Antarctic Science 23(5), 449–455 (2011) doi:10.1017/S0954102011000290

Macrofaunal communities on the continental shelf off Victoria Land, Ross Sea, Antarctica

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Abstract: In austral summer 2004 benthic macrofauna was sampled along a latitudinal gradient along the northern Victoria Land coast (Ross Sea). An Agassiz trawl was used for semi-quantitative data collection of macrozoobenthos at depths from 84 to 537 m. Multivariate analysis of abundance of higher taxonomic units discriminated between the four sample sites along the latitudinal gradient. A SIMPROF analysis emphasized these geographical clusters, as the samples showed no significant differences within each cluster. A change in community structure with depth was not observed. The dominant taxonomic groups along the Victoria Land coast were Echinodermata (39%), Arthropoda (24%), Polychaeta (14%), and Mollusca (12%), not accounting for colonial organisms. Thus, the overall structure of the benthic community off the Victoria Land coast is comparable to other Antarctic regions and shows a closer relationship to the eastern Weddell Sea shelf, which may be attributable to the extensive impact of grounded ice affecting both areas.

Received 2 September 2010, accepted 25 February 2011, first published online 15 April 2011

Key words: Agassiz trawl, cluster analysis, macrozoobenthos, SIMPROF, latitudinal gradient

Introduction

Although investigations into the Ross Sea benthos have intensified in recent decades, we still know relatively little about the structural patterns of macrozoobenthic communities as a whole. The way in which benthic communities interact and the influence of past and present biotic and abiotic factors on the structure of these communities are still far from being understood (Clarke & Crame 1992, Gutt 2000, Thatje *et al*. 2005). Recent studies have emphasized the importance of ice disturbance and primary production as main factors fostering the benthic communities of the western Ross Sea similar to other high-Antarctic regions. Other factors such as chlorophyll *a* and phaeophytin content of the sediment, substrate and habitat structure, depth and food supply are suggested to be less important but play a variable role for benthic community structure (Cummings *et al*. 2006, 2010, Thrush *et al*. 2006, Kröger & Rowden 2008).

The study by Bullivant in 1967 was the first to provide information about the distribution of macrobenthic communities in the Ross Sea based on different types of gear and video samples. Most of the following benthic studies were focused on shallow waters in McMurdo Sound and Terra Nova Bay (e.g. Dayton *et al*. 1970, Dayton 1974, Dayton & Oliver 1977, Barry & Dayton 1988, Gambi *et al*. 1997, Cantone *et al*. 2000, Cattaneo-Vietti *et al*. 2000, Schiaparelli *et al*. 2003, Chiantore *et al*. 2006). Little work has been conducted on habitats of the deeper shelf (Gambi & Bussotti 1999, Barry *et al*. 2003). Of note is that systematic analyses off the north-western Victoria Land coast are less intensive, although the BioRoss Survey, the Latitudinal Gradient Project (LGP), and related work have greatly improved our knowledge about benthic communities in this area (Cummings *et al*. 2006, De Domenico *et al*. 2006, Schiaparelli *et al*. 2006, Thrush *et al*. 2006, Choudhury & Brandt 2007, Rehm *et al*. 2007, Kröger & Rowden 2008). Data on macrozoobenthic biomass distribution showed that benthic communities along the Victoria Land coast followed a latitudinal gradient of abiotic factors (Povero *et al*. 2006). A study on the distribution of complete benthic communities based on abundance of higher taxa of smaller macrobenthic organisms revealed a similar distribution of communities along the latitudinal gradient. Still, no gradual shift of faunal composition was recorded (Rehm *et al*. 2006). Both studies emphasized the potential importance of additional regional factors in structuring the Ross Sea benthos.

The present study aimed 1) to investigate the change in larger macrozoobenthos assemblage composition based on higher taxonomic level with changing latitude, 2) to verify the results of quantitative data obtained by the analysis of community patterns of macrobenthic invertebrates obtained with a Rauschert sled (Rehm *et al*. 2006), which were sampled on the same cruise, and 3) to compare the

Table I. Sampling locations in the Ross Sea, Antarctica.

