The 1998 Danish-German Excursion to Disko Island, West Greenland

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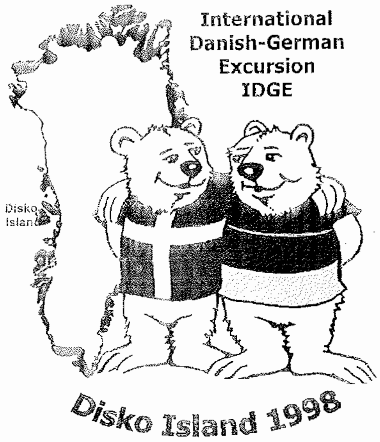
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Disko Island
Disko Island 1998

Contents

The 1998 Danish-German Excursion to Disko Island, West Greenland

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Introduction

This report summarizes the results from a biological field course organized at the University of Copenhagen Arctic Station in July - August 1998. Twelve students from the University of Copenhagen and 10 students from Hamburg University participated in this International Danish-German Expedition (IDGE). Field activities were supervised by senior researchers from both universities. The Danish team consisted of: Helge Abildhauge Thomsen (Botanical Institute), Reinhardt Møbjerg Kristensen (Zoological Museum), and Henning Heide-Jørgensen (Botanical Institute). The German teachers were: Angelika Brandt and Hilke Ruhberg (Zool. Institute and Museum). A German Ph.D. student, Jörg Nickel, also participated in the field activities, and is now (May-September 1999) back in Greenland continuing a sampling programme for his Ph.D. thesis.

The Arctic Station is located near the town Qeqertarsuaq (Godhavn) on the south coast of the Disko Island, West Greenland (Fig. 1). It was founded in 1906, and is thus the oldest research institution north of the polar circle. For a thorough introduction to the Arctic Station please consult the homepage for the institution at the address: http://www.geogr.ku.dk/as/.

The field course projects addressed both terrestrial and marine issues. Part of the field work was conducted in Mellemfjord /Akulliit on the west coast of the Disko Island. A camp site was maintained here for a period of approximately three weeks. During the field course period (15 July - 8 August 1998) we visited the Mellemfjord four times on board the Arctic Station research vessel 'Porsild'. Other projects were based on material collected in the vicinity of the Arctic Station. Project themes, field acitivies etc. are summarized in Fig. 2. In order to set the stage for the presentations to follow, we have included at the end of the introduction a few graphs illustrating meteorological observations from both the Arctic Station and the Mellemfjord /Akulliit.

Our stay in Greenland was generally successful from a scientific point of view, and a great experience for all of us in many other ways. The weather was fabulous, making mountain hikes and boat rides unforgettable. Whales were frequently sighted right in front of the Arctic Station, and the Jakobshavn glacier produced an endless line of

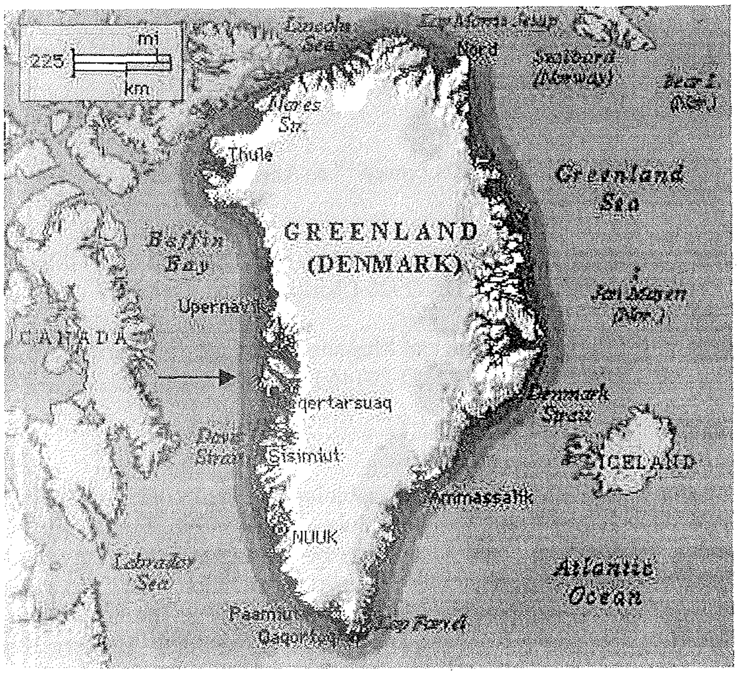

Fig. 1. Map of Greenland. The arrow points to Disko Island.

magnificent icebergs that majestically floated by the Arctic Station or grounded right in front of us.

After our return to Copenhagen and Hamburg the processing of samples and field data continued for all project teams. In order to exchange data files and discuss scientific issues of common interest, there was a short meeting for most participants in November 1998 at the University of Copenhagen Brorfelde field station.

The Univ. of Copenhagen students submitted Danish versions of their project reports in due time for a scheduled oral examination in January 1999. These contributions have later been revised as needed and published as part of a series of annual Arctic Station field excursion reports (Thomsen 1999). The Danish contributions included in this volume are to a large extent further revised and translated versions of these chapters. A few contributions, e.g. on spiders, mycorrhiza, sliding soil vegetation, and *Spio* spp. (Polychaeta), are extended abstracts. These contributions are currently being prepared for publication in more specialized, international journals.

The University of Hamburg students submitted English versions in 1999. These were reviewed by the group of teachers and most, but not all of the corrected versions are included in this report. Some of these reports on tardigrades and macrofauna will serve as a basis for subsequent analyses which will lead to masters' theses.

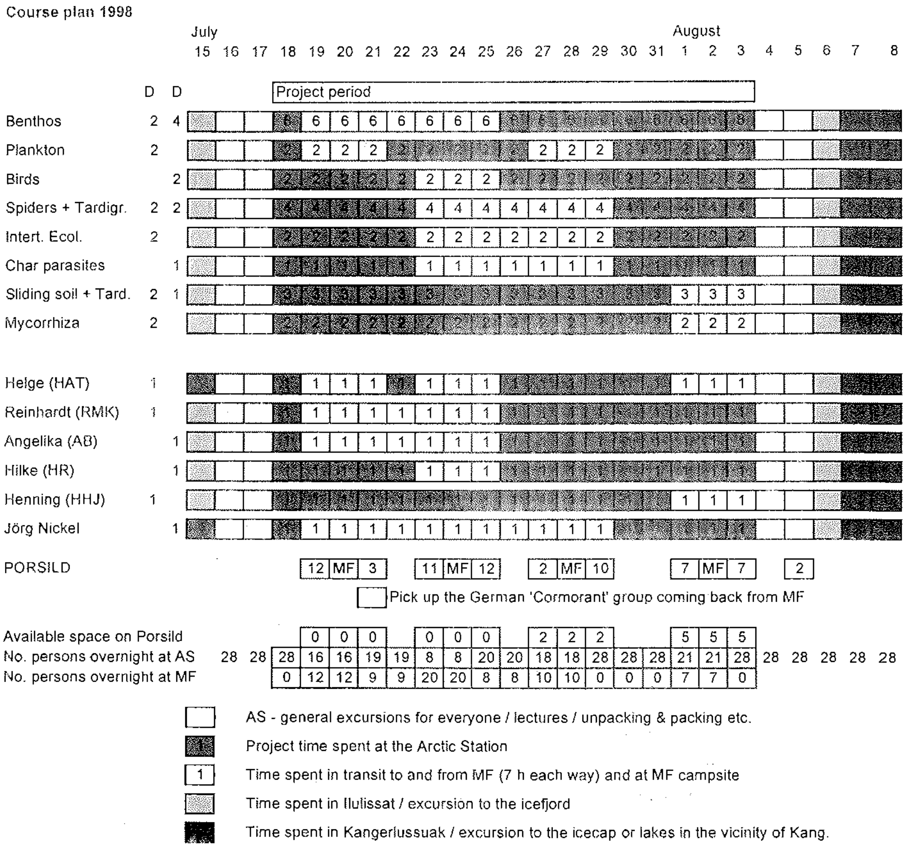

Fig. 2. Overview of course activities

Acknowledgements

First and foremost we want to thank the entire staff at the Arctic Station for providing logistic support for us in every possible way. Thanks are also due to a number of colleagues at the University of Copenhagen for assisting with sample analysis etc.: N. Scharff, D. Eibye-Jacobsen, G. H. Petersen, M. E. Petersen (Zool. Museum), and A. Michelsen and P. M. Pedersen (Botanical Institute). Benni Hansen (Roskilde Univ. Center) is acknowledged for help with the zooplankton work.

The Faculty of Science provided financial support for Danish students and two teachers. The Botanical Institute, Univ. Copenhagen, is acknowledged for financial support that allowed us to include H. Heide-Jørgensen in the team of teachers. The Danish students acknowledge the G. E. C. Gads Foundation, the Brewer J. C. Jacobsen's Carlsberg Bursary and the Greenland Nature Institute for financial support.

The faculty of biology of the University of Hamburg supported the German students. Special thank is due to Ms. E. Hjelm. However, participation of the Germans would not have been possible without the generous financial support of "Jack Wolfskin", "Globetrotter", the "University Foundation of Hamburg", the "Johanna and Fritz Buch Gedächnisstiftung" as well as "Günther Bock". Special thanks are also due to "Print 64" for help with the layout of an invitation, and especially Gisela Wegener and Katrin Linse for organizational help before the excursion started. M. Böttinger and P. Stiewe kindly assisted us with the final layout, Dr. B. Hilbig kindly corrected the English of our last version. Many kind colleagues of the Zoological Institute and Zool. Museum supported our ideas and helped with equipment.

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Thomsen, H. A. (ed) 1999. Arktisk Biologisk Feltkursus, Qeqertarsuaq 1998. Botanisk Institut, Københavns Universitet, 242 pp. ISBN: 87-987317-2-6.

Appendix:

Meteorological observations 1998 at the Arctic Station, Qeqertarsuaq (Godhavn), and Akulliit (Mellemfjord), West Greenland.

The data presented on the following pages originate from automated meteorological stations which are being operated by the Arctic Station. The Arctic Station Board is acknowledged for their permission to make use of the data.

The main station is located in the immediate vicinity of the Arctic Station. The sensors provide output (every 30 minutes) of, e.g., the following parameters: wind velocity at 600 cm, windgust at 600 cm, air temperature (600 cm), relative humidity (600 cm), incoming SW radiation (200 cm), outgoing SW (200 cm), albedo, precipitation (200 cm), temperature of sediment (-5 cm), temp. of sediment (-60 cm), temp. of sediment (-175 cm), and temperature of rock (-300 cm).

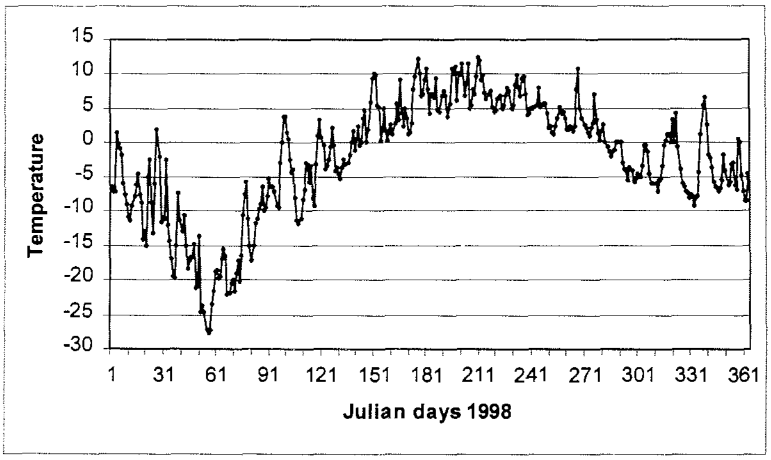

Fig. 3. Temperature at 600 cm; daily mean values obtained from the Arctic Station climate station located in Qeqertarsuaq.

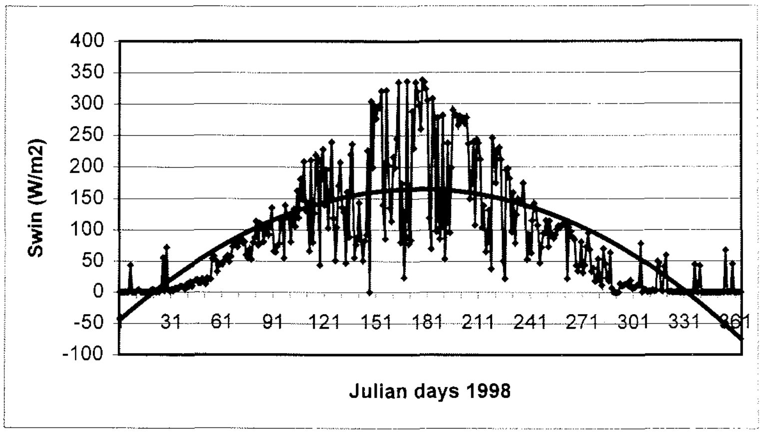

Fig. 4. Insolation (shortwave radiation daily means) at the Arctic Station climate station located in Qeqertarsuaq. A trend line is added.

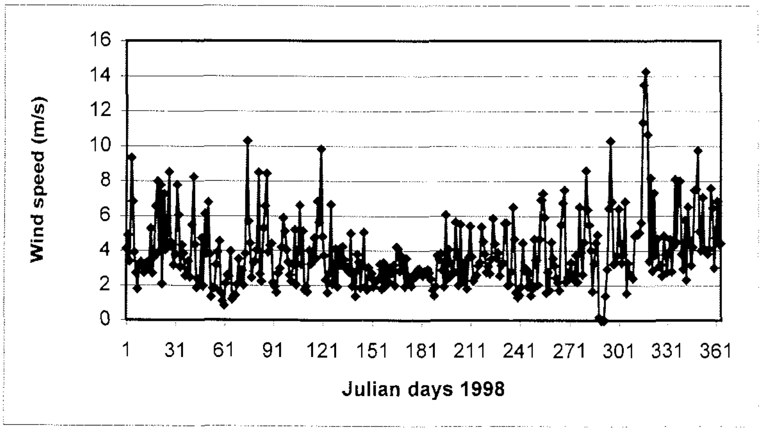

Fig. 5. Wind velocity (600 cm); daily means at the Arctic Station climate station located in Qeqertarsuaq.

A second climate station is located in Akulliit (Mellemfjord) at 69°43.862' N and 54°31.403' W. Data from 10 sensors (wind speed, wind direction, air temperature (200 cm), ground temparature (2 cm), ground temperature (10 cm), relative humidity, incoming LW radiation, outgoing LW radiation, incoming SW radiation, outgoing SW radiation) are logged and stored with a time interval of 120 minutes.

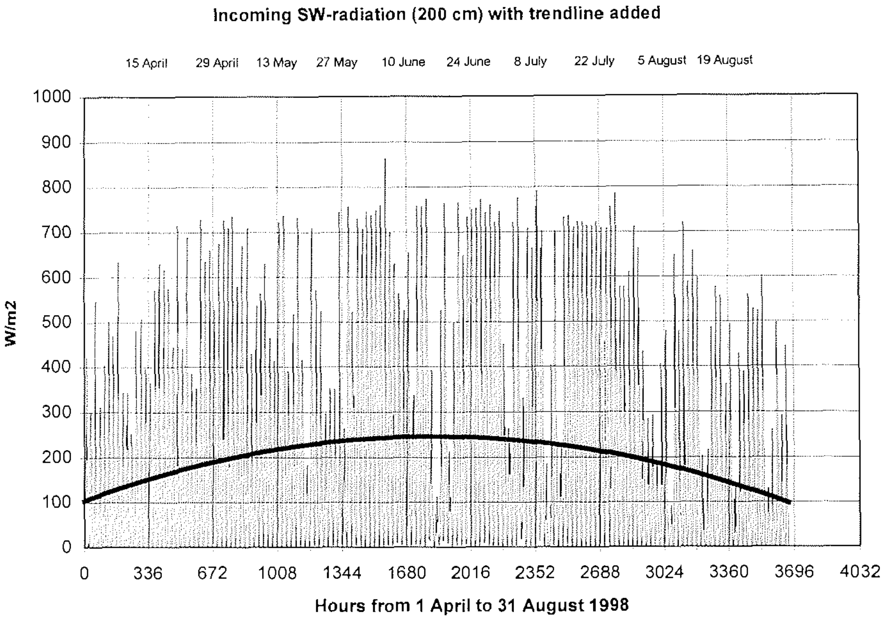

Fig. 6. Incoming SW radiation (W/m^2) from 1 April to 31 August 1998. The trendline added indicates a reduction of approximately 25 % in incoming SW radiation during the investigation period (July).

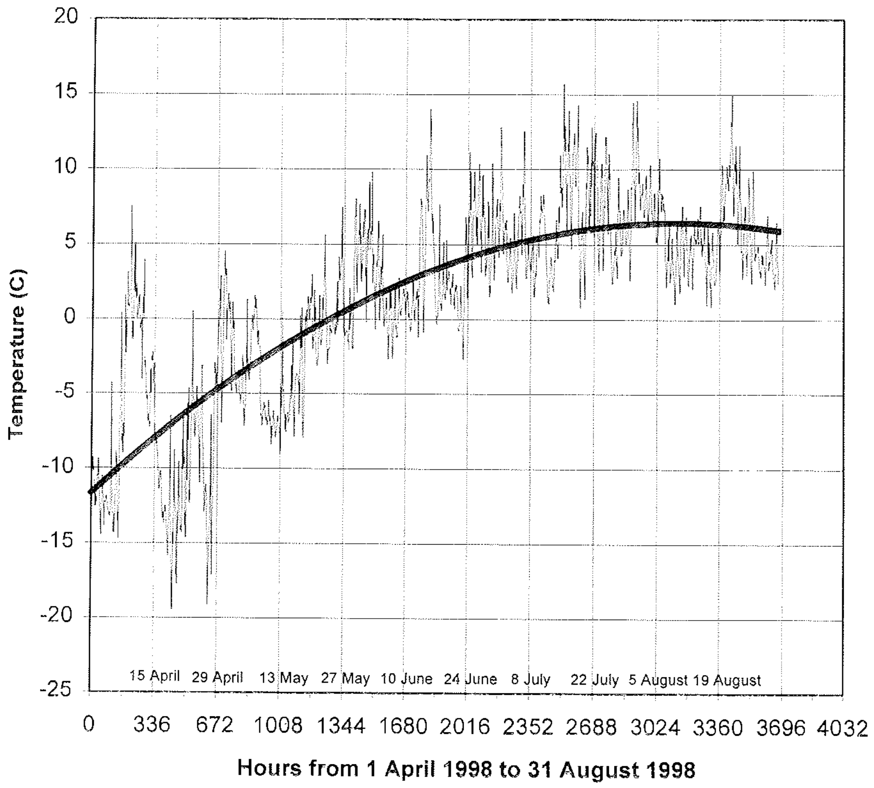

Fig. 7. Air temperature at 200 cm above ground level from 1 April to 31 August 1998. The trendline added shows an overall change from -12°C (1 April) to approximately 7°C in early August. The temperature maximum period is early August.

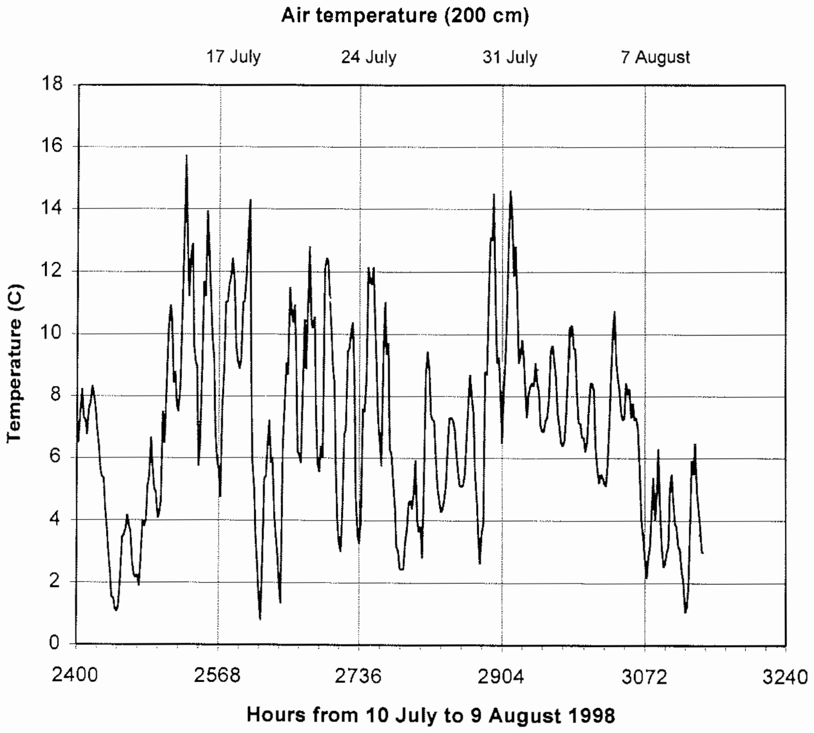

Fig. 8. The temperature regime during the Mellemfjord camp period. Maximum and minimum temperatures recorded are ca. 16°C and ca. 1°C, respectively.

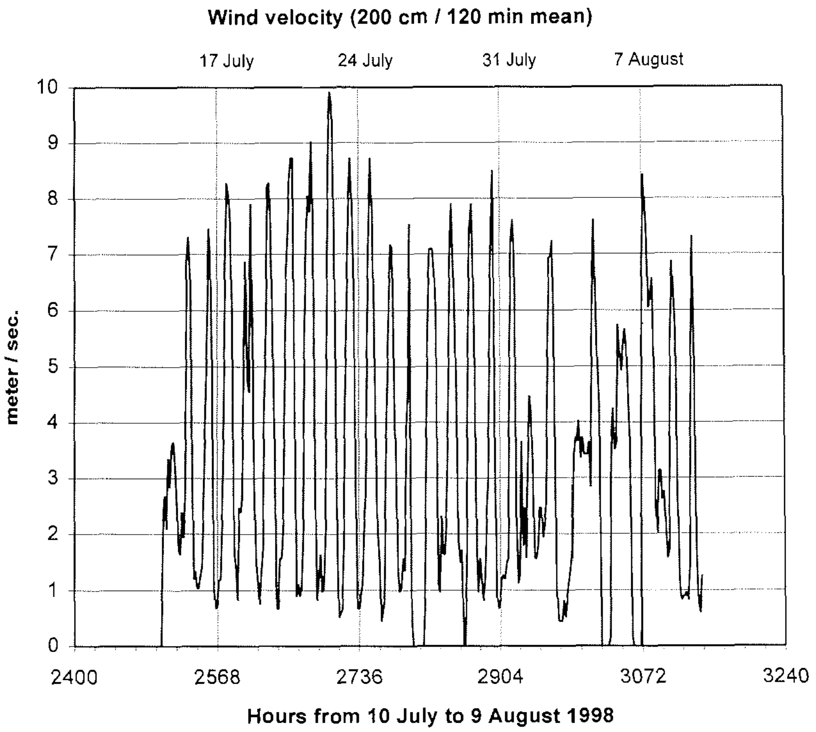

Fig. 9. Wind velocities at 200 cm from 10 July to 9 August 1998 (the Mellemfjord camp period). The maximum wind velocity is close to 10 m/s. Notice the extremely regular daily pattern. The minor tick marks represent days.

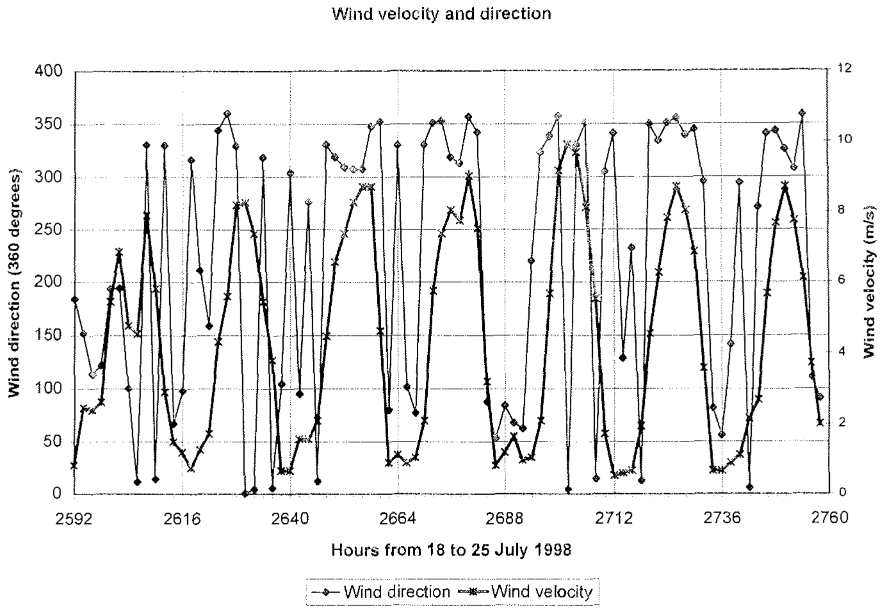

Fig. 10. A detailed analysis of wind velocity and wind direction during a one week period (18-25 July). The minor tick marks represent 2 hours intervals. The daily heating of the fiord area causes an upward expansion of the warm air masses (creating a daily thermal low pressure) and a compensating flow of air from the Davis Strait towards the bottom of the fiord. The maximum wind speeds occur at 2 p.m.

Mycorrhizal symbioses in four plant communities in Greenland in relation to different soil factors

A summary of an investigation from Qeqertarsuaq, Disko, West Greenland, July 1998

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The vast majority of higher plants are associated symbiotically with one or more kinds of terrestrial fungi. These associations are named mycorrhiza ("fungi root"). The symbiosis is most often characterized as mutualistic (Allen 1991), because the fungus receives carbon from the plant which, in return, is supplied with nutrients and water (Allen 1991). The mycorrhizal symbiosis is often described as favourable, especially for plants in nutrient-stressed situations (Smith and Read 1997). Mycorrhiza may therefore be particularly beneficial for Arctic plants which are nutrient-stressed due to limited availability of nitrogen and phosphorus (Chapin *et al.* 1978, Schimel and Chapin 1996). Large amounts of organic matter are accumulated in Arctic regions; this is the result of cold, wet soil environments, short summers, slow organic matter decomposition, and low nutrient mineralization (Nadelhoffer *et al.* 1992).

In this study four different plant communities were investigated with regard to the abundance of mycorrhizal symbioses in relation to soil pH, extractable NH_4^+, NO_3^- and PO_4^{3-}, total N and P, and soil organic matter. The four study sites were: 1) a snowbed, 2) a fell field, 3) and 4) two dwarf shrub heaths, one influenced by homothermic springs. An analysis of the coverage of plant species was carried out in six replicate plots in order to obtain a measure of the ecological significance of the different mycorrhizal types within the communities.

The dwarf shrub heaths were dominated by species in Ericales and the shrubs *Salix glauca* and *Betula nana*. However, their dominance differed between the two heath communities examined. Dominant species at the dwarf shrub heath influenced by homothermic springs (±SE): *Salix glauca* (46±7% of the total coverage), *Empetrum nigrum* ssp. *hermaphroditum* (45±9%), *Equisetum arvense* (28±6%), and *Vaccinium uliginosum* (18±6%). Dominant species at the second dwarf shrub heath examined: *Vaccinium uliginosum* (38±5%), *Empetrum nigrum* ssp. *hermaphroditum* (31±9%), *Salix glauca* (9±2%), and *Betula nana* (7±2%). The four most common snowbed species were: *Salix herbacea* (64±11%), *Equisetum arvense* (23±6%), *Sibbaldia procumbens* (17±8%), and *Polygonum viviparum* (14±5%). At the fell field the vegetation was divided into smaller islands, and the most common species within these were: *Dryas integrifolia* (11±3%), *Betula nana* (8±7%), *Salix* *glauca* (7±7%), and *Saxifraga tricuspidata* (4±4%). Graminoids and herbs were frequent only in the snowbed and at the dwarf shrub heath influenced by homothermic springs.

