POLISH POLAR RESEARCH
vol. 26, no. 2, pp. 137–155, 2005

Shallow sublittoral macrozoobenthos in Kongsfjord, West Spitsbergen, Svalbard

Honorata KACZMAREK, Maria WŁODARSKA-KOWALCZUK,
Joanna LEGEŻYŃSKA and Marek ZAJĄCZKOWSKI

Instytut Oceanologii Polskiej Akademii Nauk, Powstańców Warszawy 55, 81-712 Sopot, Poland
<maria@iopan.gda.pl>

Abstract: The shallow water benthic fauna was collected in Kongsfjord, West Spitsbergen. Sampling was conducted along two main environmental gradients: vertical gradient (depth 5–50 m) and horizontal gradient (sedimentation regime) along the fjord axis. A small rectangular dredge was used. Altogether 169 taxa were identified and four macrofaunal associations were distinguished. Bottom type and distance from the tidal glaciers seem to be the main factors responsible for species distribution. The Soft Bottom I Association occupying the fine mud of the Kongsbreen glacial bay consisted mostly of Crustacea with high dominance of scavenging amphipod *Onisimus caricus*. Bivalves prevailed in the Soft Bottom II Association, located further away from the main glacier outflows. The barren rocky shelf, deprived of vegetation by a sea urchin *Strongylocentrotus droebachiensis* was inhabited by the Rocky Shelf Association dominated by decapods. The last distinguished association (the Kelp Association) occurred on the hard bottom overgrown with macroalgae. The gastropod *Margarites helicinus* and amphipods *Ischyrocerus* spp. made up 60% of the individuals collected there.

Key words: Arctic, Svalbard, Kongsfjord, macrozoobenthos, diversity.

Introduction

The European programme BIOMARE selected a set of European Marine Biodiversity Research Sites as reference spots for large scale climate change impact studies (Warwick *et al.* 2003). Two fjords off West Spitsbergen, Kongsfjord and Hornsund, were chosen in the Arctic section of the European coastal waters. The West Spitsbergen glacial fjords offer a unique possibility of studying the multiply effects of environmental gradients which are related to the climate variability. That includes the effects of sedimentation gradients which depend on the melting of glaciers, the effects of the Atlantic and Arctic water masses, the climate warming and consequently the species migrations. Such studies require well documented knowledge of the present status of the biodiversity of the region of interest.

Kongsfjord has been an area of extensive international studies and detailed information on its physical characters and local ecosystem were reviewed by Svendsen *et al.* (2002) and Hop *et al.* (2002). The Kongsfjord macro- and meiofauna have been already studied by Włodarska-Kowalczuk *et al*. (1998), Kendall *et al*. (2003), Włodarska-Kowalczuk and Pearson (2004) and Kotwicki *et al*. (2004). Their studies, however, were based mainly on the materials taken on the soft bottom, from the depths below 30 m, available for ship's operations. In contrast, knowledge of the shallow subtidal benthos is still scarce due to sampling difficulties. Lippert *et al*. (2003) studied the phytophilous macrofauna at a single location close to the Blomstrand Island. Jørgensen and Gulliksen (2000) investigated the hard bottom fauna at the Kvadehuken at 20–30 m using the suction sampler and underwater photography.

Our study aims to present an extensive view of the diversity of the shallow water macrofauna. Wide range of habitats were examined at depths ranging from 5 to 50 m at several localities along the Konsgfjord coast. Materials collected allowed us to determine the importance of the bottom type and other factors occurring along the vertical (depth) and horizontal (fjord axis) environmental gradients for species distribution and benthic diversity.

Material and methods

Kongsfjord (Fig. 1) is situated on the west side of Spitsbergen, Svalbard. The fjord is 26 km long, 7 to 14 km wide, and its maximum depths surpass 400 m. Its outer part connects directly with the Greenland Sea *via* the trough Kongsfjordrenna and is influenced by the Atlantic waters, while the shallower inner basin is affected by large glacial outflow bringing large quantities of inorganic material. Three tidal glaciers: Blomstrandbreen, Conwaybreen and Kongsbreen comprise 18% of the coastline of the fjord (Ito and Kudoh 1997).

Material was collected at six localities: the Kongsbreen glacial bay (KB), in Dyrevika-Conwaybreen glacial bay (DR), off Gluudneset (GN), close to the Blomstrand Island (BL), at Kvadehuken (KV) and at Kapp Guissez (KG) (Fig. 1). Samples were taken at depths between 5 and 50 m and named after the locality name and sampling depth. Samples were taken with a rectangular dredge (80 × 30 cm) in July 1999. The dredging was conducted along the distance of 30–50 m. Samples were sieved on 1 mm mesh, and preserved in 4% formaldehyde solution. The animals were identified to the lowest possible taxonomic level.

The frequency – F% (the percentage of samples comprising specimens of a given species) and dominance – D% (the proportion of the abundance of the species in question in the total abundance of macrofauna) were calculated for each species.

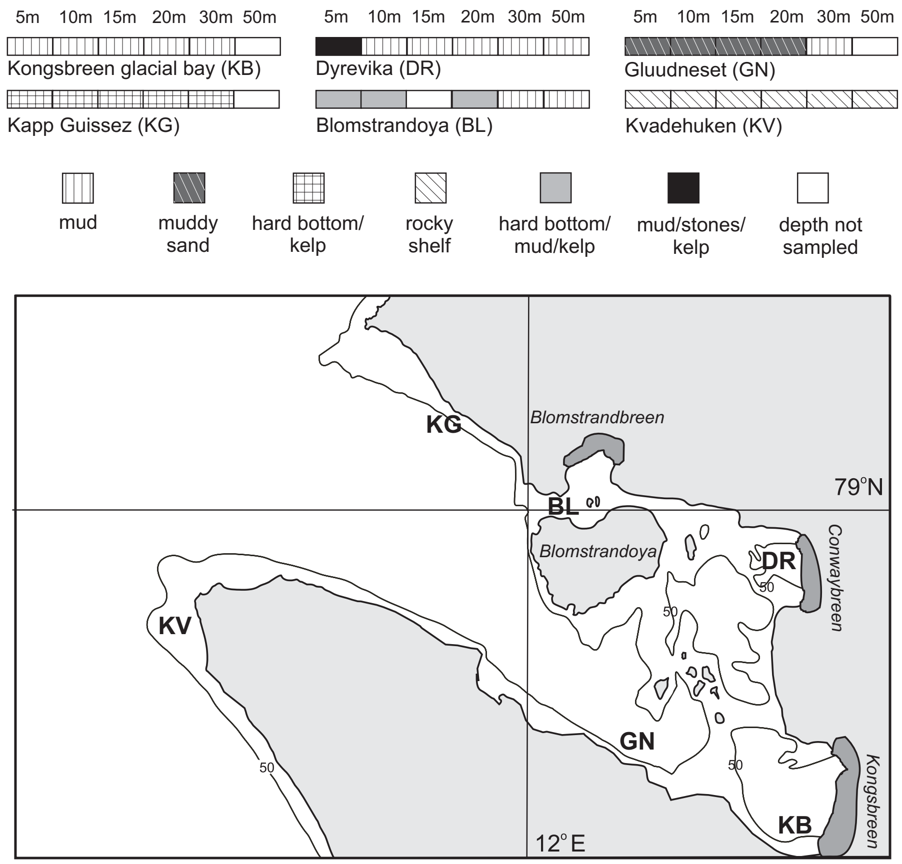

Fig. 1. Kongsfjord, location of sampling sites. The depths and bottom types of sampling sites are also presented. KB – Kongsbreen glacial bay, DR – Dyrevika, GN – Gluudneset, KG – Kapp Guissez, BL – Blomstrandoya, KV – Kvadehuken.

