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Sven Thatje · Erika Mutschke

Distribution of abundance, biomass, production and productivity of macrozoobenthos in the sub-Antarctic Magellan Province (South America)

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Abstract Distribution of abundance, biomass, productivity and production of macrozoobenthos was investigated in four study areas in the Magellan region (South Patagonian Ice-Field, Strait of Magellan, Beagle Channel, Continental Shelf). Using a Reineck box corer and a multibox corer, a total of 277 quantitative benthos samples were taken at 78 stations in water depths between 8 and 1139 m during the Joint Chilean-German-Italian Magellan "Victor-Hensen Campaign" in 1994, the "Polarstern" expedition ANT XIII/4 in 1996 and the Chilean expeditions "Cimar Fiordo II + III" in 1996 and 1997, respectively, on board RV "Vidal Gormaz". Mean abundance in the South Patagonian Ice-Field was significantly lower than in the Strait of Magellan and the Beagle Channel. Biomass and abundance decreased clearly with depth (20–300 m to 700–1500 m: 3.9 gC m^{-2} to 0.6 gC m^{-2}; 2832 ind. m^{-2} to 569 ind. m^{-2}). Average abundance, biomass and production of the whole Magellan region are lower (2318 ind. m^{-2}, 3.2 gC m^{-2}, 0.62 gC m^{-2} $year^{-1}$) than in the high Antarctic Weddell Sea. In the Magellan region, macrozoobenthos composition of abundance is mainly dominated by polychaetes (56%), followed by arthropods (16%), echinoderms (10%) and molluscs (11%). Comparisons of our present results with those of high Antarctic areas make it clear that the Magellan region has a transitional character.

Introduction

The Magellan region is one of the three classical Antarctic biogeographic provinces and the last one to separate from the Gondwana super-continent, a process that may have ended only about 20 million years ago (Brandt 1991; Arntz et al. 1994).

During the last decade comprehensive investigations were performed to extend the restricted knowledge about the marine life and environmental conditions of this area. Our knowledge about macrobenthic communities in the southernmost part of Chile is still limited and, therefore, data from this area are of great scientific interest. It is not clear, for instance, to what extent the macrobenthos of the southernmost tip of America and the Antarctic are related. For instance, we know that there are still conspicuous similarities, as shown by Linse (1997) for the molluscan fauna of both areas. However, brachyuran crabs are known to occur only in South America (Gorny, in press).

In order to provide information about general differences on the level of community, this work summarizes and extends the present knowledge about macrozoobenthos in the Magellan region on the basis of quantitative bottom samples.

Materials and methods

Data collection and analysis

Macrobenthos data obtained within the "Joint Victor Hensen Campaign 1994" (Arntz and Gorny 1996), the Chilean expeditions "Cimar Fiordo II + III" (Mutschke et al. 1995) and the "Polarstern" expedition ANT XIII/4 in 1996 (Fahrbach and Gerdes 1997) are the basis for this study.

In the Magellan region a total of 277 cores were obtained from 78 stations in four subareas (Fig. 1): the "South Patagonian Ice-Field" (SPI: area I), the "Strait of Magellan" (area II), the "Beagle Channel" (area III) and area IV, which represents "continental shelf-stations" at the eastern entrance of the Beagle Channel. This division of the study area is consistent with previous investigations (Mariani et al. 1996; Brey and Gerdes, in press; Gerdes and Montiel, in press).

Sampling from onboard RV "Vidal Gormaz" was performed with a Reineck box corer (Reineck 1963), whereas a multibox corer (Gerdes 1990) was used from onboard the RVs "Victor Hensen"

S. Thatje (✉)
Alfred Wegener Institute for Polar and Marine Research,
P.O. Box 120161, D-27576 Bremerhaven, Germany
(e-mail: sthatje@awi-bremerhaven.de)

