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Benthic macrofauna in selected fjords along the North-west coast of Svalbard

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Influence of the physical environment on the distribution of benthic macrofauna along the coasts of Svalbard

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Abstract

Qualitative benthic samples collected in September 2003 in Svalbard have been examined. They have been collected in different water masses: Atlantic water, Arctic water and in cold water of the deep fjord basins. The major sampling gears were the Agassiz trawl, RP and Sneli sledges, van Veen grab (with addition of SCUBA diving and trawling). The used gears show selectivity in the capture of species. Especially, the van Veen grab is more efficient for the capture of polychaetes. No clear-cut community patterns appear between geographical areas and water masses. This may be due to the general heterogeneity of the environment or sampling design. The main trend observed is that many high Arctic species are restricted to temperatures below zero (albeit not always below -1°C). Nineteen species new for the Svalbard fauna have been recorded. The occurrence of the large shrimp *Pasiphaea tarda* may result from an increase of the water temperature on the west coast and it could be a genuine new arrival in Svalbard. These nineteen additional species could be new arrivals since most of them are not high Arctic forms, but some of them are difficult to identify, and may have been overlooked or misidentified in earlier investigations.

Keywords: Svalbard, Arctic, benthos, water masses, gear selectivity, new records

INTRODUCTION

Studies on the benthic macrofauna of Svalbard are reviewed by Gulliksen *et al.* (1999). There is currently little non-Russian literature concerning the benthic macrofauna of the northern Spitsbergen coastal areas, but recent studies indicate that the biodiversity in the region is high (Cochrane *et al.* 1998).

The fjords in the area have their own faunal assemblages depending on a wide range of abiotic factors. Factors influencing the fjord are the presence/absence of a sill, the threshold depth if sill present, the depth of the fjord basin(s) and the influence of Atlantic versus Arctic water masses (Cochrane *et al.* 1998, Jørgensen & Gulliksen 2001, Hop *et al.* 2001). A gradient of increasing sedimentation towards the fjord head (sediment source) is assumed within glacier-influenced fjords (Gulliksen & Holte 1998). The diversity of the fjord systems

leads to a high variation in the bottom substrate and as a consequence a strong heterogeneity of the species composition in the fjordic biocenoses (Begon *et al.* 1996).

The main aim of this study was to get familiarised with the species in the area and to compare the benthic macrofauna assemblages between different localities in Svalbard. Furthermore, the efficiency and selectivity of the different sampling gears were tested. In addition the new species for Svalbard were listed and the species database updated.

MATERIAL AND METHODS

Study area

In September 2003 sampling was carried out from the R/V *Jan Mayen*. The sampling localities were situated in a number of fjords and in Hinlopen Strait (fig.1 & table 1). Except Kongsfjorden, all the fjords sampled are sill fjords and influenced by glaciers to various degrees. For the complete station list, see table 1. in Appendix 1.

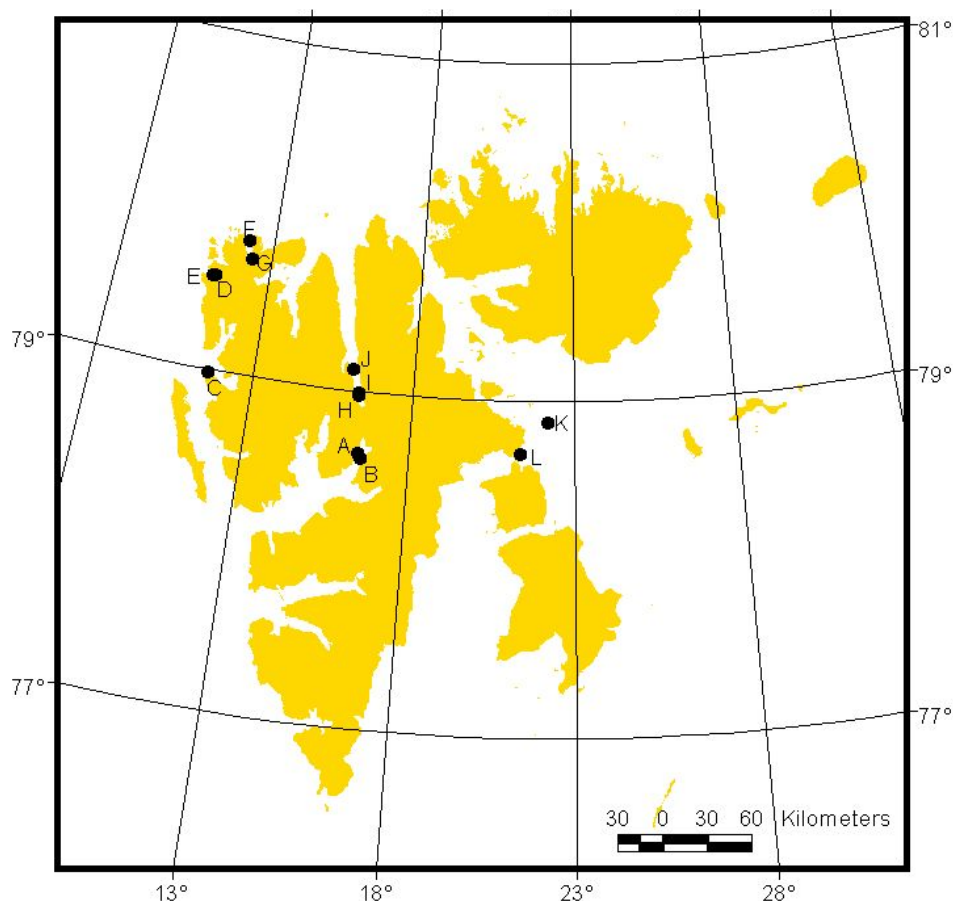


Fig. 1 Study area. Billefjorden: localities **A** (st. 112-115) and **B** (st. 119-121). Kongsfjorden: locality **C** (st. 126). Magdalenefjorden: localities **D** (st. 128-130) and **E** (st. 132-134). Raudfjorden: locality **F** (st. 141-143) and **G** (st. 145). Wijdefjorden: localities **H** (st. 168-169), **I** (st. 171-172) and **J** (st. 176-178). Hinlopen: locality **K** (st. 196-198). Hinlopen S: locality **L** (st. 199, 200, 204).

A number of stations were pooled together within localities (designated by letters). A spot is referred to as sampling locality when several samples were taken at the same sampling spot, often using various gears. Diving and trawls that were not included within the defined localities (table 1), are however included in the analyses of species composition in relation to fjords, water masses and gear and the findings are included in the species list (table 1. in Appendix 2).

Study areas	Max depth	Sill	Max sill depth	Sampling localities
<i>Billefjorden</i>	183 m	x	45 m	A: sill B: cold water basin
<i>Kongsfjorden</i>		÷	÷	C: shallow water
<i>Magdalenefjorden</i>	135 m	x	44 m	D: inner basin E: sill
<i>Raudfjorden</i>	233 m	x	130 m	F, G: cold water basin outside the sill
<i>Wijdefjorden</i>	196 m	x	50 m	H, J: off the sill, deep I: shallow water
<i>Hinlopen Strait</i>	300-400m	÷	÷	K, L: at different depths in the southern part

Table 1 Description of study area, see figure 1 for explanations of sampling locations.

Sampling

In order to gather as many benthic animal species as possible, sampling was carried out on various bottom types and at different depths, using a wide range of gears. The main sampling gears were the Rothlisberg & Pearsey (RP) epibenthic sledge (mesh size 0.5 mm) (Miskow-Norrlund *et al.* 1999), the Sneli sledge (mesh size 1 mm) (Sneli 1998) and the Agassiz trawl. Triangular dredge was used when the substrate was suspected to be too rough for other types of gear. Each gear was towed for 10 or 20 minutes at the speed of 1 knot. At most study sites, the sampling was supplemented by SCUBA diving to obtain samples from shallower depths where sampling was otherwise impossible with surface operated gear (e.g. vertical walls). SCUBA divers picked up (subjectively) organisms by hand from depths down to 30 m. In addition, the by-catch of benthic fauna from bottom trawls (Arndt & Seuthe, in prep.) were identified and added to the data. Finally, the results from a parallel quantitative soft bottom study (Fjukmoen *et al.* in prep.) were used to supplement the species list. The major physical factors (temperature, salinity and density) were measured with a CTD (SD-202) device at most sampling sites (table 1. in Appendix 1.).

On deck, larger organisms were handpicked from the Sneli and RP sledge samples before washing the remaining material through a sieve. For the Sneli sledge, a 1 mm sieve was used. RP sledge samples were decanted and then washed stepwise over 4, 2 and 1 mm sieves. Due to time limitations, the 1 mm fractions from the RP sledge were preserved in 70% ethanol and not used for this study. The Agassiz trawl and the triangular dredge contained mainly large organisms, yet if the sample was from a soft bottom, it was washed over a 1 mm sieve. For treatment of the van Veen grab samples, see Fjukmoen *et al.* (in prep.). After sorting the samples, the organisms were identified alive or fixed in 70% ethanol before identification. This was carried out to the lowest taxonomic level possible. At least one specimen of each identified taxon was preserved and deposited in a reference collection at UNIS. Some duplicates were sent to the Tromsø Museum or to specialists for further identification.

Classifications

In order to analyse the species composition in relation to gears and fjords/strait, the species were pooled in the following higher taxa (Vertebrata, Tunicata, Echinodermata, Mollusca, Crustacea, Cnidaria). Other phyla were left out, since there were very few taxa identified to lower level among these groups (e.g. Bryzoa and Hydrozoa). Furthermore, the stations have been grouped according to the water masses in which they occur: Atlantic, cold and Arctic waters. The water masses are categorised according to the definitions of Sakshaug *et al.* (1994). Cold winter-formed water is found in the cold-water basins of fjords with sills. It is locally produced and is defined by having temperatures below $-1,7^{\circ}\text{C}$ and salinities $>35\text{‰}$. Arctic water from open seas have salinities between 34.8 and 35‰ and temperatures of $<0^{\circ}\text{C}$ whereas Atlantic waters have temperatures of $>3^{\circ}\text{C}$ and salinities $>35\text{‰}$. On this cruise, the salinities did not exceed 35‰, which indicates that mixing has begun (Brattegard, pers. com.).

To compare the species composition in the different water masses, the organisms were classified in 3 biogeographical classes: **X** (widely distributed species), species recorded beyond southern Norway; **N** (northern species), species with southern limit along the coasts of Norway; **A** (Arctic species), species found only north of northern Norway. Some taxa that are not identified to the species level could not be classified and are indicated with the symbol “-“. This classification is a modification of the system used by Brattegard & Holthe (1997) and the biogeographical class of most organisms has been extracted from that document. For organisms not listed in that book, the biogeographical classification has been given by Brattegard (pers. comm.) or for amphipods has been extracted from Stephensen (1935-1942).

The species composition at the stations is presented and the differences are discussed in relation to the effects of warm versus cold-water masses. The data and species list given in the present paper will supply the already existing species database for the area created by Rune Palerud¹. The species observed are checked against the list of Gulliksen *et al.* (1999) in order to see which ones are new to the area. As far as possible, the reasons of these new occurrences are discussed. For some species, biogeographical and taxonomical remarks are given.

Statistics

The relationships of faunal assemblages between samples were tested with ordination by multi dimensional scaling (MDS) and cluster analyses (Clarke 1993) in the software program PRIMER.

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RESULTS

A complete list of the species identified during the cruise, is presented in table 1. in Appendix 2. The species composition at the different localities and stations, as well as the selective efficiency of the different sampling gears is graphically presented. A list of the species new for Svalbard fauna is given.