The collection effort resulted in 295 root samples from 51 plant species. 99 root samples representing 21 plant species were not infected with mycorrhiza. The field work included 23 plant cover analyses. Soil parameters are available for 23 samples. Figure 1 illustrates the results of the plant cover analyses with the plant species grouped according to their mycorrhizal types. Table 1 highlights selected results from the soil analyses.

Figure 1 Plant cover analyses at the four sites; plant species grouped according to their mycorrhizal types. **A:** The total coverage in % of the soil surface. **B:** The relative coverage. The four letters (see legend) refer to the four sites. Sites with the same letter are not significantly different (Tukey's HSD test or Newman Keuls test with α=0,05). * The two dwarf shrub heaths were not significantly different, neither were the snowbed and the fell field. NON: plants without mycorrhiza. ARB: arbutoid, ERI: ericoid, AM: arbuscular and ECM: ectomycorrhizal plants.

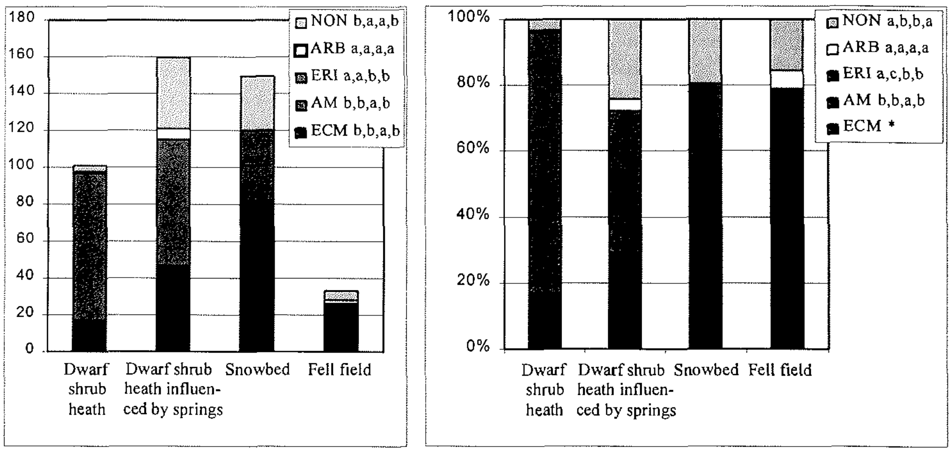

Table 1 Selected results from soil analyses. Number of replicate plots (n), soil pH, soil organic matter (SOM), extractable NH_4^+, and relation between inorganic nitrogen (NH_4^+ and NO_3^-) and inorganic phosphorus (PO_4^{3-}). Means ± SE. Means for each variable with the same letter are not significantly different (Tukey's HSD test or Newman-Keuls test with α=0,05). * The fell field and the snowbed are significantly different.

Sites	n	pH	Soil organic matter (SOM) (% of dry weight)	Ammonium (µg/g SOM)	Inorganic N /Inorganic P
Dwarf shrub heath	6	5,35 ± 0,08 b	34,59 ± 8,30 b	26,99 ± 2,68 b	5,37 ± 0,41 a
Dwarf shrub heath influenced by homothermic springs	6	5,42 ± 0,10 b	67,20 ± 2,61 a	108,25 ± 13,98 a	2,48 ± 0,45 a
Snowbed	6	5,65 ± 0,11 b	12,98 ± 1,24 c	105,26 ± 19,43 a	18,65 ± 2,91 b
Fell field	5	6,22 ± 0,08 a	7,67 ± 1,28 c	44,38 ± 6,46 b	6,31 ± 2,55 *

Based on plant root morphological structures we were able to distinguish four mycorrhizal types: arbuscular mycorrhiza, ericoid mycorrhiza, ektomycorrhiza, and arbutoid mycorrhiza. Arbuscular mycorrhiza predominates worldwide in communities with herbs and woody plants on less organic soils at low latitudes and altitudes where phosphorus is often limiting (Read 1991). Ericoid mycorrhiza dominates nutrient poor and washed out moor habitats at high altitudes and latitudes (Read 1991). Ektomycorrhiza dominates in woody ecosystems at intermediate latitudes and altitudes (Read 1991). Arbutoid mycorrhiza is only formed by a few species within Ericales and is, therefore, not widely distributed.

As expected the investigation showed that ericoid mycorrhiza dominated in plant communities on soils with high content of organic matter, presumably as a result of the ericoid mycorrhiza utilizing the large pools of organic bound nutrients (Smith and Read 1997).

Altogether we found 17 plant species infected with arbuscular mycorrhiza. Arbuscular mycorrhiza has until now never been found to be of any significance in arctic ecosystems. However, in this investigation arbuscular mycorrhiza was an important factor in the snowbed, impacting 26.3% of the relative plant coverage. Contrary to the three other communities examined the snowbed had limiting quantities of phosphorus (Table 1). This is based on the assumption that plants take up nitrogen and phosphorus approximately at a ratio of 10/1. Hence, it seems that also in Arctic ecosystems it is the capacity of arbuscular mycorrhiza to enhance the uptake of phosphorus which makes this mycorrhizal type especially advantageous in some habitats.

Plants with ectomycorrhiza were overall the most dominant functional group within the vegetation types examined. Ectomycorrhizal plants are, similar to those with ericoid mycorrhiza, able to utilize the organic nitrogen and phosphorous in the soil (Smith and Read 1997). In contrast to plants with ericoid mycorrhiza, those with ectomycorrhiza were also found in soils with low organic matter contents (Fig. 1, Table 1). We therefore conclude that plants with ectomycorrhiza generally grow in sites with more diverse soil conditions than plants which benefit from ericoid mycorrhiza.

According to Smith and Read (1997) it is the same fungal species that form both ectomycorrhiza and arbutoid mycorrhiza. Thus, it appears valid to assume that arbutoid mycorrhiza will have the same basic properties as ectomycorrhiza. Plants with arbutoid mycorrhiza were found in all four plant communities (except the snowbed) in soils with both low and high organic matter contents.

Many of the collected plant species were not colonized by mycorrhizal fungi (40-50% of the species at each site). However, the relative coverage of these plants was in general low (Fig. 1). Our investigation indicates that there is a positive correlation between the coverage of plants without mycorrhiza and the amount of inorganic N in the soil.

We have shown that the abundance of the different mycorrhizal types is dependent on soil nutrient availability and organic matter content of the soil. However, the distribution of plant and fungal species in the Arctic region also depends on a variety of other factors including snow conditions and physical parameters such as wind and water. The role of mycorrhiza in relation to plant adaptation to Arctic conditions is complex. The large proportion and coverage of plants with mycorrhiza indicates that mycorrhizal symbioses play an important part in the functioning of Arctic ecosystems.

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An analysis of plant communities and environmental factors on Pjeturssons Moraine, Disko, West Greenland

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Abstract

We have investigated patterned ground, in this paper referred to as sliding polygons, on Pjeturssons Moraine, Disko, Greenland. Nine sliding polygons were examined using an expanded Raunkiaer analysis. A pinpoint analysis was carried out on six sliding polygons. Using plant coverage in the centre zones as a discriminating factor, all polygons were subjectively referred to one of three different levels of stability. The stable border zones of the sliding polygons very much resembled the surrounding *Cassiope* heath, while pioneer plants with a low degree of coverage dominated the unstable centre zones. Chemical and biotic factors were significantly different when comparing the centre and border zones of the sliding polygons. In particular the centre zones showed significant differences when comparing the different stability levels. The concentration of nutrients was higher in the stable border zones. Jonasson and Sköld (1983) found completely different nutrient gradients in Swedish polygons (Kamasjaure). General environmental differences between the two localities, such as type of bed rock, presence or absence of permafrost and different levels of nutrient leaching might explain the contrasting results. We suggest that plant community differences associated with the three levels of stability are caused primarily by physical processes. The upwelling of soil appears to be the single most important factor controlling plant succession. The plant cover has secondarily changed the chemical environment and soil structure.

Introduction

Despite the fact that large areas in Arctic regions are exposed to soil movement and unstability caused by frost action, the investigation of plant growth controlling mechanisms in these habitats has been sparse. To our knowledge there has been no research on unstable soil in permafrost areas in Greenland since Raup (1969) investigated plant communities on polygon soil in Mestersvig, East Greenland.

More recently polygon soil has been thoroughly examined at low Arctic, northern Swedish localities (Abisko and Kamasjaure) characterized by the absence of a permafrost layer (Jonasson and Sköld 1983, Jonasson 1986, Jonasson and Callaghan 1992). The presence or absence of permafrost is likely to be an important factor behind the creation of polygon structures and the chemical properties of these.

'Patterned ground' is often used as a collective name for all sorts of soil structures caused by frost action. The patterns are usually polygonal or circular and therefore referred to as 'polygon soil' or 'soil circles' (Washburn 1956). Each polygon, with a diameter ranging from centimeters to several meters, most often has a slightly elevated middle section with little or no vegetation, surrounded by a more vegetated border.

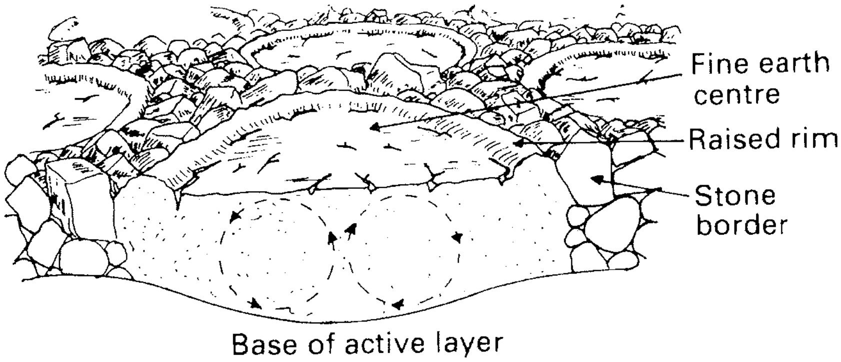


Fig. 1. The circular arrows indicate the water flow according to the free convection theory. From Jonasson & Callaghan (1992).

The polygon or circle is either *sorted* or *nonsorted* (Washburn 1956). In the centre of sorted polygons the soil is composed of small particles (clay and silt), while the border region consists of larger particles, sometimes including large stones (Fig. 1). In nonsorted circles the clay and silt content of both centre and border is high and there is no visible difference in mean soil particle size.

The creation of soil polygons is still a controversial subject. Washburn (1956) discussed several likely scenarios and Kranz *et al.* (1988) concluded that *free convection,* which is circulation of soil water caused by freeze-thaw transitions (Fig. 1), and *kryostatic pressure,* which develops in fluid water between the permafrost and the freezing upper part of the active layer at the beginning of a freezing period, are the most likely physical phenomena causing frost heaving and the subsequent creation of patterned ground.

The slope of the study area is a factor which effects the shape of the polygons. The slope causes the soil to slide downwards due to insufficient adhesion between the active layer and the permafrost (referred to as *sliding soil* by Danks 1981 and *gelifluction* by Washburn 1967). Polygons become elongate in the process giving them an oval outline. Sliding sometimes results in overlapping of neighbouring polygons.

Material and methods

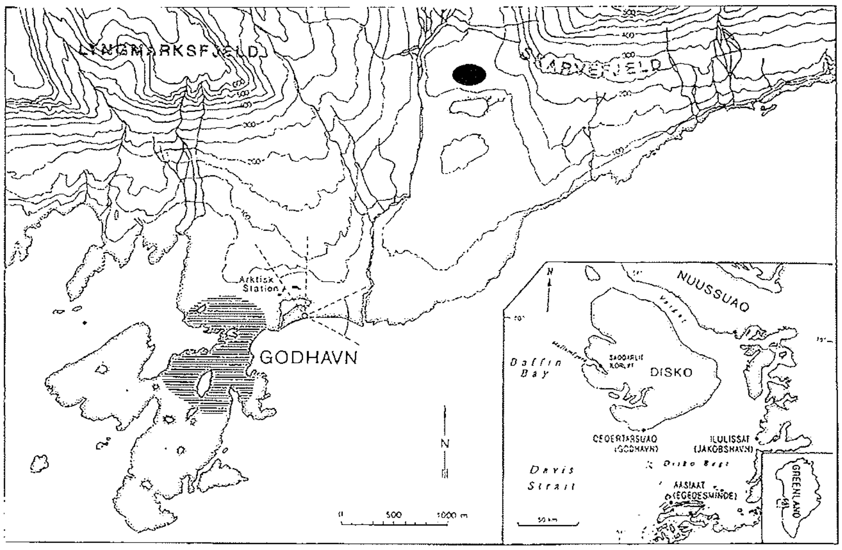


Fig. 2. Map of the Qeqertarsuaq area on Disko. The black oval shows the area of the investigation on Pjeturssons Moraine.

Study area. Pjeturssons Moraine (69°16′5′′N, 53°28′5′′W; 2 km from the coast in the valley Blæsedalen, 3 km northeast of Qeqertarsuaq, Disko, Greenland; Fig 2), is an end moraine deposited during the retrieval of the ice cap towards the end of the last ice age. It is 1400 m long, 500 m wide and 50 m high (Humlum 1978) and covered by regular polygons on level ground and sliding polygons on the faces sloping 2 - 10°. The study area was limited to nonsorted sliding polygons on the south face of the Moraine. The fine-grained basaltic bedrock in the area is of magmatic origin with a high content of oxygenated silicium, iron, magnesium and calcium (Gass *et al.* 1972).

In Blæsedalen the plant cover comprises different types of heath vegetation (Böcher 1959): (a) areas with dry soil and little snow cover dominated by pioneer plants such as *Carex rupestris* and *Vaccinium uliginosum*, (b) more wet areas with heavier snow cover which display different types of dwarf heath vegetation including *Empetrum nigrum, Betula nana* and *Salix glauca,* and (c) snowbeds dominated by *Salix herbacea* and herbs like *Sibbaldia procumbens*. *Cassiope* heath dominates in gelifluction areas (Böcher 1959).

The Qeqertarsuaq annual mean temperature (1961-1990) is ÷3,9° C (Nielsen *et al.* 1997). The annual precipitation in southern Disko was 400-500 mm during the same period (Bernes 1996). Data from 1991-1997 indicate that spring thaw of the active layer begins in early June, sometimes even earlier. Autumn frost commences during September or early October (Nielsen *et al.* 1997).

Fieldwork. All polygons were assigned to one out of three levels of stability that were subjectively defined based on the amount of vegetation. A similar procedure of subjective estimation of stability has been used before, and is accepted as a fast and simple way to obtain a qualitative estimate of frostheaving activity (Jonasson 1986). Level 1 represents the least stable soil with considerable frostheaving and almost no vegetation in the centre (polygon nos. 1, 2, and 4). Level 2 represents medium stable soil with less pronounced frostheaving and some vegetation in the centre (polygon nos. 3, 5, and 6). The most stable soils with hardly any visible frostheaving and polygon centres that are almost as vegetated as the borders (polygon nos. 7, 8, and 9) are referred to level 3.

The border (b1-b9) and centre zones (c1-c9) of the nine sliding polygons were examined using an extended Raunkiaer analysis (Böcher and Bentzon 1958) with 10 Raunkiaer-circles in each zone. All vascular plants and eight of the most dominating lichens were included in this analysis. Because small bryophyte species are very difficult to distinguish while sampling, and also due to time constraints during the field work, the bryophytes and non-dominating lichen species were not included in this analysis. The depth of the permafrost layer was measured at different positions within the sliding polygon. See Jensen & Larsen (1999) for further details. Six soil samples, each with a volume of 196,3 cm^3, and three samples of above ground biomass (each from a 10 x 10 cm area) were collected from border and centre zones of all polygons.

Laboratory work. All samples were kept in plastic bags while being transported to the Arctic Station laboratory. Here they were all weighed and dried at 105°C for 24 hours in order to initially determine the water content. Half of the dried soil samples from each zone were stored in plastic bags with a minimum of air at ÷18°C and shipped to Copenhagen. Two months later the samples were defrosted and sieved through a 2-mm screen in preparation for measurements of soil parameters: pH, conductance, extractable Mg, Ca and K and concentration of NH_4-N. A 1:5 suspension of soil and distilled water (10 g dry soil, 50 ml water) was shaken for two hours and filtered. Subsamples of the supernatant were used for conductance and pH measurements. $LaCl_3$ was added to the remaineder of the supernatant in a 10:1 ratio (supernatant: $LaCl_3$). Several dilution series were made from this solution, and the concentrations of extractable Mg, Ca and K were measured using an Atomic Absorption Spectrophotometer (AAS, Perkin-Elmer GmbH). Ten grams of the dry, sieved soil from each sample were mixed with 50 ml 0,5M K_2SO_4 and filtered. The supernatant was used to measure the concentration of extractable NH_4-N in a spectrophotometer (Hitachi AS-3000). Pore volume, bulk density, amount of organic matter, and concentration of extractable PO_4-P were also measured (see details in Jensen & Larsen 1999 for further details).

Pinpoint analysis. A pinpoint analysis of both centre and border was made on six sliding polygons (level 1: polygon # T1, T3, and T4 and level 2: polygon # T2, T5, and T6). Each sliding polygon was crossed by six parallel lines 30 or 50 cm apart. A stick was inserted vertically at 5-cm intervals into the vegetation. Vascular plant species and dominating lichens were noted when touching the stick. At the same time the location of each stick-point on the sliding polygon was noted.

Temperature monitoring. The temperature was measured continuously (6- or 10-minute intervals) for approximately one week at eight points distributed within two sliding polygons. For further information on these measurements, see Jensen & Larsen (1999).

Statistics. A Principal Component Analysis (PCA) of floristic data and a Pearson and Kendall's correlation test between chemical/biotic factors and the ordination were made using the programme PC-ORD. The r-values (from the parametric test which assumes normally distributed data) were used in all comparisons although not all data were normally distributed. The software SigmaStat was used to perform the non-parametric test Spearman Rank Correlation between chemical and biotic factors. This test does not assume normally distributed data. Differences between centre and border zones were tested using One Way ANOVA in SigmaStat. Centre and border zones were then tested individually for differences between the three levels of stability. A Kruskal-Wallis One Way ANOVA on Ranks was performed in cases where data could not be transformed into normal distributions.

Results

Vascular plant and lichen composition on the polygons. Twenty-nine vascular plant species and eight lichens were recorded from the 18 zones studied (nine sliding polygons) as part of the Raunkiaer analysis (Table 1). Five additional vascular plant species were found in the area (Table 1). *Equisetum arvense* and *Polygonum viviparum* were found in all 18 zones. The most frequent species in the polygon centre is *Equisetum arvense* with the highest score in six out of nine zones. However, it is generally very evenly distributed in sliding polygons, with a slight preference only for the centre zones. *Polygonum vivparum* seems to appear most frequently in medium stable centre zones (3, 5 and 6) and less frequently in border zones. *Cassiope tetragona* is dominant on the borders where it has the highest score in six out of nine zones.

Several species have a characteristic distribution. *Minuartia rubella* and *Koenigia islandica* are thus predominantly growing in the centres of the least stable sliding polygons. The latter species was not found in sliding polygon # 1, 2, and 3, problaly due to the late germination of this species and because # 1, 2, and 3 were analyzed during the first days of the field work. Other species, e.g., *Pyrola grandiflora* and *Poa arctica,* are most frequent on the more stable areas (c7, c8, c9 and b1-9). *Stereocaulon alpinum* and *Peltigera aphthosa* are the most frequent lichen species. They were found in 17 and 15 zones, respectively. *Cladonia stricta* is almost only found in medium stable and most stable centre zones (c3, c5-9). Scores for *Cladonia borealis* do not suggest any distributional difference between the centre and the border of a polygon.

Ordination. The PCA-ordination of the 18 zones is shown in Fig. 3. There are three distinct groups: (a) the polygon centres from stability level 1, (b) the polygon centres from stability level 2 and (c) all border zones. The polygon centres from stability level 3 are more scattered and not clearly grouped in the diagram. Zone c9 is particularly different and mixes with the border zones. The first axis clearly describes a gradient from 'most unstable' (c1-c6) through the 'more stable' (c7 and c8) to the 'most stable' (the borders). The difference between the sliding polygon centres stability level 1 (c1, c2, c4) and stability level 2 (c3, c5, c6) appears on the second axis. On this axis, the most stable centre zones and the borders are at the same level.

Table 1. Species list arranged according to a subjective evaluation of stability (1-3 / unstable - stable) Numbers refer to scores from the expanded Raunkiaer analysis (max. 30 when found in the inner circle of all 10 Raunkiaer circles).

Polygon no.:	1	2	4	3	5	6	7	8	9	1	2	4	3	5	6	7	8	9
center (c) / border (b):	c	c	c	c	c	c	c	c	c	b	b	b	b	b	b	b	b	b
Level of stability:	1	1	1	2	2	2	3	3	3	1	1	1	2	2	2	3	3	3
Species (**Bold** = lichens):																		
Cerastium arcticum	2	2	5	1	4	4	6	3		1	4	5	1				3	1
Dryas integrifolia	1	1	4	8	1	14	4	1		9	7	12	3	1	9			
Empetrum nigrum	2	1		1			10			10	12	22	14	10	7	10		21
Equisetum arvense	15	13	14	23	24	21	25	20	16	9	16	17	16	18	21	13	13	19
Festuca hyperborea	12	11	7	2	6	3	1			2		2	3	3	1			
Minuartia rubella	1		7		6	1	4										1	
Polygonum viviparum	1	4	11	20	26	22	10	14	10	5	8	10	9	2	6	3	4	4
Vaccinium uliginosum	3			5	3	1	10	4	14	17	17	22	20	5	17	11	13	18
Stereocaulon alpinum		2	2	9	8	22	19	17	7	7	5	5	9	10	18	1	6	16
Psoroma hypnorum		1				2	3			1								
Cladonia borealis		1	2		12	12	2	5				3		11	1	1		1
Poa arctica		1		3			6	3	12	7	12	6	5	4	8	11	6	8
Salix glauca		6	2	14	7	15	11	14	14	11	17	16	23	13	19	16	18	15
Stellaria monantha		1			1	1	1		5		9	8	9	5	5	5	5	13
Trisetum spicatum		2	3				1											
Koenigia islandica			9		9	3												
Juncus biglumis			2	9	10	5			2		1							1
Peltigera aphthosa			5		5	9	7	3	7	12	9	7	13	3	5	3	3	2
Pedicularis hirsuta			1		4	6	1	4	4			2	2	1	1		3	
Saxifraga cernua			1															
Silene acaulis			1															
Cassiope tetragona			1	4	15	13	11	6	26	19	24	17	22	23	21	21	16	21
Luzula confusa				1		3				2		4	2					2
Luzula arctica				5	2	1	5	3	9		4	1	3	2		2		1
Carex bigelowii				5	9	1		15					3	5	2		3	1
Juncus triglumis				1														
Cladonia stricta				15	13	8	3	4	1					4				
Pedicularis flammae				1														
Tofieldia pulsilla				2									2					
Salix herbacea					9		12	22								1	10	
Flavocetraria nivalis						3				1		2		3	1			1
Pyrola grandiflora						1	11		14	17	16	15	18	12	7	10	2	15
Peltigera rufescens						1					1			3				
Cetraria islandica						2		1	1						1			
Betula nana							3											
Poa alpina							1										3	1
Saxifraga caespitosa												1						
Total number of species:	8	13	17	19	20	25	24	17	15	16	16	19	19	20	18	14	16	19
Excl. lichens:	8	10	14	17	16	17	19	12	13	12	13	16	17	14	13	11	14	15

Additional species found in the area outside the Raunkiaer circles:
Eriophorum scheuchzeri
Huperzia selago
Ranunculus sp.
Salix arctica
Saxifraga tricuspidata

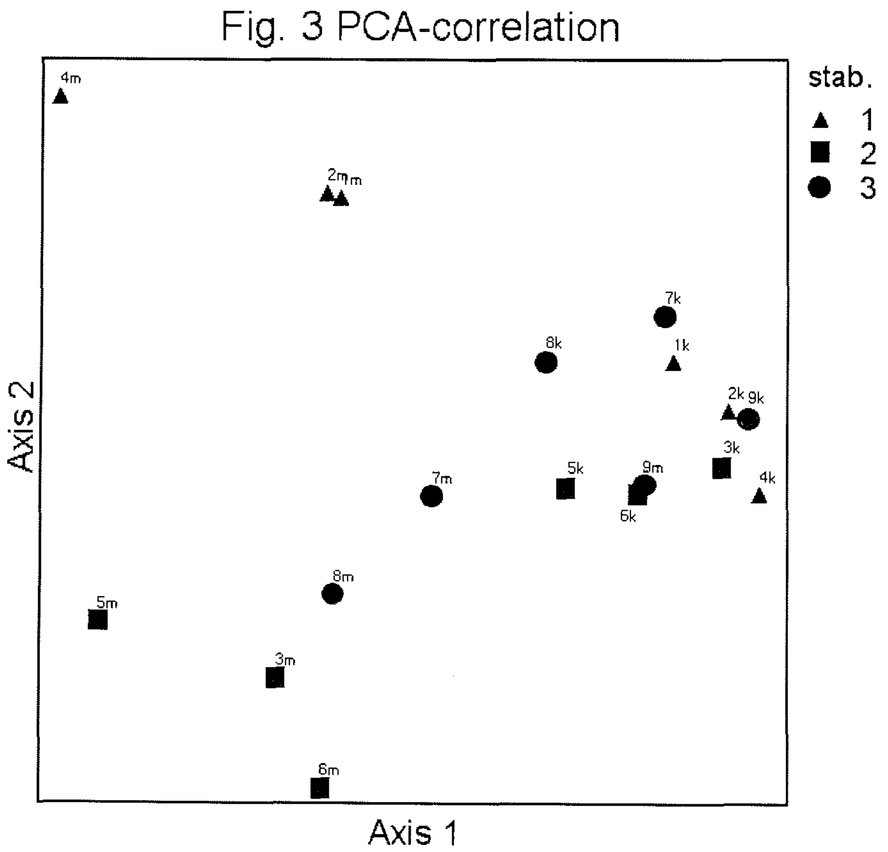


Fig. 3. The PCA ordination clearly indicates that the plant communities depend on the level of stability. The most unstable centre zones are grouped in the upper left, the semi-stable centre zones in the lower left and all border zones are grouped in the middle right. The most stable centre zones are less grouped although in the middle of the figure.

Table 2. Pearson correlations with ordination axes, N=18, d.f.=17. **Bold**=significantly (P < 0,01) correlated with axis. *Italic*=significantly (P < 0,05) correlated with axis.

Axis:	1	2	3
	r	r	r
Number of species	-0,025	**-0,623**	0,222
Wet weight	**-0,722**	-0,1	0,16
Water%	0,347	-0,029	-0,174
Ca ppm	*0,569*	0,217	-0,216
Mg ppm	**0,581**	0,179	-0,165
K ppm	**0,595**	0,068	-0,195
µg NH4-N	*0,528*	0,062	-0,243
Conductance µS	*0,542*	0,204	-0,215
pH	-0,448	**0,627**	0,168
Biomass g/m2	**0,684**	-0,285	0,058

Table 3. Spearman Rank Order Correlation between physical/chemical factors. The test was performed in SigmaStat. The numbers are coefficients of correlation (r-values). P values are shown in brackets. Bold = positive correlation, Italic = negative correlation and regular = no correlation.