The multivariate analysis was applied to species abundance in samples data using the PRIMER package (Clarke and Warwick 1994). The data were fourth root transformed and Bray-Curtis similarities were calculated. Ordination (non-metric multidimensional scaling – MDS) and classification (using group average linking) of samples were performed. Groups of samples were distinguished basing on the resultant dendrogram and MDS plot. The frequency, dominance and indices of community fidelity of each species in each group of samples were calculated. The indices of fidelity included:

DAS – degree of association concerning samples – number of samples within a group at which particular species occurred as the percentage of the total number of samples at which this species occurred

DAI – degree of association concerning individuals – number of individuals of particular species found within the group of samples as a percentage of a number of individuals of that species found in the whole material (Salzwedel *et al.* 1985).

The following criteria have been used:
- species typical for a group – frequency >50%, dominance >2%
- species characteristic for a group – typical + DAI or DAS > 60%.

Several diversity measures were used to estimate the diversity of fauna in samples: number of species per sample (*S*), Hurlbert index for 50 individuals (*ES(50)*), $\log_e$ Shannon-Wiener index (*H*) and Pielou index of evenness (*J*). The differences in these indices between groups of samples taken at the same locality, and between groups of samples taken at the same depth were tested. The normality and homogeneity of variances in these groups were tested and if needed the log transformation was applied. One-way ANOVA was used to test for differences. When the normality of distribution within groups after transformation was not achieved, the non-parametric Kruskal-Wallis test was applied to the data.

The differences in diversity indices between four groups of samples distinguished using multivariate analyses were tested using one-way ANOVA or Kruskal-Wallis test.

Results

The species list consists of 169 taxa (Table 1), the majority of which belong to: Crustacea (59 taxa), Mollusca (54 taxa) and Annelida (46 taxa). Mollusca made up 57%, Crustacea 35% and Annelida 5% of individuals collected. Eleven taxa occurred with frequency exceeding 30% and *Mysis oculata* noted in 50% samples was the most common species.

Table 1

List of collected taxa. Σ – total number of individuals collected, F% – taxon frequency in all samples, * – taxon occurrence at the depths sampled and in the Soft Bottom I (SB I), Soft Bottom II (SB II), Rocky Bottom (R) and Kelp (K) associations.

Taxa	Σ	F%	Depth [m]						Association			
			5	10	15	20	30	50	SB I	SB II	R	K
NEMERTINI												
Nemertini n. det.	34	25	*	*	*		*	*		*	*	*
ANNELIDA												
Polychaeta												
Aglaophamus malmgreni (Théel, 1879)	2	3		*						*		
Ampharete finmarchica (M. Sars, 1864)	3	9	*	*			*			*		*
Ampharetidae n. det.	2	3			*					*		
Amphitrite cirrata O.F. Müller, 1771	2	6		*		*					*	
Amphitritinae n. det.	8	9	*			*	*			*		*
Brada inhabilis (Rathke, 1843)	4	6	*					*		*		*
Brada villosa (Rathke, 1843)	4	6	*					*		*		*
Bylgides elegans (Théel, 1879)	1	3					*			*		

Table 1 – continued.

Bylgides groenlandica (Malmgren, 1867)	1	3		*						*		
Capitella capitata (O. Fabricius, 1780)	13	13	*	*			*			*		*
Chaetozone group	137	22	*	*	*		*	*		*		*
Chone sp.	1	3				*					*	
Circeis sp.	467	28	*	*	*	*	*	*		*	*	*
Cossura longocirrata Webster *et* Benedict, 1887	20	9		*		*	*			*	*	
Diplocirrus hirsutus (Hansen, 1879)	6	6	*					*		*		*
Eteone sp.	3	9	*				*	*		*		*
Euchone sp.	24	22	*	*	*		*	*		*		*
Euchone sp. / *Chone* sp.	49	25	*	*	*	*	*			*	*	*
Gattyana cirrhosa (Pallas, 1766)	3	9	*	*			*			*	*	
Glycera capitata Ørsted, 1843	1	3			*					*		
Harmothoe imbricata (Linnaeus, 1767)	5	16	*	*	*	*	*				*	*
Heteromastus filiformis (Claparéde, 1864)	3	9	*				*			*		*
Leitoscoloplos mammosus Mackie, 1987	6	16	*	*	*		*			*		*
Levinsenia gracilis (Tauber, 1879)	1	3			*					*		
Lumbrineris sp.	13	16	*		*	*	*			*		*
Lysippe labiata Malmgren, 1866	2	6			*		*			*	*	
Nephtys ciliata (O.F. Müller, 1776)	66	25	*	*	*		*		*	*		
Nereimyra punctata (O.F. Müller, 1776)	2	6	*				*			*		*
Nereis zonata Malmgren, 1867	9	13		*		*	*	*			*	
Pholoe assimilis Ørsted, 1845	22	25	*	*	*	*	*			*	*	*
Phyllodoce sp.	3	9	*				*	*		*		*
Polydora sp.	4	13	*	*	*			*		*	*	*
Polynoidae n. det.	17	6		*		*					*	
Prionospio cirrifera Wiren, 1883	1	3		*						*		
Sabellidae n. det.	2	6	*					*		*		*
Sabellides octocirrata (M. Sars, 1835)	3	9	*				*			*		*
Sabellides sp.	10	6	*					*		*		*
Samytha sexcirrata (M. Sars, 1856)	1	3					*			*		
Scoletoma fragilis (O.F. Müller, 1776)	1	3						*				
Scoloplos armiger (O.F. Müller, 1776)	11	3	*									
Syllidae n. det.	3	3		*						*		
Spio sp.	1	3	*									
Spionidae n. det.	2	6				*	*				*	
Terebellidae n. det.	2	6		*			*				*	
Terebellides stroemi agg. M. Sars, 1835	20	9	*				*	*		*		*
Thelepus cincinnatus (O. Fabricius, 1780)	1	3				*					*	
CEPHALORHYNCHA												
Priapulida												
Halicryptus spinulosus von Siebold, 1849	10	9		*	*		*			*		
Priapulus caudatus Lamarck, 1816	1	3				*						*
SIPUNCULIDA												
Sipunculida n. det.	24	25	*	*		*	*				*	*

Table 1 – continued.