Comparison of the stations and localities

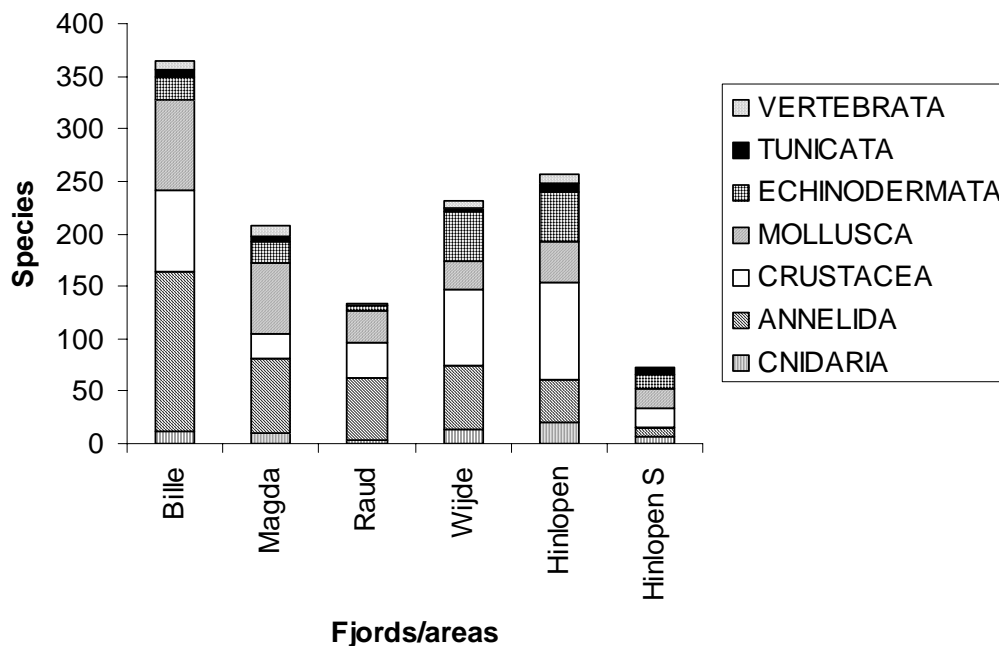


Fig. 2 Number of taxa within the major taxonomic groups found at each locality.

Billefjorden shows the highest species richness, followed by Hinlopen and Wijdefjorden, whereas the Hinlopen S indicates the lowest species diversity (fig. 2). With the exception of Hinlopen S, the annelids are the most diverse group at all localities, followed by crustaceans and molluscs. The echinoderms are most diverse at Wijdefjorden and Hinlopen but poorly represented in Raudfjorden. The crustaceans are poorly represented in Magdalenefjorden.

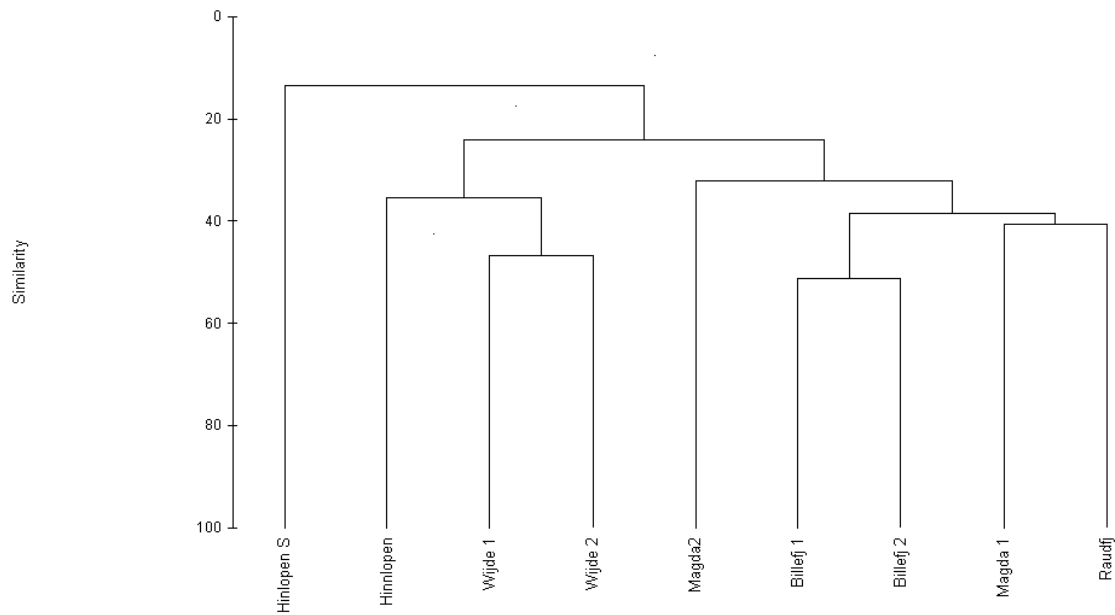


Fig. 3 Similarity of investigated localities. The numbers after the area names refer to the different localities within the fjord – generally represented by a shallow and a deeper station. Magdalenefjorden1, Raudfjorden, Wijdefjorden 1 & 2 are all cold water basins.

The cluster diagram illustrates that the species composition at localities within the same fjord are more similar to each other than are the communities between fjords. It is also apparent that Hinlopen S is influenced by Arctic water and differs from all the other investigated localities. In addition, the northern part of Spitsbergen, Wijdefjorden and Hinlopen, differ in faunal assemblages compared to the western fjords represented by Magdalenefjorden, Billefjorden and Raudfjorden.

Distribution of the different biogeographical groups in three water masses.

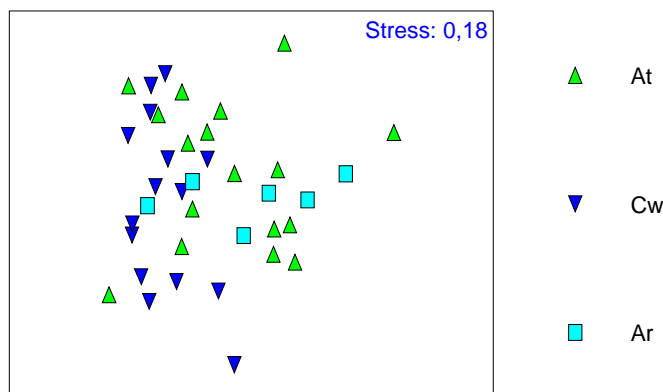


Fig. 4 Assemblage structure in Atlantic-, Cold -, and Arctic water masses. At = Atlantic Water, Cw = Cold Water, Ar = Arctic Water

The species composition in the different water masses shown in the MDS plot does not reveal any differences between deep cold water within the fjord basins, the water of Atlantic origin or the Arctic water (fig. 4).

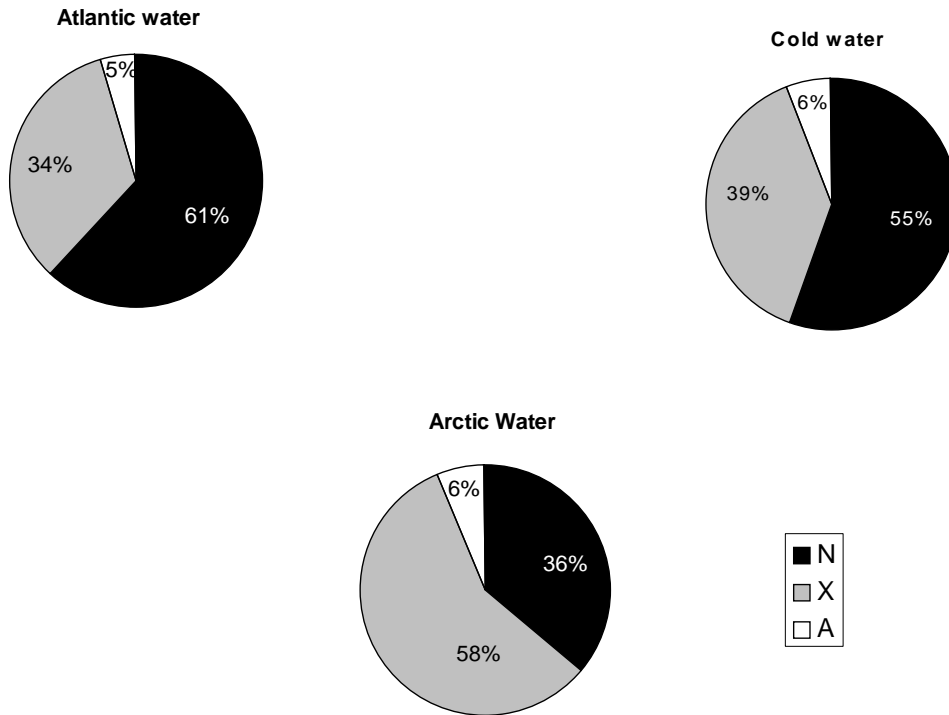


Fig. 5 Proportions of species categorized as northern (N), widely (X) and Arctic (A) distribution in the three different water masses

The Arctic species, when considered together, do not show any constancy in regard to water masses (as here defined) (fig. 5). They are equally distributed in the three different water masses. Surprisingly, the Atlantic water mass include almost the same proportion of Arctic species as the Arctic water and the cold deep basin water in the fjords. In the Arctic water, the widely distributed species are more common than in the Atlantic and cold water masses.

Selectivity of the different sampling gears

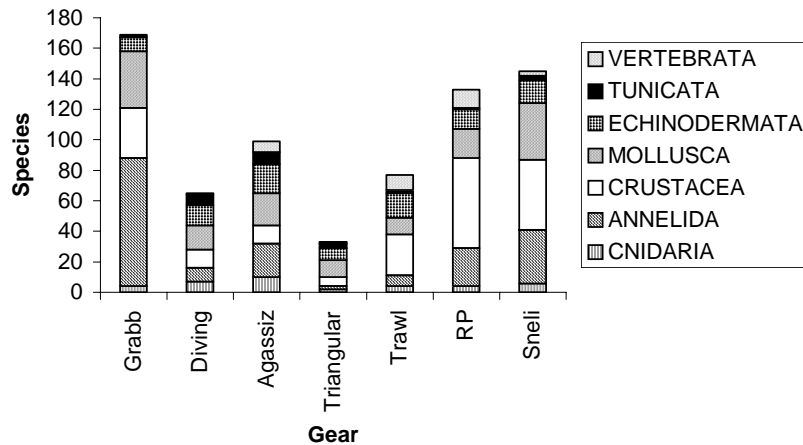


Fig. 6 Number of species grouped by phyla in the samples collected by the different sampling gears.

The efficiency of the different sampling gears is presented on the figure 6. If considering the total number of species sampled with each gear, the van Veen grab proved to be most effective (169 taxa). Also the Sneli- and the RP-sledge were rather efficient. They caught 145 and 133 taxa, respectively. On the other hand, only 33 taxa were collected with the triangular dredge. A relatively high number of crustaceans were collected with the RP sledge, but apart from the larger proportion of annelids found in the grab samples, the overall proportions of the different animal groups were generally similar regardless of the gear type.

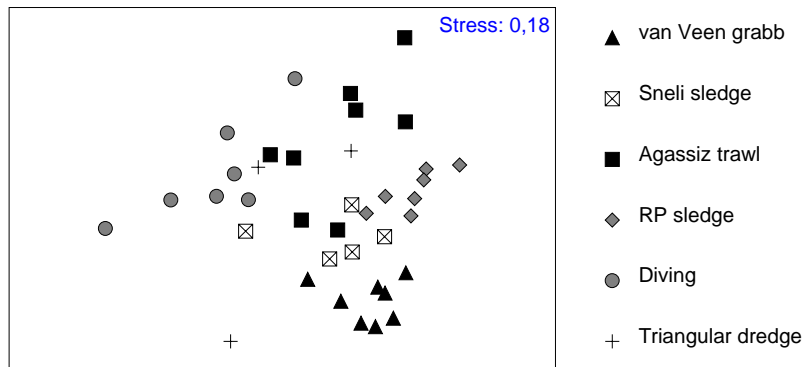


Fig. 7 MDS plot showing the differences in species composition when sampled with different gear

The species composition in the samples by the different sampling gears is shown in the MDS plot of the figure 7. The MDS plot indicates that the samples taken with van Veen grab and RP sledge are markedly clustered. Sneli sledge, Agassiz trawl and diving show slight trend of similarity between the sampling sites. Hence, the different sampling gears seem to sample selectively the same fauna regardless of sampling location.

