Abundance, diversity and species composition of the Peracarida (Crustacea: Malacostraca) from the South Greenland shelf

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64

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Re: English Language Evaluation of the Ph.D. thesis of BENTE STRANSKY.

To whom it may concern,

As an English native speaker, I have read the thesis of Mrs. Bente Stransky entitled "Abundance, diversity and species composition of the Peracarida (Crustacea: Malacostraca) from the South Greenland shelf". I hereby confirm that the English employed in this thesis is correct and clear in both grammar and content.

Yours sincerely,

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Summary

In this thesis, several aspects of the distribution patterns and species composition of epibenthic Peracarida (Crustacea: Malacostraca) on the South Greenland shelf were addressed. Based on material from three expeditions in 2001, 2002 and 2004, the abundance, diversity, community patterns of Peracarida and environmental factors influencing the species composition were investigated.

In chapter 1, 10 epibenthic samples taken in 2001 in depths between 106 and 251 m were investigated. In total, 59,234 specimens were collected, representing 219 species. The species belonged to the orders Amphipoda (58%), Isopoda (25%), Cumacea (11%) and Tanaidacea (5%). The peracarids represent a homogenously distributed community with respect to diversity and evenness, however, the species composition shows a clear separation into a southeastern and southwestern fauna. For this separation, discriminator species were assigned, and further analyses indicated that sediment and latitudinal gradients have major impact on the species composition and distribution. The dependency of peracarids on the sediment is explained mostly by their ecology, since most of the analysed specimens were either infaunal or epibenthic.

In chapter 2, a subset of four stations from chapter 1 was chosen and revisited in 2002 and 2004 for a study on the temporal variability of peracarid species composition. Additionally, the influence of changing environmental factors on the species composition over time was investigated. The abundance of peracarids decreased from the first to the third year, but with respect to diversity and evenness, the peracarid community was stable over the three years. Moderate changes in temperature and salinity did not affect the species composition, whereas sediment structure was found to be the most important environmental variable.

Chapter 3 describes the sampling device applied during this study. The Rauschert sledge proved to be a suitable semi-quantitative device for the sampling of epibenthic fauna. Its advantages are the small size, simple operation, high replicability and reliable sampling on different substrates.

Since sediment is an important factor for the distribution of Peracarida, nine surface samples from the South Greenland shelf were analysed for their grain size composition and

foraminiferal composition in chapter 4. The samples on South Greenland shelf banks are characterised by sandy sediments, which become coarser towards the northwestern study area. At all sample localities, the sediment was dominated by only one foraminiferal species, *Cibicides lobatulus*. The composition of sediment and foraminifers could be related to the complex hydrography of the study area, dominated by strong currents. These currents are particularly strong at those stations where coarse sediments and high abundances of *C. lobatulus* were found.

The fifth chapter investigates if the division of the peracarid fauna into a southeastern and southwestern study area is reflected on a larger scale, i.e. separating the Northeast Atlantic from the Northwest Atlantic. Using the Isopoda as an example, literature on distribution data of several North Atlantic sites from Norway, the Faeroe Islands, Iceland, Greenland, Davis Strait, East Canada and the Northern Seas was compiled for comparison with species occurrence in the material from South Greenland. The similarity between geographic sites on a medium and large scale was analysed based on their species composition. In the analyses, 231 species were included, and Desmosomatidae and Munnopsidae represented the families with the highest species richness. Some genera displayed a high degree of rare species, occurring at only one site. Multivariate analyses of species composition resulted in several clusters of sites, whereas the individual sites East Canada, Davis Strait and Northwest Greenland differed from all others. The Norwegian sites, the Faeroe Islands and South Iceland grouped to one biogeographic region, while the South Greenland sites were similar to each other and showed highest similarity to the Northern Seas and North Iceland. On this large scale, it is most likely that hydrographic conditions have a major influence on the clustering of sites.

Table of contents

Introduction

General Introduction

Peracarida (Malacostraca, Crustacea) are divided into nine orders (Martin & Davis 2001), Amphipoda, Isopoda, Cumacea, Tanaidacea, Mysida, Lophogastrida, Spelaeogriphacea, Thermosbaenacea and Mictacea. Until now, the relationships especially of isopods, cumaceans and tanaids within the peracarids are not undebatedly resolved (Martin & Davis 2001, Wirkner & Richter 2007). Schram (1981, 1984, 1986), Watling (1983), Dahl (1991) and Poore (2005) supposed that isopods and amphipods are sister groups, while others (e.g. Hessler 1983, Watling 1998, 1999, Richter & Scholtz 2001) suggested the amphipods to be a sister group to the remaining peracarids. Bousfield (1988), however, considered the mysids as a sister group to the amphipods. Peracarids offer a wide range of possible investigations since they are found on land, in freshwater and marine waters from shallow coastal areas down to the deep sea. Peracarids are brooders and thus, their development in the first live stages takes place in a brood pouch, the marsupium. Contrary to the development through larval stages, brooders have the advantage that their hatch is not dispersed from favourable habitat and less susceptible to predation (Pechenik 1999). However, their distribution is much more limited and susceptible to local extinction (Pechenik 1999), e.g. due to iceberg scouring (Gutt 2000). Nevertheless, peracarids inhabit all climatic zones, including polar regions where they are found in high numbers of species and high abundances (e.g. Brandt et al. 2004, 2005, 2007, Rehm et al. 2006, 2007).

The peracarid fauna around Greenland was first studied by Fabricius (1780), but mainly the material collected during the Ingolf (1885-96), Godthåb (1928) and Dana (1928-30) expeditions provided the basis for studies on peracarids by Krøyer (1838), Hansen (1888, 1916), Sars (1885, 1895), Stephensen (1933), Vibe (1939, 1950) and Just (1970, 1980). In recent years, Brandt (1995, 1996, 1997a,b,c), Brandt et al. (1996) and Brandt & Schnack (1999) have extensively investigated the peracarid fauna of the Northeast Water Polynya and adjacent areas. Just (1970, 1980) worked in the Thule area in Northwest Greenland, and a few specific studies were carried out in Greenlandic fjord systems (e.g. Lörz et al. 1999, Lörz 2000, Sejr et al. 2000, Nickel 2004). The peracarid fauna of the South Greenland shelf, however, has not been studied since the Ingolf and Godthåb expeditions. As the sampling coverage on the shelf in those studies was very sparse, the work presented in this thesis aimed at investigating the peracarid fauna on the southern Greenland shelf with a series of systematic surveys.

The continental shelf area of South Greenland is characterised by its complex hydrography (e.g. Stein 2005). Cold Arctic waters flow southwards, while warm water from the North Atlantic intermingles with these cold waters. In this respect, the South Greenland shelf represents the linkage of Arctic water regimes with those of the North Atlantic. Apart from the hydrography, a high seasonality of primary production and long ice coverage during winter shapes very specific habitats in this area (Pedersen et al. 2004). Due to the influence of the Irminger Current, however, the southwestern part of Greenland remains ice-free during winter.

One special aspect of this study is that all stations were taken along the currents on the South Greenland shelf, at first in the East Greenland Current, then with the influence of the Irminger Current and later within the West Greenland (Coastal) Current. Another specific feature of this study is the sampling of epibenthic material from three years, not only from one sampling cycle. Such sampling series are extremely rare in polar waters and therefore very valuable. In the light of discussions about global warming, studies on changes in specific habitats became more important. The oceanographic conditions around Greenland are closely linked with climate variability (Macdonald et al. 2003). Changes in oceanography potentially affect marine organisms, including the peracarid crustaceans investigated in this study. For this reason, investigations of faunal compositions of different taxa, like the Peracarida, may serve as a basis for later monitoring studies on the background of climate change and its potential effects.

The main objectives of the first two chapters (**chapters 1 & 2**) were the identification of species and the investigation of the abundance, diversity and species composition of the analysed stations. In **chapter 1**, samples taken at 10 stations in the first sampling year 2001 have been analysed. Five stations were located on the southeastern and five on the southwestern shelf banks of South Greenland. Besides the determination of species and investigation of abundance and diversity patterns, this chapter aimed at comparing species composition between southeastern and southwestern Greenland and identifying discriminator species and environmental factors, which had the largest influence on these patterns. A complete species list for the 10 analysed stations is included.

For a comparison of the peracarid species composition on a temporal scale of three sampling years, four stations from the first year (2001), taken at the same depth level, have been chosen, and these locations were revisited again in 2002 and 2004 (**chapter 2**). Moreover, temporal changes in environmental factors have been analysed and related to the species composition. A complete list of species is provided, showing changes in abundances of each single species at all four locations on a temporal scale of three sampling years.

The Rauschert sledge was used as epibenthic sampling device in several recent studies (e.g. de Broyer & Rauschert 1999, Lörz et al. 1999, Lörz 2000, de Broyer et al. 2001, Nickel 2004, Rauschert 2006, Rehm et al. 2006, 2007) and consistently showed good catch efficiency. For this reason and due to its easy operation, it was chosen for this study, and since it has never been described in detail, this is done in **chapter 3.**

Numerous studies indicated that the sediment structure has a major influence on epibenthic species distribution (e.g. Hecker 1990, Mayer & Piepenburg 1996, Serrano et al. 2006). To test this hypothesis, sediment sampling was carried out in the third sampling year 2004 in addition to epibenthic sampling. The sediment samples were analysed for their grain size composition and described in **chapter 4**, accompanied by an investigation of the foraminiferal composition at those stations. The sediment samples were taken as close to the epibenthic stations as possible to enable a comparison with the faunal patterns described in **chapters 1** & **2**. The described sediment patterns were then compared with the peracarid composition, and foraminiferal patterns with the distribution of the munnopsids (Isopoda). Foraminifers are commonly used in geology because they are strongly related to hydrography and sediment patterns. Therefore, the foraminiferal distribution could be used to confirm the hydrographic features of the study area.

The scale of an analysis is crucial for the patterns observed (Levin 1992, Fortin & Dale 2005). On a small scale, several factors such as food availability, competition and sediment structure can influence the species composition (Pearson & Rosenberg 1987, Carey 1991), while on a large scale, other factors such as currents and climate become more important (Levin et al. 2001, Tuya & Haroun 2006). Epibenthic sampling is usually geographically limited and presents only ‘snap shots’ of the current or recent situation, as the distribution of taxa changes across temporal and spatial scales. In order to put the species community patterns in **chapters 1** & **2** into a wider biogeographic context, the similarity of the peracarid species compositions of the South Greenland shelf and adjacent waters was investigated on a larger scale (**chapter 5**). For this purpose, earlier investigations performed by several authors in geographically limited areas of the North Atlantic have been summarised. These areas were allocated to geographic sites used for biogeographic comparisons. The study in **chapter 5** focuses on the northern North Atlantic (north of 65°N) and on isopod crustaceans. Isopods are, in contrast to other peracarid orders such as tanaids or cumaceans, relatively well known and have been the subject of numerous studies in the North Atlantic. All sites were analysed by presence/absence data, and clusters of sites with similar species compositions were established and discussed.

General research background

Sampling

In the light of climate change and its consequences, but also due to the need for a comprehensive view on the interrelationships between species and habitats, the “ecosystem approach” was defined as the holistic objective of marine research programmes (Browman et al. 2004). As each investigation contributes to the general knowledge of species occurrence, their dependence on environmental and biotic factors and temporal variability, international organisations such as ICES (International Council for the Exploration of the Sea) take a wide range of species and their interrelations into consideration. The epibenthic sampling for this study was performed during three cruises on board of the FRV *Walther Herwig III* during an annual fishery survey to South Greenland. The data from the fishery survey are regularly delivered to advisory bodies such as ICES and the European Commission. Since information on non-target species in addition to the commercially important fish species is required to evaluate ecosystem effects of fisheries, the annual fishery surveys document the abundance of all groundfish species and the occurrence of invertebrates. During the fishery survey, a bottom trawl is used, which also occasionally catches macrobenthic material such as large-sized Peracarida, Holothuroidea, Porifera, Asteroidea and Decapoda (especially *Pandalus borealis* Krøyer 1838), providing additional qualitative information on the occurrence of invertebrates on the shelf banks in general.

The sampling itself was kindly made possible by the Federal Research Centre for Fisheries, Hamburg, Germany and the scientists in charge. During the sampling operation, help was provided by the crew of FRV *Walther Herwig III* and some cruise participants with respect to the winch and sledge handling and the time consuming washing procedure after sampling.

Determination procedure

The sorting of all 18 epibenthic samples included in this study, the determination of all peracarids to species level and the sediment and foraminiferal analyses were done by the author.

For the determination of the peracarids, help was offered by several specialists for certain taxa, by invitation to their laboratories, by giving an introduction to the taxa and partly also identifying species together with the author. Prof. Dr. J. Svavarsson provided help with the Munnidae and Gnathiidae (both Isopoda), Dr. J. Berge helped with the identification of amphipod families, Dr. L. Buhl-Mortensen with the Oedicerotidae (Amphipoda), Dr. C. De Broyer helped extensively with the identification of the Lysianassidae (Amphipoda), Prof. Dr. A. Myers helped with the Corophiidae (Amphipoda), Dr. T. Krapp-Schickel helped with Caprellidea and Amphilochidae (both Amphipoda) and Dr. O. Coleman helped extensively with several families of Amphipoda. Prof. Dr. H. Haflidason introduced and supported the author to the geological (sediment analyses) part of the work. Dr. Saskia Brix and Stefanie Kaiser helped with the determination of Desmosomatidae, Dr. Jürgen Guerrero-Kommritz with the Tanaidacea. Lydia Kramer and Antje Fischer helped with the final determination of some Munnidae (Isopoda) and Phoxocephalidae (Amphipoda).

Definitions and abbreviations

In the following chapters, the terms “east” and “west” or “the East”/”the West”, as well as terms such as “South Greenland shelf” and similar expressions refer to geographic sites within the study area.

Abbreviations used in the chapters are usually described there. Nevertheless, the most regularly used are:

EGC	East Greenland Current
FRV	Fisheries Research Vessel
IC	Irminger Current
RS	Rauschert sledge
WGC	West Greenland Current
WH233	cruise number 233 of FRV *Walther Herwig III*
WH244	cruise number 244 of FRV *Walther Herwig III*
WH268	cruise number 268 of FRV *Walther Herwig III*

Chapter 1:

Abundance, diversity and community structures of peracarid crustaceans along the southern shelf of Greenland and environmental effects

Abundance, diversity and community structures of peracarid crustaceans along the southern shelf of Greenland and environmental effects

Abstract

The species composition of peracarids (Crustacea: Malacostraca) of the Greenland shelf south of 65°N was investigated by means of 10 epibenthic samples in relation to environmental factors. The samples were taken using a Rauschert sledge in depths between 106 and 251 m. In total, 59,234 specimens were collected belonging to 219 species. The species composition was dominated by amphipods (58% of the total abundance), while for isopods (25%), cumaceans (11%) and tanaids (5%), much lower abundances were registered. The peracarids from the South Greenland shelf represent in general a homogenously distributed community with respect to evenness (J'), diversity (H') and Hurlbert's rarefaction E (S_{500}). Multivariate analyses of the species abundances divided the peracarids into a southeastern and southwestern fauna. Among the species most contributing to the separation between East and West, *Hardametopa nasuta, Photis reinhardi* and *Phoxocephalus holboelli* were identified for the amphipods, *Pleurogonium spinosissimum, Iolella laciniata* and *Nannoniscus oblongus* for the isopods and *Leucon* cf. *nasicoides* and *Campylaspis horrida* for the cumaceans. Tanaids exhibited a patchy distribution in the study area. A correlation analysis between faunal and environmental data indicated that the separation between areas is mainly based on sediment type and latitudinal gradients. Apart from the environmental impacts on species composition, it is most probable that the species' ecology controls the distribution patterns.

Introduction

The crustacean fauna on the Greenland shelf and adjacent seas has only been fragmentarily investigated. Apart from historic expeditions and publications by e.g. Fabricius (1780), Sars (1885 and 1895), Hansen (1916) and Stephensen (1933), recent studies on the peracarid fauna (Crustacea, Malacostraca) were carried out by Just (1980), Svavarsson (1982a,b, 1984a,b, 1987a,b, 1988a,b), Svavarsson et al. (1993), Brandt (1993, 1996, 1997a,b,c), Brandt et al. (1996), Mayer & Piepenburg (1996) and Nickel (2004). Former investigations have focused on taxonomy and later, ecological approaches have been rare. Taxonomic studies mostly dealt with single orders, thus the general knowledge on the ecology of peracarids in this area is poor. Although considerable information exists, the knowledge on the benthic fauna is still not very detailed and provides limited possibility for comparison, especially since the investigations have concentrated on bathyal and abyssal fauna (e.g. Gurjanova 1930, 1933, 1946 and 1964; Svavarsson 1982a,b, 1984a,b, 1987a,b, 1988a,b, 1997; Svavarsson et al. 1990, 1993) or on different types of ecosystems like the Northeast Water Polynya (e.g. Brandt et al. 1996).

Peracarid crustaceans play an important role in the benthic fauna, especially with regard to providing food for other epibenthic invertebrates or fish, their contribution to the benthic biomass (Lampitt et al. 1986) and their impact on the environment in terms of bioturbation and bioroughness (Huettel & Gust 1992). In contrast, the impact of the environment on the species composition remains poorly understood, although most of the recent studies investigated the species communities and their dependency on environmental factors such as carbon flux, temperature, depth or conditions on the seafloor.

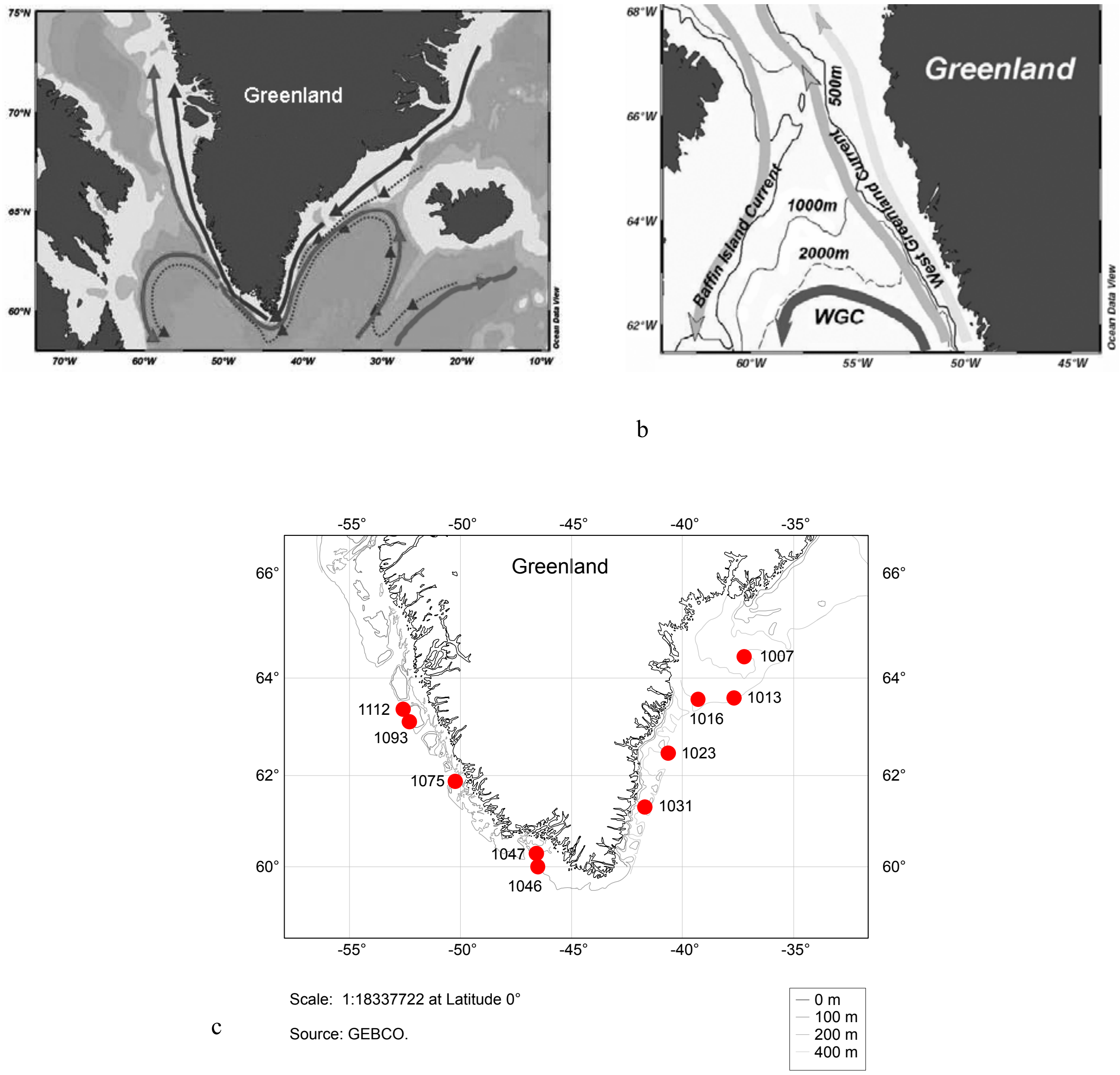
The diversity of the peracarid fauna in polar and boreal areas has been a major topic of several studies (e.g. Brandt et al. 1996, Svavarsson et al. 1990, Svavarsson 1997, Weisshappel & Svavarsson 1998, Brandt et al. 2004, 2005, 2007). A decrease in diversity with latitude as postulated by Sanders (1968) was confirmed by several authors, such as Roy et al. (1998), Clarke & Lidgard (2000), Kendall & Aschan (1993), Macpherson (2002), Rex (1983), Rex et al. (1993, 2000, 2005), although sometimes with only a weak trend, while e.g. Brandt et al. (1996) and Weisshappel & Svavarsson (1998) could not confirm the existence of a latitudinal gradient. Finally, there is no agreement in the literature if this gradient is only a regional phenomenon and it might differ considerably between taxa.

The Greenland shelf south of 63°30'N is narrow and continues directly with a steep continental slope (Dietrich 1959). The water masses can be divided from south to north into boreal/subarctic, low-arctic and high-arctic climate zones, inhabited among others by invertebrates adapted to these conditions. The Greenland shelf can be divided into two Large Marine Ecosystems (LME; Sherman et al. 1990; NOAA 2003, 2004), the East Greenland Shelf LME and the West Greenland Shelf LME. The East Greenland Shelf LME is located along the East Greenland coast and is mainly influenced by water masses of the cold East Greenland Current (EGC) transporting polar water (temperature $\leq$ 1°C, salinity $\leq$ 34.00) across the shelf southwards (Stein 1988, NOAA 2004) (Fig. 1.1a). South of the Greenland-Iceland Ridge, the EGC is influenced by the water masses of the warm Irminger Current (IC) (temperature > 4°C, salinity > 34.95). Both currents interfere at the shelf break, producing a mixture of water masses of the EGC and the IC. At Cape Farewell, the currents turn westwards and flow along the continental slope northwards as West Greenland Current (WGC; Pedersen et al. 2004). Branches of the WGC flow along the shelf break and transport intermediate water masses, while on the shelf, another branch of the WGC, which transports cold polar water originating from the EGC, flows northwards (Stein 2005a) (Fig. 1.1b). The WGC continues flowing along the West Greenland Shelf northwards into the Davis Strait at about 66° N. Here, the WGC divides into two water masses, one flowing further north into Baffin Bay, and the other turning southwards and joining the Baffin Island Current which flows southwards along the Canadian coast.

Nevertheless, topographic conditions determine the hydrographic conditions and divide the South Greenland shelf into an eastern and a western part, and it is questioned if the macrobenthic fauna reflects this division. The present study focuses on the peracarid crustaceans as a model group, including Amphipoda, Isopoda, Cumacea, Tanaidacea and Mysidacea. The main purposes of this paper are: 1) to compare patterns of species composition and distribution of peracarid crustaceans of the South Greenland shelves and 2) to investigate the patterns of diversity in the study area in relation to abiotic factors like latitude, temperature, salinity, depth and sediment characters.

Material and Methods

This work is based on samples taken during cruise WH233 on the German FRV *Walther Herwig III* in 2001 by means of a Rauschert sledge (see chapter 3). Epibenthic material has been taken at 10 epibenthic stations, five located off Southeast Greenland, five off Southwest Greenland (Fig. 1.1c, Tab. 1.1).



a

b

c

Scale: 1:18337722 at Latitude 0°

Source: GEBCO.

Fig. 1.1a-c: a) Schematic diagram of the water current systems off South Greenland; warm water masses from the Irminger Current (IC, light grey), cold polar deep water (dotted) and cold water masses from the East Greenland Current (EGC, dark) on the shelf (after Stein 2005b), b) water circulation diagram for the Davis Strait region; WGC: branch of West Greenland Current heading west; shelf break component (grey), shelf component (light grey); depth contours for 500 m (bold), 1000 m (thin) and 2000 m (dashed) are given (after Stein 2005a), c) map of the study area and stations sampled during cruise WH233 (dots).

Tab. 1.1: Station data of cruise WH 233. The sediment type was classified by visual inspection (see text for details).

Station	Date	Latitude N start	Longitude W start	Haul length [m]	Temperature bottom [°C]	Salinity bottom	Depth [m]	Sediment type
1007	23.10.2001	64°25’	37°13’	266	5.00	34.81	158.3	1
1013	24.10.2001	63°36’	37°41’	274	4.34	34.86	236.5	2
1016	25.10.2001	63°34’	39°18’	142	4.37	34.81	218.7	2
1023	26.10.2001	62°28’	40°39’	226	4.68	34.48	251.0	2
1031	27.10.2001	61°19’	41°41’	309	6.34	34.90	161.5	1
1046	29.10.2001	60°00’	46°31’	186	5.88	34.87	161.1	3
1047	31.10.2001	60°18’	46°35’	269	5.53	34.52	154.2	4
1075	04.11.2001	61°52’	50°14’	222	5.13	34.20	109.4	3
1093	06.11.2001	63°07’	52°18’	365	5.74	34.53	162.0	3
1112	13.11.2001	63°22’	52°35’	427	5.27	34.31	106.2	3

The sledge, being a semi-quantitative sampling device, was hauled over the shelf bank ground for 5 minutes, towed with a vessel speed of 1 knot over ground. The smallest mesh size was 0.5 mm. On board, samples were decanted, separating individuals from the finer sediment fraction, using a sieve grid size of 0.5 mm. Afterwards, the samples were preserved in 96% ethanol.

The peracarids were determined to species level and then a) univariate analyses for characterising the community in terms of abundance and diversity and b) multivariate analyses for comparing the community structures between samples and areas were applied. Finally, abiotic factors were linked with the species composition. For community analyses, all species were considered except for unidentified taxa (since they may contain several species), and Mysidacea, which were poorly sampled.

Species diversity was calculated including all identified species and untransformed data using the Shannon index (Shannon & Weaver 1963) and Hurlbert’s rarefaction (Hurlbert 1971). Species evenness was determined by the Pielou index (Pielou 1977).

Spearman-rank correlation matrices were used for the comparison of the number of species with measured environmental factors (temperature, salinity, depth and latitude).

Species abundances were transformed by the fourth root to diminish the influence of extremely dominant species (Field et al. 1982) and to take the semi-quantitative nature of the sampling gear into account. All species appearing at one station only were not considered in the further analyses, since their appearance might be random. All community analyses were performed using the software package PRIMER v. 6.0 (Clarke & Warwick 2001). Similarities in species composition between stations were calculated using the Bray-Curtis coefficient (Bray & Curtis 1957), while differences in environmental data were investigated using the

Euclidean distance (Clifford & Stephenson 1975), based on normalised data (Clarke & Warwick 2001). Temperature and salinity were recorded at each station by a CTD probe. Temperature and salinity were normalised by subtracting their mean values from the individual values and dividing by their standard deviation. Sediment structure was estimated during this cruise by the content of the sledge which fits well with sediment samples taken at the same positions with a small grab in 2004 (chapter 4). Sediment structure was divided into four different sediment types, representing typical characteristics of a certain site (Tab. 1.1). Type 1 was coarse gravel, type 2 consisted of mostly sand, corals, sponges and mussel shells, type 3 was allocated to sandy sediment that was rich in macroinvertebrates such as corals, crinoids and ophiuroids, and type 4 was pure sand.

The similarity matrices were used for both classification (complete linkage clustering; Lance & Williams 1967) and ordination (multi-dimensional scaling, MDS; Kruskal & Wish 1978). Dissimilarity values between environmental data were used for ordination and for linkage of community analyses to environmental variables (BIO-ENV, Clarke & Ainsworth 1993). The stress coefficient of an MDS plot indicates how faithfully the high-dimensional relationships among the samples are represented in the 2-D ordination plot (Clarke & Gorley 2006). A stress value of < 0.05 gives an excellent representation, and values < 0.1 still give a good ordination of the data. Values of > 0.3 indicate that the data are relatively randomly placed in the ordination (Clarke & Warwick 2001). Closely placed points in the MDS plot represent stations which are very similar in their species composition and points which are far apart characterise stations with different species compositions (Clarke & Gorley 2006).

When comparing stations with each other, discriminator species which are responsible for clusters of stations can be identified by the SIMPER analysis (Clarke 1993). It compares stations with each other in terms of species abundances and calculates the contribution of each single species found at those stations leading to the (dis-)similarity between stations.

The species distribution patterns and the environmental data were linked using the BIO-ENV analysis (Clarke & Ainsworth 1993). Its aim is to find the best match between biotic patterns and abiotic factors. A Spearman-rank correlation is used to compare the resemblance matrix of the biotic data with the resemblance matrix of the abiotic data. The result is the identification of either a single abiotic factor or a combination of them which correlates best with the species patterns.

Results

In total, 67,032 specimens were collected, from which 59,234 were identified to species level. The remaining 7,798 specimens were unidentifiable mostly due to damage. The total number of species was 219. In all, 136 species of amphipods, 46 species of isopods, 19 species of cumaceans and 18 species of tanaids were identified from the samples. Additionally, six mysid specimens have been collected, but these are to be considered with caution since mysids are planktonic and probably collected while towing up the sledge. Therefore, they were not further considered in the analyses.

Abundances

Amphipoda

In total, 34,328 amphipods were caught over all 10 stations. From those, 25% were caught in the East while 75% came from the western shelf. The most abundant species (more than 1% of the total abundance) are presented in Tab. 1.2. *Amphilochus manudens* was the most abundant species overall (11%), representing 30% of all specimens in the East and 4% in the West.

Tab. 1.2: Most abundant species (more than 1% of total abundance) of Amphipoda, caught during cruise WH233.

	NE-				SE-	SW-				NW-	Greenland
	Station										Total abundance
	1007	1013	1016	1023	1031	1046	1047	1075	1093	1112	[%]
Amphilochus manudens	269	506	199	1170	458	983	16	108	5	15	10.86
Photis reinhardi	0	0	0	208	8	1371	639	266	246	46	8.11
Syrrhoe crenulata	31	8	3	41	214	25	36	228	486	732	5.26
Phoxocephalus holboelli	0	0	0	52	0	39	1247	86	155	70	4.80
Tmetonyx cicada	5	152	91	30	327	6	19	260	64	687	4.78
Hardametopa nasuta	0	0	0	0	0	347	11	265	499	500	4.73
Gammaropsis cf. *melanops*	16	149	4	32	18	57	94	751	267	80	4.28
Liljeborgia pallida	6	3	1	5	310	7	0	1025	3	0	3.96
Aeginella spinosa	8	7	6	20	16	912	39	3	72	2	3.16
Odius carinatus	15	6	4	6	59	234	0	246	373	120	3.10
Ischyrocerus anguipes	0	0	0	5	254	0	80	182	373	31	2.69
Gitanopsis cf. *arctica*	25	0	0	0	0	107	27	312	336	0	2.35
Apherusa sarsi	0	0	0	0	0	0	0	6	62	702	2.24
Rhachotropis inflata	14	10	2	57	43	46	0	93	400	13	1.98
Caprella rinki	0	44	23	4	2	496	42	0	0	0	1.78
Monoculodes cf. *latimanus*	0	0	0	0	12	3	2	38	444	83	1.70
Ischyrocerus megacheir	11	194	3	18	0	277	1	5	36	0	1.59
Unciola laticornis	18	172	9	14	63	82	0	179	7	0	1.58
Gitanopsis bispinosa	0	35	13	16	5	264	2	9	163	6	1.49
Tiron spiniferum	64	0	0	62	125	27	51	38	89	22	1.39
Amphilochus tenuimanus	62	10	22	97	63	102	44	9	66	0	1.38
Caprella dubia	4	0	0	5	9	183	8	42	183	3	1.27
Harpinia propinquus	0	0	2	6	47	83	51	81	161	6	1.27
Orchomene macroserrata	1	10	11	4	18	78	2	260	19	1	1.18

Amphilochus manudens, *Tmetonyx cicada, Orchomene macroserrata, Syrrhoe crenulata, Gammaropsis* cf. *melanops* and *Aeginella spinosa* were found at all 10 stations. More than half of the species (75 species, 55%) were found in four or more samples, and 21% of the species were found at only a single station.

Species occurrence differed between East and West. From the 136 identified species, 21 occurred only in the East and 37 only in the West, while 78 species occurred in both areas. In total, 79 genera were found, of which 56 were present in both areas. Only a minor part, 23 genera (29%), was restricted to one area. The following nine genera were only found in the East: *Proaeginina, Laetmatophilus, Eusirus, Laothoes, Bathymedon, Syrrhoides, Ambasia, Kerguelenia* and *Tryphosella.* The other 14 genera were restricted to the West: *Cerops, Argissa, Guernea, Apherusa,* Melphidippidae sp. 1, *Hardametopa, Oediceros, Ambasiella, Aristias, Opisa, Pontocrates, Schisturella, Neopleustes* and *Parapleustes.*

Isopoda

In total, 14,946 isopods were identified, of which 37% were found in the East and 63% in the West. The most abundant species (more than 1% of the total abundance) are listed in Tab. 1.3.

Tab. 1.3: Most abundant species (more than 1% of total abundance) of Isopoda, caught during cruise WH233.

	NE-				SE-	SW-				NW-	Greenland
	Station										Total abundance
	1007	1013	1016	1023	1031	1046	1047	1075	1093	1112	[%]
Janira maculosa	245	836	307	804	1065	492	6	353	364	408	32.65
Munna cf. *groenlandica*	55	92	46	17	67	575	8	676	515	36	13.96
Munna cf. *minuta*	0	24	0	2	57	67	10	200	1350	22	11.59
Pleurogonium spinosissimum	0	0	0	1	17	74	2	731	126	118	7.15
Munna cf. *fabricii*	0	31	27	76	27	216	26	207	367	13	6.62
Spectrarcturus multispinatus	0	19	5	1	0	894	7	0	2	0	6.21
Eugerda cf. *globiceps*	0	0	2	0	90	48	0	81	132	5	2.40
Echinozone coronata	4	14	30	10	17	194	0	18	53	0	2.27
Iolella laciniata	31	142	33	93	2	21	0	0	0	0	2.15
Pleurogonium intermedium	0	0	0	11	5	0	43	0	206	2	1.79
Nannoniscus oblongus	27	26	53	18	134	1	0	0	0	0	1.73
Calathura brachiata	0	18	57	24	17	1	0	22	109	0	1.66
Austroniscus sp. 1	0	0	0	0	180	26	0	11	0	0	1.45
Caecognathia hirsuta	0	0	167	0	0	0	0	0	0	0	1.12
Pleurogonium inerme	0	0	0	8	0	27	66	48	0	0	1.00

Janira maculosa was the most abundant species (33%), representing 59% of the specimens in the East and 17% in the West. *Janira maculosa* and *Munna* cf. *groenlandica* are the only species found at all 10 stations. More than half of all species (26 species, 57%) were found at only three or fewer stations. From 46 identified isopod species, 15 species were restricted to the East, while seven were only present in the West, and 24 species occurred in both areas. In total, 28 genera were found, with 18 genera present in both areas. Only 10 genera were restricted to one area. The following eight genera were only found in the East: *Dendrotion, Rapaniscus, Heteromesus, Ischnomesus, Katianira, Tytthocope, Aspidarachna* and *Aega. Politolana* and *Synidotea* were restricted to the West.

Cumacea

During the cruise WH233, 6,840 cumaceans have been collected. From a total of 6,692 identified specimens, 42% were caught in the East and 58% in the West. Almost 50% of the entire abundance can be explained by the dominant species *Leucon* cf. *nasicoides* (Tab. 1.4).

Tab. 1.4: Most abundant species (more than 1% of the abundance) of Cumacea during cruise WH233.

	NE-				SE-	SW-				NW-	Greenland
	Station										Total abundance
	1007	1013	1016	1023	1031	1046	1047	1075	1093	1112	[%]
Leucon cf. *nasicoides*	0	0	0	2	1233	1260	159	191	166	320	49.78
Campylaspis horrida	62	36	67	785	88	52	0	0	3	0	16.33
Cumella carinata	0	0	0	0	0	0	0	341	28	185	8.28
Leptostylis macrura	1	0	0	0	3	5	23	86	362	6	7.26
Petalosarsia declivis	0	0	0	8	0	0	243	0	33	0	4.24
Campylaspis verrucosa	0	18	204	7	10	15	0	0	0	0	3.80
Leucon cf. *nathorsti*	32	1	3	75	40	59	2	13	25	0	3.74
Campylaspis undata	5	3	43	49	2	0	0	0	0	0	1.52
Diastylis cf. *edwardsi*	0	0	0	0	2	3	42	1	26	5	1.18
Campylaspis rubicunda	14	4	0	2	11	17	18	2	5	6	1.18

The cumaceans show a distinct pattern in their distribution. There is no species which is present at all 10 stations, and only two (*Campylaspis rubicunda* and *Campylaspis verrucosa*) were found at nine stations. Most of the species were either distributed in the East or in the Southeast and West. 42% of the cumaceans were observed at stations 1031 and 1046 alone. In total, 19 species were identified, of which 14 occurred in both areas and four only in the West. *Campylaspis undata* was the only species restricted to the East. The 19 species were assigned to 11 genera.

Tanaidacea

The lowest abundance of peracarid crustaceans was found in the tanaids with 3,268 identified specimens. From those, 81% were caught in the West. *Ansphyrapus tudes* and *Heterotanais groenlandicus* (Tab. 1.5) represented 70% of the tanaids.

Tab. 1.5: Most abundant species (more than 1% of the abundance) of Tanaidacea during cruise WH233.

	NE-				SE-	SW-				NW-	Greenland
	Station										Total abundance
	1007	1013	1016	1023	1031	1046	1047	1075	1093	1112	[%]
Ansphyrapus tudes	0	208	140	5	1	819	0	0	0	0	35.89
Heterotanais groenlandicus	0	0	0	0	0	1	1	1025	75	3	33.81
Typhlotanais sp. 2	17	31	21	93	59	109	8	3	7	0	10.65
Typhlotanais sp. 1	0	0	2	6	2	39	12	45	146	0	7.71
Pseudotanais oculatus	0	0	0	0	0	0	0	118	44	0	4.96
Paraleptognathia inermis	0	0	0	0	0	0	5	153	0	0	4.83

At the eastern stations, the abundance of 618 specimens is dominated by *Ansphyrapus tudes* and *Typhlotanais* sp. 2, representing 57% and 36% of the tanaids in the East. In the West, *Ansphyrapus tudes* and *Heterotanais groenlandicus* represent with 31% and 42% the major contributive percentage of tanaids in the West. Only *Typhlotanais* sp. 2 was present at nine of the 10 stations, whereas most of the species were only found at one or two stations (Annex 1.1).

In total, 18 species were identified, belonging to nine genera. While the abundance differed clearly between East and West, the number of species restricted to one area was equal with six species each. Six species were found in both areas. Of the nine genera, *Pseudosphyrapus* and *Cryptocopoides* were only occurring in the East, while *Heterotanais* and *Tanaissus* were only occurring in the West.

Diversity

The overall diversity index (Tab. 1.6, Fig. 1.2a) does not show a clear trend, only a slight increase from East to West. The diversity varies considerably between the different orders, and the only shared pattern is a clear decrease in diversity from station 1093 to station 1112. Additionally, the diversity decreases at station 1047, except for cumaceans and tanaids.

Tab. 1.6: Diversity (H’), expected number of species (E (S_{500})) and evenness (J’) of the individual orders and over all orders.