Station	Date	Site location Latitude	Longitude	Depth (m)	Sediment
Cape Adare					
A3	14/02/2004	71°18.7'S	170°33.5'E	305	sand
A4	14/02/2004	71°18.4'S	170°29.2'E	230	sand and pebbles
A5	15/02/2004	71°18.7'S	170°25.5'E	119	sand with pebbles and stones
Cape Hallet					
H-out 1	05/02/2004	72°15.5'S	170°28.3'E	537	mud and pebbles
H-out 2	17/02/2004	72°17.1'S	170°29.9'E	388	sandy mud and stones
H-out 3	17/02/2004	72°17.4'S	170°26.4'E	258	sand
H-in 3	16/02/2004	72°17.0'S	170°13.1'E	316	muddy sand with stones
H-in 4	16/02/2004	72°17.1'S	170°14.0'E	196	mud and sand
H-in 5	16/02/2004	72°17.2'S	170°17.9'E	84	small gravel
Coulman Island					
C 1	19/02/2004	73°24.5'S	170°23.2'E	474	mud and small gravel
C 2	18/02/2004	73°22.7'S	170°06.9'E	410	mud and pebbles
Cape Russell					
R 2	21/02/2004	74°49.0'S	164°18.1'E	364	fine sand
R 3	20/02/2004	74°49.3'S	164°11.5'E	330	rock, sand, mud, and pebbles
R 4	21/02/2004	74°50.0'S	164°05.7'E	208	rock, mud, and large stones
Santa Maria Novella	20/02/2004	74°43.2'S	164°13.1'E	366	sand with gravel and stones

Ross Sea assemblages to other Antarctic shelf regions. A semi-quantitative Agassiz trawl was employed, which allows the data to be compared to semi-quantitative studies from other Antarctic shelf areas using trawled gear (Voß 1988, Galéron *et al.* 1992, Arnaud *et al*. 1998, Arntz *et al*. 2006).

Methods

During the 19th cruise of the RV *Italica* to the Ross Sea, Antarctica, in summer 2004 a multi-geared operation was undertaken along a latitudinal gradient transect. Sampling was performed in four areas: Cape Adare, Cape Hallett,