New species for Svalbard

When sorting the samples, it appeared that a number of species (table 2) observed were not listed in the data compilation of Gulliksen *et al.* (1999) for Svalbard fauna.

POLYCHAETA	<i>Aricidea catherinae</i> Laubier, 1967	S	
	<i>Aricidea quadrilobata</i> Webster & Benedict, 1887	X	
	<i>Leitoscoloplos</i> sp.	S=>X	
	<i>Aglaophamus rubella</i> (Michaelsen, 1897)	S=>X	
	<i>Ehlersia</i> sp.	X	
	<i>Gyptis golikovi</i> (Averincev, 1989)	X	
	<i>Pholoe assimilis</i> Ørsted, 1842	S=>X	
	<i>Sabella penicillus</i> Linnaeus, 1767	X	
	<i>Aphelochaeta</i> sp.	S=>X	
	<i>Caulleriella killariensis</i> (Southern, 1914)	S=>X	
	<i>Lysippides</i> sp.	S=>X	
PYCNOGONIDA	<i>Pseudopallene spinipes</i> (O. Fabricius, 1780) (fig 1. in App.3.)	X	
AMPHIPODA	<i>Melphidippa macrura</i> G.O. Sars, 1894 (fig. 2. in App. 3.)		X
	<i>Proaeginina norvegica</i> (Stephensen, 1931)	X	
	<i>Tryphosites</i> sp.	X	
CUMACEA	<i>Leptostylis ampullacea</i> (Lilljeborg, 1855)	X	
DECAPODA	<i>Pasiphaea tarda</i> Krøyer, 1845	S	
CEPHALOPODA	<i>Gonatus fabricii</i> (Lichtenstein, 1818)	?	
PISCES	<i>Gaidropsarus argentatus</i> (Reinhardt, 1838)	N	

Table 2. The new species records with former known distribution (X= widely, S= southern and N= northern).

Some of the new records obtained during this study are the northernmost observations for those taxa (Brattegard, pers. comm.). In the case of the large and conspicuous shrimp *Pasiphaea tarda*, it could be a genuine northwards range extension, but for other species it is not clear at all if they have previously been overlooked or if they have really migrated northwards. Concerning the polychaetes, some species have probably been found before in Svalbard but have been misidentified (Pleijel, pers. comm.). The pelagic squid *Gonatus fabricii* is not included in the species list of Gulliksen *et al.* (1999) but is indicated as occurring in Svalbard, without precise locality, by Klekowski & Węśławski (1991) and has regularly been recorded in previous UNIS cruises (Berge, pers. comm.).

DISCUSSION

Methods

For comparability of samples in faunal diversity, studies from different geographical sites, similar sampling and sample-processing techniques should be used (Wlodarska-Kowalczyk *et al.* 1998). During the present study some of the localities were sampled with a variety of gears. However, all gears were not used at all localities since the gear was often chosen according to the bottom type. Furthermore, other factors may have influenced the results, e.g. sampling design, sample treatment, the number of samples and fauna identification. The higher number of species sampled with van Veen grab compared to other gears might be a result of different sorting methods. The samples from the van Veen grab, as used in Fjukmoen *et al.* (in prep.), were fully sieved and thoroughly sorted under a magnifier. In contrast, all the samples from the Sneli sledge, Agassiz trawl and RP sledge were subsampled and sorted without a magnifier. However, the van Veen grab samples can only be used in soft bottom sampling, and the presence of highly mobile epifaunal species (mostly crustaceans) is probably underestimated in the results obtained by grab-sampling (Wlodarska-Kowalczyk *et al.* 1998).

The observed gear selectivity is probably due to the design of each gear to sample a specific bottom type. However the van Veen grab and RP sledge samples were only taken at sites, where the bottom type was expected to be optimal for use of the gear. Hence, the similar bottom types might explain part of the clustering. Yet, the bottom types, which seem to be the same, may still include very different abiotic and biotic conditions (Cochrane *et al.* 1998). Therefore, the choice of gear presumably affected the observed faunal composition. Samples with several gears in combination could give a more accurate picture of fauna on each locality, since they are expected together to sample a higher variety of fauna. However, the topography and texture of the bottom often prevents the use of some gears.

Comparison of stations and localities

Previous studies have shown that Arctic benthos is characterised by species of either Pacific or Atlantic affinity (Ekman 1953, Dunton 1992). The habitat conditions in Arctic and sub-Arctic are fairly recent in a geological perspective, which may explain why there are so few true Arctic species and genera (Ekman 1953). Stromberg (1989) presented data showing that although the shallow water fauna (< 200m) of northern Spitsbergen is dominated by Arctic boreal and pan-Arctic taxa, the influence of warmer Atlantic water along the western coast brings with it Atlantic boreal species. The present results show similar trend with only approximately 6 % Arctic species. However, the number of samples was considerably higher in the Atlantic waters.

The observed increase of the widely distributed species in the Arctic water masses and that the fjords on the western part of Spitsbergen differ from those on the northern and eastern side of the island are in agreement of studies of Wlodarska-Kowalczyk *et al.* (1998). However, the results do not indicate a clear difference in the benthic faunal composition between the western fjords of Spitsbergen, which were observed by Wlodarska-Kowalczyk *et al.* (1998). The slight differences between the fjords might only reflect the different sampling gears and the processing of sample. Furthermore the number of sampling stations at each locality probably accounts for some of the differences observed. Billefjorden, which is the most thoroughly sampled area during the cruise, exhibits the highest species diversity. Hence it is

doubtful that Hinlopen S is really an area with low diversity, since it was the area with the lowest number of samples. Moreover the sampling in Hinlopen S was conducted in difficult weather conditions, which can affect the quality of samples. Nevertheless, there is difference in species composition between the Arctic and Atlantic water masses and the Atlantic waters are richest in species. At most, it was observed that the high Arctic species (which are not numerous) are usually restricted to negative temperatures, albeit with some remarkable exceptions. A fairly high number of new species may reflect the use of a wide range of sampling gear and the heterogeneity of sampling sites. These new comers might be as well a consequence of an increase in temperature.

The absence of clear-cut patterns in the Arctic studies is not uncommon. Stromberg (1989) states that: «although we sampled at 78 degrees north it may be argued that we have not sampled a community of animals that are fully adapted to an extreme Arctic environment and which might not be expected to show a diversity profile typical for this latitude. On the other hand, if the community is not totally Arctic it should nevertheless be expected to show many characteristics of the region. It would be unwise to dismiss our data as being atypical.»

Biogeographical remarks

***Pagurus pubescens* Krøyer, 1838**

According to our data, the distribution of *Pagurus pubescens* shows pronounced differences between the areas. This boreal species is present in many samples from the west coast (Billefjorden, Magdalenefjorden and Raudfjorden), which is influenced by relatively warm Atlantic waters. On the other hand, *P. pubescens* is wholly absent from the stations in Wijdefjorden (north coast) and only a single specimen has been caught in Hinlopen (east coast) at st. 186 (temperature between -0.64 and 0.71 °C). Our data conflict with those of Gulliksen *et al.* (1999), who recorded *P. pubescens* in almost all areas of Svalbard. No conclusions can be drawn from our limited data, but it is not impossible that *P. pubescens* is scarcer in the colder northern and eastern part of Svalbard, where it probably meets conditions at the limit of its physiological tolerance.

It should be pointed out that a very high percentage of specimens observed during this cruise were infected by rhizocephalan parasites. It would be interesting to see if the infection rate is influenced by abiotic factors (e.g. fjordic versus oceanic conditions).

***Pasiphaea tarda* Krøyer, 1845**

It is surprising that this large and very characteristic shrimp has never before been collected off Svalbard since several specimens have been collected at st. 124 (Kongsfjordrenna, trawl, depth 1160 m). It is a species of southern origin, which has been recorded as far north as northeastern Iceland (Grieg 1927 as *P. principalis*), Jan Mayen (Sund 1913) and Norway (Brattegard & Holthe 1997). Presumably this pelagic species has been brought from the south by the Atlantic water current, which runs along the west coast of Spitsbergen. It has probably not been caught in the cold water close to the bottom, but in the warm shallower water when the trawl was lifted up. In a previous cruise, which sampled the same area in August 2003, another *Pasiphaea* species, *P. multidentata* Esmark, 1866 has been recorded. It is also a new record for Svalbard and a large conspicuous species of southern origin.

Deepwater Arctic species

Along with widely distributed abyssal species like *Boreonymphon* sp. and *Eurythenes gryllus* Lichtenstein, 1822, the material collected at the st. 124 (off Kongsfjorden at 1160 m depth) includes a number of deepwater Arctic species not found elsewhere, such as *Cleippides quadricuspis* Heller, 1875, *Eusirus* sp. (probably *Eusirus cuspidatus* Krøyer, 1845), *Halirages* sp., *Boreomysis nobilis* G.O. Sars, 1885, *Bythocaris leucopis* G.O. Sars, 1885, *Lycenchelys muraena* (Collet, 1878), *Lycodes pallidus* Collet, 1879, *Lycodes squamiventer* Jensen, 1904 and *Lycodon flagellicauda* (Jensen, 1901). The bottom temperature at this station has not been recorded, but according to Brattegard (comm. pers.) it must have been about -1°C. The faunal content of this station confirms that on the west side of Svalbard the deepwater fauna (living at negative temperatures) has a more Arctic character than the shallow water fauna of the same area, which lives in the warm Atlantic water.

Other Arctic species

In this study, the amphipod *Acanthostepheia malmgreni* (Goës, 1866) has only been recorded in Raudfjorden (st. 143), Wijdefjorden (st. 162, 168 and 178) and Hinlopen (st.196), always at temperatures below zero. This is in agreement with the data of Stephensen (1938), which indicates that it is a high Arctic species.

A single specimen of the isopod *Synidotea bicuspidata* (Owen, 1839) has been collected in Hinlopen at st. 204 at - 0.37°C, i.e. in the Arctic water mass. This is in agreement with the high Arctic character of that species (Brattegard, comm. pers.).

Sclerocrangon ferox G.O. Sars, 1877 is a large and very conspicuous species. A large number of specimens has been collected, but at 2 stations only: st. 184 (Hinlopen, trawl, 250 m) and st. 192 (Hinlopen, trawl, 264 m). These two stations had a temperature of + 1.7°C, which is rather high for that species. Indeed Heegaard (1941), who studied East Greenland populations, stated that it is restricted to very cold waters: normally between - 1.7°C and + 1.0°C, and rarely up to + 2°C. *Sclerocrangon ferox* was not found together with *Sclerocrangon boreas* but with the other crangonid *Sabinea septemcarinata*, which is known to be able to thrive in very cold environments at the proximity of glaciers (Christiansen & Christiansen 1962).

The gastropod *Buccinum glaciale* Linnaeus, 1761 has been recorded at st. 130 (deep basin of the Magdalene fjord), at -1.8 °C. This is in agreement with the high Arctic character of that species (Klekowski & Węśławski 1991)

The tunicate *Eugyra pedunculata* Traustedt, 1886 has only been recorded at st. 196, 199, 200 and 204, i.e. on the eastern side of Spitsbergen (Hinlopen and Heleys Sundet), at temperatures between - 0.37°C and - 1.3°C. This is in agreement with Millar (1966) and Klekowski & Węśławski (1992), who indicate that it is an Arctic species, which is almost exclusively restricted to the eastern and northeastern part of Svalbard.

Melaenis loveni Malmgren, 1865 has been found in a number of locations (Billefjorden, st. 119 and 121, Wijdefjorden, st. 162 and 178 and Hinlopen, st. 196). In all these stations, it has been found at negative temperatures, which is in agreement with its Arctic character (Brattegard, pers. comm.).

Taxonomical remarks

***Anonyx* sp.**

During this cruise, in addition to numbered stations, some amphipods were collected in deepwater traps by Dr. Lionel Camus for physiological experiments. In the traps placed on the west coast (78°53.248'N 07°43.305'E, 1130 m depth) on 18.ix.2003 and retrieved on 27.ix.2003, some large *Anonyx* have been collected. They proved to be currently impossible to identify. They were as large as *A. nugax* (the common *Anonyx* species for the area) but they were blood red in colour (whilst *A. nugax* is whitish) and the shape of their third epimeral plate was different. Some slides of live animals have been taken. More research is necessary to establish their systematic position but they are potentially interesting.