		NE-				SE-	SW-				NW-Greenland
		Station									
		1007	1013	1016	1023	1031	1046	1047	1075	1093	1112
Diversity H' (log e)	Amphipoda	2.48	2.63	2.63	2.34	2.99	2.89	2.40	3.27	3.42	2.51
	Isopoda	1.09	1.39	2.32	1.48	1.59	1.89	1.87	1.91	1.94	1.41
	Cumacea	1.27	1.06	1.04	0.67	0.51	0.54	1.33	1.20	1.73	0.84
	Tanaidacea		0.43	0.70	0.77	0.81	0.57	1.47	0.83	1.29	0.56
	Overall A,I,C,T	2.87	2.96	3.34	2.85	3.08	3.31	2.83	3.60	3.73	2.91
E (S_{500})	Amphipoda	39.5	35.7	40.9	41.2	43.2	42.6	39.6	50.5	50.6	39.0
	Isopoda	9.0	15.2	24.7	19.0	17.4	15.3	13.0	15.6	14.7	11.6
	Cumacea	7.0	5.0	6.0	8.1	7.7	8.6	12.0	10.2	14.3	6.0
	Tanaidacea	1.0	3.0	7.0	6.0	7.0	5.7	6.0	6.1	7.0	2.0
	Overall A,I,C,T	47.0	48.3	59.0	56.0	55.3	55.8	53.4	64.8	68.8	47.6
Evenness J'	Amphipoda	0.66	0.69	0.69	0.58	0.72	0.69	0.58	0.76	0.78	0.60
	Isopoda	0.50	0.48	0.71	0.47	0.54	0.61	0.73	0.66	0.70	0.57
	Cumacea	0.65	0.66	0.58	0.31	0.23	0.23	0.53	0.50	0.64	0.47
	Tanaidacea		0.39	0.36	0.43	0.42	0.29	0.82	0.43	0.66	0.81
	Overall A,I,C,T	0.70	0.70	0.75	0.63	0.67	0.71	0.63	0.77	0.78	0.66

Using Hurlbert’s expected number of species (E(S_{500})) as a diversity measure, the results show no major differences between individual orders, but show the same as the overall pattern (Tab. 1.6, Fig. 1.2b). In general, the trend is similar to the Shannon diversity but with smaller variation.

The patterns of evenness J’ (Tab. 1.6, Fig. 1.2c) are similar to those of the diversity H’, but more distinct. The evenness is generally low, since in the community patterns, there are many common species (e.g. *Janira maculosa, Amphilochus manudens* and *Leucon* cf. *nasicoides*) as well as species which are scarcely sampled (e.g. *Eusirus propinquus, Tytthocope megalura, Proaeginina norvegica, Gronella groenlandica* and *Platyaspis typica*).

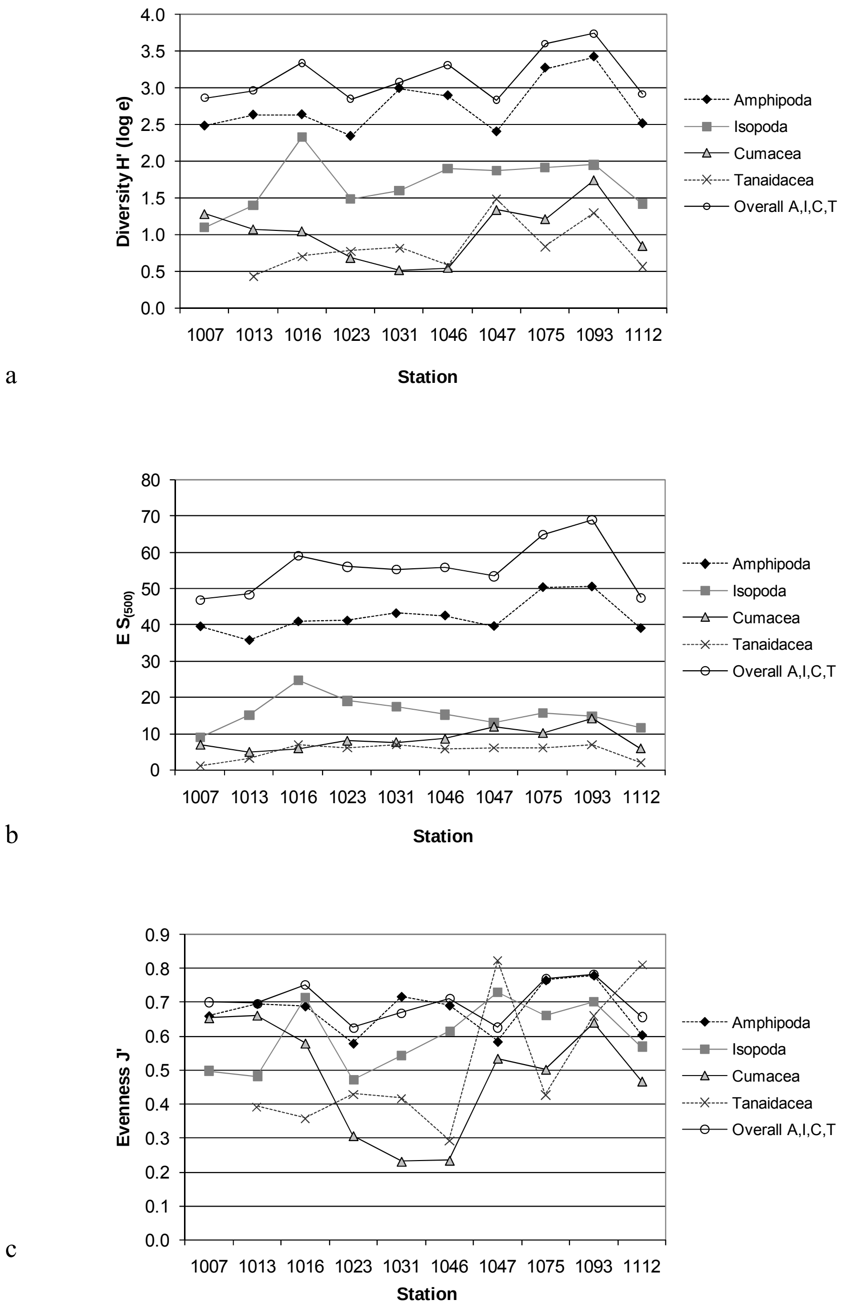


Fig. 1.2a-c: Patterns of diversity and evenness across the stations. a) Shannon diversity index H', b) Hurlbert's expected number of species E $S_{(500)}$ and c) evenness J'.

Amphipoda

The evenness of the amphipods is generally highest of all orders, although several species are very abundant. For example, at station 1093 (J' = 0.78), *Monoculodes* cf. *latimanus*, *Rhachotropis inflata* and *Westwoodilla* cf. *caecula*, and at station 1075 (J' = 0.77), *Liljeborgia pallida, Gammaropsis* cf. *melanops* and *Parapleustes biscuspis* are dominant species, also compared to other stations.

Isopoda

Diversity increased in terms of the Shannon's index as well as in Hurlbert's expected number of species from station 1007 to station 1016 and decreased afterwards, continuing in the West.

Cumacea and Tanaidacea

The pattern of diversity is almost equal in cumaceans and tanaids, showing a low diversity in these orders. Also the results for Pielou's evenness are relatively low at almost all stations, showing the lowest values at the southern stations 1031 and 1046. Stations 1047 and 1112 show the highest values of J' in the tanaids.

Correlation between the number of species and environmental factors

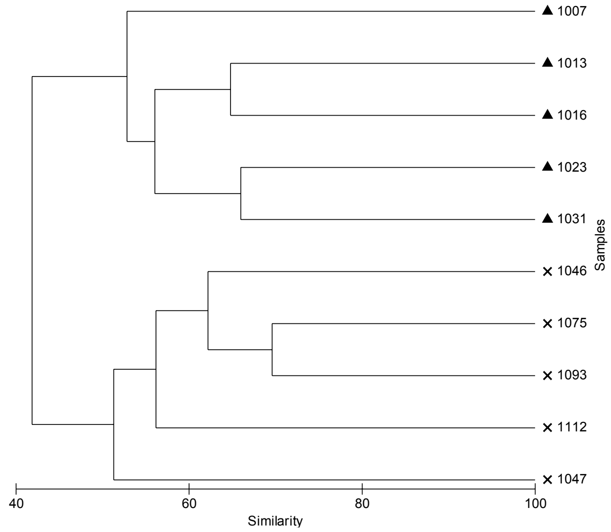
As the sediment was only classified into types (Tab. 1.1), it was not considered in the correlation analysis. In general, depth and salinity did not show any significant correlation with the number of species. The same was true for most of the correlations with temperature and latitude. For Amphipoda, a significant correlation was found between temperature and the number of species ($r = 0.69$, $p = 0.03$) over the entire study area. In the East, latitude was significantly correlated with the number of species of Amphipoda ($r = -0.95$, $p = 0.01$) and with number of species of all orders together ($r = -0.9$, $p = 0.04$).

Community analyses

Since the Amphipoda are the most abundant order with 58% of the entire abundance, they influence the species composition most.

Fig. 1.3a-j show the results of the multivariate analyses of species abundances at the 10 stations. The cluster dendrogram for all orders (Fig. 1.3a) presents a clear separation between an eastern and a western faunal assemblage. Station 1007 is more separated from the other eastern stations, as are stations 1047 and 1112 from the remaining stations in the West.

When comparing the overall MDS plot (Fig. 1.3b) with those from the individual orders (Fig. 1.3d,f,h,j), differences in faunal distributions are obvious. Generally, the amphipods influence the overall distribution pattern most due to their dominance in abundance and numbers of species. The MDS plot confirms the results from the cluster diagram and shows well how different stations 1007, 1047 and 1112 are with regard to the others. The quality of the MDS plot is given with an excellent stress value of 0.04. Plotted most closely together and therefore being most similar in their species composition are stations 1075 and 1093. Station 1007 is just slightly more similar to station 1023 than to station 1016 or station 1031. Although for example station 1046 and station 1047 have a similarity of 54%, station 1047 differs clearly from the cluster integrating station 1046, since this cluster has a similarity of 62%. Since in most of the PRIMER analyses all species are ignored which occur at only a single station, it is not taken into account that eight species are only present at station 1047 (Annex 1.1). Furthermore, the abundance of common species varies at this station. The species composition of station 1047 is about as dissimilar to station 1112 as to stations 1031, 1046 and 1093. Between East and West, stations 1031 and 1046 are geographically situated most closely to each other. This is reflected in the MDS plot that arranges those stations, despite belonging to two different clusters, closest to each other within the eastern and western clusters.


▲ 1007
▲ 1013
▲ 1016
▲ 1023
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× 1046
× 1075
× 1093
× 1112
× 1047
Samples
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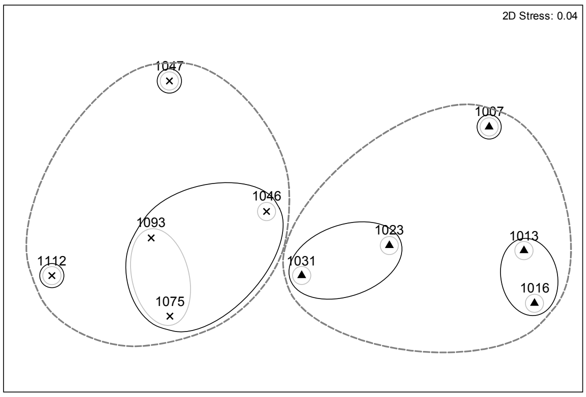
60
80
100
Similarity

a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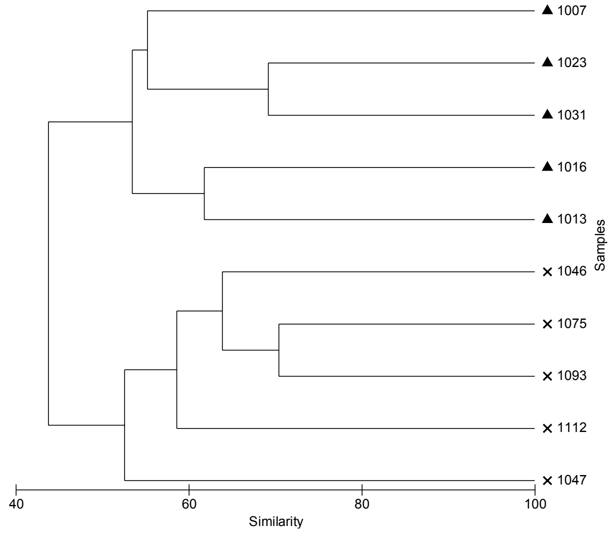
1007
1046
1093
1023
1013
1112
1031
1016
1075

b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▲ 1031
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× 1046
× 1075
× 1093
× 1112
× 1047
Samples
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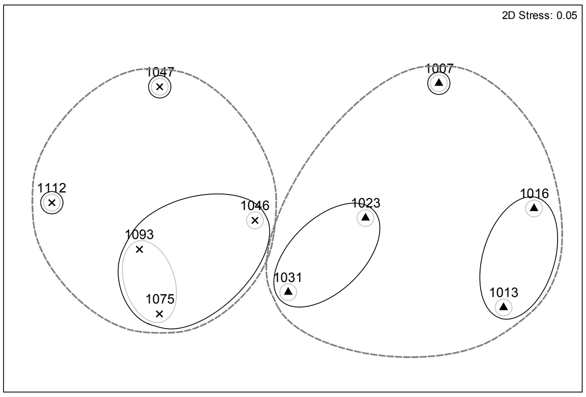
60
80
100
Similarity

c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1023
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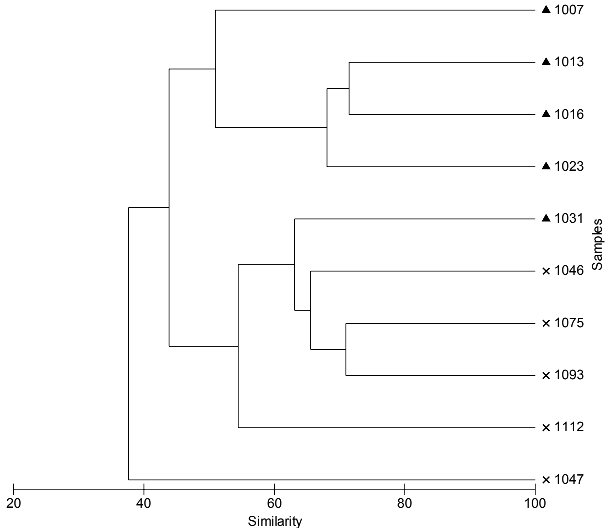
1031
1075
1013

d


▲ 1007
▲ 1013
▲ 1016
▲ 1023
▲ 1031
× 1046
× 1075
× 1093
× 1112
× 1047
Samples
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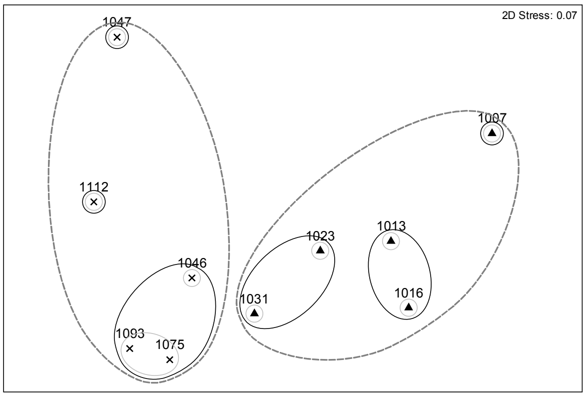
40
60
80
100
Similarity

e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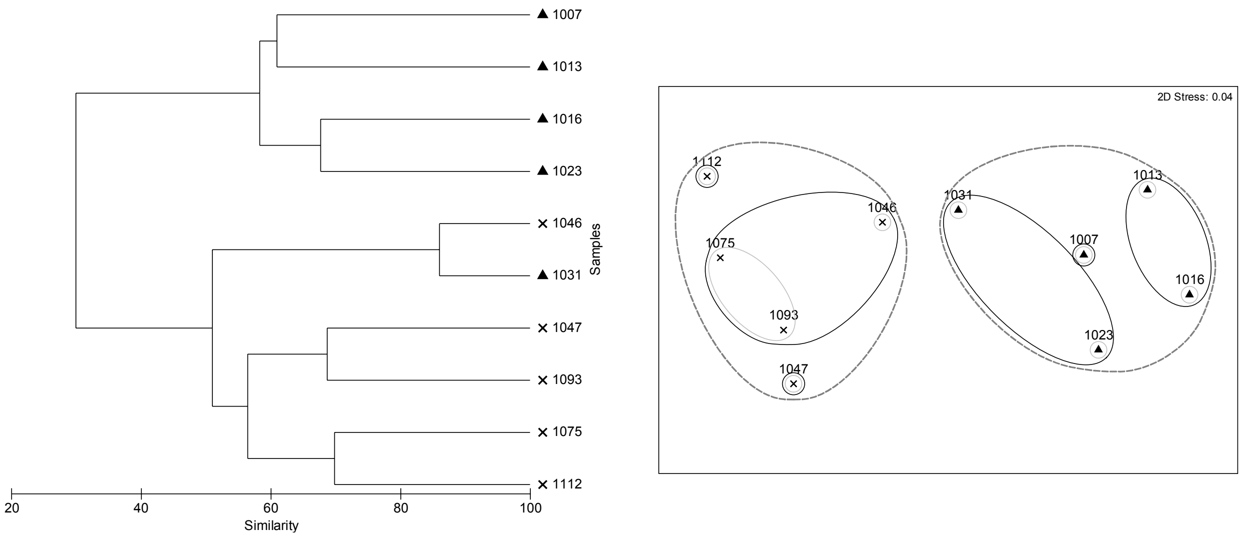
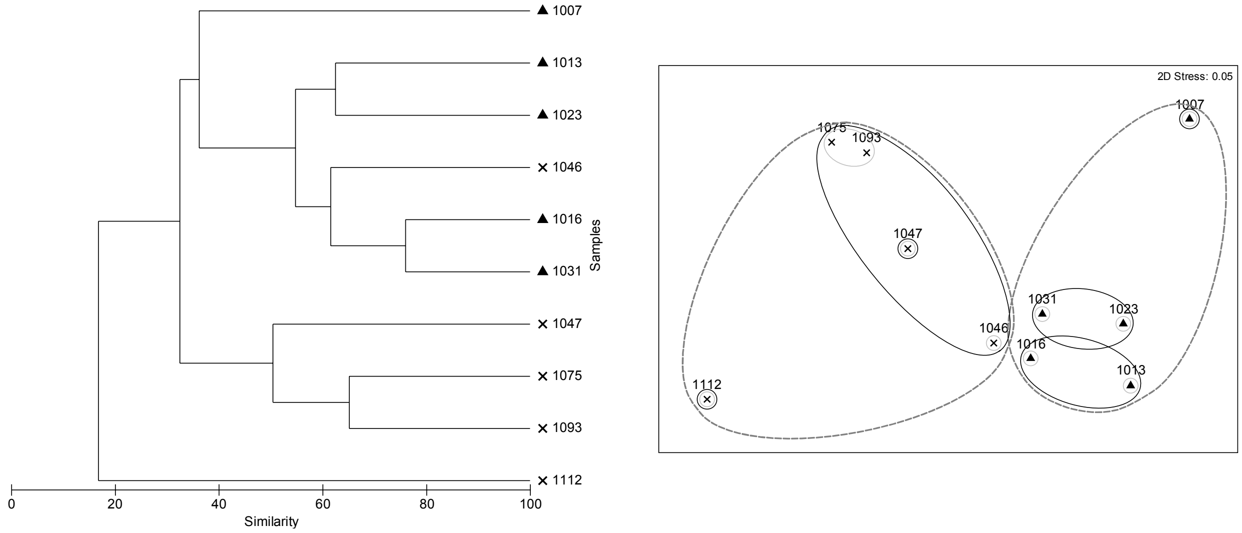
1013
1023
1046
1031
1016
1093
1075

f



g h



i j

Fig. 1.3a-j: Multivariate analyses of the species composition of all 10 stations over all orders (a, b), Amphipoda (c, d), Isopoda (e, f), Cumacea (g, h) and Tanaidacea (i, j). Left panels: Cluster dendrograms, using group-average linkage from Bray-Curtis similarities (in %) on fourth root transformed abundances; Right panels: Two-dimensional MDS configuration based on fourth root transformed abundances and Bray-Curtis similarities with superimposed clusters at similarity levels of 50% (dashed grey), 60% (dark) and 70% (light grey). Stress values of the individual MDS plots: b) 0.04, d) 0.05, f) 0.07, h) 0.04, j) 0.05. Triangles represent eastern stations, crosses the western stations.

Amphipoda

The cluster dendrogram (Fig. 1.3c) and the MDS plot (Fig. 1.3d) for the amphipods coincide almost completely with those derived over all orders. There were only slight differences in the similarity values, compared to the overall picture.

Isopoda

In the cluster diagram of the isopods (Fig. 1.3e), station 1047 in the Southwest differs from the other stations and shows only a joint similarity of 38%. The stations from the East are well separated from those in the West, except station 1031. The eastern station 1007 differs from a cluster consisting of the deeper stations 1013, 1016 and 1023. Station 1031 (Southeast) is well integrated in the western stations, although it shows relatively high similarity to some eastern stations (e.g. station 1023 64%). Stations 1075 and 1093 show again the highest similarity between stations (72%). Looking at the MDS plot (Fig. 1.3f) without the superimposed layers, it is obvious how similar the species composition of stations 1031, 1046, 1075 and 1093 is. On the other hand, station 1031 shows also a species composition similar to stations 1023, 1016 and 1013. Stations 1007 and 1047 differ clearly from the others. Generally, the MDS plot of isopods exhibits an ordination similar to that of all orders, with slightly more stretched clusters.

Cumacea

The cluster dendrogram (Fig. 1.3g) and the MDS plot (Fig. 1.3h) present a different result as in the previous orders. There are no single stations separated, and consistently two stations are clustering together at least on a 60% similarity level. In the cluster dendrogram, station 1031 (Southeast) is more similar to station 1046 than to the other eastern stations. These two stations show the highest similarity level overall (86%). The remaining eastern stations are clearly separated from the “western” stations, showing only 30% similarity overall.

The MDS plot, however, integrates station 1031 into the eastern cluster. Looking at the MDS plot without the superimposed layers, it is also clear that stations 1031 and 1046 have the most similar species composition, since they are located closest together. Stations 1031 and

1046 build a kind of linkage between an eastern and a western fauna, since the remaining western stations and the remaining eastern stations are far apart. Including the superimposed layers, the distinction between eastern and western stations and therefore their fauna is considerable.

Tanaidacea

The most obvious pattern of the dendrogram (Fig. 1.3i) is the clear separation of station 1112 from the others. Stations 1075 and 1093 cluster together with a moderate similarity level of 65%. The MDS plot (Fig. 1.3j) shows again a separation between eastern and western stations. Without superimposed clusters, the high similarities of station 1016 with station 1031 (76%) and station 1046 (65%) are obvious. Stations 1013, 1016, 1023, 1031 and 1046 form a cluster with a joint similarity of 55%. Stations 1007 and 1112, the northernmost stations in the East and West, both differ clearly from all other stations.

Identification of discriminator species (SIMPER analysis)

For the SIMPER analysis, the stations were divided into six groups on a similarity level of 60%, resulting from the MDS plot. Since stations 1007, 1047 and 1112 individually differ clearly from the remaining stations in their species composition, they each represent a group consisting of only a single station. Therefore, an internal comparison is not possible. The resulting groups were: Group 1 represented by station 1007, group 2 by stations 1013 and 1016, group 3 by stations 1023 and 1031, group 4 by stations 1046, 1075 and 1093, group 5 by station 1047 and finally group 6 by station 1112.

Amphipoda

The SIMPER analysis for the Amphipoda was not clear-cut. Although dissimilarities between groups were considerable with up to 69%, the number of species explaining the cumulative percent contribution to group separation varied between 51 and 80 species to reach a cut-off value of 90%. Among the species contributing on average 4 – 7% to the distinction between groups were *Amphilochus manudens, Tmetonyx cicada, Ampelisca aequicornis, Phoxocephalus holboelli, Harpinia crenulata, Caprella rinki,* the *Leucothoe spinicarpa* group*, Melita gladiosa* and *Apherusa sarsi*. For the separation of the East from the West, the average contribution by individual species was generally low. Nevertheless, *Hardametopa nasuta, Photis reinhardi* and *Phoxocephalus holboelli* were the species with the highest contribution for separation (2 – 3%) since they were very abundant mostly or only in the West.

Isopoda

The highest dissimilarity was found between groups 1 & 5 (76%). Relatively clear group dissimilarities were also found between groups 1 & 4 (69%), groups 2 & 5 (66%), groups 1 & 6 (67%) and groups 2 & 6 (64%). Those species which are present in one group, but not in the other compared group contribute most to the group separation. *Janira maculosa, Iolella laciniata, Nannoniscus oblongus, Disconectes furcatus, Austroniscus* cf. *norbi,* most of the *Pleurogonium* species and the *Munna* species have on average 7 – 10% contribution. These species, except for *Janira maculosa*, *Disconectes furcatus* and *Austroniscus* cf. *norbi* are also among those having the highest contribution to the separation of the eastern from the western fauna.

Cumacea

The dissimilarities between groups 2 & 4 (76%), groups 1 & 6 (80%) and groups 2 & 5 (85%), but especially between groups 2 & 6 (94%) are remarkable. The majority of these clear group distinctions can be inferred from the high dissimilarities to group 2, which consists of deep eastern stations. Generally, stations which are geographically more distant show the highest dissimilarities. In general, the dissimilarity was explained by the abundant species *Leucon* cf. *nasicoides, Leucon* cf. *nathorsti, Cumella carinata, Petalosarsia declivis, Campylaspis horrida, Campylaspis verrucosa* and *Leptostylis macrura,* with 9 – 16% contribution each.

Tanaidacea

As there were only few dominant tanaid species present in the material, the group separation was relatively clear-cut, with up to 100% dissimilarity between the northernmost stations in the East and West (stations 1007 and 1112). The species consistently contributing 13 – 29% on average were *Typhlotanais* sp. 1 and 2, *Ansphyrapus tudes*, *Heterotanais groenlandicus*, *Paraleptognathia gracilis* and *Pseudotanais oculatus*.

Influence of environmental factors on the species composition (BIO-ENV analysis)

The best results of the BIO-ENV analysis for all considered orders (Amphipoda, Isopoda, Cumacea and Tanaidacea) together are summed up in Tab. 1.7a-c. Depth and sediment type is the most important combination of environmental variables, explaining 61% of the species composition in the entire investigation area (Tab. 1.7a). Latitude and sediment type are the most important variables explaining the species distribution in the East (Tab. 1.7b). Latitude has also a major impact (almost 70%) on the species composition as a single factor. In the West (Tab. 1.7c), a combination of latitude, temperature and sediment type is affecting the species composition most (nearly 70%), and a slightly lower correlation was found for depth and sediment type. A single factor, sediment, describes the species distribution by 64%, and since this value is not much lower than for the abovementioned combinations of variables, it has the highest influence on the species composition in the West.

Tab. 1.7a-c: Best results of the BIO-ENV analysis, giving the correlation between environmental variables and species compositions for Amphipoda (A), Isopoda (I), Cumacea (C) and Tanaidacea (T) together. The codes for the environmental variables are: 1 = latitude, 2 = bottom temperature [°C], 3 = bottom salinity, 4 = depth [m] and 5 = sediment type; a) East and West together, b) only for the East and c) only for the West.

a

A,I,C,T overall	
Best result correlation	Variables
0.606	4,5
0.567	1,4,5
0.552	2,4,5
0.544	2,3,4,5
0.54	1,3-5
0.54	3-5

b

A,I,C,T only EAST	
Best result correlation	Variables
0.721	1,5
0.697	1
0.697	1,2,4
0.673	1,2
0.673	1,2,5
0.6	2
0.6	1,4

c

A,I,C,T only WEST	
Best result correlation	Variables
0.697	1,2,5
0.685	4,5
0.673	1,3,4,5
0.64	5
0.636	1,4,5

Discussion

The peracarid species composition varies considerably between study sites of the Southeast and Southwest Greenland shelves. Their distribution is rather patchy, depending presumably on a number of factors such as food availability (Holme & McIntyre 1984). The sampling of epibenthic material using sledges or other towed gear is always semi-quantitative, as infaunal organisms seem to be slightly undersampled (Brandt et al. 1996, Hilbig 2004). Nevertheless, the samples analysed in this study showed high abundances across all orders of peracarid crustaceans. This demonstrates the usefulness of the sampling gear. For an accurate comparison of the diversity between sampling sites, Gray (1994) recommends the standardisation of sampling, particularly in terms of gear and sieve size. Gray's (1994) recommendation is problematic, as apart from Nickel (2004), no other studies have been carried out using the Rauschert sledge (chapter 3) in northern waters to date, and therefore studies for faunal comparisons are limited. Moreover, Nickel (2004) investigated a fjord system, which presents a considerably different habitat to that investigated in the present study. In Antarctic waters, though, the Rauschert sledge has been used several times (e.g. de Broyer & Rauschert 1999, de Broyer et al. 2001, Arntz et al. 2006, Rehm et al. 2006), and it also showed high efficiency for catching epibenthic crustaceans. The Rauschert sledge itself is much smaller than the epibenthic sledge frequently used in the past in the Northern Seas (after Rothlishberg & Pearcy 1977, Brenke 2005), which samples a considerably smaller area and volume. The sledge is equipped with a grid keeping all large objects out off the nets (about 10 cm in size). This selective nature of the sledge excludes parts of the epibenthos being sampled in other studies carried out with other sampling gear, like for example Agassiz trawls (Rehm et al. 2006). Due to the grid, the samples did not contain any large sponges, but from other methods used during cruise WH233 such as a fishery bottom trawl, it is known that sponges are an important element of the benthic fauna especially in the East.

Even though the trawling time was only 5 minutes (compared to usually 10 - 15 minutes in other studies, e.g. Lörz et al. 1999, Lörz 2000, Nickel 2004), the number of species and abundance of peracarids is remarkably high. In total, 219 peracarid species (67,032 specimens) were identified at 10 stations, belonging to 126 genera and 59 families, which provide an insight into the recent species composition on the South Greenland shelves. Brandt et al. (1996) caught 38,322 peracarid specimens at 20 stations, belonging to 229 species in the Northeast Water Polynya (Northeast Greenland) by means of an epibenthic sledge. If only those stations of Brandt et al. (1996) are considered with a comparable depth to this study, about 15,000 specimens, belonging to about 150 species were caught. This demonstrates that the diversity is high on the South Greenland shelf. This result would also support Sanders' (1968) hypothesis of a decreasing diversity with increasing latitude, at least for the Greenland shelf. Nevertheless, regional latitudinal gradients are much more complex than originally thought (Roy et al. 1994, 1998) and less regular than often described (Rex et al. 2005). Weisshappel & Svavarsson (1998), however, did not find such a gradient for amphipods, comparing South and North Iceland. The absence of a diversity gradient was already suggested by others, e.g. Brandt (1995), Brandt et al. (1996) and Piepenburg et al. (2001). Ellingsen & Gray (2002) investigated macrobenthos of the Norwegian shelf and did not find evidence of a latitudinal trend. Likewise, the present study does not confirm the results of Rex et al. (2000) who presented a high negative correlation of species richness, diversity index H' and evenness with latitude. Moreover, Sanders' (1968) hypothesis is based on deep-sea fauna and probably cannot be transferred to shelf fauna. Even though the overall regression including all peracarid orders demonstrates that diversity decreases with increasing latitude, this result is dominated by the abovementioned trend in the amphipods which represent 58% of the entire abundance. Nevertheless, in the BIO-ENV analysis, latitude was the most important environmental factor in the East explaining the species distribution overall and in the amphipods by almost 70%. The diversity and evenness of the examined peracarid orders represent a fairly homogenous community with only small variations. Remarkably high diversity and evenness values as found at station 1016 for the isopods indicate that many species (n = 26) were found and that these have been relatively evenly distributed within the species (n = 904). In contrast, low evenness values like those found at stations 1031 and 1046 for the cumaceans and tanaids, can be explained by single species such as *Leucon* cf. *nasicoides*, *Ansphyrapus tudes* and *Typhlotanais* sp. 2, dominating these stations. Since these two stations show similar diversity, evenness and community patterns, the close clustering of these two stations especially in the cumaceans can be explained. Rex et al. (1993) used Pielou's evenness (J') to determine the contribution of the evenness of relative abundance to diversity. They found a significant decrease in evenness with latitude for isopods, which cannot be confirmed for the isopods of this study area or for the peracarids in total. Rex et al. (1993) conclude that latitudinal diversity gradients underlay different causes, however, mainly ecological and/or historical ones.

A comparison of the present species composition (Annex 1.1) with those from other publications and species lists (e.g. Hult 1941, Svavarsson et al. 1993, Brandt et al. 1996) from other North Atlantic areas, reveals that most species found in this study could have been expected in this sampling area. Species which were never reported in this area before are: *Hippomedon propinquus* cf. *sibiricus*, *Kerguelenia borealis* cf. *japonica, Orchomene macroserrata*, *Neopleustes boecki* and *Siphonoecetes typicus*. The finding of *Politolana micropthalma* was also unexpected since this species is rarely found and usually occurs on muddy bottom. In total, 48 species occurred only at single stations and were absent at all other stations, which indicates that these species are either poorly sampled, are “rare” or have a patchy distribution. Examples for patchy distributions are given in this study for some characteristic species such as the amphipods *Unciola planipes* and *Aristias topsenti,* or isopods such as *Katianira bilobata*, *Munna serrata*, *Synidotea nodulosa* or *Astacilla boreaphilis* (Annex 1.1) which were present only at a single station. The latter is only known from South Iceland and East Greenland (Stransky & Svavarsson 2006). Another indication of patchy distribution is given by the fact that only eight species (*Aeginella spinosa, Gammaropsis* cf. *melanops, Amphilochus manudens, Orchomene macroserrata, Tmetonyx cicada, Syrrhoe crenulata, Janira maculosa* and *Munna* cf. *groenlandica*) were present at all 10 stations. The degree of patchiness in species distribution in this study has to be considered with caution since the distances between sampling sites were considerable. Between the northeastern and southeastern station, the distance was 222 nautical miles (nm), from the southeastern to the southwestern 162 nm and from there to the northwestern station 265 nm. Nevertheless, since many species occur at most of the stations, it can be concluded that these are widely distributed.

Although not much is known about the ecology of the peracarids, it is assumed that species with similar living habits occur at stations with similar habitat conditions. Considering only the more abundant isopod species, some species are present only in the East, such as *Nannoniscus oblongus* and *Caecognathia abyssorum*. The rich abundance observed for these species at the eastern stations can very likely be attributed to their known co-occurence with sponges (Klitgaard 1995), which are abundant in the East. Likewise, *Disconectes furcatus,* which was predominantly found in the East, was also reported to be associated with sponges (Klitgaard 1995). *Disconectes furcatus, Eurycope producta* and *Eurycope dahli* belong to the munnopsids, which are known as good swimmers (Hult 1941, Hessler & Strömberg 1989) and therefore have the capability of migrating to more suitable habitats. This would also explain that other species of munnopsids like *Baeonectes muticus, Echinozone coronata* and *Ilyarachna hirticeps* were found in both areas, East and West. The munnopsids are also known to feed on foraminifers (Wilson & Thistle 1985, Svavarsson et al. 1993, Brandt et al. 1994, Gudmundsson et al. 2000). Moore (1985) and Svavarsson & Davíðsdóttir (1994) have shown that foraminifers (Protozoa) occur frequently as epibionts on isopods. These foraminifers belong almost entirely to the genus *Cibicides* (Svavarsson & Davíðsdóttir 1994, 1995; Svavarsson & Ólafsdóttir 1999) and were also found in the study area. They are common on a variety of epibenthic crustaceans and hard substrates such as rocks and seem to prefer an elevated substrate (Lutze & Thiel 1989). Thus, it is not surprising that munnopsids were found together with foraminifers. Like foraminifers, arcturids prefer to be attached to some upright object, including other crustaceans (Hult 1941). On these objects, they use their efficient and long filter setae of their anterior pairs of pereopods (P2-4) for catching particles. The access to an elevated feeding place (heterogenous habitat), therefore, determines the habitat association of arcturids more than the bottom type (Hult 1941). As this is known, it is clear that the munnopsids occur at locations where species with epibionts like arcturids occur as well. This is confirmed by the present data. It is known that some species as e.g. *Janira maculosa* show little susceptibility (Hult 1941). *Janira maculosa* is often found on other host species as parasite, feeding on detritus (Meinert 1877), and is associated with sponges (Robertson 1888, Klitgaard 1995). Its occurrence in both areas (East and West) might reflect its habitat preference. Common species occurring mostly in the West, like some desmosomatids and species of the genus *Pleurogonium,* are known to live on softer sediments (Hult 1941; Kaiser, pers. comm.) and feed on detritus. They might find favourable conditions in the West, where the sediment is rich in macroinvertebrates.

Within the amphipods, some species show pronounced distribution patterns in comparison with other species (Annex 1.1). Like in the isopods, some occur only in the East such as most of the ampeliscids, especially *Ampelisca aequicornis*. Ampeliscids construct tubes in which they lie with the ventral side uppermost and use their antennae for filtering detritus (Enequist 1949). This way of feeding or building tubes seems to be more frequent in the eastern study area. *Paramphithoe hystrix* is known to feed on sponges (Oshel & Steele 1985). Thus, it was expected that *P. hystrix* would occur mostly in the East. This was, however, not confirmed by the present data. Nevertheless, from using other methods such as the fishery bottom trawl during the sampling cruise, it is known that *P. hystrix* is common on the southeastern shelf. Several families occur mostly in the western study area, such as Stenothoidae (especially *Hardametopa nasuta)*, Oedicerotidae, Phoxocephalidae and Pleustidae. Vader (1983) reported that stenothoids seem to be symbionts of sea anemones. However, as sea anemones have not been found in this study, the stenothoids might not be that dependent on them as thought and might find suitable living conditions on the western shelf, being rich in crinoids or other sessile organisms. Enequist (1949) found that oedicerotids were surprisingly homogeneous with regard to feeding habits, as these freely moving or swimming organisms burrow in the upper sediment layer and feed on detritus. A similar burrowing behaviour has been described for ampeliscids and phoxocephalids, but they are more restricted to the sediment, since only the adult males can swim (Enequist 1949). Except for *Harpinia crenulata* which is more abundant in the East, the phoxocephalids obviously prefer a fine and sandy sediment composition, which is rich in detritus and typically found in the West. Species occurring mostly or exclusively in the West have in common that they are detritus feeders, such as species of the genus *Apherusa* (Enequist 1949). The lysianassids do not show a certain pattern in their distribution, and for example *Tmetonyx cicada* and *Orchomene macroserrata* occur at most of the stations. This is not surprising, considering their wide spectrum of feeding habits. Lysianassids are predators, parasites or necrophores (Enequist 1949, Vader 1983, de Broyer 1985, Sainte-Marie & Lamarche 1985, Sainte-Marie 1986a,b, de Broyer & Vader 1990). Few of them occur also in sponges (e.g. Lörz & de Broyer 2004).

Compared to isopods and amphipods, cumaceans display considerably different living modes. They are bottom-dwellers and leave the sediment only during hours of darkness (Zimmer 1941, Watling 1979). Since they live completely buried in the sediment (Gerken & Watling 1999), the substrate composition and quality is crucial. It is unknown, however, which substrate is preferred by which species (Zimmer 1941). They filter small particles from below the sediment surface or graze material from the sediment grains (Watling 1979). Cumaceans show a patchy distribution, but can be very abundant (Gerken & Watling 1999). This is confirmed with the results of the present study (Annex 1.1). Jones (1973) assumed that the genus *Campylaspis* feeds on foraminifers. In Annex 1.1, it is recognisable that all species of *Campylaspis* occur mainly in the East where many foraminifers were recorded as well. *Cumella carinata* occurs only at the northwestern stations, which might be referred to the origin of this species, the Bering Sea and off the Canadian Arctic (Vassilenko 1989). In contrast to the genus *Campylaspis*, the family Diastylidae was found almost exclusively in the western study area (Annex 1.1). They are typical filter feeders and confirm the picture already obtained for the amphipods that detritus filtering species occur mostly in the West.

Little is known about the ecology and feeding habits of tanaids. Most tanaids are raptorial feeders consuming detritus and its associated micro-organisms (Holdich & Jones 1983). They are predominantly found in association with sand, mud or gravel in which they build their tubes which can be up to 10 cm long (Holdich & Jones 1983). Since there were four times as many tanaids found in the West as in the East, the species found in this study seem to prefer sandy and fine sediment structures, where they feed on detritus as already described for the isopods. Station 1075 seems to have best condition for certain tanaid species, such as *Heterotanais groenlandicus* and *Paraleptognathia inermis*, as the highest abundance of tanaids was found at this station.