E. Mutschke
Instituto de la Patagonia, Universidad de Magallanes,
Punta Arenas, Chile

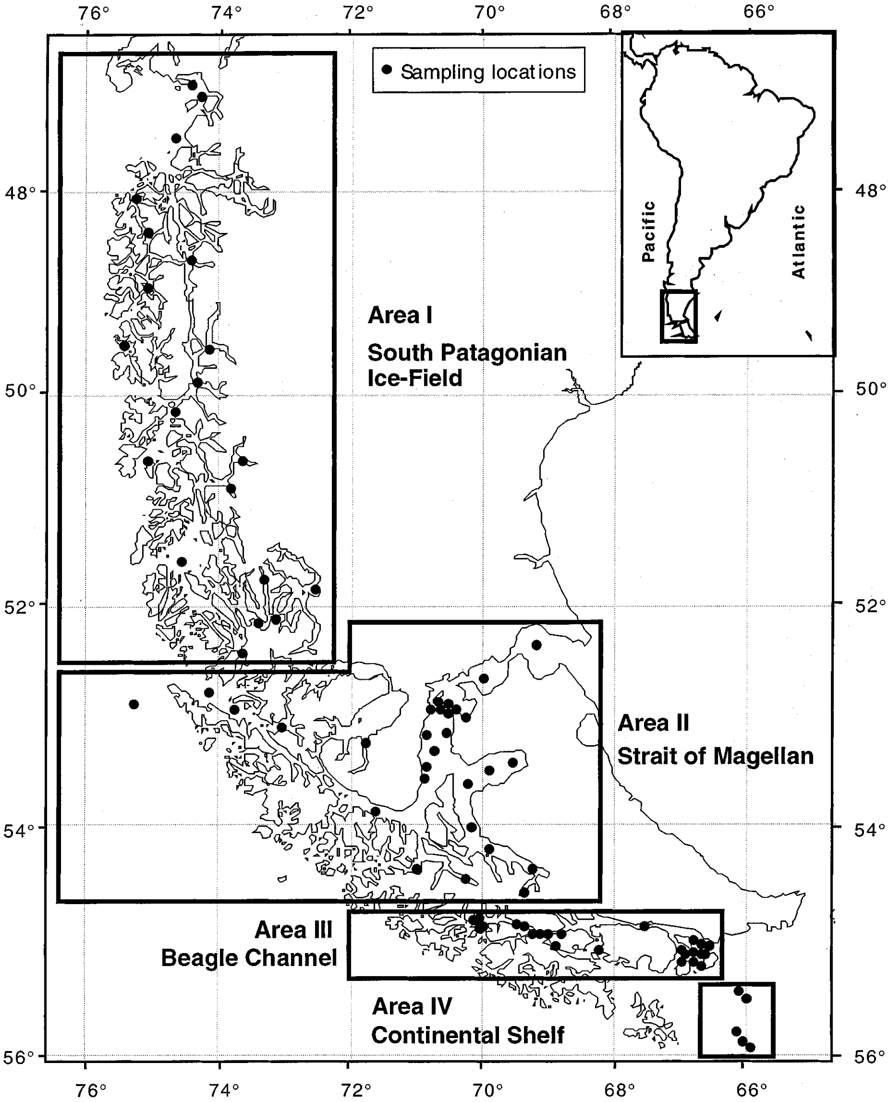


Fig. 1 Sampling sites in the four Chilean subareas

and "Polarstern". The samples were sieved on 0.5-mm mesh and preserved in 4% hexamethylenetetramine-buffered formalin prior to sorting in the laboratory. Animals were classified into 38 taxonomic groups, and abundance (ind. m^{-2}) and wet mass per group (g ww m^{-2}) were determined. For the calculation of abundance values, the colonial Hydrozoa and Bryozoa were only considered as being present (1 ind. m^{-2}).

Wet biomass data were converted to g Corg and kJ using taxon-specific conversion factors published by Cummins and Wuycheck 1971, Dayton et al. 1974, Atkinson and Wacasey 1976, Steimle and Terranova 1985, Rumohr et al. 1987, Wacasey and Atkinson 1987, Walker et al. 1987, Brey et al. 1988, Dauvin and Joncourt 1989 and Barthel 1995.

The significance of differences in abundance, biomass and production between the four subareas was tested using ANOVA and subsequent Games-Howell post-hoc test by differences on means.

Estimation of annual production/biomass ratio and production

For each taxonomic group, we estimated annual P/B by the artificial neural network of Brey et al. (1996), which uses parameters such as mean body mass, living mode, feeding type, taxon, water depth and temperature as input variables. Annual production was computed from the P/B values and group biomass. Brey et al. (1996) showed the sum of production values obtained by such an approach for populations or, as in our case, taxonomic groups to be a reasonable estimate of total community production.