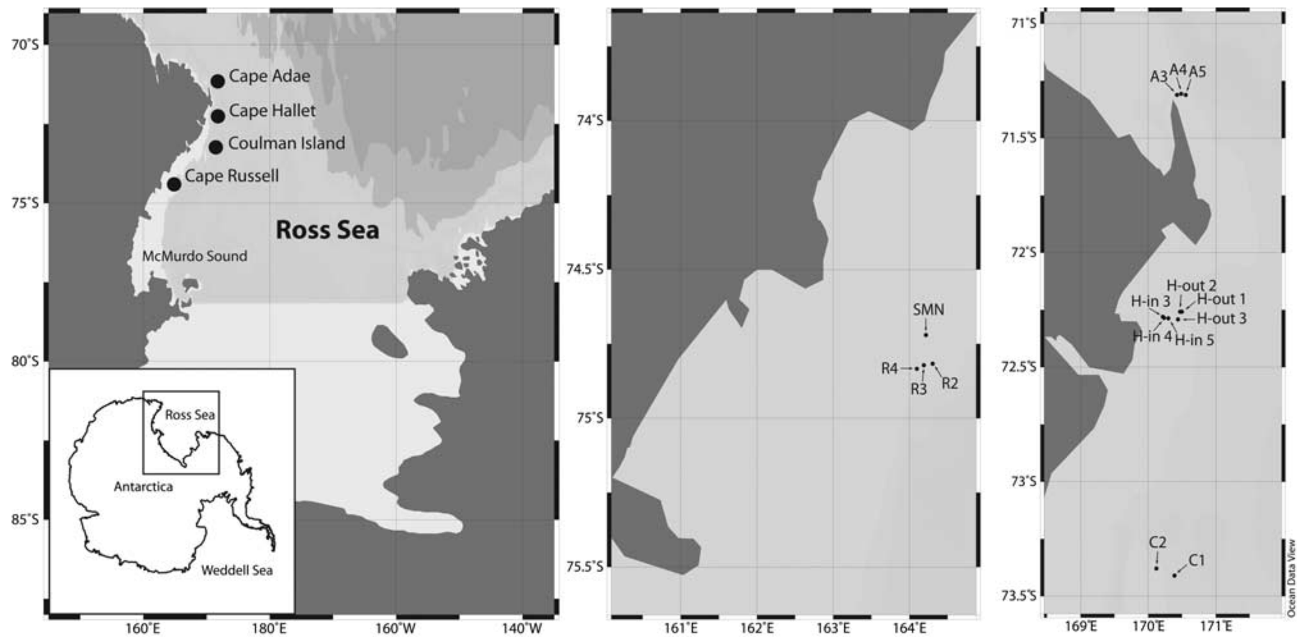

Fig. 1. Left: sampling areas (black dots) off the Victoria Land coast (Ross Sea, Antarctica). Middle and right: stations (black dots) within the sampling areas.

https://doi.org/10.1017/S0954102011000290 Published online by Cambridge University Press

Table II. Average relative abundances in percentage of dominant macrozoobenthic taxa found in the sampling areas of the coastal north-western Ross Sea shelf. For colonial taxa the median of the frequency categories is given instead of the average relative value. SD = standard deviation, mdn = median.

	Cape Adare		Cape Hallet		Coulman Island		Cape Russell		average	
	%	SD	%	SD	%	SD	%	SD	%	SD
Arthropoda	26.0	13	26.4	13	10.9	4	25.4	7	24.0	12
Pycnogonida	4.2	3	10.6	7	6.5	2	7.8	2	8.0	6
Amphipoda	20.0	12	11.0	6	1.4	0	8.9	5	11.0	8
Cirripedia	0.0	0	0.3	2	0.7	1	0.0	0	0.2	< 1
Cumacea	0.0	0	0.1	0	0.0	0	1.0	2	0.3	1
Decapoda	0.0	0	0.4	0	0.7	1	3.4	2	1.1	2
Isopoda	0.0	0	3.8	4	1.4	0	3.3	2	2.6	3
Mysidacea	1.8	2	0.1	0	0.0	0	1.1	1	0.7	1
Echinodermata	43.7	30	32.3	16	45.7	4	43.6	6	39.4	18
Asteroidea	8.2	4	2.0	1	1.4	1	3.8	2	3.7	3
Crinoidea	3.3	5	3.4	2	1.4	0	0.6	0	2.4	3
Echinoidea	4.8	3	2.8	2	0.7	1	1.6	1	2.6	3
Holothuroidea	15.6	18	2.3	2	9.4	4	9.3	3	7.8	10
Ophiuroidea	11.7	10	21.9	11	32.6	1	28.3	3	23.0	11
Mollusca	2.2	2	21.7	28	5.1	2	6.7	4	11.6	20
Bivalvia	0.4	1	16.1	28	1.4	0	2.7	1	7.4	20
Cephalopoda	0.0	0	0.2	0	0.0	0	0.0	0	< 0.1	< 1
Gastropoda	1.8	2	4.4	6	3.6	2	1.8	2	3.1	4
Polyplacophora	0.0	0	1.0	1	0.0	0	2.1	2	1.0	2
Scaphopoda	0.0	0	0.0	0	0.0	0	0.1	0	< 0.1	< 1
Polychaeta	6.4	2	9.5	3	21.7	9	22.5	8	14.0	9
Other	21.7	16	10.1	9	16.7	4	1.8	1	11.1	11
Brachiopoda	0.0	0	2.4	2	1.4	0	1.2	1	1.5	2
Nemertini	0.0	0	0.0	0	10.1	3	0.5	1	1.5	4
Plathelminthes	4.2	6	0.3	1	0.0	0	0.0	0	1.0	3
Sipunculida	0.9	1	5.0	8	2.2	2	0.0	0	2.5	6
Tunicata	16.6	11	2.4	4	2.9	1	0.1	0	4.7	8
Colonial taxa	mdn	SD	mdn	SD	mdn	SD	mdn	SD	mdn	SD
Porifera	4	1.41	1.5	0.96	1	0.00	2.5	0.83	2	1.18
Anthozoa	0	0.00	0	0.37	0	0.00	0	0.00	0	0.25
Hydrozoa	1	0.00	1	0.47	1.5	0.50	3.5	1.66	1	1.22
Bryozoa	1	0.47	2	0.00	1	0.00	1	0.43	1	0.34