	Water %	Ca	Mg	K
Wet weight	*-0,69(0,00)*	*-0,51(0,00)*	*-0,53(0,00)*	*-0,53(0,00)*
Water %	-	**0,431(0,002)**	**0,49(0,00)**	**0,51(0,00)**
Ca	-	-	**0,97(0,00)**	**0,80(0,00)**
Mg	-	-	-	**0,85(0,00)**
K	-	-	-	-
N	-	-	-	-
Conductance	-	-	-	-
pH	-	-	-	-
Biom. g/m2	-	-	-	-

	N	Conductance	pH	Biom. g/m2
Wet weight	*-0,376(0,006)*	*-0,49(0,00)*	0,165(0,247)	*-0,40(0,003)*
Water %	**0,57(0,00)**	**0,50(0,00)**	*-0,364(0,009)*	**0,476(0,00)**
Ca	**0,82(0,00)**	**0,93(0,00)**	*-0,46(0,00)*	**0,365(0,009)**
Mg	**0,862(0,00)**	**0,94(0,00)**	*-0,50(0,00)*	**0,484(0,00)**
K	**0,773(0,00)**	**0,859(0,00)**	*-0,292(0,038)*	**0,544(0,00)**
N	-	**0,892(0,00)**	*-0,49(0,00)*	**0,434(0,001)**
Conductance	-	**0,833(0,00)**	*-0,416(0,003)*	**0,522(0,00)**
pH	-	-	*-0,415(0,003)*	**0,403(0,004)**
Biom. g/m2	-	-	-	-0,198(0,163)

Table 4. One Way ANOVA test for differences between the three levels of stability in the center zones (c) and boarder zones (b) respectively. (-) means that there was no significant differences or that transformationwas not necessary.

	W. weight (c)	Water % (c)	Ca (c)	Mg (c)	K (c)	N (c)
Mult. comparison test	-	Tukey	-	Tukey	Tukey	Tukey
Transformation	-	Log10	-	-	Log10	-
P-value	0,674	0,038	0,156	0,012	0,014	<0,001
Stab 1 and 2 sign. diff.	-	no	-	no	no	no
Stab 1 and 3 sign. diff.	-	yes	-	yes	yes	yes
Stab 2 and 3 sign. diff.	-	no	-	yes	yes	yes

	Conduct. (c)	pH (c)	Biomass (c)	W. weight (b)	Water % (b)	Ca (b)
Mult. comparison test	St.-N.-Keul	Tukey	Tukey	-	-	-
Transformation	-	-	-	Log10	-	-
P-value	0,043	<0,001	<0,001	0,054	0,06	0,093
Stab 1 and 2 sign. diff.	no	yes	yes	-	-	-
Stab 1 and 3 sign. diff.	no	yes	yes	-	-	-
Stab 2 and 3 sign. diff.	yes	no	no	-	-	-

	Mg (b)	K (b)	N (b)	Conduct. (b)	pH (b)	Biomass (b)
Mult. comparison test	-	-	Tukey	-	-	-
Transformation	-	-	-	-	-	-
P-value	0,133	0,289	0,014	0,086	0,909	0,936
Stab 1 and 2 sign. diff.	-	-	no	-	-	-
Stab 1 and 3 sign. diff.	-	-	no	-	-	-
Stab 2 and 3 sign. diff.	-	-	yes	-	-	-

The correlation test between the PCA-ordination and the chemical/biotic factors (Table 2) shows that the wet weight of the soil, the concentration of Mg and K, and the above ground biomass are all correlated with the first axis ($P<0.01$). The concentration of Ca and N and conductance are also correlated with the first axis ($P<0.05$). The number of species and pH are the only factors correlated with the second axis ($P<0,01$). No variables were correlated with the third axis. There is a very strong intercorrelation between the tested chemical/biotic factors (Table 3). pH is the only variable which in some cases (wet weight of the soil and above ground biomass) is not intercorrelated with other factors. The nutrients Mg, Ca, K, and N have a strong positive intercorrelation ($0,773<r<0,97$) which is, not surprisingly, also reflected in the high positive correlation between these nutrients and conductance ($0,859<r<0,94$). pH is negatively correlated with all these factors ($|-0,292|<r<|-0,50|$), while the above ground biomass is positively correlated with these ($0,365<r<0,544$).

Comparison of stability levels – centre and border zones. A +/-1 Standard Error (S.E.) is included in Figs. 4-12. The results from the One Way ANOVA are included in Table 4. In the field there was a visible difference between soil samples from the centres and the borders of the sliding polygons. The soil from the centres was heavy and clayey with almost no humus, while the samples from the border zones were light and crumbly with a lot of humus and dead organic matter. The wet weight of the soil is higher in centre samples (58%) than in border samples (Fig. 4). The difference between the centres and the borders is further emphasized by the fact that all chemical/biotic factors are significantly different ($0,002 \geq P$) in the two zones. However, the differences between the three stability levels were often not significant. This is e.g. the case for the wet weight of the soil (Fig. 4, Table 4).

Nutrients (Mg, Ca, K, and N, Figs. 5 - 8) have higher concentrations in border zones, with a small tendency to increased concentrations for stability level 3. A deviation from this pattern is the concentration of K (Fig. 7) in c7, 8, and 9. These zones have a higher concentration (17%) than b7, 8, and 9. However, this result should be interpreted with caution since the mean value of c7, 8, and 9 has a very large standard error. Calcium shows, unlike the other nutrients, no significant differences in concentration between stability levels in the centre zones (Fig. 5). Concentrations of Mg, K, and N in stability level 3 centre zones are significantly higher than at stability levels 1 and 2. In the border zones there is a general tendency towards lower nutrient concentrations at stability level 2 (b3, 5, 6). However, this is significant only for N (stability level 2 and 3, $P=0,014$). Conductance (Fig. 9) shows a similar pattern, which could be expected from the high positive correlation between conductance and nutrient concentrations (Table 3). The pH values range from 5.5 to 6.3 and are significantly higher (7%) in the centres than in the border zones (Fig. 10). The centre zones of stability level 1 have a pronouncedly higher pH (6.3) than other zones (5.5 and 5.6). Table 4 additionally shows that c1, 2, and 4 are significantly different from c3, 5, and 6 and c7 ,8 , and 9, while no border samples are significantly different.

Fig. 4 Wet weight of soil samples taken by 196,3 cm3 soil auger

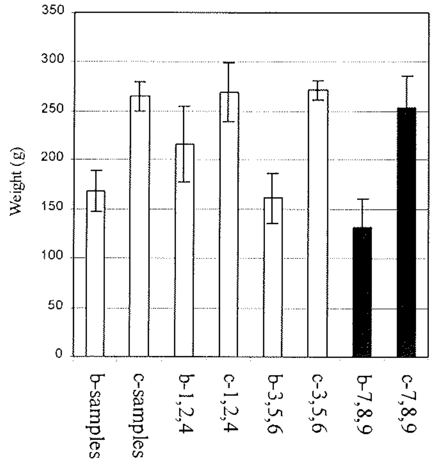


Fig. 5 Calcium in soil samples (ppm)

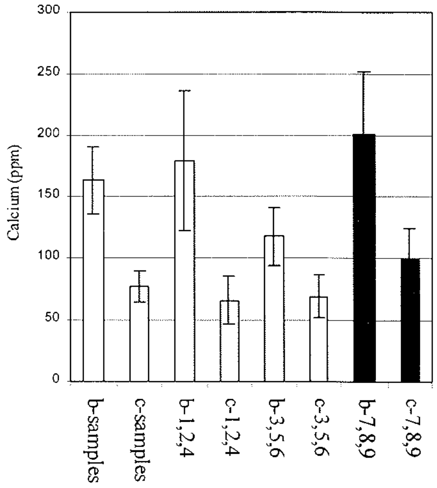


Fig. 6 Magnesium in soil samples (ppm)

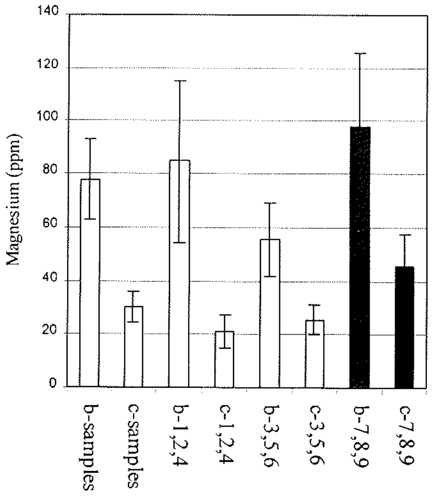


Fig. 7 Potassium in soil samples (ppm)

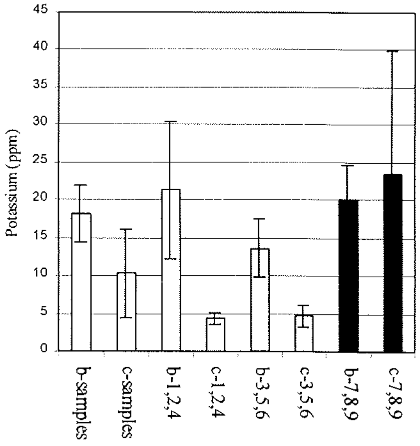


Fig. 8 Nitrogen in soil samples (ug NH4-N/g dry soil)

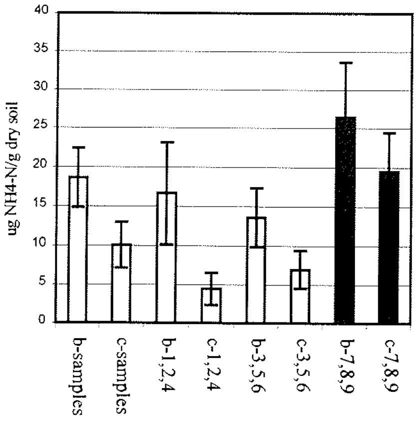


Fig. 9 Conductance of soil samples (uS)

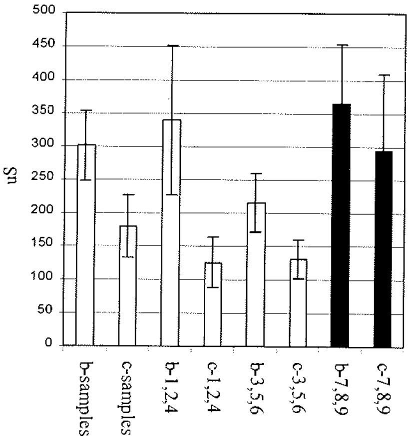


Fig. 10 pH in soil samples

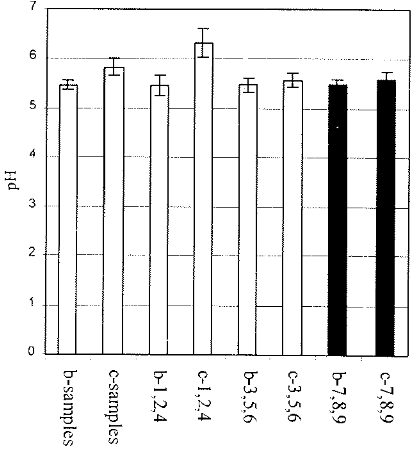


Fig. 11 Above ground biomass (g/m2)

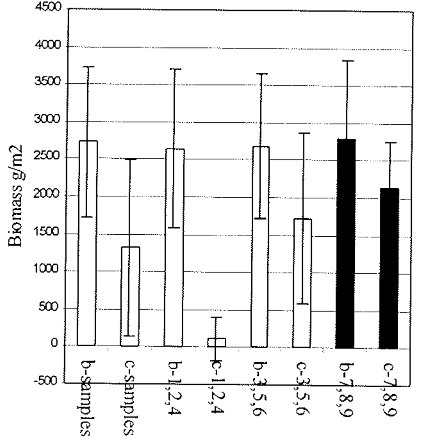
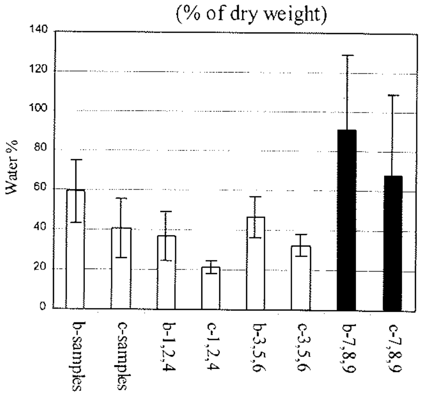


Fig. 12 Water content of soil samples (% of dry weight)



The above ground biomass is significantly higher (107%) for the border zones than for the centre zones (Fig.11). Since the above ground biomass was used as an indicator of stability level, the mean value is not surprisingly very low in c1,2,4 (116 g/m^2) and increases with stability level in the centre zones, This is, however, not completely confirmed by the statistics, since the centre zones for stability level 2 and 3 are not significantly different. The tendency is still very prominent in Fig. 11. In the border zones there are no significant differences between the three stability levels which all have mean values between 2647 g/m^2 and 3148 g/m^2. The water content (as percentage of dry weight, see Fig. 12) in the centre zones is significantly lower (31%) than in the border zones. In the centre zones the stability levels 1 and 3 are significantly different, while none of the stability levels in the border zones are different (Table 4).

The lines in each figure represent inner edge of border, center of border, and outer edge of border, respectively. An X indicates a hit for the species in question.

Fig. 13 Cassiope tetragona, T2

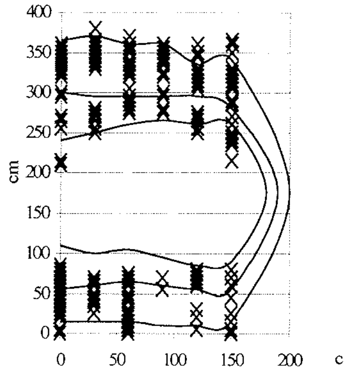


Fig. 14 Cassiope tetragona, T6

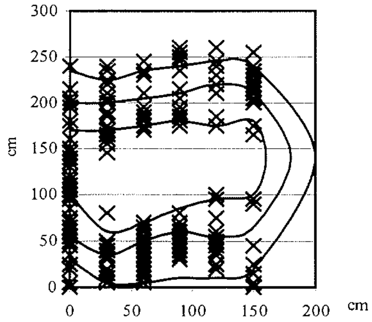


Fig. 15 Empetrum nigrum, T1

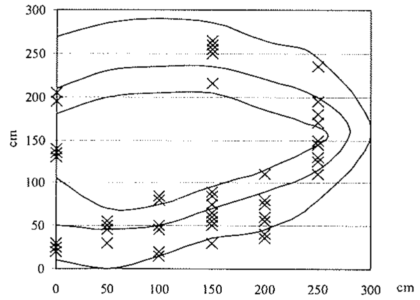


Fig. 16 Empetrum nigrum, T5

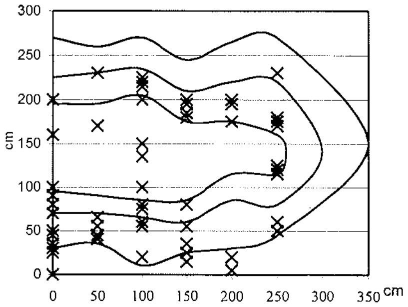


Fig. 17 Polygonum viviparum, T2

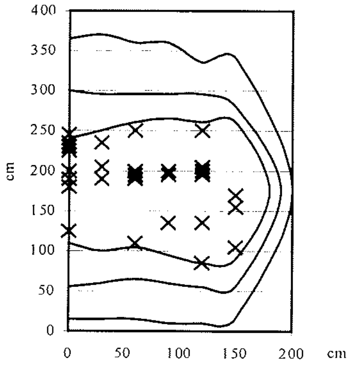
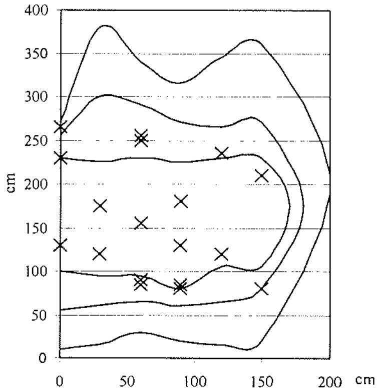


Fig. 18 Polygonum viviparum, T4



The lines in each figure represent inner edge of border, center of border, and outer edge of border, respectively. An X indicates a hit for the species in question.

Fig. 19 Equisetum arvense, T3

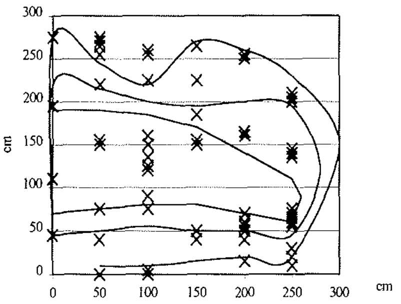


Fig. 20 Equisetum arvense, T5

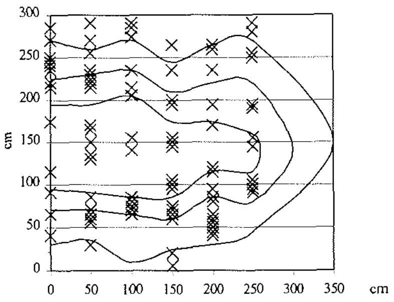


Fig. 21 Festuca hyberborea,T2

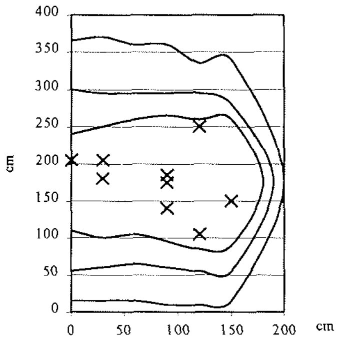


Fig. 22 Festuca hyperborea, T6

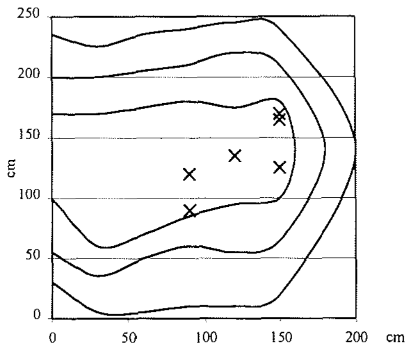


Fig. 23 Pyrola grandiflora, T4

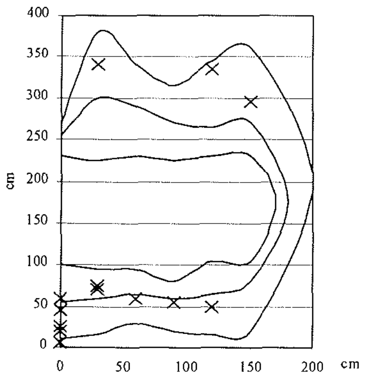
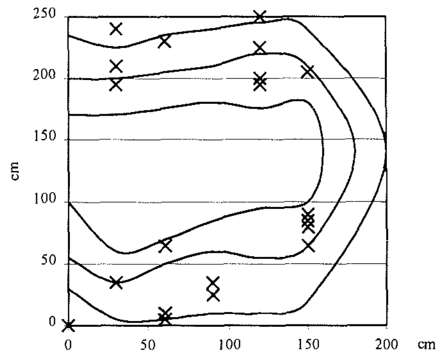


Fig. 24 Poa arctica, T6



Pinpoint data. Selected vascular plant species illustrate (Figs. 13-24) different distributional patterns within sliding polygons of stability level 1 (T1, T2, T4) and 2 (T3, T5, T6). *Cassiope tetragona* (Figs. 13-14) is very dominant on the borders while it is not found in the unstable centre zones. *Empetrum nigrum* (Figs. 15-16) also finds the best conditions of growth on the border zones. With an increased stability, as in T5, it can be found growing in the centre of the sliding polygons. A border zone preference is also evident for *Pyrola grandiflora* (Fig. 23) and *Poa arctica* (Fig. 24). *Equisetum arvense* (Figs. 19-20) is widespread in sliding polygons (both centres and borders) and its growth does not seem to be influenced by unstability. Few species have a special preference for the unstable centres of the sliding polygons. *Festuca hyperborea* (Figs. 21-22) and *Polygonum viviparum* (Figs. 17-18) grow with higher frequencies in polygon centres compared to borders.

Discussion

Vegetation. In a previous analysis of *Cassiope tetragona* heaths and related communities in Blæsedalen, Böcher (1959) found 28 vascular plant species and 17 lichen species. Nineteen vascular plant species and five lichens are recorded in both analyses. The number of species in common with the *Cassiope* heath investigated by Böcher (1959) is relatively low. However, we only examined sliding polygons on Pjeturssons Moraine, which is not representative for the entire valley. The dominant species of the border zones, i.e., *Empetrum nigrum, Equisetum arvense, Salix glauca,* and *Cassiope tetragona,* are all dominants in the *Cassiope* heath. Species mainly growing in centre zones, i.e., *Festuca hyperborea, Koenigia islandica, Minuartia rubella,* and *Juncus biglumis,* were not found by Böcher (1959). All four species grow in moist and sandy or sandy-loam soil and *Festuca hyperborea* and *Koenigia islandica* are widespread on sliding soil (Böcher *et al.* 1978). The pinpoint data support the results from the Raunkiaer analysis. *Cassiope tetragona* and *Empetrum nigrum* are widespread in the border zones (Figs. 13-14 and 15-16). Less dominant species, i.e., *Pyrola grandiflora* and *Poa arctica* (Figs. 23-24), are also found mainly in the border zones, and *Equisetum arvense* has an almost equal distribution between centre and border zones (Figs. 19-20). *Polygonum viviparum* and *Festuca hyperborea* are found mainly in the centre zones. In general, the border zones were all dominated by the same species (dwarf shrubs and mosses) and showed no differences when comparing the different levels of stability. Therefore they appear rather similar and this is further confirmed by the lack of significant differences in above ground biomass (Fig. 11, Table 4) between different levels of stability.

The chemical/biotic environment. Significant differences between centre and border zones for several measured variables clearly emphasize that they do represent two very different habitats. The centres of the very unstable sliding polygons consist of almost raw mineral soil without humus, while the border zones have a large amount of dead organic material in the soil. A comparison between the border zones of Pjeturssons Moraine polygons and a heath area in Kamasjaure should be carried out with caution. However, since the plant community of the border zones has been classified as *Cassiope* heath earlier in this paper, the comparison seems justifiable.

All nutrients were present in higher concentrations in border zones (Figs. 5 – 8). Jonasson and Skjöld (1983) found in Kamasjaure, Sweden, that nutrient concentrations were higher in the centre zones. The calcium concentration in the centres of the unstable polygons was tenfold higher in Kamasjaure (about 694 ppm) than in the centre zones of Pjeturssons Moraine polygons (77 ppm). The border zones on Pjeturssons Moraine has a mean calcium concentration of 163 ppm, whereas Jonasson and Skjöld (1983) found approximately 38 ppm in stable heath areas near the polygon sites.

Similar differences between the two areas were found for magnesium and potassium. In Kamasjaure the concentrations in the centre zones were 121 and 69,3 ppm, respectively, and in the heath area 16 and 22,1 ppm, respectively. On Pjeturssons Moraine the concentrations generally were lower and the higher concentrations were measured in the border zones (77,9 and 18,2 ppm, respectively, in the borders and 30,1 and 10,3 ppm, respectively, in the centres / Figs 6 and 7). When comparing the two Arctic localities, some fundamental differences have to be considered. In Kamasjaure the bedrock consists of acidic granite whereas the bedrock of Pjeturssons Moraine consists of basalt which is basic (Gass et al. 1972). Therefore, the mineralogy and pH of the two localities may differ to some extent. Another important difference is that permafrost is only present at Pjeturssons Moraine. However, even when these differences are taken into consideration it is remarkable that the nutrient concentrations are opposite at the two locations. The nitrogen concentration exhibits a similar pattern as the other nutrients (Fig 8). Nitrogen was not measured by Jonasson and Skjöld (1983) in Kamasjaure, but Hansen and Clemmesen (1999) found 10,2 μg NH_4-N/g dry soil on a heath area in Blæsedalen, which is about the same as for the centre zones on Pjeturssons Moraine. Higher concentrations were found in the border zones (18,6 μg NH_4-N/g dry soil).

As for Kamasjaure (Jonasson and Skjöld 1983) the mean pH was higher in the centre zones (highest in c1, 2, 4, Fig 10). The difference in pH is more pronounced with mean value of 7,2 in the centres and 5,5 on the Kamasjaure heath, and 5,8 in the centres and 5,5 in the borders on Pjeturssons Moraine. On a heath location in the outer part of Blæsedalen pH was 5,4 (Böcher 1959, Hansen and Clemmesen 1999). This further supports the classification of the border zones as heath and shows the generally low level of pH. It is surprising that the pH is lower in the unstable zones on Pjeturssons Moraine than at Kamasjaure because the bedrock in Kamasjaure is acidic. Therefore pH should be lower than for the basic basalt bedrock on Pjeturssons Moraine.

Jonasson and Sköld (1983) explain the high pH and high nutrient concentrations in the most unstable zones in Kamasjaure by the great mixing of soils and enhanced weathering of the upheaved raw soil. This is not the case for Pjeturssons Moraine, since the nutrient levels are lower in the unstable zones and therefore positively correlated with stability. Enhanced weathering of the upheaved raw soil most likely also occurs in the sliding polygons on Pjeturssons Moraine, but the permafrost layer may have a reducing effect on the depth and the effectiveness of the mixing and weathering of the soil, thereby reducing the amount of minerals released.

We suggest that the difference between the results of the two studies may be caused by a greater leaching on Pjeturssons Moraine. Even though the amount of precipitation is about the same in the two areas (Jonasson and Skjöld (1983) report 450 mm as a mean yearly value for Kamasjaure), the active layer is not as deep at Pjeturssons Moraine as in Kamasjaure. This means that the leaching on Pjeturssons Moraine would be stronger, in spite of the same amount of precipitation. The down hill slope and the impervious permafrost layer will cause the water to stream downwards and the leached nutrients could then be partly absorbed by the vegetation of the border zones. This would explain the high nutrient concentration in the border zones and the opposite nutrient pattern on Pjeturssons Moraine compared to Kamasjaure. This theory is supported by the presence of rich snow beds with many herbs at the southern border of the moraine. The findings discussed above emphasize the great variations in patterned ground and clearly show that differences between stable and unstable zones cannot be explained by single factors.

Vegetation changes the chemical/biotic environment. Our results indicate that the difference between the centre and the border zones basically is caused by the difference in stability. All factors (except pH and water content) are highly correlated (Table 3) and they all explain the first axis in the ordination (Table 2) which exactly describes the gradient in stability (Fig. 3). We conclude that the gradient of stability controls which plant species are able to grow on polygon centres and borders. Through time the plants have changed the soil environment by accumulating humus and biomass. This accumulation has been most intensive in the more stable areas where the vegetation is dense and almost nonexistent in the most unstable zones which have only scattered vegetation. The combined action of leaching and vegetation could explain the higher concentrations of extractable nutrients in the border zones of the sliding polygons of Pjeturssons Moraine.

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Puilassoq, the warmest homothermal spring of Disko Island

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Abstract

Only a few notes about the abiotic factors, flora and fauna have been published on the warmest spring of Disko, Puilassoq in Mellemfjord/Akugdlit. The spring was first described by Steenstrup in 1900, but has since been visited several times by biologists, most recently by the Danish-German Excursion 1998. The chemistry of the water, and the flora and fauna of the spring are here described for the first time. The spring consists of six outflows located on a nearly 2 m high dome, the warmest outflow being about 18°C. pH is 10.0-10.8 and conductivity 100 mho or less. About 60 species of vascular plants are present within a distance of 2 m from the never freezing water, a high number for a plant community at this northern latitude. The richness of the species is considered related to raised soil temperature, increased mineralization and decomposition, and a prolonged growing season caused by the activity of the spring. The fauna includes many species of Rotifera, 21 species of Tardigrada, four species of Oligochaeta, two species of Trichoptera, Arachnida, the beetle *Hydroporus morio*, and the fly *Scatella thermarum*.