Results

The South Patagonian Ice Field showed the lowest abundance (627 ind. m^{-2}), biomass (2.1 gC m^{-2}), production (0.393 gC m^{-2} $year^{-1}$) and P/B ratio (0.181 $year^{-1}$, Table 1).

P/B ratio estimates were in the same range in all subareas of the Magellan region, whereas biomass increased southwards to the Beagle Channel (5.2 gC m^{-2}), as did abundance (4467 ind. m^{-2}) and production (1.108 gC m^{-2} $year^{-1}$, Table 1). A subsequent Games-Howell post-hoc test showed the benthos abundance in the SPI to differ significantly (P = 0.0019) from the

Table 1 Benthos data obtained from the four Chilean subareas in the Magellan region

	South Patagonian Ice Field (area I)	Strait of Magellan (area II)	Beagle Channel (area III)	Continental Shelf (area IV)
No. of stations (no. of cores)	20 (42)[a]	29 (94)[a,b]	23 (119)[a,b]	5 (31)[b]
Depth range (m)	20–711	8–571	14–348	102–1139
Mean biomass (gC m^{-2})	2.1 ± 0.155	2.7 ± 0.173	5.2 ± 0.290	2.9 ± 0.178
Min.-max. biomass (gC m^{-2})	0.01–17.35	0.16–22.88	0.54–16.99	0.05–14.51
Mean abundance (ind. m^{-2})	627 ± 65.4	1857 ± 197.5	4467 ± 468.3	2319 ± 193.1
Min.-max. abundance (ind. m^{-2})	30–1245	174–4972	668–13521	1136–4379
Annual production (gC m^{-2})	0.393	0.738	1.108	0.684
P/B ratio (gC m^{-2})	0.181	0.261	0.208	0.236

[a] Reineck box corer
[b] Multibox corer

Strait of Magellan (area II) and the Beagle Channel (area III), whereas biomass and production showed no significant difference among all areas under investigation ($P = 0.69$, $P = 0.77$).

The Chilean sampling sites were characterized by a strong heterogeneity of abundance and biomass (Table 1). However, average abundance and biomass decreased clearly with depth (Table 2).

In the Chilean fjord and channel areas (regions I, II and III), the macrozoobenthic abundance is mainly dominated by Polychaeta ($>60\%$), followed by Arthropoda ($>12\%$) and Mollusca ($>7\%$; Fig. 2a). Area IV, the continental slope, was distinctly different in faunal composition, due largely to the increased abundance shares of echinoderms (34%) and the higher significance of Bryozoa, making up 24% of the biomass. Porifera were less important in the Magellan region; only in the Strait of Magellan (area II) do they represent 10% of the biomass (Fig. 2b).

Discussion

Sampling

Sampling in the SPI was performed with the Reineck box corer (Reineck 1963) and at the continental slope with the multibox corer (Gerdes 1990), whereas both methods were used in the Strait of Magellan and the Beagle Channel. Both gears are based on a similar mechanical principle, but the Reineck box corer is a single-box corer covering 0.017 m^2 whereas the multibox corer takes up to nine cores simultaneously which cover a sampling area of 0.066 m^2 each. Up to eight of these cores per station were used for macrobenthos analyses. With the Reineck box corer, up to three cores per station were obtained. The multibox corer allows multiple sampling and may yield a better evaluation of benthic densities, especially of those that are usually patchily distributed (Gerdes 1990). Based on this, we do not think that our results are heavily biased by these different techniques.

Sampling by grabs is generally known to underestimate rare and large epibenthic species or those that are highly motile and can easily escape. Dahm (1996), for instance, showed that density assessments based on multibox cores underestimated ophiuroid abundances by a factor of 3 in the Weddell Sea. Likewise, crustaceans, especially larger decapods such as *Peltarion spinosulum* or *Munida subrugosa,* were not found frequently in our samples, though they are known to occur in high numbers in the Magellan region (Gorny, in press).

