Sim.: average similarity; Sim./SD: ratio similarity/standard deviation; Contr.(%): percentage contribution to total similarity; Cum.(%): percentage of cumulative similarity.

	Av.Ab.	Av.Sim.	Sim./ SD	Contr. (%)	Cum. (%)
Group A (av. sim.: 54.60%)					
Gammaridea unid.	189.86	14.30	4.32	26.18	26.18
Mysidae	25.33	9.63	2.66	17.65	43.83
Cumacea indet.	12.94	7.58	6.33	13.87	57.70
Munnopsidae	7.00	7.31	4.09	13.39	71.09
Tanaidacea unid.	5.86	5.32	1.89	9.74	80.84
Group B (av. sim.: 56.37%)					
Lysianassidae	45.49	4.44	3.54	7.88	7.88
Mysidae	34.31	4.40	3.45	7.81	15.69
Gammaridea unid.	11.12	3.90	4.28	6.93	22.61
Synopiidae	12.16	3.52	3.87	6.25	28.86
Munnopsidae	14.06	3.51	5.15	6.23	35.09
Nannastacidae	5.86	2.90	1.99	5.14	40.22
Oedicerotidae	3.76	2.71	2.09	4.80	45.03
Eusiridae	5.16	2.48	1.85	4.40	49.92
Cirolanidae	2.20	2.15	2.10	3.81	53.23
Pardaliscidae	1.88	2.08	1.86	3.70	56.93
Euphausiidae	1.98	2.04	1.28	3.62	60.55
Gnathiidae	2.57	1.99	1.87	3.53	64.08
Stegocephalidae	5.63	1.93	1.36	3.43	67.51
Phoxocephalidae	1.13	1.58	1.08	2.80	70.30
Lampropidae	2.57	1.54	1.11	2.73	73.04
Hyperiidea	2.54	1.32	1.05	2.35	75.38
Janiridae	5.19	1.18	0.88	2.09	77.47
Austrodecidae	0.61	1.11	0.88	1.97	79.44
Petalophthalmidae	3.48	1.07	0.87	1.90	81.35
Group C (av. sim.: 41.02%)					
Euphausiidae	6.11	10.70	2.64	26.08	26.08
Munnopsidae	23.14	7.84	2.74	19.12	45.19
Hyperiidea	1.10	5.78	2.69	14.09	59.28
Mysidae	67.85	5.78	2.69	14.09	73.37
Eusiridae	25.78	1.94	0.58	4.72	78.09
Tanaidacea unid.	1.12	1.68	0.58	4.08	82.18
Group D (av. sim.: 46.04%)					
Gammaridea unid.	14.81	21.20	4.57	46.05	46.05
Mysidae	212.19	17.31	4.82	37.61	83.66
Group E (av. sim.: 47.45%)					
Gammaridea unid.	6.21	47.45	4.04	100.00	100.00

Group D includes 3 stations from the Antarctic Peninsula (45-657 m depth) and 3 from the Bellingshausen Sea (430-1290 m depth). The corresponding assemblage is characterised by a low taxa richness (4-8 taxa) and the main taxa in terms of major contribution to the average within-group similarity are Gammaridea and Mysidae (83.66%).

Group E includes 2 stations from the Antarctic Peninsula (102-356 m depth) and one from the Bellingshausen Sea (2028-2029 m depth) with the lowest taxa richness (1-3 taxa) of all the studied assemblages; in this group the Gammaridea account for 100% of the average within-group similarity.

Among the 66 suprabenthic taxa considered in this study, 40 account for roughly 80% of the

Table 6. – Results of SIMPER analysis. Average dissimilarities between station groups pairwise discriminated by the multivariate analysis of the 35 sampling stations and contribution (%) of each taxon to total dissimilarity within each pair. A cut-off at a cumulative dissimilarity of 80% was applied to the data analysis.