Introduction

At least a thousand springs occur on the island of Disko and more than 50 springs have a Greenlandic name. The springs have greatly influenced the daily life on Disko and they are part of old Inuit legends (Fisker 1984). Most settlements were established where running water was available the year round including the now abolished small settlements at Vaigaten such as Unartoq, Ujaragsugssuk, and Kutdligssat. However, also to day major settlements such as Qeqertarsuaq (Godhavn) and Kangerluk (Diskofjord) have their water supplies from homothermal springs. Most of the springs include in their name the word Unartoq meaning homothermal or the word Kuanit meaning a locality where *Angelica archangelica* is growing. Strangely enough, only two springs are named Puilassoq, which is Greenlandic for spring, one near Qeqertarsuaq, named Puilassungiaq, is only 1-2°C, the other, Puilassoq, is the famous hot spring in Mellemfjord (Kristensen 1987).

Historical background

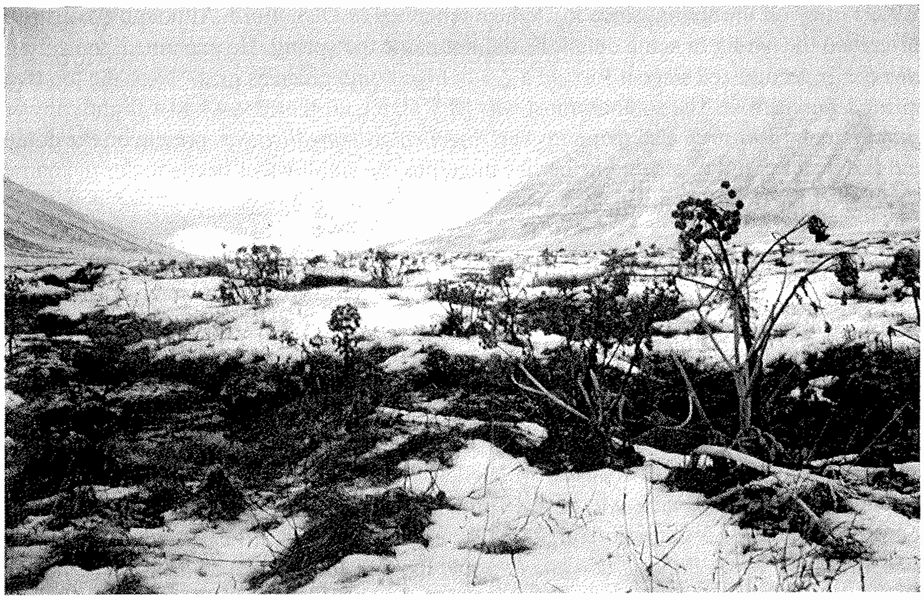
Most likely, the first European to visit the spring in Mellemfjord was KJV Steenstrup. He discovered the spring walking through Kildedalen from Disko Fjord August 18, 1898. According to his report (Steenstrup 1900) he was surprised that neither Giesecke nor Rink

(1852) had mentioned this spring, which is the warmest on the island. Nor did Porsild (1902) mention the spring, since in 1898 he remained in Diskofjord. Although Steenstrup described the spring in some detail, he did not name the spring. He explained, the spring was easily recognized since it formed a 2-3 m high dome green as grass. Near the top two springs were active. The southernmost was 18.8°C, the northernmost had a slightly lower temperature. Steenstrup also mentions that *Angelica archangelica* was present on the dome and the water is full of algae. Further, he mentions the small water beetle under the name *Hydroporus atriceps*.

Porsild (1902, 1920) has described the vegetation at several hot springs but not at Puilassoq. Hence, Halliday *et al.* (1974) in a review on hot springs in Greenland seem to be the first to use the name Puilassoq. In 1976 *RMK* and a team of geographers visited Puilassoq on July 16. The highest temperature measured was 18.0°C in the outflow corresponding to the southernmost spring of Steenstrup. Plenty of the orchid *Platanthera hyperborea* were present on the dome but no *Angelica archangelica*. Several springs within 200 m from Puilassoq were noted with a temperature ranging from 3°C to 14°C. In 1977, *RMK* walked from Kuanit Kugssat to Mellemfjord on August 10. About 3 km from Puilassoq a large spring area was covered with *Angelica archangelica* (Fig. 1). The highest temperature was 14.5°C. In several places the spring ran underground. Among the plants present were the fern *Polystichum lonchitis* and the three orchids *Platanthera hyperborea, Leuorchis albida,* and *Listera cordata.* In the spring were fry of *Salvelinus alpinus*. In Puilassoq the highest temperature was only 17.5°C. During a winter excursion Ebbe Mortensen, Gerda Kristensen and *RMK* visited Puilassoq on October 10, 1977 (Fig. 2). The highest spring temperature was 18.5°C at an air temperature of -5°C. Conductivity was 95-100 mho. Other physicchemical characteristics are presented in Table 1. The spring area in Kildedalen (Fig. 1) 3 km from Puilassoq was also visited. The temperature was still 14,5°C. Conductivity was only 64-65 mho. Arne Nørrevang, Benthe Winther Laursen, Kaj Kampp, Tonny Niilonen and *RMK* walked through Kildedalen like Steenstrup on July 8, 1978. There was only little water in Puilassoq, and only one outflow (18°C) was active. Jon Feilberg has photographed Puilassoq on July 19, 1983 and noted that plants having their northernmost occurrence on the west coast are present at a spring (12°C) a few hundred metres to the east of Puilassoq. The plants are *Platanthera hyperborea, Leuorchis albida, Listera cordata, Phleum commutatum, Epilobium palustre, Luzula parviflora,* and *Polystichum lonchitis.* However, this information seems more appropriately related to the spring in Kildedalen (14.5°C) much further away than 200 m from Puilassoq. Bent Fredskild and Wilhelm Dalgaard photographed Puilassoq on July 25, 1987. Although Puilassoq has been visited several times, no comprehensive description of the spring is available concerning water chemistry, flora and fauna. During a biology course in 1998, the spring was visited three times on July 23 and 24, and on August 2. The present description is based mainly on these three visits and also published in Danish (Heide-Jørgensen and Kristensen 1999).

Description of the spring Puilassoq

The homothermal spring Puilassoq (GPS-position: 69°40.3'N and 54°23.2'W) at the head of Mellemfjord is located on slightly west exposed ground approximately 25 m a.s.l. There are six separate outflows with low flow on an approximately 2 m high dome of soil. On the south face of the dome *Salix glauca* is dominant. Consequently, the recent colour is not so



Figs. 1-2. Homothermal springs free of snow in winter, Disko. **Fig. 1.** Vigorous *Angelica archangelica* around 14.5°C warm spring in Kildedalen about 3 km from Puilassoq, Mellemfjord. **Fig. 2.** Outflow no. 2, Puilassoq Oct.10, 1977. Photo: E Mortensen and R M Kristensen.

grass-green as during the visit of Steenstrup (1900) and larger stones are exposed only adjacent to the outflows (Figs. 3-4). Neither do we accept the theory of Steenstrup (1900) that the dome is an remnant of a moraine nor that it should be a pingo (frost-heave). To us the dome looks like a mound spring, *i.e.* the dome is mainly built of organic material (humus) over time. The stones seem to be less exposed than hundred years ago and are considered natural like the ones scattered in the terrain around the dome.

Below, the six outflows are numbered clockwise starting at the SW corner of the dome:

Outflow 1: springs near the top of the dome, where a few stones are exposed. The outflow was covered with algae, sulphur bacteria, and cyanobacteria (blue-green algae). There was a dense growth of the orchid *Platanthera hyperborea* at the edges along the stream down the dome. The outflow had a pH of 10.7 and a temperature of 17.2°C.

Outflow 2: This is the most active outflow (Figs. 2-3) having the highest temperature (18.0°C) and a pH was 10.8. It also springs near the top and the water runs a distance of 200 m to the fiord, although underground in places. On its way the water is cooled to 10.6°C at its discharge to Mellemfjord, where the stream has cut a gorge in the mud (Marrait). A single *Angelica archangelica* grew near the outflow besides the dome (Fig. 3).

Outflow 3a and 3b: Water was only running in 3b, while 3a formed a shallow depression with standing water about half way up the dome. The water surface was covered by an oily film from bacteria (Fig. 4). 3b is located slightly below 3a and completely surrounded by the verdigris green moss *Mniobryum wahlenbergii.* A single non-flowering *Angelica archangelica* was present at the waterline. Both outflows are east-exposed, the temperature was 15.4°C and the pH 10.4.

Outflow 4: Water seeped at the base of the dome and formed a south-exposed mudhole. The temperature was only 13.0°C and the pH 10.3.

Outflow 5: This outflow was not observed in 1976-78 and may be artificially formed. It has parallel sides and water only seeps slowly. The outflow is located at the base of the dome where large stones are exposed. Temperature was 13.0°C and pH 10.0. A few *Platanthera hyperborea* were growing in the outflow. The square shape indicates that the outflow has been dug up and perhaps a soil sample may once have been collected leading to formation of a new outflow.

Temperature and water chemistry

As described above the outflows differ in water temperature (13.0-18.0°C) with the coldest outflows at the base and the warmest near the top of the dome. The reason may be different distances from each outflow to the permafrost, or the water supply may originate from more than one underground vein of water. It is interesting that the temperature varies through the year being highest during winter. Steenstrup measured 18.8°C on Aug. 18, 1898, *RMK* measured 17.5°C, 18.5°C, 18.0°C and 18.0°C on Aug.10, 1977, Oct.11, 1977, July 8, 1978 and July 24, 1998. Jon Feilberg measured 16°C on July 19, 1983 (unpubl., however this value is not considered comparable). A yearly temperature variation of >1°C is considered large since many homothermal springs are known to hold a highly constant temperature.

Figs. 3-4. Puilassoq, Mellemfjord, Aug. 2, 1998. **Fig. 3.** The dome seen from NW with outflow no. 2. A few metres below the outflow bright area with, *Mniobryum wahlenbergii* (centre). Further downstream a few large stone are visible. Note flowering *Angelica archangelica* (left side). *Platanthera hyperborea* and *Bartsia alpina* present to the right. **Fig. 4.** Almost standing water in outflow no. 3a with exposed stones, oily film from bacteria, and vegetative *A. archangelica.* Photo: Fig. 3; R M Kristensen. Fig. 4; H S Heide-Jørgensen.

Table 1. Water chemistry etc. for Puilassoq.

Physical and chemical data from Oct. 11, 1977 (Temp. and pH from several visits)			
Highest temperature	17.5-18.5°C	NO_3^-	1.1 mg/l
pH	9.5 (10.0-10.8)	NH_4^+	0.2 mg/l
Conductivity	95-100 mho	Na^+	22 mg/l
Total hardness	0.36°	K^+	0.2 mg/l
Alkalinity	0.9 meq/l	Mg^{++}	0.17 mg/l
F^-	0.08 mg/l	Ca^{++}	2.5 mg/l
Cl^-	7 mg/l	Fe (<8)	0.67 mg/l
SO_4^{--}	6 mg/l	Mn^{++}	<0.01 mg/l
HCO_3^-	55 mg/l	SiO_2	23 mg/l
PO_4^{---}	0.02 mg/l	$NaHCO_3$	65 mg/l

However, Porsild (1902) mentions that the Greenlandic 'Unartut' (plural of Unartoq) do not hold a constant temperature. Haliday *et al.* (1974) are of the opinion that oscillating temperatures primarily are occurring in springs in West Greenland. In Puilassoq, the water flow is so modest that it cannot be excluded that external factors like radiation balance, snow melting, permafrost, evaporation, precipitation, or differences in thermometer positioning may have influenced the results.

The water chemistry is presented in Table 1. Conductivity was measured at 20°C about an hour after sampling. The spring is very poor in minerals and the water may be characterised as distilled. The relatively high pH is primarily caused by the content of sodium bicarbonate. pH measurements in brackets were performed in the field since the pH value falls soon after sampling and the permanent pH obtained in the laboratory is much lower. Further details and interpretations are given in Kristensen (1987).

Table 2. Flora list for Puilassoq. The nomenclature follows Böcher *et al.* 1978. A species is marked as No if it is not represented on the distribution maps in Fredskild (1995), where ° is included in *Cerastium arcticum*, * is included in *Poa pratensis* and + is included in the *Stellaria longipes* group with glabrous sepals.

Species	Marked in Fredskild 1995	In the north limited to homothermal springs	Distribution according to Böcher 1975
Arabis alpina	Yes	No	Low Arctic, oceanic
Angelica archangelica	No	Yes	Low Arctic, oceanic
Bartsia alpina	Yes	No	Low Arctic, oceanic
Botrychium lunaria	Yes	Partly	Boreal
Campanula gieseckiana	Yes	No	Low Arctic
Cardamine pratensis	Yes	No	Low Arctic
Carex bigelowii	Yes	No	Low Arctic
Carex canescens	No	No	Boreal
Carex rariflora	Yes	No	Low Arctic
Cassiope tetragona	Yes	No	Arctic, continental
Cerastium alpinum°	Yes	No	Arctic
Chamaenerion latifolium	Yes	No	Arctic
Diphasiastrum alpinum	Yes	No	Low Arctic
Diphasiastrum complanatum	No	Partly	Boreal, continental
Dupontia psilosantha	No	No	Middle Arctic
Empetrum nigrum ssp. *hermaphroditum*	No	No	Low Arctic
Epilobium anagallidifolium	No	No	Low Arctic, oceanic
Epilobium hornemannii	Yes	Yes	Low Arctic, oceanic
Equisetum arvense	Yes	No	Boreal
Equisetum variegatum	Yes	No	Low Arctic
Eriophorum angustifolium	Yes	No	Boreal
Eriophorum scheuchzeri	Yes	No	Arctic
Gnaphalium norvegicum	No	Partly	Low Arctic, oceanic
Juncus arcticus	No	No	Low Arctic
Luzula confusa	Yes	No	Low Arctic, oceanic
Luzula groenlandica	No	No	Low Arctic, continental
Pedicularis flammea	Yes	No	Low Arctic
Pedicularis hirsuta	Yes	No	Arctic, continental
Phleum commutatum	Yes	Yes	Low Arctic, oceanic
Platanthera hyperborea	Yes	Yes	Boreal woodland
*Poa arctica**	Yes	No	Boreal
Polygonum viviparum	Yes	No	Arctic, continental
Pyrola grandiflora	Yes	No	Arctic, continental
Ranunculus pygmaeus	No	No	Middle Arctic
Salix arctica	Yes	No	High Arctic
Salix glauca	Yes	No	Low Arctic
Salix herbacea	Yes	No	Low Arctic, oceanic
Saxifraga caespitosa	Yes	No	Arctic
Saxifraga foliolosa	Yes	No	High Arctic
Sibbaldia procumbens	Yes	No	Low Arctic, oceanic
Stellaria monantha+	Yes	No	Not classified
Taraxacum croceum	Yes	No	Low Arctic, oceanic
Thalictrum alpinum	Yes	Partly	Low Arctic, oceanic
Tofieldia pusilla	Yes	No	Low Arctic
Triglochin palustre	Yes	No	Boreal
Trisetum spicatum	Yes	No	Arctic
Vaccinium uliginosum	Yes	No	Low Arctic
Veronica alpina	Yes	No	Boreal
Woodsia glabella	No	No	Arctic

Flora

The flora list in Table 2 represents the dome and the vegetation in a 2 m broad zone on each side of the water stream to about 50 m from the dome. The most species rich vegetation is found less than 1 m from the stream. Eight biologists and students have contributed to the list during a 2 hour visit to the locality on Aug. 2, 1998.

The distribution on Disko and in all of Greenland of the 49 listed vascular plants in Table 2 appears from maps in Fredskild (1995). Eleven species of Table 2 are not represented by dots covering the Puilassoq area on Fredskild's maps. However, the dots on the maps (Fredskild 1995) are based on herbarium sampling and in some cases a dot represents more than one locality not far from one another. Therefore, all of the eleven species should not be considered as new observations for Puilassoq. For example, it is known that several *Angelica archangelica* were present when the locality was visited in 1898 by Steenstrup (1900).

No doubt the number of species around the spring is greater than it appears from Table 2. Jon Feilberg has kindly provided a flora list from a visit on July 19, 1983. This list contains 36 species. Of these 25 are identical to species in Table 2. The additional 11 species are: *Calamagrostis neglecta, Cerastium cerastoides, Cystopteris fragilis, Festuca rubra, Huperzia selago, Juncus castaneus, Luzula multiflora* ssp. *frigida, Lycopodium annotinum, Poa glauca, P. pratensis,* and *Pyrola minor*. Combining the lists, the total number of species for the locality is about 60. We also observed, *e.g., Huperzia selago* and *Cystopteris fragilis* but in the surrounding heath of dwarf shrubs in too great a distance from the spring to be included in Table 2.

Of the 11 species in Table 2 not recorded in Fredskild (1995) *Luzula groenlandica* is new for Disko. This species has a continental distribution in Greenland and is not collected north of 70°N. Hence, the observation of a continental species in the oceanic Mellemfjord is noteworthy, but the warmth from the spring may have been decisive for establishment of the species. Although the identification was controlled by several excursion participants, collection and further control are in this case desirable. *Carex canescens* is known from three localities on the SE-coast of Disko. *Diphasiastrum complanatum* has a similar distribution but with more known localities. Further north in Greenland, this species has only been collected from one locality at 70°N. This also applies to *Gnaphalium norvegicum* and *Pyrola minor* (observed by Jon Feilberg). The more northern locality is located on the north side of Mellemfjord. *Dupontia psilosantha* is collected at the north coast of Disko and at the head of the large fiords north and south of Mellemfjord. *Juncus arcticus* and *Woodsia glabella* are widely distributed on Disko and their presence is not a surprise, although this is the first published observation from Mellemfjord. Widely distributed on Disko including Mellemfjord are also *Empetrum nigrum* ssp. *hermaphroditum* and *Ranunculus pygmaeus*. *Angelica archangelica* thrive best at homothermal springs with temperatures below 10-12°C. At the north side at the base of the dome, a flowering plant only about 30 cm high was growing (Fig. 3) near outflow no. 2, and on the dome itself only a vegetative rosette was observed at outflow 3a (Fig. 4). Puilassoq is besides Kvandalen and two localities on the north side of Mellemfjord the most northern locality for *A. archangelica* in Greenland.

With the addition of *Pyrola minor* (Feilberg's list) Table 2 also lists which species are often associated with homothermal springs in the most northern part of their distribution area according to Porsild (1902, 1920), Haliday *et al.* (1974), Heide-Jørgensen and Johnsen (1998), and our own observations. The presence of these southern species and the high total number of species of the locality are ascribed mainly to higher soil temperature and prolonged growing season in the immediate vicinity of the spring. Porsild (1902) discusses their possible status as being interglacial relicts contra late postglacial immigrants.

Two tufts with three and five flowering shoots, respectively, of *Phleum commutatum* were observed at the edge and outflow no. 2. This species is considered a useful indicator for climate change. *Phleum commutatum* has its northern limit at the homothermal springs of Disko with Puilassoq as the most northern locality. Unfortunately, there is no reliable information from earlier visits to Puilassoq of the growth and number of specimens. At Østerlien and in Engelskmandens Havn, both at Qeqertarsuaq, *P. commutatum* is now less frequent than in the late 1960's when population studies were performed (Callaghan 1974) and both authors visited both localities. It is likely that the decline is a consequence of falling temperatures over the last 50 years in the Disko area (Heide-Jørgensen and Johnsen 1998). Therefore, currently *P. commutatum* may only thrive in the close vicinity of springs where the effect of the warm water is the greatest. At Puilassoq *Angelica archangelica* seems to decline, since Steenstrup (1900) notes, that several specimen were growing on the dome. In 1998 as mentioned, only one vegetative rosette was seen on the dome itself (Fig. 4), where *Salix glauca* is dominating on the south face (Fig. 3 in Heide-Jørgensen and Kristensen 1998).

Saxifraga foliolosa has a northern distribution in Greenland. It propagates vegetatively by bulbils and in the northern part of the distribution area the only terminal flower is rarely developed (Fig. 16 in Heide-Jørgensen and Johnsen 1997). At Puilassoq all main shoots develop the terminal flower and generally the plants were large and well developed in response to increased soil temperature and increased mineralization and decomposition as well as a prolonged growing season caused directly or indirectly by the activity of the spring. For the same reasons, the vegetation on and besides the dome and along the stream is comparatively luxuriant for this northern latitude.

Among the other species in Table 2 it is noted that at least 14 specimens of *Botrychium lunaria* were growing within 2-3 m^2 on the lower part of the NW exposed side of the dome, and *Platanthera hyperborea* was present in several vigorous stands along the stream and on the dome (Fig. 3). We searched for other species which are often associated with homothermal springs such as *Alchemilla glomerulans*, *Leuchorchis albida, Listera cordata, Luzula parviflora* and *Polystichum lonchitis*. All of these are known from other homothermal springs in Mellemfjord, but they were not found here. Mosses, lichens, and fungi were not investigated, but *Mniobryum wahlenbergii* (Fig. 3), which occurs at almost all homothermal springs, was present in large cushions, although, according to (Hansen *et al.* 1989), it thrives better at the cooler springs. Near the outflows where temperature is the highest, purple sulphur bacteria and the blue-green algae genera *Oscillatoria* and *Anabaena* dominated. Where the temperature in the stream from outflow no. 2 had fallen a few degrees, a *Nostoc* sp. occured with a mushroom-like thallus (Fig. 7 in Heide-Jørgensen and Kristensen 1998). The yellow-green algae *Tribonema* sp. (Fig. 8 in Heide-Jørgensen and Kristensen 1998) was growing vigorously in the same stream at a water temperature of 12°C.

Fauna

Since Reisinger and Steinböck (1927) published their data on marine flatworms in Engelskmandens Havn, the meiofauna of the homothermal springs has come under review (Kristensen 1977). It is now known that some springs such as Engelskmandens Havn are slightly radioactive (Kristensen 1987), but most are very poor in electrolytes and the water can be compared almost to distilled water. However, only few investigations are available on animal life in the electrolyte-poor springs and most investigations have only been published in student reports from field courses in Arctic Biology. Lettevall (1962) discovered a new water mite *(Pseudolebertia groenlandica)* in the springs at Østerlien. This possible endemic species for the springs of Disko has later been observed in many cold homothermal springs in Disko Fjord and Kildedalen. It is not observed in the warmer springs (Kristensen unpubl.) and it is not present in Puilassoq. The meiofauna and the terrestrial soil fauna are only poorly investigated in Puilassoq but there is a rich fauna of Rotifera and Tardigrada. During our visit sampling for Oligochaeta and Tardigrada was performed by the German team (see elsewhere this issue). Four species of Oligochaeta were observed: *Fridericia ratzeli, Enchytraeus buchholzi, Buchholzia appendiculata*, and *B. fallax*. Sampling of spiders was performed by Danish students (see elsewhere this issue). The beetle fauna is poor in relation to, *e.g.*, Engelskmandens Havn and large numbers were only observed of the water beetle *Hydroporus morio* Aubé, 1838. This is considered the same species as the one Steenstrup mentions as *H. atriceps*. Furthermore, two larvae of caddis flies were observed, *Agrypnia zonella and Limnephilus festratus.* As far as known, it is the first observation of the genus *Limnephilus* so far north. Both water beetles and caddis worms were living in outflow no. 2 downstream in water between 10° and 12°C. Finally, a large population of the fly *Scatella thermarum* was present. The adult resided on the water surface while the larvae occurred between the subsurface algae. This fly is only known from Iceland and Greenland (Tuxen 1944). Most observation are from springs much warmer than Puilassoq. Tuxen mentions that the fly can be found in springs at temperatures up to 65°C.

Since 1976 soil and moss samples have been collected for tardigrades during each visit to the spring. No tardigrade species has been discovered which is not already known from other homothermal springs on Disko. This is a surprise, since the presence of more southern species could be expected. The species listed in Table 3 were observed at Puilassoq during the visits of *RMK.*

At first glance, 21 species of Tardigrada from Puilassoq indicate a very high species diversity. However, when the results of sampling tardigrades around several homothermal springs are considered as compiled in student reports (Hansen *et al.* 1989), the number is not a surprise. In the cold homothermal spring at Nipissat, students found no less than 19 species. For all of Greenland only 43 freshwater/terrestrial species are recorded (Maucci 1996). However, this figure is fictive, since for Disko alone more than 100 species have been sampled (Kristensen unpubl.). None of the 21 species can be characterized as belonging to a southern fauna, since many are cosmopolitans. But it may be mentioned that two species, *E. nadjae* and *M. minimus,* have been described from homothermal springs on Disko (Kristensen 1982). More recently *E. nadjae* has also been found in homothermal springs on the Faeroe Islands and in cold springs in Italy (Bertolani and Kristensen 1987).

Table 3. List of Tardigrada from Puilassoq.

Heterotardigrada
1 *Pseudechiniscus faccetalis* (in soil)
2 *Pseudechiniscus suillus* (in moss on stones)
3 *Testechiniscus spitsbergensis* (in moss on stones)

Eutardigrada
4 *Amphibolus nebulosus* (in mud with algae)
5 *Amphibolus weglarskae* (in soil)
6 *Dactylobiotus dispar* (in mud)
7 *Dactylobiotus ambiguus* (in mud)
8 *Doryphoribius macrodon* (in algae)
9 *Diphascon scoticum* (in hydrophilic moss)
10 *Eohypsibius nadjae* (in soil)
11 *Hypsibius arcticus* (in algae)
12 *Hypsibius dujardini* (in hydrophilic moss)
13 *Isohypsibius bakonyiensis* (in soil)
14 *Isohypsibius elegans* (in algae)
15 *Macrobiotus echinogenitus* (in algae)
16 *Macrobiotus harmsworthi* (in moss on stones)
17 *Macrobiotus richtersi* (in soil)
18 *Mesocrista spizbergense* (in hydrophilic moss)
19 *Microhypsibius minimus* (in algae on moss from lower part of outflow no. 2)
20 *Murrayon pullari* (in mud)
21 *Platicrista angustata* (in *Mniobryum*)

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Tardigrades in the Soil of Greenland

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Abstract

Thirteen species and additionally eggs of four more species were identified from three different locations during a field course on Disko Island, West Greenland, in July and August, 1998. For each location an association of different species was registered. Only four species were found in more than one locality. The soil sample taken at Kuanit shows the highest diversity and the biggest number of specimens. *Diphascon tenue*, *Hypsibius zetlandicus*, and *Isohypsibius marcellinoi* are new reports for Greenland.

1. Introduction

In the Arctic a special formation of soil, called raw humus, is the most frequent soil type. Compared to European areas a less biological activity is typical for Arctic soils and animals are only found in the upper few centimeters of the soil. The edaphon, as the biocoenosis of the soil is called, consists of collembols, rotifers, nematodes, mites, and tardigrades. Also particularly in damp sites chironomids, copepods, and ostracods do occur. This low level of microfauna diversity underlines that tardigrades may play an important role in the life community of this soil. The soils are continuously wet throughout the summer as permafrost prevents meltwater from percolation downwards. Raw humus is characterised by a mat of organic material being decomposed slowly due to the low summer temperatures. This quality of the Arctic soil suggests a favourable tardigrade environment and the presence of a large tardigrade population, however this has not been investigated until now. This study investigates the occurence of tardigrades in Arctic raw humus. Tardigrades habitat preferences are attempted to be determined by thorough investigation of vegetation, soil structure, abiotic factors, and fauna of each sampling location.

2. Material and methods

2.1. Location

The investigation was carried out on Disko Island, Greenland between the 18th of July and the 2nd of August 1998. Samples were taken from permafrost soil at three different locations:

Location 1:

a former snowbed in **Blaesedalen** (GPS: N 69°15.823'/ W 53° 29.104'/ altitude: 90 m a.s.l.). The snow had melted just a few days ago so that the water content of the soil was expected to be high. The area at the bottom of the snowfield was characterised by earth hummocks (Fig. 1).

Location 2:

Kuanit, (GPS: N 69°15.810'/W 53°26.321'/ altitude: 50m a.s.l.) an area formed by vulcanism and characterised by homothermic springs. Samples were taken in a relatively dry ground depression (Fig. 2).