All MDS ordination plots showed a clear difference between an eastern and a western fauna. Nevertheless, a general conclusion for all orders concerning the differences in abundances between East and West is difficult, as the orders have a different way of living. The separation into an eastern and a western fauna is mainly based on species which show a distribution limited to mostly either the East or the West, such as *Hardametopa nasuta*, *Leucon* cf. *nasicoides*, *Photis reinhardi*, *Phoxocephalus holboelli*, *Pleurogonium spinosissimum*, *Campylaspis horrida* and *Nannoniscus oblongus.*

As a link between the eastern and western fauna, the southernmost stations in the East (station 1031) and the West (station 1046) showed high similarities to each other. Several species co-occur at these stations in similarly high abundances, such as *Leucon* cf. *nasicoides*, *Janira maculosa* and *Amphilochus manudens*, which causes the observed similarity.

The MDS plots displayed well that certain stations are clearly separated from the other stations and therefore represent considerable differences in their species composition. Station 1047 showed a clear separation from the other stations. Although *Janira maculosa* is present at this station, its abundance is much lower than at all other stations (also valid for e.g. *Munna* cf. *fabricii, Munna* cf. *groenlandica, Hardametopa nasuta). Synidotea nodulosa* is the only isopod species exclusively present at this station, and the same is true for amphipods like e.g. *Rhachotropis inflata* and *Odius carinatus*. But this station differs more in the absence or lower abundance of species that are common at most of the other, particularly, closer stations (e.g. *Calathura brachiata, Eugerda* cf. *globiceps, Echinozone coronata*). For stations 1007 and 1112, the situation is similar but the pattern less distinct.

Many abiotic factors, such as depth, temperature, salinity, sediment type and input of organic matter may affect the species composition and distribution of marine invertebrates (e.g. Rex

1981, Brandt 1995). These factors might be interrelated and often difficult to distinguish (Rex 1981). The depth range of the samples in the present study is relatively narrow, compared to other investigations recently carried out in the North Atlantic Ocean (among others Svavarsson et al. 1993, Brandt et al. 1996). Therefore, it was not expected that depth would have any major influence on the species distribution. However, the deeper stations from the East Greenland shelf (stations 1013, 1016 and 1023) generally show a fairly high similarity in their species composition and in their ordination to each other in the MDS plots. The shallower stations of the West Greenland shelf (stations 1075 and 1112), though, do not show this resemblance. Regressions of species richness against depth did not show any correlation. In the BIO-ENV analysis, however, depth in combination with sediment type was the most important factor on the West Greenland shelf.

The allocation of stations to sediment types used in this study does not represent sediment analyses. Since the results from sediment analyses (chapter 4) carried out on a later survey at the same positions, showed equivalent results, it was preferred to work with types. In this classification, it is already visible that at the eastern stations only sediment types 1 and 2 have been found, while in the West, only types 3 and 4 have been observed. This phenomenon is not unexpected, as the influence of the warm Irminger Current (IC) affects the habitat and provides good environmental conditions for other benthic organisms, such as ophiuroids. Comparing the sediment with the species composition and the species ecology, more specimens as well as species (except isopods) have been found on the western shelf as expected. Sediment, however, was one of the most important abiotic factors explaining the species composition in the BIO-ENV analyses. Piepenburg et al. (2001) concluded in their evaluation of several studies in the northern North Atlantic that seabed, besides food availability, affects the benthic community most. It seems likely that big rocks and strong currents which sweep the smaller and softer sediment parts away, are not suitable for sediment-depending specimens such as cumaceans and tanaids. On the contrary, isopods are mostly epibenthic, but among many others, ischnomesids, eurycopids, ilyarachnids or desmosomatids are probably deposit feeders and can also burrow in the upper few centimetres of the sediment (Hessler & Strömberg 1989). Among the amphipods, species ecology differs clearly. Although some of them are also sediment-depending (e.g. ampeliscids and oedicerotids burrow in the sediment), they have a higher number of species which are more mobile than the other orders.

The temperature and salinity profile of each station can differ considerably, depending on the surrounding water masses (see chapter 2). Generally, the water masses of the cold East Greenland Current (EGC) dominate on the Eastern shelf, while the IC's influence is highest at the shelf break and the continental slope (see http://www.klima-bml.de/wh067/). Nevertheless, it is impossible to separate these two water masses clearly since they interfere, and temperature and salinity profiles show strong (short- and long-term) temporal variation. All stations were taken on the shelves, so it can be expected that they always show some influence of the cold polar water transported by the EGC or later by the West Greenland Coastal Current (WGCC). At the eastern stations, the water column in the upper layer is relatively warm and the influence of the IC is dominating. Below that, at 100-150 m depth, the temperature decreases considerably and forms an intermediate water mass of EGC and IC. The decrease in temperature shows the influence of the EGC. Especially at stations 1013 and 1016, the influence of the EGC is strong (Tab. 1.1). In the Southeast at station 1031, the situation is different. With clearly higher temperature and salinity values (Tab. 1.1) than the other eastern stations, the profile shows that the water masses at the bottom are in contrast to the upper layers (see chapter 2). The bottom water masses are clearly influenced by the IC. Station 1031 represents more the hydrographic situation of the western stations. This might also explain the similarity in species composition of isopods, cumaceans and tanaids between station 1031 and the western stations, especially station 1046. In the East, the temperature was high at the surface and decreased with depth, while this was contrasted by the western stations. Except for station 1075, all western stations were taken on the outer side of the shelf banks. They are located in a water mass which presents a mixture of warm WGC water and cold water from the coastal current (Fig. 1.1b). Temperature profiles (as in chapter 2) show a clear influence of the warm branch of the IC at the bottom. Station 1075 is located closer to the coast and shows lower values in temperature and especially salinity as on the other western stations. This explains a clear influence of cold polar water, originated in the WGC branch transporting cold polar water from the EGC along the West Greenland coast (Stein 2005a).

Slight salinity variations as measured in this study seem not to have much influence on the species composition, neither in the East nor in the West. In contrast, Weisshappel & Svavarsson (1998) have observed that salinity had a major influence on the species composition, although it only varied slightly. In their study, Weisshappel & Svavarsson (1998), however, used salinity rather as an indicator of the origin of water masses than to explain differences in species composition by means of this single factor.

Temperature was slightly lower at the deeper stations which did not have any effect on the species composition, though. This result is expected since Brandt (1995) could not demonstrate any effect on organisms with changing temperature within in-situ experiments. In some areas, Palerud (1992) and Weisshappel & Svavarsson (1998) observed a high correlation between temperature and species composition with increasing depth.

As already assumed by Weisshappel & Svavarsson (1998) for amphipods, the patterns of diversity are presumably shaped by various environmental factors in certain parts of the study area, and these factors might differ from those influencing the diversity patterns of other marine taxa in the study area.

Conclusions

Peracarid crustaceans are rich in species numbers and abundance on the South Greenland shelves and show a fairly homogenous community, with only small variations regarding evenness and diversity. Nevertheless, the fauna of the East is different from that of the West, which is mainly caused by different environmental factors and the habitat preferences of species to suitable sediments. This dependency was different for the individual orders. For amphipods, a latitudinal gradient with decreasing diversity was found. This gradient was absent in all other examined orders. Sediment structure also seems to strongly affect species composition, since the sediments are different between East and West and the species composition and their ecology usually fits well with these sediment patterns. The factors controlling the peracarid faunal abundance vary and should be seen as site-specific and as part of a group of controlling factors.

For future investigations, it would be advisable to include more elements of the benthic community (other invertebrate taxa) and as much detail as possible on the abiotic factors to obtain a more integrative understanding of the ecosystem, in particular the interrelationships between different taxa and their dependence on the environment. This approach would be especially interesting with regard to long-term series under the aspect of climate change. Temporal trends in species composition and diversity of peracarid crustaceans as a model group in dependency of environmental factors were investigated in chapter 2.

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Annex

Annex 1.1: Species list of all 10 stations in taxonomic order.

Family	Species	NE-				SE-	SW-			NW-Greenland	
						Station					
		1007	1013	1016	1023	1031	1046	1047	1075	1093	1112
Amphipoda											
Aoridae	*Autonoe borealis* (Myers, 1976)	2	0	0	0	0	23	0	85	113	6
Caprellidae	*Aeginella spinosa* Boeck, 1861	8	7	6	20	16	912	39	3	72	2
	Aeginina longicornis (Krøyer, 1843)	0	0	0	0	2	28	9	0	9	2
	Caprella ciliata Sars, G.O., 1895	0	2	0	0	0	0	0	0	8	0
	Caprella dubia Hansen, 1887	4	0	0	5	9	183	8	42	183	3
	Caprella rinki Stephensen, 1916	0	44	23	4	2	496	42	0	0	0
	Cercops holboelli Krøyer, 1843	0	0	0	0	0	0	0	70	14	0
	Proaeginina norvegica (Stephensen, 1931)	2	0	0	0	1	0	0	0	0	0
	Caprellidae spp.	0	18	2	0	18	481	7	0	40	1
Corophiidae	*Protomedeia fasciata* Krøyer, 1842a	0	0	0	0	10	0	218	0	0	0
Dulichidae	*Dulichia* cf. *falcata* (Bate, 1857)	0	18	0	1	4	38	9	10	82	2
	Dulichia spinosissima Krøyer, 1845	0	0	0	0	0	16	1	0	2	1
	Dyopedos porrectus Bate, 1857	0	1	0	0	2	116	68	19	7	1
	Dyopedos sp. 1	0	0	0	0	0	0	1	0	0	0
	Paradulichia typica Boeck, 1871	0	15	6	1	0	0	33	0	2	1
Ischyroceridae	*Ericthonius megalops* (Sars, G.O., 1879)	0	0	0	0	1	0	2	1	0	0
	Ischyrocerus anguipes Krøyer,1838	0	0	0	5	254	0	80	182	373	31
	Ischyrocerus latipes Krøyer, 1842a	0	329	0	0	0	0	3	0	0	0
	Ischyrocerus megacheir (Boeck, 1871)	11	194	3	18	0	277	1	5	36	0
	Ischyrocerus megalops Sars, G.O., 1894	0	0	0	2	8	0	6	11	41	2
	Ischyrocerus T1 Just, 1980	0	0	0	0	0	0	0	0	1	0
	Siphonoecetes typicus Krøyer, 1845	0	0	0	4	0	1	32	0	0	7
Photidae	*Photis reinhardi* Krøyer, 1842a	0	0	0	208	8	1371	639	266	246	46
	Gammaropsis cf. *melanops* Sars, G.O., 1879	16	149	4	32	18	57	94	751	267	80
	Gammaropsis sp. 1	0	0	0	0	0	0	1	0	0	0
Podoceridae	*Laetmatophilus tuberculatus* Bruzelius, 1859	4	58	4	49	2	0	0	0	0	0
	Podoceridae spp.	0	0	0	2	0	0	0	0	0	0
Unciolidae	*Unciola laticornis* Hansen, 1887	18	172	9	14	63	82	0	179	7	0
	Unciola leucopis (Krøyer, 1845)	5	2	0	92	2	21	2	65	13	5
	Unciola planipes Norman,1867	0	0	0	0	0	0	265	0	0	0
	Unciola spp.	0	0	0	0	0	0	0	3	0	0
	Corophiidea spp.	1	539	62	68	2	12	11	213	26	18
Amphilochidae	*Amphilochus manudens* Bate, 1862	269	506	199	1170	458	983	16	108	5	15
	Amphilochus tenuimanus Boeck, 1872	62	10	22	97	63	102	44	9	66	0
	Gitanopsis cf. *arctica* Sars, G.O., 1892	25	0	0	0	0	107	27	312	336	0
	Gitanopsis bispinosa (Boeck, 1871)	0	35	13	16	5	264	2	9	163	6
	Amphilochidae spp.	6	10	10	18	4	23	2	4	26	0
Ampeliscidae	*Ampelisca aequicornis* Bruzelius, 1859	1	40	34	4	0	0	0	0	0	0
	Ampelisca eschrichtii Krøyer, 1842a	2	0	0	0	0	0	0	0	0	0
	Ampelisca macrocephala Lilljeborg, 1852	3	0	0	0	0	0	30	1	13	0
	Byblis crassicornis Metzger, 1875	0	3	0	0	0	0	0	0	0	0
	Byblis gaimardi (Krøyer, 1846a)	9	0	11	1	3	5	5	2	6	1
	Haploops setosa Boeck, 1871	0	11	0	1	0	0	0	0	4	8
	Haploops sp. 1	0	0	0	0	1	0	0	0	0	0
	Ampeliscidae spp.	0	0	0	0	0	0	0	2	3	0
Argissidae	*Argissa hamatipes* (Norman, 1869)	0	0	0	0	0	0	17	0	2	0
Atylidae	*Atylus smitti* Goës, 1866	0	0	0	0	2	2	0	0	4	4
Dexaminidae	*Guernea* sp. 1	0	0	0	0	0	0	0	60	132	92
Epimeriidae	*Paramphithoe hystrix* (Ross, 1835)	1	1	0	0	0	1	3	0	2	1
Eusiridae	*Eusirus propinquus* Sars, G.O., 1893	0	0	1	0	1	0	0	0	0	0
	Rhachotropis aculeata (Lepechin, 1780)	0	0	1	0	5	0	0	2	3	2
	Rhachotropis inflata (Sars, G.O., 1882)	14	10	2	57	43	46	0	93	400	13
	Rhachotropis oculata (Hansen, 1887)	0	0	0	0	0	0	11	0	0	0
Calliopiidae	*Apherusa bispinosa* (Bate, 1856)	0	0	0	0	0	0	0	0	0	14
	Apherusa sarsi Shoemaker, 1930a	0	0	0	0	0	0	0	6	62	702
	Cleippides tricuspis (Krøyer, 1846a)	0	2	1	0	0	0	1	0	6	10
	Laothoes meinerti Boeck, 1871	3	16	3	12	1	0	0	0	0	0
Iphimediidae	*Acanthonotozoma cristatum* (Ross, 1835)	0	4	0	0	0	1	0	0	0	0
	Acanthonotozoma serratum (Fabricius, 1780)	1	7	0	15	31	53	5	31	20	2

Continuation of Annex 1.1:

Family	Species	NE-				SE-	SW-				NW-Greenland
						Station					
		1007	1013	1016	1023	1031	1046	1047	1075	1093	1112
Leucothoidae	*Leucothoe spinicarpa* (Abildgaard, 1789) group	6	49	21	28	22	31	0	133	7	0
Liljeborgiidae	*Liljeborgia fissicornis* (Sars, M., 1858)	1	0	2	11	0	0	18	0	0	0
	Liljeborgia cf. *macronyx* Sars, G.O., 1895	0	1	0	0	0	0	0	0	0	0
	Liljeborgia pallida (Bate, 1857)	6	3	1	5	310	7	0	1025	3	0
	Liljeborgia sp. 1	0	0	0	0	0	0	0	14	0	0
	Liljeborgia spp.	0	0	3	9	0	0	0	0	0	0
Melitidae	*Melita dentata* (Krøyer, 1842a)	0	0	0	0	3	0	2	10	0	13
	Melita gladiosa Bate, 1862	0	16	83	13	44	8	0	21	26	34
	Melita obtusata (Montagu, 1813)	0	0	0	0	0	51	3	71	1	2
	Melitidae spp.	0	1	0	2	7	0	0	0	0	6
Melphidippidae	*Melphidippida borealis* Boeck, 1871	0	0	0	0	0	0	17	0	0	0
	Melphidippida goesi Stebbing, 1899	1	2	1	0	0	1	1	0	11	0
	Melphidippidae sp. 1	0	0	0	0	0	87	0	0	0	0
Ochlesidae	*Odius carinatus* (Bate, 1862)	15	6	4	6	59	234	0	246	373	120
Oedicerotidae	*Bathymedon saussurei* Boeck, 1871	0	0	0	4	12	0	0	0	0	0
	Monoculodes borealis Boeck, 1871	0	0	0	1	8	5	0	0	3	3
	Monoculodes cf. *latimanus* (Goës, 1866)	0	0	0	0	12	3	2	38	444	83
	Monoculodes cf. *norvegicus* (Boeck, 1861)	0	0	0	34	69	2	0	10	0	0
	Monoculodes cf. *packardi* Boeck, 1871	0	0	0	0	0	0	0	0	1	0
	Monoculodes cf. *pallidus* Sars, G.O., 1892	0	0	0	0	0	0	27	0	0	0
	Monoculodes cf. *subnudus* Norman, 1889	0	0	0	0	0	3	0	0	81	4
	Monoculodes cf. *tesselatus* Schneider, 1883	0	0	0	0	0	0	0	0	39	14
	Monoculodes tuberculatus Boeck, 1871	0	0	0	0	14	9	2	72	119	2
	Monoculodes spp.	1	0	40	0	68	4	0	17	0	0
	Oediceros cf. *borealis* Boeck, 1871	0	0	0	0	0	0	8	0	13	3
	Oediceros sp. 1	0	0	0	0	0	0	0	0	3	0
	Paroediceros lynceus (Sars, M.,1858)	28	0	14	14	50	57	15	2	4	18
	Paroediceros spp.	7	0	0	0	0	0	0	0	0	0
	Pontocrates spp.	0	0	0	0	0	0	85	0	0	0
	Westwoodilla cf. *brevicalcar* (Goës, 1866)	0	0	0	0	0	0	0	2	40	3
	Westwoodilla cf. *caecula* (Bate, 1856)	0	0	0	0	0	0	0	27	269	33
	Westwoodilla cf. *megalops* (Sars, G.O., 1882)	0	0	0	0	1	4	7	50	148	34
	Oedicerotidae spp.	9	0	0	22	50	20	40	25	25	32
Pardaliscidae	*Pardalisca abyssi* Boeck, 1871	0	0	2	0	0	0	0	0	0	0
	Pardalisca cuspidata Krøyer, 1842a	0	0	0	5	23	1	0	26	0	17
Pleustidae	*Neopleustes boecki* (Hansen, 1888)	0	0	0	0	0	61	1	50	37	0
	Parapleustes biscuspis (Krøyer, 1838)	0	0	0	0	0	3	1	90	1	0
	Pleustes tuberculatus Bate, 1858	0	5	2	3	0	14	2	2	0	0
	Stenopleustes cf. *nodifer* Sars, G.O., 1883	0	0	0	0	0	4	0	7	22	0
	Stenopleustes sp. 1	0	11	0	2	2	33	3	38	46	0
	Pleustidae juveniles	0	0	5	0	3	0	2	10	279	0
Stegocephalidae	*Andaniopsis pectinata* Sars, G.O., 1882	0	19	6	32	80	23	0	64	16	0
	Phippsia roemeri Schellenberg, 1925	0	9	0	0	0	5	0	0	1	0
	Stegocephalus inflatus Krøyer, 1842a	0	0	0	5	0	2	0	0	3	2
	Stegocephalidae spp.	0	1	0	0	0	0	0	0	0	0
Stenothoidae	*Hardametopa nasuta* (Boeck, 1871)	0	0	0	0	0	347	11	265	499	500
	Metopa norvegica (Lilljeborg, 1851a,b)	0	0	0	0	2	5	1	28	29	9
	Metopa cf. *propinqua* Sars, G.O., 1892	10	3	0	3	25	1	4	24	140	33
	Stenothoidae spp.	45	45	69	83	303	243	168	520	1510	241
Synopiidae	*Bruzelia tuberculata* Sars, G.O., 1882	2	4	14	108	87	22	0	0	0	0
	Syrrhoe crenulata Goës, 1866	31	8	3	41	214	25	36	228	486	732
	Syrrhoides serrata (Sars, G.O., 1879)	0	4	4	0	0	0	0	0	0	0
	Tiron spiniferum (Stimpson, 1853)	64	0	0	62	125	27	51	38	89	22
	Synopiidae spp.	0	0	0	1	0	0	1	0	7	0
Urothoidae	*Urothoe elegans* (Bate, 1856)	32	0	5	34	30	45	50	2	19	3
Lysianassidae	*Ambasia atlantica* (Milne-Edwards, 1830)	0	0	2	1	3	0	0	0	0	0
	Ambasiella murmanica (Brüggen, 1905)	0	0	0	0	0	0	0	1	1	5
	Anonyx debruyni Hoek, 1882	1	0	0	0	0	0	0	0	23	48
	Anonyx cf. *nugax* (Phipps, 1774)	2	0	4	6	2	0	0	52	0	0
	Anonyx sp. 1	0	0	0	0	0	1	0	0	0	0

Continuation of Annex 1.1:

Family	Species	NE-				SE-	SW-			NW-Greenland	
						Station					
		1007	1013	1016	1023	1031	1046	1047	1075	1093	1112
Lysianassidae	*Anonyx* sp. 2	0	0	0	0	0	0	1	0	0	0
	Anonyx sp. 3	0	0	0	0	1	0	0	3	0	0
	Aristias topsenti Chevreux, 1900	0	0	0	0	0	0	0	20	0	0
	Aristias tumidus (Krøyer, 1846a)	0	0	0	0	0	0	0	17	0	9
	Gronella groenlandica (Hansen, 1887)	0	0	0	0	1	0	0	2	0	0
	Hippomedon gorbunovi Gurjanova, 1930	2	0	1	0	3	5	0	2	5	1
	Hippomedon propinquus cf. *sibiricus* Gurjanova, 1962	4	0	3	1	0	0	0	0	0	0
	Kerguelenia borealis cf. *japonica* Gurjanova, 1962	2	48	3	0	0	0	0	0	0	0
	Lysianella petalocera Sars, G.O., 1882	4	15	0	19	20	1	0	53	2	0
	Onisimus plautus (Krøyer, 1845)	1	0	0	0	0	0	4	0	0	0
	Orchomene cf. *lepidula* Gurjanova, 1962	0	0	1	0	0	0	0	3	3	1
	Orchomene macroserrata Shoemaker, 1930b	1	10	11	4	18	78	2	260	19	1
	Orchomene pectinata Sars, G.O., 1882	1	0	0	3	2	4	10	0	1	44
	Opisa eschrichtii (Krøyer, 1842a)	0	0	0	0	0	0	0	1	7	5
	Schisturella sp. nov.	0	0	0	0	0	0	0	9	0	0
	Socarnes bidenticulatus (Bate, 1858)	0	0	0	2	1	0	0	1	1	0
	Socarnes vahli (Krøyer, 1838)	0	0	0	1	7	160	17	74	0	11
	Tmetonyx cicada (Fabricius, 1780)	5	152	91	30	327	6	19	260	64	687
	Tryphosella schneideri (Stephensen, 1925)	1	0	158	0	2	43	0	7	3	0
	Tryphosella sp. 1	0	0	0	0	1	0	0	0	0	0
	Tryphosella sp. 2	0	0	0	1	0	0	0	0	0	0
	Lysianassidae sp. 1	0	0	0	0	1	0	0	0	0	0
	Lysianassidae sp. 2	0	0	0	0	0	0	0	0	0	4
	Lysianassidae sp. 5	0	0	1	0	0	0	0	0	0	0
	Lysianassidae sp. 6	0	0	2	0	0	0	0	0	0	0
	Lysianassidae spp.	0	3	63	1	30	15	0	68	0	3
Phoxocephalidae	*Harpinia crenulata* (Boeck, 1871)	0	26	36	23	44	29	0	0	0	0
	Harpinia cf. *plumosa* (Krøyer, 1842a)	0	0	0	0	0	0	0	2	2	0
	Harpinia propinquus Sars, G.O., 1891	0	0	2	6	47	83	51	81	161	6
	Harpinia sp. 1	0	0	0	9	1	0	0	0	0	0
	Harpinia spp. 1	0	0	1	7	8	9	1	2	0	0
	Harpinia spp. 2	0	0	1	0	6	9	0	5	0	0
	Paraphoxus oculatus (Sars, G.O., 1879)	0	0	1	0	0	0	0	16	0	1
	Phoxocephalus holboelli (Krøyer, 1842a)	0	0	0	52	0	39	1247	86	155	70
	Phoxocephalidae spp.	1	8	2	18	10	19	106	42	36	25
Hyperiidae	*Themisto gaudichaudi* Guérin, 1828	1	4	4	2	0	1	0	0	3	5
Indet	Amphipoda spp.	0	1	26	0	3	26	1	0	78	0
	Amphipoda sp. 1	0	0	0	0	0	0	0	0	4	0
Isopoda											
Anthuridae	*Calathura brachiata* Stimpson, 1853	0	18	57	24	17	1	0	22	109	0
Dendrotionidae	*Dendrotion paradoxum* Hansen,1916	0	0	3	0	0	0	0	0	0	0
Desmosomatidae	*Eugerda* cf. *globiceps* (Meinert, 1890)	0	0	2	0	90	48	0	81	132	5
	Eugerdella cf. *armata* (Sars, G.O., 1864)	0	0	59	0	0	0	0	18	0	0
	Rapaniscus cf. *crassipes* Hansen, 1916	0	1	0	0	0	0	0	0	0	0
	Nannoniscus oblongus Sars, G.O., 1869	27	26	53	18	134	1	0	0	0	0
	Austroniscus cf. *norbi* Svavarsson, 1982 b	0	0	0	9	0	0	0	0	32	12
	Austroniscus sp. 1	0	0	0	0	180	26	0	11	0	0
	Austroniscus sp. 4	0	1	17	0	0	0	0	0	0	0
Ischnomesidae	*Heteromesus frigidius* Hansen,1916	0	0	7	1	0	0	0	0	0	0
	Ischnomesus spp.	0	0	0	1	0	0	0	0	0	0
Janiridae	*Iolella laciniata* (Sars, G.O., 1872)	31	142	33	93	2	21	0	0	0	0
	Iolella spinosa (Harger, 1879)	0	0	0	0	0	4	2	2	10	5
	Janira maculosa Leach, 1814	245	836	307	804	1065	492	6	353	364	408
Katianiridae	*Katianira bilobata* Gurjanova, 1930	0	0	0	0	7	0	0	0	0	0
	Katianira chelifera Hansen,1916	0	3	7	0	0	0	0	0	0	0
Munnidae	*Munna* cf. *fabricii* Krøyer, 1846a	0	31	27	76	27	216	26	207	367	13
	Munna cf. *groenlandica* Hansen,1916	55	92	46	17	67	575	8	676	515	36
	Munna cf. *hanseni* Stappers, 1911	2	25	17	57	0	0	1	0	0	0
	Munna cf. *minuta* Hansen, 1910	0	24	0	2	57	67	10	200	1350	22
	Munna serrata Kussakin, 1962	0	0	0	0	0	0	0	0	0	58
	Munna spp.	1	64	4	32	1	25	2	73	18	28

Continuation of Annex. 1.1:

Family	Species	NE-				SE- Station	SW-			NW-Greenland	
		1007	1013	1016	1023	1031	1046	1047	1075	1093	1112
Munnopsidae	*Baeonectes muticus* (Sars, G.O., 1864)	0	0	0	6	2	1	0	21	60	1
	Disconectes furcatus (Sars, G.O., 1870b)	0	0	13	26	36	0	0	9	0	16
	Disconectes phallangium (Sars, G.O., 1864)	0	0	1	0	0	0	0	0	0	0
	Eurycope dahli Svavarsson, 1987	0	0	3	12	0	0	0	2	0	0
	Eurycope producta Sars, G.O., 1866	0	4	6	18	5	2	1	0	0	0
	Tytthocope megalura (Sars, G.O., 1872)	0	1	1	0	0	0	0	0	0	0
	Eurycopinae spp.	0	0	0	10	0	0	0	0	0	0
	Aspidarachna clypeata Sars, G.O., 1870b	0	0	7	0	0	0	0	0	0	0
	Echinozone arctica Hansen, 1916	0	0	0	0	0	14	0	0	7	0
	Echinozone coronata (Sars, G.O., 1870b)	4	14	30	10	17	194	0	18	53	0
	Echinozone spp.	0	0	0	0	0	4	0	0	0	0
	Ilyarachna hirticeps Sars, G.O., 1870b group	0	0	7	1	33	2	0	14	18	0
Paramunnidae	*Pleurogonium inerme* Sars, G.O., 1883	0	0	0	8	0	27	66	48	0	0
	Pleurogonium intermedium Hansen, 1916	0	0	0	11	5	0	43	0	206	2
	Pleurogonium pulchra Hansen, 1916	0	1	16	1	0	0	0	0	0	0
	Pleurogonium spinosissimum (Sars, G.O., 1866)	0	0	0	1	17	74	2	731	126	118
	Asellota spp.	0	0	0	1	0	0	0	0	0	0
Gnathiidae	*Caecognathia abyssorum* Sars, G.O., 1872	2	39	0	25	11	1	0	1	0	0
	Caecognathia elongata Krøyer, 1846a	0	0	0	0	8	0	0	40	22	0
	Caecognathia hirsuta (Sars, G.O., 1877)	0	0	167	0	0	0	0	0	0	0
	Caecognathia females and juveniles	4	56	227	193	110	0	1	267	150	0
Aegidae	*Aega psora* (Linnaeus, 1758)	1	0	0	0	0	0	0	0	0	0
Cirolanidae	*Politolana micropthalma* (Hoek, 1882)	0	0	0	0	0	1	0	0	0	0
Idoteidae	*Synidotea nodulosa* Krøyer, 1846a	0	0	0	0	0	0	11	0	0	0
Arcturidae	*Astacilla boreaphilis* Stransky & Svavarsson, 2006	0	0	5	0	0	0	0	0	0	0
	Astacilla granulata (Sars, G.O., 1877)	0	0	0	0	0	19	1	0	0	0
	Astacilla pusilla (Sars, G.O., 1873)	1	0	0	0	0	0	0	0	0	0
	Astacilla juveniles	0	1	0	1	0	18	0	0	0	0
	Spectrarcturus multispinatus Schultz, 1981	0	19	5	1	0	894	7	0	2	0
	Arcturidae sp. nov.	0	0	0	0	0	1	0	0	0	0
Antarcturidae	*Pleuroprion hystrix* (Sars, G.O., 1877)	0	7	8	1	0	0	0	0	0	0
	Arcturidae spp.	0	6	1	0	1	23	1	1	1	0
Cumacea											
Diastylidae	*Brachydiastylis resima* Krøyer, 1846b	0	0	0	0	0	7	0	4	25	0
	Diastylis cf. *edwardsi* Krøyer, 1841	0	0	0	0	2	3	42	1	26	5
	Diastylis lucifera (Krøyer, 1841)	0	0	0	0	0	0			6	0
	Diastylis spinulosa Heller, 1875	1	0	0	0	0	0	1	1	27	0
	Leptostylis ampullacea (Lilljeborg, 1855)	0	0	0	0	0	0	2	5	0	0
	Leptostylis macrura Sars, G.O., 1870a	1	0	0	0	3	5	23	86	362	6
	Leptostylis villosa Sars, G.O., 1869	0	0	0	0	0	0	1	0	25	0
	Leptostylis spp.	0	0	0	0	0	0	0	0	19	0
Lampropidae	Lampropidae spp.	6	0	0	8	0	0	3	0	0	0
	Hemilamprops cf. *uniplicatus* (Sars, G.O., 1872)	4	0	8	12	0	0	4	0	1	0
	Platyaspis typica (Sars, G.O., 1870a)	0	0	1	1	0	0	0	1	0	0
Leuconidae	*Leucon* cf. *nasica* Krøyer, 1841	0	0	0	0	4	1	1	0	1	0
	Leucon cf. *nasicoides* Lilljeborg, 1855	0	0	0	2	1233	1260	159	191	166	320
	Leucon cf. *nathorsti* Ohlin, 1901	32	1	3	75	40	59	2	13	25	0
	Leucon spp.	0	0	0	1	17	47	4	12	7	3
	Eudorellopsis deformis (Krøyer, 1846b)	0	0	0	0	0	3	2	6	23	2
Nannastacidae	*Campylaspis horrida* Sars, G.O., 1870a	62	36	67	785	88	52	0	0	3	0
	Campylaspis rubicunda (Lilljeborg, 1855)	14	4	0	2	11	17	18	2	5	6
	Campylaspis undata Sars, G.O., 1865	5	3	43	49	2	0	0	0	0	0
	Campylaspis verrucosa Sars, G.O., 1866	0	18	204	7	10	15	0	0	0	0
	Cumella carinata (Hansen, 1887)	0	0	0	0	0	0	0	341	28	185
	Nannastacidae spp.	0	5	12	0	4	0	0	0	0	0
Pseudocumatidae	*Petalosarsia declivis* (Sars, G.O., 1865)	0	0	0	8	0	0	243	0	33	0

Continuation of Annex. 1.1:

Family	Species	NE-				SE-	SW-			NW-Greenland	
						Station					
		1007	1013	1016	1023	1031	1046	1047	1075	1093	1112
Tanaidacea											
Sphyrapodidae	*Ansphyrapus tudes* (Norman & Stebbing, 1886)	0	208	140	5	1	819	0	0	0	0
	Pseudosphyrapus anomalus (Sars, G.O., 1869)	0	0	0	0	3	0	0	0	0	0
Leptocheliidae	*Heterotanais groenlandicus* Hansen, 1913; sensu Vanhöffen, 1914	0	0	0	0	0	1	1	1025	75	3
Leptognathiidae	*Leptognathia breviremis* (Lilljeborg, 1864)	0	0	2	0	1	0	0	0	0	0
	Leptognathia crassa Hansen, 1913	0	2	0	7	0	0	0	0	0	0
	Leptognathia subaequalis (Hansen, 1913)	0	0	0	0	3	0	0	0	0	0
	Leptognathia sp. 1	0	0	0	3	0	0	0	0	0	0
	Leptognathia sp. 2	0	0	0	0	0	2	0	1	0	0
	Leptognathia spp.	0	0	0	8	0	1	2	18	14	1
Nototanaidae	*Tanaissus lilljeborgi* (Stebbing, 1891)	0	0	0	0	0	0	3	0	0	0
Pseudotanaidae	*Cryptocopoides arcticus* (Hansen, 1887)	0	0	2	0	0	0	0	0	0	0
	Pseudotanais oculatus Hansen, 1913	0	0	0	0	0	0	0	118	44	0
	Pseudotanais sp. 1	0	0	1	0	0	0	0	0	2	0
	Pseudotanais spp.	0	0	1	0	0	2	0	0	0	0
Typhlotanaidae	*Typhlotanais* sp. 1	0	0	2	6	2	39	12	45	146	0
	Typhlotanais sp. 2	17	31	21	93	59	109	8	3	7	0
Paratanaoidea	*Paraleptognathia gracilis* (Krøyer, 1842b)	0	0	4	0	4	4	1	8	9	1
	Paraleptognathia inermis (Hansen, 1913)	0	0	0	0	0	0	5	153	0	0
	Paraleptognathia multiserrata (Hansen, 1913)	0	0	0	1	0	0	0	0	5	0
	Paraleptognathia sp. 1	0	0	0	0	0	1	0	0	0	0

Chapter 2:

Geographic and temporal variation in diversity and community patterns of Peracarida (Crustacea: Malacostraca) on the South Greenland shelf

Geographic and temporal variation in diversity and community patterns of Peracarida (Crustacea: Malacostraca) on the South Greenland shelf

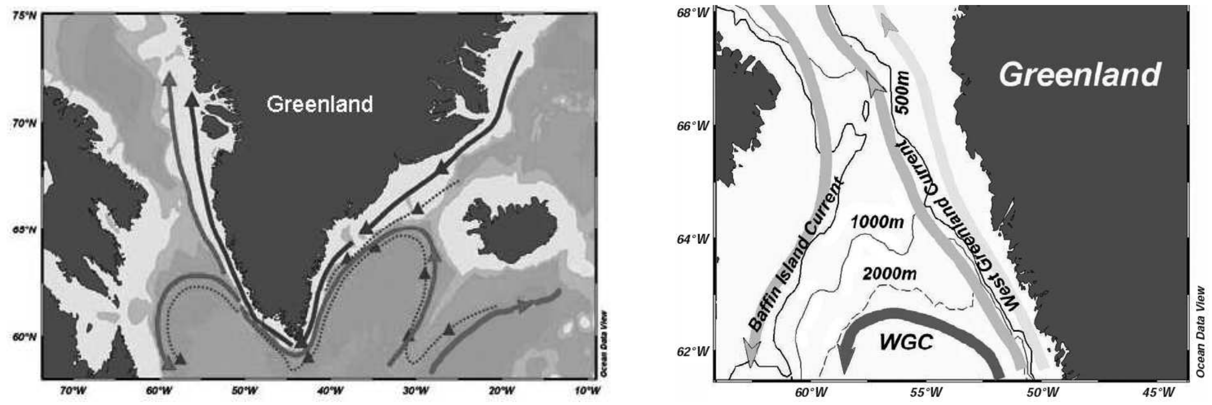
Abstract

The temporal variability in peracarid (Crustacea: Malacostraca) species composition on the South Greenland shelf was studied by analysing corresponding sets of four stations over a sampling period of three years. Moreover, the influence of environmental factors on changes in species composition over time was investigated. Samples were taken by means of a Rauschert sledge in depths about 160 m. Analyses of the samples revealed that South Greenland peracarids are very abundant, but show a decrease in their abundance from 33,389 specimens in the first sampling year (2001) to 32,497 specimens in 2002 and 28,554 specimens in 2004. Nevertheless, with respect to evenness and diversity, the peracarid community was stable over the three years. Moderate changes in temperature and salinity had negligible effects on species composition, but sediment structure was found to be the most important environmental variable for the peracarids. The sediment type at the investigated locations did not display major changes over the studied time-span, whereas salinity and temperature varied over short time scales. The dependency of peracarids on the sediment is explained mostly by their ecology, since most of the analysed specimens were either infaunal or epibenthic.

Introduction

During the last two centuries, numerous expeditions to the North Atlantic and the Arctic have been carried out. The South Greenland shelf, however, has only been investigated rarely with respect to peracarid crustaceans, although Sars (1885, 1899) and others (e.g. Hansen 1916) took several samples in this region. Those and more recent investigations (Svavarsson et al. 1990, 1993; Brandt et al. 1996) in adjacent deep waters have shown that peracarids can be rich both in biomass and diversity on the Greenland shelf, its continental slope and abyss (Svavarsson et al. 1990, 1993; Brandt 1993, 1995). Bousfield (1982), Brandt (1995) and Brandt et al. (1996) observed that gammaridean amphipods are most diverse in depths down to 300 m, especially in temperate and cold waters. Isopods in Arctic waters seem to have a diversity maximum at greater depths than amphipods (below 300 m, Brandt et al. 1996; between 800-1000 m, Svavarsson et al. 1990). Many peracarids are bottom-depending animals. The Amphipoda, for example, have usually good swimming capabilities and others like Cumacea and Tanaidacea display a more infaunal lifestyle. Sediment structure is therefore an important factor for peracarids. The South Greenland shelf is characterised by water masses that differ considerably in temperature, salinity and current velocity (e.g. Dietrich 1959, Stein 1988, Lavender et al. 2000, Stein 2005a, Holliday et al. in press).

The Greenland shelf south of 63°30’N is narrow and continues directly with a steep continental slope (Dietrich 1959). The water masses can be divided from south to north into boreal/subarctic, low-arctic and high-arctic climate zones inhabited among others by invertebrates adapted to these conditions. The Greenland shelf can be divided into two Large Marine Ecosystems (LME) (NOAA 2003, 2004), the East Greenland Shelf LME and the West Greenland Shelf LME. The East Greenland Shelf LME is located along East Greenland’s coast and is mainly influenced by water masses of the cold East Greenland Current (EGC) transporting polar water (temperature ≤ 1°C, salinity ≤ 34.00) across the shelf southwards (Stein 1988, NOAA 2004) (Fig. 2.1a). South of the Greenland Iceland Ridge, the EGC is influenced by the water masses of the warm Irminger Current (IC) (temperature > 4°C, salinity > 34.95). Both currents interfere at the shelf break, producing a mixture of water masses of the EGC and the IC. At Cape Farewell, the currents turn westwards and flow along the continental slope northwards as West Greenland Current (WGC) (Pedersen et al. 2004), which is a part of the West Greenland Shelf LME (NOAA 2003). Branches of the WGC flow along the shelf break and transport intermediate water masses, while on the shelf, however, another branch of the WGC, which transports cold polar water originating from the EGC, flows northwards (Stein 2005a) (Fig. 2.1b). The WGC continues to flow along the West Greenland Shelf northwards into the Davis Strait at about 66° N. Here, the WGC divides into two water masses: one flows further north into Baffin Bay and the other turns southwards and joins the Baffin Island Current flowing southwards along the Canadian coast.