***Eualus gaimardii gibba* Krøyer, 1841**

During the cruise, a large number of *Eualus gaimardii* (H. Milne Edwards, 1837) has been collected. All males exhibited a triangular protrusion on the posterodorsal part of the third pleonite (more developed in some specimens than in others). Therefore all of them should be referred to the controversial forma *gibba* (Krøyer, 1841). Since the dorsal projection exists in males only (Krøyer 1842) and since no other difference with the nominal form has been detected so far, the females cannot be identified beyond the specific level. However, presumably all those females belong to the forma *gibba*. The forma *gibba* reaches its southern limit in northern Norway, where it is restricted to rather deep water (Greve 1963). In Svalbard, during this cruise, it has been recorded at various depths, often very shallow and even on the lower side of pack ice. In the eastern Atlantic, the typical form is found from northern Norway (Greve 1963) to Denmark (Hansen, 1908). The occurrence of the forma *gaimardii* in Svalbard requires confirmation, and the systematic position of the various “forms” or “subspecies” of *E. gaimardii* deserve a careful study. Indeed, as suggested by Squires (1990) at least some of them could possibly be valid species, refuting the opinion of Heegard (1941) who considered all of them as mere infrasubspecific taxa.

***Ischyrocerus* sp.**

The *Ischyrocerus* sp. collected at st. 204 (Hinlopen, 50 m depth, -0.37°C) are problematic. These large specimens exhibit affinities with *I. megacheir* (Boeck, 1871) and *I. spitzbergensis* Schellenberg, 1924 but also significant differences in the shape of the first coxal plate and the third epimeral plate. They require further study.

CONCLUSION

During the present study no clear faunal assemblage patterns have been detected in Svalbard benthic communities, neither between different fjords nor between water masses. It was found, that sampling methods do influence the observed faunal composition. More conclusive results could possibly be obtained in using, as far as possible, the same gear at each station. A more thorough processing of the samples could also provide more detailed results and hence allow fine analyses.

Most of the species newly recorded are of southern origin. In some cases this could be interpreted as genuine range extensions, as in the case of the large and conspicuous shrimp *Pasiphaea tarda*, but in other cases this could also result from the detection of previously overlooked species. Finally, it appears that the few high Arctic species avoid positive temperatures.

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APPENDIX 1

Station list

St. No.	Latitude	Longitude	Place name	Date	Time	Gear	Depth m	Temp. °C	Salinity ‰
112	78° 37,764' N	16° 25,359' E	Billefjord	17-Sep-03	8:08	Grab	38	3,73	33,28
113	78° 37,828' N	16° 25,064' E	Billefjord	17-Sep-03	8:43	Sneli-sledge	37	3,73	33,28
114	78° 37,611' N	16° 24,852' E	Billefjord	17-Sep-03	9:22	Agassiz	37	3,73	33,28
115	78° 37,929' N	16° 25,552' E	Billefjord	17-Sep-03	10:55	RP-sledge	37	3,73	33,28
117	78° 35,365' N	16° 35,099' E	Billefjord	17-Sep-03	11:30	Diving	0-30	3,88-3,74	32,21-33,28
118	78° 36,012' N	16° 31,357' E	Billefjord	17-Sep-03	12:01	Grab	161	±1,70	34,74
119	78° 35,743' N	16° 30,627' E	Billefjord	17-Sep-03	12:46	RP-sledge	160	±1,70	34,74
120	78° 35,704' N	16° 30,464' E	Billefjord	17-Sep-03	13:37	Agassiz	160	±1,70	34,74
121	78° 35,921' N	16° 30,971' E	Billefjord	17-Sep-03	14:26	Sneli-sledge	160	±1,70	34,74
124	78° 57,132' N	7° 44,86' E	Kongsfjordrenna	18-Sep-03	5:43	Trawl	1160	*	*
126	78° 58,692' N	11° 29,815' E	Kongsfjorden	18-Sep-03	11:29	Triang. dredge		3,5-2,3	34,77-34,80
128	79° 33,815' N	11° 5,53' E	Magdalenefjorden	18-Sep-03	16:18	Grab	134	±1,81	35,00
129	79° 33,523' N	11° 7,819' E	Magdalenefjorden	18-Sep-03	17:04	RP-sledge	135	±1,81	35,00
130	79° 33,62' N	11° 7,161' E	Magdalenefjorden	18-Sep-03	17:50	Agassiz	135	±1,81	35,00
132	79° 33,45' N	11° 3,948' E	Magdalenefjorden	18-Sep-03	18:30	Grab	55	5,63	34,42
133	79° 33,468' N	11° 3,622' E	Magdalenefjorden	18-Sep-03	18:58	Agassiz	54	5,67	34,42
134	79° 33,54' N	11° 3,383' E	Magdalenefjorden	18-Sep-03	19:43	Sneli-sledge	54	5,67	34,42
139	79° 47,513' N	11° 59,838' E	Raudfjorden	19-Sep-03	12:41	Grab	35	4,73	34,25
141	79° 48,068' N	12° 1,519' E	Raudfjorden	19-Sep-03	13:43	Grab	210	±1,25	34,57
142	79° 47,995' N	12° 1,881' E	Raudfjorden	19-Sep-03	14:33	Agassiz	210	±1,25	34,57
143	79° 47,955' N	12° 1,779' E	Raudfjorden	19-Sep-03	15:15	RP-sledge	210	±1,25	34,57
145	79° 41,883' N	12° 14,602' E	Raudfjorden	19-Sep-03	17:01	Triang. dredge	70	3,33	34,32
162	79° 0,438' N	16° 11,842' E	Wijdefjorden	20-Sep-03	19:34	Trawl	163	±1,63	34,64
168	78° 58,183' N	16° 17,107' E	Wijdefjorden	21-Sep-03	6:55	RP-sledge	162	±1,45	34,60
169	78° 58,413' N	16° 16,679' E	Wijdefjorden	21-Sep-03	7:58	Agassiz	162	±1,45	34,60
171	78° 59,701' N	16° 15,61' E	Wijdefjorden	21-Sep-03	8:42	Diving	0-30	2,48-2,53	33,46-33,47
172	78° 59,359' N	16° 16,649' E	Wijdefjorden	21-Sep-03	8:51	Triang. dredge	62	2,71	34,12
176	79° 7,623' N	16° 2,743' E	Wijdefjorden	21-Sep-03	11:15	Grab	217	±1,56	34,63
177	79° 7,792' N	16° 2,196' E	Wijdefjorden	21-Sep-03	12:44	Agassiz	215	±1,56	34,63
178	79° 7,779' N	16° 2,215' E	Wijdefjorden	21-Sep-03	12:44	RP-sledge	217	±1,56	34,63
180	79° 25,866' N	15° 33,123' E	Wijdefjorden	21-Sep-03	15:27	Grab	52	3,75	34,33
182	79° 53,075' N	15° 42,149' E	Widjefjorden	21-Sep-03	19:27	Diving	0-30	4,17-4,32	34,09-34,27
183	79° 39,545' N	18° 58,864' E	Hinlopen	22-Sep-03	4:11	Trawl	240	1,73*	34,69*
184	79° 39,929' N	18° 55,699' E	Hinlopen	22-Sep-03	5:13	Trawl	250	1,73*	34,69*
186	79° 40,201' N	19° 47,822' E	Hinlopen	22-Sep-03	8:36	Diving	0-30	±0,64-0,71	31,97-33,42
189	79° 39,339' N	19° 50,95' E	Hinlopen	22-Sep-03	10:46	Trawl	237	1,73	34,69
192	79° 38,891' N	19° 5,25' E	Hinlopen	22-Sep-03	13:54	Trawl	264	1,73*	34,69*
193	79° 33,049' N	18° 46,204' E	Hinlopen	22-Sep-03	16:47	Diving	163	*	*
195	78° 54,153' N	22° 12,193' E	Hinlopen	23-Sep-03	0:38	Trawl	139	1,73*	34,69*
196	78° 52,153' N	22° 13,354' E	Hinlopen	23-Sep-03	1:39	Sneli-sledge	120	±0,76	34,10
197	78° 52,991' N	22° 11,591' E	Hinlopen	23-Sep-03	2:10	RP-sledge	122	±0,76	34,10
198	78° 53,974' N	22° 8,533' E	Hinlopen	23-Sep-03	2:49	Agassiz	134	±0,76	34,10
199	78° 40,399' N	21° 22,804' E	Heleysundet	23-Sep-03	6:42	Diving	60	±1,31-±1,28	32,45
200	78° 40,476' N	21° 22,765' E	Heleysundet	23-Sep-03	8:35	Diving	60	±1,31-±1,28	32,45
204	78° 40,623' N	21° 23,796' E	Hinlopen, S	23-Sep-03	15:47	Sneli-sledge	50	±0,37	33,63

Table 1. Station list for all the stations where species were identified.

* No CTD was taken in close vicinity of the station - closest CTD data have been chosen e.g. temperature and salinity values are approximate. In some cases (stations 124 and 193), the nearest CTD station was considered to far away.

APPENDIX 2

Species list: All taxa recorded at each station.

SPECIES NAME	GEAR																																															
	Grabb	Sneli	Agassiz	RP	Divin	Grabb	RP	Agassiz	Sneli	Trawl	Triangular	Grabb	RP	Agassiz	Grabb	Agassiz	Sneli	Grabb	Grabb	Agassiz	RP	Triangular	Trawl	RP	Agassiz	Divin	Triangular	Grabb	Agassiz	RP	Grabb	Divin	Trawl	Trawl	Divin	Trawl	Sneli	RP	Agassiz	Divin	Divin	Sneli						
	38	37	37	37	0-30	161	160	160	160	1200		134	135	135	55	54	54	35	210	210	210	70	163	162	162	0-30	62	217	215	217	52	0-30	240	250	168	237	264	0-30	139	120	122	134	0-30	0-30	50			
	At	At	At	At	At	Cw	Cw	Cw	Cw	At	At	Cw	Cw	Cw	At	At	At	At	Cw	Cw	Cw	At	Cw	Cw	Cw	At	At	Cw	Cw	Cw	At	At	Ar	Ar	Ar	Ar	Ar	Ar	Ar	Ar	Ar	Ar	Ar	Ar				
	Bille	Bille	Bille	Bille	Bille	Bille	Bille	Bille	Bille	Kongs	Kongs	Maggda	Maggda	Maggda	Maggda	Maggda	Maggda	Raud	Raud	Raud	Raud	Raud	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde	Wijde					
	112-03	113-03	114-03	115-03	117-03	118-03	119-03	120-03	121-03	124-03	126-03	128-03	129-03	130-03	132-03	133-03	134-03	139-03	141-03	142-03	143-03	145-03	162-03	168-03	169-03	171-03	172-03	176-03	177-03	178-03	180-03	182-03	183-03	184-03	186-03	189-03	192-03	193-03	195-03	196-03	197-03	198-03	199-03	200-03	204-03			
PORIFERA																																																
Porifera indet.	-																																															
Calcareo indet.	-						x		x																x																							
Demospongiae indet.	-																																															
CNIDARIA																																																
Anthozoa indet.	-		x																																													
Capnella sp.	-																																															
Gersemia rubiformis	N																																															

APPENDIX 3



Fig. 1 *Pseudopallene spinipes* (O. Fabricius, 1780), st. 204.



Fig. 2 *Melphidippa macrura* G.O. Sars, 1894, Wijdefjord, st. 178.

