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Meiofaunal assemblages associated with scallop beds (*Adamussium colbecki*) in the coastal sediments of Terra Nova Bay (Ross Sea, Antarctica)

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Abstract: Meiofaunal community structure in coastal sediments of Terra Nova Bay (Ross Sea) was related to quantity and biochemical composition of sedimentary organic matter. The sediments were generally characterized by large amounts of chloropigments and labile compounds (dominated by proteins), indicating high inputs of primary organic matter. Meiofaunal densities were very high and comparable to those from the most productive areas worldwide. Sediments with high densities of the scallop had low meiofaunal densities especially in the top 2 cm, suggesting that scallop clapping contributed to meiofauna resuspension. However, it is not possible to exclude the probability that meiofauna are part of the scallop diet. Scallop beds apparently have an important role in structuring meiofaunal communities with nematodes dominant where *Adamussium colbecki* is absent, and gastrotrichs dominant (44–51%) in *A. colbecki* beds, reaching the highest density reported so far.

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Introduction

Although knowledge of the ecology of meiofauna has increased notably in the last few years, little information is available from Antarctica (Herman & Dahms 1992, Vanhove *et al.* 1995, 1998). Quantitative studies on coastal meiofaunal communities in the Weddell Sea indicate high densities compared with major sublittoral sediments worldwide (Vanhove *et al.* 1998). This study was a part of an integrated investigation (ROSSMIZE: Ross Sea Marginal Ice Zone Ecology) on planktonic and benthic communities of the Ross Sea (Antarctica) and aimed to:

i) assess the abundance and composition of the meiofaunal assemblages in the coastal sediments of Terra Nova Bay,
ii) relate meiofauna spatial distribution to environmental constraints (such as particle fluxes and biochemical composition of sediment organic matter),
iii) compare these results with previous studies in the Weddell Sea and in other sublittoral areas worldwide.

Materials and methods

Sediment samples were collected in Terra Nova Bay (Ross Sea, Antarctica) during the third leg of the 10th Italian Antarctic Expedition in January 1995. Replicate samples were taken from the inner part of a modified Van Veen grab (0.6 m^2) at three stations: ADA1 (40 m depth) and ADA2 (69 m depth) in ice free waters and Tethys (127 m depth) under the pack ice. ADA1 and ADA2 were characterized by 73% of coarse sand and 27% sand–mud sediments (Fabiano *et al.* 1999) with scallop *(Adamussium colbecki)* densities of 85 and 18 ind m^{-2}, respectively (corresponding to a biomass of about 857 ± 195 and 151 ± 34 g DW m^{-2}, respectively, Albertelli *et al.* 1996). Tethys was characterized by sandy sediments and no scallops. For quantitative meiofaunal analysis, three replicate cores (each 10.7 cm^2 surface area) were taken to a depth of 8 cm in the sediment, sectioned in three different layers (0–2, 2–4 and 4–6 cm) and fixed with buffered 4% formalin in 0.4 μm prefiltered seawater solution. Additional cores were taken for organic matter analysis and frozen at -20°C.

Meiofaunal samples were sieved through 1000 and 32 μm mesh nets, extracted by centrifugation in Ludox HS (density 1.18 g cm^{-3}), counted and classified after staining with Rose Bengal (0.5 g l^{-1}). All soft bodied organisms were studied at x1000. Additional samples were observed prior to fixation to improve identification of soft bodied taxa.

Sedimentary water content (%) was estimated as the difference between wet and dry weight (determined by drying at 60°C until constant weight). Chloroplastic pigments (chl *a* and phaeopigments) were determined according to Lorenzen & Jeffrey (1980). Chloroplastic pigment equivalents (CPE) were defined as the sum of chl *a* and phaeopigments. Lipids were extracted from dried sediment samples by direct elution with chloroform-methanol (1:1, Bligh & Dyer 1959) and analyses carried out according to Marsh & Weinstein (1966). Protein content was determined according to Hartree (1972). Carbohydrates were analysed according to Gerchakov & Hatcher (1972). For each analysis *c.* 0.5 g of sediment was used, with four replicates per sediment layer. For each biochemical analysis, blanks were made using the same sediments, but after calcination (450°C, 2 h). Biopolymeric carbon (BPC) was defined as the sum of protein, carbohydrate and lipid carbon equivalents, calculated using 0.49, 0.4 and 0.75 as respective conversion factors (Fichez 1991).

Particle fluxes were estimated using two sediment traps, one at station ADA1 (ice-free waters) and one at Tethys station (under pack ice), representative of the two different ecological conditions (Albertelli *et al.* 1998, Pusceddu *et al.* 1999a). Analyses for phytopigment, protein, lipid and carbohydrate in fresh trap material were as described for sediments.