ARTHROPODA												
Pycnogonida												
Pycnogonida n. det.	4	6			*			*			*	*
Crustacea												
Amphipoda n. det. juv.	28	3			*							*
Anonyx nugax (Phipps, 1774)	10	16		*	*		*	*	*	*		*
Anonyx sarsi Steele *et* Brunel, 1968	70	19	*	*				*		*		*
Apherusa sarsi Shoemaker, 1930	3	3	*									
Arrhis phyllonyx (M. Sars, 1858)	19	19		*		*	*		*	*		
Brachydiastylis resima (Krøyer, 1841)	1	3						*		*		
Caprella septentrionalis Krøyer, 1838	167	34	*	*	*	*				*	*	*
Corophium crassicorne Bruzelius, 1859	68	3	*									
Corophium sp.	81	6	*	*						*		
Decapoda larvae n. det.	30	28	*	*	*	*	*	*		*		*
Diastylis goodsiri (Bell, 1855)	1	3				*			*			
Diastylis lucifera (Krøyer, 1841)	4	6	*					*	*	*		
Diastylis rathkii (Krøyer, 1841)	26	19	*	*			*		*	*	*	
Diastylis sp.	2	3						*		*		
Eryhtrops erythropthalma (Goes, 1864)	1	3						*				
Eualus gaimardi (Milne Edwards, 1837)	176	28	*	*	*	*	*	*			*	*
Gammarellus homari (O. Fabricius, 1779)	53	34	*	*	*	*						*
Gammarus setosus Dementieva, 1931	1	3	*									
Halirages fulvocinctus (M. Sars, 1858)	98	19	*	*	*	*	*			*		*
Hyas araneus (Linné, 1766)	8	13	*	*	*	*				*	*	*
Ischyrocerus spp.	705	44	*	*	*	*	*	*		*	*	*
Isopoda n. det.	2	3					*			*		
Janira sp.	1	3					*				*	
Lamprops fuscatus Sars, 1864	160	22	*	*		*	*			*		*
Lebbeus polaris (Sabine, 1821)	168	25		*	*	*	*	*		*	*	*
Melita dentata (Krøyer, 1842)	1	3		*								*
Melita formosa Murdoch, 1866	1	3					*			*		*
Melita palmata (Montagu, 1804)	1	3					*			*		
Metopa sp.	2	3			*							*
Monoculodes borealis Boeck, 1871	320	9	*	*						*		*
Monoculodes longirostris (Goes, 1866)	1	3		*						*		
Monoculodes sp.	2	3				*						*
Munna sp.	3	9	*		*		*			*		*
Munnopsis sp.	2	3						*		*		
Mysis oculata (O. Fabricus, 1780)	414	50	*	*	*	*	*	*	*	*		*
Mysis sp.	1	3			*							*
Onisimus caricus Hansen, 1886	512	13		*	*	*	*		*			
Onisimus edwardsi (Krøyer, 1846)	12	9	*	*		*						*
Onisimus spp. juv.	3	3	*						*			
Orchomenella minuta (Krøyer, 1846)	62	25	*	*		*	*		*		*	*

Table 1 – continued.

Pagurus pubescens (Krøyer, 1838)	11	16		*		*	*				*	*
Pandalus borealis Krøyer, 1844	2	3						*			*	
Parapleustes assimilis (Sars, 1882)	24	9	*		*							*
Parapleustes bicuspis (Krøyer, 1838)	22	13		*	*			*		*		*
Parapleustes monocuspis (Sars, 1893)	23	19	*	*	*	*	*					*
Paroediceros lynceus (M. Sars, 1858)	825	38	*	*	*	*	*	*	*	*		*
Pleustes panoplus (Krøyer, 1838)	90	22	*	*	*	*	*			*		*
Pleustidae n. det.	401	19	*	*	*	*		*		*	*	*
Pleusymtes glabroides (Dunbar, 1954)	22	9		*		*	*				*	
Pontoporeia femorata Krøyer, 1842	1	3	*									
Rhachotropis inflata (Lepechin, 1780)	3	3				*					*	
Sclerocrangon spp.	261	34	*	*	*	*	*				*	*
Spirontocaris spinus (Sowerby, 1805)	17	13			*	*	*	*		*	*	*
Spirontocaris turgida (Krøyer, 1842)	50	19			*	*	*	*		*	*	*
Stilomysis grandis (Goes, 1863)	1	3			*					*		
Syrrhoe crenulata Goes, 1866	2	6				*	*				*	*
Tanaidacea n. det.	2	6		*	*					*		
Unciola leucopis (Krøyer, 1838)	10	6	*		*					*		
Weyprechtia pinguis (Krøyer, 1838)	79	19	*	*	*		*			*		*
MOLLUSCA												
Caudofoveata												
Chaetoderma sp.	1	3			*					*		
Polyplacophora												
Tonicella marmorea (O. Fabricius, 1780)	6	6			*		*				*	*
Tonicella rubra (Linné, 1767)	43	9		*		*					*	
Gastropoda												
Boreocingula castanea (Møller, 1842)	5	6		*				*		*		*
Boreotrophon truncatus (Ström, 1767)	1	3		*	*						*	*
Buccinum sp. juv.	18	22	*	*	*	*	*	*		*	*	
Buccinum scalariforme Møller, 1842	1	3					*			*		
Buccinum terranovae Beck, 1869	1	3			*					*		
Buccinum undatum (Linné, 1758)	18	16	*	*	*		*			*	*	*
Cylichna cf. *alba* (Brown, 1827)	12	13		*	*	*	*			*		
Cylichna cf. *oculata* (Mighels *et* Adams, 1842)	40	19	*	*	*	*				*		*
Elachisina globuloides (Warén, 1972)	11	13			*	*	*	*		*		
Erginus rubellus (O. Fabricius, 1780)	19	19		*		*	*			*	*	*
Euspira pallida (Broderip *et* Sowerby 1829)	2	6					*	*		*		
Frigidoalvania cruenta (Odhner, 1915)	184	19		*	*	*	*	*		*		
Lepeta caeca (Müller, 1776)	1	3						*			*	
Margarites groenlandicus (Gmelin, 1791)	16	16		*	*	*					*	*
Margarites helicinus (Phipps, 1774)	3081	44	*	*	*	*	*	*		*	*	*
Menestho albula (O. Fabricius, 1780)	5	6				*		*		*		
Menestho truncatula Odhner, 1915	217	13		*		*	*	*		*		
Oenopota impressa (Mrøch, 1969)	11	16	*	*	*	*	*			*		

Table 1 – continued.

Oenopota sp.	9	16	*	*	*	*	*			*		
Philine sp.	22	6		*	*					*		
Puncturella noachina (Linné, 1771)	1	3		*							*	
Retusa sp.	345	19		*	*	*	*	*		*		
Solariella varicosa (Mighels *et* Adams, 1842)	4	3					*				*	*
Trophon clathratus (Linné, 1767)	1	3					*			*		
Bivalvia												
Arctinula groenlandica (G.B. Sowerby II, 1842)	64	22		*	*	*	*	*		*		
Astarte borealis (Schumacher, 1817)	27	9		*		*	*			*		
Astarte montagui (Dillwyn, 1817)	61	16		*		*	*	*		*		
Axinopsida orbiculata (G.O. Sars, 1878)	1067	28	*	*	*	*	*	*		*		
Boreacola maltzani Verkrüzen, 1876	112	6	*		*					*		
Ciliatocardium ciliatum (O. Fabricius, 1780)	42	19		*	*		*	*		*		
Diplodonta torelli Jeffreys, 1847	1	3				*				*		
Ennucula tenuis (Montagu, 1808)	1245	22		*	*	*	*	*		*		
Hiatella arctica (Linné, 1767)	47	31		*	*	*	*	*		*	*	*
Liocyma fluctuosa (Gould, 1841)	591	16	*	*	*	*	*			*		
Lyonsia arenosa (Møller, 1842)	61	13		*	*	*	*			*		
Macoma calcarea (Gmelin, 1791)	295	25		*	*	*	*	*		*		
Macoma moesta Deshayes, 1855	2	6		*		*				*		
Musculus corrugatus (Stimpson, 1851)	39	13		*	*	*	*			*		
Musculus discors (Linné, 1767)	3	6			*					*	*	
Mya truncata Linné, 1758	196	47	*	*	*	*	*	*	*	*		*
Nuculana minuta (Müller, 1776)	2	3					*			*		
Nuculana pernula Müller, 1779	459	25		*	*	*	*	*		*		
Pandora glacialis Leach, 1819	9	13		*	*		*	*		*		
Serripes groenlandicus (Bruguiere, 1798)	84	31	*	*	*	*	*	*	*	*		
Thracia myopsis Møller, 1842	12	9		*		*	*			*		
Thyasira dunbari Lubinski, 1976	202	19		*	*		*	*		*		
Thyasira gouldi (Philippi, 1845)	117	13			*		*	*		*		
Yoldia hyperborea Torell, 1859	197	13		*		*	*	*		*		
Yoldiella frigida (Torell, 1859)	20	3						*		*		
Yoldiella lenticula (Møller, 1842)	421	28	*	*	*	*	*		*	*		
Yoldiella solidula Warén, 1989	240	31		*	*	*	*	*		*	*	
ECHINODERMATA												
Ophiocten sericeum (Forbes, 1852)	6	9		*			*	*		*	*	
Ophiopholis aculeata (Linné, 1767)	4	9		*			*	*		*	*	
Ophiura robusta (Ayres, 1851)	1	3				*				*		
Strongylocentrotus droebachiensis (Müller, 1776)	77	9		*			*	*		*	*	
CHORDATA												
Ascidiacea												
Ascidiacea n. det.	6	6		*	*					*		