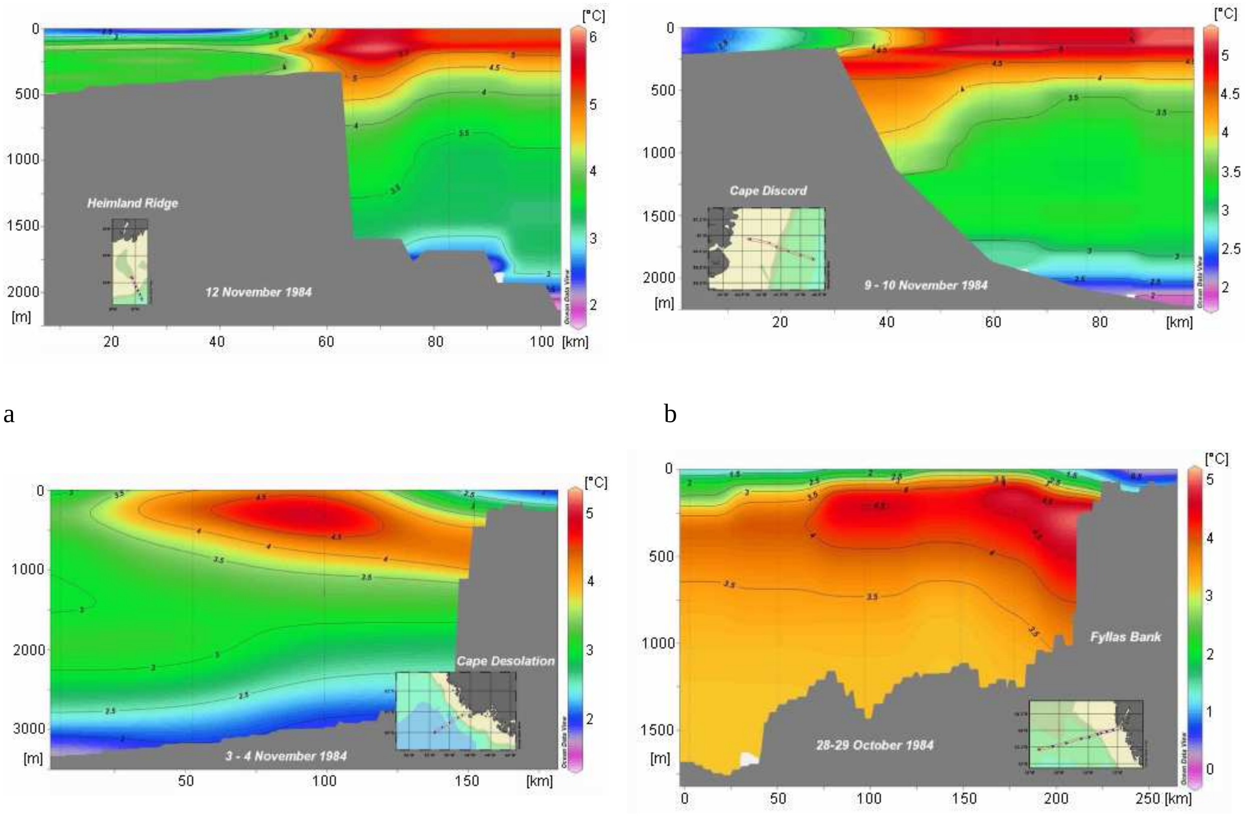


a b

Fig. 2.1a-b: a) schematic diagram of the water current systems off South Greenland; warm water masses from the Irminger Current (IC, light grey), cold polar deep water (dotted) and cold water masses from the East Greenland Current (EGC, dark) on the shelf (after Stein 2005b) and b) water circulation diagram for the Davis Strait region; WGC: branch of West Greenland Current heading west; shelf break component (grey), shelf component (light grey); depth contours for 500 m (bold), 1000 m (thin) and 2000 m (dashed) are given (after Stein 2005a).

In the region off Southeast and Southwest Greenland, where the epibenthic samples were taken, annual groundfish surveys are carried out since 1982. At certain localities (see http://www.klima-bml.de/wh067/), the oceanographic conditions were mapped by means of CTD profiles. The profiles of four locations (Heimland Ridge, Cape Discord, Cape Desolation and Fyllas Bank) close to the epibenthic sampling stations (Fig. 2.2a-d) give an overview of the water masses in these areas. Although these profiles are from 1984, the main structures are still similar and are related to long-term ocean climate observations by Stein (2004, 2005a).

The Heimland Ridge is mostly covered by cold low saline waters of the EGC, while the warm waters of the IC reach only the shelf break (Stein 2006). The Cape Discord shelf bank is mainly influenced by cold water (Stein 2006). Off Cape Desolation, the cold on-shore and the warm off-slope component of the WGC and the cold bottom-water layer (Denmark Strait Overflow) can be observed. Between surface and bottom layers, the Labrador Sea Water and the North Atlantic Deep Water are located (Stein 2006). At Fyllas Bank, the cold, low saline waters of the polar component of the WGC emerge. West of the slope, the warm component of the WGC reaches far into the west (Stein 2006).



a

b

c

d

Fig. 2.2a-d: Oceanographic conditions at the four epibenthic station locations off Southeast and Southwest Greenland - based on the CTD measurements during the 1984 cruise of FRV "*Walther Herwig II*" at a) Heimland Ridge, b) Cape Discord c) Cape Desolation and d) Fyllas Bank. Data source: Federal Research Centre for Fisheries, Hamburg, Germany.

Effects of climate change in the Northern Seas are currently widely discussed (Macdonald et al. 2005). The effects of temporal changes in abiotic factors like temperature, salinity and sediment structure on the species composition, however, have not been studied for the peracarid fauna off South Greenland. A previous study (chapter 1) documented a clear geographic distinction of the peracarid species composition between Southeast and Southwest Greenland. To investigate geographic and temporal variation in species composition, diversity and community patterns, as well as the influence of abiotic factors on the peracarid composition, four locations distributed evenly around South Greenland were revisited during three sampling years (2001, 2002 and 2004).

Material and Methods

This work is based on samples taken by means of a Rauschert sledge (see chapter 3) during cruises WH233, WH244 and WH268 with the German FRV *Walther Herwig III* in 2001, 2002 and 2004. During each cruise, epibenthic material has been taken at four stations, respectively, two located off Southeast Greenland and two off Southwest Greenland (Tab. 2.1, Fig. 2.3). To eliminate the depth effect on the investigated fauna, all samples were taken in approximately the same depth (160 m).

Tab. 2.1: Station data of cruises WH233, WH244 and WH268, showing sample location (haul start positions), haul length, bottom temperature and salinity, depth and sediment type. The sediment type was classified by visual inspection (see text for details).

Cruise	Station	Date	Latitude N	Longitude W	Haul length [m]	Temperature bottom [℃]	Salinity bottom	Depth [m]	Sediment type
WH233	2001-1	23.10.01	64°25.22'	37°12.73'	266	5.00	34.81	15 8.3	1
	2001-2	27.10.01	61°18.75'	41°40.88'	309	6.34	34.90	161.5	2
	2001-3	29.10.01	59°59.99'	46°30.83'	186	5.88	34.87	161.1	3
	2001-4	06.11.01	63°07.44'	52°17.50'	365	5.74	34.53	162.0	3
WH244	2002-1	25.10.02	64°25.34'	37°12.60'	186	4.74	34.83	15 8.5	2
	2002-2	30.10.02	61°18.76'	41°40.90'	214	3.62	33.91	165.0	2
	2002-3	01.11.02	60°00.18'	46°31.02'	314	4.44	34.03	167.0	3
	2002-4	06.11.02	63°07.63'	52°17.72'	224	5.98	34.85	162.5	3
WH268	2004-1	16.10.04	64°25.17'	37°12.57'	301	5.68	34.95	14 9.8	2
	2004-2	21.04.04	61°18.66'	41°40.91'	170	5.92	34.70	156.6	2
	2004-3	23.10.04	59°59.94'	46°31.05'	282	6.22	34.67	160.1	3
	2004-4	28.10.04	63°07.22'	52°16.84'	244	4.48	33.96	151.8	3

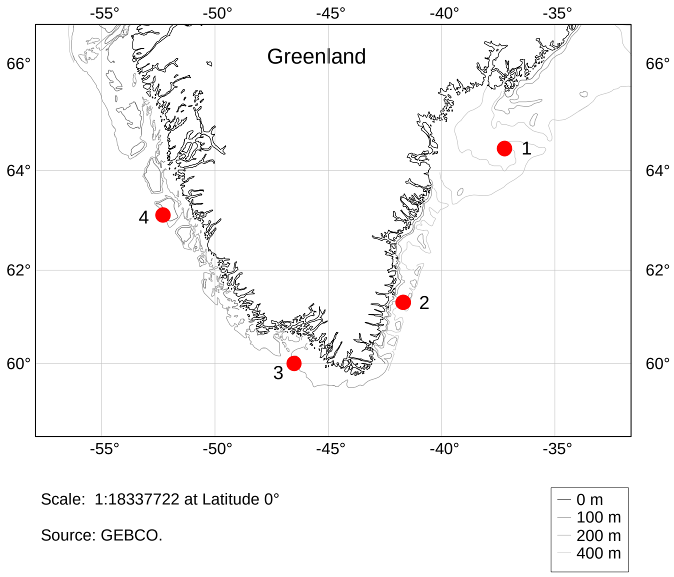


Fig. 2.3: Map of the study area and the four locations sampled during WH233, WH244 and WH268 (dots). Each dot represents three stations, taken in the three years of investigation at corresponding locations.

The sledge, which is a semi-quantitative sampling device (see chapter 3), was hauled over the shelf ground for 5 minutes, towed with 1 knot over ground. The smallest mesh size was 0.5 mm. On board, the samples were decanted, separating individuals from the finer sediment fraction, using a sieve size of 0.5 mm. Afterwards, the samples were preserved in 96% ethanol.

Peracarids were determined to species level and then a) univariate analyses for characterising the community in terms of abundance and diversity and b) multivariate analyses for comparing the community structures between areas and sampling years, and by linking abiotic factors with species composition were applied. All peracarid species which were not badly damaged and undeterminable were further considered in the analyses. Species diversity was calculated using the Shannon index (Shannon & Weaver 1963) and Hurlbert's rarefaction (Hurlbert 1971).

For further analyses, the species abundances were transformed by the fourth root to diminish the influence of extremely dominant species (Field et al. 1982). All species occurring at only one station were not used in the analyses. All community analyses were performed using the PRIMER v. 6.0 software package (Clarke & Warwick 2001). Similarities in species composition between stations were calculated using the Bray-Curtis coefficient (Bray & Curtis 1957), while differences in environmental data were investigated using the Euclidean distance (Clifford & Stephenson 1975), based on normalised data (Clarke & Warwick 2001). Temperature and salinity were recorded at each station by a CTD probe. Temperature and salinity were normalised by subtracting their mean values from the individual values and dividing by their standard deviation. Water profiles have been produced using Ocean Data View (ODV) v. 3.0 (Schlitzer 2005).

During the first two years, sediment structure was described using the contents of the sledge. This estimation corresponds well with sediment samples taken by means of a sediment grab at the same positions in 2004 (see chapter 4). As these more exact data from the third year cannot directly be applied to the first two years, only sediment types were used in the analysis. Thus, sediment structure was divided into four different sediment types, which were characteristic for a certain site (Tab. 2.1). Type 1 was coarse gravel, type 2 consisted of mostly sand, and type 3 was sandy and rich in macroinvertebrates such as corals, crinoids and ophiuroids.

The similarity matrices were used for both classification (complete linkage clustering; Lance & Williams 1967) and ordination (multi-dimensional scaling, MDS; Kruskal & Wish 1978).

Dissimilarity values between environmental data were used for ordination (MDS) and for linking community analyses to environmental variables (BIO-ENV; Clarke & Ainsworth 1993). The stress coefficient of an MDS plot indicates how faithfully the high-dimensional relationships among the samples are represented in the 2-d ordination plot (Clarke & Gorley 2006). A stress value of < 0.05 gives an excellent representation, and values < 0.1 still give a good ordination of the data. Values of > 0.3 indicate that the data are relatively randomly placed in the ordination (Clarke & Warwick 2001). Points in the MDS plot which are far apart correspond to large differences in species compositions (Clarke & Gorley 2006).

When comparing stations with each other, the identification of discriminator species being responsible for station groupings delivers important biological information. One possibility to find these discriminator species is the SIMPER analysis (Clarke 1993). It compares stations with each other in terms of species abundances and calculates the contribution of each single species found at these stations, leading to the (dis-)similarity between stations.

The species distribution patterns and the environmental data were linked using the BIO-ENV analysis (Clarke & Ainsworth 1993). Its aim is to find the best match between biotic patterns and abiotic factors. A Spearman-rank correlation is used to compare the resemblance matrix of the biotic data with the resemblance matrix of the abiotic data. The result is the identification of either a single abiotic factor or a combination of factors which correlate best with the species patterns.

Results

Abundance and Diversity

A total of 94,440 individuals were collected at the 12 stations (Annex 2.1). 34% were collected during the first year in 2001, while 33% each were found in the samples taken in 2002 and 2004. Mysidacea have not been found at the 12 stations. In this material, 83,893 individuals were identified to species level, and the remaining 10,547 specimens were mostly too damaged for further determination. In total, 205 species were identified, belonging to four orders, 55 families and 111 genera. Amphipoda were most frequently found, both in terms of abundance (52%) and number of species (134). 30% of the specimens belonged to the Isopoda (34 species), 11% to the Cumacea (20 species), and 7% were Tanaidacea (17 species). 74% of the specimens belonged to the 27 most common species comprising more than 1% of the total abundance (Tab. 2.2). *Janira maculosa* was the most common species. Among the most common species, *Tmetonyx cicada* and *Liljeborgia pallida* are the only species for which in all three years considerably more specimens were found in the East than in the West. Nevertheless, some species such as *Leucon* cf. *nasicoides*, *Spectrarcturus multispinatus* and *Amphilochus manudens* showed a general indication of a decrease in abundance from the first to the third year. *Baeonectes muticus* showed the reverse trend, while *Janira maculosa* showed considerable variation in abundance. Besides the increase in abundance for most species from the first to the second year at location 1, there was also a general decrease in abundance from the second to the third year at this sampling site. Some species, such as *Photis reinhardi*, *Gitanopsis* cf. *arctica* and *G. bispinosa*, most species of the oedicerotids, *Hardametopa nasuta* and most species of the phoxocephalids, occur mainly at the western stations.

Tab. 2.2: Abundance of the most common species (> 1% of the total abundance) and their percentage of abundance. A = amphipod, I = isopod, C = cumacean and T = tanaid species.

	NE-			SE-			SW-			NW- Greenland			Total abun-dance [%]
	2001-	2002-1	2004-	2001-	2002-2	2004-	2001-	2002-3	2004-	2001-	2002-4	2004-	
Janira maculosa (I)	245	1211	521	1065	703	534	492	989	811	364	104	429	8.90
Photis reinhardi (A)	0	0	0	8	2	0	1371	2929	2281	246	33	149	8.37
Leucon cf. *nasicoides* (C)	0	0	0	1233	1118	1078	1260	931	352	166	26	39	7.39
Amphilochus manudens (A)	269	630	610	458	248	191	983	759	683	5	2	2	5.77
Munna cf. *minuta* (I)	0	125	60	57	13	7	67	391	66	1350	574	1092	4.53
Aeginella spinosa (A)	8	19	13	16	23	9	912	1397	914	72	15	84	4.15
Ansphyrapus tudes (A)	0	0	1	1	0	0	819	1303	1052	0	0	0	3.79
Munna cf. *groenlandica* (I)	55	261	98	67	45	10	575	536	316	515	103	312	3.45
Hardametopa nasuta (A)	0	0	0	0	0	0	347	742	201	499	303	427	3.00
Spectrarcturus multispinatus (I)	0	0	0	0	0	0	841	754	355	2	0	12	2.34
Syrrhoe crenulata (A)	31	105	123	214	134	104	25	20	12	486	192	192	1.95
Odius carinatus (A)	15	34	23	59	44	20	234	215	181	373	61	358	1.93
Munna cf. *fabricii* (I)	0	3	25	27	11	6	216	364	271	367	82	138	1.80
Typhlotanais sp. 2 (T)	17	101	32	59	21	22	109	858	197	7	6	12	1.72
Baeonectes muticus (I)	0	2	9	2	8	11	1	46	22	60	246	839	1.49
Caprella rinki (A)	0	0	5	2	8	0	496	392	204	0	2	0	1.32
Ischyrocerus anguipes (A)	0	0	0	254	0	0	0	313	11	373	56	49	1.26
Gammaropsis cf. *melanops* (A)	16	123	64	18	7	2	57	94	101	267	36	227	1.21
Echinozone coronata (I)	4	29	26	17	20	28	194	230	255	53	24	107	1.18
Tmetonyx cicada (A)	5	18	1	327	331	27	6	52	72	64	51	25	1.17
Amphilochus tenuimanus (I)	62	172	180	63	11	19	102	127	56	66	19	89	1.15
Campylaspis horrida (C)	62	212	197	88	54	67	52	110	105	3	0	1	1.13
Eugerda cf. *globiceps* (I)	0	52	41	90	91	149	48	2	5	132	24	301	1.11
Rhachotropis inflata (A)	14	134	7	43	57	26	46	4	8	400	29	166	1.11
Pleurogonium spinosissimum (I)	0	0	0	17	17	22	74	131	151	126	55	313	1.08
Monoculodes cf. *latimanus* (A)	0	0	0	12	24	9	3	10	1	444	24	337	1.03
Gitanopsis bispinosa (A)	0	11	20	5	7	8	264	121	87	163	40	117	1.00

10% of the species were present at all 12 stations. Examples of these are the most abundant species *Janira maculosa*, but also *Leucon* cf. *nathorsti* and *Campylaspis rubicunda* with a low percentage (0.54 and 0.23%) of the total abundance. More than half of the specimens were found at five or fewer stations.

The diversity patterns of the two (non-related) diversity indices Shannon (H') and Hurlbert's expected number of species E (S_{500}) coincide quite well within the corresponding stations over the three sampling years (Fig. 2.4a-b). The diversity between geographic sites differs, demonstrating that the stations in the Northwest are more diverse than the other stations. Station 2001–1 differs considerably from the corresponding stations taken in 2002 and 2004 at the same location, documenting an increase in diversity over the three years.

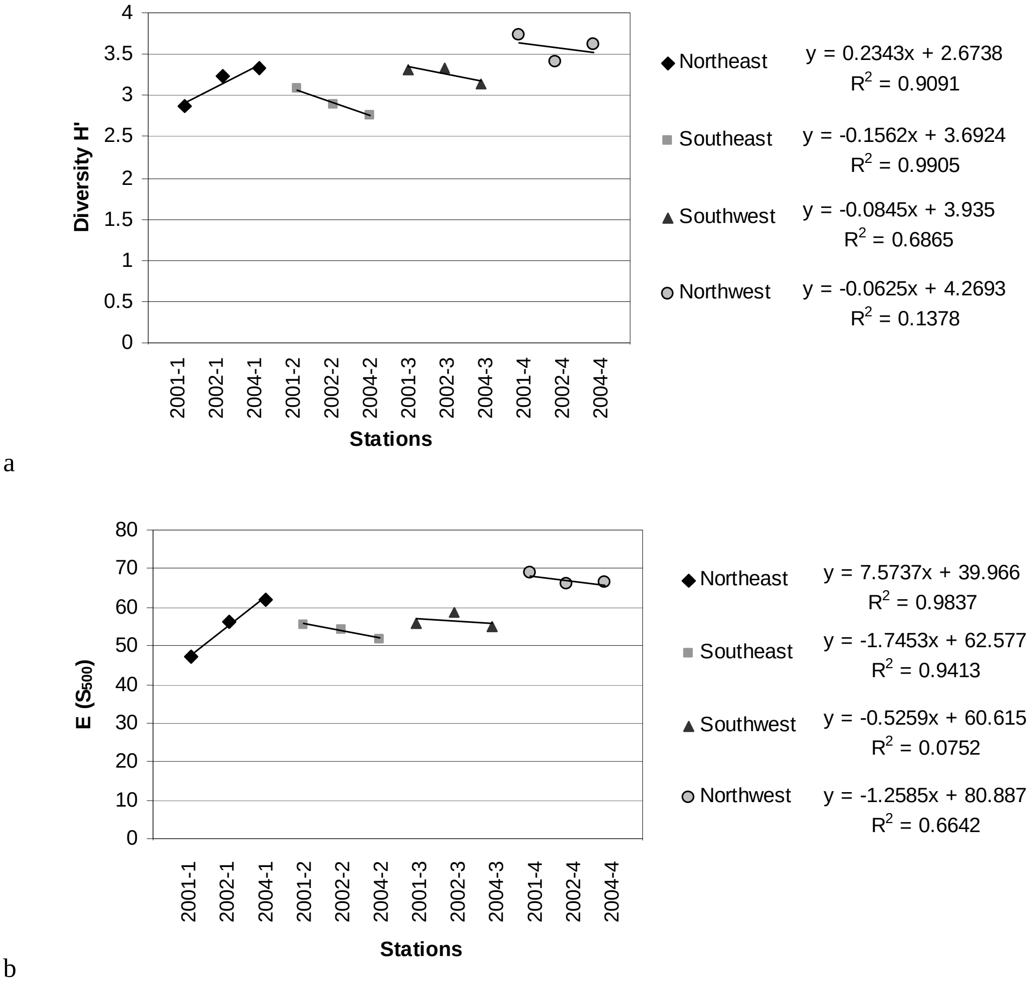
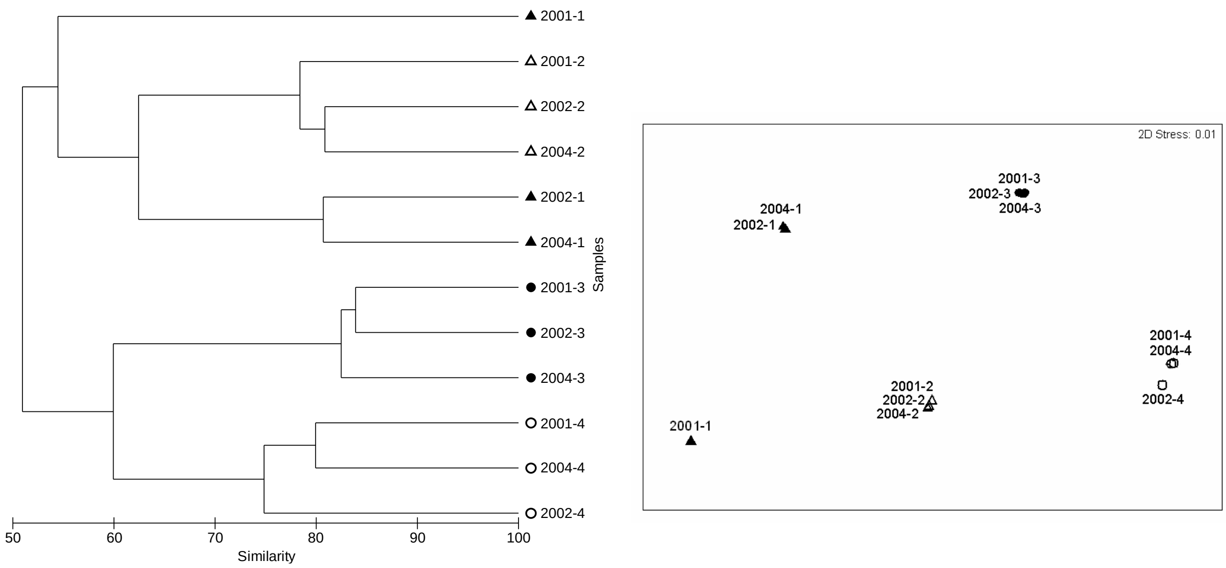


Fig. 2.4a-b: Diversity indices per station group over the three sampling years. a) Shannon Index H'; b) Hurlbert's expected number of species (E (S_{500})).

Multivariate community patterns

The cluster dendrogram (Fig. 2.5a) separates eastern and western faunas in all sampling years. Stations from the same locations taken in different years form clusters with an average similarity level of almost 80%, except for the northeastern station taken in the first year (2001–1). This station is clearly separated from the remaining eastern stations. The similarity in species composition between station clusters over the years is at least 75% and between the areas East and West 60%.



a b

Fig. 2.5a-b: Multivariate analyses of the species composition of all 12 stations. a) Cluster dendrogram, using group-average clustering from Bray-Curtis similarities on fourth root transformed abundances; b) Two-dimensional MDS configuration based on fourth root transformed abundances and Bray-Curtis similarities (Stress = 0.01). Triangles represent eastern stations and circles the western stations.

Like the dendrogram, the MDS plot (Fig. 2.5b) illustrates the high similarity in species composition between sampling years. It also confirms the separation of station 2001-1.

In multivariate analyses of the single orders Amphipoda, Isopoda and Tanaidacea, the corresponding stations clustered together although not as closely as in the overall view, but the MDS patterns were similar. The Cumacea generally showed a high similarity between years, but unlike the other orders, the southern locations clustered on a level of 75% as one group in the MDS plot.

Discriminator species (SIMPER analysis)

Station groups have been established according to the MDS plot on a similarity level of 70%. In the SIMPER analysis for all orders and in the analysis for the amphipods only, the number of species explaining the cumulative percentage of contribution to group separation varied between 80 and 119 species to reach a cut-off value of 90%, respectively.

For the isopods and tanaids, the northeastern station differed between the first sampling year (2001) and the following two sampling years (2002, 2004), forming two different groups. The southeastern, southwestern and northwestern stations (taken in all years) formed one group each. For the cumaceans, the southern stations (Southeast and Southwest) were allocated to one group, separated from a group consisting of the northeastern stations and from a group of northwestern stations. The average dissimilarities between these groups were inferred from differences in the average abundances of a few discriminator species (Tab. 2.3).

Tab. 2.3: Average dissimilarities between station groups and discriminator species (the three species contributing most to the group separation) for Isopoda, Tanaidacea and Cumacea. NE = Northeastern location, SE = Southeastern location, SW = Southwestern location and NW = Northwestern location.

Comparison	Average dissimilarity	Discriminator species
Isopoda		
NE (2001) - NE (2002, 2004)	48.52	*Eurycope producta*, *Munna* cf. *minuta*, *Eugerda* cf. *globiceps*
NE (2001) - SE (all years)	59.72	*Eugerda* cf. *globiceps*, *Austroniscus* cf. *norbi*, *Ilyarachna hirticeps* group
NE (2001) - SW (all years)	64.44	*Spectrarcturus multispinatus*, *Munna* cf. *fabricii*, *Munna* cf. *minuta*
NE (2001) - NW (all years)	75.41	*Munna* cf. *minuta*, *Baeonectes muticus*, *Munna* cf. *fabricii*
NE (2002, 2004) - SE (all years)	27.18	*Austroniscus* cf. *norbi*, *Eurycope producta*, *Pleurogonium spinosissimum*
NE (2002, 2004) - SW (all years)	38.95	*Spectrarcturus multispinatus*, *Pleurogonium spinosissimum*, *Pleurogonium inerme*
NE (2002, 2004) - NW (all years)	45.11	*Pleurogonium spinosissimum*, *Nannoniscus oblongus*, *Eurycope producta*
SE (all years) - SW (all years)	39.23	*Spectrarcturus multispinatus*, *Austroniscus* cf. *norbi*, *Munna* cf. *groenlandica*
SE (all years) - NW (all years)	37.42	*Munna* cf. *minuta*, *Nannoniscus oblongus*, *Baeonectes muticus*
SW (all years) - NW (all years)	35.53	*Spectrarcturus multispinatus*, *Munna* cf. *minuta*, *Baeonectes muticus*
Tanaidacea		
NE (2001) - NE (2002, 2004)	60.28	*Leptognathia* sp. 1, *Paraleptognathia multiserrata*, *Typhlotanais* sp. 2
NE (2001) - SE (all years)	64.53	*Paraleptognathia gracilis*, *Typhlotanais* sp. 1, *Pseudosphyrapus anomalus*
NE (2001) - SW (all years)	78.53	*Ansphyrapus tudes*, *Typhlotanais* sp. 1, *Typhlotanais* sp. 2
NE (2001) - NW (all years)	77.01	*Typhlotanais* sp. 1, *Heterotanais groenlandicus*, *Pseudotanais oculatus*
NE (2002, 2004) - SE (all years)	58.92	*Paraleptognathia gracilis*, *Leptognathia* sp. 1, *Pseudosphyrapus anomalus*
NE (2002, 2004) - SW (all years)	67.03	*Ansphyrapus tudes*, *Typhlotanais* sp. 1, *Leptognathia* sp. 2
NE (2002, 2004) - NW (all years)	69.25	*Heterotanais groenlandicus*, *Typhlotanais* sp. 1, *Pseudotanais oculatus*
SE (all years) - SW (all years)	56.57	*Ansphyrapus tudes*, *Typhlotanais* sp. 1, *Typhlotanais* sp. 2
SE (all years) - NW (all years)	50.86	*Heterotanais groenlandicus*, *Pseudotanais oculatus*, *Typhlotanais* sp. 1
SW (all years) - NW (all years)	54.95	*Ansphyrapus tudes*, *Typhlotanais* sp. 2, *Pseudotanais oculatus*
Cumacea		
NE (all years) - SE & SW (all years)	49.34	*Leucon* cf. *nasicoides*, *Hemilamprops* cf. *assimilis*, *Hemilamprops* cf. *uniplicata*
NE (all years) - NW (all years)	72.62	*Campylaspis horrida*, *Leucon* cf. *nasicoides*, *Leptostylis macrura*
SE & SW (all years) - NW (all years)	55.96	*Leucon* cf. *nasicoides*, *Campylaspis horrida*, *Leptostylis macrura*

Isopoda

The highest dissimilarities (76% and 64%) were found between the northeastern station taken in 2001 and the northwestern and southwestern stations taken in all years (Tab. 2.3). In general, the group separation became more distinct with increasing geographic distance. The high dissimilarities can be explained by the presence of species in one area and the absence of those species in another area, e.g. *Munna* cf. *minuta*, *Munna* cf. *fabricii*, *Spectrarcturus multispinatus* and *Baeonectes muticus*. The lowest dissimilarities were found between the northeastern stations taken in 2002 and 2004 and the southeastern stations (27%), as well as between the southwestern and northwestern stations (35%).

Tanaidacea

Within the Tanaidacea, station groups differed more than for the Isopoda, but the group separation pattern was similar. The northeastern stations were more dissimilar to the southeastern and northwestern stations (Tab. 2.3).
Ansphyrapus tudes, *Typhlotanais* sp. 1, *Typhlotanais* sp. 2, *Heterotanais groenlandicus* and *Pseudotanais oculatus* contributed most to these group separations.

Cumacea

Cumacea station groups differed most between the northeastern and northwestern stations (Tab. 2.3), inferred from differences in species abundance of *Campylaspis horrida*, *Leucon* cf. *nasicoides* and *Leptostylis macrura*. The group of southern stations differed as much from the northeastern stations as from the northwestern stations.

Linkage of environmental data to species composition (BIO-ENV analysis)

The best set of environmental data determining the species distribution was found with the BIO-ENV analysis. Temperature and salinity values in 2002 differed slightly from those in 2001 and 2004. Latitude and depth in the interannual comparison documented that almost the same stations were revisited. The sediment type was also very similar in all three years, only station 2001–1 differed. The ordination of stations using biotic (Fig. 2.5b) and abiotic data (Fig. 2.6a) differed considerably.

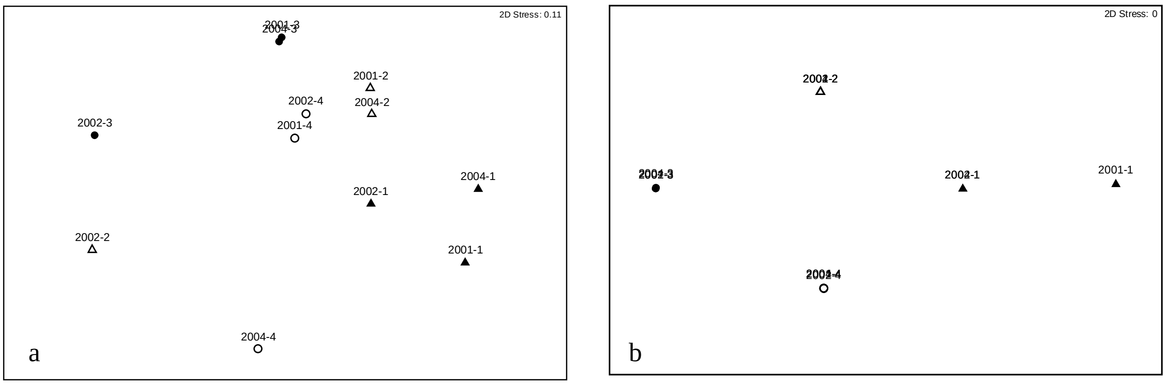


Fig. 2.6a–b: Two-dimensional MDS configuration of the interannual comparison of three years and four stations, based on fourth root transformed environmental values and Euclidean distances between stations. a) all environmental factors (Stress = 0.1) and b) only latitude and sediment type as environmental factors (Stress < 0.01). Triangles represent eastern stations, and circles western stations.

The consideration of only latitude and sediment type (Fig. 2.6b) produced an MDS plot that agreed best with the biotic plot (Fig. 2.5b) and thus with the species distribution. The correlations between the biotic and abiotic data showed that sediment type was the decisive factor for the species distribution (Tab. 2.4).

Tab. 2.4: Best results of the BIO-ENV analysis, including all four orders. Environmental variables are coded with numbers, which are: 1 = latitude N, 2 = bottom temperature [°C], 3 = bottom salinity, 4 = depth [m] and 5 = sediment type (see Tab. 2.1).

A,I,C,T overall	
Best result correlation	Variables
0.805	5
0.570	1,5
0.511	1,4,5
0.491	4,5
0.447	3,5

Discussion

Most specimens were found off West Greenland, although the number of species was almost equal in the East and West. This was also observed in chapter 1 where amphipods were the most dominant order. The abundances were high in all orders and at all stations. The exception is station 2001-1, especially in combination with the results of the BIO-ENV analysis, where either the sampling conditions or the sediment structure differed between the first sampling year and the two following years. The precise position of location 1 differed only slightly between years, but station 2001-1 was probably sampled in an area of heterogeneous sediment with large stones and coarse gravel, indicated by a different sediment type. Species which seem to prefer more sandy sediments were missing in the first year but were present in the following years. The number of species is 50% higher in the following year, and some species occurred which were not present the year before, for example, members of the oedicerotid amphipods (i.e. *Monoculodes* cf. *norvegicus* and *Paroediceros lynceus*). Although *Janira maculosa* is said to show little susceptibility to habitat (Hult 1941), it also occurred in a much lower abundance in 2001 than in the following year. A clear increase in the abundance was also recognisable for the munnopsid isopods and even more obvious for cumaceans and tanaids, which are infaunal animals (Gerken & Watling 1999, Holdich & Jones 1983). They only occurred with few specimens in the Northeast in general, however, the abundance at station 2001-1 is markedly low; only 119 cumaceans and 17 tanaids were found at this station. Many species showed a clear pattern in their occurrence towards the western stations. This pattern might be explained by the feeding habits of these species, as most of these are detritus feeders (Enequist 1949) or feed on other animals such as sea anemones (Vader 1983).

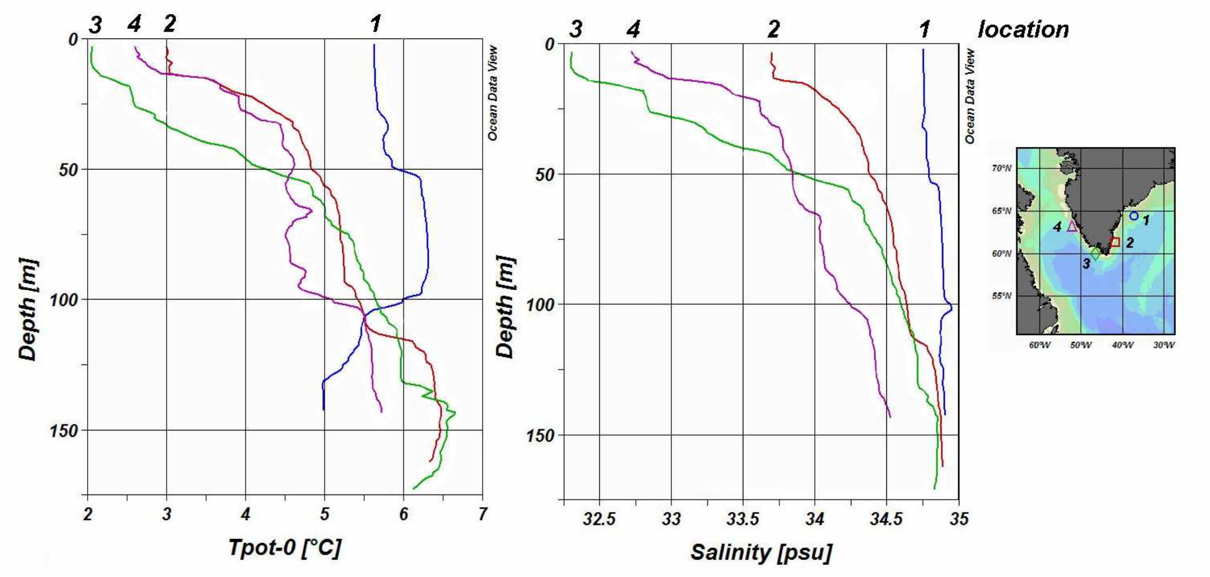
The dissimilarities of the SIMPER analysis and the almost equal distances between station clusters in the MDS plots indicate that there was only slight species replacement between stations. The species composition differed between East and West. Since diversity indices were consistent over the years, the standardisation of sampling conditions provided valid temporal comparisons.

Pielou (1977), Texeido et al. (2002), Begon et al. (2003), Gutt & Starmans (2003), Garcia-Charton et al. (2004) showed that animals, terrestrial or marine, are seldom dispersed homogenously but display a rather random or patchy distribution. The fact that 58 species occurred at only one or two stations and several species such as *Proaeginina norvegica*, *Ischyrocerus anguipes, Westwoodilla* cf. *caecula, Austroniscus* cf. *norbi* and *Austroniscus* sp. 1 were rare or absent from most of the samples but were abundant at some other stations, suggests that these species might not be rare, but patchily distributed. However, whether the distribution of taxa is uniform or patchy, depends on both biological and environmental forces (Gutt & Starmans 2003). Moreover, distribution or occurrence of species in samples is scale-dependent (Gutt & Starmans 2003, Magurran 2004), dependent on the analysis and even on the observer (Magurran 2004).

Distribution patterns for polar megabenthos are always affected by factors that cause aggregation and patchiness, such as food supply and/or habitat disturbance, e.g. by iceberg scouring (Gutt et al. 1996; Gutt 2000; Gutt & Starmans 2001, 2003). Iceberg scouring occurs rarely on the southern Greenland shelf (Gutt 2001), however, extensive fishing activities with bottom-contacting gear represent a major disturbance for the benthic community (Kaiser et al. 2000, Board 2002). Demersal fishing has been extensive on the South Greenland shelf until the mid-1990s and is still common for catching deep-sea shrimp *Pandalus borealis* Krøyer (1838). As one possible factor, disturbance influences the abundance and distribution across local to regional scales (Thrush et al. 2005). Therefore, patterns of species or communities depend on interactions between various biological and environmental factors that affect those patterns before or during the sampling (Fortin et al. 2003).

Diversity and community patterns were stable over the three sampling years 2001, 2002 and 2004. This was not expected due to the abovementioned interactions, and furthermore, since temperature and salinity fluctuated between sampling years. The results showed that temperature and salinity are not among the abiotic factors influencing species composition. Abundance decreased slightly each year, indicating temporal changes in species distribution. As this study only covers three years, these changes, however, cannot be quantified with certainty. Mayer & Piepenburg (1996) and Weisshappel & Svavarsson (1998) found that salinity and temperature had a major influence on community patterns. Rex (1981) and Brandt (1995) have concluded from their results that several abiotic factors, such as depth, temperature, salinity, sediment type and input of organic matter may affect the species composition and distribution of marine invertebrates. These factors might be interrelated and often difficult to distinguish (Rex 1981, Levin et al. 2001).