Station group pairwises	AB	AC	AD	AE	BC	BD	BE	CD	CE	DE
Average dissimilarites	68.15	66.52	62.69	78.77	65.36	76.27	89.91	71.97	87.54	66.15
PYCNOGONIDA										
Nymphonidae	1.96	2.83	2.85	2.93	1.99	1.91	1.89	3.19	3.40	
Austrodecidae	1.65		2.62		2.01	1.72	1.96			
LOPHOGASTRIDA										
Eucopiidae		1.72							3.33	
MYSIDA										
Petalophthalmidae	2.08	2.91			2.72	2.29	2.23	2.58		
Mysidae	2.03	6.45	6.85	13.38	4.03	3.38	5.85	9.61	10.27	29.64
AMPHIPODA										
Eusiridae	3.12	5.25			3.32	3.60	3.55	6.89	7.78	
Lysianassidae	5.74	2.79			4.51	6.20	6.10	3.45	3.66	
Oedicerotidae	3.36				2.99	3.20	3.59	2.57		
Pardaliscidae	2.72				2.31	2.97	2.95			
Phoxocephalidae	2.32				2.59	2.54	2.54			
Podoceridae					1.39					
Stegocephalidae	2.98	4.06			2.92	3.21	3.15	4.93	5.12	
Stenothoidae	1.77				1.96	1.90	1.84			
Synopiidae	4.36				4.06	4.72	4.66			
Urothoidae	1.77				1.95	1.89	1.85			
Gammaridea unid.	4.33	11.49	7.57	10.39	2.93	1.39	1.35	8.07	7.45	7.07
Caprellidea	2.43	3.91	4.34	4.29	1.69					
Hyperiidea	2.14	3.81	3.40	2.15	1.67	2.30	2.38	4.73	6.99	5.37
CUMACEA										
Bodotriidae	1.83				2.02	1.95	1.91			
Nannastacidae	3.64				4.04	3.94	3.90			
Lampropidae	2.47				2.73	2.66	2.61			
Leuconidae						1.23				
Diastylidae	1.51				1.66	1.69	1.56			
Cumacea unid.	2.99	7.75	7.93	8.01	1.95	1.99	1.92		2.72	7.20
ISOPODA										
Anthuridea	2.11	1.62		2.19	2.23	2.19	2.18			
Desmosomatidae	1.22	3.33	4.30	4.49	1.80	1.74	1.70			
Haploniscidae					1.42					
Janiridae	2.27				2.60	2.52	2.48			
Munnidae					1.49	1.46	1.45			
Munnopsidae	1.49	2.98	8.47	9.69	2.09	4.26	5.44	8.83	11.11	
Paramunnidae	1.73	2.77	3.51	3.52						
Aegidae		1.72						2.54	3.33	
Cirolanidae	2.75				2.65	2.69	2.93			
Gnathiidae	2.50	1.96	3.74	2.57	3.01	2.35	2.93	2.57		5.74
Serolidae	1.52	2.87	2.67		1.90	1.75	1.60	3.80	3.83	5.60
Valvifera	1.96	3.36	4.34	4.53						
TANAIDACEA										
Tanaidacea unid.	2.90	3.70	7.61	7.79	2.09			3.79	4.05	
EUPHAUSIACEA										
Euphausiidae	1.83	4.02	4.79	4.84	1.75	2.31	2.43	6.37	9.21	9.56
DECAPODA										
Hippolytidae			3.78			1.93		3.58		7.33
Crangonidae			3.14			1.28		2.54		5.04

average dissimilarity for different combinations of pairwise groups of stations and only 4 taxa account for dissimilarities between any pairwise station groups: Mysidae, Gammaridea, Hyperiidea and Euphausiidae (Table 6). The highest dissimilarity values in the segregation of the pairwise stations groups were obtained for Mysidae (AE, CD and DE), Lysianassidae (AB, BC, BD and BE), Gammaridea (AC) and Munnopsidae (AD and CE).

Relationship between biotic and environmental variables

The results of the BIO-ENV procedure applied to the biotic data and the selected abiotic variables are shown in Table 7. As a whole, the Spearman rank correlation values show low significance. The highest correlation is a combination of water depth with sediment mud content ($\rho = 0.310$). Particularly, depth is the variable matching the best result (ρ =

TABLE 7. – Result of BIOENV analysis to select the number of abiotic variables which best match the biotic matrix. Bold values indicate best matches. Variables: 1, depth; 2, Eh; 3, organic matter (%); 4, gravel (%); 5, coarse sand (%); 6, medium sand (%); 7, fine sand (%); 8, mud (%).