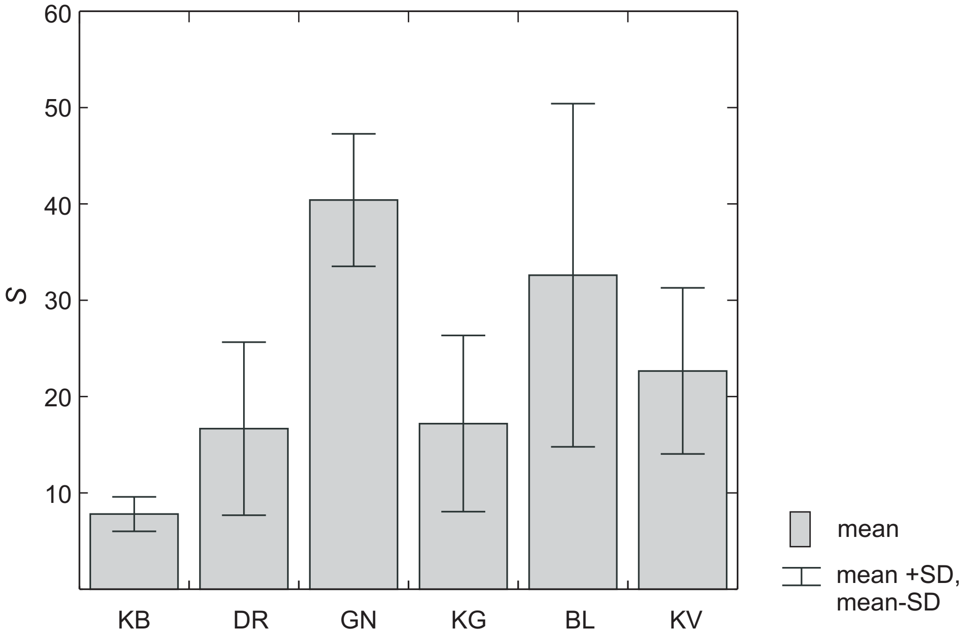

Fig. 2. Number of species per sample (*S*) in samples taken at different sites:

The number of individuals found in a sample was 500 on average. The number of animals in a sample varied from 4 (DR20) to 3045 (KV5). Number of species per sample ranged from 6 (KB10, DR10) to 56 (BL50) with the mean value 22.6 ±14SD. The lowest numbers of species were found in samples collected close to Kongsbreen (Fig. 2). The values of Shannon-Wiener index varied from 0.57 (KV50) to 2.84 (GN20), Hurlbert index varied from 3.8 (KB30) to 20.1 (GN10). The highest value of Pielou index was noted for sample DR20 (0.97) and the lowest for sample KV5 (0.23).

There was a significant difference in number of species per sample between groups of samples taken at different localities (Kruskal-Wallis test, $H = 15.5$; $p < 0.05$) (Fig. 2). No other differences ($p < 0.05$) of diversity measures were found either between groups of samples taken at different localities or between groups of samples taken at different depths.

Based on the results of cluster and MDS plot, four groups of samples were distinguished:

– Soft Bottom I Association – samples collected in the Kongsbreen glacial bay (KB5, KB10, KB15, KB 20, KB30),
– Soft Bottom II Association – samples collected at the other soft bottom localities (DR10, DR15, DR30, GN10, GN15, GN20, GN30, BL30, BL50)
– Rocky Bottom Association – samples collected on the rocky shelf off Kvadehuken (KV10, KV20, KV30, KV50)

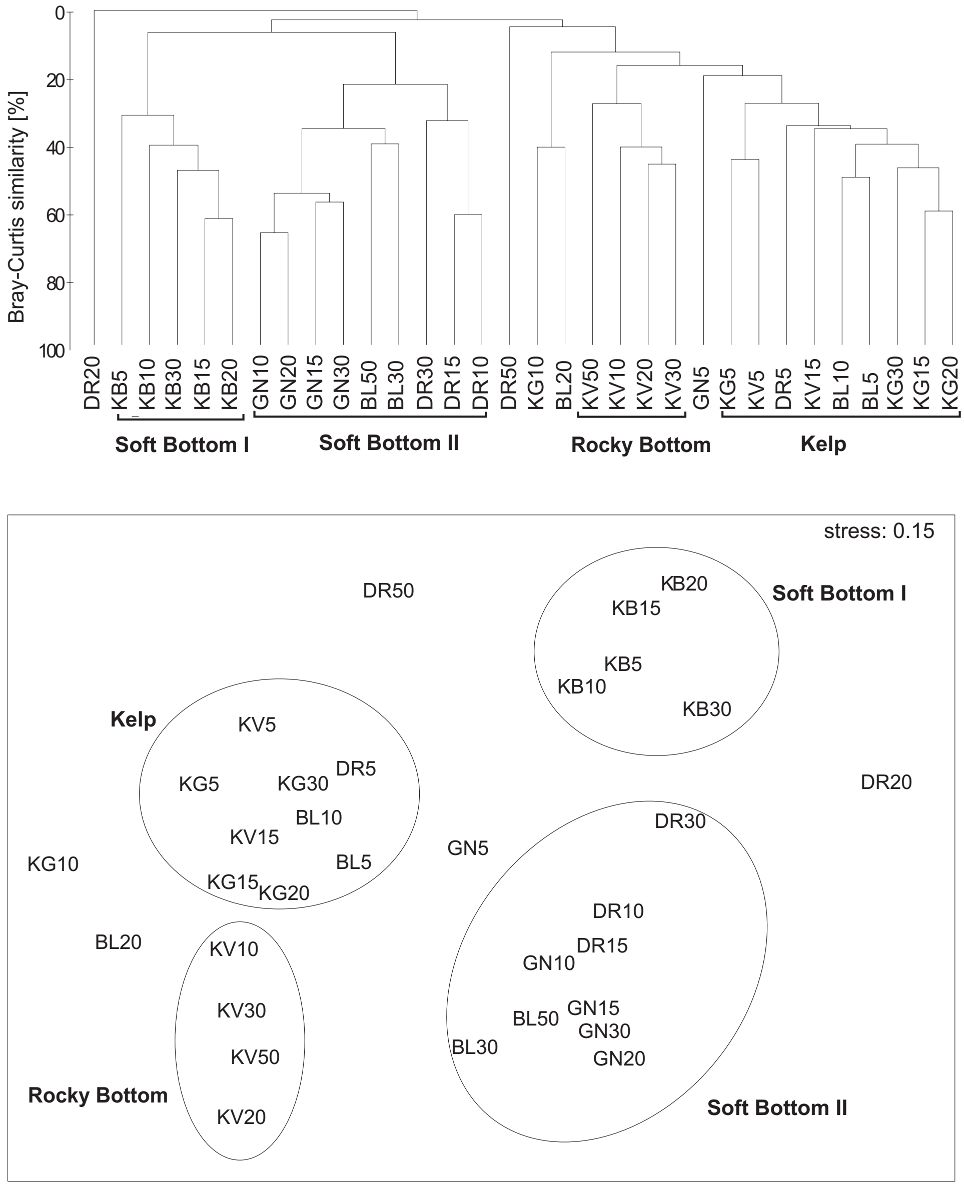

Fig. 3. The dendrogram and MDS plot of Bray-Curtis similarities of fourth-root-transformed data of taxa abundance in samples.

