POLISH POLAR RESEARCH
vol. 32, no. 4, pp. 341–354, 2011 doi: 10.2478/v10183-011-0024-6

Distribution and diversity of cumacean assemblages in Admiralty Bay, King George Island

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Abstract: Eleven species of cumaceans were found in 105 samples collected in Admiralty Bay (King George Island) in the summers of 1984/85 and 1985/86, from 20 to 500 m depth range. Four cumacean assemblages were distinguished using the multivariate analysis. They were characterized by the dominance of one or two species often with low density values. Two assemblages were found in open waters of Admiralty Bay. The first inhabited on sandy-clay-silt and silty-clay-sand bottom deposits in the depth range from 140 to 330 m, with *Campylaspis maculata* (1.6 ± 2.1 ind./0.1m^2; F = 72.4%) and *Leucon* sp. (1.4 ± 1.6 ind./0.1m^2; F = 68.9%) as key species. The second assemblage was found in the depth range from 50 to 120 m with silty-sand sediments, and it was characterized by the presence of *Vauthompsonia inermis* (6.5 ± 6.6 ind./0.1m^2; F = 92.0%). A third assemblage was found in shallow waters influenced by glaciers in the bottom area of Ezcurra Inlet. It was characterized by sandy-clay-silt sediments and the presence of *Eudorella splendida* (14.6 ± 9.4 ind./0.1m^2; F = 100.0%) as a core species. The last assemblage was found in the shallow sublittoral (50–100 m) of Ezcurra Inlet and the central basin, with *Diastylis anderssoni armata* (1.5 ± 1.1 ind./0.1m^2; F = 85.7%) and *Diastylopsis goekei* (1.1 ± 1.0 ind./0.1m^2; F = 71.4%) as the most frequent and abundant species. *V. inermis* is considered a eurytopic species with high frequency in the whole material, and was present in all four distinguished assemblages. *E. splendida* and *D. goekei* were also recorded in each of the assemblages, but their total frequency was lower.

Key words: Antarctic, South Shetlands, Cumacea, benthic communities, glacial fjord.

Introduction

Cumacea are group of small crustaceans, usually not exceeding a few millimeters of body length, which are found in benthic marine habitats all over the world. Cumaceans lack planktonic larvae, and juveniles (mancae) released from the marsupium have as limited mobility as the adults. In consequence, cumaceans classified as crustaceans with low dispersal ability (McLaughlin 1980; Corey 1981; Bishop 1982). Most cumaceans feed on fine particles filtered out from the water column, organic matter from the sediments, or on epiphytes grazed from

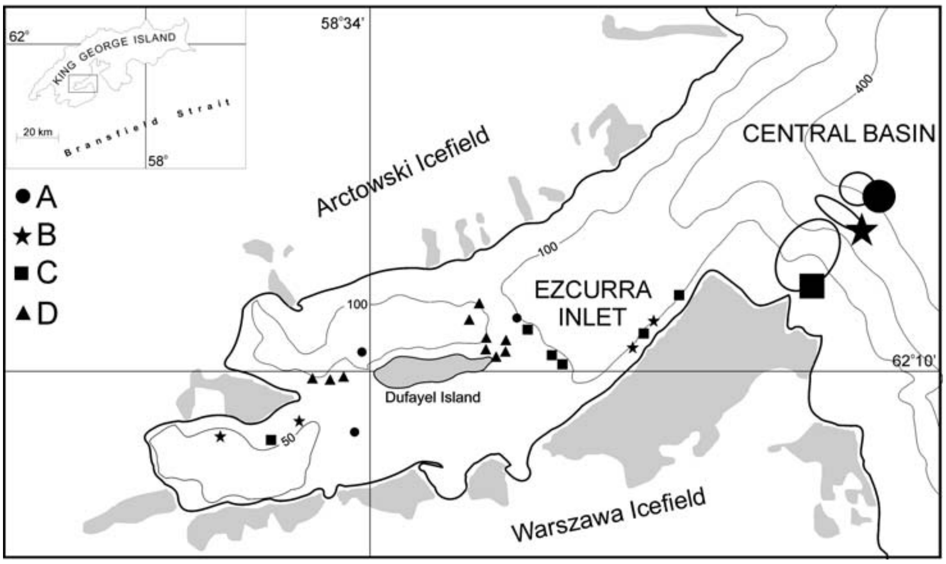

Fig. 1. Distribution of samples from the groups distinguished in the cluster analysis.

sand grains; some scavengers or predators are also known in this group (Błażewicz-Paszkowycz and Ligowski 2002).