Number of variables	Correlation	Selections
1	**0.291**	1
2	**0.310**	1, 8
2	0.283	1, 2
2	0.273	1, 3
2	0.266	1, 5
3	**0.300**	1, 2, 8
3	0.283	1, 3, 8
3	0.281	1, 2, 5
3	0.264	1, 3
3	0.263	1, 5, 8
3	0.260	1, 2, 6
3	0.249	1, 3, 5
4	0.281	1, 2, 5, 8
4	0.278	1-3, 8
4	0.264	1-3, 5
4	0.255	1, 2, 6, 8
4	0.251	1, 3, 5, 8
4	0.243	1-3, 6
5	0.269	1-3, 5, 8
5	0.245	1-3, 6, 8

0.291) when each abiotic variable is considered separately.

DISCUSSION

The BENTART-03 and BENTART-06 sampling programmes studied for the first time the suprabenthic assemblages from the Bellingshausen Sea and the western Antarctic Peninsula.

The 35 stations yielded at least 66 taxa at family level or higher, mainly amphipods, isopods, cumaceans, pycnogonids, decapods and mysids. Peracarid crustaceans represented 83.3% of the total number of taxa.

The suprabenthic fauna sampled in the study area was numerically dominated by peracarid crustaceans, of which amphipods were most numerous, followed by mysids, isopods, cumaceans and tanaidaceans, representing more than 96% of all collected individuals. The abundance and diversity of these motile crustaceans in the near-bottom environment demonstrate the existence of a suprabenthic habitat in Antarctic waters, as already mentioned by San Vicente *et al.* (1997) for the South Shetland Islands and in the Bransfield Strait.

The suprabenthic abundances showed a clear decreasing vertical gradient from the sediment-water interface to the uppermost water layer sampled by the Macer-GIROQ sledge. This vertical gradient was also observed in almost all taxa except for the euphausiids, which avoid close contact with the sea bottom. Such a near-bottom vertical distribution pattern is a typical feature of suprabenthic species of most marine areas (Mees and Jones, 1997), including Antarctic waters (Corbera, 2000; Ramos, 2003; San Vicente *et al.*, 2006, 2007).

Although sampled in comparable near-bottom environments, the relative abundances of the major suprabenthic taxa (Mysida, Amphipoda, Cumacea, Tanaidacea and Isopoda) are highly variable according to the southern geographical regions investigated (Linse *et al.*, 2002; Lörz and Brandt, 2003; Rehm *et al.,* 2007; San Vicente *et al*., 2007). Variations in physical factors such as current direction and speed, sea-ice cover, sediment structure, topography and food supply may cause differences in the composition of suprabenthic assemblages from place to place in the Southern Ocean. Also, in agreement with Brenke (2005), we think that such a variability is partially due to distinct sampler performances and to more or less accurate estimates of towing distances on the sea floor.

The peracarid composition of southern deeper-sea areas (below 2000 m depth) shows distinct differences to that on the Antarctic shelf, especially in the increase of isopod dominance (Brandt *et al.,* 2007a,b). Deeper BENTART 2003 and 2006 sampled stations (1000-2000 m depth) showed that Amphipoda, Mysida and Isopoda in decreasing order were the most abundant taxa. Our data support that the clear break observed in the peracarid faunal composition between shelf and deep sea in the Southern Ocean takes place in deeper waters than in other world oceans (Brökeland *et al.,* 2007). This is probably the result of combined processes such as the depth of the Antarctic shelf due to the weight of the ice shield on the continent (Brökeland *et al.,* 2007), the impact of the glacial periods on the development of a higher potential of eurybathy of Antarctic organisms (Brey *et al.,* 1996), and the exchange between shallow and deep fauna and vice versa described as Antarctic submergence or emergence (Brandt *et al.,* 2007a,b).

According to San Vicente *et al.* (2007), and to results of the present study, the highest suprabenthos abundances were always recorded in the lowermost 10-50 cm near-bottom water layer. Therefore, more realistic estimates of suprabenthos abundance are certainly obtained when samplings are carried out as close as possible to the sea floor, where motile crustaceans are known to concentrate at least during daytime.