– Kelp Association – samples collected on the hard bottom overgrown with macroalgae (DR5, KG5, KG15, KG20, KG30, BL5, BL10, KV5, KV15) (Fig. 3).

The faunal composition was related to the bottom type and the distance to the tidal glaciers. The relation of faunal composition to the bottom type is well visual-

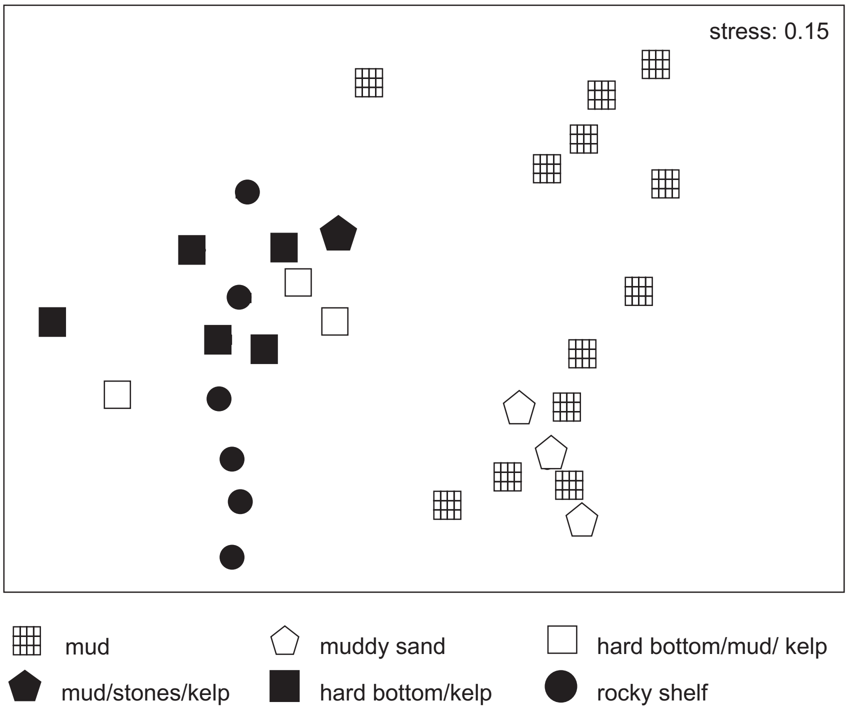

Fig. 4. The MDS plot of fourth-root-transformed data of taxa abundance in samples. The superimposed symbols indicate the bottom type at the sampling station.

ized on the MDS plot with the symbols of different bottom types superimposed (Fig. 4).

Significant differences in number of species per sample (log transformed, F = 30.12) and Hurlbert index (F = 8.24) between associations were found with use of ANOVA (p <0.05) and in Shannon-Wiener index with use of Kruskal-Wallis test (H = 11.19, p <0.05). No significant differences in Pielou index were noted (Fig. 5).

The Soft Bottom I Association included only 14 taxa and was strongly dominated by two amphipods: *Onisimus caricus* and *Paroediceros lynceus* which together constituted 85.7% of all animals. Both species were typical, and *O. caricus* was also the only characteristic one for the association. Among other taxa, frequently occurring but not abundant species: a polychaete *Nephtys ciliata* and a mollusc *Mya truncata* were classified as typical (Table 2).

Altogether 123 taxa were found in the Soft Bottom II Association and as many as 52 of them were classified as characteristic for this association. Mollusca, yielding 92% of the fauna and represented by 10 typical and 30 characteristic species, were the most prominent element of the association (Fig. 6). Frequently noted bivalves: *Ennucula tenuis* and *Axinopsida orbiculata* were the most abundant, making 20% and 16% of animals collected, respectively. Other species: *Mya truncata*,

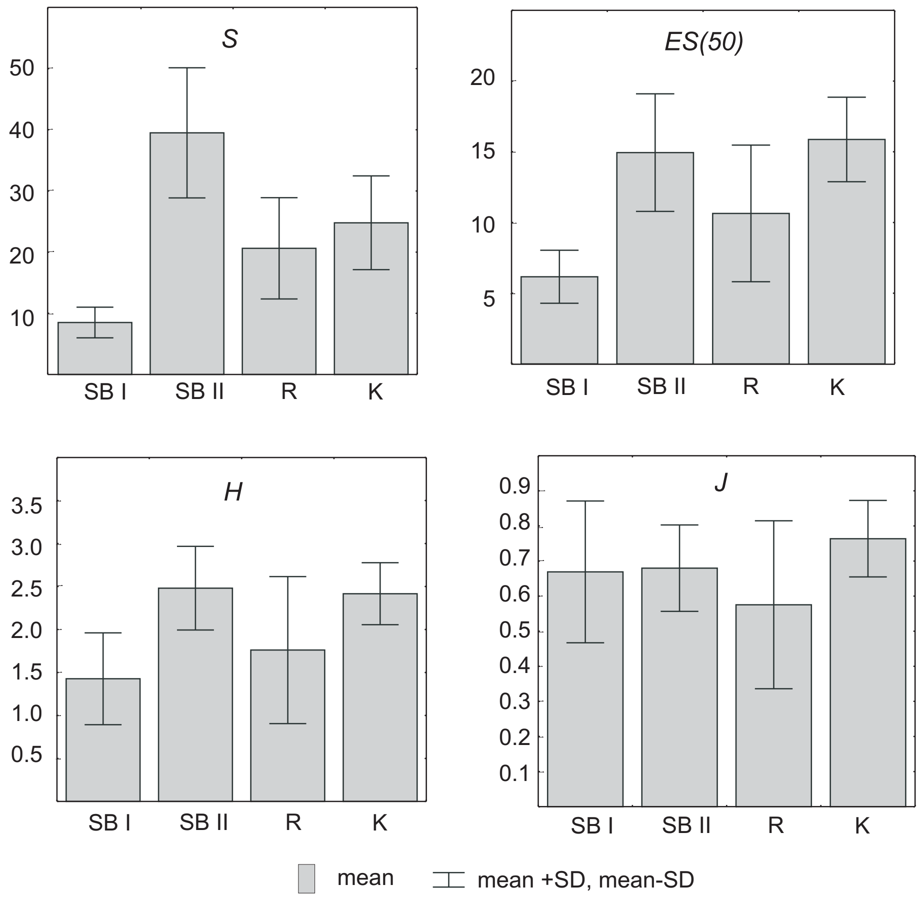

Fig. 5. Diversity measures in associations: *S* – number of species per sample, *ES(50)* – Hurlbert index for 50 individuals, *H* – Shannon-Wiener index, *J* – Pielou index, SB I – Soft Bottom I, SB II – Soft Bottom II, R – Rocky Bottom, K – Kelp.

Table 2

Basic quantitative characteristics of dominants in the Soft Bottom I Association: Σ – total number of individuals, F% – frequency, D% – domination, DAI – degree of association concerning individuals, DAS – degree of association concerning samples. Only taxa of dominance exceeding 2% are presented. Typical species – in bold, characteristic species – underlined.

Taxa	Σ	F%	D%	DAI	DAS
Onisimus caricus	512	80	66.1	100	80
Paroediceros lynceus	152	80	19.6	18	31
Serripes groenlandicus	32	40	4.1	38	18
Nephtys ciliata	26	60	3.4	39	33
Mya truncata	16	60	2.1	8	19
Arrhis phyllonyx	12	60	1.6	63	43
Diastylis rathkii	10	40	1.3	38	29

Table 3

Basic quantitative characteristics of dominants in the Soft Bottom II Association (explanations as in Table 2).