As the hydrographic conditions in the sampling area vary on geographic and temporal scales, the location and timing of the sampling are crucial for the interpretation of the species distribution patterns. Thermal fronts are variable and can change fairly quickly, which could explain why temperature and salinity are so different between years. In Fig. 2.7a-c, temperature and salinity profiles are displayed from the epibenthic stations in all three sampling years. The differences between locations are considerable. In comparison with the previous two years, the profile patterns did not change to a large extent. The influence of warm water of the Irminger Current (IC) at the bottom is dominant, although quick and major changes in the mixture of water masses cause variations, which could be the reason for deviating temperature and salinity values in the second sampling year. Stein (2006, 2007) showed that the temperature on the South Greenland shelf was increasing in the recent years.



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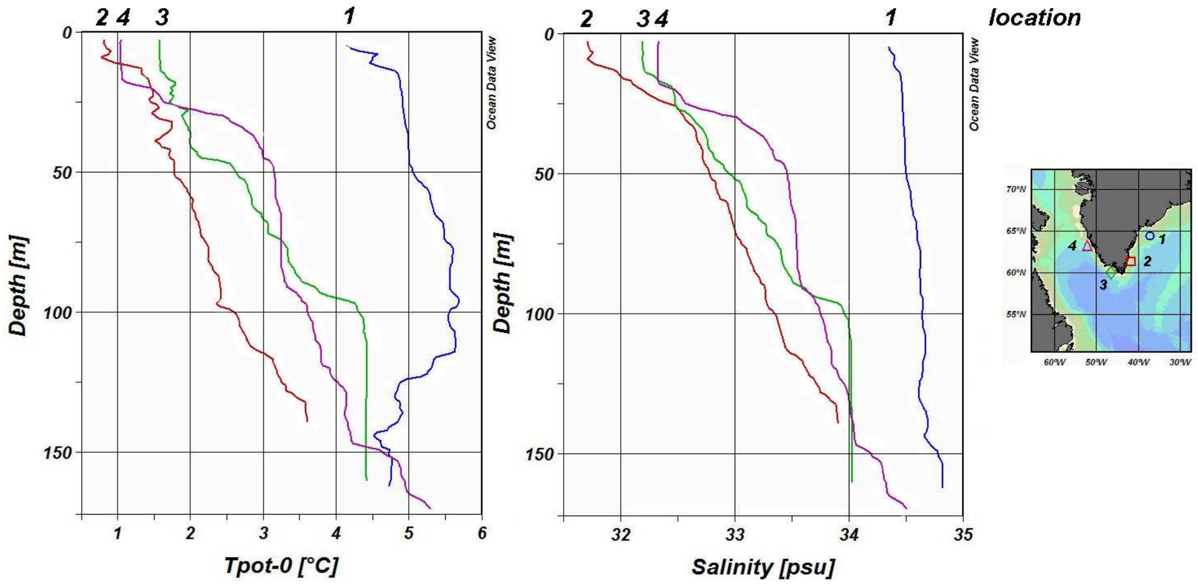

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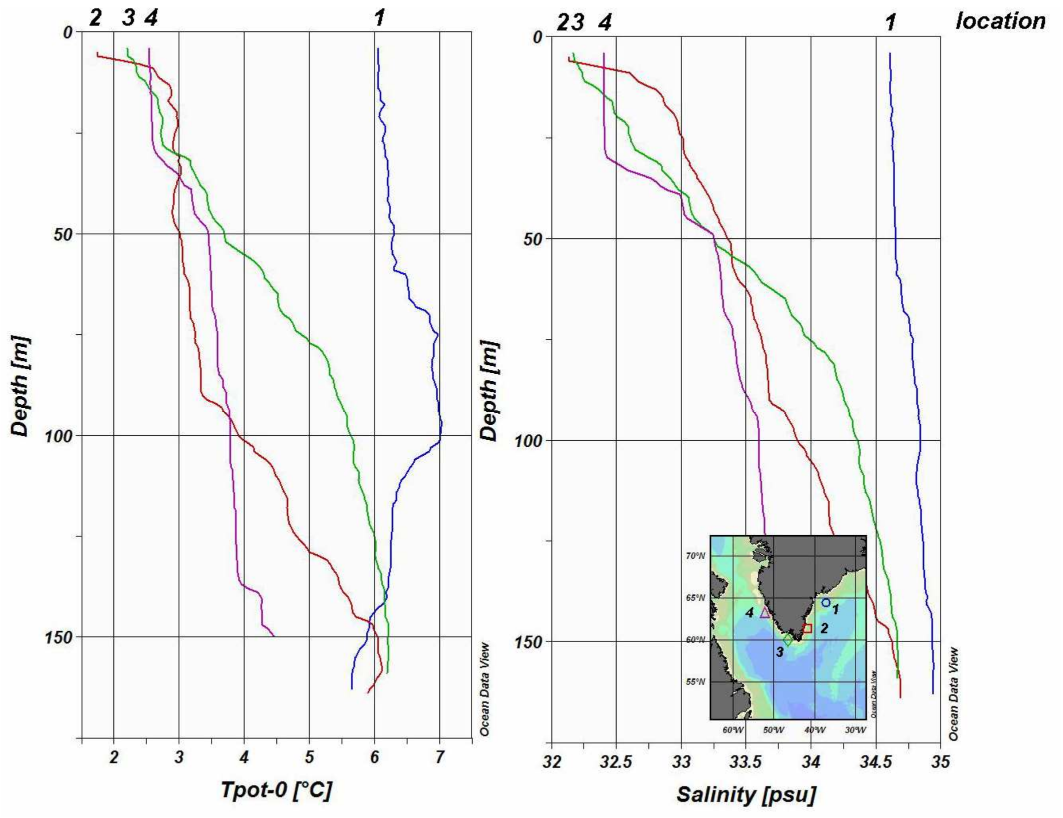

c

Fig. 2.7a-c: Temperature and salinity profiles at the epibenthic sampling sites during cruises a) WH233 (2001), b) WH244 (2002) and c) WH268 (2004).

The Southwest Greenland shelf is largely free of ice over the year due to the influence of warm water from the IC (Pedersen et al. 2004). This provides good habitat conditions for benthic communities, as sedimentation, lateral advection and different patterns of food supply (Suess 1980; Grebmeier et al. 1988; Graf 1989, 1992; Carey 1991; Rex et al. 2006) occur all year round. The highest number of invertebrates (especially brittle stars and crinoids) was in Southwest Greenland, where sandy sediment (type 3) enables the sessile fauna to settle. Sediment type was identified to be the most important factor influencing faunal patterns by this study and e.g. Hecker (1990) and Mayer & Piepenburg (1996).

Since latitude did not differ between stations at the same location, it cannot explain the differences in the species composition in the interannual comparison. When comparing the diversity patterns between the eastern and the western area, it is clear that they differ considerably between orders. In the interannual comparison of corresponding northeastern stations, diversity strongly increased from 2001 to 2004, except for the Cumacea. This might be explained by the much lower abundance and absence of certain species at station 2001–1.

Conclusions

Peracarid crustaceans are abundant on the South Greenland shelf, however, the southeastern Greenland shelf showed fewer specimens and species than the southwestern Greenland shelf. The species composition and distribution patterns of peracarid crustaceans are strongly influenced by the sediment type. Sandy bottom, rich in other invertebrates, seem to be the preferred habitat for most peracarids. Over a sampling period of three years, the community of peracarid crustaceans varied only slightly in diversity and abundance. Even considerable changes in temperature and salinity did not influence the species composition and community patterns markedly. Due to a general warming trend in the study area, it would be interesting to follow the species composition over several more consecutive years or to investigate changes in species composition patterns after a period of 5 to 10 years.

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Annex

Annex 2.1: Species list of all 12 stations in taxonomic order.

		NE-			SE-			SW-			NW-Greenland		
Family	Species	Station											
		2001	2002	2004	2001	2002	2004	2001	2002	2004	2001	2002	2004
			-1			-2			-3			-4	
Amphipoda													
Aoridae	*Autonoe borealis* (Myers, 1976)	2	9	9	0	0	1	23	14	2	113	17	117
Caprellidae	*Aeginella spinosa* Boeck, 1861	8	19	13	16	23	9	912	1397	914	72	15	84
	Aeginina longicornis (Krøyer, 1843)	0	3	0	2	4	2	28	83	17	9	10	4
	Caprella ciliata Sars, G.O., 1895	0	0	0	0	0	0	0	0	0	8	0	2
	Caprella dubia Hansen, 1887	4	8	10	9	2	0	183	52	6	183	6	117
	Caprella rinki Stephensen, 1916	0	0	5	2	8	0	496	392	204	0	2	0
	Cercops holboelli Krøyer, 1843	0	0	0	0	0	0	0	42	0	14	0	0
	Proaeginina norvegica (Stephensen, 1931)	2	108	31	1	4	0	0	0	0	0	0	0
	Caprellidae spp.	0	11	5	18	23	0	481	504	124	40	26	46
Corophiidae	*Protomedeia fasciata* Krøyer, 1842a	0	0	0	10	0	0	0	0	0	0	0	0
Dulichidae	*Dulichia* cf. *falcata* (Bate, 1857)	0	10	18	4	0	2	38	23	5	82	20	61
	Dulichia spinosissima Krøyer, 1845	0	0	0	0	0	0	16	25	8	2	1	0
	Dyopedos porrectus Bate, 1857	0	0	0	2	0	0	116	53	0	7	0	0
	Paradulichia typica Boeck, 1871	0	21	47	0	0	0	0	0	0	2	0	1
	Ericthonius megalops (Sars, G.O., 1879)	0	0	0	1	0	0	0	0	0	0	0	0
Ischyroceridae	*Ischyrocerus anguipes* Krøyer, 1838	0	0	0	254	0	0	0	313	11	373	56	49
	Ischyrocerus latipes Krøyer, 1842a	0	29	0	0	0	0	0	1	0	0	0	0
	Ischyrocerus megacheir (Boeck, 1871)	11	28	5	0	1	0	277	256	33	36	4	7
	Ischyrocerus megalops Sars, G.O., 1895	0	0	0	8	1	0	0	2	6	41	4	7
	Ischyrocerus T1 Just, 1980	0	0	0	0	0	0	0	1	0	1	0	0
	Ischyrocerus sp. 1	0	74	13	0	0	0	0	0	0	0	0	0
	Ischyrocerus sp. 2	0	4	0	0	0	0	0	0	0	0	0	0
Photidae	*Siphonoecetes typicus* Krøyer, 1845	0	0	0	0	0	0	1	9	2	0	0	0
	Photis reinhardi Krøyer, 1842a	0	0	0	8	2	0	1371	2929	2281	246	33	149
	Gammaropsis cf. *melanops* Sars, G.O., 1879	16	123	64	18	7	2	57	94	101	267	36	227
Podoceridae	*Gammaropsis* sp. 2	0	1	0	0	0	0	0	0	1	0	0	0
	Laetmatophilus tuberculatus Bruzelius, 1859	4	40	37	2	0	0	0	0	0	0	0	0
Unciolidae	*Unciola laticornis* Hansen, 1887	18	88	23	63	33	9	82	172	162	7	0	0
	Unciola leucopis (Krøyer, 1845)	5	0	0	2	0	0	21	25	10	13	9	9
	Corophiidea spp.	1	0	0	2	0	0	12	1150	10	26	0	23
Amphilochidae	*Amphilochus manudens* Bate, 1862	269	630	610	458	248	191	983	759	683	5	2	2
	Amphilochus tenuimanus Boeck, 1872	62	172	180	63	11	19	102	127	56	66	19	89
	Gitanopsis cf. *arctica* Sars, G.O., 1892	25	0	0	0	0	0	107	67	5	336	37	118
	Gitanopsis bispinosa (Boeck, 1871)	0	11	20	5	7	8	264	121	87	163	40	117
	Amphilochidae spp.	6	33	20	4	11	22	23	52	34	26	9	51
Ampeliscidae	*Ampelisca aequicornis* Bruzelius, 1859	1	4	2	0	0	0	0	2	1	0	0	0
	Ampelisca eschrichtii Krøyer, 1842a	2	0	0	0	0	0	0	0	0	0	0	0
	Ampelisca macrocephala Lilljeborg, 1852	3	2	0	0	0	0	0	23	17	13	0	1
	Ampelisca spinipes Boeck, 1861	0	0	0	0	0	0	0	1	0	0	0	0
	Byblis gaimardi (Krøyer, 1846a)	9	9	15	3	8	2	5	6	11	6	0	0
	Haploops setosa Boeck, 1871	0	0	0	0	0	0	0	0	0	4	2	0
	Haploops sp. 1	0	0	0	1	0	0	0	0	0	0	0	0
	Ampeliscidae spp.	0	0	0	0	0	0	0	5	2	3	0	0
Argissidae	*Argissa hamatipes* (Norman, 1869)	0	0	7	0	0	0	0	0	0	2	1	0
	Astyra abyssi Boeck, 1871	0	6	7	0	0	2	0	0	1	0	0	0
Atylidae	*Atylus smitti* Goës, 1866	0	0	0	2	2	0	2	3	0	4	2	1
Dexaminidae	*Guernea* sp. 1	0	0	0	0	0	0	0	0	0	132	10	16
Epimeriidae	*Paramphithoe hystrix* (Ross, 1835)	1	5	2	0	0	0	1	0	1	2	0	1
Eusiridae	*Eusirus propinquus* Sars, G.O., 1893	0	1	0	1	2	0	0	0	0	0	1	15
	Rhachotropis aculeata (Lepechin, 1780)	0	1	0	5	2	0	0	0	0	3	2	0
	Rhachotropis inflata (Sars, G.O., 1882)	14	134	7	43	57	26	46	4	8	400	29	166
	Rhachotropis spp.	0	8	0	0	0	0	0	0	0	0	0	0
Calliopiidae	*Apherusa bispinosa* (Bate, 1856)	0	0	0	0	0	0	0	0	0	0	1	0
	Apherusa sarsi Shoemaker, 1930a	0	0	0	0	0	0	0	0	0	62	125	160
	Cleippides tricuspis (Krøyer, 1846a)	0	0	0	0	0	0	0	6	4	6	3	20
	Laothoes meinerti Boeck, 1871	3	41	14	1	18	11	0	0	0	0	0	0

Continuation of Annex 2.1:

			NE-			SE-			SW-			NW-Greenland	
Family	Species						Station						
		2001	2002	2004	2001	2002	2004	2001	2002	2004	2001	2002	2004
			-1			-2			-3			-4	
Iphimediidae	*Acanthonotozoma cristatum* (Ross, 1835)	0	3	4	0	0	0	1	2	3	0	0	0
	Acanthonotozoma serratum (Fabricius, 1780)	1	5	8	31	31	17	53	86	41	20	4	29
Leucothoidae	*Leucothoe spinicarpa* (Abildgaard, 1789) group	6	55	40	22	17	4	31	82	98	7	2	39
Liljeborgiidae	*Liljeborgia fissicornis* (Sars, M., 1858)	1	1	3	0	0	0	0	1	0	0	0	0
	Liljeborgia pallida (Bate, 1857)	6	44	38	310	193	229	7	2	2	3	0	0
Melitidae	*Melita dentata* (Krøyer, 1842a)	0	0	0	3	9	4	0	0	0	0	0	0
	Melita gladiosa Bate, 1862	0	32	6	44	22	12	8	35	40	26	8	28
	Melita obtusata (Montagu, 1813)	0	0	1	0	0	0	51	90	46	1	0	0
	Melitidae spp.	0	0	0	7	0	0	0	0	0	0	0	0
Melphidippidae	*Melphidippida goesi* Stebbing, 1899	1	14	8	0	0	0	1	2	7	11	5	17
	Melphidippidae sp. 1	0	0	0	0	0	0	87	0	0	0	0	0
Ochlesidae	*Odius carinatus* (Bate, 1862)	15	34	23	59	44	20	234	215	181	373	61	358
Oedicerotidae	*Bathymedon saussurei* Boeck, 1871	0	5	11	12	2	2	0	0	0	0	0	0
	Monoculodes borealis Boeck, 1871	0	0	7	8	11	2	5	15	5	3	3	39
	Monoculodes cf. *latimanus* (Goës, 1866)	0	0	0	12	24	9	3	10	1	444	24	337
	Monoculodes cf. *norvegicus* (Boeck, 1861)	0	25	44	69	51	73	2	3	0	0	0	0
	Monoculodes cf. *packardi* Boeck, 1871	0	9	19	0	0	0	0	0	0	1	0	0
	Monoculodes cf. *pallidus* Sars, G.O., 1892	0	0	3	0	0	0	0	0	0	0	0	0
	Monoculodes cf. *subnudus* Norman, 1889	0	0	1	0	0	0	3	10	1	81	0	91
	Monoculodes cf. *tesselatus* Schneider, 1883	0	0	0	0	0	0	0	0	0	39	5	12
	Monoculodes tuberculatus Boeck, 1871	0	2	3	14	10	10	9	8	3	119	35	133
	Monoculodes spp.	1	0	0	68	0	25	4	0	6	0	18	0
	Oediceros cf. *borealis* Boeck, 1871	0	0	0	0	0	0	0	5	0	13	0	1
	Oediceros sp. 1	0	0	0	0	0	0	0	0	0	3	0	0
	Oediceros sp. 2	0	0	0	0	0	0	0	3	0	0	0	0
	Paroediceros lynceus (Sars, M.,1858)	28	115	62	50	16	9	57	123	90	4	4	8
	Paroediceros spp.	7	0	0	0	0	1	0	0	0	0	0	0
	Pontocrates spp.	0	108	55	0	0	0	0	0	0	0	0	0
	Westwoodilla cf. *brevicalcar* (Goës, 1866)	0	0	0	0	0	4	0	0	0	40	13	10
	Westwoodilla cf. *caecula* (Bate, 1856)	0	0	0	0	0	0	0	0	4	269	61	28
	Westwoodilla cf. *megalops* (Sars, G.O., 1882)	0	0	0	1	0	2	4	9	0	148	18	27
	Oedicerotidae juveniles	0	0	0	0	0	0	0	0	0	0	0	147
	Oedicerotidae spp.	9	17	11	50	5	6	20	4	6	25	12	39
Pardaliscidae	*Pardalisca cuspidata* Krøyer, 1842a	0	1	0	23	5	17	1	1	3	0	0	0
Pleustidae	*Neopleustes boecki* (Hansen, 1888)	0	0	0	0	0	0	61	38	27	37	0	0
	Parapleustes biscuspis (Krøyer, 1838)	0	0	0	0	0	0	3	5	0	1	0	0
	Pleustes tuberculatus Bate, 1858	0	0	4	0	0	0	14	16	7	0	0	1
	Stenopleustes cf. *nodifer* Sars, G.O., 1883	0	0	0	0	0	0	4	0	1	22	6	12
	Stenopleustes sp. 1	0	17	48	2	1	2	33	37	11	46	31	58
	Pleustidae juveniles	0	23	83	3	0	0	0	0	0	279	81	241
Stegocephalidae	*Andaniopsis pectinata* Sars, G.O., 1882	0	1	0	80	76	9	23	7	36	16	4	28
	Phippsia roemeri Schellenberg, 1925	0	0	0	0	0	0	5	13	7	1	0	0
	Stegocephalus inflatus Krøyer, 1842a	0	0	0	0	1	0	2	27	8	3	4	2
Stenothoidae	*Hardametopa nasuta* (Boeck, 1871)	0	0	0	0	0	0	347	742	201	499	303	427
	Metopa norvegica (Lilljeborg, 1851a,b)	0	7	0	2	0	4	5	8	0	29	0	9
	Metopa cf. *propinqua* Sars, G.O., 1892	10	14	3	25	8	9	1	19	21	140	13	41
	Stenothoidae spp.	45	293	285	303	138	94	243	306	210	1510	316	1084
Synopiidae	*Bruzelia tuberculata* Sars, G.O., 1882	2	9	4	87	36	48	22	46	37	0	0	0
	Syrrhoe crenulata Goës, 1866	31	105	123	214	134	104	25	20	12	486	192	192
	Syrrhoides serrata (Sars, G.O., 1879)	0	4	2	0	0	0	0	0	1	0	0	0
	Tiron spiniferum (Stimpson, 1853)	64	143	42	125	36	19	27	31	16	89	12	44
	Synopiidae spp.	0	0	0	0	0	0	0	0	0	7	0	0
Urothoidae	*Urothoe elegans* (Bate, 1856)	32	111	58	30	10	9	45	38	17	19	7	9
Lysianassidae	*Ambasia atlantica* (Milne-Edwards, 1830)	0	2	0	3	9	7	0	0	0	0	0	0
	Ambasiella murmanica (Brüggen, 1905)	0	0	0	0	0	0	0	1	0	1	1	7
	Anonyx debruyni Hoek, 1882	1	0	0	0	0	0	0	8	0	23	13	11
	Anonyx cf. *nugax* (Phipps, 1774)	2	1	3	2	8	1	0	0	5	0	0	12
	Anonyx sp. 1	0	0	0	0	0	0	1	0	0	0	2	0
	Anonyx sp. 3	0	0	0	1	0	0	0	0	0	0	0	0
	Anonyx sp. 4	0	1	0	0	0	0	0	0	0	0	0	0
	Aristias topsenti Chevreux, 1900	0	6	3	0	0	0	0	0	0	0	0	0
	Gronella groenlandica (Hansen, 1887)	0	0	0	1	0	0	0	0	0	0	0	0

Continuation of Annex 2.1:

Family	Species	NE-			SE-			SW-			NW-Greenland		
		Station											
		2001	2002 -1	2004	2001	2002 -2	2004	2001	2002 -3	2004	2001	2002 -4	2004
Lysianassidae	*Hippomedon denticulatus* (Bate, 1857)	0	1	0	0	0	0	0	0	0	0	0	0
	Hippomedon gorbunovi Gurjanova, 1930	2	0	4	3	1	3	5	18	5	5	4	9
	Hippomedon propinquus cf. *sibiricus* Gurjanova, 1962	4	28	22	0	1	0	0	0	0	0	0	0
	Hippomedon robustus Sars, G.O., 1895	0	0	0	0	1	0	0	0	1	0	0	0
	Kerguelenia borealis cf. *japonica* Gurjanova, 1962	2	2	0	0	0	0	0	1	1	0	0	0
	Lysianella petalocera Sars, G.O., 1882	4	17	32	20	24	21	1	6	1	2	2	0
	Onisimus plautus (Krøyer, 1845)	1	0	0	0	0	0	0	0	0	0	0	0
	Orchomene cf. *lepidula* Gurjanova, 1962	0	0	0	0	0	0	0	0	0	3	0	25
	Orchomene macroserrata Shoemaker, 1930b	1	2	2	18	5	2	78	84	64	19	4	27
	Orchomene pectinata Sars, G.O., 1882	1	1	2	2	0	2	4	12	0	1	1	3
	Opisa eschrichtii (Krøyer, 1842a)	0	1	1	0	1	2	0	0	1	7	3	4
	Socarnes bidenticulatus (Bate, 1858)	0	0	0	1	0	1	0	0	1	1	0	5
	Socarnes vahli (Krøyer, 1838)	0	0	0	7	6	2	160	136	121	0	0	1
	Tmetonyx cicada (Fabricius, 1780)	5	18	1	327	331	27	6	52	72	64	51	25
	Tmetonyx sp. 1	0	0	0	0	4	0	0	0	0	0	0	0
	Tmetonyx sp. 2	0	0	0	0	1	0	0	0	0	0	0	0
	Tryphosella schneideri (Stephensen, 1925)	1	0	3	2	2	0	43	88	26	3	7	1
	Tryphosella sp. 1	0	0	0	1	0	0	0	0	0	0	0	0
	Lysianassidae sp. 1	0	0	0	1	0	0	0	0	0	0	0	0
	Lysianassidae sp. 2	0	0	0	0	0	0	0	0	0	0	0	3
	Lysianassidae sp. 3	0	0	0	0	0	1	0	0	0	0	0	0
	Lysianassidae sp. 4	0	0	0	0	0	0	0	0	0	0	0	3
	Lysianassidae spp.	0	1	0	30	0	0	15	0	0	0	0	0
Phoxocephalidae	*Harpinia crenulata* (Boeck, 1871)	0	5	1	44	16	18	29	48	76	0	0	0
	Harpinia cf. *plumosa* (Krøyer, 1842a)	0	0	0	0	0	0	0	0	0	2	0	1
	Harpinia sp. 1	0	0	0	1	0	0	0	0	0	0	0	0
	Harpinia spp. 1	0	0	2	8	1	3	9	6	4	0	0	2
	Harpinia spp. 2	0	0	0	6	6	2	9	15	4	0	0	2
	Phoxocephalus holboelli (Krøyer, 1842a)	0	0	0	0	0	0	39	78	40	155	17	26
	Phoxocephalidae spp.	1	0	0	10	7	2	19	26	12	36	3	12
	Themisto abyssorum Boeck, 1871	0	0	0	0	0	0	0	0	0	0	0	3
	Themisto gaudichaudi Guérin, 1828	1	0	6	0	0	7	1	7	1	3	0	0
	Amphipoda spp.	0	0	3	3	0	1	26	0	0	78	0	1
	Amphipoda sp. 1	0	0	0	0	0	0	0	3	0	4	5	17
Isopoda													
Anthuridae	*Calathura brachiata* Stimpson, 1853	0	1	6	17	12	5	1	9	7	109	11	39
Desmosomatidae	*Eugerda* cf. *globiceps* (Meinert, 1890)	0	52	41	90	91	149	48	2	5	132	24	301
	Nannoniscus oblongus Sars, G.O., 1869	27	136	109	134	76	59	1	6	8	0	0	0
	Austroniscus cf. *norbi* Svavarsson, 1982	0	0	37	0	146	280	0	0	0	32	63	0
	Austroniscus sp. 1	0	43	0	180	0	0	26	50	47	0	0	47
	Austroniscus sp. 3	0	0	0	0	0	0	0	4	0	0	0	0
Janiridae	*Iolella laciniata* (Sars, G.O., 1872)	31	64	21	2	0	4	21	18	14	0	0	0
	Iolella spinosa (Harger, 1879)	0	0	0	0	0	0	4	0	0	10	9	29
	Janira maculosa Leach, 1814	245	1211	521	1065	703	534	492	989	811	364	104	429
Katianiridae	*Katianira bilobata* Gurjanova, 1930	0	0	0	7	1	1	0	2	1	0	0	0
Munnidae	*Munna* cf. *boecki* Krøyer, 1839	0	0	0	1	0	0	0	0	0	0	0	0
	Munna cf. *fabricii* Krøyer, 1846a	0	3	25	27	11	6	216	364	271	367	82	138
	Munna cf. *groenlandica* Hansen,1916	55	261	98	67	45	10	575	536	316	515	103	312
	Munna cf. *hanseni* Stappers, 1911	2	0	0	0	0	0	0	0	0	0	0	0
	Munna cf. *minuta* Hansen,1910	0	125	60	57	13	7	67	391	66	1350	574	1092
	Munna spp.	1	8	9	0	8	0	25	25	18	18	13	37
Paramunnidae	*Pleurogonium inerme* Sars, G.O., 1883	0	0	0	0	24	4	27	114	41	0	67	178
	Pleurogonium intermedium Hansen, 1916	0	0	0	5	0	0	0	0	0	206	0	0
	Pleurogonium pulchra Hansen, 1916	0	0	1	0	0	0	0	0	0	0	0	0
	Pleurogonium spinosissimum (Sars, G.O., 1866)	0	0	0	17	17	22	74	131	151	126	55	313
Munnopsidae	*Baeonectes muticus* (Sars, G.O., 1864)	0	2	9	2	8	11	1	46	22	60	246	839
	Disconectes furcatus (Sars, G.O., 1870b)	0	6	6	36	2	1	0	0	0	0	0	0
	Disconectes latirostris (Sars, G.O., 1882)	0	0	0	0	0	0	0	2	3	0	0	0
	Disconectes phallangium (Sars, G.O., 1864)	0	0	0	0	1	0	0	0	0	0	0	0
	Eurycope producta Sars, G.O., 1869	0	289	173	5	6	26	2	33	23	0	3	5

Continuation of Annex 2.1:

		NE-			SE-			SW-			NW-Greenland		
Family	Species	Station											
		2001	2002	2004	2001	2002	2004	2001	2002	2004	2001	2002	2004
			-1			-2			-3			-4	
Munnopsidae	Eurycopinae spp.	0	26	8	0	1	2	0	1	1	0	0	0
	Echinozone arctica Hansen, 1916	0	0	2	0	2	7	14	33	16	7	0	9
	Echinozone coronata (Sars, G.O., 1870b)	4	29	26	17	20	28	194	230	255	53	24	107
	Echinozone spp.	0	0	0	0	0	1	4	6	0	0	0	0
	Ilyarachna hirticeps Sars 1870b group	0	14	10	33	16	29	2	0	6	18	4	109
	Asellota spp.	0	0	0	1	0	0	23	64	16	1	0	0
Gnathiidae	*Caecognathia abyssorum* Sars, G.O., 1872	2	4	2	11	2	0	1	0	0	0	0	0
	Caecognathia elongata Krøyer, 1846a	0	0	0	8	2	7	0	0	0	22	4	16
	Caecognathia females and juveniles	4	9	13	110	41	15	0	2	0	150	27	162
Aegidae	*Aega psora* (Linnaeus, 1758)	1	0	0	0	0	0	0	0	1	0	0	0
Cirolanidae	*Politolana micropthalma* (Hoek, 1882)	0	0	0	0	0	0	1	0	0	0	0	0
Arcturidae	*Astacilla granulata* (Sars, G.O., 1877)	0	0	0	0	0	0	19	12	18	0	0	0
	Astacilla pusilla (Sars, G.O., 1873)	1	5	0	0	0	0	0	0	0	0	0	0
	Astacilla juveniles	0	0	0	0	0	0	18	2	8	0	0	0
	Spectrarcturus multispinatus Schultz, 1981	0	0	0	0	0	0	841	754	355	2	0	12
	Arcturidae sp. nov.	0	0	0	0	0	0	1	0	0	0	0	0
Cumacea													
Diastylidae	*Brachydiastylis resima* Krøyer, 1846b	0	0	0	0	0	0	7	0	0	25	3	3
	Diastylis cf. *edwardsi* Krøyer, 1841	0	0	0	2	0	0	3	0	2	26	6	4
	Diastylis lucifera (Krøyer, 1841)	0	0	0	0	0	0	0	0	0	6	1	0
	Diastylis spinulosa Heller, 1875	1	0	0	0	0	0	0	0	0	27	6	11
	Leptostylis ampullacea (Lilljeborg, 1855)	0	0	1	0	0	0	0	0	0	0	0	26
	Leptostylis macrura Sars, G.O., 1870a	1	1	0	3	3	3	5	8	3	362	37	142
	Leptostylis villosa Sars, G.O., 1869	0	0	0	0	0	0	0	0	0	25	1	3
	Leptostylis spp.	0	0	0	0	0	0	0	0	0	19	0	0
Lampropidae	*Hemilamprops* cf. *assimilis* Sars, G.O., 1883	0	49	65	0	0	0	0	0	0	0	0	0
	Hemilamprops cf. *uniplicata* (Sars, G.O., 1872)	4	15	5	0	0	0	0	0	0	1	0	0
	Platyaspis typica (Sars, G.O., 1870a)	0	0	0	0	0	0	0	0	0	0	0	1
	Lamprobidae spp.	6	14	11	0	0	0	0	0	0	0	0	0
Leuconidae	*Leucon* cf. *nasica* Krøyer, 1841	0	0	0	4	0	1	1	1	0	1	0	0
	Leucon cf. *nasicoides* Lilljeborg, 1855	0	0	0	1233	1118	1078	1260	931	352	166	26	39
	Leucon cf. *nathorsti* Ohlin, 1901	32	97	60	40	33	40	59	25	28	25	6	5
	Leucon spp.	0	0	0	17	5	0	47	5	4	7	1	3
	Eudorellopsis deformis (Krøyer, 1846b)	0	0	0	0	0	0	3	0	0	23	5	9
Nannastacidae	*Campylaspis horrida* Sars, G.O., 1870a	62	212	197	88	54	67	52	110	105	3	0	1
	Campylaspis rubicunda (Lilljeborg, 1855)	14	46	55	11	1	1	17	9	23	5	5	3
	Campylaspis undata Sars, G.O., 1865	5	15	13	2	0	2	0	3	5	0	0	0
	Campylaspis verrucosa Sars, G.O., 1865	0	0	0	10	0	7	15	4	6	0	0	0
	Cumella carinata (Hansen, 1887)	0	0	0	0	0	0	0	0	0	28	3	24
	Nannastacidae spp.	0	0	0	4	1	0	0	0	0	0	0	0
Pseudocumatidae	*Petalosarsia declivis* (Sars, G.O., 1865)	0	0	0	0	10	0	0	0	0	33	0	9
Tanaidacea													
Sphyrapodidae	*Ansphyrapus tudes* (Norman & Stebbing, 1886)	0	0	1	1	0	0	819	1303	1052	0	0	0
	Pseudosphyrapus anomalus (Sars, G.O., 1869)	0	0	0	3	1	1	0	0	0	0	0	0
Leptocheliidae	*Heterotanais groenlandicus* Hansen, 1913; sensu Vanhöffen, 1914	0	0	0	0	0	0	1	1	0	75	18	56
Leptognathiidae	*Leptognathia breviremis* (Lilljeborg, 1864)	0	0	0	1	0	0	0	0	0	0	0	0
	Leptognathia crassa Hansen, 1913	0	4	0	0	1	0	0	0	1	0	0	0
	Leptognathia subaequalis (Hansen, 1913)	0	0	0	3	0	2	0	0	1	0	0	0
	Leptognathia sp. 1	0	4	4	0	0	0	0	0	0	0	0	0
	Leptognathia sp. 2	0	0	0	0	0	0	2	17	3	0	0	2
	Leptognathia spp.	0	9	2	0	1	1	1	54	50	14	13	6
Pseudotanaidae	*Tanaissus lilljeborgi* (Stebbing, 1891)	0	0	0	0	2	3	0	0	0	0	3	9
	Pseudotanais oculatus Hansen, 1913	0	1	0	0	1	0	0	0	0	44	12	9
	Pseudotanais sp. 1	0	0	0	0	0	0	0	0	0	2	0	0
	Pseudotanais spp.	0	0	0	0	0	0	2	0	0	0	0	0
Typhlotanaidae	*Typhlotanais* sp. 1	0	0	4	2	8	4	39	229	96	146	19	135
	Typhlotanais sp. 2	17	101	32	59	21	22	109	858	197	7	6	12
Paratanaoidea	*Paraleptognathia gracilis* (Krøyer, 1842b)	0	0	0	4	5	6	4	4	1	9	4	4
	Paraleptognathia inermis (Hansen, 1913)	0	0	2	0	3	0	0	0	0	0	0	0
	Paraleptognathia multiserrata (Hansen, 1913)	0	1	1	0	0	0	0	0	0	5	0	0
	Paraleptognathia sp. 1	0	0	0	0	0	0	1	0	0	0	0	0

Chapter 3:

Description of the Rauschert sledge and its sampling efficiency

Description of the Rauschert sledge and its sampling efficiency

Abstract

A small semi-quantitative sledge for sampling epibenthic fauna, the Rauschert sledge, is described. It has already been in use at moderate depths in the Southern Ocean and Greenland for catching peracarid crustaceans and proved to be suitable as a sampling device due to its small size, simple operation and reliable sampling on different substrates. Short instructions are given for the sampling operations using this device.

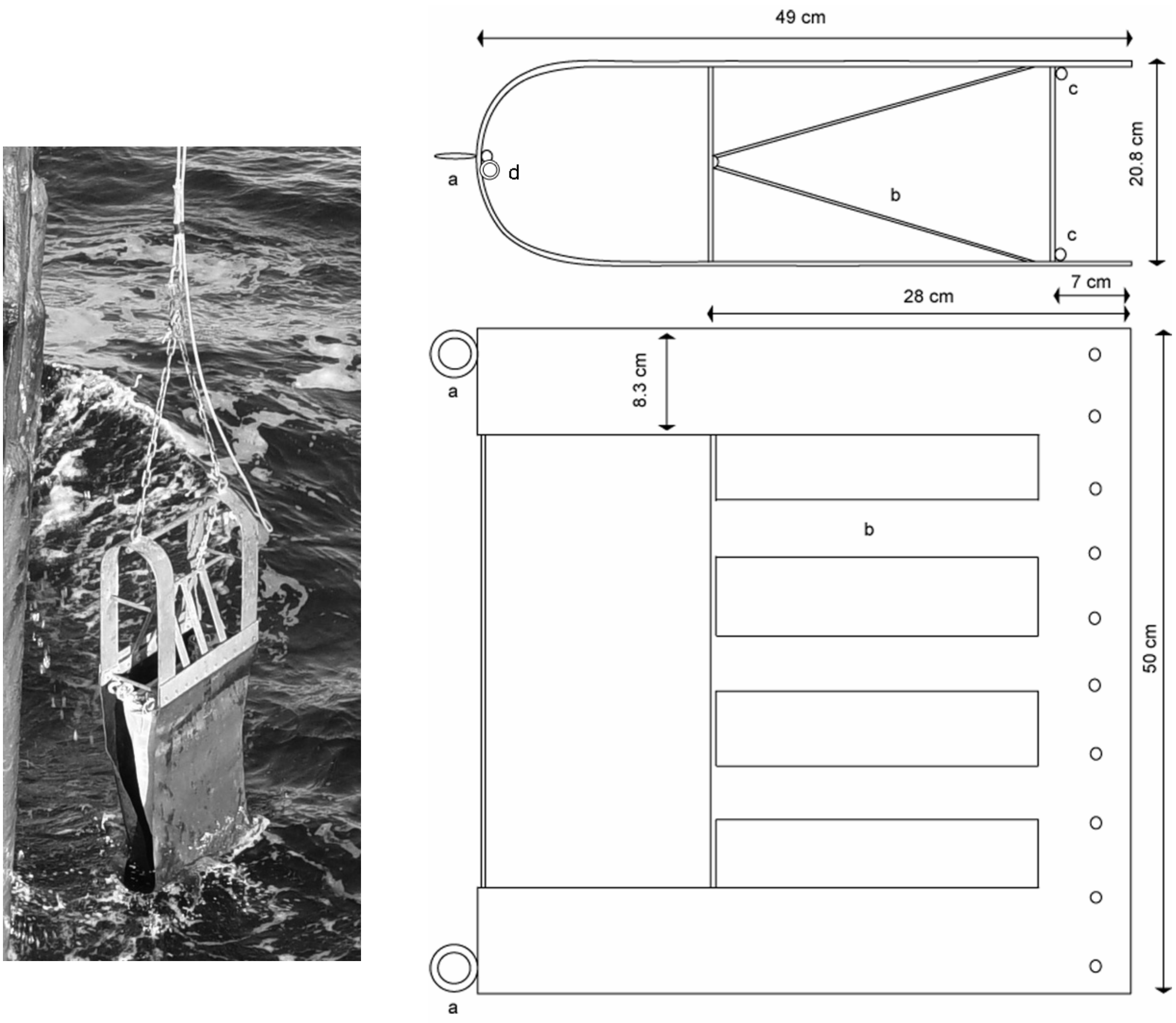
Introduction

Methods for the sampling of epibenthic material have been studied for a long time, and several attempts have been made to improve the sampling procedure, including the invention of new sampling devices and their modifications (e.g. Ockelmann 1964, Hessler & Sanders 1967, Blomquist & Lundgren 1996, Sneli 1998, Rothlishberg & Pearcy 1977, Buhl-Jensen 1986, Brattegard & Fosså 1991, Brandt & Barthel 1995, Brenke 2005). A historical overview of the development of sampling devices is provided by Brenke (2005). The choice of the most suitable gear is dependent on the sampling requirements, the sediment type and the size of the organisms being investigated (Gage & Tyler 1991). In addition, quantitative and/or qualitative sampling usually becomes more difficult with increasing depth, and therefore, the choice of the sampling device becomes even more important at deeper sites (Brenke 2005). Nevertheless, handling, deployment time and catch efficiency has to be reasonable in relation to the available ship time during an expedition.

Ockelmann (1964), Sanders et al. (1965) and Blomquist & Lundgren (1996) developed different sledges which provided basic ideas for the development of the Rauschert sledge. However, the design of the frames and the attachment of the nets deviate from all of them. In this chapter, the Rauschert sledge is presented as a sampling device for macrobenthic animals.