Coulman Island, and Cape Russell, with a depth gradient being sampled at each location (Table I, Fig. 1).

An Agassiz trawl (AGT) was used with a standard 120 cm x 55 cm opening and a 20 mm mesh size. This type of equipment is used to capture large macrozoobenthic organisms, and complemented samples collected using a small mesh Rauschert dredge during the same cruise (Rehm *et al*. 2006). The dredge was hauled with a mean velocity of 1 knot over distances ranging from 60–380 m and a depth range from 84–388 m.

On deck, subsamples were taken from the AGT catches and transferred into 4% buffered formalin. To keep sampling effort unbiased, random subsamples with constant volume (6 l barrels) were taken from whole and unsorted hauls using a shovel. Once back on shore, samples were transferred to 70% ethanol and sorted into major taxonomic groups using a stereomicroscope where necessary (compare Table II and supplemental Table SI). Abundances were documented for each group; colonial groups such as sponges, cnidarians, and bryozoans, were recorded according to six frequency categories with regard to the distribution of the taxa within the whole catch (0–5; absent to very abundant if the group was dominating the sample). Absolute abundances of countable organisms have been analysed simultaneously with uncountable (colonial) organisms in different ways. A simple and less accurate method is to integrate colonial organisms with presence/absence values into the similarity matrix (e.g. Salzwedel *et al*. 1985, Thatje *et al*. 1999, Starmans *et al*. 1999). A further method used is to calculate the relative coverage of colonial taxa and multiply the result with a factor to adjust relative values to the level of the compared absolute data (e.g. Gutt & Starmans 1998, Barry *et al*. 2003). We used a different way to adjust both types of data. To reduce the weight of highly abundant taxa absolute abundances were transformed with the square root prior to the cluster analyses. As a result, 96% of the values of the species station matrix ranged from 0–5, which is the same interval as for the categories of the colonial taxa. Thus, for the creation of the similarity matrix we used a combined datasheet with square-root transformed absolute data and the six frequency categories for colonial taxa. The software package Primer (Clarke & Gorley 2000) was used to complete a group-averaged cluster analysis of abundances on the basis of Bray-Curtis Index (Bray & Curtis 1957). Cluster analysis was combined with a SIMPROF test completed to 95% confidence limits, which determines the statistical significance of the clusters.

Results

A total of 27 different taxonomic groups were identified within the samples (Table II). Number of groups per station ranged from 9 (Cape Adare) to 22 (Cape Hallett). Amphipoda and Polychaeta were the only groups found at all stations. Abundances recorded ranged from one to 1346 specimens within a single group. The highest number of any one group found at a station was the bivalve *Adacnarca nitens* Pelseneer, 1903 found at Cape Hallett (H-in 5), which were all found attached to a hydrozoan species. This population sample of *Adacnarca nitens* included the full range of known size classes, from juvenile to adult stages. Considering the north-western coastal Ross Sea shelf as a whole, the Echinodermata clearly dominate (41% of total abundance) followed by Crustacea (22%). Polychaeta, Others, and Mollusca are similar in abundance (15%, 13%, and 9%, respectively).