SOFT-BOTTOM MACROFAUNA IN FOUR SVALBARD FJORDS

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ABSTRACT

A macrobenthic community study was conducted in four glacial fjords, Spitsbergen, September 2003. The objective was to investigate whether similarities in environmental characteristics in different fjords and at different depths within fjords could be related to similarities in macro-benthic community composition. Grab samples (van Veen, 0.1 m²) were collected at one shallow and one deep locality in each of the fjords. All samples were highly dominated by deposit feeding polychaetes and bivalves. Density of macrofauna varied between 369 and 110 specimens per 0.1 m² whereas taxon richness varied between 51 and 20. Clustering of samples showed a difference in community structure between those stations sampled in sill areas and those sampled in the basins or on the slope of the fjords, depending on differences in sediment characteristics. The basin and slope communities were further divided into two subgroups correlating with distance to open ocean. Slightly higher taxon richness was observed for the inner (36 ±10) compared to the outer stations (24 ±4). The results indicate that the main factor structuring fauna composition is the grain size. In homogenous soft-bottom habitats the most important feature structuring the fauna composition seems to be the distance to open ocean.

INTRODUCTION

Fjords with tidal glaciers occur in high numbers in the Svalbard archipelago. Freshwater run-off and high sedimentation rates of inorganic matter can be quite high in these fjords, exposing the benthic fauna to increasing physical disturbances towards the head of the fjords (Elverhøi et al. 1983). Depth and distance to the source of freshwater input and sediment inflow are important factors determining the structure and the composition of benthic communities within fjords (Dale et al. 1989). Diversity (Gulliksen et al. 1985) and biomass (Görlich et al. 1987) have been reported to decrease towards the inner part of fjords. Differences in sedimentation rates, water temperatures and salinities can be found between deep basins and sills and on the slopes along the sidewalls of the fjords. An investigation was carried out in order to relate patterns in benthic faunal composition to environmental characteristics. The main aims were to: 1) investigate differences in faunal composition between shallow and deep localities within the fjords, 2) investigate if similarities in environmental characteristics in different fjords are related to similarities among macro-benthic communities. For the purpose of this study we investigated soft-bottom macrofauna in the four glacial fjords Billefjord, Magdalenefjord, Raudfjord and Wijdefjord.

MATERIAL AND METHODS

Study site

The Arctic archipelago Svalbard, situated in the Barents Sea, is surrounded by both Atlantic and Arctic water masses. Along the west coast of the largest island, Spitsbergen, the North

Atlantic Current transports warm and saline water masses northwards, while Arctic water masses are mainly found on the east coast. In the deep basins of the fjords cold and saline deep water, which has been locally formed by winter freezing of the sea surface water, is often present (Pfirman et al. 1994). The inflow of Atlantic water and its influence on benthic fauna in the fjords is highly variable and depends on fjord size and geomorphology. The four fjords investigated in this study (figure 1) exhibit a wide range of variation for these characteristics.

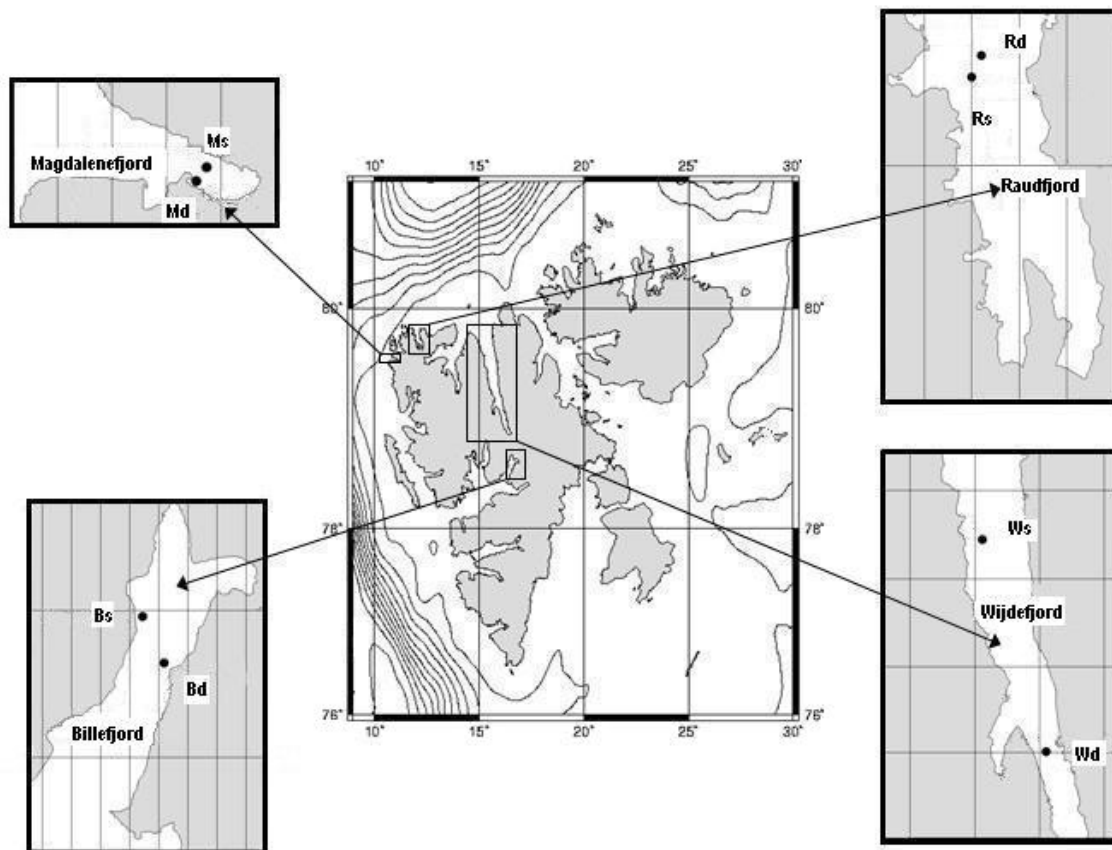


Figure 1. Map of Svalbard archipelago indicating the stations sampled and their position in the fjords. (B Billefjord, M Magdalenefjord, R Raudfjord, W Wijdefjord, s shallow station, d deep station).

Billefjord is a tributary fjord of the 100 km long Isfjord situated on the west coast of Spitsbergen. The distance from the head of Billefjord to Isfjord is around 27 km. The deep basin in Billefjord has a maximum depth of 170 m while the sill is rather shallow (22 m).

Magdalenefjord is a short fjord, only 9 km long, situated on the west coast of Spitsbergen. The maximum depth of the deep basin is 128 m and the sill depth is 44 m. From the north coast of Spitsbergen, Raudfjord stretches 20 km southwards. The basin is 233 m in the deepest part and the sill depth is 130 m. The fourth fjord sampled, Wijdefjord, is a 110 km long twin basin fjord. The middle basin, where the samples were taken, has a maximum depth of 246 m and a sill depth of 48 m.

Sampling

Benthic macrofauna was sampled on board R/V *Jan Mayen* in the four fjords in September 2003. Two stations were sampled in each fjord, at one shallow (39-57 m) and one deep locality (134-219 m) (figure 1). Two of the shallow stations were located on the sill of the fjord (Raudfjord and Wijdefjord), while two were located on slopes (Billefjord and Magdalenefjord). In total, eight stations were sampled. Temperature, density and salinity in the water column were recorded with a CTD (SD-202) at all stations prior to sampling. Three replicate samples for macrofauna analysis were taken with a van Veen 0.1 m² grab at each station. Sediment properties (colour, qualitative assessment of granulometric composition, and smell), disturbance level of sediment, and larger macrofauna at the sediment surface were recorded. Samples were subsequently sieved with a 1 mm round-holed sieve, with treatment according to the ISO Water quality - guidelines for quantitative investigations of marine softbottom macrofauna (in prep.). The macrofauna was sorted and identified alive to lowest possible taxonomic level and counted. Due to time constraints, all three replicate samples were processed only for the stations in Billefjord. In Magdalenefjord two replicate samples were processed per station, and in Raudfjord and Wijdefjord a single sample was processed for each station. The taxon lists from each station were cross-checked to standardize the identifications carried out by the different workers. The following abbreviations will be used in the text to discriminate between samples; first letter from the name of the fjord with capital letter followed by “s” or “d” for shallow and deep respectively, followed by a number indicating the number of replicate e.g. Md2 for the second replicate taken in the deep station in Magdalenefjord.

Data analysis

Species abundance. A “top-ten” taxon list, including the abundance of the ten most common taxa for each grab sample, was produced. Total abundance, species richness and species diversity (H') was calculated for all samples. The Bray-Curtis (Bray & Curtis 1957) similarity between the different samples was analysed, and a cluster analysis (hierarchical, group average sorting) was performed on the obtained similarity matrix with PRIMER (v5) statistical software (Clarke & Gorley 2001). Data input was untransformed abundance data.

Functional groups. All species were categorized according to feeding modes and ability of movement. Categorisation into feeding modes included sub-surface detritivores, surface detritivores, suspensivores, carnivores and omnivores, and was based on Holte (1998) and Pearson & Cochrane (pers. comm.). Categorisation into ability of movement included sessility, motility and discrete motility, and was based on the morphology of the taxa and on an unpublished study by Pearson & Cochrane (pers. comm.). Following this division, the assignment “sessile” was applied both for truly sessile groups such as balanids, and for e.g. sabellid polychaetes which are able to move within their tube but which are considered unlikely to survive if the tube is destroyed.

RESULTS

Sediment

With two exceptions, the composition of the sediment did not vary substantially between the different stations. In the shallow stations sampled in Raudfjord and Wijdefjord the sediment samples comprised a mixture of soft sediment and gravel. In all other stations a 1-2 cm thick loose sediment surface layer underlain by layers of silt and clay was found. The sediment was well oxygenated at all stations.

Water physical properties

Sub-zero temperatures were measured in the near-bottom water in all deep basins in the four fjords. The surface temperature in Raudfjord and Magdalenefjord was in the range of 4.7-5.7 °C, whereas in Wijdefjord and Billefjord it was in the range of 3.6-3.8 °C. Bottom water salinity was similar in all four fjords, with one exception, the shallow stations in Billefjord where near bottom water salinity was more than 1 PSU (practical salinity units) lower compared to the three other fjords.

Table 1. Near-bottom salinity and temperature measured at the eight stations sampled (B Billefjord, M Magdalenefjord, R Raudfjord, W Wijdefjord, s shallow station, d deep station).

Station	Depth Bottom (m)	Depth CTD (m)	Temp. (°C)	Salinity	Distance to open ocean (km)	Number of adjacent tidal glaciers	Estimated volume of tidal glaciers (Km ³)*
Bs	35	27	3.74	33.28	94	1	36
Bd	161	144	-1.70	34.74	94		
Ms	50	50	5.62	34.41	7	4	9
Md	137	130	-1.81	34.99	7		
Rs	55	43	4.76	34.32	5	6	17
Rd	205	205	-1.25	34.57	5		
Ws	48	48	3.59	34.29	30	5	110
Wd	218	161	-1.61	34.64	65		

* Based on Hagen et al. 1993.

Macrofauna

Taxonomic composition. In total, 3307 specimens and 166 different taxa were identified from the samples. Polychaetes and molluscs dominated and comprised 53% and 39% of the specimens, respectively. Polychaetes comprised 45% of the taxa registered in the samples, while crustaceans comprised 20% and molluscs 19%. Of all specimens found, 99% belonged to the 16 most common taxa. *Thyasira*² and Cirratulidae indet. were present in all samples, while *Chaetozone*, *Lumbrineris* and *Ennucula tenuis* occurred in all but one. *Polycirrus* was present in all fjords except for Magdalenefjord. Many taxa were rare and were only found in one or a few stations. The polychaetes *Chone paucibranchiata*, *Euchone papillosa* and *Sabellides borealis* were present only at the deeper localities.

Some taxa in the “top-ten” list occurred only in the samples from Billefjord. *Aphelochaeta*,

² In many cases in the text, we provide generic names only, without specification of “sp” or “spp”, since we in those cases do not have accurate information regarding the actual number of species of that taxon in the samples.