Description and Operation

The Rauschert sledge (RS) consists of two parts: the steel frame and the nets attached to the frame (Fig. 3.1a). The frame (Fig. 3.1b) is made of corrosion-proof stainless steel and measures in outer dimensions 50.0 x 49.0 x 20.8 cm (width x length x height). It is designed symmetrically which allows the sledge to operate on both sides, depending on which side settles on the bottom first. The frame mainly consists of two runners on the sides (each 8.3 cm in breadth, 49 cm in length), which allow the sledge to slide over obstacles and also prevent the sledge from dipping too deeply into the sediment at the same time. The frame is stable since the runners are connected at the front by a round steel bar and at the back by two flattened steel bars (7 cm long, 33.4 cm wide). The height is stable due to four upright round steel bars. The frame of the RS is also equipped with a grid of three steel bars between the runners (position b in Fig. 3.1b), which prevents objects larger than approximately 5-10 cm blocking the opening of the nets. At two rings in the front of the runners (position a in Fig. 3.1.b), two steel chains of 61 cm length are attached and present the linkage between the frame and the wire trawling the sledge over ground. At the chains ends, another wire of 233 cm length is attached, leading to a shackle with a weight of 10 kg and the towing wire. Since the entire sledge with all parts weighs only about 19 kg (see Tab. 3.1), a 10 kg weight is added in the front to ensure that the light sledge will sink properly while deployed at low speed until it hits the ground. In case the gear gets blocked at the ground and breaks the front shackle, there is a safety wire attached at the side of the RS (Fig. 3.1a) and the shackle with the weight. Thus, the load of the RS is then transferred to the safety wire, and the RS should turn around and free itself.



a b

Fig. 3.1a-b: a) RS during heaving after epibenthic sampling off South Greenland, b) RS from lateral view (up) and from above (down). a: ring for a steel chain of 61 cm length (trawling), b: grid of three steel runners, c: rings to attach the nets, d: ring for the attachment of a small chain for disturbing the sediment.

Tab. 3.1: Technical details of the Rauschert sledge (* small parts such as shackles, chains and screws are not included).

	Weight [kg]	Dimensions [cm]
Frame	14	50.0 x 20.8 x 49.0
Set of three nets	1	39.0 x 15.0 x 96.0 (500 µm mesh size) 39.0 x 15.0 x 73.0 (1 cm mesh size) 40.0 x 16.0 x 36.0 (1.5 cm mesh size)
Rubber mats	~ 4	50.0 x 90.0 x 0.3
Total	~ 19*	50.0 x 176 x 20.8

At the inner side of the runners (position d in Fig. 3.1b), a small chain is attached which should disturb the sediment in front of the net, increasing the catch of small epifauna.

The second part of the RS consists of a set of three nets and two rubber mats. The linkages between the frame and the nets are provided by four steel rings on the inner sides of the runners (position c in Fig. 3.1b). In order to protect the sampling material from damage and to facilitate pre-sorting, three nets of different mesh sizes are used. These lay inside each other and are connected with the frame by one shackle at each ring (Fig. 3.1b). The opening of the net measures 0.06 m². The innermost net is made of polyfilament net twine and has the widest mesh size (1.5 cm) of the three nets. It is the smallest net and holds back all objects larger than this mesh size. In the middle, a polyfilament-twine net with 1 cm mesh size is located. The outer net is the main collecting net with a mesh size of 500 µm, made of polyester monofilament. The dimensions in Tab. 3.1 were measured in dry condition. During sampling, however, the meshes of the two inner nets widen and thus dimensions provided in Tab. 3.1 will be exceeded.

Two rubber mats with a size of 50 x 90 cm and ~ 3 mm thickness, one above and one underneath the nets, protect the nets from damage. There are 10 holes in the flattened steel bars to which the rubber mats are attached, and on top of them, additional steel sheets (7 x 10 cm) are screwed onto the steel frame.

During the entire operation (lowering, trawling and heaving), the vessel speed is 1 knot over ground. The wire length is normally calculated at 1.5 times water depth. The lowering of the RS is carried out with a winch speed of 1 m/s, heaving with 0.5 m/s. During the 5 minutes trawling time, the winch is stopped. These are only values for orientation and might be adjusted to different sampling conditions. After heaving, a comfortable positioning of the RS facilitates washing, and emptying the nets is easiest by hanging the RS onto a hook at a height that both nets and rubber mats are freely moving underneath. The nets are closed by a common net knot (which is in use for e.g. bottom trawls) and can easily be opened above a collecting box.

Results and Discussion

The semi-quantitative RS has been used at different locations and depths under the term 'Rauschert dredge'. Rauschert initially used it in several expeditions in the Southern Ocean (e.g. de Broyer & Rauschert 1999, de Broyer et al. 2001, Rauschert 2006). It was used in the Mellemfjord of the western Greenlandic Disko Island (Lörz et al. 1999, Lörz 2000, Nickel 2004) at depths between 50-145 m, and recently in the Ross Sea (Rehm et al. 2006, 2007), at depths between 84-515 m. For the analyses in chapters 1 & 2, the RS was deployed on the South Greenland shelf at depths between 106-251 m.

In chapters 1 & 2, a total of 18 epibenthic stations were analysed and 122,307 individuals of peracarid crustaceans (74,126 amphipods, 34,086 isopods, 12,127 cumaceans, 7,738 tanaids and six mysids) were found, documenting the efficiency for catching peracarid crustaceans. Twelve of the 18 stations were sampled as replicates of the previous years (see chapter 2). Apart from the amphipods, the number of species was similar between the replicates (Fig. 3.2, Tab.3.2), while the abundances clearly differed between the replicates (Tab. 3.2). Brattegard & Fosså (1991) demonstrated that different tow lengths affected the abundance, but not the number of species. In this study, the tow lengths differed between replicates, but showed no correlation with the number of species (Amphipoda: $r = -0.03$, $p = 0.94$; Isopoda: $r = 0.11$, $p = 0.73$; Cumacea: $r = -0.11$, $p = 0.74$; Tanaidacea: $r = -0.11$, $p = 0.74$) or abundance (Amphipoda: $r = 0.06$, $p = 0.98$; Isopoda: $r = -0.04$, $p = 0.90$; Cumacea: $r = 0.08$, $p = 0.81$; Tanaidacea: $r = 0.05$, $p = 0.88$). Nevertheless, Fig. 3.2 and Tab. 3.2 show that the replicability of the Rauschert sledge is high.

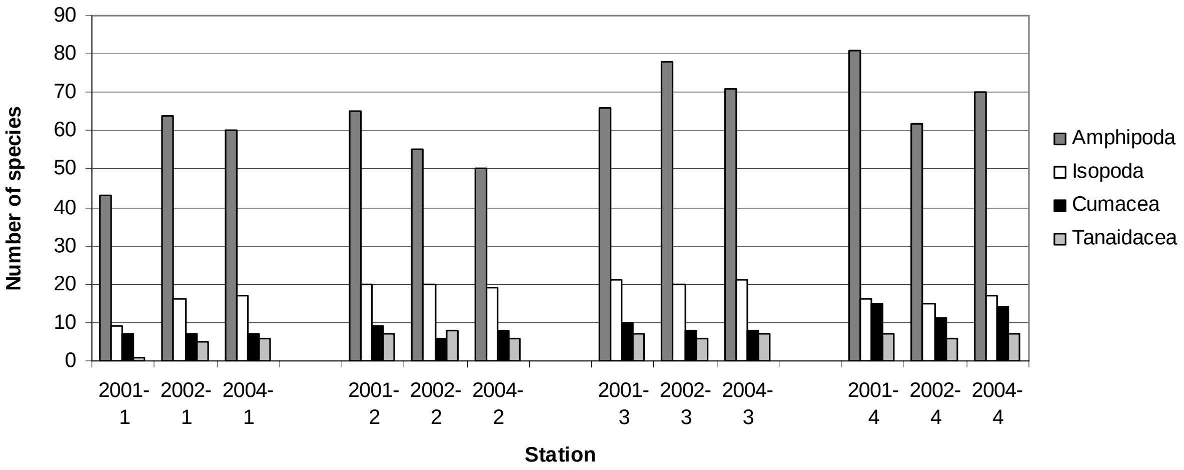


Fig. 3.2: Number of species in the replicates at four locations.

Tab. 3.2: Abundance, number of species and tow length of the replicates at the four locations.

		Station											
		2001	2002 -1	2004	2001	2002 -2	2004	2001	2002 -3	2004	2001	2002 -4	2004
Abundance	Amphipoda	681	2425	1793	2688	1642	1059	6755	9414	6025	6127	1449	3822
	Isopoda	368	2245	1147	1781	1198	1190	2627	3726	2437	3373	1373	3975
	Cumacea	119	435	396	1393	1219	1199	1422	1091	524	756	99	280
	Tanaidacea	17	111	44	73	42	38	975	2412	1351	288	62	227
Number of species	Amphipoda	43	64	60	65	55	50	66	78	71	81	62	70
	Isopoda	9	16	17	20	20	19	21	20	21	16	15	17
	Cumacea	7	7	7	9	6	8	10	8	8	15	11	14
	Tanaidacea	1	5	6	7	8	6	7	6	7	7	6	7
Tow length [m]		266	309	186	365	186	214	314	224	301	170	282	244

During the sampling, it was shown that the RS sinks only a few centimetres into the sediment probably because of its low weight and the runners. This may explain why cumaceans and tanaids were also caught in high abundances. Rehm et al. (2006, 2007) confirmed the catch efficiency of the RS and pointed out that cumaceans were caught in high abundances in the Ross Sea despite exhibiting a more endobenthic lifestyle (5,287 specimens at 18 stations). They also documented a high catch efficiency of the RS for other taxa such as molluscs, annelids and echinoderms. Lörz et al. (1999) and Lörz (2000) compared the efficiency of three different sampling gears (RS, Van Veen grab and triangle dredge) for peracarid crustaceans. These authors concluded that the RS is the most appropriate device with regard to practicability and catch efficiency. The Van Veen grab showed good results for endobenthic taxa, however, its sampling area is too small to catch rare species, and agile organisms usually get washed away due to the bow wave effect before the gear hits the ground. It is therefore not suitable for sampling epibenthic animals. The triangle dredge, on the contrary, samples unselectively.

During the sampling operations within this study, neither the frame nor the nets of the RS were damaged or got lost. Although several large sponges off Southeast Greenland destroyed bottom trawls of the fishery survey, they did not damage the RS. Five minutes trawling time was sufficient for the sampling area. Longer trawling durations, e.g. 10 minutes, resulted in overfilled nets. Rauschert (pers. comm.) also deployed the gear for 5-10 minutes, while Lörz et al. (1999), Lörz (2000) and Nickel (2004) preferred a trawling time of 15 minutes, probably due to a comparatively sparse fauna in the fjord system investigated.

The RS has been proven to be very successful for epibenthic sampling, in particular for small epibenthic and infaunal peracarids. This sampling device has several advantages such as the small size, the simple operation and the symmetrical design allowing either side to reach the bottom and take samples. A disadvantage of the RS is in comparison with the epibenthic sledge, the absence of an opening-closing mechanism, which avoids contamination with organisms of pelagic water layers (Brenke 2005). The degree to which larger and faster specimens, e.g. some agile amphipods, can escape the small opening of the RS is also unknown. The small chain which should disturb the sediment including smaller epi- and infauna might in contrast to its original purpose cause more active species to swim away.

Using other methods such as bottom trawls, many amphipods and isopods (e.g. *Paramphithoe hystrix, Stegocephalus inflatus*, *Aega psora*) were found at localities close to the RS stations which are only poorly sampled with the RS. As in chapters 1 & 2, also Nickel (2004) and Rehm et al. (2006, 2007) documented low abundance of mysids in the RS. Hence, for sampling hyperbenthos, the RS is not suitable.

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Chapter 4:

Sediments and benthic foraminifers along the southern Greenland coast

Sediments and benthic foraminifers along the southern Greenland coast

Abstract

Sediment from nine surface samples from the South Greenland shelf was analysed for its grain size composition and abundance of foraminifers in the grain size fraction > 150 – 250 µm. The samples on South Greenland shelf banks are characterised by sandy sediments, but become coarser towards the northwestern study area. At all sample locations, the sediment was dominated by only one foraminiferal species, *Cibicides lobatulus*, which occurred in high abundances (max. 12,568 specimens per 1 g dry sediment of grain size fraction > 150 – 250 µm). The composition of sediment and foraminifers could be related to the complex hydrography of the study area, dominated by strong currents. The currents in the study area have particularly high velocities at stations with coarse sediments and high abundances of *C. lobatulus*. Finally, the relationship between the abundance of foraminifers and munnopsids (Peracarida: Crustacea) was investigated.

Introduction

The South Greenland shelf has only been sparsely investigated with regard to quantitative analyses of the sediment and foraminiferal contents (Rvachev 1963, 1964; Sommerhoff 1973, 1975). Sommerhoff (1973, 1975) carried out extensive topographic studies of the South Greenland shelf, and within this frame, he also carried out sediment analyses. Based upon the sea bottom topography, Sommerhoff (1973, 1975) and others have shown that the shelf is clearly glacially formed. Similarly, the sediments of the shelf can be classified as glacial due to their unsorted grain size distribution (from clay to boulders) and the degree of roundness of the gravel particles. Sommerhoff (1973, 1975) showed that on the shelf edge, the fraction of coarse sediments (> 1 mm) is remarkably high, whilst sandy sediment dominates on the shelf banks. On the outer shelf, there is a sudden transition on the small scale between rocky and sandy sediments. On the contrary, fine sediments (from clay to sand) are mostly found in the troughs between the shelf banks. Nevertheless, the surface and near-surface structure of the sea floor has proven to influence the distribution patterns of epibenthic organisms.

Foraminifers are single-celled organisms, found in almost every marine environment (Murray in press), from marshes (Alve & Murray 1999) down to the deep sea (Akimoto et al. 2001). About 40,000 species of foraminifers are known, most of them are benthic, and only a few hundred are planktonic (Murray in press). Benthic foraminifers are known to exhibit a wide range of trophic mechanisms such as suspension and substrate feeding or parasitism, and they can be omni-, herbi- or carnivores (Gooday et al. 1992). Benthic foraminifers have been used extensively as indicators of changes in the environment, as their species composition, abundance and distribution mainly depend on spatial and temporal variations in the environment. Therefore, foraminifers are preferably used as proxies for specific environmental parameters which cannot be measured by other means (Murray 2001). In this context, they enable the confirmation for an observed sediment structure and deliver paleoenvironmental information (Mackensen et al. 1985, Corliss & Emerson 1990). Nevertheless, the way how certain environmental factors control the distribution of foraminifers is poorly understood (Murray 2001). For a long time, water depth (e.g. Mackensen et al. 1985) and the hydrography of water masses (e.g. Hald & Vorren 1984, Jennings et al. 2004, Lloyd 2006, Horton & Murray 2007) were the only major factors assumed to be characteristic for foraminiferal distribution. However, their distribution is usually set into context with the grain size of the associated sediment, its organic and oxygen content and hydrographic features (Murray 1991). For each species, different environmental factors - single or in combination - might limit their distribution (Murray 2001). Sejrup et al. (2004) could prove for the first time that foraminiferal assemblages show a significant relationship with temperature and salinity. Besides environmental factors, the foraminiferal distribution can be influenced by biological factors such as competition, bioturbation or predation (Belanger & Streeter 1980, Murray 2001), as benthic foraminifers are an important food source for peracarid crustaceans (e.g. for munnopsids) and a variety of other organisms (Buzas 1978, Brand & Lipps 1982, Wilson & Thistle 1985, Gooday et al. 1992, Svavarsson et al. 1993, Brandt et al. 1994).

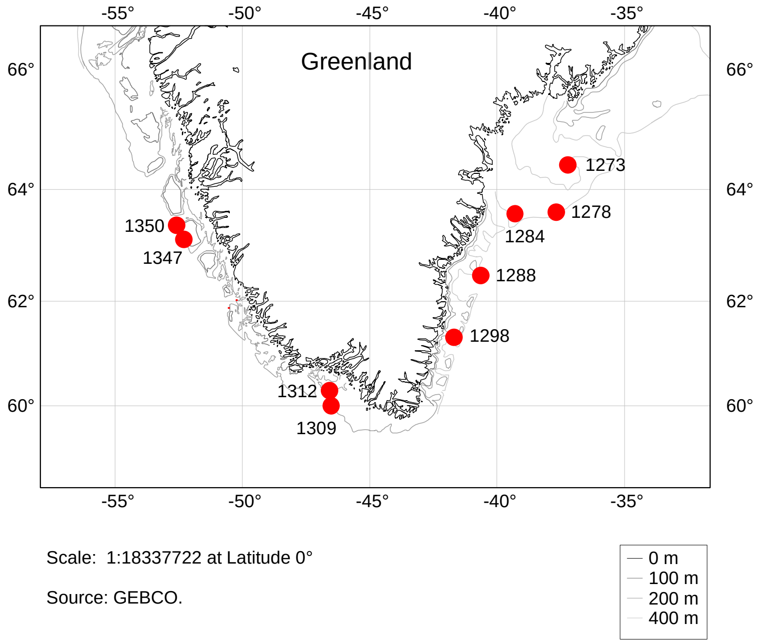
During recent years, several investigations on the distribution and habitat associations of benthic foraminifera have been carried out on the continental shelves in the North Atlantic (e.g. Qvale & van Weering 1985, Moodley et al. 1993, Conradsen et al. 1994, Alve & Murray 1995). Apart from Lloyd (2006), no recent comparison between foraminiferal fauna and the sediment structure on the Greenland shelf has been carried out. Greenlandic fjords, however, have earlier been investigated by Herman et al. (1972), Jennings & Helgadottir (1994) and Madsen & Knudsen (1994), and the Thule area in Northwest Greenland was studied by Feyling-Hanssen & Funder (1990). So far, the distribution of foraminifers has not been put into a wider ecological context, and comparisons between their distribution and that of other taxa are rare.

In a companion study (chapters 1 & 2), the distribution of Peracarida (Crustacea: Malacostraca) on the South Greenland shelf was investigated by epibenthic sampling during three expeditions. In those studies, the sediment type was classified by visual inspection and has proven to influence the peracarid distribution most. In order to quantify the sediment composition, sediment samples were taken during the third expedition at concurrently sampled epibenthic stations. These sediment samples were analysed in this study along with the total (living and dead) foraminiferal fauna. The foraminiferal results were then set in context with the peracarid fauna from the study area.

Material and Methods

The study area and its hydrographic conditions are already extensively described in chapters 1 & 2. There have been only few attempts to measure the velocity of the currents around Greenland directly (e.g. Aagaard & Coachman 1968, Dickson & Brown 1994, Hansen & Østerhus 2000, Holliday et al. in press), and hence only few absolute volume transport estimates exist (Holliday et al. in press). The velocity of the Denmark Strait Overflow was measured with a mean velocity of 21.4 cm/s, and the volume transport was calculated to be 2.7-3.0 Sverdrup (Sv, 1 Sv = 10^6 m^3/s) (Dickson & Brown 1994, Hansen & Østerhus 2000, Pickart et al. 2005), and there was no decrease in velocity with increasing depth (Aagaard & Coachman 1968). The additional inflow of the Irminger Sea Water results in an increase of the transport off the shelf to up to 10.7 Sv and even reaches 35 Sv when passing Cape Farewell offshore (Dickson & Brown 1994, Lavender et al. 2000, Cuny et al. 2002, Pickart et al. 2005). On the shelf, estimates for transport of 2.4-4 Sv and velocity of 35-40 cm/s at Cape Farewell and on the way northwards are common (Clarke 1984, Cuny et al. 2002, Stein 2005, Holliday et al. in press).

For the purpose of analyses on the structure and contents of the sediment on the southern Greenland shelf, nine surface sediment samples were taken (Fig. 4.1) during cruise WH 268 in 2004 with the FRV *Walther Herwig III* using a small grab, similar to a Van Veen grab (Fig. 4.2). Samples were located as close as possible to the epibenthic sampling presented in chapters 1 & 2 (Tab. 4.1), with five stations off Southeast Greenland and four off Southwest Greenland. After heaving, sediment samples of approximately 100 ml volume each have been taken from the top 2 cm sediment layer at each station and were preserved in 96% ethanol, including Rose Bengal as staining agent, and stained for several weeks. Rose Bengal is considered to be appropriate for staining, as the protoplasmic contents of those foraminiferal species that were alive at the time of sampling are stained red (Murray & Bowser 2000). Temperature and salinity were recorded at each station by a CTD probe.



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Source: GEBCO.

Fig. 4.1: Map of the study area and positions of the sediment stations (dots) during the cruise WH268.

Fig. 4.2: Photograph showing the grab used for sediment sampling during the cruise WH268.

Tab. 4.1: Station list of sediment samples.

Station	Date	Latitude [N]	Longitude [W]	Temperature bottom [°C]	Salinity bottom	Depth [m]
1273	16.10.04	64°24.52'	37°12.99'	5.68	34.95	149.8
1278	17.10.04	63°36.67'	37°40.48'	4.66	34.87	228.0
1284	18.10.04	63°34.08'	39°18.61'	5.97	34.99	203.1
1288	19.10.04	62°28.14'	40°37.39'	5.76	34.92	236.8
1298	21.04.04	61°19.05'	41°40.84'	5.92	34.70	156.6
1309	23.10.04	60°00.00'	46°31.06'	6.22	34.67	160.1
1312	23.10.04	60°17.83'	46°35.12'	5.92	34.43	149.6
1347	28.10.04	63°07.75'	52°17.82'	4.48	33.96	151.8
1350	29.10.04	63°21.79'	52°35.35'	4.25	33.79	112.2

Subsequently, the samples were wet-washed through sieves with mesh sizes of 63, 150, 250, 500 and 2000 µm. The residues of each size fraction were dried at 50°C for 48 hours and weighted to the nearest mg.

For the determination of the foraminifers and the calculation of their abundance, the grain size fraction of 150 µm – 250 µm, which is commonly used for these purposes, was analysed. In the data analysis, the total foraminiferal fauna including living and dead specimens was analysed, as both elements are good indicators of recent environmental conditions (Scott & Medioli 1980, Murray 1991).

The abundances of foraminifers in the samples were calculated by counting the individuals per species in five chambers on a counting plate in two consecutive cycles, determining the average by chamber, raising these to the total of 50 chambers of the plate (whereof the subsample weight was taken), and finally raising those abundances to 1 g sediment dry weight.

Results

Sediment analyses

Only a minor part of the sediment consists of the smallest fraction < 63 µm, ranging between 1 and 9% (Tab. 4.2). The four fractions > 63 µm, > 150 µm, > 250 µm and > 500 µm – 2 mm are the grain sizes characterising sandy sediments. At the eastern stations, these sandy grain sizes contribute 77 – 93% of the total sediment. In the west, the contributive part of this sandy fraction decreased towards the north to 58 – 83%, while the fraction of the coarse grain size

(> 2 mm) increased towards the northwestern stations to about one third of the total sediment (Tab. 4.2, Fig. 4.3).

Tab. 4.2: Distribution of sieve size residues into sediment fractions [%].

		Sieve size fraction					
	Station	> 2 mm	> 500 µm	> 250 µm	> 150 µm	> 63 µm	< 63 µm
Southeast	1273	13.11	9.18	28.41	33.31	14.42	1.57
	1278	15.78	33.14	33.63	10.42	2.83	4.21
	1284	5.57	32.03	29.09	15.79	8.10	9.42
	1288	4.21	22.29	34.59	24.29	12.12	2.51
	1298	19.70	13.30	30.20	23.46	10.29	3.05
Southwest	1309	14.13	26.08	20.21	28.36	8.41	2.82
	1312	24.52	4.49	22.29	38.88	8.41	1.40
	1347	20.77	12.82	31.84	22.32	5.42	6.82
	1350	33.18	20.97	18.63	10.41	7.45	9.35

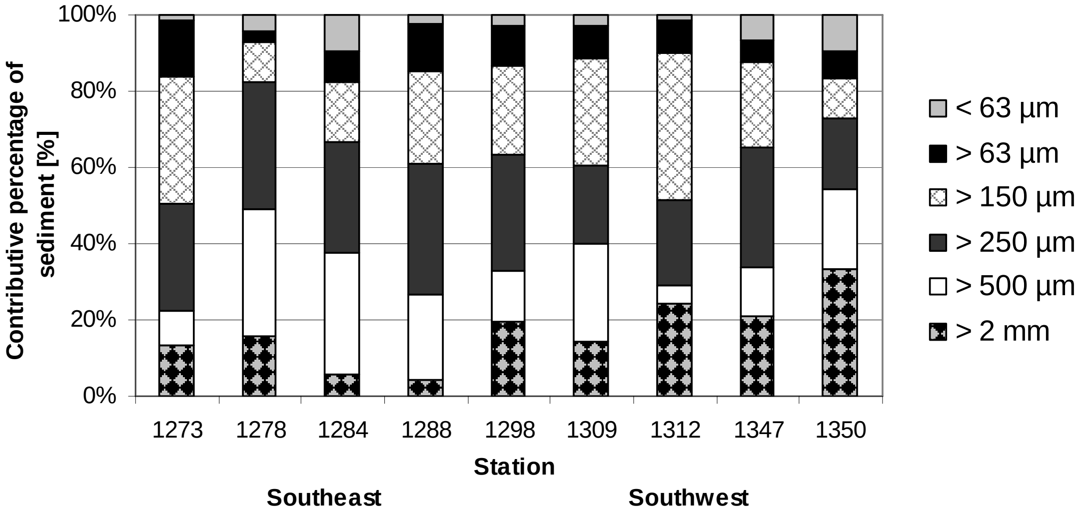

Fig. 4.3: Distribution of sieve size residues into sediment fractions.

Foraminiferal abundances

In the total analysis of the grain size fraction > 150 – 250 µm, eight calcareous foraminiferal species were identified (Tab. 4.3), six benthic and two planktonic ones. *Cibicides lobatulus* was the dominant foraminifer species (Tab. 4.3, Fig. 4.5), representing 78% of the total abundance. The remaining 22% were divided into the benthic species *Elphidium excavatum,* *Islandiella* cf. *helena, Nonionellina labradorica, Oolina melo, Quinqueloculina* cf. *stalkeri* and the planktonic species *Globigerina bulloides* and *Neoglobigerina pachyderma* sinistral.

Tab. 4.3: Abundance of living and dead calcareous foraminiferal species of in the grain size fraction > 150 – 250 µm, calculated for 1 g dry sediment.

						Station				
	Living species	**1273**	**1278**	**1284**	**1288**	**1298**	**1309**	**1312**	**1347**	**1350**
benthic	*Elphidium excavatum* (Terquem, 1876)	0	0	0	0	0	0	0	545	0
	Cibicides lobatulus (Walker & Jacob, 1798)	176	672	0	0	0	845	0	182	2810
	Islandiella cf. *helena* Feyling-Hanssen & Buzas, 1976	0	0	0	374	0	0	0	182	0
	Nonionellina labradorica (Dawson, 1860)	176	0	276	0	0	0	0	363	187
	Oolina melo d'Orbigny, 1839	0	0	0	0	0	0	0	182	0
	Quinqueloculina cf. *stalkeri* Loeblich & Tappan, 1953	0	0	0	0	0	169	0	0	0
planktonic	*Globigerina bulloides* d'Orbigny, 1826	176	0	276	0	0	0	0	0	0
	Neoglobigerina pachyderma sinistral (Ehrenberg, 1861)	0	0	0	374	0	0	0	0	0
	SUM	527	672	552	747	0	1014	0	1453	2997
	Dead species									
	Cibicides lobatulus (Walker & Jacob, 1798)	826	1562	2843	4933	77	1522	0	10080	9856
	other foraminifers	141	386	2622	1719	39	372	0	2488	1049
	SUM	966	1948	5465	6652	116	1893	0	12568	10905

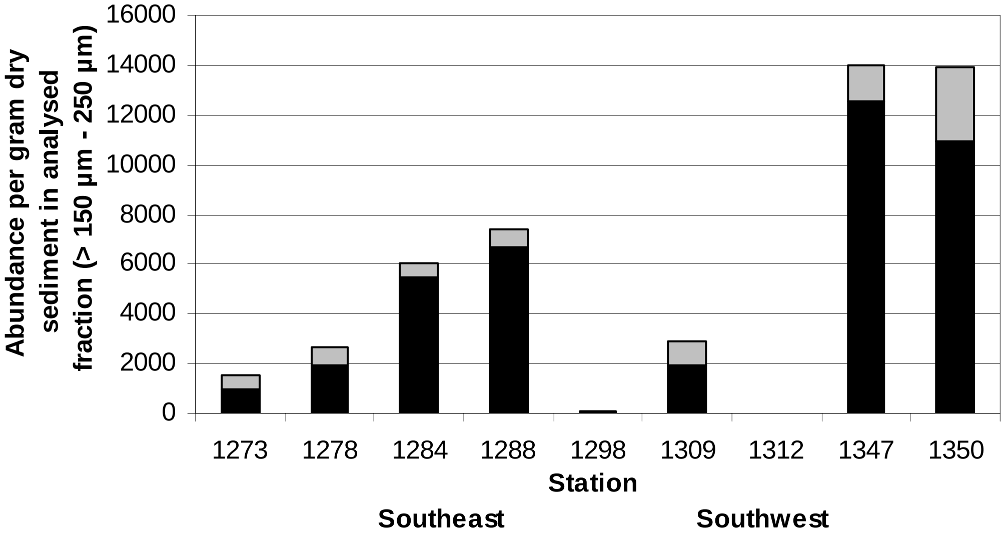

Fig. 4.4: Abundance of dead (black bars) and living (grey bars) foraminifers at the nine stations in the grain size fraction > 150 – 250 µm.

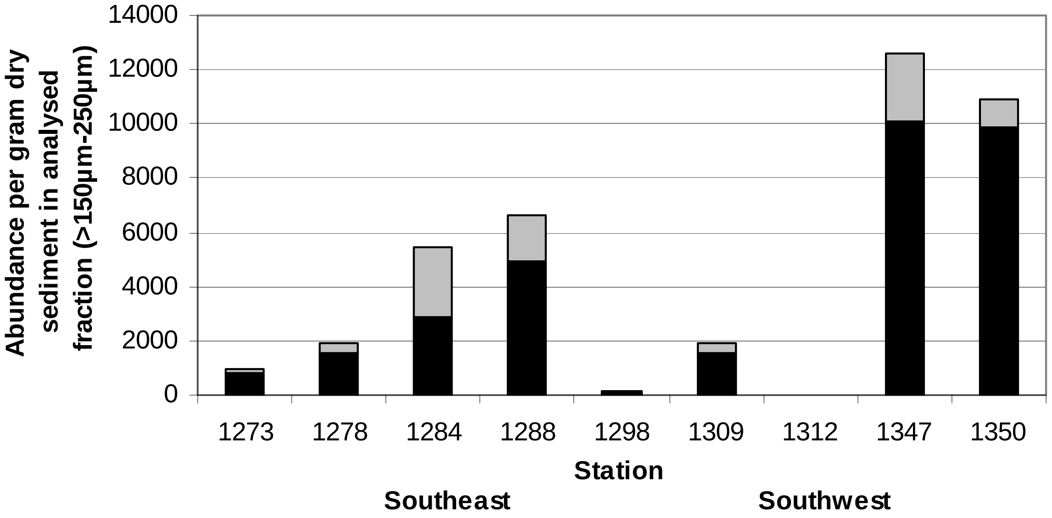

Fig. 4.5: Abundance of dead foraminifers at the nine stations in the grain size fraction > 150 – 250 µm. *Cibicides lobatulus* in black bars, grey bars represent all other foraminifers.

The abundance of foraminifers increased clearly from the northeastern station 1273 towards the eastern station 1288 (Fig. 4.4, Fig. 4.5). Then, the abundance decreased clearly at the southeastern station 1298 and the southwestern stations 1309 and 1312. At the latter station, foraminifers were completely absent. The abundances at the two northwestern stations were, however, remarkably high with about 10,000 specimens of *C. lobatulus* each. The fraction of *C. lobatulus* was always at least 66% of the total abundance. Only at station 1284, the ratio between *C. lobatulus* and other foraminifers was about 1:1. In the East, the abundance of *C. lobatulus* showed no significant correlation with the measured abiotic factors (temperature: r = 0.12, p = 0.85; salinity: r = 0.55, p = 0.34; depth: r = 0.79, p = 0.11). In the West, the abundance of *C. lobatulus* was only significantly correlated with temperature (r = -0.97, p = 0.04), but not with salinity (r = -0.92, p = 0.08) and depth (r = -0.58, p = 0.42).

In the analysed grain size fraction, only few living (stained) foraminifers were observed (Tab. 4.3, Fig. 4.4). *C. lobatulus* was again the dominant species. Additionally, the distribution of the living foraminifers was patchy (Tab. 4.3).

Discussion

The sampling with a small grab, as used in this study, covers only a small area, compared with the area sampled by a trawled sampling device such as the Rauschert sledge (see previous chapters) or the epibenthic sledge (Brenke 2005). Thus, the sediment samples may not be representative compared to the area sampled for e.g. the peracarid crustacean fauna analysed in chapters 1 & 2. The analysis of surface sediment provides amongst other things knowledge about sedimentation, currents and the substrate for benthic organisms. These environmental factors are all important when interpreting the mechanisms which control the distribution of foraminifers (Sejrup et al. 1981).

On the shelf banks, where the sampling stations of this study were located, the sediment structure can generally be described as sandy. Similar conditions were also reported by Rvachev (1963) for the southwestern Greenland shelf and by Holtedahl & Bjerkli (1982) and Sejrup et al. (1981) for the Norwegian shelf. The distribution of the surface sediments on the continental shelf is strongly related to the present current regime (Sejrup et al. 1981). Sediments which consist to a major part of sand (in this study 90-95%) are generally known for strong currents (Rvachev 1963). This observation is in concordance with data from Clarke (1984), Dickson & Brown (1994), Hansen & Østerhus (2000), Cuny et al. (2002) and Stein (2005). Sandy sediments are usually found peripheral to gravelly sandy sediments, which are known from areas exposed to currents (Sejrup et al. 1981). The contribution of the gravel fraction to the sediment is slightly increasing towards the northwestern stations. This might be explained by the location of the two northwestern stations. These were taken relatively close to the shelf edge and, thus, might be already influenced by the strong currents flowing northwards on the shelf edge (Stein 2005, Pickart et al. 2005). Variations in sediment structures depend on the relief shape of southern Greenland shelf (Rvachev 1963). It is not surprising that the muddy fraction (< 63 µm) is consistently low, as muddy sediments are more commonly found in areas where the currents are relatively weak, e.g. in fjord systems or estuaries (e.g. Sejrup et al. 2001, Horton & Murray 2007).

Numerous parameters, more or less interrelated, control the ecology and distribution of benthic foraminifera on different spatial scales (Belanger & Streeter 1980, Murray 2001, Horton & Murray 2007). These are physical-environmental parameters such as depth (Debenay & Redois 1997), temperature and salinity (Jennings et al. 2004, Lloyd 2006), substrate structure (Debenay & Redois 1997, Klitgaard-Kristensen et al. 2002, Lloyd 2006), oxygen concentration (Caralp 1989, Debenay & Redois 1997, Wollenburg & Mackensen 1998, Altenbach et al. 1999, Fontanier et al. 2002; Husum & Hald 2004), nutrient supply (Lutze & Thiel 1989, Debenay & Redois 1997) and currents (Hald & Vorren 1984, Jennings et al. 2004). Also latitudinal and bathymetric zonation, topography and contents of calcium carbonate are known to influence the distribution patterns of foraminifers (Saidova 2005). Biological interactions, such as competition and predation, may influence the foraminiferal distribution as well (Belanger & Streeter 1980, Murray 2001). In a varying environment (such as a shelf area), probably different factors or a combination of factors might limit the distributions both temporally and spatially (Murray 2001). In one area, this can result in strong correlations between certain species and one particular factor, while in another area, this correlation is not given. In this study, not all abovementioned environmental and biological parameters could be measured and investigated. Some variability in the faunal abundance and distribution may be related to these undetermined variables.

Compared with previous studies in the northern North Atlantic (e.g. Alve & Murray 1995, Klitgaard-Kristensen & Buhl-Mortensen 1999, Klitgaard-Kristensen et al. 2002, Rytter et al. 2002, Husum & Hald 2004, Jennings et al. 2004, Sejrup et al. 2004, Saidova 2005, Lloyd 2006), the species richness and diversity of the foraminiferal fauna of the South Greenland shelf was very low. Also in comparison with a study in the Bay of Biscay (Fontanier et al. 2002), the species richness in South Greenland was low. In contrast to the number of species, though, the abundances of dead foraminifers found in the study area were generally remarkably high. Lloyd (2006) investigated the distribution of benthic foraminifers in the Disko Bay (West Greenland, about 660 km north of the northwestern stations of this study). He found agglutinated and calcareous species, while in South Greenland (present study), only calcareous species were found. His analyses further showed that *C. lobatulus* dominated those sand-rich stations where the water masses are warm and less saline (3.2°C, 33.27 psu) in combination with coarse sediment. This is in agreement with the results for *C. lobatulus* in this study in South Greenland, especially at the northwestern stations. *C. lobatulus* is epifaunal, a strongly current-related species (e.g. Hald & Vorren 1984, Klitgaard-Kristensen et al. 2002) and common on sandy to especially gravel substrate (Conradsen 1993, Klitgaard-Kristensen & Sejrup 1996, Hald & Korsun 1997). It is further known that the distribution of *C. lobatulus* depends on firm substrates such as hydroids, shells or rock surfaces which project above the sea floor (Klitgaard-Kristensen & Sejrup 1996, Murray 2001). This species does not live on associated gravel or sandy sediment, only their dead tests accumulate there

(Murray 2001). Therefore, a suitable surface is also provided by peracarid crustaceans, which is demonstrated by e.g. Svavarsson & Davíðsdóttir (1994) and Svavarsson & Ólafsdóttir (1999, 2000). In southwestern Greenland, the abundance of *C. lobatulus* was highest and showed strong correlation with temperature and salinity. Nevertheless, the abundance was highest in (similar) temperature and salinity ranges that Lloyd (2006) described as preferable for *C. lobatulus*. This also demonstrates that temperature and salinity, however, were probably out of the preferable range for *C. lobatulus* at the two southwestern stations, since the abundance of *C. lobatulus* at these stations was much lower than at the two northern stations.

The low foraminiferal abundances at stations 1298, 1309 and 1312, however, cannot be explained by the measured environmental data and sediment analyses, as these did not provide any clear difference of those stations to the other stations. Differences in the species composition of living and dead foraminiferal assemblages are often considerable (Murray 1991, Jorissen & Wittling 1999, Gooday & Hughes 2002). Horton & Murray (2007) explain the higher abundances in dead foraminiferal assemblages in contrast to its living counterpart with the accumulation of many generations over a long period of time. Schröder-Adams et al. (1990) analysed the foraminifers from continental shelves in the Arctic and Baffin Bay and documented that in their study area living specimens were extremely rare, showing an abundance of less than 3% of the total abundance. This relation corresponds to that of the South Greenland area. Schröder-Adams et al. (1990) further found a foraminiferal fauna that was dominated by *C. lobatulus*.

The remaining living foraminifers of this study showed a low abundance and a patchy distribution. There are several explanations for the patchiness and low abundance for living foraminifers. The sampling with the grab does not provide optimum sampling conditions. Additionally, the abundance of living foraminifers can differ throughout the year between species and location due to seasonal reproduction (Klitgaard-Kristensen & Sejrup 1996). Conclusions on the abundance and distribution of living foraminifers as in other studies on *E. excavatum, I.* cf. *helenae* and *N. labradoricum* are therefore not generally applicable to this study. *E. excavatum* seems to tolerate large variations in salinity, temperature and oxygen content of the water mass (Risdal 1964, Lutze 1965) and is one of the main components in Arctic fjords (e.g. Elverhøi et al. 1980). Sejrup et al. (2004) and Jennings et al. (2004) found *E. excavatum* to become more abundant with cooler water and a variable salinity on the Norwegian and the Icelandic shelves. Since *E. excavatum* was only found at one station in this study (station 1347), it is difficult to conclude a general statement with regard to the results of Sejrup et al. (2004) and Jennings et al. (2004). Nevertheless, it can be confirmed that the temperature at station 1347 is among the coldest measured off South Greenland within this study. Generally, *E. excavatum* seems to be one of the dominant Arctic species occurring in the North Atlantic (Holtedahl & Bjerkli 1982). Hald & Korsun (1997) found *N. labradoricum* as a very abundant species in fjords in Svalbard. The sediments in their analyses were dominated by silt and clay and different to that in the current study. However, these sediment characteristics generally fit to the distribution found for *N. labradoricum* in the present study: The stations where *N. labradoricum* was found had the largest fraction of silt of all stations (except for station 1273). Other factors which are decisive for *N. labradoricum* in Hald & Korsun's (1997) analysis are high salinity and temperature, as well as great depth. The influence of all these factors can not be supported by the present study, as no correlation was found; neither by other studies (e.g. Sejrup et al. 2004).