A latitudinal transect (71° to 74°S) was sampled from north to south, along the Victoria Land coastline. The only north–south gradient identified is an increase in the relative abundance of Polychaeta (6% at Cape Adare, 23% at Cape Russell) within the assemblage. Polychaeta vary as to their position in the assemblage, contributing the least at Cape Hallett but being the second dominant group at Coulman Island (Table II). Less speciose taxa like the Sipunculida and Nemertini were grouped to ‘Other’ organisms, which also have a varied position within the assemblages. Cape Adare sees the highest percentage of others (22%), resulting primarily from a high tunicate count at A4 (21%). The lowest abundance of ‘Other’ organisms is seen at Cape Russell (2%), with Cape Hallett and Coulman Island exhibiting intermediate numbers of ‘Other’ organisms (10% and 17%, respectively). Molluscs contribute between 2 and 22% to total abundance with the minimum at Cape Adare and the maximum at Cape Hallett. The high contribution results from a mass occurrence of the bivalve *Adacnarca nitens* at station H-in 5 (82% of total abundance). Relative mollusc abundance of Cape Hallett omitting this station is 2.5% which is similar to relative mollusc abundance at Cape Russell 2.7% (Cape Adare < 1%, Coulman Island 1.4%). In this case molluscs display the same gradient as Polychaeta with the highest contribution to the southern benthic community. Relative abundance of crustaceans (22%) and echinoderms (41%) show less variation between sample areas with minima off Coulman Island (Crustacea 11%) and Cape Hallett (Echinodermata 32%).

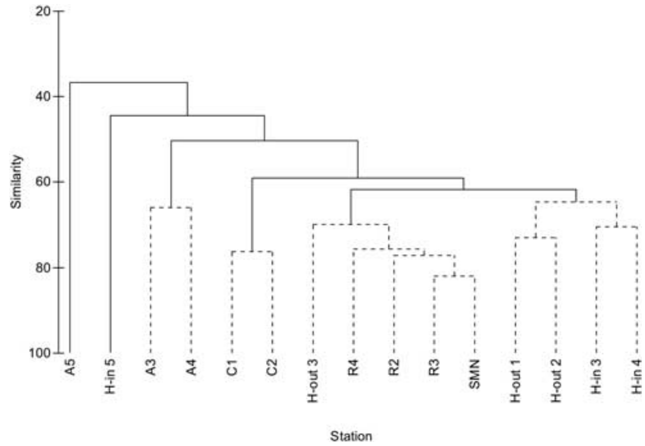

Fig. 2. Dendrogram showing clusters of macrozoobenthos stations off Victoria Land in the Ross Sea, Antarctica. Square root transformation applied to data. SIMPROF analysis completed to 95% confidence limits (indicated by dotted lines).

Cluster analysis carried out on major macrobenthic taxa shows a clear difference in assemblage according to the geographical position of the sample areas along the latitudinal gradient. According to the SIMPROF analysis stations for clusters (Fig. 2) are not significantly different. These clusters represent the four sampling areas Cape Adare, Coulman Island, Cape Hallett and Cape Russell (Bray Curtis similarities: 66%, 76%, 70%, 63%). However, there are three exceptions: Station A5 and H-in 5 grouped with no other station at a similarity level of 37% and 46%, respectively. Station H-out 3 was placed within the Cape Russell cluster.