It is believed that cumaceans are soft-bottom dwellers, although attentive observations have demonstrated that habitats with coarse sediments are also chosen (Martin *et al.* 2010). It is assumed that most cumaceans have narrow preferences to the type of sediment. Together with their low dispersal, this makes them potentially useful indicators of changes in environmental conditions (Wieser 1956; Corbera and Cardell 1995; Băcescu and Petrescu 1999).

Currently 86 species of Cumacea are recorded south of Antarctic Convergence and most of them are endemic taxa. In term of species number they are classified as the fourth group of peracarids, following Amphipoda, Isopoda and Tanaidacea (De Broyer and Danis 2011). Cumacea are considered as an important element of benthic communities in terms of abundance and species richness (Dayton and Oliver 1977; Modlin and Dardeau 1987; Wang and Dauvin 1994; Corbera and Cardell 1995; Dos Santos and Pires-Vanin 1999). Most of the data from the Southern Ocean covers taxonomy and zoogeography (Jones 1971; Ledoyer 1993; Mühlenhardt-Siegel 1996; Petrescu and Wittmann 2003; Mühlenhardt-Siegel 1999; Mühlenhardt-Siegel 2011; and references therein). Only a few papers have addressed distribution patterns, assemblage characteristics or environmental preferences until now; if any, they have deal with the deeper part of the continental shelf, or they are based on qualitative or semiquantitative samples only (Corbera 2000; Rehm *et al.* 2007; Corbera *et al.* 2009; San Vicente *et al*. 2011). Information about Antarctic cumaceans can be found also in studies dedicated to shelf benthic communities (Lowry 1975; Dayton and Oliver 1977; Gallardo *et al*. 1977; Richardson and Hedgpeth 1977).

Admiralty Bay is recognized as one of best-studied Antarctic regions, with comprehensive data on benthic communities (Siciński *et al*. 2011). Among peracarids recorded in the Bay two groups of crustaceans, tanaids and amphipods, have been extensively studied (Jażdżewski *et. al.* 1991; Błażewicz-Paszkowycz and Jażdżewska 2000; Blazewicz-Paszkowycz and Sekulska-Nalewajko 2004; Jażdżewski 2011). The only papers dedicated to cumaceans of Admiralty Bay present a preliminary list of species with some general notes on their distribution and zoogeography (Błażewicz and Jażdżewski 1995), or their contribution to benthic biomass and abundance (Jażdżewski *et al.* 1986; Pabis and Siciński 2011).

The aim of this study was to examine the patterns of distribution of cumacean assemblages in Admiralty Bay along the axis of the fjord, from the inner part of Ezcurra Inlet to the central basin of the Bay, along a gradient of factors including distance from the glaciers and increasing depth.

Study area

Admiralty Bay is made up of four main basins, a central basin and three inner fjords: Ezcurra Inlet, Martel Inlet and MacKellar Inlet. Ezcurra Inlet is a narrow fjord with shores covered by glaciers. It is also strongly influenced by mineral sedimentation (Pęcherzewski 1980; Braun and Grossmann 2002). The central basin is the deepest part of Admiralty Bay, reaching almost 550 m in depth, and it opens into the Bransfield Strait. Glaciers covering the shores of the central basin are distributed mainly along the eastern coast (Braun and Grossmann 2002). There is also a clear gradient of quantity of mineral suspension along the main axis of Ezcurra Inlet, decreasing from the inner to the outer part. The highest amounts of suspended matter were recorded in front of the glacier cliffs in the inner part of this fjord, while the lowest were observed in the central basin (Pęcherzewski 1980; Siciński 2004).

Sediments in the inner area are characterized by clay fractions in contrast to the outer part and the central basin, in areas of lower glacier influence, where sediments are described as silty-sand and silty-clay-sand (Siciński 2004). Water turbidity was relatively high in the Ezcurra Inlet and much lower in the central basin (Lipski 1987). Waters of Ezcurra Inlet also had the lowest values of chlorophyll α content (Tokarczyk 1986).