Location 3:

Puilassoq, close to the homothermic springs (GPS: N 69°40.297/ W 54°22.976'/ altitude: 35m a.s.l.).The water of the first spring (homo I) has a temperature of 17,4°C (pH 10,3-10,4) while the second spring (homo II) has a temperature of about 17,9°C (pH 10,7 –10,8) (Fig. 3).

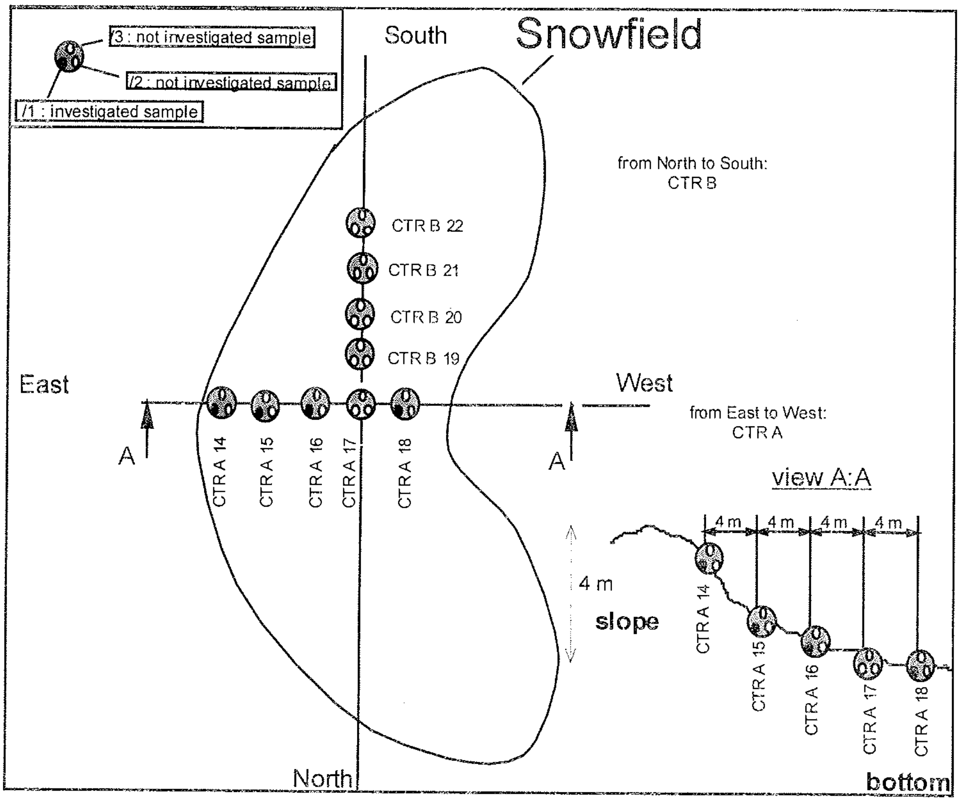

Fig. 1: Illustration of location 1 - Blaesedalen, snowfield

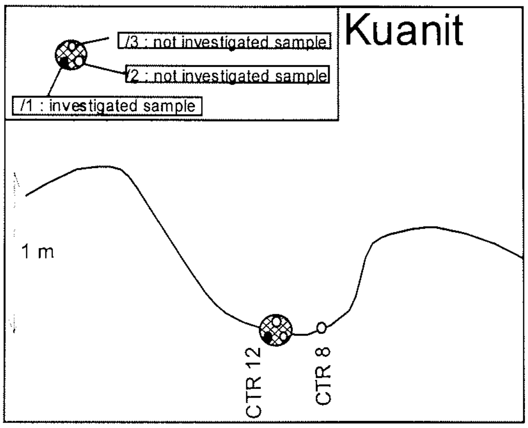

Fig. 2: Illustration of location 2 - Kuanit, profile of the ground depression

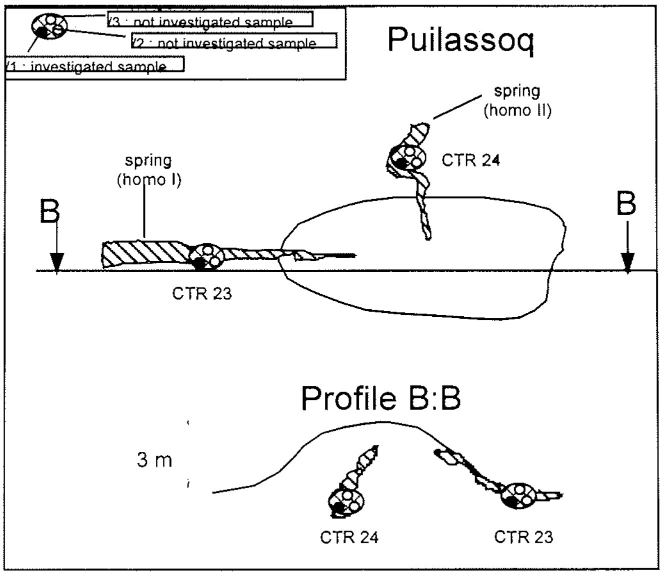

Fig. 3: Illustration of location 3 - Puilassoq

2.2. Sampling

The samples were taken utilising a 100 ml steel tube which takes soil cylinders from a maximum depth of 4 cm. Per location one sample of 300 ml was taken to analyse abiotic factors such as water content, pH, and nutrients. Furthermore an attempt was made to investigate the vegetation nearest to the collecting locality.

2.3. Abiotic factors

Soil temperature was measured directly in situ utilising a thermometer. To investigate other abiotic factors like pH, nitrate and ammonium a soil laboratory (Merck / Agro Quant 14602) was used. First a soil suspension with KCl (0,1M) was produced, this suspension was then filtered. For pH determination test strips (pH-fix 0-14, Macherey-Nagel) were used, whereas ammonium and nitrate were determined by colometric tests where the concentration is measured semiquanitatively by visual comparison (Ammonium: Aquamerck-Ammonium test 0,5-10 mg No. 1.12657/ Nitrate: Nitrate-Test Merck 10- 150 mg/l No. 11170). The water content of the different soil samples was determined by sample drying for 24 hours at 110°C and weight comparison.

2.4. Methods of extraction, counting and fixation

After removing the vegetation from the top of the soil cylinder, the remainder was divided into three parts (surface, upper and lower part), in order to analyse the tardigrade population on different soil levels. The method of drying the sample for transport turns out to be not useful, because the tardigrades died. In order to keep them alive, which makes the examination easier, each sample was frozen.

For the extraction a traditional method was used: A part of the slowly defrosted sample was washed through a series of sieves (1mm/ 500µm/64µm) to separate the animals from the soil. The remainder from the last sieve (64µm) was transferred to a petri dish and examined under the microscope (40x) (Fig. 4). Each tardigrade as well as tardigrade eggs or exuvia were fixed in Polyvinyllactophenol (ADAMS & CZIHAK, 1964) on a microscopic slide.

The mounted specimens were determined mainly by Reinhardt M. Kristensen and with reference to "The Phylum Tardigrada" (RAMAZZOTTI & MAUCCI, 1983) and "Generic revision of the Echiniscidae" (KRISTENSEN, 1987). If other references were used, it is mentioned in the text of 3.4.

Additionally notes of the accompanying soil fauna were taken in order to understand the community structure of tardigrades.

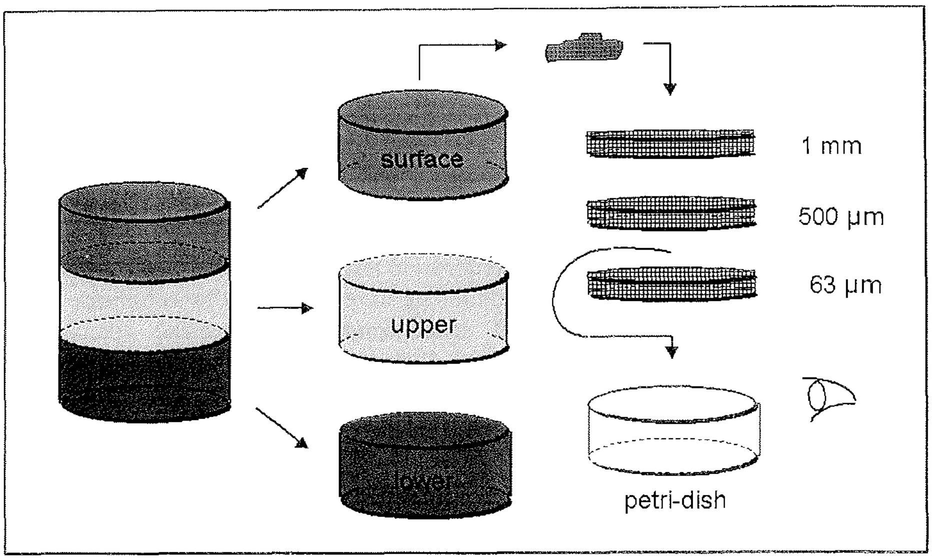

Fig. 4: Extraction method

Because of the time consuming sorting and difficult determination of the Tardigrada only a few samples could be examined from the following sites until now:

Tab. 1: Samples investigated

Locality	Number of samples investigated	Name of sample	Fraction sorted
Snowfield (Blaesedalen)	5	CTR 4/2 CTR A 14/1 CTR A 15/1 CTR A 16/1 CTR A 18/1	surface total surface surface lower, upper part
Kuanit	1	CTR 12/1	surface
Puilassoq	2	CTR 23/1 (homoI) CTR 24/1 (homoII)	surface surface

3. Results

In total 13 species were determined and additionally eggs of four species.

The tardigrades found in Blaesedalen (snowfield) belong to seven different species. Also eggs of three more species were identified. At Kuanit six different species were found, plus one egg of a different species (*Macrobiotus* spec.). Close to the homothermic springs in Puilassoq two different species were mounted plus eggs of three more species.

All identified specimens, exuvia and eggs are summarized in Table 2.

Tab. 2: Summary of the determined tardigrades, cysts, exuvia, and eggs from all three locations

	Species	Blaesed.	Kuanit	Puilassoq
Specimens	*Amphibolus nebulosus*	X		
	Amphibolus weglarskae		X	
	Diphascon alpinum	X		
	Diphascon tenue	X		
	Doryphoribius macrodon	X	X	
	Dorypharibius macrodon (simplex state)		X	
	Hypsibius arcticus		X	
	Hypsibius convergens	X		
	Hypsibius zetlandicus		X	
	Isohypsibius marcellinoi	X		
	Macrobiotus harmsworthi	X	X	
	Macrobiotus richtersi		X	
	Pseudechiniscus facettalis			X
	Pseudechiniscus suillus			X
Cysts	*Doryphoribius macrodon*	X	X	
	Hypsibius zetlandicus		X	
Exuvia	*Doryphoribius macrodon*	X	X	
	Pseudechiniscus facettalis			X

Eggs	*Amphibolus nebulosus*			X
	Diphascon conjungens	X		
	Hypsibius arcticus		X	
	Macrobiotus ariekammensis	X		
	Macrobiotus echinogenitus			X
	Macrobiotus harmsworthi		X	X
	Macrobiotus richtersi	X		
	Macrobiotus spec.		X	

In total 65 tardigrades, 6 cysts, 10 exuvia, and 31 eggs were registered whereas 19 specimens, 1 cyst, 1 exuvia, and 5 eggs were obtained from samples of Blaesedalen (Tab. 5). At Kuanit 30 specimens, 5 cysts, 3 exuvia, and 11 eggs were found (Tab. 6). At least 16 specimens, 6 exuvia and 15 eggs were obtained from the Puilassoq samples (Tab. 7). All abiotic factors are listed in Table 3, all additionally counted taxa are listed in Table 4.

Tab. 3: Abiotic factors

Locality	**Sample**	**Date**	**Temp. [°C]**	**pH**	**Nitrate [mg/l]**	**Ammonia [mg/l]**	**Water Content [%]**
snowfield	CTR 4/2	18.07.98	13,4				
	CTR A 14/1	28.07.98	10,6	5	0	0,5	31,7
	CTR A 15/1	28.07.98	10,8	5	0	0,5	44,3
	CTR A 16/1	28.07.98	10,8	5	0	0,5	20,3
	CTR A 18/1	128.07.98	10,3	5	0	1	56
Kuanit	CTR 12/1	127.07.98	11	6	10	0,5	65
Puilassoq	CTR 23/1	102.08.98	14	7	10	2	76,8
	CTR 24/1	102.08.98	17,5	7	10	2	67

Tab. 4: Additional collected fauna found in the soil

	Snowfield (Blaesedalen) CTR / CTR A					Kuanit CTR	Puilassoq CTR	
Sample No.:	**4**	**14**	**15**	**16**	**18**	**12**	**23**	**24**
Acari		X		X	X	X	X	X
Collembola		X		X	X			X
Cricomenatidae		X						
Copepoda / Harpacticidae						X	X	
Nematoda	X	X		X	X	X		X
Rotatoria (Bdelloida)		X	X	X	X	X	X	X
Rotatoria (Monogononta)				X		X		
Tardigrada (specimens, cysts)	X	X	X	X		X	X	

3.1. Snowfield in Blaesedalen

All samples of this locality included only the soil's O-horizon. It is characterised by organic material and a small amount of silt. All tardigrades, eggs and exuvia from this location are listed in Table 5.

Tab. 5: Specimens, cysts, exuvia and eggs collected in Blaesedalen [Numbers]

Station	CTR 4/2	CTR A 14/1	CTR A 15/1	CTR A 16/1
Specimens	*Amphibolus nebulosus* [1] *Doryphoribius macrodon* [7] *Hypsibius convergens* [1] *Isohypsibius marcellionoi* [1]	*Diphascon tenue [1]*	*Diphascon alpinum* [1]	*Diphascon alpinum* [4] *Macrobiotus harmsworthi* [2] Tardigrada spec. [1]
Cysts	*Doryphoribius macrodon* [1]			
Exuvia				*Doryphoribius macrodon* [1]

Eggs		*Macrobiotus ariekammensis* [1]		*Macrobiotus richtersi* [1] *Hebesuncus conjungens* [2] Tardigrada spec. [1]

CTR 4/2:

The sample was taken in a small wet ground depression between two hummocks at the bottom of a former snowfield. The total surface of the soil cylinder was examined.

The location was characterised by several higher plants (e.g., *Carex biglowii, Salix herbacea, Oxyria digyna)*, lichens (*Stereocaulon* spec.) and many liverworts.

Next to one cyst, ten tardigrades of four different species (Tab. 5) were found.

CTR A 14/1:

The sample was taken from the slope of a former snowfield. All three parts of the soil cylinder were examined.

This locality was also characterised by liverworts, mosses (Bryidae), lichens (*Stereocaulon* spec.), and several higher plants, for example *Equisetum arvense*, *Poa alpina*, *Cassiope tetragona*, *Saxifraga ceruna*, while *Eqisetum arvense* was the dominating plant.

In the surface layer no tardigrades were found, whereas in the upper part one specimen of *Diphascon tenue* and in the lower part one egg of *Macrobiotus ariekammensis* could be identified. In the surface and upper part only Collembola, Rotatoria (Bdelloida), Acari, and Nematoda including Criconematidae were collected, while the lower part only contained a few number of Nematoda.

CTR A 15/1:

The sample was taken at a distance of 4 m next to CTR A 14/1 downslope. Here, the soil horizon was only a thin layer of 4-5 cm covering bedrock. Only the surface part of the sample was analysed.

The vegetation on the soil cylinder contained mainly liverworts.

One specimen of *Diphascon alpinum* (Tab. 5) was found.

CTR A 16/1:

The sample was taken at a 4-m distance from CTR A 15/1 in the middle of the former snowfield in a small ground depression. The vegetation was dominated by liverworts, but also other mosses (Bryidae), lichens (*Stereocaulon* spec.) and higher plants such as *Ranunculus pigmaeus, Polygonum viviparum,* and *Salix herbacea.*

In 2,5g soil from the surface layer, seven tardigrades of two different species, one exuvia, and four eggs were found (Tab. 5).

In addition to the tardigrades 98 bdelloid Rotatoria (+3 cysts), 51 Rotatoria (Monogononta), 8 Acari, 9 Nematoda, and 1 Collembola were found.

CTR A 18/1:

This sample was taken close to the former snowfield on top of a hummock. The vegetation was nearly the same as described for CTR 4. In 10 g soil of the lower part and 5 g soil of the upper part no tardigrades, cysts, exuvia, or eggs were found.

In the lower part Nematoda (12 specimens), 10 Acari, 1 Collembola, and 3 Rotatoria were found. From the upper third only 4 Acari and 4 Nematoda were collected.

3.2. Kuanit

From this locality only one sample was analysed (CTR 12/1). The soil cylinder included the O-horizon of the soil. It consisted only of organic material with remnants of old leaves from mosses (Bryidae) and of algae (Chlorophyceae, Bacillariaphyceae).

The vegetation in the hollow was characterised by the moss *Drepanucladus unicatus* (Bryidae). In 2,5 g soil of the surface fraction, 30 tardigrades were found, belonging to 6 different species. Also 5 cysts, 1 exuvium, and 11 eggs were collected (Tab. 6). Besides the tardigrades, 74 copepods (Harpacticidae), 23 bdelloid rotatorians (+3 cysts), 2 rotatorians (Monogononta), 42 nematodes and 84 mites were found.

Tab. 6: Specimens, cysts, exuvia and eggs collected at Kuanit [numbers]

Sample	CTR 12/1
Specimens	*Amphibolus weglarskae* [1] *Doryphoribius macrodon* [16] *Doryphoribius macrodon* (simplex state) [2] *Hypsibius arcticus* [1] *Hypsibius zetlandicus* [3] *Macrobiotus harmsworthi* [6] *Macrobiotus richtersi* [1]
Cysts	*Doryphoribius macrodon* [4] *Hypsibius zetlandicus* [1]
Exuvia + eggs	*Doryphoribius macrodon* [3]
Eggs	*Hypsibius arcticus* [1] *Macrobiotus harmsworthi* [9] Macrobiotus spec. [1]

3.3. Puilassoq

The two samples investigated from this locality included only the O-horizon. Similar to Kuanit soils the soil was also characterised by organic material.

CTR 23/1:
The soil mainly contained algae, belonging to the Chlorophyceae, Bacillariaphyceae and Desmediaceae. This sample was taken from a locality that was characterised by several higher plants, e.g., *Phyllodoce cerulea, Salix herbacea, Vaccinum uliginosun, Bartia alpina, Leuchorchis albida*, also *Sphagnum* was found. In 1 g of the surface sample 16 tardigrades, 6 exuvia, and 15 eggs were found (Tab. 7). In addition to the tardigrades, 59 cysts of bdelloid Rotatoria, 4 Acari, and 4 Copepoda (Harpacticidae) were found.

CTR 24/1:
In this sample, besides the detritus of moss, many Bacillariaphyceae were found in the soil. The flora investigated close to the „homothermic spring II" consisted of *Salix herbacea, Bartia alpina, Equisetum arvense, Polygonum viviparum, Veronica alpina, Chamaenerion angustifolium,* and liverworts like *Marchantia polymorpha.* The vegetation removed from the soil cylinder was mainly *Mniumbryum wahlenbergii* (Bryidae). In 1 g of the sample, no tardigrades, eggs, exuvia, or cysts were caught. In the soil only 26 Nematoda, 5 Rotatoria (Bdelloida), 4 Acari, and 5 Collembola were found.

Tab 7: Specimens, cysts, exuvia, and eggs collected at Puilassoq [number]

Sample	CTR 23/1
Specimens	*Pseudechiniscus facettalis* [8] *Pseudechiniscus suillus* [3] Tardigrada spec. [5]
Cysts	
Exuvia	*Pseudechiniscus facettalis* [4] Tardigrada spec [2]
Eggs	*Amphibolus nebulosus* [1] *Macrobiotus echinogenitus* [11] *Macrobiotus harmsworthi* [3]

3.4. Tardigrades sampled

Amphibolus nebulosus (Dastych, 1983)
Habitus and egg as described by DASTYCH (1983).
One specimen was found in the soil of a former snowfield at Blaesedalen (CTR 4/2), only one egg was sighted at Puilaffoq (CTR 23/1), both from the surface of the sample.
Distribution:
This species has already been recorded from Greenland, found in moss by GRÖNGAARD et al.(1990), by MAUCCI (1996), and in a homothermic spring on Disko Island. It was collected in mosses on a hummock and in mosses from a bank of a periodically dried stream on Svalbard (DASTYCH,1985). It is reported also from Norway.

Amphibolus weglarskae (Dastych, 1972)
Only one specimen was found at Kuanit (CTR 12/1). It was collected from the first cm of the soil.
Distribution:
It is recorded from Poland by DASTYCH (1987) and from Italy. Referring to RAMAZZOTTI (1983) it has been collected from damp moss and also in water.

Diphascon alpinum Murray, 1906
This species was found in the surface layer of two samples (CTR A 15/1, CTR A 16/1) from Blaesedalen (snowfield). In the mostly dry sample (CTR A 16/1) four specimens were found, while CTR A 15/1 only consists of one specimen.
Distribution:
Already recorded from Greenland where it was found in moss of a snowpatch and in moss on a moist *Vaccinum* heath, often in association with *Salix herbacea*. It was also collected by PETERS & DUMJAHN (1999) on Disko Island. It is also reported from Svalbard (WEGLARSKA, 1965/ DASTYCH, 1985); in moss, soil and litter of deciduous forest in Finland (HALLAS, 1977) and in the soil of a Danish beech forest (HALLAS & YEATES, 1972).

Diphascon (= Hebesuncus) conjungens (Thulin, 1911)
Only two eggs of this species were collected. No specimens were found. The eggs were sampled at the locality of Blaesedalen in the surface layer.
Distribution:
This species is reported from Poland and Svalbard (DASTYCH, 1985, 1987). It has been reported from all over Europe, as well as in North America, and Disko Island, Greenland (PETERS & DUMJAHN,1999).

Diphascon tenue Thulin, 1928
One specimen was found on the slope of the snowfield (CTR 14/1), it was collected in the upper part of the soil cylinder (depth: 2-3 cm).
Distribution:
According to MAUCCI (1996), until now this species has neither been found on Greenland nor on Iceland. It has been collected in mosses from Svalbard (WEGLARSKA, 1965, DASTYCH, 1985, MAUCCI, 1996), the Carpathians, on the Faroe Islands, in Sweden and Norway.

Doryphoribius macrodon Binda, Pilato & Dastych, 1980
Habitus as described by BINDA et al.,1980.
Sixteen specimens, four cysts, and three exuvia with eggs were found in the surface layer of the soil taken in a small ground depression at Kuanit (CTR 12/1). Also seven specimens, one cyst, and one exuvium were found in the soil of the former snowfield in Blaesedalen (surface/CTR A 16/1).
Distribution:
On Svalbard this species has been found in mosses from hummocks by DASTYCH (1985).

Hypsibius arcticus (Murray, 1907)
One specimen and one egg were collected from the soil in a small ground depression at Kuanit (CTR 12/1). Both were found in the surface layer (depth: 1-2 cm).
Distribution:
RAMAZZOTTI (1983) describes this species as cosmopolitan, living in freshwater and moss.

Hypsibius convergens (Urbanowicz, 1925)
One specimen was found in the soil of a former snowfield in Blaesedalen (CTR 4/2), the soil belongs to the surface layer.
Distribution:
This species seems to be cosmopolitic (records from: Europe, North and South America, Fernando Poo Island, Kerguelen Island, India, Turkey, and Faroer Island). It has been collected from moss on Svalbard (WEGLARSKA, 1965) and is reported also by PETERSEN (1951) from Greenland. MIHELCIC (1952) has found this species in leaflitter as well as in the soil of a coniferous forest and in Rendsina. WEGLARSKA (1968) has collected it on roots of higher plants *(Carex* sp., *Acantholimon* sp.*)* in the Himalaya.

Hypsibius zetlandicus (Murray, 1907)
Three specimens and one cyst were found in the surface soil in a small hollow at Kuanit (CTR 12/1).
Distribution:
According to RAMAZZOTTI (1983), this species has been reported from the Carpathians, Scotland, Shetland Island, Finland, and Svalbard. This is a new report for Greenland.

Isohypsibius marcellinoi (Binda & Pilato, 1971)
One specimen was found in the surface layer of a former snowfield from Blaesedalen (CTR 4/2)
Distribution:
RAMAZZOTTI (1983) describes this species living in moss and in aquatic environment. This is a new report for Greenland.

Macrobiotus ariekammensis Weglarska,1965
Eggs like those described by DASTYCH (1985).
One egg was found in the soil of the slope of a former snowfield (CTR A 14/1). It was found in the lower layer (depth: 3-4 cm) of the sample.
Distribution:
This species has been reported from Svalbard (WEGLARSKA, 1965/ DASTYCH, 1985).

Macrobiotus echinogenitus Richters,1904

Only eggs of this species were found. Eleven individual eggs were sighted in the surface layer of the soil collected close to the homothermic spring (homoI/CTR 23/1) at Puilassoq.

Distribution:

This species has been found before in moss on Greenland by MAUCCI (1996) in moss. It has been reported earlier by PETERSEN (1951). DASTYCH (1985) and WEGLARSKA (1965) have located it on Spitsbergen. The latter report is not certain (MAUCCI, 1996) because it may represent a misidentification of *M. crenulatus*. The species was also found in lichens, as well as in higher plants (e.g., *Saxifraga*) and in Rendsina by MIHELCIC (1952). Also it has been found on roots of higher plants *(Carex* sp., *Acantholimon* sp.) in the Himalaya (WEGLARSKA, 1968). HALLAS (1977) has collected this species in Finland.

Macrobiotus harmsworthi Murray 1907

Eight specimens and 12 eggs were found in the soil samples. Six specimens and nine eggs were collected in the soil of a small hollow at Kuanit (CTR 12/1), whereas two specimens were found in the sample collected at the bottom of the snowfield (CTR A 16/1). Only one egg could be mounted from the sample taken at Puilassoq next to a homothermic spring (CTR 23/1). Only the surface part of the three samples were investigated.

Distribution:

MAUCCI (1996) considered this species to be cosmopolitican. He has found it on Greenland, Iceland and Svalbard. On Greenland it has already been found before by GRÖNGAARD et al. (1990) and PETERS & DUMJAHN (1999) in moss on Disko Island. Also it has been recorded by PETERSEN (1951), who has collected it from moss on a snowpatch and from moss in a moist *Vaccinium* heath.

In soil it has already been found by MIHELCIC (1952) in a coniferous forest and in Rendsina. HALLAS also has collected it in *Betula* litter in Finland (1977) and Denmark (1972). It has been sighted on roots of higher plants *(Carex* sp., *Acantholimon* sp.) in the Himalaya (WEGLARSKA, 1968) and in mosses from Poland (DASTYCH, 1987) and on Svalbard (WEGLARSKA, 1965/ DASTYCH, 1985). Aside from mosses, it is recorded from lichens and in tussocks of *Dryas* and *Saxifraga*.

Macrobiotus richtersi Murray, 1911

One specimen was collected in the surface part of the soil cylinder from Kuanit (CTR 12/1), one egg was found in the soil taken from the bottom of a former snowfield in Blaesedalen (CTR 16/1, surface).

Distribution:

It is recorded as a common and widely distributed species, ranging over Europe, America, Africa, New Zealand, New Guinea, Asia, and Svalbard, usually found in moss. At Disko Island it has been found by GRÖNGAARD et al.(1990) in homothermic springs. PETERSEN (1951) found it in *Tortula ruralis* (moss) of a dry snowpatch. Aside from mosses it has been collected in tussocks of higher plants (e.g. *Saxifraga*), in leaflitter, in the soil of a coniferous forest, in grass, and in Rendsina by MIHELCIC (1952). ROMPU et al. (1994) have reported it from different localities in the soil under trees and under grass in Zimbabwe.