Discussion

Composition of benthic community

The dominance of Echinodermata along the northern Victoria Land coast is comparable to the distribution patterns of other Antarctic regions (e.g. Galéron *et al.* 1992, Gerdes *et al.* 1992, Arnaud *et al.* 1998, Gutt & Starmans 1998, Gutt *et al.* 2005). Ophiurids contribute most to echinoderm abundance, which is also evident from benthic communities of the shelf of other Antarctic regions sampled with hauled gear (e.g. Voß 1988, Galéron *et al.* 1992, Arnaud *et al.* 1998). Polychaeta and Mollusca were abundant groups (14% and 12%, respectively of total abundance), which is comparable to Agassiz trawl samples (10 mm mesh size) from the eastern Weddell Sea (Voß 1988, Galéron *et al.* 1992). However, mollusc abundances are low at regions with less extended shelf areas (Arnaud *et al.* 1998, Arntz *et al.* 2006).

Arthropods, and Amphipods in particular, displayed a comparatively increased proportion of abundance (22% and 11%, respectively of total abundance) towards other surveys based on similar gear, though still in the range of taxon distribution of the eastern Weddell Sea (Voß 1988, Arnaud *et al*. 1998, Arntz *et al*. 2006). Thus, the eastern Weddell and the western Ross Seas are more similar with regard to the portion of bivalve and arthropod abundances than to other Antarctic shelf communities. Both regions are subject to intense impact of iceberg scours (Gerdes *et al*. 1992, 2003, Thrush *et al*. 2006), which is suggested to be one of the main factors influencing diversity off Victoria Land (Thrush *et al*. 2006, Kröger & Rowden 2008) and which entail a largely increased ratio of crustaceans and an increased ratio of molluscs compared to undisturbed areas (Gerdes *et al*. 2008).

Benthic community structure along the Victoria Land coast

Our data show a clear difference in assemblage according to the geographical location along the latitudinal gradient. However, only polychaetes are gradually distributed along the Victoria Land coast displaying the maximum portion of abundance at Cape Russell. Although variation is seen between sites, this pattern cannot be attributed simply to latitude as there are evidently more complex interactions taking place. Thrush *et al*. (2006) point out that benthic communities along the western coast of the Ross Sea are mainly shaped by ice disturbance, solar radiation, polynyas, and advection of planktonic production, providing a complex regime, which they suppose to result in a non-linear change of biodiversity. Patterns of polychaete assemblages of the north-western Ross Sea confirm a non-linear correlation with latitude (Kröger & Rowden 2008). Similar findings were shown by the distribution of cumacean assemblages, though abundance increased and community changed with latitude, no linear shift was recorded (Rehm *et al*. 2007). Also, no correlation between latitude and macrobenthic communities was recorded by Cummings *et al*. (2010), who identified sediment grain size, the ratio of sediment chlorophyll *a* to phaeophytin content, and depth as explanatory factors influencing macrobenthic communities. Main driving factors for polychaete assemblage structure as identified by Kröger & Rowden (2008) are sponge spicule content, sediment chlorophyll *a* content, sediment sorting coefficient, and distance to nearest iceberg scour. Macrozoobenthic community patterns described on the basis of biomass also showed a latitudinal gradient partially depending on an environmental and trophic gradient, but on a smaller scale communities are influenced by a complex of factors independent of the latitudinal gradient (Povero *et al*. 2006).

The northernmost community at Cape Adare is characterized by an increased portion of Amphipoda, though the general contribution of crustaceans is the same as in most other communities along the Victoria Land coast. Fresh iceberg scours were found at Cape Adare during the Victoria Land Transect project (Thrush *et al*. 2006), which are characterized by motile groups such as amphipods and crinoids that act as first colonizers of disturbed areas, whereas their contribution to abundance decreases in older scars (e.g. Peck *et al*. 1999, Gutt 2000, Teixidó *et al*. 2007, Gerdes *et al*. 2008). The impoverished cumacean community of Cape Adare, recorded during the same cruise, points also in this direction (Rehm *et al*. 2007), as smaller less motile organisms follow by passive advection during succession (Gerdes *et al*. 2008). On the other hand, the Cape Adare community has the highest proportion of ascidians (Tunicata), which are also part of the more advanced community succession stages following iceberg scours (Gerdes *et al*. 2008). This is due to the fact that there are differences in faunal composition between stations. Station A3 shows patterns of communities of older ice scours, such as high abundance of Porifera, although Echinoderm abundance is exceptional high (42% Holothuroidea, 25% Ophiuroidea) which is characteristic for young ice scours. In contrast, at station A5 typical elements of young iceberg scours are seen (Gerdes *et al*. 2008); namely, amphipods (33%), ascidians (27%) and crinoids (10%) show the highest proportions. Station A4 displays intermediate patterns between young and older scours; a possible explanation could be the sample touching new and older scours at the same time. This is not unlikely, as the area is exposed to frequent ice impact (Keys 1983).