Material and methods

Sampling. — A total of 105 samples was taken using a van Veen grab (0.1 m^2) in two summer seasons of 1984/1985 and 1985/86 from almost whole depth range of Admiralty Bay, from 20 to 500 m. These samples were collected along the gradient of glacier influence from the inner part of Ezcurra Inlet to the open parts of the central basin. The material was sieved on a 0.5 mm-mesh sieve. Cumaceans were recorded in 71 samples. These samples were used in the cluster analysis; all 105 samples were used in the diagram of bathymetric distribution.

Data analysis. — The similarities between the samples were measured using the Bray-Curtis similarity index. The data matrix with non-transformed density values (ind./0.1m^2) was used. A data transformation was not applied because of the low density values of all species in the analyzed material. Hierarchical agglomerative clustering was performed using the group-average method (Clarke and Warwick 1994). Species richness (S – number of species per sample), diversity (Shannon index $H' = - \Sigma p_i \ln p_i$), evenness (Pielou $J' = H'/\ln S$) and density (ind./0.1m^2) were measured for each sample (Magurran 2004). Differences between these indices for all distinguished assemblages were tested using the non-parametric Kruskal-Wallis test and post hoc testing with use of the STATISTICA 6 package.

Granulometric data were available for only 37 samples (see Siciński 2004). Including data on the sediment type in the analysis allows the interpretation of the distribution patterns and habitat preferences of the cumaceans.

Results

Characteristics of assemblages. — Eleven species (685 individuals) were found in the analyzed material. Four assemblages (A–D) were distinguished in the cluster analysis (Figs 1, 2). Each of these assemblages is characterized mainly by the regular presence of one species, usually occurring only in very low densities. The most frequent and eurytopic species that was found in each of the assemblages was *Vauthompsonia inermis* Zimmer 1909, with 52.1% of total frequency. *Leucon* sp. was another frequent species (38%) present in all the assemblages except assemblage B. Two other species, *Eudorella splendida* Zimmer, 1902 and *Diastylopsis goekei* Roccatagliata *et* Heard, 1992, were also present in all four assemblages, although with clearly lower frequency in the whole material (Table 1). Despite the differences in species composition and number of species recorded in each of distinguished assemblages, the values of species richness were similar (Fig. 3). There was no significant difference in the species richness and Shannon index values between the assemblages (Kruskal-Wallis test, $p < 0.05$). Significant differences in the density values were found between following assemblage pairs: A/C, A/D, B/C, B/D and C/D. No significant differences were found between any other pairs; Kruskal-Wallis test and post hoc testing, $p < 0.05$. Significant differences were also found for evenness but only between the pair A/D (Kruskal-Wallis test and post hoc testing, $p < 0.05$).

Assemblage A. — This cluster grouped the samples collected in the deeper regions of central basin (from 140 to 330 m) and three samples from the deeper part