Pseudechiniscus facettalis Petersen,1951
Eight specimens and four exuvia were found in the surface layer of the soil cylinder, collected close to a homothermic spring (homoI /CTR 23/1) at Puilassoq.

Distribution:
The species is reported from Greenland, Italy, Tierra del Fuego, Yugoslavia, Austria, Turkey, Greece and the Republic of Andorra (RAMAZZOTTI, 1983). PETERSEN (1951) described it from Greenland found in *Dicranum scoparium* associated with moist acid soil.

Pseudechiniscus suillus (Ehrenberg, 1853)
Three specimens were found in the surface layer, collected close to the homothermic spring (homo I/ CTR 23/1) at Puilassoq.
Remarks:
MAUCCI (1996) proposed that *Pseudechiniscus suillus* has not been reported from Greenland until now, since PETERSEN (1951) entirely described *P. suillus* 'forma facettalis'. However, it was found in moss on Disko Island by GRÖNGAARD et al.(1990) and by PETERS & DUMJAHN (1999). Also it has been found in Poland (DASTYCH, 1987) and in Finland (HALLAS, 1977). On Svalbard it has been collected from moss (WEGLARSKA, 1965, MAUCCI 1996) and additionally in *Dryas octopetala* (DASTYCH ,1985). MIHELCIC (1952) also found it in tussocks of higher plants (e.g., *Saxifraga*) and in grass.

4. Discussion

Despite the small number of samples investigated from three different localities, the results suggest that there is an association of different species in each location (Blaesedalen, Kuanit, Puilassoq). Only four species *(Amphibolus nebulosus, Doryphoribus macrodon, Macrobiotus harmsworthi,* and *Macrobiotus richtersi)* could be located in more than one locality. Moreover, it seems that the tardigrade fauna of the soil in Blaesedalen (snowfield) has a different composition, although the samples were taken of only four meters apart. This underlines the necessity to survey each sample separately to make an attempt of describing some ecological parameters for tardigrades.
Some species were found just once or only as an egg, exuvia, or cyst. Considering the small amount of data collected it cannot be deduced whether these species prefer this habitat or whether the occurrence is random, because terrestrial tardigrades are known for their „insular distribution" (RAMAZZOTTI, 1983). It is quite difficult to detect a relationship between tardigrade fauna and abiotic factors, because these were measured only once. Furthermore it is difficult to be sure whether the collected tardigrade belongs to the edaphon, because all investigated tardigrades were found in moss before.

4.1. Species found in more than one locality

Amphibous nebulosus was found in the soil of the snowfield (Blaesedalen) in sample CTR 4/2 with one specimen while at Puilassoq (sample CTR 23/1) one egg was

collected. Both soils were taken in a wet area. CTR 4/2 was taken from a wet hollow between two hummocks. CTR 23/1 had a moisture content of 76,8% and can be regarded as a soil with freshwater influence (algae, Harpacticidae). DASTYCH (1985) has found this species before in moss an a thufur (=hummock) and in moss from a bank of a dried stream. This report may confirm that the species prefers habitats with a high water content. This species is known to be carnivorous, eating rotiferans and other tardigrades.
Doryphoribius macrodon and Macrobiotus richtersi were both found in the soil of the snowfield (CTR 4/2, CTR A 16/1) and at Kuanit (CTR 12/1).The soil of CTR A 16/1 and CTR 12/1 showed comparable temperatures as well as the same content of ammonium. PH and nitrate concentration were higher at Kuanit than in Blaesedalen. The water content of both samples differed extremely (Tab. 3). Both samples show a high diversity of taxa with nearly the same structure but a difference in abundance (Tab. 4). Because of the differences and the small amount of data it cannot be generalised whether this species has a preference to high moisture or other parameters. It is most likely that the soil taken at Kuanit can be regarded as favourable for *Doryphoribius macrodon* because aside from 16 specimens and three exuvia, four cysts were found. Also it has formerly been reported from moss on and between thufur (DASTYCH,1985) as a habitat which is quite comparable to the location of sample CTR A16/1 and CTR 4/2.
Macrobiotus harmsworthi is considered to be cosmopolitan (MAUCCI, 1996). Specimens were found in sample CTR A 16/1 at Blaesedalen, specimens and eggs were found at Kuanit, and only eggs were found in sample CTR 23/1 at Puilassoq. The additional parameters measured for these samples were different, especially the water content ranged from 20,3% (CTR A 16/1) to 76,8% (CTR 23/1). Obviously moisture does not seem to be a limiting factor for the occurence of this species. Usually this species is found in moss but it has already been found in soil by MIHELCIC (1952); HALLAS (1977); HALLAS & YEATES (1972), and WEGLARSKA (1968). It was collected from soil of coniferous and deciduous forest and in Rendsina (MILHECIC, 1952), which might be an indicator for tolerance toward variation of pH (Table 3).

4.2. Samples taken at Blaesedalen

Tardigrade composition varies even among the five samples investigated from the former snowfield because the samples were taken beginning from top of the slope (CTR A 14/1) to the bottom (CTR 18/1). WALLWORCK (1976) found that even one hummock can be devided in different ecological zones because of the different moisture characteristics.
Only *Diphascon alpinum* and *Doryphoribius macrodon* were found in two samples of this locality (Tab. 5).

Species found in sample CTR 4/2:
In this sample ten specimens and one cyst belonging to four different species were found: *Doryphoribius macrodon, Hypsibius convergens, Isohypsibius marcellionoi,* and *Amphibolus nebulosus.*
Doryphoribius macrodon was the dominating species of this sample. The cosmopolitan *Hypsibius convergens* is reported from moss and different kinds of soil (see 3.4.). Like *Amphibolus nebulosus, Isohypsibius marcellionoi* is known for occasionally living in

aquatic environment (RAMAZZOTTI, 1983). This description corresponds with the quality of the soil, which was collected in a wet hollow between two hummocks at the bottom of the snowfield.

Species found in sample CTR A 14/1:
This sample taken from the slope of the former snowfield can be regarded as well - drained soil (RIEGER, 1974). In the upper section only one specimen of the bacteriophagous *Diphascon tenue,* which is a new report for Greenland, and in the lower section one egg of *Macrobiotus ariekammensis* were found. In the surface no tardigrades were collected although other groups like collemboles, mites, and nematodes were present and on top of the soil typical plants like liverworts, lichens, and mosses (Bryidae) were found. Nutrients, pH and temperature do not differ from other samples from the snowfield. It is therefore questionable whether the measured parameters are the reason for unfavourable conditions for tardigrades. A possible reason for their absence is might be the fact that snow is covering this area for a long time of the year. WALLWORCK (1976) suggested for other groups of the edaphon (mites) that the absence of a species from one habitat does not necessarily imply that the conditions there are intolerable. The reason for the absence might also be that the species did not have the opportunity to disperse to this habitat.

Species found in CTR A 15/1:
Only one specimen of the bacteriophagous *Diphascon alpinum* was found in the surface layer. As for sample CTR A 14/1, the reason for the absence of tardigrades here is not clear, although one can consider that the sample was taken right in the middle of the slope, where snow is persistant most of the year. It is highly likely that the diversity or abundance is not governed by the moisture content of the soil, for in sample CTR 16/1 the water content is much lower (20,3 %) and more tardigrades were found.

Species found in CTR A 16/1
The identified specimens belong to two different species: the bacteriophagous *Diphascon alpinum* and the predator *Macrobiotus harmsworthi.* Both were also found in other samples *(D. alpinum*: CTR A15/1; *M. harmsworthi* CTR 23/1,12/1). In addition, eggs and one exuvia were found: the eggs belonging to *Macrobiotus richtersi* and *Hebesuncus conjungens*, both common and widespread species. An exuvia from *Doryphoribius macrodon* was found in another sample (CTR 12/1), too. This sample shows a high diversity of tardigrades but a low abundance (Tab. 2). It seems like all these species are able to inhabit different substrates. Three have already been located in soil samples: *Macrobiotus harmsworthi* (reported by MILHELCIC 1952; HALLAS 1977; HALLAS & YEATES 1972, WEGLARSKA 1968), *Macrobiotus richtersi* (reported by MILHELCIC 1952; ROMPU et al. 1994), and *Diphascon alpinum* (reported by HALLAS, 1977; HALLAS & YEATES 1972).

In Addition to the soil habitat *Macrobiotus richtersi* was found in freshwater environment, in moss on a dry snowpatch, and in tussocks of higher plants. This suggests that *Macrobiotus richtersi* and *Diphascon alpinum* are tolerant to wide ranges of moisture. Nevertheless, the low water content of this sample (20,3 %) might be questionable because of the high occurrence of Rotatoria, especially Monogononta. This taxon is normally an indicator for a high water content.

4.3. Samples taken at Kuanit

Apart from *Doryphoribius macrodon, Macrobiotus richtersi* and *Macrobiotus harmsworthi*, which were found also in other localities, the soil contained specimens of *Amphibolus weglarskae, Hypsibius arcticus* (+ egg), *Hypsibius zetlandicus* (+1cyst), and one egg of *Macrobiotus* spec. This sample shows the highest diversity of all samples taken at Disko Island. Also the density is relatively high (30 Tardigrades/ 2,5g). As mentioned before, the soil of this locality shows typical characteristics of freshwater influence (Harpacticidae, algae, high water content), therefore it seems to be suitable as a habitat for *Amphibolus weglarskae* and *Hypsibius arcticus*. Referring to RAMAZZOTTI (1983) they have been found in water before.

4.4. Sample taken at Puilassoq

Apart from the eggs of *Amphibolus nebulosus* and *Macrobiotus harmsworthi,* eggs of *Macrobiotus echinogenitus* were collected. All identified individuals belong to the species *Pseudechiniscus facettalis* and *Pseudechiniscus suillus.* This sample is the only one which showed Heterotardigrada (Echiniscidae). Here, especially *Pseudechinisus facettalis* occurs with a high frequency. Echiniscidae are known as tardigrades who need a high oxygen concentration, therefore these tardigrades are rare in soil. Like the soil collected at Kuanit, this soil shows a typical freshwater influence. With the exception of *Amphibolus nebulosus,* none of the species is described for aquatic environment. *Macrobiotus harmsworthi* and *Macrobiotus echinogenitus* have been collected in soil before. While MILHELCIC (1954) found that neither *Pseudechiniscus suillus* nor *Macrobiotus echinogenitus* like high moisture, the present investigation shows different results. *Pseudechiniscus facettalis* is reported from moss on acid soil, but the pH of the sample was 7. This relatively high pH for an Arctic soil might be caused by the proximity of the homothermic spring (pH 10,3), but it is conspicuous that *Sphagnum* is also growing there.

4.5. Methodological remarks

Along with the tardigrades the typical taxa of the Arctic soil fauna such as nematodes, rotifers, mites, collemboles, and copepods were found. It seems unrealistic to describe a kind of „soil community" because of the great variety of the tardigrade composition of each sample. The method being used is not suitable for a definite quantitative study of the edaphon, because the bigger animals might remain in the upper sieves. However, the additional notes of the accompanying fauna and flora may help to characterise the soil conditions. As known from former investigations (WALLWORCK, 1976), some taxa for example prefer dry habitats and a higher pH (like spring tails), other show more preference to higher moisture and lower pH (like mites).

One might also consider that tardigrades, which adhere on soil, will not be washed down. However, by controlling the remainders of the upper sieves no tardigrades or eggs were found. Freezing the samples was a good method as tardigrades of most samples (except Kuanit) were still alive and could be sorted out more easily.

However, it became apparent that the traditional method used for picking the animals was not suitable because of time consuming examination. Therefore it might be more suitable to use a kind of Baermann funnel (HALLAS & YEATES, 1972) or a centrifuge (HALLAS, 1975) for further investigations.

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Ecological aspects of tardigrade distribution on Disko Island, West Greenland

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Abstract

This paper describes the results of an investigation on the tardigrade fauna from Disko Island, West Greenland. Along two vertical transects in a Low Arctic and a High Arctic environment 249 tardigrades were collected out of moss samples from alcaline and non - carbonate bedrock. Every species is discussed and compared with the results of comprehensive studies in the Arctic environment (Dastych, 1985; Grøngaard et.al., 1990; Maucci, 1996). Indications for a strong habitat preference regarding altitude and bedrock were not found but some species show a wider ecological amplitude than those described in earlier studies.

Introduction

Tardigrades are small aquatic metazoa with direct development rarely of more than 1mm length. They colonise permanently humid habitats like the marine environment, brackish and freshwater biotopes, but also temporary hydrous terrestrial habitats, or even deserts.

Tardigrades depend on a surrounding film of water to remain in an active state.

Being faced with a desiccating environment, terrestrial and some marine tardigrades undergo anhydrobiosis, this means a cryptobiotic state during which trehalose replaces the structural water of cellular compounds and a tun is formed (Westh and Ramløv 1991). This tun state enables tardigrades to withstand periodic drying of the habitat and thereby increasing their life span. Similar adaptations are known from some rotifers, nematodes and crustaceans.

Little is known about the factors leading to habitat preferences of different limnoterrestrial tardigrade species. However, numerous observations from a variety of heights have suggested that some species prefer certain altitudes and / or certain kinds of bedrock - where the pH varies with different substrates - and have a restricted range (Nelson 1975; Maucci 1980; Ramazzotti and Maucci 1983; Dastych 1985, 1988).

Studying the tardigrades in Tatra National Park, Poland, Dastych (1980) stated that the number of individuals increased with increasing altitude, while the numbers of species slightly decreased. Regarding his study of the tardigrade fauna in West Spitsbergen it is interesting to note that he came up with different results (Dastych 1985).

Concerning the altitudinal distribution Dastych stated a decrease of the number of species with increasing altitude and species which he considered to be associated with non - carbonate bedrock in Poland (Dastych 1980) were found exclusively on carbonate bedrock in West Spitsbergen (Dastych 1985).

Kathman and Cross (1991) investigated the importance of altitude on tardigrade distribution on Vancouver Island, Canada. In this study parametric statistical techniques and quantitative replicate samples were used for the first time in order to determine the suggested relationship between altitude and tardigrade distribution.

Analyzing the data of more than 7000 individuals collected in mosses from six altitudes, Kathman and Cross (1991) found no correlation between altitude and the distribution of tardigrades, instead they suggested that the abiotic factors of the microhabitats like substratum pH would possibly be more important for tardigrade distribution.
In this study an attempt is made to compare the observed tardigrade fauna from Disko Island, W. Greenland, with earlier investigations in the Arctic environment (Petersen 1951; Dastych 1985; Grøngaard, Kristensen & Petersen 1990; Maucci 1996) especially on the backround of altitudinal distribution and the kind of bedrock.

Material and Methods

During a field excursion on Disko Island, West Greenland in July and August 1998 we collected dry cushion shaped mosses of groups 4 resp. 5 (Kinchin 1994) in a Low - Arctic and a High - Arctic environment in 5 altitudes from Gneiss and Basalt bedrocks to investigate the inhabiting species composition of the xerophilous tardigrade fauna.
Ten samples were taken per height from rocks along two vertical gradients from 0 m above sea level (a.s.l.) up to 400 m a.s.l. every 100 metres and were stored in paper bags for transportation. Geographical positions were measured with two Magellan GPS 2000 data loggers calibrated for high latitudes and a Thommen altimeter with a range from 0 m - 5000 m a.s.l.
The Low - Arctic area in which samples were taken is located north - west of the Arctic Station in Godhavn below the ice cap of the Lyngmarken glacier (Ly). During an eight day excursion to the Mellemfjord on the west coast of Disko Island we were able to collect the same type of mosses in a High Arctic environment along a vertical gradient of an unnamed mountain on the Mellemfjord south shore (MF). Stations and routes of the two transects are pictured in maps 1 and 2. Samples were collected on the 26th and 27th of July (MF) and on the 2nd and 3rd of August respectively (Ly).
Geographical positions, altitude above sea level, kind of bedrock and directions of exposure are summarized in table 1.

Table 1

Sample No.	Location	GPS - Data	Altitude metres a.s.l	Bedrock	Exposure
1.1 - 1.10	MF	N 69.42.76 W 54.35.77	0	basalt	south
3.1 - 3.11	MF	N 69.42.08 W 54.37.38	100	basalt	south
5.1 - 5.10	MF	N 69.42.07 W 54.37.77	200	basalt	south
7.1 - 7.10	MF	N 69.42.14 W 54.38.12	300	basalt	south
9.1 - 9.7	MF	N 69.42.34 W 54.38.15	400	basalt	south

Sample No.	Location	GPS - Data	Altitude metres a.s.l	Bedrock	Exposure
1.1 - 1.10	Ly	N 69.15.563 W 53.32.698	0	gneiss	SW
3.1 - 3.11	Ly	N 69.15.806 W 53.32.833	100	gneiss	north, vertical
5.1 - 5.10	Ly	N 69.15.952 W 53.33.685	200	basalt	west, vertical
7.1 - 7.10	Ly	N 69.16.031 W 53.33.642	300	basalt	Rocks lying on the ground
9.1 - 9.7	Ly	N 69.16.292 W 53.33.925	400	basalt	Rocks lying on the ground

One sample from each altitude was selected by chance and sample sizes were standardized to 1.8 grams of moss (dry - weight).

The samples were moistened in a water filled Petri dish for a couple of hours and the moss was then squeezed several times before examination of the rinsed out debris took place by using a Zeiss stereomicroscope with 40 x - 60 x magnification.

Tardigrades were sorted out with a micropipette and transferred into either Faure mounting medium or, mostly, into polyvinyllactophenol with the help of an Irwin Loop. Further investigations of the mounted and Glyceel - sealed specimens were made with a Zeiss light microscope at 1000 x magnification and oil immersion in Hamburg, as well as with a differential interference contrast Nomarski-technique Zeiss microscope in Copenhagen.

An attempt has been made to categorise the species found into three altitudinal distribution groups : I. Species with a distribution along the entire gradient
II. Species with a distribution only in the upper zone of the transect (300 m - 400 m a.s.l.)
III. Species with a distribution only in the lower zone of the transect (0 m - 200 m a.s.l.)

Furthermore, three species groups with regard to their bedrock preferences are distinguished :

I. Species found on alcaline and on non - carbonate bedrock
II. Species found only on alcaline bedrock (basalt)
III. Species found only on non - carbonate bedrock (gneiss)

For determining the species the following references were used : „ Il Phylum Tardigrada“, G. Ramazzotti and W. Maucci, 1983; „ The Tardigrade Fauna of Greenland“,
B. Petersen, 1951; „ Generic revision of the Echiniscidae (Heterotardigrada) with a discussion of the family“, R. M. Kristensen, 1987; „ The Biology of Tardigrades“, I.M. Kinchin, 1994;„ Tardigrada“, E. Marcus, 1936.

Results

A total of 249 tardigrades were collected and identified, belonging to 15 species and 10 genera. Except of two localities (MF, 100 m a.s.l.; Ly, 200 m a.s.l.) tardigrades were

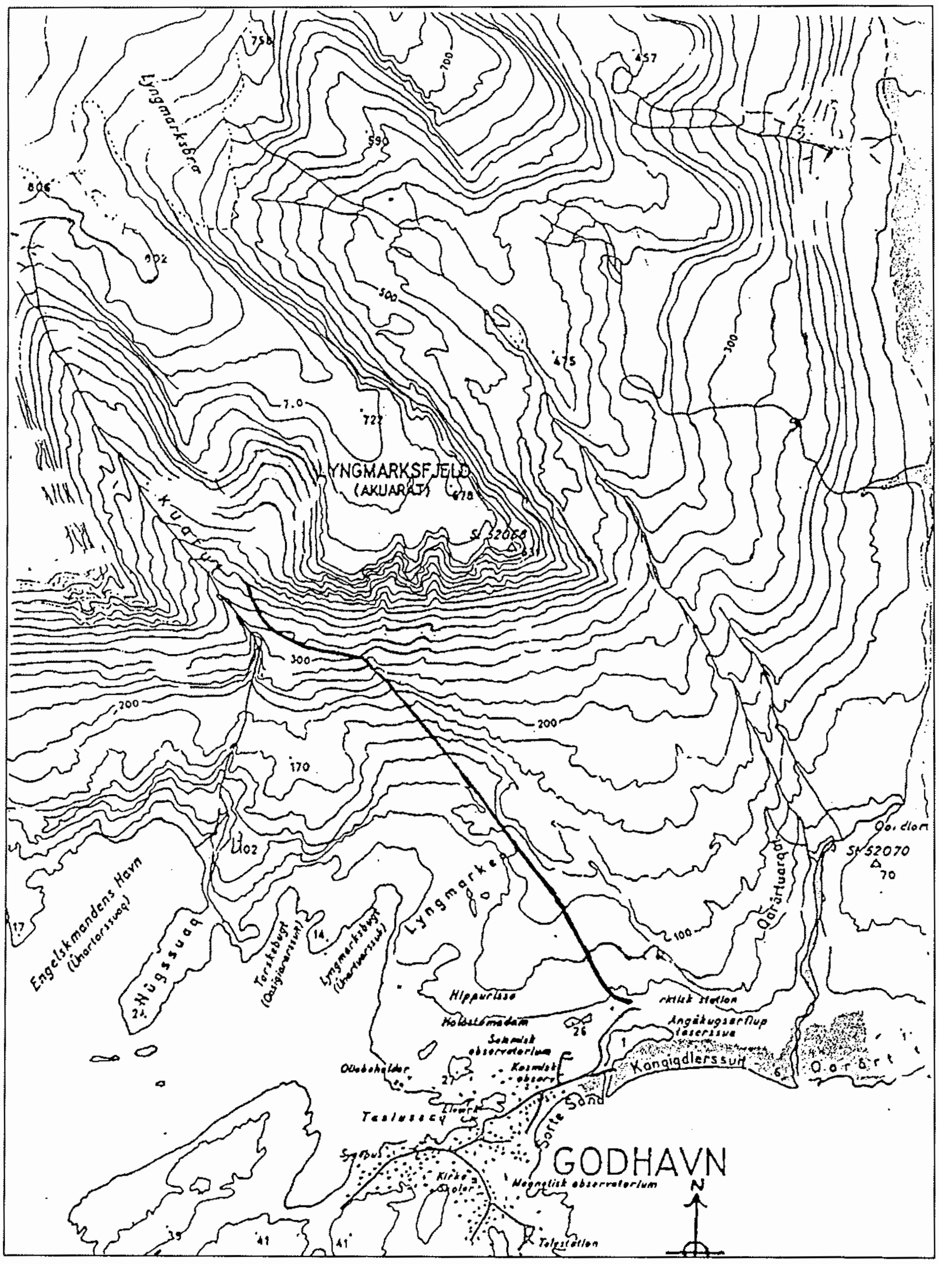
found in all samples. The highest number of species and individuals was found in the sample from 0 m a.s.l. of the transect in the Lyngmarken area, where 97 tardigrades of 8 genera were collected. All species found were formerly described from Greenland.
A summary of the species found in each altitude is given in tables 2 and 3.

Table 2 Transect Lyngmarken

Family	Species	0 m	100 m	200 m	300 m	400 m
Echiniscidae	*Echiniscus arctomys*				13	
	Echiniscus blumi	21				
	Echiniscus wendti	11			4	26
	E. arctomys/wendti				3	1
	Pseudechiniscus suillus				1	
	Testechiniscus spitsbergensis	5				2
Macrobiotidae	*Macrobiotus hufelandi*	32				1
	Macrobiotus islandicus	3	4			
	Minibiotus intermedius	7				31
Hypsibiidae	*Diphascon alpinum*	1				
Calohypsibiidae	*Calohypsibius ornatus*		1		4	
Milnesiidae	*Milnesium tardigradum*	16			3	8
Total		97	5	0	28	69

Table 3 Transect Mellemfjord

Family	Species	0 m	100 m	200 m	300 m	400 m
Echiniscidae	*Echiniscus arctomys*	3				1
	Echiniscus merokensis				3	
	Echiniscus wendti			2		4
	Pseudechiniscus suillus				8	2
Macrobiotidae	*Macrobiotus harmsworthi*			1		
	Macrobiotus hufelandi			2	1	
	Macrobiotus islandicus	1				
Hypsibiidae	*Ramazzottius oberhaeuseri*			3		4
	Hebesuncus conjungens	2		2		
Calohypsibiidae	*Calohypsibius ornatus*			2		
Milnesiidae	*Milnesium tardigradum*	1		8		
Total		7	0	20	12	11



Map 1 Transect area Lyngmarken

Map 2 Transect area Mellemfjord

Differences between areas are graphically illustrated in Figures 1.- 4.

Fig. 1 Distribution of tardigrade species in different altitude zones in the Lyngmarken - Transect

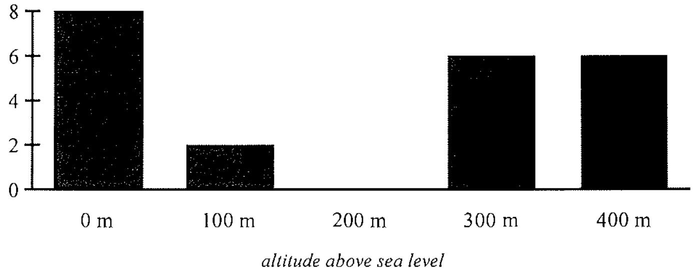


Fig 2 Distribution of tardigrade specimens in different altitude zones in the Lyngmarken - Transect

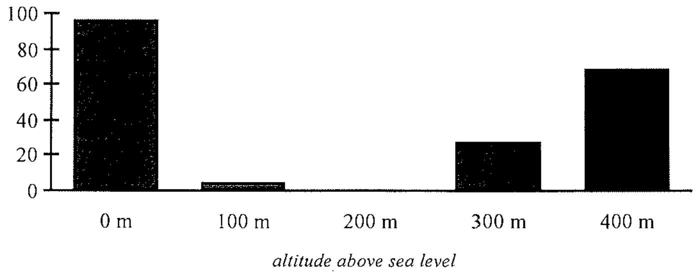


Fig. 3 Distribution of tardigrade species in different altitude zones in the Mellemfjord - Transect

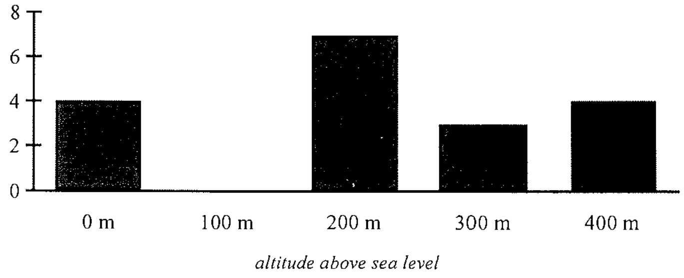
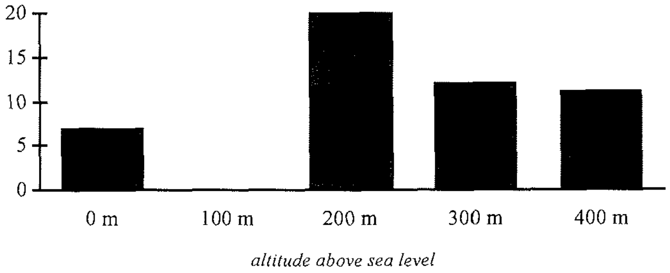


Fig. 4 Distribution of tardigrade specimens in different altitude zones in the Mellemfjord - Transect



In none of the areas species with a distribution over the entire gradient were found, however, species that have a wide distribution along these vertical gradients are:
Echiniscus wendti, Testechiniscus spitsbergensis, Macrobiotus hufelandi, Calohypsibius ornatus and *Milnesium tardigradum.*
Species with a distribution only in the upper zone of both transects are:
Echiniscus arctomys, Echiniscus merokensis and *Pseudechiniscus suillus.*
Species with a distribution only in the lower zone of both transects are:
Echiniscus blumi and *Macrobiotus islandicus.*

Concerning the distribution related to the kind of bedrock, species found on both Basalt and Gneiss comprise: *Echiniscus wendti, Testechiniscus spitsbergensis, Macrobiotus hufelandi, Macrobiotus islandicus, Minibiotus intermedius, Calohypsibius ornatus,* and *Milnesium tardigradum.*
The species which were exclusively found on Gneiss are: *Echiniscus blumi* and *Diphascon alpinum.*
Species showing a preference for alcaline bedrocks and thus found on Basalt are: *Echiniscus arctomys, Pseudechiniscus suillus, Macrobiotus harmsworthi, Ramazzottius oberhaeuseri,* and *Hebesuncus conjungens.*

Discussion

A generalized classification apparently will not mirror the situation because of the sometimes small numbers of specimens in the samples. Regarding the attachment of some species to the bedrock there are significant differences to earlier investigations. This suggests a seperate discussion for each species.