Although the clusters of the communities of Cape Hallet and Cape Russell were the most similar, the SIMPROF analysis marked both clusters as being significantly different. The benthic community of Cape Russell, in contrast to Cape Hallett, is influenced by the Terra Nova Bay polynya, which is an area of high productivity (Saggiomo *et al*. 2002) dominated by diatoms during the summer months (Arrigo *et al*. 1999). The supply of diatoms may explain the increased numbers of Cumaceans in the Cape Russell area, as these are a typical food source for cumaceans (Blazewicz-Paszkowycz & Ligowski 2002). In general cumacean abundance is higher in this area than in more northern areas along the Victoria Land coast and the species *Vaunthompsonia inermis* (Zimmer, 1909), which feeds on diatoms as recorded from Admiralty Bay, King George Island (Blazewicz-Paszkowycz & Ligowski 2002), is more abundant in the Cape Russell area than off Cape Hallett (Rehm *et al*. 2007). Further groups, which were more abundant to the south, are ophiurids and polychaetes. This is in accordance with the observations of macrozoobenthic biomass distribution, which showed increased ophiurid and polychaete abundances in correlation to sediment grain size (Povero *et al*. 2006). The finest sediments of our study occurred off Coulman Island corresponding with a clear dominance of Ophiuroidea and Polychaeta. Cape Hallett displays the highest bivalve contribution to the benthic community; though this is due

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to the mass occurrence of *Adacnarca nitens* at station H-in 5 (see also Higgs *et al*. 2009). Comparing the distribution of bivalves within the Cape Hallet area (ignoring station H-in 5) shows that relative bivalve abundance of Cape Hallet is similar to the relative bivalve abundance of Cape Russell.

Results of the present study and from the analyses of smaller macrozoobenthic organisms sampled during the same survey with a small mesh Rauschert Sled (Stransky 2008) are consistent with regard to community distribution off the Victoria Land coast (Rehm *et al*. 2006). Both analyses recover a nearly identical resolution of clusters emphasising the suitability of both gear for preliminary assessment of macrozoobenthic community structure.

Conclusion

Macrozoobenthic assemblages in the western Ross Sea show overall similarity to other high-Antarctic shelf communities, especially of the eastern Weddell Sea. Furthermore, this study confirmed the view of a non-linear change of diversity and community structure along the Victoria Land coast. As discussed, for isopods, cumaceans, and polychaetes (Choudhury & Brand 2007, Rehm *et al*. 2007, Kröger & Rowden 2008) valuable information beyond a first assessment of benthic communities may by obtained with a higher taxonomic resolution.

Acknowledgements

We are indebted to Ricardo Cattaneo-Vietti for providing the opportunity to participate at the 19th expedition of the Programma Nazionale di Ricerche in Antartide (S.C.r.l.). We would also like to thank Susanne Gatti, Olaf Heilmayer, and, especially, Mariachiara Chiantore for organising and their help during the cruise. Furthermore, we are grateful to the crew of RV *Italica* for assistance and comfortable time at sea. Travelling funds were provided by the German Science Foundation (DFG) to the principal author (Br 1121/23-1). We thank the reviewers for their helpful comments.

Supplemental material

A supplemental table will be found on http://dx.doi.org/10.1017/ans.2011.29

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