Only two living planktonic species (*G. bulloides, N. pachyderma* sinistral) were found in this study. Qvale & van Weering (1985) already showed that planktonic forms usually occur in low abundances and that the ratio between planktonic and benthic foraminifers varies strongly on the shelves, since the currents there are too strong, and unstable conditions in surface waters limit their distribution. Moreover, the presence of only two planktonic species in the study area indicates influx of warm water from the gyre south of Iceland, which provides unfavourable conditions for planktonic foraminifers (Haflidason, pers. comm.).

In this study, the foraminiferal distribution did not show significant correlation with environmental parameters such as temperature, salinity and depth. The current patterns in the study area, however, are most likely determining the distribution of foraminifers on the South Greenland shelf.

In chapter 2, the distribution, diversity and community patterns of epibenthic Peracarida (Crustacea: Malacostraca) were investigated along the South Greenland shelf. The analyses in chapter 2 showed that the distribution of peracarids depended on the sediment to a large extent. Four of the stations analysed in that chapter correspond to four sediment samples taken for this study in close vicinity of the epibenthic stations (Tab. 4.4). In chapter 2, the sediment structure was only roughly classified by visual inspection, since the quantifying sediment analyses from this study could not be applied to all investigated faunal stations. Nevertheless, the analyses with exact sediment data from this chapter did not change the general perception of the influence of the sediment characteristics on the faunal distribution patterns. Therefore, it can be concluded that the estimations of the sediment were generally in agreement with the analyses of this chapter.

Tab. 4.4: Corresponding stations from the analyses in chapter 2 and from this chapter.

Station from chapter 2	Station from this chapter
2004-1	1273
2004-2	1298
2004-3	1309
2004-4	1347

Moodley et al. (1993) hypothesised that the density of foraminifers is affected by the presence of other benthic organisms. The knowledge about the feeding habits of peracarids is only fragmentary, but many of them are assumed to be detritus feeders (e.g. Wolff 1962, Buhl-Mortensen 1996) and foraminifers in peracarid guts have been assumed to be ingested incidentally (Wolff 1962, Moodley et al. 1993). Nevertheless, munnopsids (Isopoda) are known to feed selectively on foraminifers (Wilson & Thistle 1985, Svavarsson et al. 1993, Brandt et al. 1994). They are equipped with strong mandibles to facilitate the crushing of the foraminifers.

In this context, the comparison of abundance of foraminifers and peracarids was only carried out for the munnopsids with the hypothesis that munnopsids prey on foraminifers. At the stations taken for this comparison, *Baeonectes muticus, Disconectes furcatus, D. latirostris, Eurycope producta, Echinozone arctica, E. coronata* and the *Ilyarachna hirticeps*-group were found. Their abundance is highest at station 1347, as it is the case for the foraminifers. From this observation, it can only be speculated to which extent munnopsids co-occur with foraminifers and if they are potentially affected by other factors such as food, sediment structure or hydrography.

In general, it is more probable that the described currents have a bigger influence on the species composition of peracarids than predation or competition. As described in chapters 1 & 2, sediment had major impact on the species composition of peracarid crustaceans. This study, however, indicates that the sediment structure is characterised by the current velocities. The higher the velocity of a current, the coarser the sediment, as small particles such as mud and silt are transported further to calmer areas such as estuaries or bays, where they can sink and give these areas their characteristic sediment structure (e.g. Rvachev 1963, Gage & Tyler 1991). On the background of the high observed abundances of peracarid crustaceans on the South Greenland shelf, it can be assumed that the current patterns and sediment structure probably provide preferable habitats for these taxa.

Conclusions

The sediment structure on the southern Greenland shelf can be characterised as sandy. It varied from purely sandy in the East to gravelly sandy in the Northwest. The fraction of coarser grain sizes increased towards the northwestern stations of the study area, which can be explained by high current velocities at these sampling sites close to the shelf edge. The fraction of silt is low at all stations. The abundance of foraminifers is dominated by *Cibicides lobatulus*, but the species composition of foraminifers shows a patchy distribution which is influenced by sediment structure, salinity and temperature.

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Chapter 5:

Spatial distribution and biogeography of Isopoda (Peracarida: Crustacea) from South Greenland and adjacent waters

Spatial distribution and biogeography of Isopoda (Peracarida: Crustacea) from South Greenland and adjacent waters

Abstract

In a comparison of several North Atlantic sites from Norway, the Faeroe Islands, Iceland, Greenland, Davis Strait, East Canada and the Northern Seas, the species composition of isopods (Crustacea: Malacostraca: Peracarida) was investigated on different spatial scales. Based on species occurrence in new material from South Greenland and literature data, the similarity between geographic sites was analysed. Among the 231 included species, Desmosomatidae and Munnopsidae represented the families with the highest species richness. Some genera had a high number of rare species (e.g. *Nannoniscus*, *Leptanthura*) occurring at only one site, and most species showed a wide bathymetric range. Multivariate analyses of species composition resulted in several clusters of sites, whereas the individual sites East Canada, Davis Strait and Northwest Greenland differed from all others. The Norwegian sites, the Faeroe Islands and South Iceland grouped to one biogeographic region, while the South Greenland sites were similar to each other and showed highest similarity to the sites from the Northern Seas and North Iceland. On this large scale, it is most likely that the hydrographic conditions have a major influence on the species distribution patterns.

Introduction

Since expeditions in the late 19th and early 20th century, numerous international and national research programmes and expeditions with a focus on the benthic crustaceans have been carried out in the northern North Atlantic. Recent studies (e.g. Brandt et al. 2004, 2005, in press) and samples from the BIOICE and BIOFAR 1 & 2 projects around Iceland and the Faeroe Islands (Nørrevang et al. 1994, Sigvaldadóttir et al. 2000, Sørensen et al. 2000, Stransky & Svavarsson 2006) showed high abundances and high numbers of species of the benthic crustaceans in the polar deep sea. Such increased sampling intensity changed our view on the patterns of marine diversity and distribution. Nevertheless, the distribution and life-history of a wide range of benthic taxa is still poorly understood. Their distribution patterns can depend on food supply (Suess 1980, Grebmeier et al. 1988, Graf 1989, Carey 1991), disturbance (Gutt & Starmans 2003, Barnes & Conlan 2007), competition (Thrush et al. 2005) and other environmental factors (Brandt et al. 1996, Weisshappel & Svavarsson 1998, Tuya & Haroun 2006).

The distribution of taxa can only be estimated on a defined scale, as they are usually heterogeneously distributed (Texeidó et al. 2002, Begon et al. 2003, Gutt & Starmans 2003, Garcia-Charton et al. 2004). The setting of a scale is extremely important (Levin 1992, Fortin & Dale 2005), since factors such as food or sediment influence the communities on a smaller scale (Gray 1974, Pearson & Rosenberg 1987) than factors such as climate on a larger scale (Tuya & Haroun 2006). Large-scale hydrographic patterns such as temperature and currents are among the major forces impacting the distribution of biota in all habitats, including epibenthic communities (Levin et al. 2001).

Peracarid crustaceans are an important macrobenthic group and occur from shallow waters down to the deep sea (Grassle & Maciolek 1992). They are known for high abundances and diversities (e.g. Grassle & Maciolek 1992; Svavarsson et al. 1990, 1993; Brandt 1993, 1995; Brandt et al. 1996, 2004, 2005, in press; Svavarsson 1997). Within the peracarids, the isopods represent a particularly well investigated taxon, especially in the northern hemisphere, and offer a good basis for biogeographic comparisons in the northern North Atlantic.

The northern North Atlantic is characterised by two major water masses. The cold polar water from the Arctic Ocean flows southwards through the Nares Strait and mainly through the Fram Strait and further along Iceland, where it hits the warm water masses of the North Atlantic. Around a latitude of 65°N, the Greenland-Iceland-Faeroe Ridge separates the relatively warm southern water masses from those of the cold Northern Seas (NOAA 2004). This ridge is not only a barrier for water masses (Malmberg 1985, Stein 1988, Hansen & Østerhus 2000); it also divides the marine fauna of Iceland into southern and northern components (Weisshappel 2000, 2001). South Greenland is influenced by the cold East Greenland Current and the warm Irminger Current (Pedersen et al. 2004). Off West Greenland, the West Greenland Current (WGC) follows the continental slope northwards and transports warm water through the Davis Strait into Baffin Bay (Melling et al. 2001, Stein 2005). On its way, the WGC loses much of its heat due to recirculation with cold Arctic water, which flows from the Arctic Sea via Baffin Bay westerly through the Davis Strait and southwards with the Baffin Island Current (Melling et al. 2001, Stein 2005). The east coast of northern Canada is therefore dominated by the influence of cold Arctic water (Cuny et al. 2002).

Besides the hydrography on a large scale, the type and structure of the sediment on the South Greenland shelf seems to have a major impact on the distribution and species composition of the epibenthic fauna on a medium scale (chapters 1 & 2). Based on these environmental forces, the peracarids were grouped into a southeastern and southwestern fauna. This study investigates if this division is reflected on a larger scale, i.e. separating the Northeast Atlantic from the Northwest Atlantic. Using the order of Isopoda as an example, grouping of sampling sites on a medium and large scale was analysed based on their species composition.

Material and Methods

The new data used in this study were derived from material collected during three expeditions on the FRV *Walther Herwig III* to South Greenland (cruises WH233, WH244 and WH268 in the years 2001, 2002 and 2004, respectively). Details on the sampling locations, environmental data and the sampling device are given in chapters 1 & 2. These data are put into perspective with distributional data from isopods occurring around Greenland, Iceland, the Faeroe Islands, Norway, East Canada and the Northern Seas from the literature (see Sars 1885, 1899; Hansen 1916; Gurjanova 1930, 1933; Stephensen 1937, 1943; Hult 1941; Wolff 1962; Just 1970, 1980; Thistle 1980; Schultz 1981; Negoescu & Wägele 1984; Svavarsson 1982a,b, 1984a,b, 1987a,b, 1988a,b, 1999; Svavarsson et al. 1993; Schotte et al. 1995; Klitgaard 1995, 1997; Brandt et al. 1994, 1996; Malyutina & Kussakin 1996a,b; Brandt 1997; Brattegard & Holthe 1997; Negoescu & Svavarsson 1997; Johansen & Brattegard 1998; Brandt & Retzlaff 2002; George 2004; Kensley 2004, Cunha & Wilson 2006, Stransky & Svavarsson 2006 and Brix & Svavarsson, in prep.).

As basis for this study, distributional data for isopods from the abovementioned publications and the species distributions from chapter 1 & 2 were considered. All studies, including that of chapter 1 & 2 could be allocated to clearly defined geographic sites (Fig. 5.1), as the spatial range of their expeditions was limited to a certain area. These sites are also defined by their topographic or hydrographic settings such as the Greenland-Iceland-Faeroe Ridge. In this analysis, 12 geographic sites were considered: South Norway (southern coast up to 65°N), North Norway (northern coast from 65°N), the Faeroe Islands, South Iceland (south of the Greenland-Iceland-Faeroe Ridge), North Iceland (north of the Greenland-Iceland-Faeroe Ridge), the Northern Seas (Norwegian, Greenland, Iceland Seas and the Arctic Ocean), Southeast Greenland (south of 65°N), Southwest Greenland (south of 65°N), Northeast

Greenland (75°N - North East Water Polynya), the Davis Strait (the entire area between Northwest Greenland and East Canada) and East Canada (coast between 50°-65°N).

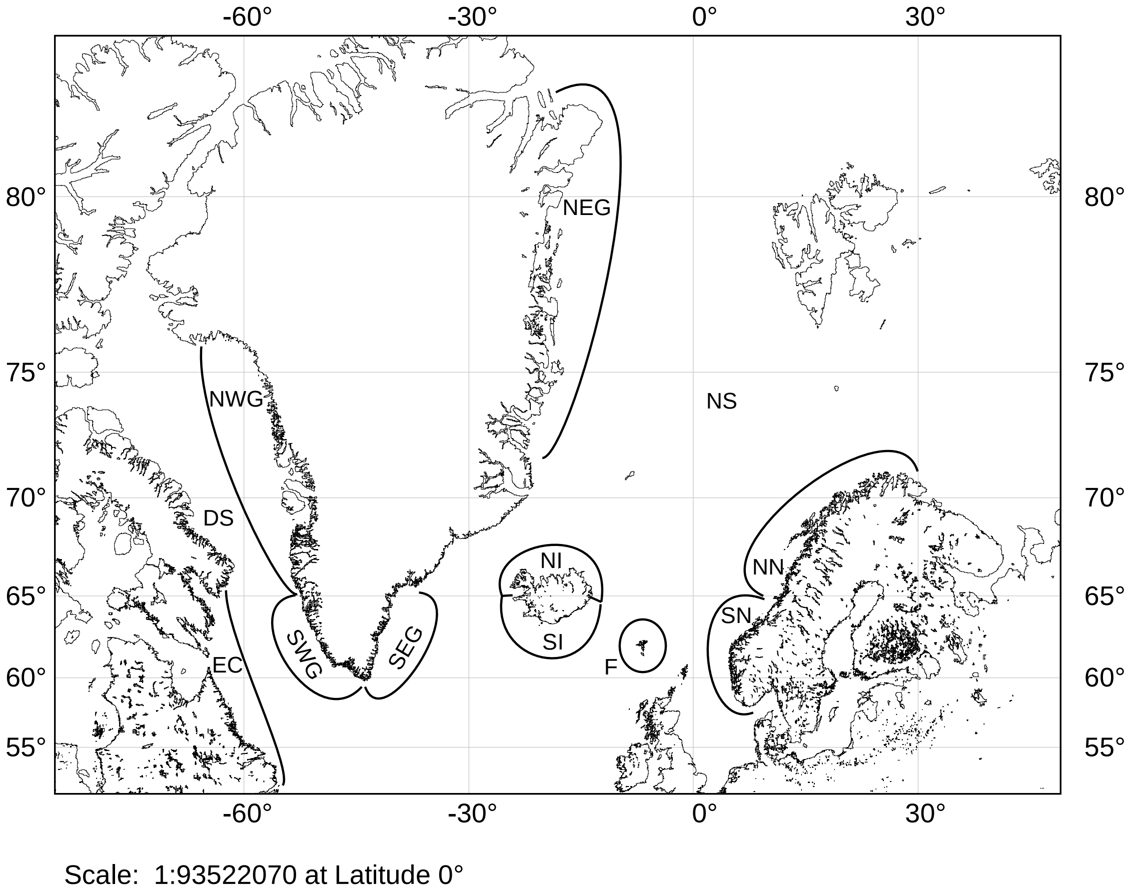


Fig. 5.1: Schematic map of the analysed sites (map contour source: GEBCO). SN = South Norway, NN = North Norway, F = Faeroe Islands, SI = South Iceland, NI = North Iceland, NS = the Northern Seas (Norwegian, Greenland, Iceland Seas and the Arctic Ocean), SEG = Southeast Greenland, SWG = Southwest Greenland, NWG = Northwest Greenland, DS = the Davis Strait and EC = East Canada.

This study took account of revised species systematics for desmosomatids and nannoniscids (Brix, unpublished data), which are considered as one family. *Ilyarachna dubia* is not listed, since it is not clear if it represents a true species or a juvenile form of *Ilyarachna hirticeps* (Thistle 1980). Species that occur only in the Arctic Ocean (north of 82°N), but were never reported from the other areas, are not included in the analysis. Cymothoida spend at least part of their life cycle as parasites on fish or other crustaceans (Kaestner 1993, Schotte 2006) and thus, their distribution depends on the distribution of the host. Consequently, they are not included in the distributional analysis, but appear in the list of species for the sake of completeness (Annex 5.1).

Community analyses were performed using the software package PRIMER v. 6.0 (Clarke & Warwick 2001). No transformation of the data was carried out, since the analyses were based on presence/absence data. Similarities in species composition between sites were calculated using the Bray-Curtis coefficient (Bray & Curtis 1957), and the similarity matrices were used for both classification (complete linkage clustering; Lance & Williams 1967) and ordination (multi-dimensional scaling, MDS; Kruskal & Wish 1978).

Results

General distributional patterns

In total, 59 species were reported from South Greenland (Fig. 5.2, Annex 5.1). Asellotes were the dominant group, representing 83% of the species, followed by valviferans (15%) and anthurideans (2%). The species can be allocated to 16 families. Some families such as the Acanthaspidiidae, Dendrotionidae, Haploniscidae, Katianiridae, Leptanthuridae, Idotheidae, Mesidotheidae and Antarcturidae occur with only one or two species, while others like the Desmosomatidae, Munnidae, Munnopsidae and Paramunnidae are present with several species. Desmosomatidae and Munnopsidae are the families that are most diverse off South Greenland, as the number of different species within the families is high (Fig. 5.2).

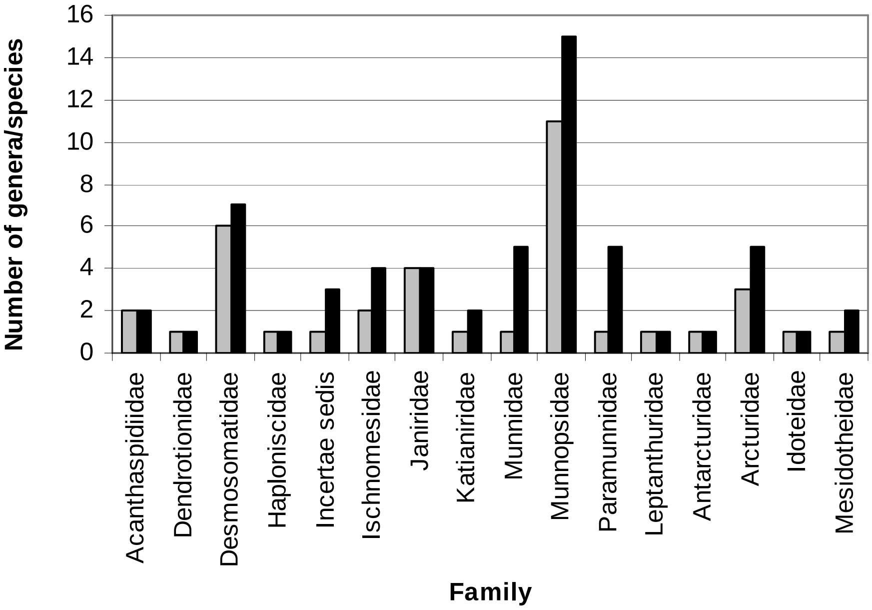


Fig. 5.2: Number of genera (grey bars) and species (black bars) per family off South Greenland.

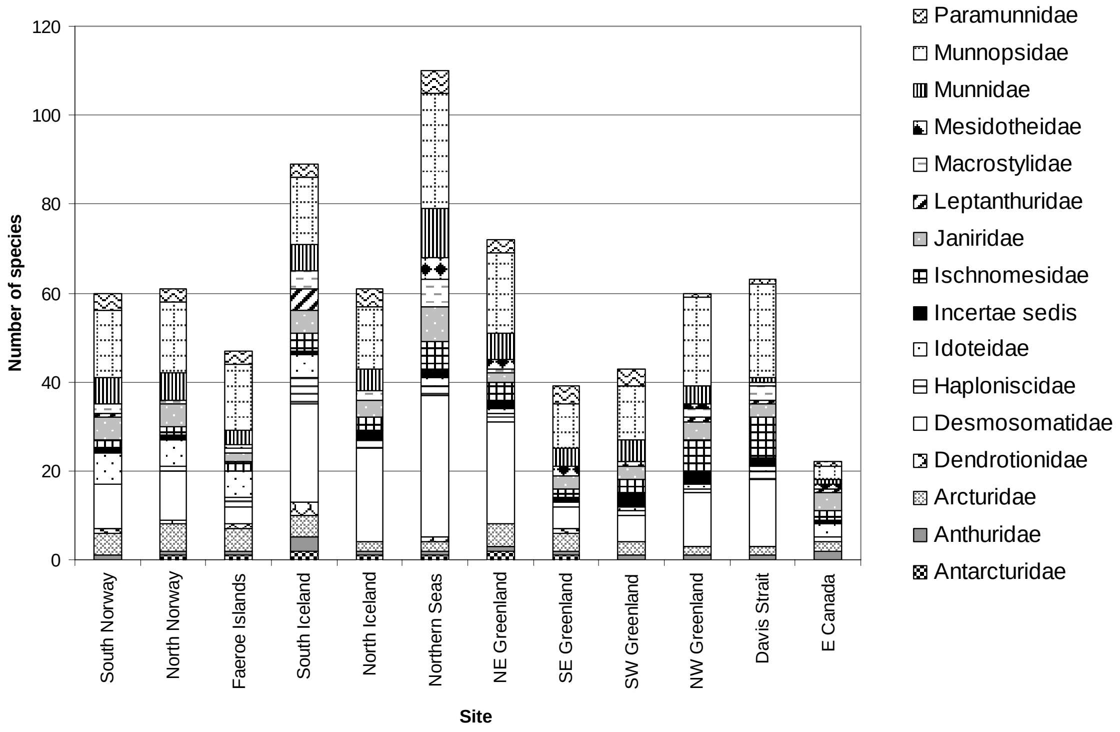


Fig. 5.3: Number of species known from all sites, including their allocation to families.

Across all sites, a total number of 231 species were reported (Fig. 5.3, Annex 5.1). The proportion between suborders in the overall material was similar to that observed off South Greenland: asellotes dominated with 79%, valviferans contributed 13%, anthurideans 6% and sphaeromatids 1%. The species were allocated to 23 families and 82 genera (Fig. 5.4, Annex 5.1). Some families were rich in numbers of species and genera. For example, Desmosomatidae were represented with 56 species (from 22 genera), Munnopsidae with 47 species (from 17 genera) and Ischnomesidae with 17 species (from three genera). In contrast, some families such as the Munnidae showed a low diversity in genera (only one), but a high diversity in species (14). This pattern is similar in the macrostylids (10 species, one genus). The Northern Seas, i.e. the region comprising the Norwegian, Greenland and Iceland Seas, was the site where most species (113) are known from, whereas East Canada was the site with the lowest number of reported species (23; Fig. 5.3). For clarity, families with only one or two species (Mictosomatidae, Sphaeromatidae, Thambematidae, Acanthaspidiidae, Antheluridae, Katianiridae and Limnoriidae) were not included in Fig. 5.3. Within the species-rich families, munnopsids generally occur with a similar number of species at the sites, whereas the desmosomatids show an irregular pattern of species occurrence at all sites. Remarkably, desmosomatids are rare around the Faeroe Islands, Southeast and Southwest Greenland and

East Canada, while they dominate the species composition around Iceland, in the Northern Seas and off northeast Greenland. Ischnomesids contribute considerably to the species composition at Northwest Greenland, the Davis Strait and in the Northern Seas.

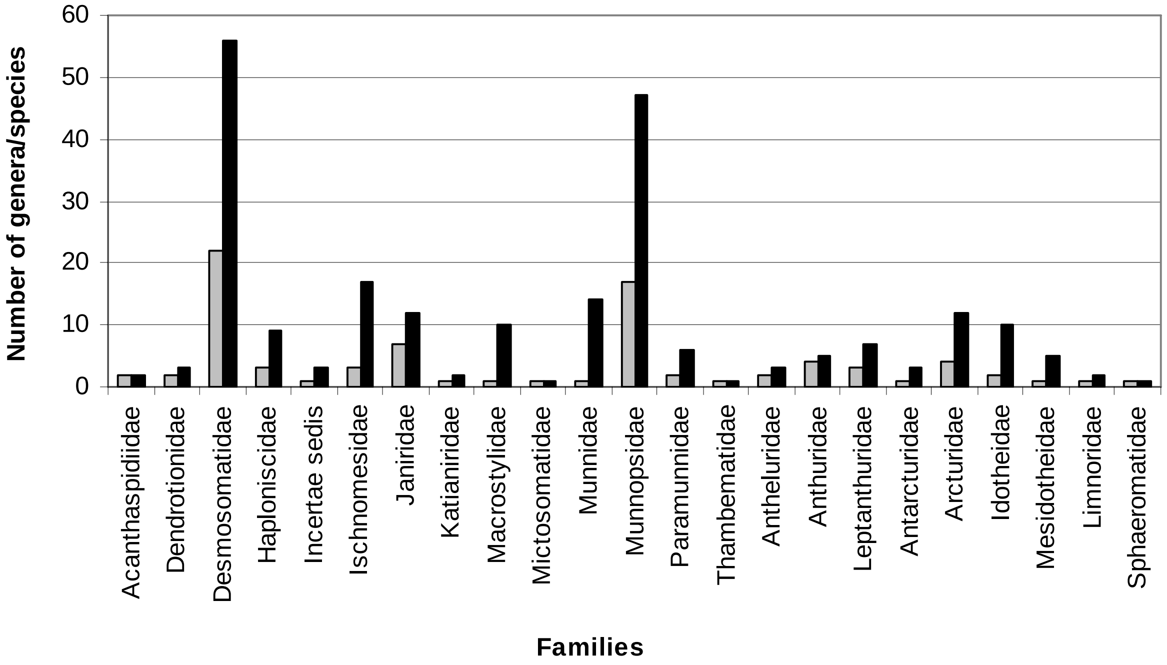


Fig. 5.4: Number of genera (grey bars) and species (black bars) per family across all sites.

The depth ranges of the analysed species are listed in Annex 5.1. More than half of the species (53%, 122 species) showed a wide bathymetric distribution from shallow water to the deep sea. This is especially pronounced in the desmosomatids and munnopsids, e.g. *Ilyarachna frami* occurs between 8 - 5223 m depth. 10% (24 species) of the species are restricted to shallow water (e.g. *Caecijaera borealis* and species of the genera *Leptanthura* and *Idothea*). Typical deep-sea families such as the Haploniscidae, Ischnomesidae and Macrostylidae are less eurybathic and occur mainly in the deep sea, with 24% (56 species) reported exclusively from depths greater than 1000 m (many species of the genera *Haploniscus*, *Haplomesus* and *Macrostylis*). Desmosomatids are also known as a deep-sea family and several species can only be found in the deep sea of the investigated area (species of the genera *Mirabilicoxa* and *Nannoniscus*). The species-rich munnids are most common in shallow to intermediate waters (0 - about 700 m).

Rare species

In the entire analysis, 77 species occur at only a single site (Northern Seas and NE Greenland are both high-arctic and thus here regarded as one Arctic site) and might be regarded as rare or "apparently endemic" species (Fig. 5.5). Since this number represents one third of all analysed isopod species, the "endemic" fraction is relatively high in the northern North Atlantic. Especially within the genus *Leptanthura*, "endemites" are common (five of seven species). Generally, in all species-rich families, "endemic" species are found.

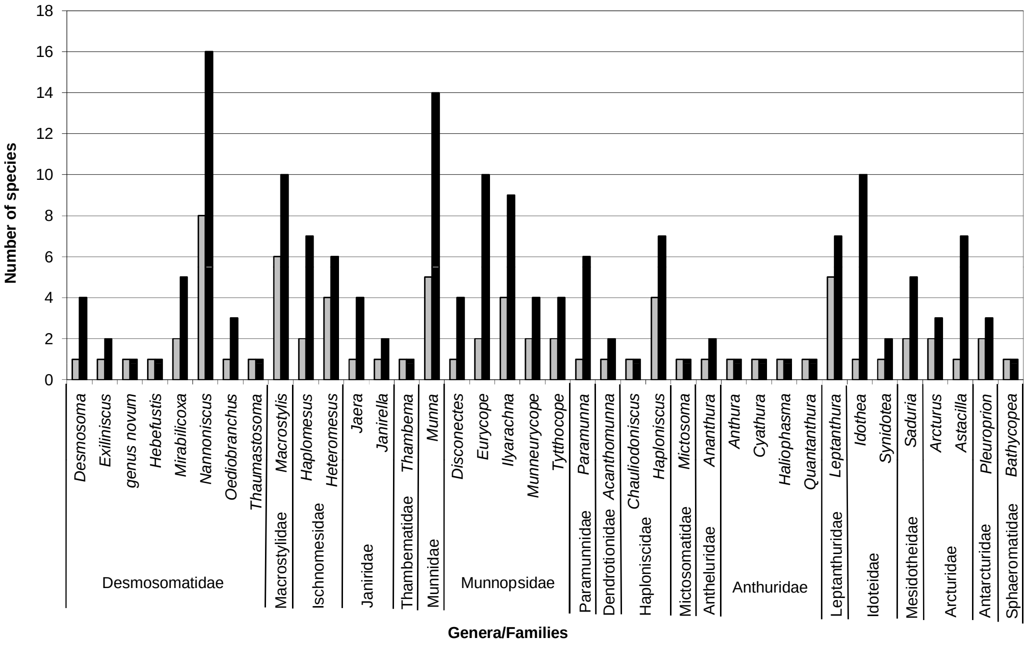
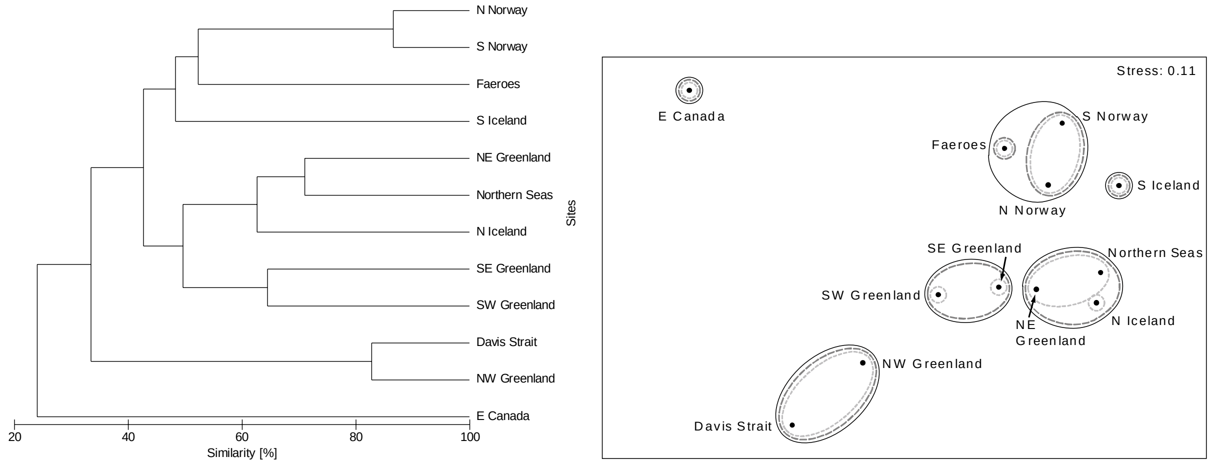


Fig. 5.5: Number of "apparently endemic" species (grey bars) and total number of species (black bars) per genus, only for those genera in which "endemites" were found.

Where does the south Greenlandic fauna belong to?

The groups resulting from hierarchic clustering and MDS ordination of individual sites represent regions that can be well distinguished (Fig. 5.6a-b). The species composition of East Canada is separated from the other sites at a dissimilarity level of 76% and the cluster consisting of Northwest Greenland and the Davis Strait is separated from the other sites with 67% dissimilarity.



a b

Fig. 5.6a-b: Multivariate analyses of the species composition of all sites. a) Cluster dendrogram, b) Two-dimensional MDS configuration based on Bray-Curtis similarities with superimposed clusters at similarity levels of 50% (black thin line), 60% (grey large-dashed line) and 70% (light grey small-dashed line). Stress value of the MDS plot: 0.11.

Southeast and Southwest Greenland show one of the lowest dissimilarities between two sites (36%). The fauna of Southwest Greenland differs from South Iceland by 66%, whilst it was less different from North Iceland (by 55%). Southeast Greenland differs in its species composition by 63% from South Iceland, but shares the same species composition (49% dissimilarity) with North Iceland.

Fig. 5.6a shows that the sites of South Greenland cluster with the Arctic sites (50% similarity). The species composition of South Iceland is, however, more similar to that of the Faeroe Islands and Norway.

Discussion

In a marine environment, organisms are not evenly distributed, neither vertically or horizontally. Moreover, they can have a patchy distribution over time and space. Usually, there are considerable differences in species composition between sites. The distribution and composition depends on different factors ranging from local to global scales (Rex et al. 2006). As peracarid crustaceans are brooders, i.e. their development from larvae to juveniles is carried out in a brood pouch (marsupium), their distribution as well as geneflow is restricted to the either active or passive (due to currents, hosts) migration of the adults (Brandt 1992).

Sampling and bathymetric distribution

The distribution of species is often biased by the sampling effort employed at different depth ranges. Most records from North Iceland, the Northern Seas, Northeast Greenland, Northwest Greenland and the Davis Strait are mainly based on deep-sea sampling (e.g. Just 1970, 1980, Brandt et al. 1994, 1996, Svavarsson 1982a,b, 1984a,b, 1987a,b, 1988a,b, 1999; Svavarsson et al. 1993). At these sites, typical deep-sea families (such as Haploniscidae, Macrostylidae, Ischnomesidae and Desmosomatidae) are well represented, and typical shallow water species such as idotheids are missing. On the contrary, the data of e.g. the Norwegian sites are mostly based on sampling along the coast and on the shelves (e.g. Sars 1885, 1899; Hult 1941, Brattegard & Holthe 1997) and therefore not strictly comparable with studies focused on deep-sea sampling.

As species of the munnopsids show a wide bathymetric range, it is not surprising that they occur at almost all sites with a high number of species. Sars (1899) and Hult (1941) have already documented the eurybathic distribution of *Ilyarachna hirticeps* and *Ilyarachna longicornis* from the deep sea to shelf sites. This was also confirmed by more recent data (Thistle 1980, Svavarsson et al. 1993, Brandt et al. 1996).

Zoogeography

Many species that are poorly represented in this study belong to families which have their main distribution elsewhere. The genus *Haliophasma* (Anthuridae) consists of 26 species known to science, of which only one was recorded in the study area. Most species of this genus occur in the southern hemisphere (Negoescu & Svavarsson 1997). The genus *Arcturella* (Arcturidae) to date consists of 15 species, but only one is found in the study area (*Arcturella dilatata*). The other species of this genus are mainly reported from the central North Atlantic or from the South Atlantic (Schotte et al. 1995). The genus *Paramunna* is also poorly represented in this study. Although this genus is relatively rich in species (18), *P. bilobata* and *P. brevipes* (Bate & Westwood 1868) are the only species occurring in the North Atlantic, whereas the others are documented mostly from the Southern Ocean or the South Atlantic. Similar distribution patterns are given for *Acanthomunna* (Dendrotionidae). *Acanthaspidia typhlops* is one of a few exceptions within the genus *Acanthaspidia* (Acanthaspidiidae) found in the North Atlantic. *A. typhlops* is found at most of the sites in this study, while almost all other species of this genus are only known from the southern hemisphere. The same proves true for *Ianthopsis pulchra* (Acanthaspidiidae).

Body size

Gage & Tyler (1991) and Rex et al. (2006) suggested that larger organisms are more abundant in productive shelf areas, whereas the abundance of smaller organisms increases with depth. This could be generally confirmed by the present study, since e.g. macrostylids and haploniscids are relatively small-sized isopods and occur mostly in the deep sea. Larger organisms such as many janirids, anthurids, lepthanthurids, idotheids and arcturids are more common in shallower waters.

Several other studies (see Rex & Etter 1998 for an overview) on the dependence of body size on depth showed contradictory results. Among the few studies that investigated this dependency for crustaceans, Wilson (1983) showed an increase of body size with increasing depth for one munnopsid species. This pattern was also found by Wolff (1962) for several isopod genera. Svavarsson et al. (2001) demonstrated that the relationship between body size and depth depended on the investigated taxonomic level. The body size was not related to depth for all analysed isopods, but it increased significantly on suborder level (Asellota) and family level (Munnopsidae) (Svavarsson et al. 2001). Rex et al. (2006) explained the observed relationship with supply of nutrients, which again is correlated with other factors, such as changes in faunal composition (Carney 2005) and body size (Thiel 1975). On larger scales, there are too few data available with regard to food availability (Rex et al. 2006) in order to relate the patterns of this study to biotic factors such as supply of nutrients. It is unknown whether and how many factors might be interrelated with each other and influence the distribution of species.

Finally, it remains unclear whether consistent geographic trends in size actually exist, except for the suggestion that deep-sea species seem to be smaller in average than shallow-water species (Rex & Etter 1998). It further remains unclear, which factors such as food availability, temperature, predation and competition contribute most to the observed patterns (Svavarsson et al. 2001, Rex et al. 2006).

Rare species (apparent endemism) and their limited dispersal

In all investigations, it is important to consider the spatial scale (Levin 1992, Fortin & Dale 2005, Murray in press), as the degree of rarity of a species is relative and depends on the scale measured (Magurran 2004). Rare species can be defined on several criteria; two of these are either abundance of individuals or geographic range (which can be a scale from a specific habitat to all oceans) (Murray in press). From a biogeographic perspective, a species restricted to one area may be considered to be rare (or endemic), while in a distributional sense or in terms of abundance, it might be common (Magurran 2004, Murray in press). From 50 species considered to be “endemic” for the Northern Seas (Svavarsson et al. 1993), 17 have by now been recorded from other sites outside the Northern Seas. This example shows that the expression “endemic” has to be treated with care, since some of the “endemites” might only be rare, patchily distributed or poorly sampled. In the following, the term “rare” will be used, as the real degree of “endemism” is unknown.

The recording of patchiness in species distribution depends to some extent on the sampling intensity and sampling device. The sampling effort increased markedly during the past few years, in the north especially around Iceland, where 1050 biotic samples have been taken during the BIOICE project (Sigvaldadóttir 2000). In this study, 33% of all rare species were recorded from South Iceland, whereas the northeastern Arctic sites provide 45% of the rare species. The evolution of asellote isopods is thought to have originated in the deep-sea by some authors (Hessler et al. 1979, Brandt 1992, Svavarsson et al. 1993). Svavarsson et al. (1993) showed that in shallower areas of the Northern Seas, fewer rare species occur as immigration from Atlantic species can take place. At the same time they postulated that the high number of rare species occurring in the Northern Seas (including NE Greenland) might be attributed to the recent history of the Northern Seas, the hydrography of that area, and the topographic barrier due to the Greenland-Iceland-Faeroe Ridge. Thus, the ridge might have restricted the migration of deep-sea species not only from the Northern Seas into southern areas of the Atlantic, but also vice versa, as only few Atlantic deep-sea species (e.g. of the family Haploniscidae) contribute to the isopod fauna of the Northern Seas (Svavarsson et al. 1993). For the common deep-sea families such as the Haploniscidae, the depth of the ridge of 300-400 m (sills 600 m) (Malmberg 1985) seems to be a major barrier (Svavarsson et al. 1993). This might be the reason why they have inhabited the Northern Seas with only two recorded species (*Haploniscus bicuspis* and *Haploniscus ingolfi*). Another example of limited zoogeographic distribution due to the ridge is provided by the Anthuridea, for which 16 species were found in total and eight exclusively from South Iceland (Negoescu & Svavarsson 1997). Most of these species were found in the deep-sea basins south of Iceland and might show limited distribution ranges due to the ridge. Hydrographic conditions around the ridge might be a barrier for species migrating into the North Atlantic, as e.g. four of five “endemic” shallow-water species of the genus *Munna* (*M. coeca, M. pellucida, M. roemeri, M. spitzbergensis*) appear only in the Northern Seas. The geographic isolation caused by the ridge might have affected most of the deep-sea species, as already suggested for isopods by Svavarsson et al. (1993), for *Astacilla boreaphilis* by Stransky & Svavarsson (2006) and for species of ischnomesids by Cunha & Wilson (2006). In the genus *Heteromesus*, 16 species were described. Six of them were recorded from the northern North Atlantic and Arctic Ocean and they all showed a narrow range of distribution. *Heteromesus longiremis* is the only species of the genus which has been sampled from the equator to about 62°N (Cunha & Wilson 2006). Thus, the records of *H. longiremis* of the current study represent its northernmost limit. Cunha & Wilson (2006) mentioned that *Heteromesus frigidius* is the only species of this genus found exclusively north of the Greenland-Iceland-Faeroe Ridge. Since in chapter 1, *H. frigidius* also was found off southeastern Greenland in depths between 218 and 236 m, this might argue against the hypothesis that the ridge acts as a barrier for deep-sea species (Svavarsson et al. 1993). Additionally, *H. frigidius* was also found off South Iceland and around the Faeroe Islands, supporting the possibility of this species to pass the ridge.