Comments on the species found

Echiniscus arctomys Ehrenberg, 1853
This species is difficult to distinguish from *Echiniscus wendti* and is considered to occur in higher altitudes (R.M. Kristensen pers. comm.). Therefore, the finding of this species in the sample from 0 m a.s.l. (MF) might be a misidentified for *Echiniscus wendti.* It was found exclusively on alcaline bedrock and has not been reported from Spitsbergen (Dastych 1985).

Echiniscus blumi Richters, 1903
E. blumi was found only in one sample from the Lyngmarken - Transect in 0 m a.s.l. from non - carbonate bedrock. Regarding the findings in the Tatra Mountains and in West Spitsbergen (Dastych 1980; 1985) on non - carbonate respectively on carbonate bedrock exclusively, there seems to be no significant preference of this species for a specific bedrock. *E. blumi* is a widespread species, probably cosmopolitan.

Echiniscus merokensis Richters, 1904
Only we found only three specimens of this species, all in the 300 m sample of the transect taken in the Mellemfjord area. More numerous data from West Spitsbergen (Dastych 1985) indicate a wide distribution along vertical gradients (10 - 1100 m a.s.l.) as well as occurence on the two types of bedrock. It is also considered to be a species of cosmopolitan distribution.

Echiniscus wendti Richters, 1903
With the exception of the samples from 100 m a.s.l. (Ly and MF), *E. wendti* was found in all altitudes and on both types of bedrock. Dastych (1985) described the optimum of its occurence lying above 700 m a.s.l. and stated a strong association to non - carbonate bedrocks. Maucci (1996) stated a widespread distribution of this species in Greenland. As mentioned before, distinguishing *E. wendti* and *E. arctomys* is, depending of the quality of the preparation, sometimes very difficult. With respect to this problem a species called *E. arctomys/wendti,* which is showing characters of both species, is mentioned in Table 2. Four specimens were found of this species, all of them in the upper zone of the Lyngmarken transect on alcaline bedrock.

Pseudechiniscus suillus (Ehrenberg), 1853
Eleven individuals of this species were found in both transects altogether. Although this species was always found together with *Echiniscus arctomys* or *Echiniscus wendti* in the upper levels of both transects, *Pseudechiniscus suillus* was not found below 300 m a.s.l.*Pseudechiniscus suillus* is reported from Greenland (Petersen 1951; Maucci 1996) as well as from other localities around the world.

Testechiniscus spitsbergensis (Scourfield), 1897
This species was found only in the Lyngmarken transect and though it is considered to be an abundant species in Arctic environments (Dastych 1985; Maucci 1996) there were only seven individuals were found. Formerly known as *Echiniscus spitsbergensis,* it has been reported from Greenland (Petersen 1951) and from many other Arctic, Subarctic or montane environments.With respect to findings from Spitsbergen, where Dastych (1985) reported a strong attachment to alcaline bedrock, it is noteworthy that here more specimens were found on non - carbonate bedrock. The specimens were collected at 0 m a.s.l. and at 400 m a.s.l. which underlines the wide altitudinal range in which this species occurs (Dastych 1985).

Macrobiotus harmsworthi Murray, 1907
In this study only one specimen of this species was found (200 m a.s.l., MF) although it is considered to be very common in Arctic areas (Dastych 1985; Maucci 1996).

Macrobiotus hufelandi Schultze, 1833

This is a very frequently reported species and considered to have cosmopolitan distribution with a wide altitudinal range. As there is no significant habitat preference documented in earlier investigations, the numerous findings from the Lyngmarken transect at 0 m a.s.l. most probably do not represent any trends.

Macrobiotus islandicus Richters, 1904

Although this species is described as abundant and rather numerous in Arctic environments (Dastych 1985; Maucci 1996), only eight specimens were found in both transects. It was detected both on gneiss and basalt in altitudes between 0 m and 100 m a.s.l.

Minibiotus intermedius (Plate), 1888

The findings of this species in 0 m a.s.l. and 400 m a.s.l. in the Lyngmarken transect emphasizes the observations from Spitsbergen where Dastych (1985) described it as a species with a wide altitudinal range. Maucci (1996) characterized it as a species "which shows no particular environmental preferences" (p. 193), demonstrated here by findings on both gneiss and basalt.

Diphascon alpinum Murray, 1906

D. alpinum is considered to be one of the more common and widespread species of the genus *Diphascon* (Ramazzotti and Maucci 1983). Its occurence in Greenland was described by Petersen (1951). In this study only one specimen was found at 0 m a.s.l. in a sample from the Lyngmarken transect.

Hebesuncus conjungens (Thulin), 1911

Four specimens of this species were found in the 0 m a.s.l. and 200 m a.s.l. samples from the Mellemfjord transect. According to Petersen (1951), Dastych (1985), Ramazzotti and Maucci (1983) and Maucci (1996) it is widely distributed in Arctic regions as well as in other climates although findings are not very numerous.

Ramazzottius oberhaeuseri (Doyère, 1840)

The seven specimens of this species were found exclusively in the samples from the Mellemfjord transect at 200 m a.s.l. and 400 m a.s.l. on basalt.*R. oberhaeuseri* was reported by Petersen (1951) and Dastych (1985) who found this species frequently in heights between 5 and 1100 m a.s.l. and on both alcaline and non - carbonate bedrocks. This is also considered to be a cosmopolitan species.

Calohypsibius ornatus (Richters, 1900)

Seven representatives of this species were found in samples from 100 m, 200 m and 300 m a.s.l of both transects and from both alcaline and non - carbonate bedrocks.This species was reported from Greenland by Marcus (1936) and Maucci (1996) and by Dastych (1985) from Spitsbergen. In contrast to the findings in Spitsbergen, *C. ornatus* was found in a lower altitudinal zone.

Milnesium tardigradum Doyère, 1840

Numerous specimens of this species were found in samples from 0 m, 200 m, 300 m and 400 m a.s.l. of both transects and from both alcaline and non - carbonate bedrocks.

It is described as a very common and cosmopolitan species showing no significant habitat preference (Dastych 1985; Maucci 1996). In addition to the discussed species above, four specimens of *Proechiniscus hannae* were found in the Lyngmarken area. This species was found in samples which were taken during a preparation period and therefore is not mentioned in the tables.

Concluding Remarks

All fifteen species of tardigrades that were found in samples from the two transects are coping with a wide altitudinal range and substratum with different pH and thus can be considered as eurytopic.

In contrast to the study of the tardigrade fauna of Spitsbergen (Dastych 1985) it is interesting to note that some species like *E. blumi, P. suillus, M. harmsworthi* and *H. conjungens* were found on different substrates than those they clearly prefer in Spitsbergen.

Regarding the sometimes small numbers of specimens found, this study cannot give an accurate and quantitative picture of tardigrade distribution in the sampled areas.

Therefore, a classification like the one from Spitsbergen (Dastych 1985) is not attempted.

For further studies it might be useful to extend the vertical gradients to much higher altitudes as there has been recorded a significant drop in tardigrade species numbers above 700 m a.s.l. (Dastych 1985). With respect to the sometimes insular distribution of tardigrades in mosses, it must be mentioned that the extraction method as well as the determined sample sizes that were used in this study should be changed.

A larger amount of moss and a more specific extraction method like sieving will most probably result in finding more specimens in the samples.

The Arctic environment is characterized by quite arid and windy conditions, thus allowing dry soil components dispersal by wind. In this respect, it seems possible that otherwise pH - neutral or slightly acidic substratum like gneiss could be covered with eolic drifted alcaline particles which may change for example the nutritional situation for the associated flora and fauna.

In a qualitative investigation Grøngaard et al. (1990) examined the tardigrade population in the Lyngmarken area along a vertical transect with a range up to the glacier in 800 m a.s.l. In contrast to our study that investigation was also regarding different types of habitats such as cryoconit holes in the glacier ice. The 25 species that were found include all species which were found in this study except of three species: *Echiniscus arctomys, Diphascon alpinum* and *Calohypsibius ornatus.* The findings of both investigations strongly suggest a much wider distribution of most species along the vertical gradient than it could be derived from only one investigation. For example, *Milnesium tardigradum, Minibiotus intermedius,* and *Testechiniscus spitsbergensis* were only found in 200 m a.s.l. or above by Grøngaard et al.(1990), whereas in this study they were found over the entire vertical gradient.

It has to be mentioned that two of the samples (200m a.s.l. Ly and 100 m a.s.l. Mf) were probably collected in a slightly wet condition thereby allowing fungi to destroy much of the fauna before examination took place in Hamburg.

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Rapid assessment of spider species richness in the Arctic (Disko, West Greenland)

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Assessment of species richness is a valuable tool in nature management. The simple and low-diversity ecosystem of the Arctic presents a possibility to test rapid assessment methods for estimation of local species richness. Two collectors sampled the spider fauna of Disko Island, West Greenland, between mid July and early August 1998. Two localities were sampled: a presumed - for Arctic conditions - high diversity area with homothermic springs (Engelskmandens Havn) and a presumed low diversity area (Mellemfjord). The collections yielded 501 adult specimens - representing 24 species (see Sum Table). Two collection methods were used: ground hand collection and pitfall trapping. A new species to Greenland, *Pelecopsis paralella* (Wider, 1834) was found in the low diversity area.

The estimators Chao 2 (Chao 1987) and Jackknife 1 (Heltshe & Forrester 1983) were applied to the data to estimate the local species richness of the sites. The estimate from the homothermic spring area was roughly 17-22 species and 10-13 species from the presumed low diversity area.

The effect of method and collector on the estimates and on the number of adults and species per sample was tested. Method and collector have a significant effect on the estimate obtained. Method has a significant effect on the number of species and adults per sample. Ground hand collection yields far more species than pitfall trapping, but each method yields unique species.

A protocol for rapid assessment of species richness in the Arctic can be outlined based on our results.

The findings from this project will be published separately in the Journal of Arachnology.

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Sum table: Abundance data by locality, method and date, with records of distribution according to Platnick (1997)

		Engelskmandens Havn							Mellemfjord						Grand Total	Distribution
		Ground Hand Collection				Pitfalls		Total	Ground Hand Collection				Pitfalls	Total		
Family	**Species**	**18**	**20**	**21**	**22**	**short**	**long**		**25**	**26**	**27**	**28**	**short**			
Dictynidae	*Dictyna major (Menge, 1869)*	2	7	2	1			12							12	holarctic
Hahnidae	*Hahnia glacialis (Soerensen, 1898)*		3					3							3	holarctic
Linyphiidae	*Collinsia holmgreni (Thorell, 1871)*								19	3	30	25	17	94	94	palearctic
	Dismodicus variegatus (Jackson, 1938)	4	5	6	5			20							20	Greenland
	Hilaira frigida (Thorell, 1872)	2	2	5	4	3	1	17	1					1	18	holarctic
	Hilaira vexatrix (O.P.C., 1877)								13	7	14	7	28	69	69	nearctic
	Lepthyphantes complicatus (Emerton, 1882)	2	9	3	6			20							20	holarctic
	Lepthyphantes turbatrix (O.P.C., 1877)	1	3	1	1			6							6	nearctic
	Mecynargus borealis (Jackson, 1930)								1		1	3		5	5	holarctic
	Oreonetides vaginatus (Thorell, 1872)	2	6	11	13		1	33							33	holarctic
	Pelecopsis paralella (Wider, 1834)												1	1	1	palearctic
	Pocadicnemis pumila (Blackwall 1841)			1		1		2							2	holarctic
	Porhomma convexum	1	1		1			3							3	palearctic
	Sciastes extremus (Holm, 1967)						38	38							38	Greenland
	Scotinotylus alpinus (Banks, 1896)				2			2							2	nearctic
	Scotinotylus sacer (Crosby, 1929)				1			1							1	holarctic
	Semjicola obtusus (Emerton, 1915)			2	1	2		5	2		2			4	9	nearctic
	Tiso aestivus (L. Koch, !872)	2		1	3			6							6	palearctic
	Walckenearia clavicornis (Emerton, 1882)								1		2		1	4	4	holarctic
	Walckenearia cuspidata (Blackwall, 1833)	4		5	1	2	14	26							26	palearctic
Lycosidae	*Arctosa insignita (Thorell, 1872)*								1					1	1	holarctic
	Pardosa glacialis (Thorell, 1872)			1	3	1	1	6		1	5	2	5	13	19	nearctic
	Pardosa groenlandica (Thorell, 1872)		2			28	77	107							107	holarctic
Philodromidae	*Thanatus arcticus (Thorell, 1872)*			2				2							2	holarctic
Grand Total		20	38	40	42	37	132	309	38	11	54	37	52	192	501	2 en/12 hol/5 pal/5 ne

Observations of passerine birds in Blæsedalen, Disko Island, West Greenland

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Introduction

The main reason for our three week field excursion to Disko Island, Greenland was to inventory the presence of four native passerine birds. We investigated the following species: the snow bunting (*Plectrophenax nivalis* Linnaeus, 1758), the lapland bunting (*Calcarius lapponicus* Linnaeus, 1758), the wheatear (*Oenanthe oenanthe* Linnaeus, 1758) and the redpoll (*Carduelis flammea* Linnaeus, 1758). The main purpose was to investigate the decrease and increase of the bird population in the valley, Blæsedalen, since the last inventory was done by Danish students (Christensen *et al.* 1983) in 1982.

Recently Frimer (1991) presented data on densities and distribution of breeding passerine birds in the coastal area of Disko Island immediately east of the town of Qeqertarsuaq (Godhavn). This area is protected and has a low tourist activity compared to our study area, which is partly overlapping in transect II with the study done by Frimer in 1990. Using the research methods developed by Sharrock (1976) we defined the number of breeding places, breeding birds, and young birds. Furthermore we observed the birds behaviour where there was intrusions by humans into their area and their choices of breeding places. Sharrock (1976) developed a system how to accurately count breeding place distribution of all bird species in Britain and Ireland.

Material and methods

In order to determinate the local species of birds we used the following literature: Gènsbøl (1996) and Boertmann & Fjeldså (1988). Binoculars (7x50, 124m on 1000m, Zeiss) and a GPS (Global Positioning System) for observing. The geographic map of Godhavn and surroundings (Kursus i arktisk geomorfologi, Geomorfologisk Laboratorium, Geogr. Inst., Kbh. Univ., 1976) we used for mapping.

Our research, based on the method developed by Sharrock (1976), was to describe the breeding behaviour of the named passerine birds. We sectioned off an area into several transects and then investigated each transect by touring it in a "criss-cross" fashion. We noted the parameters of the study area on our map and in the observation book. Corresponding to the project of 1982 we used the same symbols ▲,● and ■, to mark the three different categories on the map: possible, probable or confirmed breeding places. The definition of the categories (Sharrock 1976) are explained in table 1.

The study area "Blæsedalen" (The Valley of Wind) is a valley orientated from north to south. It is at about 23 km long and 0.5 km to 2.0 km wide. In the middle part of the valley two rivers flow together to form the Indlands Delta with an enoumous area of river-beds. One of the rivers (Bielven) we marked as the northern borderline of our study area. The main river named Røde Elv flows southwards and discharges into the Disko Bay. A small lake called Morænesøen (approximately 200m x 300m) is located in the middle of the valley. It forms a wetland area with humid conditions with dense vegetation of *Salix glauca* scrub. Otherwise this area is characterised by a hilly terrain (Pjetursson Moræne). The southern part of the valley is dominated by a maritime landscape, i.e. sand, pebbles, stone and sparse vegetation. The few basaltic rocks and stones are lichen-covered and occasional rock poppies (*Papaver radicatum*) do occur. North of this meagre landscape heather growing among rocky grounds represent the typical vegetation. The condition of the soil in Blæsedalen is manifold. It is dry were small birch bushes (*Betula nana*) and heather, or wet around the lake and the river delta.

Table 1. Definition of the categories by Sharrock (1976)

Category	Symbol	Definition
Possible breeding	▲	Bird recorded in breeding season in possible nesting habitat, but no other indication of breeding noted
Probable breeding	●	Singing male present (or breeding calls heard) on more than one date in same place
		Bird (or pair) apparently holding territory
		Courtship and display; or agitated behaviour or anxiety calls from adults, suggesting probable presence of nest or young nearby; or broodpath on trapped female
		Visiting probable nest-site
		Nest-building (including excavating nest-hole)
Confirmed breeding	■	Distraction-display or injury-feigning
		Used nests found
		Recently fledged young
		Adult carrying faecal sac
		Adult(s) with food for the young
		Adult(s) entering or leaving nest-site in circumstances indication occupied nest (including colonies)
		Nest and eggs, or bird sitting and not disturbed, or eggshells found away from nest
		Nest with young or downy young of ducks, gamebirds, waders, etc.

Investigated Passerine birds

According to Delin & Svensson (1998) and Salomonsen (1950) the four investigated passerine birds are defined as follows:

The **Snow bunting** *(Plectrophenax nivalis* Linnaeus, 1758): The snow bunting is the most common bird of Greenland and can be observed all over the country in mostly rocky areas. The snow bunting prefers the stony ground and meagre vegetation of the coastal regions. Usually they build their nests at a minimum of 50 cm above the ground, under stones, in quarries, rocky gaps and also in walls of old houses.

The **Lapland bunting** (*Calcarius lapponicus* Linnaeus, 1758) The lapland bunting, also called the lapland longspur, favours humid and swampy grounds and can be found sitting on rocks, birches or willows. The nest is a deep and bowl-formed holes in the ground, often covered with moss and hidden under bushes.

The **Wheatear** (*Oenanthe oenanthe* Linnaeus, 1758): The wheatear is a very lively and agitated bird who prefers a solitary life. The nest is often hidden in stony heaps, gaps and rocks.

The **Redpoll** (*Carduelis flammea* Linnaeus, 1758): The redpoll is the smallest breeding bird of Greenland with only about 12,5 cm long. Usually this bird is found in inferior parts of the country, seldom in coastal regions. The redpoll is a very lively bird and likes hovering around, even during breeding periods. As most of the other birds the redpoll does not instinctively defend its territory. It often breeds in colonies and is very companionable. The nest is mostly built of willow branches close to or right on the ground or attached to bushes, stones and tree trunks.

Results

Charts and maps:
The charts and distribution maps are presented in the following order:

a) Table 2-4: The charts of quantity of the counted species of birds, divided in the sections and the probability of breeding. Legend: ♂ = male bird, ♀ = female bird, j = juvenile bird, f = families.
b) Map 1: The map of the Blæsedalen, on which our sections are marked. The restrictions we defined according to the GPS-system.
c) Map 2-5: The maps of dissemination of the four passerine birds.

The **snow bunting:** Our observations showed a higher population of male snow buntings than female birds in Blæsedalen. We never saw the snow buntings sitting in bushes or on the ground, instead they perched on stones and rocks. The nests were located closely together. We observed the male birds feeding the young. This map shows that the concentration of breeding places are in certain areas of the valley. Most breeding places and bird families were found in the rocky surroundings. Further away from the coast the number of breeding nests decreased. The nests were deeply hidden in stony gaps or holes. Many young birds had left the nest already, but were still fed by the parents. The snow bunting was the most active bird in the area, but seemed to be disturbed by our presence.

Table 2. Counted **snow buntings** in the various transects

	Possible breeding			Probable breeding			Confirmed breeding				
	♂	♀	J	♂	♀	j	♂	♀	J	f	Total
Transect I	6	2	3	5	3	4	7	4	6	8	40
Transect II	3	1	2	4	3	2	4	1	4	4	24
Transect III	2	2	3	1	2	0	1	3	2	3	16
Transect IV	0	0	1	2	1	2	1	0	2	1	9
Transect V	1	0	0	0	0	0	0	0	1	1	2
Transect VI	1	0	1	0	0	0	1	0	0	1	3
Transect VII	0	0	0	0	0	0	0	0	0	0	0
Total	13	5	10	12	9	8	14	8	15	18	94

The **lapland bunting**: We saw more female lapland buntings than males. In the southern transects (I, II) of Blæsedalen we saw only a few breeding birds and generally a very small number of lapland buntings. We found the situation different in the humid area around the lake (sections III, IV), as well as at the river arms of the Røde Elv or other humid and wet areas of the valley where the bird population was quiet large. All together the lapland bunting can be described as a shy and escaping bird, it has a clear distracting behaviour when disturbed. Then it flies up from the nest and sings loudly in order to distract the intruder. This behaviour often led us to their exact nesting place. Besides the snow bunting the lappland bunting was the most frequently observed bird in Blæsedalen.

Table 3. Counted **lapland buntings** in the various transects

	Possible breeding			Probable breeding			Confirmed breeding				
	♂	♀	J	♂	♀	j	♂	♀	j	f	Total
Transect I	0	4	2	0	0	0	1	0	0	1	7
Transect II	1	3	1	0	2	0	0	3	0	3	10
Transect III	1	3	1	2	3	1	1	5	2	5	18
Transect IV	2	2	0	3	1	0	2	4	3	5	17
Transect V	0	1	1	1	3	0	0	4	3	4	13
Transect VI	1	0	0	1	2	2	1	2	1	2	10
Transect VII	0	2	0	2	2	2	1	1	0	1	10
Total	5	15	5	9	13	5	6	19	9	21	85

The **wheatear**. The wheatear prefers the central area of Blæsedalen and was hardly noticed in the coastal area. The favourite territory was rocky ground partly covered with heather. We rarely saw the bird and mostly noticed it only because of its singing voice. It was easily located by the typical singing clicking sound. The table shows that the wheatear was rarely observed. We observed two larger groups of wheatears close to and directly at the Arctic Station. It was groups consisting mainly of younger birds. Here the shy birds were calmer and could be observed easier. In fact, a few younger birds came inside the main building of the Arctic Station to catch the blow flies.

Table 4. Counted **wheatear** in the various transects

	Possible breeding			Probable breeding			Confirmed breeding				
	♂	♀	J	♂	♀	J	♂	♀	j	f	Total
Transect I	0	0	0	0	0	0	0	0	0	0	0
Transect II	0	0	11	0	0	0	0	0	0	0	11
Transect III	0	0	0	0	0	0	1	0	1	1	2
Transect IV	0	2	0	0	0	0	0	0	0	0	2
Transect V	1	0	0	2	1	2	1	0	0	1	7
Transect VI	0	0	0	0	0	0	0	0	0	0	0
Transect VII	0	0	0	2	0	0	1	1	3	2	7
Total	1	2	11	4	1	2	3	1	4	4	29

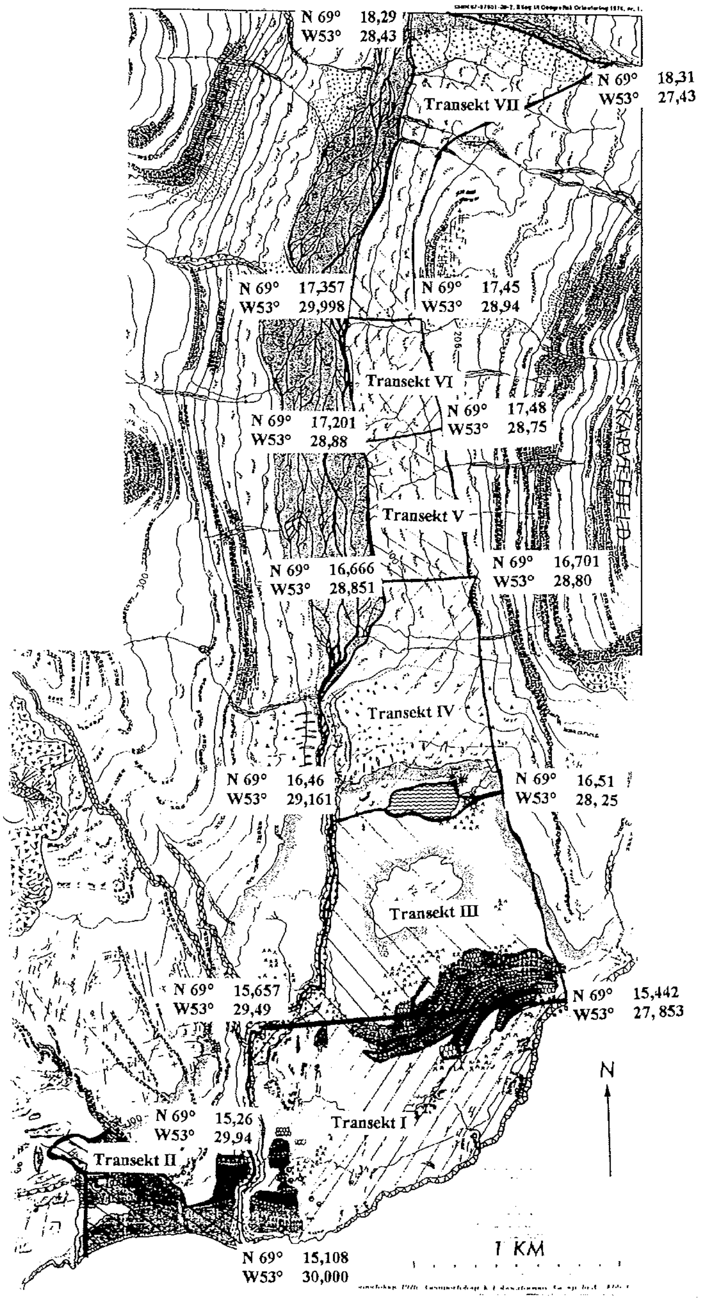
The **redpoll**. These redpoll nests were mostly found in scrubs of willow and dwarf birch. The redpoll is the rarest of all the investigated birds in Blæsedalen. We saw and heard it very infrequent. Their nests were found in the declivity areas behind the Arctic Station. We observed the redpoll perching in bushes, on stones, small rocks or fences, on roofs or telegraph wires and it did not fear the humans.