Horizontal and vertical patterns of the measured variables were investigated by means of analysis of variance (ANOVA with replication) with station location and depth in the sediment core as sources of variation. When a significant difference for the main effect was observed ($P < 0.05$) a Tukey's pairwise comparison test was also performed. A Spearman-Rank correlation was also performed to test relationships between variables.

Results and discussion

The sediments of Terra Nova Bay were characterized by large amounts of sedimentary chloropigments and labile compounds indicating the presence of large inputs of primary organic matter (Table I). Sedimentary water content (integrated for the entire sediment core) ranged from 20% at ADA1 to about 38% at both ADA2 and Tethys. Chlorophyll *a* concentrations were 3.5 ± 1.3, 15.5 ± 3.6 and 8.8 ± 0.9 μg g^{-1}, at ADA1, ADA2 and Tethys respectively. Phaeopigment concentrations displayed a similar spatial pattern. Phytopigment concentrations (CPE, as sum of chl *a* and phaeopigments) displayed significant differences between stations (ANOVA, $P < 0.001$, $F = 9.215$) with values at ADA2 (integrated value, 57.7 ± 14.6 μg g^{-1}) significantly higher (Tukey's test, $P < 0.001$) than those at ADA1 (11.2 ± 3.5 μg g^{-1}). CPE concentrations decreased, although not significantly, with depth in the sediment core (66, 70 and 34% at ADA1, ADA2 and Tethys, respectively).

All major biochemical components were significantly correlated with CPE (r_s = 0.91, 0.88 and 0.85 for lipids, proteins and carbohydrates, respectively) and displayed concentrations comparable with coastal sediments of other highly productive areas (see Danovaro 1996 for comparison).

Sedimentary biopolymeric carbon (BPC) concentrations at ADA2 (1.77 ± 0.31 mgC g^{-1}) were significantly higher (ANOVA, $F = 25.727$, $P < 0.001$) than those at ADA1 (0.41 ± 0.03 mgC g^{-1}; Tukey's test, $P < 0.001$) and significantly higher than those at Tethys (1.25 ± 0.11 mgC g^{-1}; Tukey's test, $P < 0.001$). Tethys displayed also BPC concentrations significantly lower than those at ADA2 (Tukey's test, $P < 0.03$) and significantly higher than those at ADA1 (Tukey's test, $P < 0.001$).

Sedimentary proteins were the dominant biochemical class of organic compounds (71% of the BPC) followed by lipids (16%) and carbohydrates (14%). The protein to carbohydrate ratio (ranging from 3–6) indicates the presence of a highly productive system (Pusceddu *et al.* 1999b). These results indicate that at ADA2 and Tethys larger amounts of organic matter were available for benthic consumers than at ADA1. Sedimentary organic matter accumulation reflected greater OM fluxes under the pack ice (Table II). In contrast, chl *a* fluxes were higher in ice-free waters (at ADA1 14 μg m^{-2} d^{-1}). Meiofaunal densities were highly variable and appeared to be influenced by sedimentary OM concentrations. Meiofaunal densities reported at ADA2 and Tethys (4.6 ± 2.0 and 5.7 ± 2.1 ind 10^6 m^{-2}; respectively, Table III) are comparable with those reported from the most productive areas worldwide (Vanhove *et al.* 1998) and about 15–20 fold higher than those observed at ADA1 (0.3 ± 0.18 ind. 10^6 m^{-2}). This difference is higher than expected from the OM content in the sediments. In fact, all investigated organic compounds at ADA1 were only 4–6 times lower than at ADA2 and Tethys. It is therefore likely that the scallop bed at ADA1 had a considerable effect on sedimentary conditions, even reducing the available

Table I. Water content (%) and organic matter composition (± standard deviation) in the coastal sediments at Terra Nova Bay. Organic matter reported as chlorophyll *a* (chl *a*), phaeopigments (Phaeo), lipids (LIP), proteins (PRT) and carbohydrates (CHO). Also reported are integrated values (Int.) for the entire sediment core (± standard errors, s e).