Heteromastus filiformis, Edwardsiidae and *Diastylis goodsiri* were found in both the deep and the shallow water station. *Polycirrus medusa* was only found in the deep stations, while the molluscs *Astarte* and *Dacrydium vitreum* appeared in shallow stations only. In general, bivalves were found in high numbers in the shallow stations, while polychaetes, particularly *Lumbrineris*, dominated the samples in the deeper stations in Billefjord. Some species were found only in Magdalenefjord, i.e. *Praxillella praetermissa* and *Golfingia margaritacea* and in low numbers. There was a high abundance of bivalves in Magdalenefjord, although *Ennucula tenuis*, *Thyasira* and *Macoma calcarea* occurred in higher densities at the deep station. In the deep station in Raudfjord large numbers of *Leitoscoloplos* were found, as were *Lumbrineris*, *Maldane sarsi*, *Polycirrus* and *Thyasira* while *Pomatoceros*, *Balanus balanus*, Spirorbidae and *Leptochiton asellus* occurred in the shallow stations only. Notably, these grab samples also contained a lot of stones. The sample from the deep station in Wijdefjord contained high numbers of Cirratulidae, *Polycirrus*, *Myriochele oculata*, *Lumbrineris* and *Yoldiella*. *Terebellides stroemi* and Spirorbidae were present only at the shallow station.

Table 1. “Top-ten” list with numerical abundance of the most common taxa in shallow (s) and deep (d) samples from the stations in Billefjord (B), Magdalenefjord (M), Raudfjord (R) and Wijdefjord (W). Also included is the total number of taxa, total number of specimens and diversity of the samples.

	Species	Bs			Bd			Ms		Md		Rs	Rd	Ws	Wd
		1	2	3	1	2	3	1	2	1	2	1	1	1	1
Annelida	Aglaophamus	1	1	1	1	4	5								8
	<i>Aphelochaeta</i> sp.		5	6	6	7	3								
	<i>Chaetozone</i> spp.	6	6	3	2	2	1	12	15		12	1	5	18	18
	Chone				1	5				1					
	Cirratulidae indet.	27	39	48	20	17	17	16	3	4	12	3	1	27	53
	Euchone papillosa				1	1				7	1		1		
	<i>Eunoe</i> sp.								2						
	<i>Gattyana</i> sp.				1							4		3	
	Heteromastus	1	2		2	7	10								
	Lanassa									8					
	Laphania boeckii		6												
	Leaena					1								1	
	<i>Leitoscoloplos</i> sp.	1	3	3	4	2	3	8	3				36	16	1
	<i>Lumbriclymene</i> sp.				11	1									
	<i>Lumbrineris</i> spp.	10	10	12	50	30	25	2		13	3	10	61	9	61
	Lysippe labiata		2		6	2	3	2				1		1	
	Maldane sarsi	4	7	11				28	5	10	7		33		1
	Myriochele oculata	12	8	13	1		1	2		8	5		8	2	24
	Nephtyidae indet. juv.					3									
	Pectinaria								4						
	<i>Pholoe</i> spp.	1	2	7	1	2				1	3	6	2	2	
	Polycirrus arcticus	8	9	6	6	18	6						2		3
	Polycirrus medusa				16	4	1								
	<i>Polycirrus</i> spp.	4	1		1	1	3					3	27	4	14
	Polynoidae indet.		1				1			2		2	2	8	
	<i>Pomatoceros</i> sp.											13			
	Praxillella							4	2						
Sabellides borealis									5			7			
Spirorbidae indet.											162		60		
Terebellidae indet.	1	3		7						1	2	2	3		
Terebellides	18	2	1		3	3				2			18		
Cnidaria	Edwardsiidae indet.	12	4	16			4								
Crustacea	Arrhis phyllonyx	2	6	1	4	1								1	
	<i>Balanus balanus</i>										6				
Echinodermata	Diastylis goodsiri		1			1	3								
	Myriotrochus	2				8			13					1	
	Ophiecten		1	1	1		1	3	1		1		2	2	
	Ophiura robusta										6		6		
	Ophiuroidea indet. juv.	12	8		1					1	2		15		
Hemichordata	Enteropneusta indet.										8				
Mollusca	<i>Astarte</i> spp.	21	15	41											
	<i>Cylichna</i> spp.	3	1				1	1	1	4	7				
	Dacrydium	8	5	8											
	Ennucula tenuis	2	1		2	2	3	9	31	71	76	1	11	4	
	Leptochiton asellus										6		5		
	Macoma calcarea	2	2					2	6	20	35			1	
	<i>Nuculana</i> sp.	3	4	2						1	17		3		
	Skeneidae indet.											5			
	<i>Thyasira</i> spp.	16	5	15	12	3	16	12	48	118	177	3	86	4	2
	<i>Yoldiella</i> spp.	82	40	56	15	6	22		1	6	4		5		26
	Nemertini	Nemertini indet.			1	1	1				6			1	
	Priapulida	Priapululus caudatus	2						3	3				1	
Sipunculida	Golfingia						2	1							

Total number of taxa	51	49	34	34	33	28	20	20	29	22	52	30	48	26
Total number of specimens	308	232	284	173	142	142	110	131	316	369	297	312	250	239
Shannon-Wiener diversity H' (log e)	3.02	3.18	2.70	2.65	2.87	2.73	2.42	2.02	2.22	1.77	2.33	2.35	3.01	2.28

Density of macrofauna varied between 369 (Md2) and 110 (Ms1) specimens per 0.1 m². Taxon richness varied between 51 (Bs1) and 20 (Ms1 and 2) per 0.1m². Diversity of the samples, measured as Shannon Wieners diversity index, varied between 3.18 (Bs2) and 1.77 (Md2).

The cluster analysis (figure 2) separates the samples into two distinct groups with a similarity of approximately 20%. One cluster is formed by the two samples taken in the sill area of Raudfjord and Wijdefjord, while the rest form the second cluster. This latter cluster is further divided into two subgroups, with a similarity of approximately 30%, correlating with distance to open ocean. These groups were labelled inner (stations far away from the open ocean) and outer (stations close to the open ocean), with a slight difference in species richness between the inner (36 ±10) and the outer stations (24 ±4).

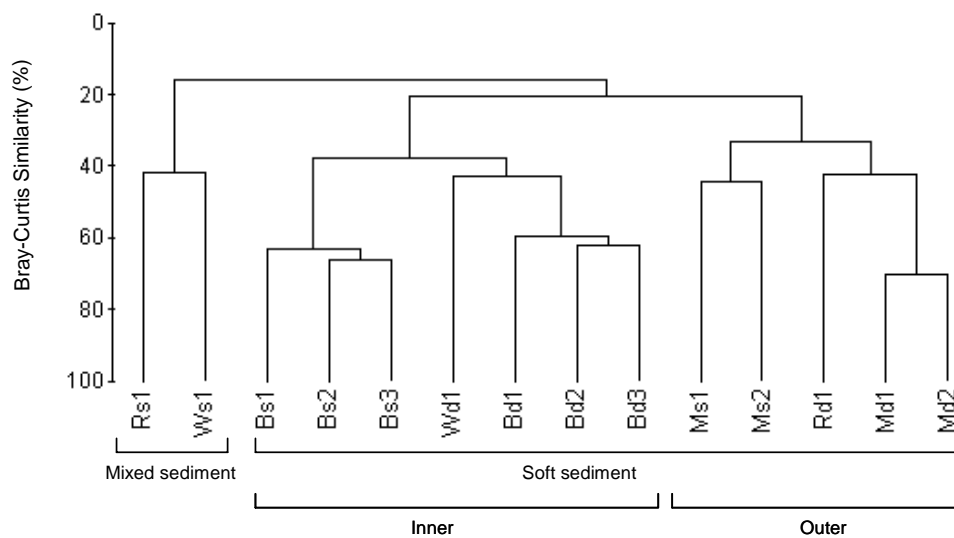


Figure 2. Dendrogram resulting from cluster analysis (hierarchical, group average sorting) of abundance of all taxa found in the samples. (B Billefjord, M Magdalenefjord, R Raudfjord, W Wijdefjord, s shallow station, d deep station).

Functional groups. The majority of the stations were dominated by detritivores, i.e. sub-surface detritivores (figure 3). Suspensivores were only found in larger quantities in the shallow stations in Billefjord, Raudfjord and Wijdefjord. Within all fjords except for Magdalenefjord, the fraction of carnivores was higher in the deep stations compared to the shallow stations.

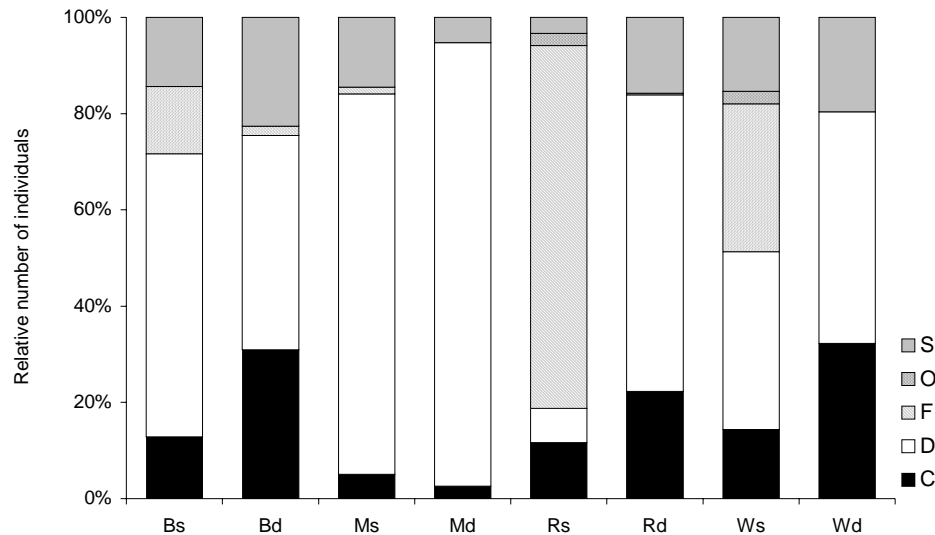


Figure 3. Feeding mode of the benthic macrofauna found in the four shallow water (s) and the four deep water (d) localities in Svalbard. S Surface detritivore, O Omnivore, F Suspensivore, D Sub-surface detritivore, C Carnivore, B Billefjord, M Magdalenefjord, R Raudfjord, W Wijdefjord. Estimations are based on the "top-ten" taxa abundance list from all samples (see Table 1 and text).

Some variation in motility of the fauna appears to be associated with depth. A larger fraction of the motile fauna was found in the deep stations compared to the shallow stations (figure 4). In Billefjord, and in Raudfjord and Wijdefjord in particular, a larger fraction of sessile fauna was present in the shallow stations. In both of these samples cobbles with sessile epifaunal species were found, i.e. balanids and spirorbids in Rs1 and spirorbids in Ws1.

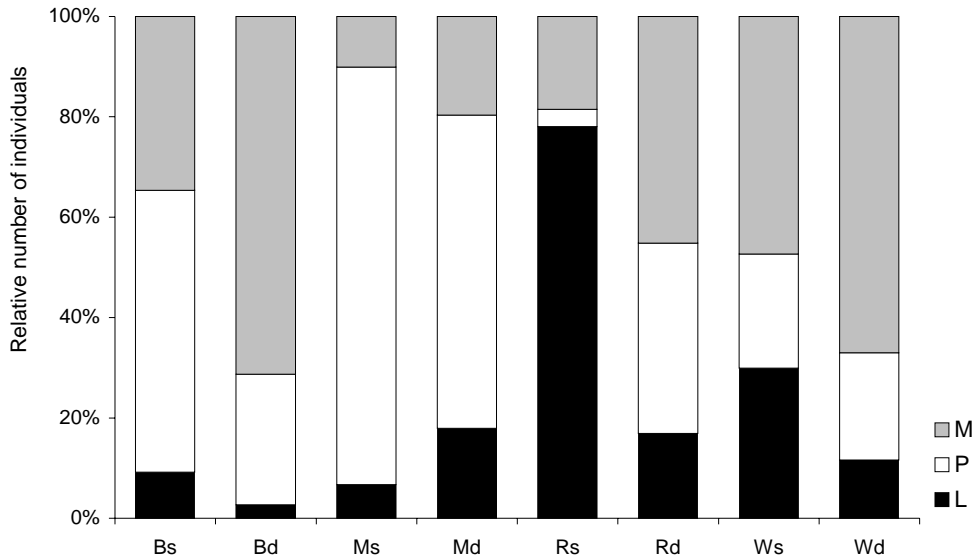


Figure 4. Division of all specimens found in the four shallow water (s) and the four deep water (d) localities in Svalbard according to their ability to move. M Motile, P Discretely motile, L Sessile, B Billefjord, M Magdalenefjord, R Raudfjord, W Wijdefjord. Estimations are based on the "top-ten" taxa abundance list from all samples (see Table 1 and text).