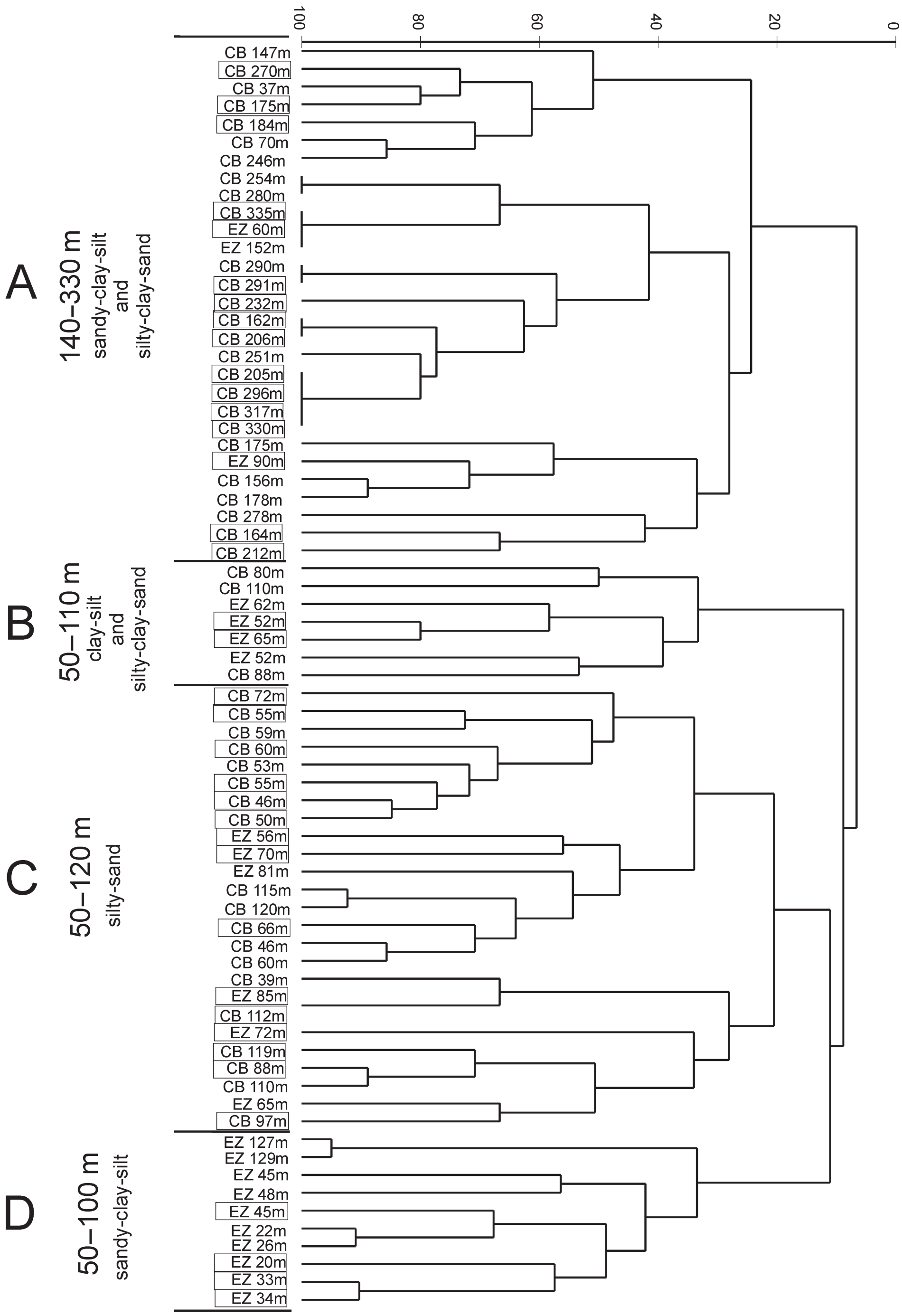

Fig. 2. Dendrogram of samples from Bray-Curtis similarity analysis of non-transformed density values, group-average clustering method: A–D – assemblages, EZ – Ezcurra Inlet, CB – central basin. Samples with information on sediment type are marked with frames.

Table 1

Mean densities [ind./0.1m^2] with standard deviation and frequency values for each distinguished assemblage and frequency in the whole material. Most frequent and abundant species are marked in bold.