Taxa	Σ	F%	D%	DAI	DAS
Ennucula tenuis	1245	78	19.9	100	88
Axinopsida orbiculata	1032	89	16.5	97	80
Nuculana pernula	459	89	7.3	100	89
Yoldiella lenticula	419	78	6.7	100	70
***Retusa* sp.**	345	67	5.5	100	86
Macoma calcarea	295	89	4.7	100	89
Yoldiella solidula	239	100	3.8	100	82
Menestho truncatula	217	44	3.5	100	80
Thyasira dunbari	202	67	3.2	100	86
Yoldia hyperborea	197	44	3.2	100	80
Frigidoalvania cruenta	184	67	2.9	100	86
Mya truncata	165	100	2.6	84	56
Liocyma fluctuosa	162	44	2.6	27	67

Yoldiella solidula, Macoma calcarea and *Nuculana pernula* occurred with high frequency, but were not very numerous (Table 3). The most abundant Polychaeta (*Chaetozone* group) and Amphipoda (*Paroediceros lynceus*) reached the dominance of 1.5% and 0.2%, respectively.

Fifty two taxa were found in the samples of the Rocky Bottom Association. Crustacea and Mollusca were the most abundant taxa making up 59% and 18%, respectively, of all individuals (Fig. 6). The dominating decapods, *Lebbeus po-*

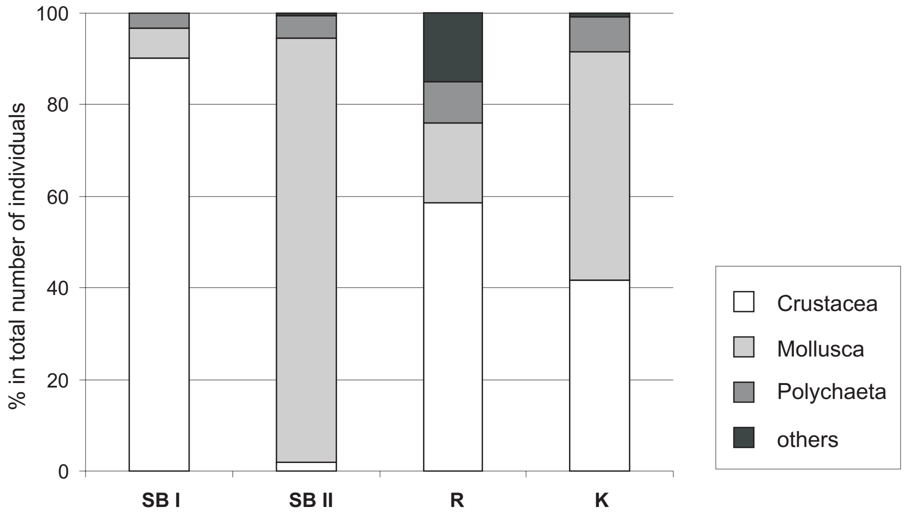

Fig. 6. The percentages of main taxonomical groups in total number of individuals in associations: SB I – Soft Bottom I, SB II – Soft Bottom II, R – Rocky Bottom, K – Kelp.

Table 4
Basic quantitative characteristics of dominants in the Rocky Shelf Association (explanations as in Table 2).

Taxa	Σ	F%	D%	DAI	DAS
Lebbeus polaris	93	100	16.9	55	44
***Sclerocrangon* spp.**	75	75	13.6	29	27
Strongylocentrotus droebachiensis	72	25	13.1	94	25
Tonicella rubra	42	50	7.6	98	50
***Ischyrocerus* spp.**	31	75	5.6	4	20
Spirontocaris turgida	31	75	5.6	62	43
Eualus gaimardi	25	50	4.5	14	20
Pleusymtes glabroides	22	75	4.0	100	75
Hiatella arctica	20	100	3.6	43	36
Polynoidae n. det.	17	50	3.1	100	67
Mysis oculata	15	50	2.7	4	12
Erginus rubellus	12	75	2.2	63	43

Table 5
Basic quantitative characteristics of dominants in the Kelp Association (explanations as in Table 2).

Taxa	Σ	F%	D%	DAI	DAS
Margarites helicinus	3031	78	49.0	98	47
***Ischyrocerus* spp.**	659	100	10.7	93	60
Pleustidae n.det.	390	33	6.3	97	43
Circeis sp.	379	44	6.1	81	40
Mysis oculata	373	89	6.0	90	47
***Sclerocrangon* spp.**	185	78	3.0	71	64
Caprella septentrionalis	161	89	2.6	96	67
Eualus gaimardi	151	78	2.4	86	70

laris and *Sclerocrangon* spp. had relatively low values of DAI and DAS. The echinoid *Strongylocentrotus droebachiensis* occurred in high abundance (13%) but only in one sample. The set of the characteristic taxa included: a chiton *Tonicella rubra*, a gastropod *Erginus rubellus*, a decapod *Spirontocaris turgida*, an amphipod *Pleustymes glabroides* and polychaete Polynoidae n. det. (Table 4).

The Kelp Association occurred on hard bottom overgrown with macroalgae and was represented by 74 taxa. A gastropod *Margarites helicinus* was the most numerous species accounting for 49% of the total individuals collected. This species, together with five crustacean taxa, was classified as characteristic for the association. Crustacea made up 43% of the fauna. Among them *Ischyrocerus* spp. had the highest dominance (10.7%) and 100% frequency (Table 5).

Discussion

The species list consist of 169 taxa, all of which are known from the published checklists of the coastal fauna of Svalbard (Gulliksen and Holthe 1992).

Samples were taken with a dredge, which may have affected the species composition. This gear does not dig deeply enough to sample the majority of the burrowing animals inhabiting the upper 10 cm of sediment (Holme 1964). For that reason some species of Polychaeta could have been underrepresented in this analysis. On the other hand dredges are much more effective in sampling highly mobile animals and epibenthic organisms (*e.g.* crustaceans) when compared *e.g.* to box-corers or grabs.

The sampling was carried on along two main gradients in fjordic benthic habitats: the horizontal, sedimentation gradient along the fjord axis and vertical, depth gradient. In addition there were significant differences in the type of sampled substrate – ranging from mud to vegetated or barren rocky bottom. That allows to relate the distribution of the fauna to the main environmental gradients and distinguish the major factors responsible for species distributions and community structure. Thorson (1957) stated that the main factor influencing the benthic associations distribution is the type of substrate. The relation between the sediment characteristics and the macrobenthic organisms distribution was observed by several authors (*e.g.* Rhoads 1974; Gray 1974). Snelgrove and Butman (1994) confirmed the correlation of infaunal invertebrate distributions to sediment characteristics, however these authors stated that other environmental factors, correlated to sediment grain size, are actually responsible for observed patterns. These include: organic matter content, microbial abundance, near-bed flow conditions, particles flow and larval supply. Pearson (1980) considered several factors to influence the fjords benthic fauna distribution: sediment type (related to currents and the horizontal circulation of waters), vertical circulation, the level of stagnation and eutrophication, fluctuations of salinity and temperature and biological interactions resulting from the limited exchange with the open waters. These factors are interdependent and the organisms may be influenced by the combination of several factors rather than a single one.