DISCUSSION

Assessing diversity between areas requires standardised methods. The ISO Water quality - guidelines for quantitative investigations of marine soft bottom macrofauna (in prep.) recommends 5 replicate samples of 0.1m² for each station in studies where a high statistical power is required. A smaller number of replicates can be used in studies where a high statistical power is not essential. In this study, 1-3 replicate samples were incorporated from each station, which can provide only a vague picture of the faunal composition at the sampled localities. This is shown in station Bs where the increase in taxa is 35% between the first and the second sample and 7% between the second and third. Station Bd shows a similar trend. In a parallel, more extensive study, where benthic macrofauna was sampled in the same fjords over much larger areas using Sneli sledge (Sneli, 1998), RP-sledge (Brattegard & Fosså 1991), bottom trawl and Agassiz-trawl, 265 taxa were reported (d'Acoz et al. in prep.), compared to 166 in our samples. This shows that both the area sampled and the gear used are important factors affecting what fauna is collected. The number of taxa that can be collected with a van Veen grab can be limited, but advantages include sampling of a given area, which is essential for comparative studies. Another advantage is the collection of infauna, which is the most suitable when assessing environmental conditions. Different parameters (e.g. abundance and biomass) also provide different pictures of the faunal composition in a given area. Due to practical reasons, however, biomass analyses were not implemented in this survey.

Analysis of the soft bottom samples taken in the study areas suggests that three major

components are responsible for the clustering of stations i.e. sediment, distance to open ocean and depth. In the following these components will be discussed in the order as depicted in the dendrogram (figure 2), not by order of estimated importance. All our soft-bottom samples were dominated by deposit feeding polychaetes and bivalves, as has been observed in many inner fjord locations in Spitsbergen (e.g. Holte & Gulliksen 1998, Wlodarska-Kowalczyk et al. 1998). At any given site within the fjords the depositional rates of inorganic material are highly dependent on size of and distance to glaciers. In general, a thick layer of fine particulate sediment can be found in the deep basins in the fjords, while, due to the action of currents and gravitational processes, the sediment on the slopes of the fjords and on the sills is coarser (Elverhøi et al. 1983). In the two sill stations in Wijdefjord and Raudfjord (Ws and Rs, respectively) the sediment was composed of soft sediment mixed with an important volume of cobbles and pebbles. The larger stones provide hard bottom islands on which fauna normally associated with typical rocky bottom localities can be found. The fauna sampled on the sill was therefore composed of a mixture of both hard bottom (e.g. Spirorbidae, *Balanus balanus* and *Leptochiton asellus*) and soft bottom taxa (e.g. *Chaetozone*, Cirratulidae and *Terebellides stroemi*). This is reflected in the dendrogram where Rs and Ws cluster together but show a very low similarity with the other stations.

On the slope stations (Bs and Ms) the grab samples contained only fine particulate matter, probably indicating a low inclination of the slopes and/or low current action. Due to the lack of data on sedimentation rates and the coarse description of sediment composition at the stations, the difference in depositional rates on the slopes and in the deep basin localities can only be interpreted by examination of the structure of the benthic assemblage. High sedimentation of inorganic matter causes clogging of the filtering apparatus (Levinton 2001), reducing the abundance of filter feeders. The presence of the filter-feeding bivalves *Dacrydium vitreum* and *Astarte* in the shallow slope of Billefjord may indicate lower sedimentation rates compared to the deep basin where filter feeders are a much smaller group. In Raudfjord and Wijdefjord filter feeding worms were found in high number in the sill stations whereas only a very low number of filter feeders were found in the deep stations (figure 3), thus indicating similar deposition rates in these fjords. The results of our study indicate that sediment properties (i.e. grain size) is a major factor structuring the composition of the benthic samples, although further studies and more detailed sediment analyses are required for any more detailed conclusions.

The similarity analysis further divided the samples into those located close to open ocean (outer) and those located deep within a fjord (inner) (figure 2). Wlodarska-Kowalczyk et al. (1998) observed a similar division examining seven glacial bays in Spitsbergen. In their study a zoogeographical examination showed a higher abundance of individuals representing relict Arctic species in semi-enclosed basins with weak water exchange. The stations in Magdalenefjord and Raudfjord, located close to the open ocean, had higher temperatures in the intermediate water layer than Billefjord and Wijdefjord, located at long distances from the open ocean (table 1). This may indicate that these stations experience higher degrees of water exchange with the warm, Atlantic Current. In order to assess whether some stations were more influenced by Atlantic water than others, we divided all species in three groups according to their zoogeographical distribution (Brattegard pers. comm.). In the samples only one specimen representing an Arctic species was found (Bd). In all stations there was an equally large proportion of species found all along the coast of Norway and species that are found along the northern coast of the Norwegian mainland (appendix I). No conclusions regarding the different influence of Atlantic water in the four fjords could therefore be drawn based on the analysis and the analysis is not included in the results. Only one replicate sample

was analysed from Raudfjord and Wijdefjord. For this reason we cannot discount the possibility that their position within the outer and inner clusters are random, and that the clustering of stations rather is a division into different fjords, i.e. Billefjord and Magdalenefjord. More stations and replicates within each fjord are required in order to examine the question in more detail.

Although we only investigated one station each in the deep and shallow localities, and no strict conclusion can be based on this, the likely causes of the division into samples in deep and shallow localities will still be discussed. In Billefjord a higher abundance and number of taxa was found in the shallow samples compared to the deep samples. Similar observations have been made in Sassenfjord, Spitsbergen (Kendall & Aschan 1993) and in an east Greenland fjord where it was suggested to reflect differences in sediment characteristics, from a more heterogenous mixture in shallow areas to more homogenous sediment in the deeper parts (Sejr et al. 2000). Changes in sediment structure from deep to shallow localities were not detected in Billefjord, although our methodology was not appropriate to assess finer differences. In Magdalenefjord the trend was reversed and a higher abundance of specimens was found in the deep samples. This may represent a sampling artefact as the two grab samples in the shallow localities only contained 8 litres of sediment each, compared to 20 litres in the deepwater samples. However, since most of the macrofauna is found in the upper few centimetres of the sediment, we consider differences in physical properties of the environment to be a more plausible explanation. Important factors varying with depth, and which can have an effect on fauna composition, are light attenuation, amount of suspended matter in the water, currents, variation in salinity, temperature and oxygen content (Dale et al. 1989). But, because only a few of these factors were measured, none can be singled out as more important for the topological relationships in the dendrogram than others.

CONCLUSION

The objective of this study was to investigate if similarities in environmental characteristics in different fjords and at different depths within fjords could be related to similarities in macrobenthic community composition. The results indicate that the main factor structuring fauna composition is the grain size as in the example from the sill. In homogenous soft-bottom habitats the most important feature structuring the fauna composition seems to be the length of the fjord and the distance to open ocean.

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Appendix I

Appendix I: Complete taxa list of all replicate samples from Billefjord, Magdalenefjord, Raudfjord and Wijdefjord indicated by the capital letter of each fjord and "d" and "s" referring respectively to deep and shallow stations.

Taxa	Author	Zoo- geographical distribution*	Feeding mode**	Motility***	Stations													
					Bs			Bd			Ms		Md		Rs	Rd	Ws	Wd
					1	2	3	1	2	3	1	2	1	2	1	1	1	1
FORAMINIFERA																		
<i>Hyperammina subnodosa</i>	Brady, 1884	-			x	x		x							x			
CNIDARIA																		
Actiniaria indet.		-										1						1
Cerianthidae indet.		-						1	2	1								
Edwardsiidae indet.		-	C	P	12	4	16			4								
Hydrozoa indet.		-													x			
NEMATODA																		
Nematoda indet.		-				1											2	
NEMERTINI																		
<i>Cerebratulus</i> sp.	Renier, 1804	-			2					2	1	1	1				3	1
Nemertini indet.		-					1	1	1				6					1
PRIAPULIDA																		
<i>Priapulidus caudatus</i>	Lamarck, 1816	X			2							3	3					1
SIPUNCULIDA																		
<i>Golfingia margaritacea</i>	(M. Sars, 1851)	X										2	1					
Sipuncula indet.		-			1									1				

Appendix I

Taxa	Author	Zoo- geographical distribution	Feeding mode	Motility	Stations															
					Bs			Bd			Ms		Md		Rs	Rd	Ws	Wd		
					1	2	3	1	2	3	1	2	1	2	1	1	1	1		
ANNELIDA																				
<i>Aglaophamus malmgreni</i>	(Théel, 1879)	X			1	1	1	1	4	5								8		
<i>Ampharete lindstroemi</i>	Malmgren, 1867	X				1														
Ampharetidae indet.		-			1						1						3			
<i>Amphicteis sundevalli</i>	Malmgren, 1865	A			1															
<i>Amphitrite cirrata</i>	O. F. Müller, 1771	X															2			
Amphitritinae indet.		-															1			
<i>Aphelochaeta</i> sp.	Blake, 1991	-				5	6	6	7	3										
<i>Aricidea catherinae</i>	Laubier, 1967	X				2	1	1												
<i>Aricidea quadrilobata</i>	Webster & Benedict, 1887	X								1										
<i>Aricidea</i> spp.	Webster, 1879	-	D	P	1		2											1		
<i>Brada</i> spp.	Stimpson, 1854	X																2		
<i>Branchiomma</i> sp.	Kölliker, 1858	X															1	1		
<i>Capitella capitata</i>	(O. Fabricius, 1780)	X																1		
<i>Caulleriella killariensis</i>	(Southern, 1914)	X			7	3	1			1										
<i>Chaetozone</i> spp.	Malmgren, 1867	-	D	P	6	6	3	2	2	1	12	15		12	1	5	18	18		
<i>Chone paucibranchiata</i>	(Krøyer, 1856)	N	F	L				1	5				1							
Cirratulidae indet.		-	D	M	27	39	48	20	17	17	16	3	4	12	3	1	27	53		
<i>Cossura</i> sp.	Webster & Benedict, 1887	X				2	1		1				4	1						
Dorvilleidae indet.		-			1			1										1		
<i>Eteone flava/longa</i>	(O. Fabricius, 1780)	X			2	1										1	1			
<i>Euchone papillosa</i>	(M. Sars, 1851)	X						1	1				7	1		1				
<i>Eunoe</i> sp.	Malmgren, 1865	-											2							

Appendix I

Spirorbidae indet.		-	F	L									162	60				
Taxa	Author	Zoo-	Feeding		Stations								Rs	Rd	Ws	Wd		
		geographical distribution	mode	Motility	Bs			Bd			Ms						Md	
					1	2	3	1	2	3	1	2	1	2	1	1	1	1
<i>Syllis</i> sp.	Savigny, 1818	-	C	M	1	2												
Terebellidae indet.		-			1	3		7					1	2	2	3		
<i>Terebellides stroemi</i>	M. Sars, 1835	X			18	2	1		3	3					2		18	
<i>Trichobranchus glacialis</i>	Malmgren, 1866	X															1	
<i>Trichobranchus</i> sp.	Malmgren, 1866	-															2	
CRUSTACEA																		
Amphipoda indet.		-																1
<i>Anonyx</i> sp.	Krøyer, 1838	-			1													
<i>Arrhis phyllonyx</i>	(M. Sars, 1858)	X			2	6	1	4	1									1
Asellota indet.		-							1									
<i>Balanus balanus</i>	(L., 1758)	X	F	L											6			
<i>Brachydiastylis resima</i>	(Krøyer, 1846)	X									1	1					2	
<i>Centromedon pumilus</i>	(Lilljeborg, 1865)	X													2			
Copepoda indet.		-				1						1						2
<i>Diastylis goodsiri</i>	(Bell, 1855)	N				1			1	3								
<i>Diastylis spinulosa</i>	Heller, 1875	N								1								
<i>Eudorella emarginata</i>	(Krøyer, 1846)	X			1													
<i>Eudorella</i> spp.	Norman, 1867	-																3
<i>Halirages</i> sp.	Boeck, 1871	-													1			
<i>Haliragoides</i> sp.	G.O. Sars 1895	-													1			
<i>Leucon nasica</i>	(Krøyer, 1841)	X	S	M					1	2								
<i>Leucon</i> sp.	Krøyer, 1846	-													1			