Station	Depth (m)	Depth (core) (cm)	Water content %	Chl *a* μg g^{-1}	Phaeo μg g^{-1}	LIP mg g^{-1}	PRT mg g^{-1}	CHO mg g^{-1}
ADA1	40	0–2	22 ± 3	6.6 ± 3.5	13.2 ± 7.0	0.12 ± 0.04	0.67 ± 0.15	0.13 ± 0.01
		2–4	19 ± 3	2.0 ± 1.0	5.0 ± 2.5	0.21 ± 0.03	0.47 ± 0.02	0.08 ± 0.03
		4–6	19 ± 1	1.9 ± 0.5	4.8 ± 1.1	0.06 ± 0.02	0.45 ± 0.05	0.16 ± 0.06
		Int. ± s e	20 ± 1	3.5 ± 1.3	7.7 ± 2.3	0.13 ± 0.04	0.53 ± 0.19	0.12 ± 0.01
ADA2	69	0–2	42 ± 6	23.2 ± 10.2	65.5 ± 28.0	0.76 ± 0.15	3.05 ± 0.33	0.65 ± 0.10
		2–4	38 ± 1	15.5 ± 6.8	42.2 ± 18.0	0.55 ± 0.10	2.92 ± 0.32	0.29 ± 0.04
		4–6	35 ± 5	7.8 ± 3.4	18.8 ± 8.0	0.16 ± 0.03	1.59 ± 0.17	0.34 ± 0.05
		Int. ± s e	38 ± 2	15.5 ± 3.6	42.2 ± 11.1	0.49 ± 0.14	2.52 ± 0.38	0.43 ± 0.09
Tethys	127	0–2	38 ± 14	10.9 ± 7.9	28.5 ± 21.0	0.56 ± 0.11	1.35 ± 0.38	0.23 ± 0.05
		2–4	38 ± 6	7.9 ± 1.9	18.9 ± 5.4	0.35 ± 0.17	2.26 ± 0.16	0.37 ± 0.12
		4–6	37 ± 3	7.5 ± 2.9	18.7 ± 5.7	0.29 ± 0.10	1.48 ± 0.06	0.29 ± 0.04
		Int. ± s e	38 ± 1	8.8 ± 0.9	22.0 ± 2.6	0.40 ± 0.07	1.70 ± 0.23	0.30 ± 0.03

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Table II. Characteristics of particles from sediment traps at two stations, (Albertelli *et al.* 1998, Pusceddu *et al.* 1999a).

Station	Depth (m)	Chl *a* µg m⁻² d⁻¹	Lipids mg m⁻² d⁻¹	Proteins mg m⁻² d⁻¹	Carbohydrates mg m⁻² d⁻¹
ADA1	40	13.9 ± 2.0	0.53± 0.04	2.33 ± 0.19	0.83 ± 0.18
Tethys	127	5.9 ± 1.7	29.5 ± 25.9	5.2 ± 3.3	9.8 ± 6.7

interstitial space (reflected in terms of water content). Analysis of the vertical distribution of meiofauna in the sediments of Terra Nova Bay revealed an extremely reduced meiofaunal abundance in the top 2 cm of ADA1 (only about 20% of the total density; Fig. 1). By contrast, at ADA2, and particularly at Tethys, meiofauna displayed a typical vertical pattern with 48–61% of the total density concentrated in the top 2 cm. Direct observations using a ROV camera carried out at the sampling stations showed the presence of much resuspended sediment at ADA1. This, in turn, has been demonstrated to be mainly due to the intense shell valve "clapping" activity of the scallop (Albertelli *et al.* 1998). In addition, since ADA1 was the shallowest station, it was likely to be characterized by higher sediment resuspension anyway. Both of these factors may contribute to meiofauna resuspension, so it is possible to hypothesize that these phenomena disturbed and resuspended meiofauna from the surface sediments. However, as meiofauna have body sizes (i.e. 30–1000 µm) largely overlapping the size of suspended POM, it is not possible to exclude the feasibility of scallops actively filtering this component. Although a reduced meiofaunal concentration was observed in the top 2 cm of the sediment, all these factors were less evident at ADA2 where lower *A. colbecki* densities occurred.

There is a clear evidence of the effect of resuspension (Fleeger *et al.* 1995, Thistle *et al.* 1995) and macrofaunal disturbance (e.g. Albertelli *et al.* 1999) on meiofauna. The presence of *A. colbecki* assemblages also apparently played an important role in structuring meiofaunal communities. Analysis of meiofaunal composition revealed that nematodes were largely dominant only at Tethys (91% of the total