Macrobenthos patterns in relation to the environment

The South American sampling area belongs to the cold-temperate region (Brattström and Johanssen 1983). It is a very heterogenous shelf area with thousands of islands and many channels and fjords. Differences among the benthic communities are assumed to reflect these variable environmental conditions in the four Chilean subareas. The SPI (48°20′S–53°30′S) is the largest mid-latitudinal and meridional ice mass, covering an area of about 13,000 km^2 (Warren and Sugden 1993). The channels and fjords of this area are heavily influenced by fresh water originating from the run-off of melting gla-

Table 2 Depth distribution of macrozoobenthos in the Magellan region

Depth range	No. of stations	Mean N (ind. m^{-2})	Range (ind. m^{-2})	Mean biomass (gC m^{-2})	Range (gC m^{-2})
8–100 m	26	3639	296–13521	5.041	0.38–22.88
101–300 m	34	2025	30–6680	2.842	<0.01–16.99
301–500 m	9	1024	385–2807	1.075	0.04–3.33
501–700 m	7	750	296–1245	1.423	0.01–9.44
701–1500 m	2	569	89–1049	0.618	<0.01–1.23

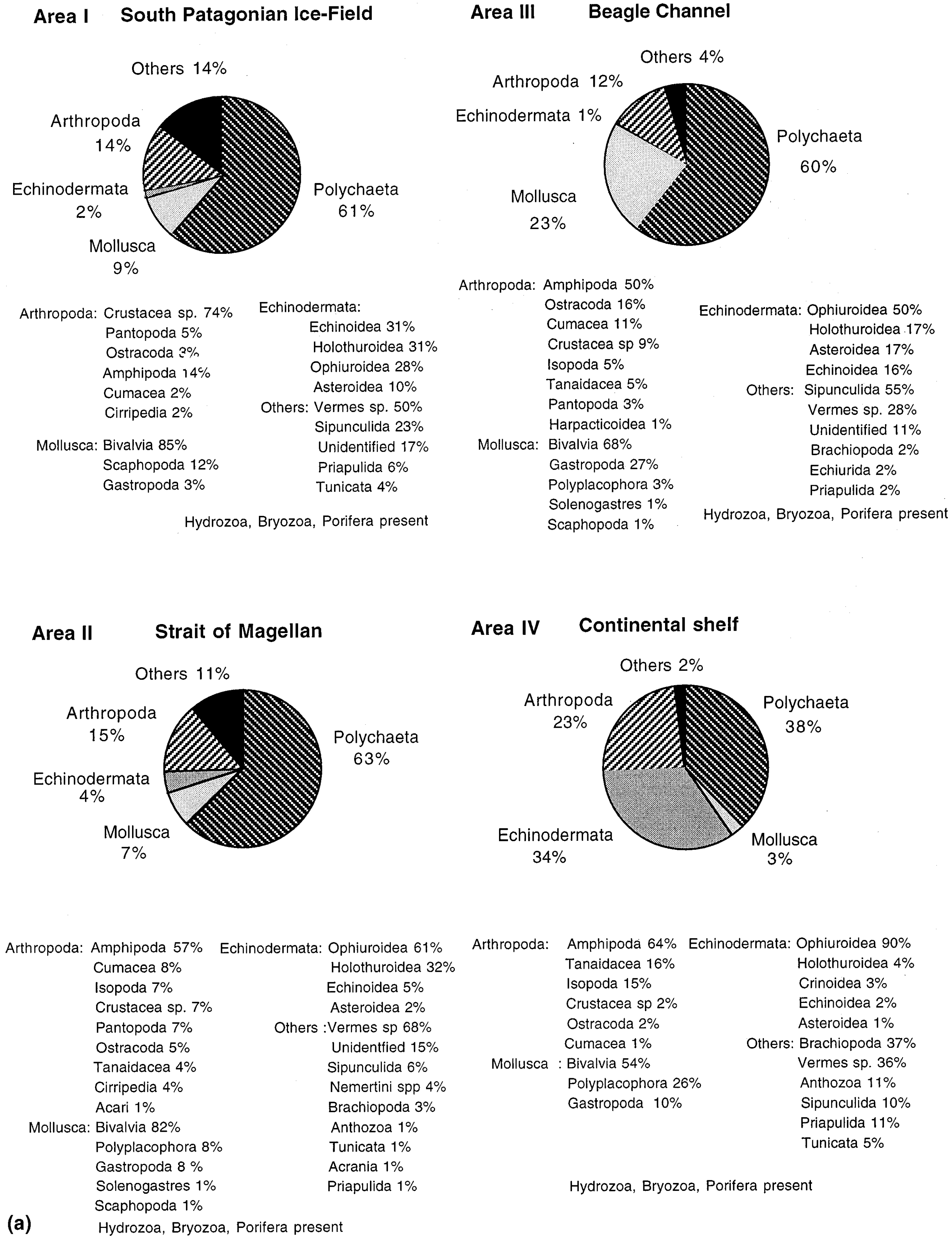
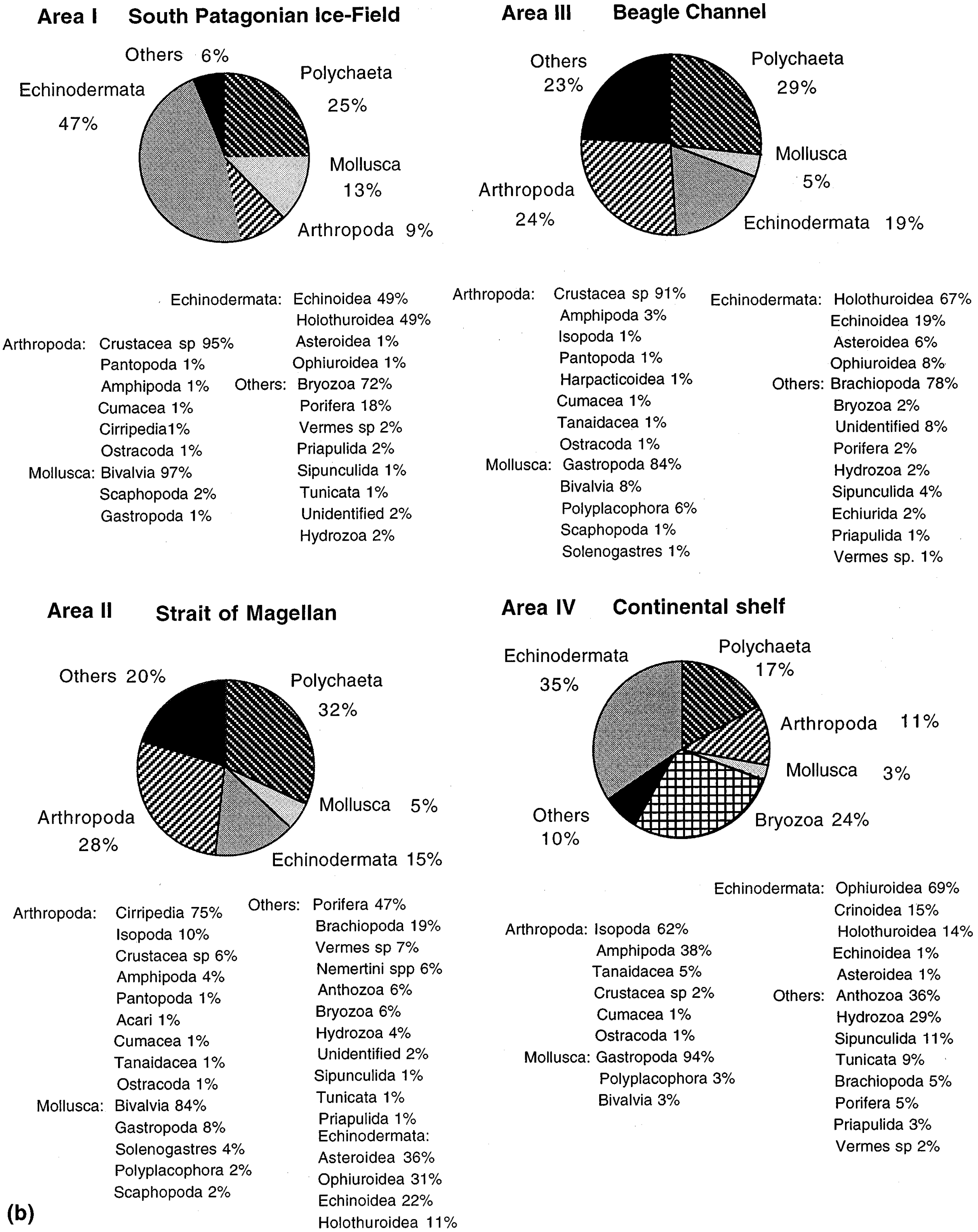