	A (29 samples)		B (7 samples)		C (25 samples)		D (10 samples)		All (71 samples)
	Density [ind./0.1m^2]	F [%]	Density [ind./0.1m^2]	F [%]	Density [ind./0.1m^2]	F [%]	Density [ind./0.1m^2]	F [%]	F [%]
Vaunthompsonia inermis Zimmer, 1909	0.2±0.5	20.6	0.4±1.1	14.2	**6.5±6.6**	**92.0**	1.1±1.5	66.6	**52.1**
Vaunthompsonia meridionalis Sars, 1886	–	–	–	–	0.2±1.0	4.0	0.2±0.6	11.1	2.8
Eudorella splendida Zimmer, 1902	0.2±0.6	13.7	0.2±0.4	28.5	0.7±1.3	32.0	**14.6±9.4**	**100.0**	33.8
Eudorella gracilior Zimmer, 1907	0.03±0.1	3.4	–	–	1.1±2.2	48.0	1.9±4.3	22.2	21.1
Leucon sp.	**1.4±1.6**	**68.9**	–	–	0.3±1.2	8.0	4.3±5.6	55.5	38.0
Campylaspis maculata Zimmer, 1907	**1.6±2.1**	**72.4**	–	–	0.1±0.4	12.0	1.2±3.7	11.1	35.2
Cumella australis Calman, 1907	0.1±0.4	6.8	0.1±0.3	14.2	–	–	0.7±1.9	22.2	7.0
Diastylis anderssoni armata Ledoyer, 1993	–	–	**1.5±1.1**	**85.7**	1.1±3.4	16.0	0.2±0.6	11.1	15.4
Diastylis corniculata Hale, 1937	0.06±0.2	6.8	–	–	–	–	–	–	2.8
Ekleptostylis debroyeri Błażewicz-Paszkowycz *et* Heard, 2005	0.2±0.9	13.7	–	–	–	–	–	–	5.6
Diastylopsis goekei Roccatagliata *et* Heard, 1992	0.03±0.1	3.4	**1.1±1.0**	**71.4**	1.2±3.3	32.0	1.0±1.4	44.4	25.3

of Ezcurra Inlet (Figs 1, 2). The assemblage is characterized by very low cumacean density (Fig. 3). A constant element of this assemblage was *Campylaspis maculata* Zimmer, 1997 (1.6 ± 2.1 ind./0,1m^2; F = 72.4%) followed by *Leucon* sp. (1.4 ± 1.6 ind./0.1m^2; F = 68.9%). From the nine species recorded in this assemblage two species – *Diastylis corniculata* Hale, 1937 and *Ekleptostylis debroyeri* Błażewicz--Paszkowycz and Heard, 2001 were present exclusively in this assemblage (Table 1). The sediments from 16 samples from this cluster were sandy-clay-silt and silty-clay-sand.

Assemblage B. — This cluster grouped the samples taken from Ezcurra Inlet and the central basin at a depth range from 50 to 100 m (Figs 1, 2). It is characterized by low cumacean density values, with 3 ind./0.1m^2 (Fig. 3). Only five species were found in this assemblage with *Diastylis anderssoni armata* Ledoyer, 1993 (1.5± 1.1 ind./0.1m^2; F = 85.7%) and *Diastylopsis goekei* (1.1± 1.0 ind./0.1m^2; F = 71.4%) as the most frequent and abundant (Table 1). Data on sediment type were