Apart from the isopods, the restriction in the distribution due to the ridge was also found in amphipods (Weisshappel & Svavarsson 1998, Weisshappel 2000, 2001).

The high fraction of rare species is even more pronounced for species of the munnopsids, where 12 of 47 species are “endemic”. From these 12 species, 10 (*Disconectes coxalis, Eurycope cryoabyssalis, E. ratmanovi, Ilyarachna derjugini, I. frami, I. torleivi, Munneurycope incisa, Paramunnopsis justi, Tytthocope laktionovi, T. neupokoevi*) are restricted to the Northern Seas.

Faunal affinities to adjacent North Atlantic areas

This study compared the isopod species occurrence between North Atlantic sites on a large scale. As e.g. North and South Norway, or the Davis Strait and Northwest Greenland, seem to be similar in their species composition, a small-scale investigation might deliver a different picture. In an investigation of the Norwegian shelf, Ellingsen & Gray (2002) found a separation into a northern and a southern cluster based on a high dissimilarity level. Community composition shows strong geographic variation at small scales and is influenced by several environmental factors such as predation, food or sediment (Gray 1974, Pearson & Rosenberg 1987). On a large scale, community composition shows an unexpected complexity and is associated with climate processes and their environmental consequences (Levin et al. 2001, Tuya & Haroun 2006).

As marine systems usually have less geographic barriers than terrestrial systems (Heip 2003), the distribution of species can be quite wide, especially when facilitated by larval dispersal (Murray in press). In marine systems, hydrodynamic processes such as currents can support dispersal but can also act as a barrier (Murray in press) as described for the Greenland-Iceland-Faeroe Ridge. Thus, hydrodynamic processes are important environmental forces that impact species distribution.

East Canada is well separated from all sites, also from the two other northwestern sites. This separation might be explained by the influence of warm North Atlantic water masses (formed especially by the Irminger Current) and the convection of the water masses in the Labrador Basin (Pickart et al. 2003). Another cause for the clear distinction of this site might be the arguably poor sampling effort with regard to the occurrence of isopods off East Canada.

The separation of Northwest Greenland and Davis Strait from the other sites might be given by the special hydrography of that area. Cold Arctic water provides Arctic conditions at these sites (Cuny et al. 2002), which are different from those found at e.g. Southwest Greenland. The species composition of Southwest Greenland is on this large scale most similar to Southeast Greenland. The sediment structure, which was an important factor for the separation of these areas on a small scale (chapters 1 & 2), seems to have less impact on a larger scale, as large-scale hydrography appears to be the reason for the similarity of these two sites (see chapters 1 & 2). Southwest Greenland is separated from the geographically relatively close site in East Canada. Nazareth & Steensboe (1998) showed that the North Atlantic water masses are warmer and more saline than those originating from the Labrador Sea, separating these two sites.

The two sites off South Greenland cluster together with the three sites north of Iceland, which are characterised by the influence of Arctic water masses. The fauna can be described as Arctic, occurring at only these sites, or as Arctic-boreal, occurring at most of the North Atlantic sites. Arctic water masses flow southwards over the Greenland-Iceland Ridge and are mixed with Atlantic water while entering the deep North Atlantic (Hansen & Østerhus 2000). This allows exchange between these sites. It is still not completely understood how the ridge acts as a barrier for species distribution. *Austroniscus norbi*, previously known only from the deep Northern Seas, or *Heteromesus frigidius,* which has been recorded from South Greenland (see chapter 1 & 2), belong to the few species which managed to pass the ridge southwards.

As no major topographic barrier is located between Southeast Greenland and South Iceland, these sites have been expected to be more similar in their species composition than they are. It can be assumed that the cold water overflow through the Denmark Strait (e.g. Malmberg 1985, Stein 1988) influences the distribution of species and is an obstacle for dispersal between South Iceland and Southeast Greenland. A separation of South Iceland from other geographically close areas has also been found by Jennings et al. (2004) for foraminifers and explained by hydrographic patterns.

Although South Iceland is clustered together with the sites of the Faeroe Islands, South and North Norway, the multivariate analysis of species occurrence illustrated that it also differs clearly from those three sites. The fauna of South Iceland might be adapted to the Modified East Icelandic Water (MEIW), which overflows the Iceland-Faeroe Ridge along the eastern coast of Iceland in a 100-150 m thick bottom layer and transports cold water (3-7°C) westwards (Hansen & Østerhus 2000). In addition to the MEIW, the Norwegian Sea Deep Water and the Norwegian Sea Arctic Intermediate Water cross the Iceland-Faeroe Ridge and the Faeroes-Shetland Channel on three different paths and flow southwestwards (Hansen &

Østerhus 2000). In contrast to the site off South Iceland, these two latter water masses do not influence the fauna around the Faeroe Islands to a large extent, since the data found in the literature were almost all reported from the shelf banks or on the continental slope, but not in the deep water layers, where the water exchange takes place. The sites at the Faeroe Islands and in South and North Norway are all characterised by the influence of North Atlantic water masses flowing northwards mainly over the Iceland-Faeroe Ridge and through the Faeroes-Shetland Channel (Hansen & Østerhus 2000).

Conclusions

The majority of isopod species occurred at several sites, allowing multivariate comparisons between sites based on species compositions on a larger scale. The South Greenland isopod fauna was most similar to the Arctic isopod fauna from the Northern Seas, Northeast Greenland and North Iceland. These sites constituted one major biogeographic region, while another included the sites of the Faeroe Islands, South and North Norway. Including all sites, thus on a large scale, these biogeographic regions and remaining sites are probably influenced most of all by similar hydrographic conditions.

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Annex

Annex 5.1: Species list of all geographic sites. SN = South Norway, NN = North Norway, F = Faeroe Islands, SI = South Iceland, NI = North Iceland, NS = Northern Seas, NEG = Northeast Greenland, SEG = Southeast Greenland, SWG = Southwest Greenland, NWG = Northwest Greenland, DS = Davis Strait, EC = East Canada (see also Fig. 5.1).

Suborder - Family	**Genus**	**Species**	**Depth range [m]**	**Geographic site**											
				SN	NN	F	SI	NI	NS	NEG	SEG	SWG	NWG	DS	EC
Anthuridea															
Antheluridae	*Ananthura*	*Ananthura abyssorum* (Norman & Stebbing, 1886)	intertidal, shallow											+	
	Ananthura	*Ananthura sulcaticauda* Barnard, 1925	intertidal - 35				+	+							
Anthuridae	*Haliophasma*	*Haliophasma mjoelniri* Negoescu & Svavarsson, 1997	501-1105				+								
	Anthura	*Anthura gracilis* (Montagu, 1808)	304-1212	+											
	Quantanthura	*Quantanthura tyri* Negoescu & Svavarsson, 1997	304-1295				+								
	Cyathura	*Cyathura polita* Stimpson, 1855	9-2500												+
	Calathura	*Calathura brachiata* Stimpson, 1853	0-1500	+	+	+	+	+	+	+	+	+	+	+	+
Leptanthuridae	*Leptanthura*	*Leptanthura affinis* (Bonnier, 1896)	957				+								
		Leptanthura chardyi Negoescu, 1992	1295-1950				+								
		Leptanthura micrura Kensley, 1982	516-2870				+								
		Leptanthura tenuis (Sars, 1873)	20	+											+
		Leptanthura thori Barnard, 1925	intertidal-6				+								
		Leptanthura victori Negoescu, 1985	intertidal-20				+								
	Malacanthura	*Malacanthura truncata* (Hansen, 1916)	intertidal										+	+	
Asellota															
Acanthaspidiidae	*Acanthaspidia*	*Acanthaspidia typhlops* (Sars, 1879)	74-1020		+	+	+	+	+	+	+	+	+	+	
	Ianthopsis	*Ianthopsis pulchra* (Hansen, 1916)	310; 1993-2912				+	+	+	+	+	+	+	+	
Dendrotionidae	*Acanthomunna*	*Acanthomunna hystrix* (Hansen, 1916)	268-1505				+								
	Dendrotion	*Dendrotion spinosum* Sars, 1872	2636-2646	+	+	+	+		+						
		Dendrotion paradoxum Hansen, 1916	219; 1243-5240				+				+				
Desmosomatidae	*Austroniscus*	*Austroniscus norbi* Svavarsson, 1982	106-251; 2470-3612					+	+	+	+	+			
		Austroniscus groenlandicus (Hansen, 1916)	10-132; 180-1525					+		+		+			
	Chelator	*Chelator insignis* (Hansen, 1916)	1065-2702				+						+	+	
	Cryodesma	*Cryodesma agnari* Svavarsson, 1988a	45-449; 970-3642					+	+	+					
	Desmosoma	*Desmosoma zenkewitschi* (Gurjanova, 1946)	65						+						
		Desmosoma latipes (Hansen, 1916)	200-1102					+					+	+	
		Desmosoma lineare (Sars, 1864)	17-699	+	+		+		+	+					
		Desmosoma stroembergi Svavarsson, 1988a	180-492; 794-1288					+	+	+					
	Echinopleura	*Echinopleura aculeata* (Sars, 1864)	15-681	+	+		+		+						
	Eugerda	*Eugerda reticulata* (Gurjanova, 1946)	232-492; 794-1501; 2500				+	+	+	+					
		Eugerda filipes (Hult, 1936)	50-1300	+	+				+			+			
		Eugerda tenuimana (Sars, 1866)	4-830; 4698	+	+	+	+	+	+	+					+

Continuation of Annex 5.1:

Suborder - Family	Genus	Species	Depth range [m]	Geographic site											
				SN	NN	F	SI	NI	NS	NEG	SEG	SWG	NWG	DS	EC
	Eugerdella	*Eugerdella armata* (Sars, 1864)	17-478	+	+			+	+	+	+	+			
		Eugerdella coarctata (Sars, 1899)	24-2702	+	+		+		+					+	
		Eugerdella natator (Hansen, 1916)	2626-4833										+	+	
		Eugerdella polita (Hansen, 1916)	1070-1505				+							+	
	Exiliniscus	*Exiliniscus clipeatus* Siebenhaller & Hessler, 1981	3834-5023				+								
		Exiliniscus hanseni (Just, 1970)	80-3920					+	+	+					
	genus novum	genus novum *fletcheri* Paul & George, 1975	1253-1740						+						
	Hebefustis	*Hebefustis cornutus* Siebenhaller & Hessler, 1977	3806				+								
	Mirabilicoxa	*Mirabilicoxa acuminata* Hessler, 1970	3834-4800				+								
		Mirabilicoxa birsteini (Menzies, 1962)	2401-2600; 5166					+							
		Mirabilicoxa gracilipes (Hansen, 1916)	2194-2702				+						+	+	
		Mirabilicoxa longispina (Hansen, 1916)	2496-5321										+	+	
		Mirabilicoxa similis (Hansen, 1916)	530-2194				+						+	+	
	Nannoniscoides	*Nannoniscoides angulatus* Hansen, 1916	74-1525			+		+	+	+					
	Nannoniscus	*Nannoniscus aequiremis* Hansen, 1916	260; 885						+	+					
		Nannoniscus affinis Hansen, 1916	1505				+								
		Nannoniscus analis Hansen, 1916	2258										+	+	
		Nannoniscus arcticus Hansen, 1916	75-699						+	+					
		Nannoniscus arctoabyssalis Just, 1980	3965-3970						+						
		Nannoniscus armatus Hansen, 1916	232-321							+				+	
		Nannoniscus inermis Hansen, 1916	2258										+	+	
		Nannoniscus intermedius Siebenhaller & Hessler, 1981	508-523				+								
		Nannoniscus laticeps Hansen, 1916	552					+	+						
		Nannoniscus minutus Hansen, 1916	1096					+					+	+	
		Nannoniscus oblongus Sars, 1869	158-5843	+	+	+	+	+	+	+	+	+	+	+	
		Nannoniscus plebejus Hansen, 1916	1505				+	+							
		Nannoniscus profundus Svavarsson, 1982	1001-3016						+	+					
		Nannoniscus reticulatus Hansen, 1916	80-1525					+	+	+					
		Nannoniscus simplex Hansen, 1916	1070-1505				+								
		Nannoniscus spinicornis Hansen, 1916	310; 2465						+	+					
	Oediobranchus	*Oediobranchus nanseni* Just, 1980	180-3920				+	+	+	+					
		Oediobranchus plebejum (Hansen, 1916)	80-1666					+	+	+					
		Oediobranchus polare (Gurjanova, 1946)	40-510						+						
	Prochelator	*Prochelator lateralis* (Sars, 1899)	50-2021	+	+	+	+		+			+	+	+	
	Pseudergella	*Pseudergella hessleri* Just, 1980	800-3620				+	+							
	Pseudogerda	*Pseudogerda arctica* Svavarsson, 1988a	50-425; 774-2681					+	+	+					
		Pseudogerda globiceps (Meinert, 1890)	34-1300			+	+			+	+	+			
		Pseudogerda intermedia (Hult, 1936)	30-2258	+	+				+			+			
	Pseudomesus	*Pseudomesus brevicornis* Hansen, 1916	80-2105				+	+	+	+					
	Rapaniscus	*Rapaniscus crassipes* Hansen, 1916	219-2754		+		+		+	+	+				
	Regabellator	*Regabellator armatus* (Hansen, 1916)	3521										+	+	
	Thaumastosoma	*Thaumastosoma platycarpus* Hessler, 1970	2886-3753				+								
	Whoia	*Whoia angusta* (Sars, 1899)	50-2500	+	+		+		+						
		Whoia dumbshafensis Svavarsson, 1988a	50-774; 1100-2024						+	+					

Continuation of Annex 5.1:

Suborder - Family	**Genus**	**Species**	**Depth range [m]**	**Geographic site**											
				SN	NN	F	SI	NI	NS	NEG	SEG	SWG	NWG	DS	EC
Haploniscidae	*Chauliodoniscus*	*Chauliodoniscus armadilloides* (Hansen, 1916)	2636-2925				+								
	Haploniscus	*Haploniscus aduncus* Lincoln, 1985	198-5024				+								
		Haploniscus ampliatus Lincoln, 1985	1632-3697				+	+							
		Haploniscus bicuspis (Sars, 1877)	900-2925		+	+	+	+	+	+					
		Haploniscus foresti Chardy, 1974a	320-492; 854-2465, 3610-4100				+								
		Haploniscus hamatus Lincoln, 1985	1450-3321			+									
		Haploniscus ingolfi Wolff, 1962	3388-3521						+	+					
		Haploniscus spinifer Hansen, 1916	1993-2912				+						+	+	
	Hydroniscus	*Hydroniscus abyssi* Hansen, 1916	1873									+		+	
Incertae sedis	*Tole*	*Tole laciniata* (Sars, 1872)	158-251	+	+			+	+	+	+	+	+	+	
		Tole spinosa (Harger, 1879)	106-161; 774-1505				+	+	+	+		+	+	+	+
		Tole vilhelminae (Stephensen, 1913)	823-1353									+	+		
Ischnomesidae	*Haplomesus*	*Haplomesus angustus* Hansen, 1916	698-2137				+	+	+					+	
		Haplomesus gorbunovi Gurjanova, 1946	698-5494						+	+					
		Haplomesus insignis Hansen, 1916	2158										+	+	
		Haplomesus modestus Hansen, 1916	4060-5293										+	+	
		Haplomesus ornatus Menzies, 1962	510-4150											+	
		Haplomesus quadrispinosus (Sars, 1865)	698-3474		+	+		+	+	+	+	+	+	+	
		Haplomesus tenuispinis Hansen, 1916	1438-1505										+	+	
	Heteromesus	*Heteromesus dentatus* Hansen, 1916	698-2104				+								
		Heteromesus frigidius Hansen, 1916	219; 698-4100	+		+	+	+	+	+	+				
		Heteromesus longiremus Hansen, 1916	2140									+	+	+	+
		Heteromesus oryktus Cunha & Wilson, 2006	914-956									+			
		Heteromesus schmidtii Hansen, 1916	3178-3663				+								
		Heteromesus wolffi Chardy, 1974b	2702-5497												+
	Ischnomesus	*Ischnomesus armatus* Hansen, 1916	10-1100										+	+	
		Ischnomesus bispinosus (Sars, 1865)	50-260; 774-2681	+	+				+						
		Ischnomesus norvegicus Svavarsson, 1984	112-220						+	+					
		Ischnomesus profundus Hansen, 1916	0-128										+	+	
Janiridae	*Caecijaera*	*Caecijaera borealis* Kussakin, 1962	0-10					+	+						
	Ianiropsis	*Ianiropsis breviremis* (Sars, 1882)	0-10	+	+				+						
	Jaera	*Jaera albifrons* Leach, 1814	0-20	+	+	+	+	+	+			+	+		+
		Jaera forsmani Bocquet, 1950	0-20						+						
		Jaera ischiosetosa Forsman, 1949	0-876	+	+				+						
		Jaera praehirsuta Forsman, 1949	0-2147	+	+				+						
	Janira	*Janira alta* Stimpson, 1853	9-167				+								+
		Janira maculosa Leach, 1814	106-251; 2158-2583	+	+	+	+	+	+	+	+	+	+		+
	Janiralata	*Janiralata tricornis* (Kroeyer, 1846)	873-913						+	+	+	+	+	+	+
	Janirella	*Janirella laevis* Hansen, 1916	1047-1508										+	+	
		Janirella spongicola Hansen, 1916	31-1384				+								
Janiridae	*Janthopsis*	*Janthopsis pulchra* Hansen, 1916	106-621				+	+			+			+	
Katianiridae	*Katianira*	*Katianira bilobata* Gurjanova, 1930	32-3709						+	+	+				
		Katianira chelifera Hansen, 1916	36-774				+				+				

Continuation of Annex 5.1:

Suborder - Family	**Genus**	**Species**	**Depth range [m]**	**Geographic site**											
				SN	NN	F	SI	NI	NS	NEG	SEG	SWG	NWG	DS	EC
Macrostylidae	*Macrostylis*	*Macrostylis abyssicola* Hansen, 1916	698-3921						**+**				**+**	**+**	
		Macrostylis angulata Mezhov, 1999	3714						**+**						
		Macrostylis elongata Hansen, 1916	1591-1690				**+**								
		Macrostylis longipes Hansen, 1916	1350-1412					**+**							
		Macrostylis longiremis (Meinert, 1890)	140-235	**+**	**+**		**+**		**+**						
		Macrostylis magnifica Wolff, 1962	3521											**+**	
		Macrostylis spinifera Sars, 1864	4-1760	**+**	**+**		**+**		**+**			**+**	**+**	**+**	
		Macrostylis subinermis Hansen, 1916	232-411; 830-3474			**+**	**+**	**+**	**+**	**+**					
		Macrostylis vigorata Mezhov, 1999	2665-2667						**+**						
		Macrostylis viriosa Mezhov, 1999	4050						**+**						
Mictosomatidae	*Mictosoma*	*Mictosoma ramosum* (Hansen, 1916)	216-800				**+**								
Munnidae	*Munna*	*Munna acanthifera* Hansen, 1916	80				**+**	**+**	**+**	**+**			**+**	**+**	
		Munna boeckii Kroeyer, 1839	0-366	**+**	**+**	**+**	**+**	**+**	**+**	**+**					
		Munna coeca Gurjanova, 1930	0-251; 774						**+**						
		Munna fabricii Kroeyer, 1846	19-1505	**+**	**+**		**+**	**+**	**+**	**+**	**+**	**+**	**+**		**+**
		Munna groenlandica Hansen, 1916	0-251						**+**	**+**	**+**	**+**	**+**		
		Munna hanseni Stappers, 1911	40-594			**+**	**+**	**+**	**+**	**+**	**+**	**+**			
		Munna kroeyeri Goodsir, 1842	1-281	**+**	**+**		**+**								
		Munna limicola Sars, 1866	35	**+**	**+**				**+**						
		Munna minuta Hansen, 1910	86-251	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**		
		Munna palmata Lilljeborg, 1851	80	**+**	**+**										
		Munna pellucida Gurjanova, 1930	42-156						**+**						
		Munna roemeri Gurjanova, 1930	35-85						**+**						
		Munna serrata Kussakin, 1962	106-458									**+**			
		Munna spitzbergensis Gurjanova, 1930	1-774						**+**						
Munnopsidae	*Aspidarachna*	*Aspidarachna clypeata* Sars, 1870	840-2580	**+**	**+**			**+**	**+**	**+**	**+**				
	Baeonectes	*Baeonectes muticus* (Sars, 1864)	106-251; 3110-3410	**+**	**+**	**+**	**+**		**+**	**+**	**+**	**+**	**+**		
	Belonectes	*Belonectes parvus* (Bonnier, 1896)	106-2258			**+**							**+**	**+**	
	Disconectes	*Disconectes coxalis* Kussakin, 1983	274-536						**+**						
		Disconectes furcatus (Sars, 1870)	54-1597	**+**	**+**	**+**	**+**		**+**	**+**	**+**	**+**	**+**	**+**	
		Disconectes latirostris (Sars, 1882)	99-1003	**+**	**+**				**+**						
		Disconectes phalangium (Sars, 1864)	18-1508	**+**	**+**				**+**	**+**	**+**	**+**	**+**	**+**	
	Echinozone	*Echinozone arctica* Hansen, 1916	45-3423		**+**			**+**	**+**	**+**		**+**			
		Echinozone coronata (Sars, 1870)	109-251; 2160-2580	**+**	**+**		**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	
	Eurycope	*Eurycope brevirostris* Hansen, 1916	46-2207			**+**	**+**	**+**	**+**	**+**					
		Eurycope complanata Bonnier, 1896	3300-3970										**+**	**+**	
		Eurycope cornuta (Sars, 1864)	198-1525; 2085-3709	**+**	**+**			**+**	**+**	**+**			**+**		**+**
		Eurycope cryoabyssalis Just, 1980	220-3709						**+**						
		Eurycope dahli Svavarsson, 1987	109-2380					**+**	**+**	**+**	**+**	**+**			
		Eurycope hanseni Ohlin, 1901	460-2750					**+**	**+**						
		Eurycope inermis Hansen, 1916	72-2681			**+**	**+**	**+**	**+**	**+**			**+**	**+**	
		Eurycope parva Bonnier, 1896	450-1445			**+**								**+**	
		Eurycope producta Sars, 1866	20-1260	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	**+**	
		Eurycope ratmanovi Gurjanova, 1946	2500						**+**						

Continuation of Annex 5.1:

Suborder - Family	Genus	Species	Depth range [m]	Geographic site											
				SN	NN	F	SI	NI	NS	NEG	SEG	SWG	NWG	DS	EC
	Ilyarachna	*Ilyarachna bergendahli* Ohlin, 1901	3965		+				+	+	+				
		Ilyarachna derjugini (Gurjanova, 1946)	18-3270						+						
		Ilyarachna frami Just, 1980	8-5223						+						
		Ilyarachna hirticeps Sars, 1870	106-4885	+	+	+	+	+	+	+	+	+	+	+	
		Ilyarachna longicornis Sars, 1870	2702-3521	+	+	+	+	+	+	+		+	+		
		Ilyarachna polita Bonnier, 1896	216-820				+								
		Ilyarachna spinosissima Hansen, 1916	174-2681										+	+	
		Ilyarachna thori Wolff, 1962	2583			+	+								
		Ilyarachna torleivi Svavarsson, 1988b	3521						+	+					
	Microprotus	*Microprotus antarctica* (*bicornis*) Vanhoeffen, 1914	1260-3709									+	+	+	
	Munneurycope	*Munneurycope elongata* Wolff, 1962	1500-2800											+	
		Munneurycope incisa (Gurjanova, 1946)	2583						+						
		Munneurycope murrayi (Walker, 1903)	840-2702			+	+					+		+	
		Munneurycope nodifrons (Hansen, 1916)	4-1203										+	+	
	Munnopsis	*Munnopsis eximius* Hansen, 1916	40-1469			+	+						+	+	
		Munnopsis typica Sars, 1861	640-2702	+	+	+	+	+	+	+	+	+	+	+	+
	Munnopsurus	*Munnopsurus giganteus* (Sars, 1879)	2681; 3709-3970	+	+	+		+	+	+					
		Munnopsurus longipes (Tattersall, 1905)	0-3240			+							+	+	
	Paramunnopsis	*Paramunnopsis justi* Svavarsson, 1988b	50-478						+	+					
		Paramunnopsis oceanica (Tattersall, 1905)	840-2626				+						+	+	
	Pseudarachna	*Pseudarachna hirsuta* (Sars, 1864)	2150-2630	+					+						
	Pseudomunnopsis	*Pseudomunnopsis beddardi* Tattersall, 1905	3320			+							+	+	
	Storthyngura	*Storthyngura magnispinis* (Richardson, 1908)	698										+	+	+
	Syneurycope	*Syneurycope parallela* Hansen, 1916	198-1525									+		+	
	Tytthocope	*Tytthocope laktionovi* (Gurjanova, 1946)	698						+						
		Tytthocope megalura (Sars, 1872)	150-280	+	+		+	+	+	+	+				
		Tytthocope neupokoevi (Gurjanova, 1946)	20-219						+						
		Tytthocope pygmaea (Sars, 1879)	3-364	+	+				+						
Paramunnidae	*Paramunna*	*Paramunna bilobata* Sars, 1866	198-940	+											
	Pleurogonium	*Pleurogonium inerme* Sars, 1883	109-251	+	+		+	+	+	+	+	+			
		Pleurogonium intermedium Hansen, 1916	106-256			+		+	+	+	+	+			
		Pleurogonium latimanum Hansen, 1916	10-274									+	+	+	
		Pleurogonium pulchra Hansen, 1916	10-552				+	+	+		+				
	Pleurogonium	*Pleurogonium rubicundum* (Sars, 1864)	799-1505	+	+	+			+						
		Pleurogonium spinosissimum (Sars, 1866)	106-1600	+	+	+	+	+	+	+	+	+			+
Thambematidae	*Thambema*	*Thambema amicorum* Stebbing, 1912	218-236, 1448-1505		+					+					
Sphaeromatidea															
Limnoriidae	*Limnoria*	*Limnoria borealis* Kussakin, 1963	18-260				+	+							
		Limnoria lignorum (Rathke, 1799)	0-20	+	+	+	+								+
Sphaeromatidae	*Bathycopea*	*Bathycopea typhlops* Tattersall, 1905	810-941			+									

Continuation of Annex 5.1:

Suborder - Family	Genus	Species	Depth range [m]	Geographic site											
				SN	NN	F	SI	NI	NS	NEG	SEG	SWG	NWG	DS	EC
Valvifera															
Antarcturidae	*Pleuroprion*	*Pleuroprion frigidium* Hansen, 1916	0-20							+					
		Pleuroprion hystrix (Sars, 1877)	218-1150		+	+	+	+	+	+	+				
		Pleuroprion murdochi (Benedict, 1898)	40-200				+								
Arcturidae	*Arcturella*	*Arcturella dilatata* (Sars, 1883)	45–1050	+		+	+								
	Arcturus	*Arcturus baffini* Sabine, 1824	2790–3340		+	+	+	+	+	+	+	+	+	+	
		Arcturus hastiger Richardson, 1909	12–1160							+					
		Arcturus scabrosus Norman, 1904	130–550			+									
	Astacilla	*Astacilla arietina* Sars, 1882	18–774	+	+					+					
		Astacilla borealphilis Stransky & Svavarsson, 2006	145–960				+				+				
		Astacilla caeca Benedict, 1898	79-85												+
		Astacilla granulata (Sars, 1877)	90-320		+	+	+		+	+		+	+	+	+
		Astacilla intermedia (Goodsir, 1842)	232-1150	+	+		+								
		Astacilla longicornis (Sowerby, 1806)	40-200	+	+	+	+	+		+					
		Astacilla pusilla (Sars, 1873)	158; 810-942	+	+	+					+				
	Spectrarcturus	*Spectrarcturus multispinatus* Schultz, 1981	18-260								+	+			
Idoteidae	*Idothea*	*Idothea balthica* Pallas, 1772	0-40	+	+	+	+								+
		Idothea chelipes (Pallas, 1766)	intertidal	+	+										
		Idothea emarginata Fabricius, 1793	0-33	+	+	+	+								
		Idothea granulosa Rathke, 1843		+	+	+	+	+							
		Idothea neglecta Sars, 1897	6-250	+	+	+	+								
		Idothea pelagica Leach, 1815	5-343	+	+	+	+								
		Idothea phosphorea Harger, 1873	3-1504; 2681												+
		Idothea viridis Slabber, 1775	1996-2465	+		+									
	Synidotea	*Synidotea bicuspidata* (Owen, 1839)	2201-2600						+						
		Synidotea nodulosa Kroeyer, 1846	5-1445						+	+	+	+	+	+	+
Mesidotheidae	*Saduria*	*Saduria entomon* (Pallas, 1766)	0-90						+	+	+				
		Saduria megalura Sars, 1879	20-56			+			+						
		Saduria polaris (Gurjanova, 1946)	9-740						+						
		Saduria sabini (Kroeyer, 1846)	45-270						+	+	+	+	+	+	+
		Saduria sibirica (Birula, 1896)	610-804						+						
Cymothoida															
Anuropidae	*Anuropus*	*Anuropus panteni* Brandt & Retzlaff, 2002	350-450								+				
Aegidae	*Aega*	*Aega arctica* Lütken, 1859	212-1428	-	+		+	+	+	+	+	+	+	+	
		Aega crenulata Lütken, 1859	180-1000	+	+	+	+	+	+	+		+	+		
		Aega monophtalma Johnston, 1834	608	+	+	+	+								
		Aega psora (Linnaeus, 1758)	45-1150	+	+	+	+	+	+	+	+	+	+		+
		Aega stroemii Lütken, 1859	205-860	+	+	+	+								
		Aega tridens Leach, 1815	201	+	+	+	+	?							
		Aega ventrosa Sars, 1859	216-1428	+	+	+	+	?	+	?	-	+	+	+	
	Rocinela	*Rocinela danmoniensis* Leach, 1815	160-1243	+	?	+	+	+							
		Rocinela maculata Schioedte & Meinert, 1879										?	+		
	Syscenus	*Syscenus atlantica* Kononenko, 1988	730-740; 2000									+			+
		Syscenus infelix Harger, 1880	41-2071	+	?	+						+			+

Continuation of Annex 5.1:

Suborder - Family	Genus	Species	Depth range [m]	Geographic site											
				SN	NN	F	SI	NI	NS	NEG	SEG	SWG	NWG	DS	EC
Cirolanidae	*Cirolana*	*Cirolana borealis* Lilljeborg, 1851	384	+	+	+									
		Cirolana schmidtii Hansen, 1905	840-1040			+							+	+	
	Eurydice	*Eurydice grimaldii* Dollfus, 1888	300-875	+	+	+	+	?			+				
		Eurydice inermis Hansen, 1890		+											
		Eurydice pulchra Leach, 1815		+	+										
		Eurydice truncata (Norman, 1868)		+											
	Metacirolana	*Metacirolana hanseni* (Bonnier, 1896)	847-942			+									
	Natatolana	*Natatolana borealis* (Lilljeborg, 1851)	30-90	+	+	+									
	Politolana	*Politolana micropthalma* (Hoek, 1882)	265	+	+						-	+			
Gnathiidae	*Caecognathia*	*Caecognathia abyssorum* Sars, 1872	128-887	+	+	+	+	+	+	+	+	+	?		
		Caecognathia bicolor Hansen, 1916	775-2210				+								
		Caecognathia elongata Kroeyer, 1846	0-3000	-	+	?	+	+	+	+	+	+	+	+	+
		Caecognathia hirsuta (Sars, 1877)	198-1775	+	+	+			+	+	+	-	+	+	
		Caecognathia robusta (Sars, 1879)	208-845		+	+	+	+	+	+	+	+	+	+	
		Caecognathia stygia (Sars, 1877)	180-2681			+		+	+	+	+				
	Gnathia	*Gnathia albescens* Hansen, 1916	842-1030			+									
		Gnathia dentata (Sars, 1872)		+	+										
		Gnathia maxillaris (Montagu, 1804)		+	+										
		Gnathia oxyuraea (Lilljeborg, 1855)	0-533	+	+										
Cabiropidae	*Clypeoniscus*	*Clypeoniscus meinerti* (Giard & Bonnier, 1895)				?	?	?				+	?		
	Parapodascon	*Parapodascon stebbingi* Giard & Bonnier, 1895			+		?	?	+			+	+		
Cryptoniscidae	*Liriopsis*	*Liriopsis pygmaea* (Rathke, 1843)		+	?										
	Cyproniscus	*Cyproniscus cypridinae* (Sars, 1882)		+	+										
Bopyridae	*Athelges*	*Athelges bilobus* Sars, 1898		+	?										
		Athelges paguri (Rathke, 1843)		+	?										
		Athelges tenuicaudis Sars, 1899		+	+										
	Bopyroides	*Bopyroides cluthea* (Scott, 1902)		?											
		Bopyroides hippolytes (Kroeyer, 1838)		+	+	+	+	+	+	+	+	+	+		+
	Hemiarthrus	*Hemiarthrus abdominalis* (Kroeyer, 1840)	45-50	+	+					+					
	Notophryxus	*Notophryxus clypeatus* Sars, 1885	270-940						+	+					
		Notophryxus ovoides Sars, 1882		+	?										
	Pleurocrypta	*Pleurocrypta galateae* Hesse, 1865		?											
		Pleurocrypta longibrachiata (Bate & Westwood, 1868)		+	?										
		Pleurocrypta marginata Sars, 1899		+	?										
		Pleurocrypta microbranchiata Sars, 1899		+	?										
	Pseudione	*Pseudione affinis* (Sars, 1882)		+	?										
		Pseudione crenulata Sars, 1899		+	?										
		Pseudione hyndmanni (Bate & Westwood, 1868)		+	+	+	+	?							
Dajidae	*Dajus*	*Dajus mysidis* Kroeyer, 1842			+				+	+	+	+	+		+
	Phryxus	*Phryxus abdominalis* Sars, 1882		?	+		+	+	+	+	+	+	+		+
	Apsidophryxus	*Aspidophryxus peltatus* Sars, 1882		+	+		+	+							
Hemioniscidae	*Hemioniscus*	*Hemioniscus balani* Buchholz, 1866		+	+										
	Asconiscus	*Asconiscus simplex* Sars, 1899		+	+										
	Portunion	*Portunion maenadis* (Giard & Bonnier, 1887)		+	+										
	Astacilloecheus	*Astacilloechus ingolfi* Hansen, 1916	474			+	+								

Conclusions and perspectives

Conclusions and perspectives

Several aspects of the distribution patterns of epibenthic peracarids on the South Greenland shelf could be addressed in this thesis, providing new information on the abundance, diversity, community patterns and environmental factors influencing the species composition. The biologic analyses of peracarid crustaceans carried out in **chapters 1 & 2** point to high abundances, to a fairly homogenous community regarding the diversity, but also to a clear geographic differentiation into a southeastern and southwestern Greenland peracarid fauna.

In all, 59,234 (**chapter 1**) and 83,893 (**chapter 2**) specimens were identified, presenting 219 (**chapter 1**) and 205 species (**chapter 2**). The observed high abundances and diversity are in accordance with other studies in adjacent areas (Svavarsson et al. 1993, Brandt et al. 1996), but represent a considerable extension of distribution data on the South Greenland shelf since Hansen (1916), Stephensen (1937, 1943) and others.

With regard to species occurrence, it was surprising that already at four locations (**chapter 2**) almost the same number of species was found as at 10 stations in **chapter 1**. This suggests that the total number of species occurring in the study area was covered already with four locations and that the sampling locations selected for the temporal comparisons in **chapter 2** represent the different species communities well.

The geographic separation of the peracarid fauna into East and West (**chapter 1**) was given in all three sampling years covered in this study (**chapter 2**). On a wider temporal scale, it would be worthwhile revisiting the study area in several years time, in order to investigate changes in the peracarid community structure within decadal or longer periods. Moreover, the deviating species composition results for the northeastern station taken in the first sampling year (**chapter 2**) illustrates the need for replicate sampling. As the Rauschert sledge (**chapter 3)** delivered consistent and reliable epibenthic sampling during the entire sampling period, this sampling device showed high replicability and can be recommended for further epibenthic studies.

Several environmental factors were considered in this study and tested for their influence on the peracarid species composition. In **chapter 1**, a significant correlation of decreasing species diversity with increasing latitude was observed in the eastern study area, especially for the amphipods. In the western study area, no significant latitudinal trends were found. As the latitudinal range of this study and the coverage of samples within this range was relatively small, however, general conclusions on large-scale diversity patterns such as described by Roy et al. (1998) and Rex et al. (2005) cannot be derived. This study indicates that other environmental factors, mainly the sediment structure and hydrography, influence the species distribution patterns to a larger degree than the latitude.

The sediment and foraminiferal analyses in **chapter 4** confirm the geographic differences in habitat structure along the southern shelf of Greenland, with purely sandy sediments documented for the East, while the fraction of coarser grain sizes increased slightly in the West. This observation was supported by the analysis of the foraminiferal fauna, dominated by one species (*Cibicides lobatulus*) which is known to occur on sandy-coarse sediments and along strong currents. **Chapter 4** indicated that the sediment structure is mainly characterised by the strength of the currents, which is especially high in the western sampling area (Holliday et al. in press).

Hydrographic patterns have also been identified as having major impact on large-scale distribution of isopods (**chapter 5**). The isopod distribution patterns correspond with the pathways of the current systems of the northern North Atlantic, as the sites located along the main current pathway (Northeast, Southeast and Southwest Greenland) are most similar in their species composition. **Chapter 5** can also be seen as a pilot study, since only isopods were considered, i.e. further large-scale comparisons using the other peracarid orders are possible.

Nevertheless, the faunal comparisons in **chapter 5** already indicated that the geographic scaling of a study has to be taken into consideration when interpreting differences in species composition between sampling sites. In relative terms, the clear separation of the peracarid fauna between Southeast and Southwest Greenland found in **chapters 1** and **2** are minor on a wider geographic range across the North Atlantic (**chapter 5**). The investigation of the southern Greenland shelf in this study, however, added recent knowledge to the biogeographic map of peracarid crustaceans in the North Atlantic. In this context, the geographic focus of future similar studies should be on the continental slope, deep-sea and ridges between the intensively sampled areas on the shelves, e.g. between Iceland and

Greenland, to investigate the links between species communities and possible migration routes.

During the expeditions WH244 and WH268, more stations have been sampled than could be analysed within the frame of this study. The remaining stations of these two cruises were taken at corresponding locations to those of WH233 (**chapter 1**). Considering the background knowledge gained in **chapters 1-5**, further geographic and temporal comparisons could be carried out using this material.

For future investigations, it would be advisable to include more elements of the benthic community (other invertebrate taxa) and abiotic factors as detailed as possible to obtain a more integrative understanding of the ecosystem, in particular the interrelationships between different taxa and their dependence on the environment. This approach would be especially interesting with regard to long-term series under the aspect of climate change.

During the identification of the species, several taxonomic questions were raised. On the one hand, relationships within single orders showed numerous unsolved problems, on the other hand, it became obvious that for several species, a redescription is absolutely essential (e.g. *Spectrarcturus multispinatus* Schultz 1981 (Arcturidae: Isopoda) and *Ischyrocerus* species T1 Just 1980 is very likely to be *Ischyrocerus anguipes* Krøyer 1838). In the material for this study, one species was found to be new to science (*Astacilla boreaphilis* Stransky & Svavarsson 2006 (Arcturidae: Isopoda)) and three species probably new to science (*Schisturella* n. sp. (Lysianassidae: Amphipoda), *Dulichia* n. sp. (Podoceridae: Amphipoda) and *Magotanais* n. sp. (Colletteidae: Tanaidacea)) were found.

In the end, our understanding of epibenthic species diversity and community dynamics on the North Atlantic shelves can only be expanded if taxonomic studies as presented in this thesis are continued. These studies should then be drawn together with studies on other invertebrate taxa in the same investigation area and on the same taxa in adjacent areas. Having observed the impact of environmental variables on the species communities, the concurrent recording of abiotic data is essential for any future study of this kind.

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