Fig. 2 **a** Relative proportions of taxa in macrozoobenthic abundance **b** Relative proportions in macrozoobenthic biomass



ciers and heavy rainfalls. There is a conspicuous gradient of decreasing salinity and temperature towards the glacier tongues (Pinochet and Salinas 1996). The sediment composition in this area is affected by glacier scouring, which leads to the deposition of mud and gravel. Our data allow us to differentiate between an impoverished fjord community and a richer channel community. This pattern was also evident in the composition of Agassiz trawl catches carried out in this region (W.E. Arntz, personal communication). Large and long-lived echinoderms and molluscs, mostly bivalves, were found, making up 60% of the whole biomass.

The Strait of Magellan with its adjacent channels and fjords (area II) and the Beagle Channel (area III) are characterized by strong currents, inducing various types of sediment (Brambati et al. 1991): deposition zones of mud and clay in the Paso Ancho (Mariani et al. 1996) and in the Beagle Channel, as well as muddy habitats in the adjacent Bahía Inútil and Seno Almirantazgo which are, in addition, strongly affected by the sediment input due to the rub-down of glaciers. The sediments at the Pacific and Atlantic sites are coarser. Moreover, high proportions of shell debris (*Chlamys* sp.) occurred at the Pacific coast. Mean temperature and salinity are higher in the strait (7–9°C, 30‰S; Artegiani and Paschini 1991) than in the SPI area (4–6°C, 14–30‰S; Pinochet and Salinas 1996). The benthos is dominated by polychaetes. The abundance of this taxon increased towards the Atlantic, a finding that was also observed by Mariani et al. (1996). In terms of environmental conditions, the Beagle Channel is more similar to the SPI (Colizza 1991), with lower surface salinity and temperature (27%S, 6.5–8°C; Antezana et al. 1996). However, in macrobenthic composition it is more similar to the Strait of Magellan. The only difference was the higher presence of molluscs and the lower density of sponges in the Beagle Channel.

Sediments at the continental slope (area IV) are characterized by fine sand, mixed with shell debris. Echinoderms, arthropods and especially bryozoans dominated the macrobenthic community. Generally, the faunistic composition was more similar to the Antarctic shelf (Gerdes et al. 1992) than to the other Magellan sampling sites.

Comparison to Weddell Sea benthos

Based on data from the Paso Ancho and the Beagle Channel, which showed the highest abundance and biomass of the Magellan region, Brey and Gerdes (in press) reported that benthic community production and productivity were higher in the Magellan region than in the Weddell Sea. They assumed a better food supply and higher ambient temperatures to be responsible for this finding. Conversely, the analysis of our larger database suggests that production and productivity, as well as abundance and biomass, are lower in the Magellan region (Table 1) than in the high Antarctic (3.6 gC m^{-2}, 0.3 gC m^{-2}, 3806 ind. m^{-2}, 12 gC m^{-2}, Brey and Gerdes, in press).

Antarctic biomass, especially on the shelf, has frequently been shown to be outstandingly high (Dayton et al. 1974; White 1984; Brey and Gerdes 1997). Lower values from shallow waters (< 10 m) have been proposed to be mainly caused by ice impact or by low and seasonally pulsed food supply (Dayton and Oliver 1977; White 1984). However, subtidal areas such as those in the Magellan region can also be characterized as rather stressful environments, due to tidally varying temperature, salinity and currents (Levinton 1982). The decrease of abundance and biomass with water depth is a common pattern and has been reported from numerous regions such as, for instance, from the high-Antarctic Weddell and Lazarev Seas (Brey and Gerdes, 1998).

We have detected a clear increase of abundance, biomass and production with latitude within the Magellan region. However, it is not clear whether this gradient extends towards the Antarctic Peninsula, as suggested by the data available for this region from the literature (e.g. Richardsen and Hedgpeth 1977; Mühlenhardt-Siegel 1988). Future community analyses at species level are needed to work out more detailed differences and similarities between the Magellan study area and the Antarctic Peninsula.

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