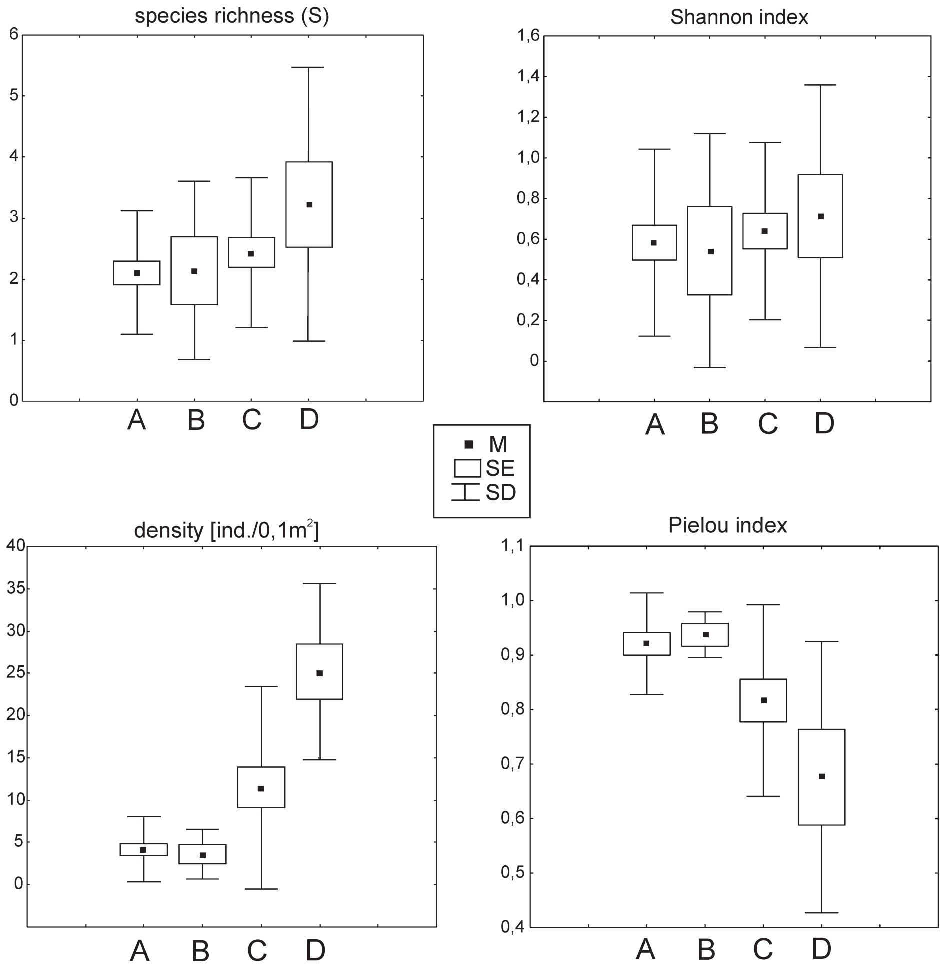

Fig. 3. Comparison of density (N), species richness (S), diversity (Shannon index) and evenness (Pielou index) for the four distinguished assemblages. M – mean, SE – standard error, SD – standard deviation.

available for only two of the seven samples, one having silty-clay-sand deposits and one with clay-silt sediments.

Assemblage C. — This cluster grouped the samples from the central basin and the outer part of Ezcurra Inlet at the depths from around 50 to 120 m (Figs 1,2). It is the assemblage with relatively high total density values (Fig. 3). Among eight species that were found in this assemblage the most frequent and abundant was *Vauthompsonia inermis* (6.5± 6.6 ind./0.1m^2; F = 92.0%) (Table 1). The sediments were silty-sand.

Assemblage D. — This cluster grouped the samples from the inner and middle parts of Ezcurra Inlet in relatively shallow depths, mainly from 20 to 45 m (Figs 1, 2). This is the assemblage with highest density values (Fig. 3). Nine species were noted in this assemblage. The most frequent and abundant was *Eudorella splendida* (14.6 ± 9.4 ind./0.1m^2; F = 100.0%). Other frequent but less abundant species were *V. inermis* (1.1 ± 1.5 ind./0.1m^2; F = 66.6%) and *Leucon* sp. (4.3 ± 5.6 ind./0.1m^2; F = 55.5%). The bottom deposits were sandy-clay-silt.

Distribution along the depth gradient. — Distribution of the cumaceans found in analysed material revealed three groups of species. The first included species associated with the shallower part of the shelf down to 185m: *D. andersoni armata*, *D. goekei*, *E. gracilior, V. meridionalis* G.O. Sars, 1887 and *V. inermis*. The second group, represented by two species: *D. corniculata* and *E. debroyeri*, was associated mainly with deeper shelf habitats from 150 to 230 m. The last group is composed of four species: *C. australis*, *C. maculata*, *E. splendida*, and *Leucon* sp. They clearly showed a wider bathymetrical range in Admiralty Bay, occurring from the shallow sublittoral down to 335 m. No cumaceans were found in the samples collected deeper than 335 m (Fig. 4).

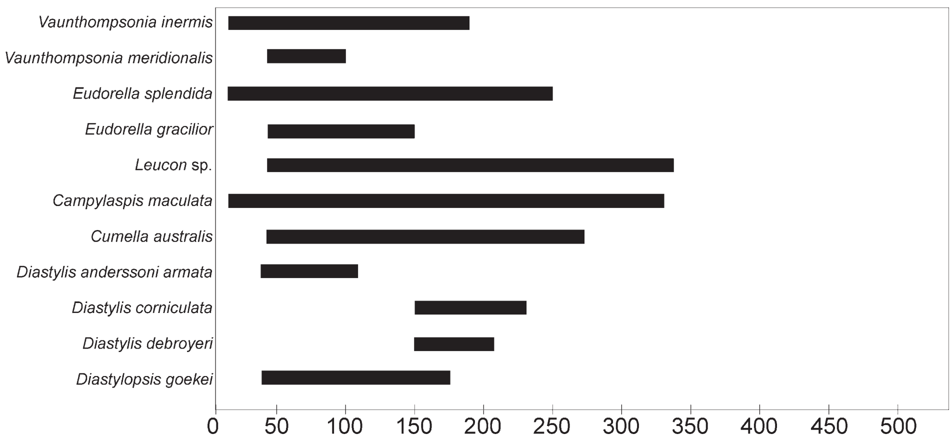

Fig. 4. Depth ranges of species found in the collection studied.