The composition of shallow water fauna in Kongsfjord seems to be primarily dependent on the bottom type. The multivariate analyses of species/abundance data separated groups of samples taken on similar substrates. The horizontal gradient of glacier-derived mineral material sedimentation was of secondary importance. However substrate type is actually dependent on near-bed particles flow conditions. Elverhøi *et al.* (1983) estimated that the Kongsbreen transports 2.6×10^5 m^3 of mineral material to the sea each season. This material is sedimented mostly in the inner basin. The high load of fine sediment material is deposited on the bottom. The shallow sublittoral in outer parts of the fjord is subjected to both: the stronger currents and very low sedimentation of inorganic material. That results in the presence of different types of hard bottom from gravel to vegetated and barren rocky shelves. In the analyses of the species distribution we did not found any effects of the vertical i.e. depth gradient. The differences in hydrodynamic regimes, fluctuations in temperature and salinity which occur within the 5–50 m depth range, did not seem to interfere with the horizontal patterns – substrate type/sedimentation level gradients.

Two soft-bottom associations were found in the inner and central part of the fjord. The Soft Bottom I Association located on the muddy bottom close to the most active tidal glacier – Kongsbreen – was very poor in species. The most numerous (D 66%) and the most specific (DAS 80% and DAI 100%) for this group of samples was a scavenging amphipod *Onisimus caricus*. The Kongsfjord scavenging fauna was studied with the use of baited traps by Legeżyńska (2001). She noted *Onisimus caricus* exclusively in the Kongsbreen glacial bay, where it made up to 96% of individuals attracted to the traps deployed between 5 and 30 m. According to her study, summer diet of *Onisimus caricus* consists mainly of pelagic Calanoida and Mysidacea. It has been assumed that concentration of the species in glacial bays is probably connected with mass mortality of marine zooplankton caused by reduced salinity close to glacier cliffs during summer (Zajączkowski and Legeżyńska 2001). Neither *Onisimus caricus*, nor other necrophagous amphipods were found in the Van Veen grab samples collected in the same area and therefore was omitted in the Włodarska-Kowalczuk and Pearson's (2004) analyses of dominants of soft bottom macrofauna in Kongsfjord. Our study confirms that it is an abundant component of glacial bay fauna, however, as it is a highly vagile epibenthic animal, its presence can be recorded only using qualitative sampling methods – dredges or necrophagic traps. On the other hand the samples collected on muddy bottom – close to the Kongsbreen front and at 20–50 m in Dyrevika did not contain infaunal Bivalvia and Polychaeta described by Włodarska-Kowalczuk and Pearson (2004) as typical for glacial bay soft bottom. The absence of infauna in samples must resulted from the bad performance of the dredge on the fine mud.

The Soft Bottom II Association was much richer in species and contained several infaunal organisms typical for glacial proximal areas. The most species-rich group were Mollusca (34% of total species number). The dominant and typical species in this association were *Ennucula tenuis* (D 19.9%), and *Axinopsida orbiculata* (D 16.5%). In Włodarska-Kowalczuk and Pearson's (2004) study these species were found to be characteristic of the association which was transitional between highly impacted by inorganic sedimentation glacial bay community and association inhabiting central basin and experiencing low levels of sedimentation and stable sediments. Similarly as in the Włodarska-Kowalczuk and Pearson's (2004) transitional association, *Ennucula tenuis* and *Axinopsida orbiculata* were accompanied by less numerous *Yoldiella solidula*, *Y. lenticula*, and *Thyasira dunbari*. These nuculid and thyasirid bivalves are the most numerous in glacier-proximal unstable sediments exposed to high rates of inorganic sedimentation

(Włodarska-Kowalczuk *et al.* 1998). The other important component of Soft Bottom II Association included species which are known to occur on mixed muddy-sandy-gravelly bottom (*Mya arenaria*, *Macoma calcarea*) or sandy bottom (*Liocyma fluctuosa*) (Ockelmann 1958). They require coarser sediments and less turbid waters than "typical glacial bay species".

The Rocky Bottom Association was located on the rocky shelf off Kvadehuken. The fauna was dominated by decapods: *Lebbeus polaris*, *Sclerocrangon* spp., *Spirontocaris turgida* and *Eualus gaimardi* commonly distributed in offshore Spitsbergen waters (Węsławski 1987) and typical rocky bottom mollusks: *Tonicella rubra* and *Hiatella arctica* (Jørgensen and Gulliksen 2000). The key species of the association was a sea urchin *Strongylocentrotus droebachiensis*. It feeds on brown algae and its mass occurrence deprives the bottom of the vegetation (Scheibling and Hatcher 2001).

The Kelp Association was composed in 43% of crustaceans and in 50% of molluscs. The high percentage of molluscs resulted from the mass occurrence of a small gastropod *Margarites helicinus*. It is often found in Spitsbergen shallow waters, down to the limit of brown algae occurrence, as it dwells on cauloids of *Laminaria saccharina* and *L. digitata* (Różycki and Gruszczyński 1986). Crustaceans were more diverse. The set of the dominating crustaceans, including amphipods *Ischyrocerus* spp. and *Caprella septentrionalis* and mysid *Mysis oculata*, is typical of the shallow vegetated waters of the Svalbard archipelago (Węsławski 1990; Węsławski *et al.* 1997). The serpulid *Circeis* sp. was abundant on kelps' phylloids. It is a sedentary, suspension-feeding polychaete (Hartmann-Schröder 1996), very unlikely to occur in turbid waters of inner basin of the fjord.

We noted a decrease in species richness along the fjord axis towards the glacier front. A decrease in diversity towards the glacier fronts or glaciofluvial outflows in Arctic fjords were observed both for hard and soft-bottom fauna (Farrow *et al.* 1983; Feder and Jewett 1986; Schmid and Piepenburg 1993; Kendall 1994; Holte *et al.* 1996; Włodarska *et al.* 1996). That is related to the disturbance caused by the sedimentation of mineral material transported to the sea by the glacial melt waters. The high inorganic sedimentation may be deleterious to benthic organisms as they are buried, the filtering organs are clogged, the respiration and nutrition, as well as settlement of larvae hindered (Moore 1977).

The comparisons of diversity between associations distinguished in present study are difficult as they occur at different bottom types. The lowest number of species in the muddy bottom may be related to the proximity of glacier, but it may also be an artifact resulting from low efficiency of dredge in sampling this kind of substrate.

Acknowledgments. — The study was supported by the grant 3PO4F04722 from the Polish State Committee for Scientific Research. We would like to thank Mr Jakub Dopierała for help and great company during expedition to Konsgfjord. We wish to thank Ms Sławomira Gromisz for help with Polychaeta identifications.

References

CLARKE K.R. and WARWICK R.M. 1994. *Change in marine communities: an approach to statistical analyses and interpretation*. Plymouth Marine Laboratory, Plymouth: 144 pp.

ELVERHØI A., LØNNE Ø. and SELAND R. 1983. Glaciomarine sedimentation in a modern fjord environment – Spitsbergen. *Polar Research* 1: 127–149.

FARROW G.E., SYVITSKI J.P.M. and TUNNICLIFFE V. 1983. Suspended particulate loading on the macrobenthos in a highly turbid fjord: Knight Inlet, British Columbia. *Canadian Journal of Fisheries and Aquatic Sciences* 40: 273–288.

FEDER H.M. and JEWETT S.C. 1986. The subtidal benthos. *In*: D.W. Hood and S.T. Zimmerman (eds) *The Gulf of Alaska. Physical environment and biological resources*, U.S. Ocean Assessments Division, Alaska office: 347–396.

GRAY J.S. 1974. Animal-sediment relationships. *Oceanography and Marine Biology: an Annual Review* 12: 223–261.

GULLIKSEN B. and HOLTHE T. 1992. Liste over marine invertebrates og fisk innenfor Svalbards teritorialfarvahn. Norsk Polarinstitutt Rapportserie, Oslo: 77 pp.

HARTMANN-SCHRÖDER G. 1996. *Annelida, Borstenwürmer, Polychaeta*. Gustav Fischer Verlag, Jena: 585 –653.