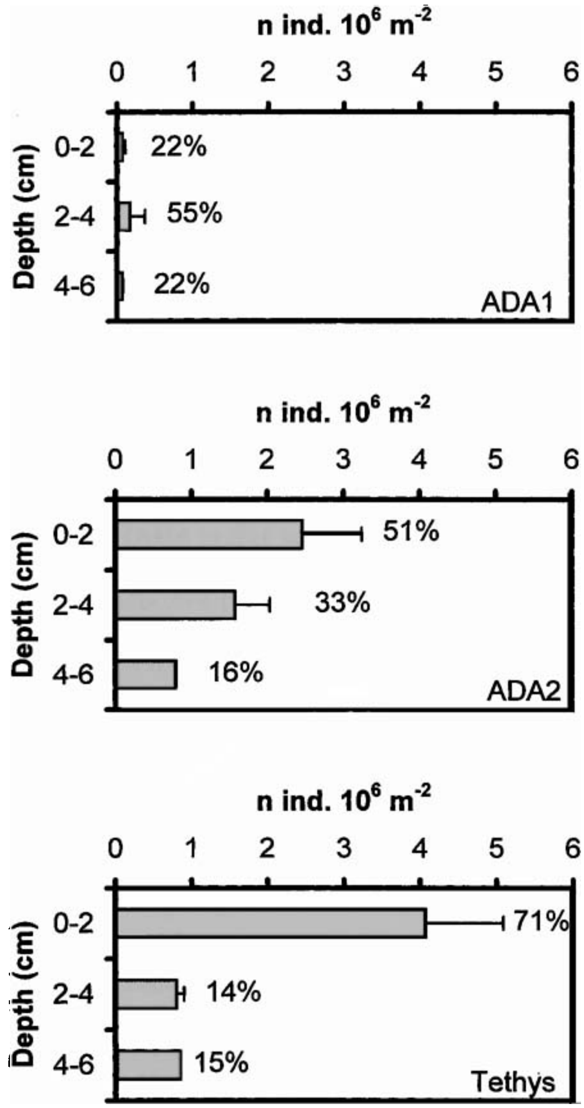

Fig. 1. Vertical distribution (0–6 cm depth) of meiofaunal assemblages at ADA1, ADA2 and Tethys. The percentage contribution of each layer to the total density is also reported.

Table III. Comparison of meiofaunal density with other Antarctic and lower latitude coastal areas. Reported are also sampling devices utilized in the different studies.

Locality	Depth (m)	Sampling device Ind x 10⁶ m⁻²	Mean abundance	Reference
Sites worldwide	1–230	Various	2.9#	Rudnick *et al.* 1985
Northern Baltic (Boreal)		Ftg	2.3–7.9	Elmgren *et al.* 1984
NE Svalbard shelf (Arctic)	226	Box	1.1	Pfannkuche & Thiel 1987
Kerguelen Arch. (Subantarctic)	4–193	Box	0.02–4.8	Bovée & Soyer 1975
Îles Kerguelen (Subantarctic)	Intertidal	Manual coring	5.9	Bouvy & Soyer 1989
Signy Island (Antarctic)	10	Manual coring	4.9–13.2	Vanhove *et al.* 1998
Weddell Sea (Antarctic)	339*	Multi+Box	3.1	Herman & Dahms 1992
Weddell Sea (Antarctic)	226°	Multi+Box	2.5	Vanhove *et al.* 1995
Terra Nova Bay (Ross Sea, Antarctic)	40+	Grab	0.3	present study
	69	Grab	4.6	present study
	127	Grab	5.7	present study

#value summarized from Rudnick *et al.* 1985; *reported the shallowest station 235, a non coastal station; °reported K1, a non coastal station; +ADA1 characterized by the presence of a large *Adamussium* bed; Multi = multicorer; Box = boxcorer; Ftg = flow through gravity corer

Table IV. Meiofaunal community structure in the sediments of Terra Nova Bay. Reported is percentage contribution of major taxa to the total meiofaunal density in three stations characterized by different *Adamussium colbecki* abundance.

Taxa	ADA1 (85 ind m^{-2})	Station ADA2 (18 ind m^{-2})	Tethys (No Scallops)
Nematodes	51.0	46.1	90.8
Gastrotrichs	44.4	50.8	3.1
Copepods	4.1	1.8	5.7
Polychaetes	0.0	0.8	0.1
Other	0.5	0.5	0.3

meiofaunal density), whereas ADA1 and ADA2 were characterized by large densities of gastrotrichs, which were found in the highest values reported in literature so far. Gastrotrichs accounted for 44 and 51% at ADA1 and ADA2 respectively in contrast to only 3.2% at Tethys (Table IV). Harpacticoid copepods accounted for 1.8–5.7% of the total density (ADA2 and Tethys, respectively). Juvenile polychaetes were present only at ADA2 and Tethys (0.8 and 0.2%, respectively), being absent at ADA1.

In conclusion scallop beds produce changes in the sedimentary conditions (in terms of reduced water content), lower amounts of available OM and reduced meiofaunal densities (especially in the upper sediment layers).

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