Discussion

In Admiralty Bay cumaceans form assemblages of a very few species and mostly with one clear dominant. Similar observations were found in deeper parts of the Bellingshausen Sea, in the western region of Antarctic Penisula (Corbera *et al.* 2009) and in the South Shetland Islands (Corbera 2000). Depth and type of substratum have often been mentioned as the most important factors influencing the distribution of cumacean assemblages (Corbera and Cardell 1995; Dos Santos and Pires-Vanin 1999; Corbera 2000; Corbera *et al.* 2009) and the present results support those observations. The distinguished assemblages suggest that particular cumacean species can be used to define benthic communities. It may be a result of their presumably narrow tolerance to environmental factors, such as sediment quality, influence of glaciers or depth.

The bathymetric distribution of the eleven cumacean species presently analysed is clearly wider in the whole Southern Ocean than it is in Admiralty Bay. It is concluded that in this relatively small basin the species occur only at well-defined, relatively-narrow depth ranges. All cumaceans of Admiralty Bay are considered shallow-water taxa, never present below shelf depths. The only exception is *Diastylis corniculata* which shows some preferences for deep water. It has been found below 1200 meters (Rehm *et al.* 2007) and it was absent in depths shallower than 150 m in Admiralty Bay. Another two species with relatively wide bathymetric ranges are *Eudorella gracilior* and *Cumella australis*, which have been known from the shallow sublittoral down to a depth of 800 m (Ledoyer 1993; Corbera 2000; Rehm *et al*. 2007). In contrast *Diastylis andersoni armata* has been recorded only from depths below 200 m (Mühlenhard-Siegel 1999; Corbera 2000; Błażewicz-Paszkowycz and Heard 2001; Petrescu and Wittmann 2003). Surprisingly, in Admiralty Bay this species was recorded only in the shallow sublittoral, even at 40 m depth. Moreover, this species was absent in the deeper shelf of Admiralty Bay (assemblage A). Another diastylid, *E. debroyeri*, has not been recorded in the Antarctic since its original description. It occurred over a wide depth range, from 90 to 530 m, although it was clearly more abundant below 200 m (Błażewicz--Paszkowycz and Heard 2001). The genus *Ekleptostylis* and its relative *Leptostylis* are considered to be deep-water taxa (Bacescu 1992; Roccatagliata and Mühlenhardt-Siegel 2000) justifying the distribution found in Admiralty Bay. The presence of the deep-water species in the Antarctic shelf is an example of polar emergence, demonstrated for many crustaceans (Brandt 1999; Błażewicz-Paszkowycz 2005), and is exemplified by the Antarctic population of *Ekleptostylis*.

Our observations support earlier assumptions that the depth of around 300 m is a biological boundary for many species of Antarctic Cumacea. It is shown by a clear shift in the set of species present above or below this depth (Ledoyer 1993; Corbera 2000; Rehm *et al.* 2007).

The other factor shaping the distribution of Cumacea in Admiralty Bay is the influence of glaciers. Fine sediments brought into the bay by glaciers undoubtedly restrict the bathymetric ranges of most cumaceans. It is concluded that the type of sediments and the distance from the glaciers are the main factors affecting the character of the assemblages found in this basin. Similar patterns were observed for polychaetes (Siciński 2004; Pabis and Siciński 2010), amphipods (Jażdżewska 2011) and tanaids (Błażewicz-Paszkowycz and Jażdżewski 2000). However, in those studies differences in diversity were also observed, while for the cumacean assemblages the values of the Shannon index were similar.