HOLME N.A. 1964. Methods of sampling the benthos. *Advances in Marine Biology* 2: 171–260.

HOLTE B., DAHLE S., GULLIKSEN B. and NAES K. 1996. Some macrofaunal effects of local pollution and glacier-induced sedimentation with indicative chemical analyses in the sediments of two Arctic fjords. *Polar Biology* 16: 549–557.

HOP H., PEARSON T., HEGSETH E.N., KOVACS K.M., WIENCKE C., KWAŚNIEWSKI S., EIANE K., MEHLUM F., GULLIKSEN B., WŁODARSKA-KOWALCZUK M., LYDERSEN C., WĘSŁAWSKI J.M., COCHRANE S., GABRIELSEN G.W., LEAKEY R., LØNNE O.J., ZAJACZKOWSKI M., FALK-PETERSEN S., KENDALL M., WÄNGBERG S-A., BISCHOF K., VORONKOV A., KOVALTCHOUK N.A., WIKTOR J., POLTERMANN M., DI PRISCO G., PAPUCCI C. and GERLAND S. 2002. The marine ecosystem of Kongsfjorden, Svalbard. *Polar Research* 21: 167–208.

ITO H. and KUDOCH S. 1997. Characteristics of water in Kongsfjorden, Svalbard. *Proceedings of the National Institute of Polar Research Symposium on Polar Meteorology and Glaciology* 11: 211–232.

JØRGENSEN L.L. and GULLIKSEN B. 2000. Rocky Bottom Fauna in Arctic Kongsfjord (Svalbard) studied by means of suction sampling and photography. *Polar Biology* 24: 133–121.

KENDALL M.A. 1994. Polychaete assemblages along a depth gradient in a Spitsbergen Fjord. *In*: J.C. Dauvin, L. Laubier and D.J. Reish (eds) *Acte de la 4eme Confrence internationale des Polychetes*. *Mémoires du Muséum National d'Histoire Naturelle* 162, Zoologie: 463–470.

KENDALL M.A., WIDDICOMBE S. and WĘSŁAWSKI J.M. 2003. A multi-scale of the biodiversity of benthic infauna of the high-lautitude Kongsfjord, Svalbard. *Polar Biology* 26: 283–388.

KOTWICKI L., SZYMELFENIG M., DE TROCH M. and ZAJĄCZKOWSKI M. 2004. Distribution of meiofauna in Kongsfjorden, Spitsbergen. *Polar Biology* 27: 661–669.

LEFAUCONNIER B., HAGEN J.O. and RUDANT J.P. 1994. Flow speed and calving rate of Kongsbreen glacier, Svalbard, using SPOT images. *Polar Research* 10: 56–65.

LEGEŻYŃSKA J. 2001. Distribution patterns and feeding strategies of lyasianassoid amphipods in shallow waters of an Arctic fjord. *Polish Polar Research* 22: 173–186.

LIPPERT H., IKEN K., RACHOR E. and WIENCKE C. 2003. Macrofauna associated with macroalgae in the Kongsfjord (Spitsbergen). *Polar Biology* 26: 591–600.

MOORE P.G. 1977. Inorganic particulate suspensions in the sea and their effects on marine animals. *Oceanography and Marine Biology: an Annual Review* 15: 225–363.

OCKELMANN W.K. 1958. The zoology of East Greenland, Marine Lamellibranchiata. *Meddelelser om Grønland* 122 (4): 1–256.

PEARSON T.H. 1980. Macrobenthos in fjords. *In*: H.J. Freeland, D.M. Farmer and C.E. Levings (eds) *Fjords oceanography*. Plenum Press, New York: 569–602.

RHOADS D.C. 1974. Organism-sediment relations on the muddy sea floor. *Oceanography and Marine Biology: an Annual Review* 12: 263–300.

RÓŻYCKI O. and GRUSZCZYŃSKI M. 1986. Macrofauna associated with laminarians in the coastal waters of West Spitsbergen. *Polish Polar Research* 7: 337–351.

SALZWEDEL H., RACHOR E. and GERDES D. 1985. Benthic macrofauna communities in the German Bight. *Veroffentlichungen des Instituts für Meeresforschungen Bremerhaven* 20: 199–267.

SCHEIBLING E.R. and HATCHER B.G. 2001. The ecology of *Strongylocentrotus droebachiensis*. *In*: J.M. Lawrence (ed) *Edible sea urchins: biology and ecology*. Elsevier Science: 271–306.

SCHMID M.K. and PIEPENBURG D. 1993. The benthos zonation of the Disko Fjord, West Greenland. *Meddelelser om Grønland, Bioscience* 37: 3–21.

SNELGROVE P.V.R. and BUTMAN C.A. 1994. Animal-sediment relationships revisited: cause versus effect. *Oceanography and Marine Biology: an Annual Review* 32: 111–117.

SVENDSEN H., BESZCZYŃSKA-MØLLER A., HAGEN J.O., LEFAUCONNIER B., TVERBERG V., GERLAND S., ØRBÆK J.B., BISCHOF K., PAPUCCI C., ZAJĄCZKOWSKI M., AZZOLINI R., BRULAND O., WIENCKE C., WINTHER J-G. and DALLMANN W. 2002. The physical environment of Kongsfjorden-Krossfjorden, an Arctic fjord system in Svalbard. *Polar Research* 21: 133–166.

THORSON G. 1957. Bottom communities (sublittoral or shallow shelf). *In*: J.W. Hedgepth (ed.) *Treatise on marine ecology and paleoecology*. Memoirs of the Geological Society of America 1: 461–534.

WARWICK R.M., EMBLOW C., FERAL J.P., HUMMEL H., VAN AVESAATH P. and HEIP C. 2003. *European Marine Biodiversity Research Sites. Report of the European Concerted Action: BIOMARE. Implementation and Networking of large scale, long term Marine Biodiversity Research in Europe*. Netherlands Institute for Ecological research, Centre for Estuarine and Marine Research Ecology, Yerseke: 135 pp.

WĘSŁAWSKI J.M. 1987. Distribution of Decapoda (Crustacea) in South Spitsbergen costal waters with remarks on their ecology and breeding biology. *Polish Polar Research* 8: 121–134.

WĘSŁAWSKI J.M. 1990. Distribution and ecology of South Spitsbergen costal marine Amphipoda (Crustacea). *Polish Archives of Hydrobiology* 37: 503–519.

WĘSŁAWSKI J.M., ZAJĄCZKOWSKI M., WIKTOR J. and SZYMELFENIG M. 1997. Intertidal zone of Svalbard. 3. Littoral of a subarctic, oceanic island: Bjornoya. *Polar Biology* 18: 45–52.

WŁODARSKA M., GROMISZ S. and WĘSŁAWSKI J.M. 1996. A comparison of the macrofauna community structure and diversity in two Arctic glacial bays – a “cold” one off Franz Josef Land and “warm” one off Spitsbergen. *Oceanologia* 38: 251–283.

WŁODARSKA-KOWALCZUK M., WĘSŁAWSKI J.M. and KOTWICKI L. 1998. Spitsbergen glacial bays macrobenthos – a comparative study. *Polar Biology* 20: 66–73.

WŁODARSKA-KOWALCZUK M. and PEARSON T. 2004. Soft-bottom macrobenthic faunal associations and factors affecting species distributions in an Arctic glacial fjord (Kongsfjord, Spitsbergen). *Polar Biology* 25: 155–167.

ZAJĄCZKOWSKI M.and LEGEŻYŃSKA J. 2001. Estimation of zooplankton mortality caused by an Arctic glacier outflow. *Oceanologia* 43: 341–351.

Received 24 June 2004
Accepted 25 April 2005