The mean suprabenthos abundances herein mentioned for the Bellingshausen Sea (206 ind./100 m^2; depth range: 85-3280 m) are significantly lower ($U_{obs} = 4.55$, $p<0.001$) than values reported from the western Antarctic Peninsula / Bransfield Strait (1908 ind./100 m^2; depth range: 45-649 m; San Vicente *et al.*, 2007; same methodology as in this study). These results confirm that the Bellingshausen Sea is a vast 'benthic desert' driven by an oligotrophic regime (Mouriño, pers. comm.), as previously reported by Saiz-Salinas *et al.* (2008) for macro-infauna and by Ramil (pers. comm.) for epibenthos from the same geographical area (BENTART 03-06 cruises). According to their composition at family level, five main suprabenthic assemblages were detected in the study area, mainly structured by environmental features gradually changing with the depth gradient (sediment mud content). Assemblages were discriminated according to their taxa richness (decreasing values with depth gradient) and to the relative contribution of some dominant taxa such as amphipods (Lysianassidae, Oedicerotidae, Synopiidae), mysids (Mysidae, Petalophthalmidae), isopods (Munnopsidae, Cirolanidae, Gnathiidae), cumaceans (Nannastacidae) and euphausiids (Euphausiidae).

In accordance with their known demersal scavenging behaviour (De Broyer *et al.*, 2001), the high contribution of Lysianassidae in suprabenthic assemblages from the study area, mainly in its deepest part (16.3% and 12.4% of total abundance in the Bellingshausen Sea and Southwest Antarctic Peninsula samples, respectively; only 3.8% off the northwestern coast of the Antarctic Peninsula, San Vicente *et al.,* 2007) suggests that this region of the Southern Ocean offers low-quality nutritive resources for detritivorous peracarids. In the study area, the multivariate analysis of data emphasised the role of two main structuring abiotic factors: the depth gradient and the mud content of surficial sediments. However, further unmeasured environmental and biotic factors such as epibenthic habitat complexity and predation impact may also be responsible for the observed distributions (De Broyer *et al.*, 2001; Lörz and Brandt, 2003). Except for their coastal zones <100 m depth (see Saiz-Salinas *et al.,* 1997; Arnaud *et al.*, 1998), the Bellingshausen Sea and western Antarctic Peninsula are characterised by soft bottoms, high sedimentation rates and low primary production, a situation that is exacerbated still further by the influence of physical disturbances (iceberg scouring). This benthic situation is quite different to those reported from the Weddell and Ross seas, where dense three-dimensional communities of long-lived filter-feeders have been described. The lack of such spatial complexity in benthic microhabitats could also be an important factor affecting suprabenthic assemblages in the Bellingshausen Sea and SW Antarctic Peninsula, as previously mentioned by San Vicente *et al.* (2007) for some suprabenthic communities from the South Shetland Islands and Bransfield Strait.

Physical disturbances linked to intense iceberg traffic (iceberg scouring over the sea-floor and fall of iceberg drop-stones onto the sea-floor) were frequently observed during BENTART cruises in the Bellingshausen Sea. Expected subsequent responses of the macrofauna communities were described by Saiz-Salinas *et al.* (2008) and Aldea *et al.* (2008). Furthermore, the presence of large stones (related to iceberg thaw) on the bottom renders benthos sampling in the Bellingshausen Sea difficult, especially in the case of drag-along samplers (Agassiz trawl and suprabenthic sledge). Such methodological difficulties may be responsible for suprabenthos underestimates at some sampling sites, as suggested also by Matallanas and Olaso (2007) concerning the demersal fish fauna of the Bellingshausen Sea.

The present contribution is the first attempt to describe poorly-known suprabenthic assemblages from remote marine Antarctic regions. Subsequent studies on the abundant suprabenthos material collected during BENTART cruises will focus on species identification to provide new data on their geographical and bathymetrical distribution as well as new structural analyses of assemblages at a detailed taxonomical level. From an ecological perspective, our main objective within the framework of the BENTART research programme is to obtain a better knowledge of marine biodiversity as well as a better understanding of assemblage organisation and related ecological processes occurring in these under-studied regions of the Southern Ocean.

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