In an analysis made in the Bellingshausen Sea, the species richness (number of species per sample) was consistently low in samples collected with a suprabenthic sledge, never exceeding seven taxa per sample (from a total number of 35 species) (Corbera *et al.* 2009). Although their results are consistent with our observations, it is worth emphasizing that those authors used different sampling gear and over a wider depth range. This might be also the reason why we did not observe an increase in species richness with increasing depth, as has been observed in other areas such as the South Shetland Islands (Corbera 2000), the Ross Sea (Rehm *et al.* 2007) and the Bellingshausen Sea (Corbera *et al.* 2009). Equally, these three studies were each based on a relatively small number of semiquantitative samples.

The most eurytopic cumacean species in Admiralty Bay was *V. inermis*. This species was recorded as the most abundant in the shelf assemblage (85–385 m) on muddy/fine sand sediments of Peter I Island (Bellingshausen Sea) (Corbera and Ramos 2003; Corbera *et al.* 2009). A similar observation was made by San Vicente *et al.* (2007) in the South Shetland Islands region, in an assemblage found at depths ranging from 45 to 420 m. The prevalence of *V. inermis* might be the result of its relatively good swimming ability, thus its potentially greater dispersion capabilities (Corbera 2000). Two other species, *Eudorella splendida* and *Diastylopsis goekei*, were less frequent, but they were present in each distinguished assemblage. *E. splendida* demonstrated a clear preference for shallow and disturbed areas of Ezcurra Inlet. Studies of its stomach contents show this species to be a non-selective detritus feeder (Błażewicz-Paszkowycz and Ligowski 2002) and such feeding preferences might explain its tolerance of this disturbed area. Błażewicz and Jażdżewski (1995) mentioned *E. splendida* as dominant in Admiralty Bay; however, despite its relatively high total dominance, it reveals preferences to a quite well-defined type of habitat, namely the areas affected by mineral suspension inflow. Similar observations were made for another species of the same genus, *E. emarginata*, in Norwegian and Spitsbergen fjords, where it was clearly more abundant in the sites with high sedimentation rates (Holte 1998; Włodarska-Kowalczuk *et al.* 1998; Włodarska-Kowalczuk *et al.* 1999). Lenihan and Oliver (1995) found *E. splendida* to be a dominant species in iceberg scours together with opportunistic polychaetes like *Tharyx* sp. In the studies from Artur Harbour and Chile Bay (Antarctic Peninsula) another species of the genus, *E. gracilior*, was the most common and abundant cumacean (Gallardo *et al.* 1977; Richardson and Hedgpeth 1977). Generally, the species found in Admiralty Bay are typical for similar shelf, soft-bottom Antarctic communities (Gallardo *et al.* 1977; Richardson and Hedgpeth 1977; Corbera 2000).

Błażewicz and Jażdżewski (1995) assumed that further species might be added to their list of cumaceans if deeper parts of Admiralty Bay, and possibly those closer to its entrance to the Bellingshausen Strait were accesible. In the analyzed material a few samples from a depth of about 500 m were studied, but no further species were found. Corbera (2000) and San Vicente *et al.* (2007) reported 29 species of cumaceans in the material from the BENTART-95 cruise around the South Shetland Islands in a similar depth range (49–649 m). Results similar to those from Admiralty Bay have been reported in two other, relatively small, basins of this region, Chile Bay (eight species) (Gallardo *et al.* 1977) and Artur Harbour (nine species) (Lowry 1975, Richardson and Hedgpeth 1977). No doubt using different sampling methods, or finer mesh sizes, could supplement the results; however Admiralty Bay is one of the most intensively sampled areas in the Antarctic (Sicinski *et al.* 2011) and rather few new cumaceans might be expected to be found in this basin.

Future studies should be focused more on the analysis of habitat preferences, in relation to a wider list of environmental factors.

Acknowledgments. — We thank Jacek Siciński (University of Łódź) for collecting the material and making it available for our study. We are grateful to Angelika Brandt (University of Hamburg) and Jordi Corbera (Museu de Mataró) for their constructive comments on the manuscript and to Roger Bamber (ARTOO) for improving the English. The study was funded by the University of Łódź.

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Received 24 February 2011
Accepted 15 September 2011