Appendix I

<i>Chaetoderma</i> sp.	Lovén, 1845	-				3		1						2	1	4	2	
Taxa	Author	Zoo-geographical distribution	Feeding mode	Motility	Stations													
					Bs			Bd			Ms		Md		Rs	Rd	Ws	Wd
					1	2	3	1	2	3	1	2	1	2	1	1	1	1
<i>Cuspidaria</i> sp.	Nardo, 1840	-			2	4	4											
<i>Cylichna occulta</i>	(Mighels & Adams, 1842)	N					1											
<i>Cylichna</i> spp.	Lovén, 1846	-			3	1				1	1	1	4	7				
<i>Dacrydium vitreum</i>	(Holbøll, in Møller 1842)	N			8	5	8											
<i>Ennucula tenuis</i>	(Montagu, 1808)	X	D	P	2	1		2	2	3	9	31	71	76	1	11	4	
Gastropoda indet.		-						1		1								
<i>Lepeta caeca</i>	(Müller, 1776)	X													2		1	
<i>Leptochiton asellus</i>	(Gmelin, 1791)	X													6		5	
<i>Macoma calcarea</i>	(Gmelin, 1791)	X	F/S	P	2	2					2	6	20	35			1	
<i>Margarites</i> sp.	J.E. Gray, 1847	-													1		2	
<i>Moelleria costulata</i>	(Møller, 1842)	N															1	
<i>Mya arenaria</i>	L., 1758	X												2			1	
<i>Mya truncata</i>	L., 1758	X									1			1				
<i>Mysella dawsoni</i>	(Jeffreys, 1864)	N			1								1					
Naticidae indet.		-				2												
Neogastropoda indet.		-													1			
<i>Nuculana</i> sp.	Link, 1807	-			3	4	2						1	17		3		
Polyplacophora indet.		-													1			
<i>Puncturella</i> sp.	Lowe, 1827	X													1			
Pyramidellidae indet.		-			2	1												
Rissoidae indet.		-					1		1							1		
Skeneidae indet.		-													5			
<i>Thracia</i> sp.	de Blainville, 1824	-											1					

Appendix I

<i>Thyasira</i> spp.	Lamarck, 1818	-	D	P	16	5	15	12	3	16	12	48	118	177	3	86	4	2
		Zoo-geographical distribution	Feeding mode	Motility	Stations													
Taxa	Author				Bs	Bd	Ms	Md	Rs	Rd	Ws	Wd						
					1	2	3	1	2	3	1	2	1	2	1	1	1	1
<i>Velutina velutina</i>	(Müller, 1776)	X			1													
<i>Yoldiella</i> spp.	Verrill & Bush, 1897	-			82	40	56	15	6	22	1	6	4		5			26
BRACHIOPODA																		
<i>Terebratulina</i> sp.	(L., 1758)	X																1
BRYOZOA																		
Bryozoa indet.		-													x			x
ECHINODERMATA																		
<i>Ctenodiscus crispatus</i>	(Retzius, 1805)	N																2
Echinoidea indet. juv.		-													2			3
<i>Eupyrgus scaber</i>	Lütken, 1857	N														3		
<i>Myriotrochus rinkii</i>	Steenstrup, 1852	N			2			8				13						1
<i>Ophiocten sericeum</i>	(Forbes, 1852)	N				1	1	1		1	3	1			1		2	2
<i>Ophiopholis aculeata</i>	(L., 1767)	X													1		4	
<i>Ophiura robusta</i>	(Ayres, 1851)	X	C	M											6		6	
Ophiuroidea indet. juv.		-			12	8		1					1	2			15	
<i>Strongylocentrotus</i> spp.	Brandt, 1835	-													1			
TUNICATA																		
Ascidiacea indet.		-																1
<i>Botryllus schlosseri</i>	(Pallas, 1766)	X	F	L											x			

Taxa	Author	Zoo- geographical distribution	Feeding mode	Motility	Stations													
					Bs			Bd			Ms		Md		Rs	Rd	Ws	Wd
					1	2	3	1	2	3	1	2	1	2	1	1	1	1
HEMICHORDATA																		
Enteropneusta indet.		-																8

*Zoogeographical distribution: "A" indicates taxa that has only been found north of mainland Norway.
 "N" indicates taxa that has its southern distribution limit somewhere along the coast of Norway.
 "X" indicates taxa found both north and south of mainland Norway. "-"

**Feeding mode: "C" indicates carnivore taxa
 "D" indicates detritivore taxa
 "F" indicates filter-feeders
 "S" indicates suspension-feeders

***Motility: "M" indicates motile taxa
 "P" indicates discretely motile taxa
 "L" indicate sessile taxa

Appendix II

Sample log

Locality	Station no	Grab no	Date	Local time	Depth m	Position		Volume l	Sediment	Weather	Comments
Billefjorden	112	1	9/17/2003	10:10	38.5	78° 37,870' N	16° 26,030' E	20	Brown on top, sandy silt and clay	nice	
Billefjorden	112	2	9/17/2003	10:25	38.5	78° 37,870' N	16° 26,030' E	20	Brown on top, sandy silt and clay	nice	Ophiourids and polychaet-tubes
Billefjorden	112	3	9/17/2003	10:45	38.5	78° 37,870' N	16° 26,030' E	20	Brown on top, sandy silt and clay	nice	Faecal pellets, small bivalves
Billefjorden	118	1	9/17/2003	13:45	161	78° 35,950' N	16° 31,580E	18	Brown on top, sandy silt and clay	nice	Brittlestars, tubeworms
Billefjorden	118	2	9/17/2003	14:10	161	78° 35,950' N	16° 31,580E	20	Brown on top, sandy silt and clay	nice	
Billefjorden	118	3	9/17/2003	14:25	161	78° 35,950' N	16° 31,580E	20	Brown on top, sandy silt and clay	nice	
Magdalenefjorden	128	1	9/18/2003	18:20	134	79° 33,815' N	11° 5,530' E	20	Grayish, 1-2 cm brown top layer	nice	polychaeta tubes
Magdalenefjorden	128	2	9/18/2003	18:30	137	79° 33,815' N	11° 5,530' E	20	Grayish, 1-2 cm brown top layer	nice	anemone
Magdalenefjorden	128	3	9/18/2003	18:40	137	79° 33,815' N	11° 5,530' E	20	Grayish, 1-2 cm brown top layer	nice	
Magdalenefjorden	132	1	9/18/2003	-	55	79° 33,45' N	11° 3,948' E	8	Light coloured thin top layer over gray sediment	nice	
Magdalenefjorden	132	2	9/18/2003	-	42	79° 33,45' N	11° 3,948' E	8	Light coloured thin top layer over gray sediment, a little sandy on surface. Lots of stones/gravel	nice	
Magdalenefjorden	132	3	9/18/2003	-	49	79° 33,45' N	11° 3,948' E	12	Light coloured thin top layer over gray sediment	nice	ophiuroids visible
Raudfjorden	139	1	9/19/2003	15:00	54	79° 47,513' N	11° 59,838' E	7	Gravel with black clay in between, gravel clean on top	nice	

Appendix II

Locality	Station no	Grab no	Date	Local time	Depth m	Position		Volume l	Sediment	Weather	Comments
Raudfjorden	139	2	9/19/2003	15:05	54	79° 47,513' N	11° 59,838' E	14	Gravel with clay, clean on top	nice	echinoidea, cirripeds
Raudfjorden	139	3	9/19/2003	15:10	57	79° 47,513' N	11° 59,838' E	7	Gravel with clay, clean on top	nice	shell fragments
Raudfjorden	141	1	9/19/2003	15:15	208	79° 48,068' N	12° 1,519' E	17	Light brown top layer over grayish black. A lot of macroalgae material	nice	
Raudfjorden	141	2	9/19/2003	15:35	205	79° 48,068' N	12° 1,519' E	18	Light brown top layer over grayish black	nice	polychaeta
Raudfjorden	141	3	9/19/2003	16:05	201	79° 48,068' N	12° 1,519' E	17	Light brown top layer over grayish black	nice	
Wijdefjorden	177	1	9/21/2003	13:30	219	79° 7,623' N	16° 2,743' E	16	Red brown silt surface 1.5 cm over dense brown gray with black stripes, rough surface, faecal pellets	nice	nephtys, tubeworms, ophiuroid, solenogaster,
Wijdefjorden	177	2	9/21/2003	13:45	218	79° 7,623' N	16° 2,743' E	16	Red brown silt surface 1.5 cm over dense brown gray with black stripes	nice	amphipods, ophiuroid, faecal pellets, bioturbation
Wijdefjorden	177	3	9/21/2003	13:55	219	79° 7,623' N	16° 2,743' E	16	Red brown silt surface 1.5 cm over dense brown gray with black stripes	nice	sea star
Wijdefjorden	180	1	9/21/2003	17:32	50	79° 25,866' N	15° 33,123' E	8	Gray brown sediment, many stones	nice	lithothamnion, epifauna, ophiuroid
Wijdefjorden	180	2	9/21/2003	17:37	49	79° 25,866' N	15° 33,123' E	15	Gray brown sediment, many stones	nice	lithothamnion, Strongylocentrotus
Wijdefjorden	180	3	9/21/2003	17:55	48	79° 25,866' N	15° 33,123' E	15	Gray brown sediment, many stones	nice	

All samples were taken with a van Veen grab 0.1m²

Appendix II

DIARY

A complete sample log is given in Appendix II.

16.09.03

There were held a two-hour meeting where we discussed our project. Many ideas came up regarding localities, number of stations and replicates, and sample equipment. Our main aim ended up re-sampling previously visited stations in Billefjorden and compiling taxa inventory and linking it up with project 1.

Issues:

- Assess faunal changes
- Assess environmental change
- Analyse faunal diversity statistics and taxonomic surrogacy (focus on polychaetes)
- Interpret faunal community structure - e.g. functional groups, feeding types/motility related to sediment type, basins, and Atlantic/arctic fauna
- Provide baseline data for future programmes (e.g. cooperation with king crab research)

17.09.03

Sampled stations 112.1-3 and 118.1-3 in Billefjorden.

Marco made a dive with his sucking device, but lost the sampling-bag and came to the surface with no material.

Sorting and identification.

Mini-meeting

18.09.03

Sampled stations 128.1-3 and 132.1-3 in Magdalenefjorden.

Sorting and identification.

Mini-meeting

19.09.03

Sampled stations 139.1-3 and 141.1-3 in Raudfjorden.

Sorting and identification.

Mini-meeting

20.09.03

Celebrated unis' 10th anniversary!

Sorting and identification.

Mini-meeting

21.09.03

Sampled stations 177.1-3 and 180.1-3 in Wijdefjorden.

Sorting and identification.

Mini-meeting

22.09.03

Finished the species identification of 177.1 and 180.1 at 0600 a.m.!

Mini-meeting

Appendix II

23.09.03

Punched the species list and started the introduction, material and methods chapters. Lots of walrus on the ice!

Mini-meeting

24.09.03

Dear diary!

Worked on the species lists, and continued the introduction, material and methods chapters. Started to go north but ended up in a storm – returned to Wahlenbukta at midnight. Winds up to 26m/s and waves 10 m high made Amund seasick!

Mini-meeting

25.09.03

Finished the species list and started on the results chapter.

Mini-meeting

26.09.03

Worked on the results chapter

27.09.03

Worked on the results and discussion chapters

28.09.03

Cleaned the boat.