Table 5. Counted **redpoll** in the various transects

	Possible breeding			Probable breeding			Confirmed breeding				
	♂	♀	J	♂	♀	j	♂	♀	j	f	Total
Transect I	0	0	0	0	0	0	0	0	0	0	0
Transect II	1	0	1	3	1	1	2	0	1	2	10
Transect III	0	0	0	1	0	0	1	2	0	2	4
Transect IV	0	0	0	0	0	0	0	0	0	0	0
Transect V	0	0	0	0	0	0	0	0	0	0	0
Transect VI	0	0	0	0	0	0	0	0	0	0	0
Transect VII	0	0	0	0	0	0	0	0	0	0	0
Total	1	0	1	4	1	1	3	2	1	4	14

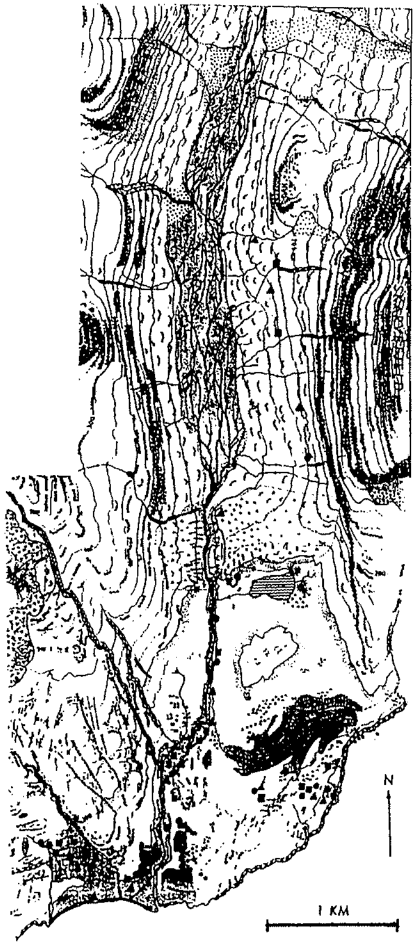
Map of the Blæsedalen with GPS data

Map 1



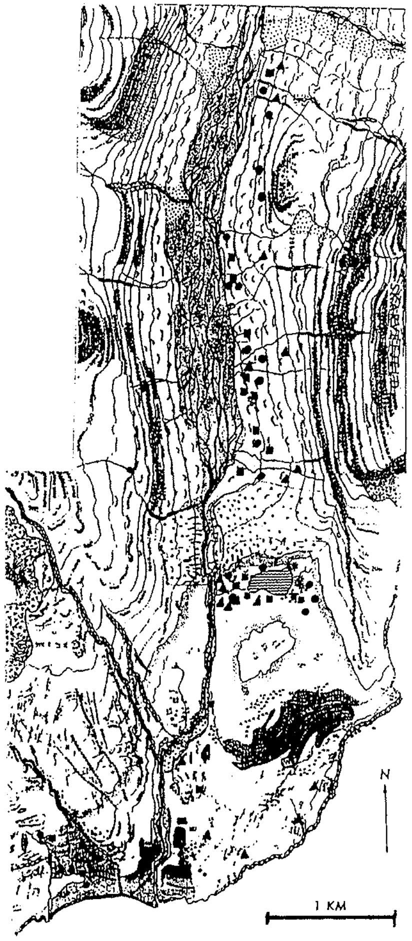
Map 2

Map of observed snow bunting



Map 3

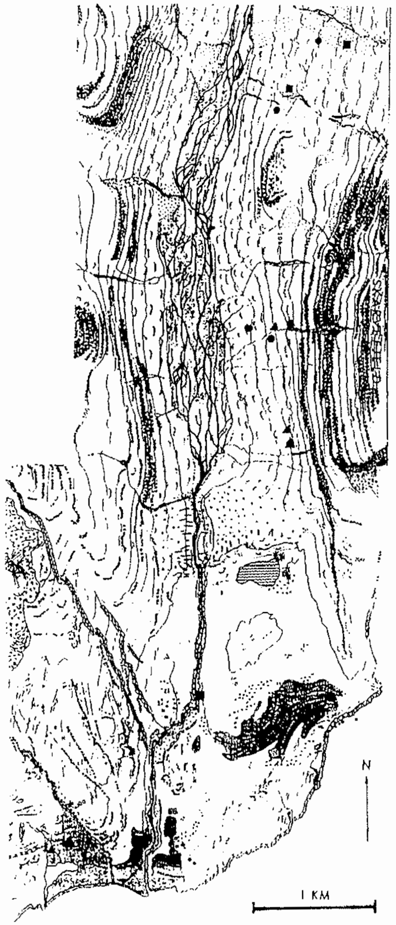
Map of observed lappland bunting



possible breeding ▲
probable breeding ●
confirmed breeding ■

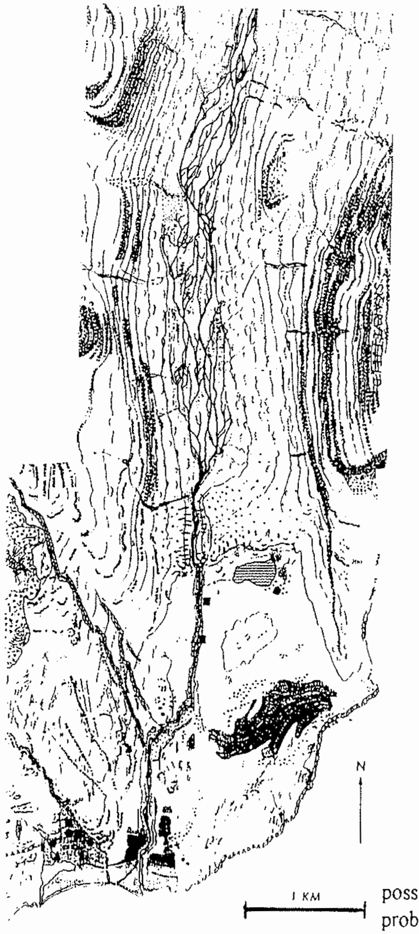
Map 4

Map of observed wheatears:



Map 5

Map of observed redpolls:



possible breeding ▲
probable breeding ●
confirmed breeding ■

Discussion

Anthropological influences in the Blæsedalen

In a brochure (Tourist Information Disko-Island*)* and in few books about Greenland and Disko Island, hiking tours through the Blæsedalen are advertised. During our investigation we observed many groups of hikers. The tourist follows small tracks leaving behind litter everywhere. We, the students of this excursion, were disturbing elements in this area, especially when we left the usual hiking routes and criss-crossed the territory. As per "Qeqertarsuaq Tourist Information" the amount of visitors increases steadily. In 1982 no tourists were registered, whereas in 1997 6400 overnight guests were counted. Many of them participated in tours through Blæsedalen. Because of the increasing number of tourists a youth-hostel was recently rebuilt in the former scientific station, The Ionsfære Station, in the valley. Next to this building there is a camp site. Both were opened for tourists in 1994. The electricity for the hostel is produced by a large generator.

Disturbance from tourism

Disturbance tourism could hold a lot of negative effects on birds and their breeding. It has to be assumed that disturbances cause reversible and irreversible damages and changes in the ecosystems which are often caused by unnatural factors of the organisms, populations or biological balance of the ecosystems, mostly human beings. Generally it is feared that some birds which are not able to cope with the increasing disturbances will decrease and finally disappear from their natural surroundings. The effect of a source of disturbance is measured by the reaction of one individual or a group of individuals. The number of adults is normally defined by the terminus "fitness". It describes the contribution of one individual to the following generations of the population.

Examples of anthropological impacts to the propagation are known: during an investigation of *Charadrius melodus* (Linnaeus, 1758) in Canada, the different behaviour and the changed rate of mortality of young birds was probably caused by visitors of the investigated area. In coastal areas with high visitor frequency a lower number of young birds survived their 17th day. The number of fledged young birds in one brood in a rarely visited area was 1.8 young/parents, while in a more highly visited area the number decreased to 0.5 young/parents. It was noticed that the number of breeding pairs in all examined coastal sections was reduced from 69 to 53.

A report on the *Tringa hypoleucus* (Linnaeus, 1758) showed that at highly visited parts of the coast (i.e. for fishing, hiking) the birds relocated to other sections. Furthermore these birds repeatedly had territorial fights, maybe due to stress. The number of breeding pairs at fishing nooks compared to the number of breeding pairs in quiet areas declined significantly. It is commonly know fact that repeated disturbance causes a higher rate of egg napping and a drop of temperature for the brooded egg (Ingold et al., 1982).

Another consequence of disturbances might be a future different behaviour of the animals: birds of *Anas penelope* (Linnaeus, 1758) in hunting areas eat at nighttime and rest at daytime whereas normally *Anas penelope* rests at night and eats during the day.

Frank (1992) described the influence of tourists activity from two highly frequented hiking routes and a camp site: In 263 of 492 cases it was proven that the resting and food-searching birds were disturbed by the presence of hikers. The birds reacted by hopping or flying away from the source of disturbance. Considering the high amount of energy used by flying it is not surprising that frequently disturbed birds (rate of 2.57 disturbances per hour) also do have an increased rate of metabolism (24-50% higher than that of normal birds). This disturbance could therefore result in an energy deficiency in the birds.

Mapping

Records of the **snow bunting**

The snow bunting was most often seen close to the lake or in the southern parts of the valley with its rocky grounds. According to our observation the snow bunting seems to favour this kind of areas. Very rarely were these species seen alone. We therefore assume that they prefer to coexist with birds of their own kind. The fact that most of the nests were located close to the hiking routes led us to realise that these birds do not feel disturbed by tourists passing their nests. Along the coast we rarely found snow bunting and their nests. We conclude that the geographic landscape and habitat in the southern part of the valley is more suitable for their nesting.

Records of the **lapland bunting**

Most of the lapland bunting lived in the lake transects III, IV. In the southern part of the valley (transects I, II) the number of birds observed was much lower. This might have been due to the landscape. It is likely that the stony landscape of the south is not very suitable for their breeding and building nests. As previously mentioned the lapland bunting prefers a humid bushy landscape to breed its young. The territory north of the lake is very similar, so this species has sufficient possibilities to breed or build nests in this area.

Records of the **wheatear**

The shy and unobtrusive wheatear was rarely observed and is obviously not an abundant species in Blæsedalen. We sometimes heard its singing but could not see it. However having found some young specimens we regarded it as likely that the wheatear has built some nests in the valley and some pairs of the species are breeding there. As the nests are always well hidden and located in inaccessible regions it is probable that quite a number of nests were not found.

Records of the **redpoll**

This species was the rarest of all the observed species. The redpoll seemed shyer and more attentive than the other birds in this area. It seems that the environment of this area might not be suitable for this species. The redpoll breeds twice a year which could be the reason that their females were encountered less often.

Comparison of the study of 1982 to the one of 1998

The snow bunting and the lapland bunting were the most frequently seen birds in Blæsedalen, both in 1982 and in 1998. A significant reduction of breeding birds however can be recognised in the area close to the youth hostel. Of all the investigated birds in Blæsedalen the snow bunting is still the one breeding most in the valley. Our investigation (1998) clearly shows a relocation of breeding places to the southern region and to the banks of the Indlandsdelta of Rødeelv.

Comparison with the data from 1982 we noticed a reduction of recorded lapland buntings particularly in the southern areas, but also in other parts of the valley. The population of the lapland bunting has seemingly decreased significantly. This is especially true for those parts of Blæsedalen where, compared to 1982, there was an increased number of visitors to the valley, i.e. on hiking routes in the south and the area around the youth hostel. In the inaccessible northern areas the lapland bunting is more abundant now than when recorded in 1982. An even higher number of breeding specimens were found at the lake, here we observed more lapland buntings than the Danish students did in 1982. We think that as far as the wheatear is concerned the breeding places around the new located youth hostel are not attractive any more. In 1982 nests were still found in this region, nowadays one can hardly observe them there anymore. Even though the total population of the wheatear clearly declined, its presence in the northern parts has remained constant since 1982. No striking changes could be observed in the redpoll population since 1982. We were unable to give map data for the western and northern area as studied by the Danish group in 1982. In 1982 a larger area was investigated, and so a different number of birds was recorded. Nevertheless the relation of the frequency of observation between species remained nearly the same. Like in 1982, the redpoll was most often recorded close to the Arctic Station, whereas it was found rarely in the valley itself. The redpoll was the rarest bird observed by us in the valley. This could be due to the unfavourable habitat conditions for this species in Blæsedalen in 1998.

The opening of the youth hostel in 1994, with its camp site and generator, certainly destroyed a large breeding area for all bird species. Being a new source of noise in the territory, the youth hostel and the generator can cause reversible or irreversible changes in the ecosystem of Blæsedalen. Another source of disturbance for the breeding birds is the accessibility of Blæsedalen for tourists. Moreover, a high number of visitors affect the mortality rate of young birds, lacking the care of the parents (Ingold et al. 1982). Furthermore the disturbances caused by tourists on hiking routes included an increased number of flights of the birds resulting in a higher energy expenditure (Frank 1992). None of these disturbances were recorded in 1982, therefore we assume that especially tourism may be a reason for the present observed differences in the bird counts in Blæsedalen. Both the retreat of the lapland bunting from the southern parts of the valley and the obvious reduction of the redpoll numbers might be explained by tourist activities in Blæsedalen.

A variety of factors influences both growth and reduction of a bird population, most of these are anthropologic. Primarily ecological factors might effect the birth rate and mortality of the investigated species. The number of individuals in a population always varies from year to year, even when an average is defined, because every population is subject to changes in environmental dynamics. Additional factors influencing the birth rate could be the food availability. An undernourished mother is likely to have a smaller number of offspring (i.e. birds do produce more eggs if the nourishment is of high quality and quantity.). Many birds need a large territory, sufficient to raise their young.

Defending it against others of their own species is essential to them. If their area is diminished the birth rate can decline. Physical reaction to situations causing stress could appear as the reduction of sperm production, or a lower copulation rate. This phenomen is called the general adaptation syndrome. These above mentioned factors also influence and regulate the rate of mortality. A decrease in food supply or a reduction in size of territory might cause an increase in mortality rate. A single event can also be a important factor for changes within a population. Floods or other catastrophes could change the abiotic surroundings dramatically and thus destroy a whole colony of breeding birds (Kalusche 1978).

For a more exact assessment of the current situation in Blæsedalen several bird monitoring expeditions between 1983 and 1997 would have been necessary. Only after more frequent monitoring would it have been possible to evaluate the consequences of the opening of the youth hostel in 1994, the use of the generator since 1995, and the increased tourism among the local bird population. However, we only have data from the two years. Therefore we cannot definitely argue that the reduction of the investigated bird population in 1998 is due to the change in the environment. Alternatively it could have been a year of a less bird birth due to normal natural developments.

Potential Errors

Some probable flaws of this project might have to be considered:

Counting the birds at their breeding places we attempted to eliminate caunting them more than once. We avoided counting single birds because this would entail an even higher risk of double-counts. Nevertheless this potential flaw has to be taken into account, as it might have caused a slight statistical error. For this long-term exploration the weather conditions in the valley were excellent. The average day temperatures were about 20°C with sunshine most of the time. During the few times when we had clouds or fog the temperature dropped remarkably. During foggy periods observation was not possible. We had some foggy weather during excursions at transect III, IV and V. At these locations the observations were interrupted for max. one hour each. When windy the conditions were more difficult. At the coastal part the valley was always very windy, whereas inland the valley was relatively calm. One day, during the investigation of transect II, the wind was too heavy to continue any observations (the wind force was around five). The gathered section II data were later replaced by new observations.

The hours of observation were always between 9 a.m. and 7 p.m.. Darkness did not influence the investigation, as it was the season of the midnight sun. Taking a probable biological rhythm of the birds into consideration (i.e. feeding, resting), the limited duration of observation could have resulted in counting artefacts.

Summary

A different number of mapped breeding-places can be established between the project of 1982 and 1998. Due to the scarcity of data and only 2 in 16 years of investigation it cannot be concluded that the differences observed, especially regarding snow- and lapland buntings, are due to the increased local tourist activities, or are caused by

natural changes of the populations, but the high densities of passirine birds in the protected area close to our investigated area, could indicate that tourist activities may have an influence on the passeine bird population. In the future this could be proven only by monitoring the birds of Blæsedalen for several consecutive years. Future investigations may help to support or reject our hypotheses.

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The intertidal macrofauna and macroalgae at five Arctic localities (Disko, West Greenland)

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Abstract

The overall objective of this study was to compare the macroalgae and macrofauna at selected Arctic intertidal localities and along a depth gradient at each site. Five localities, two near Qeqertarsuaq (Godhavn) and three at Mellemfjord, were investigated. They were chosen with respect to differences in exposure to wind and ice scouring. Eight to twelve samples of a fixed area (15 x 15 cm), and representing two or three transects were collected from each site. During this investigation 41 animal taxa and 32 algae were found. Individuals of animals were quantified, and the biomass of the algae determined as dry weight. The results indicate both marked vertical differences along transects and distributional patterns that can be related to degree of exposure.

Introduction

The intertidal zone in general is well studied in temperate and tropical regions. Many investigations have examined the distribution of both animals and seaweed (e.g. Colman 1939, Evans 1947, Lewis 1964, Hagermann 1966). Studies concerning one group of fauna associated with the macroalgae or the fauna on a single species of macroalgae have been worked out (e.g., Boaden *et al.* 1975, Beckley & McLachlan 1980, Seed & O'Connor 1981, Beckley 1982, Gunhill 1982, Fletcher & Day 1983, Lewis 1987, Martin-Smith 1993, Mettam 1994). However, only a few studies of this kind exist from Arctic areas. In Arctic Canada and Norway (Spitsbergen) qualitative studies were made of the zonation of both fauna and flora in the intertidal zone at coastlines with variable wave exposure (Ellis 1955, Ellis & Wilce 1961, Hansen & Haugen 1989). Other studies focus exclusively on algae (Wilce 1959, 1964, Lee 1973).

Descriptive studies of the Greenland littoral fauna were published by Madsen (1940). Other, more specific studies focused on the distribution of two common intertidal species, *Semibalanus balanoides* and *Littorina saxatilis,* var. *groenlandica* (Petersen 1962, 1966).

The vertical zonation of the Arctic intertidal zone does not differ substantially from that of other regions (Wilce 1964, Christensen 1971, Lee 1973, Pedersen 1976, Hansen & Schlütter 1990). The terminology used below is from the 'Lewis system' (Lewis, 1964).

The vegetation is dominated by brown algae (Phaeophyceae) of the genus *Fucus* on a sheltered coast with suitable substratum. The *Fucus* belt typically comprises two different species, *Fucus vesiculosus* in the upper part of the intertidal zone, and *F. evanescens* in the lower part. The perennial *Fucus* species disappear when the degree of exposure is too high because the settling requires relatively stable conditions. High energy systems are frequently dominated by ephemeral green algae (Ulvophyceae). On moderately exposed localities the *Fucus* belt will submerge.

The degree of wave exposure also has an influence on the morphology of macroalgae. This fact, in combination with the low temperature regime of the Arctic (Hoek 1984), may result in algal morphotypes that are significantly different from those of lower latitudes and sometimes hard to identify. *Fucus* spp. is particularly variable in morphology, e.g., with regard to shape of receptacles and presence/absence of vesicles. In *Fucus vesiculosus* the vesicles are absent in plants from the upper part of the intertidal zone or at heavily exposed sites.

The aim of this study was to compare the macroalgae and the associated macrofauna at selected intertidal localities (low energy – high energy) and along a depth gradient at each locality. Degree of exposure and ice scouring will a priori be considered among the most important factors, with regard to differences in (1) species diversity, (2) algal biomass, and (3) number of individuals from animal taxa. A similar approach was taken by Colman (1940), Evans (1947), Stephenson & Stephenson (1949), Lewis (1964) and Beckley & McLachlan (1979). Other habitat characteristics, such as type of substratum, the slope of substratum, freshwater outlets, etc. were to a lesser extent incorporated into the selection of sites. The degree of exposure is subjectively evaluated based on, e.g., community structure and site specific geographic characteristics. The exposure scale published by Dalby *et al.* (1978) for Norwegian coasts (based on faunal community patterns) will be used here to describe our West Greenland localities.

The project concept was based on investigations from the Arctic which conclude that the macrofauna is characterized by low biomass and limited biodiversity (Ellis 1955, Ellis & Wilce 1961, Hansen & Haugen 1989, Madsen 1940, Petersen 1966). It was therefore a surprise to find numerous animal taxa and large numbers of individuals particularly at the sheltered locality. This resulted in a modification of the sample processing programme after the actual sampling had taken place.

Methods

Field work. Five localities were investigated: two near Qeqertarsuaq and three at Akulliit /Mellemfjord. Three transects were sampled from each locality. Parallel transects were placed approximately perpendicular to the shore. The first sample (1) was taken from "zero of map", bordering to the sublittoral zone (LALW - lowest astronomical low water). The last sample was taken at the upper limit of *Fucus* plant occurrence. 4-7 samples were collected along each transect. The actual number of samples depended on the vertical extension of the littoral zone, thus reflecting both differences in the slope of the shore and the degree of exposure. All collections took place at low tide (Farvandsvæsenet 1997). The field data comprised: (1) distance between neighbouring samples, (2) elevation of individual samples, (3) salinity, (4) water temperature, (5) slope of substratum, and (6) GPS co-ordinates (Table 1). In order to calculate the elevation of each sample, a reference point was identified at low tide 1 m above actual water level. The collecting was carried out by hand and using scrapers

of different kinds. A screwdriver was used in the small crevices in basalt rock. All organisms within a defined area (15 x 15 cm) were collected at each sampling event.
An initial sample treatment took place at the Arctic Station or at the Akulliit camp site. Samples were sieved through a 425 µm-mesh screen and fixed with buffered formalin for further processing in Copenhagen. Macrofauna is here (partly as a consequence of the sample treatment) defined as animals >500 µm. This is also in agreement with e.g. Higgins & Thiel (1988).

Laboratory work. After an initial elimination of the fixative and fine particles (< 225 µm) samples were sorted into three fractions: (1) benthic algae, (2) epiphytic algae, and (3) animals. The epiphytes include the few drifting algae present in the samples.

Dry weight determinations of algal fractions were made at 120°C until constant weight.

Identification of *Fucus* spp. took place during the initial sorting of samples. Microscopic examination of mature receptacles was needed to distinguish between *F. vesiculosus* without bladders and *F. evanescens*. The identification of epiphytes was based on slides prepared prior to the dry weight analysis.

The animals were immediately sorted into major taxonomic groups. After counting specimens, the animals were preserved in 70% ethanol for further determination.

Description of localities. This report comprises an analysis of material from 4 localities. Due to time constraints it was not possible to include material from loc. 3 (Akulliit) in this report. Environmental parameters and geographical co-ordinates of each site are listed in Table 1.

Locality 1. Qeqertarsuaq, between Udkiggen and a small harbour, Ukossak (Fig. 1). A small, sheltered cove (exposure 9 according to Dalby *et al.* 1978) protected from the ocean by an island Qeqertausaq. At low tide it is possible to walk from Disko to Qeqertausaq. The substrate was gneiss, appearing as 'rock' in the upper littoral zone, 'stones' in the middle and 'sand/gravel' in the lower part. Because of the high degree of shelter, large amounts of organic material (with many polychaetes) was permanently deposited. Twenty-one samples (7 x 3) were collected along 12 m long transects (A, B, C). Ten of these have been analysed in preparation for this report (A and B, samples 1, 2, 4, 6, 7). *Fucus* plants dominated throughout the littoral zone. Most individuals were relatively large and without any signs of physical damage. Plants from the upper part of the eulittoral zone showed some sign of damage, probably due to herbivory. Few epiphytes were observed, most likely due to the relatively high number of *Littorina* snails present.

Locality 2. Qeqertarsuaq, close to "Ukossak" harbour (Fig.1). The substrate was gneiss (rocks). The locality was facing the open ocean and very exposed to waves (exposure 1 in Dalby *et al.* 1978), ice scouring, and rafting. Large surfaces of smooth rock were covered with ephemeral green algae. Small *Fucus* plants grew among *Mytilus edulis* (numerous) and *Semibalanus balanoides* in surface cracks of the bedrock. The plants displayed the characteristic features of damaged specimens (ice scouring ?). This community was best developed on the sheltered lee sides of the rocks.
This site was relatively steep and the algal cover quite homogeneous. It was necessary to use a sharp scraper to remove the small green algae from the substrate. Twelve (4 x

3) samples were collected along 5 m long transects (D, E, F). All samples have been analysed.

Locality 3. Akulliit S (Fig.1). The substrate was boulders and stones of gneiss with vegetation that consisted mainly of *Fucus* plants with intertwingled drifting algae. A dark basalt sand/gravel sediment was evident at low water mark (no vegetation). Few *Littorina* snails were found on this locality (compare loc. 1). Twelve (4 x 3) samples were taken along 4.3-m transects. The samples have not been processed further.

Locality 4. Akulliit N, close to the homothermic spring "Unartukavsak" (Fig.1). The coast was semi-exposed, with rolling stones of gneiss overgrown with microscopic green algae forming a green belt along the shore. No *Fucus* plants above the low water mark. Movements of the stones most likely prevents settling of larger macroalgae. A few *Fucus* plants (and others) were scattered on stones in the sublittoral zone. This type of locality is generally unsuitable for macroalgal growth. The Dalby *et al.* (1978) exposure index cannot be applied to this locality. Red salt mites (halacarids) were the only animals observed at this locality. Only one sample was collected (with scalpel and razor blades). Quantitative sampling was impossible at this site. Transects measured 5.3 m on the average.

Locality 5. Akulliit N, "Jernpynten" (Fig.1). A very exposed locality (exposure 2 in Dalby *et al.* 1978) facing the open sea (Baffin Bay). The substrate was basalt rock with very uneven/rough surface. Small, bushy *Fucus* plants dominated the locality, obviously morphologically affected by the environment. They grew from crevices, where few *Littorina* snails and *Semibalanus balanoides* were also found. Twelve (4 x 3) samples were collected along 1.2 m transects. Eight of these (from transect N and O) were processed further.

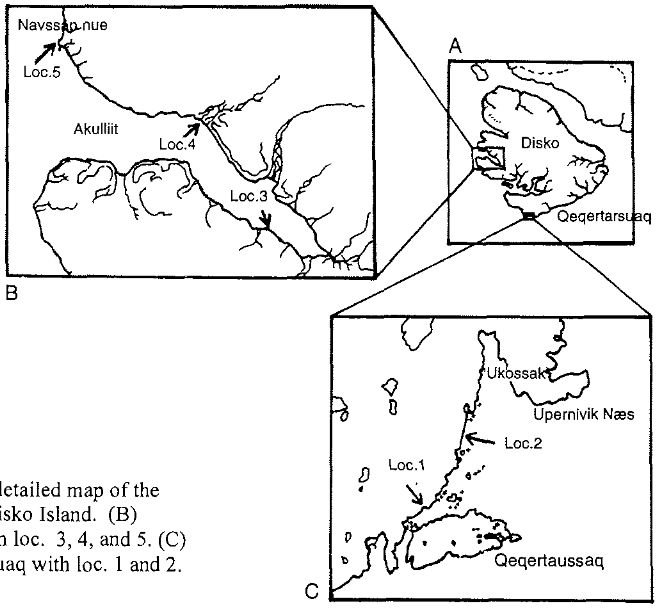


Fig. 1. Map of Disko and detailed map of the localities examined. (A) Disko Island. (B) Akulliit (Mellemfjord) with loc. 3, 4, and 5. (C) The shore near Qeeqertarsuaq with loc. 1 and 2.

Locality and date	Co-ordinates	Water temp.	Salinity	Length of transect	Vertical extension	Slope
1 20.07.98	69°14.20N/53°32.38W	9.0°C	30‰	12.0 m	1.0 m	5°
2 22.07.98	69°14.17N/53°32.26W	9.5°C	32‰	5.5 m	1.6 m	10°
3 25.07.98	69°41.35N/54°28.57W	9,5°C	32‰	3.4 m	0.9 m	12°
4 27.07.98	69°45.09N/54°34.41W	8.5°C	33‰	5.3 m	0.5 m	6°
5 28.07.98	69°49.51N/54°55.48W	8.0°C	35‰	1.2 m	1.0 m	90°

Table 1. Sampling date, geographical co-ordinates etc. from loc. 1-5.

Results

Thirty samples of each 0.0225 m^2 from four localities form the basis of the quantitative/qualitative comparison of localities. More than 41 animal taxa (10317 specimens) and 32 taxa of macroalgae were found. The distribution of animals and algae will be further analysed in the following section. The taxa found are listed in Table 2. The average biomass per unit area, and other main results are summarised in Table 3. The occurence of organisms in specific samples is tabulated in Tables 4 and 5. These tables are placed at the end of the chapter.

Macrofauna

CNIDARIA. Hydrozoa were present at loc. 1 and 5 as epiphytes on *Fucus* plants. Because of difficulties in counting individuals from colony forming animals, we have subjectively estimated the abundance of hydrozoans and categorised them (Table 4) as either: frequent (freq.), common (com.), or rare (sel.). Hydrozoans were found only in the lower part of the eulittoral zone at loc. 1, and at loc. 5 in the upper parts of the transects (Table 4). Several species were observed. This group will not be further analysed in this paper.

PLATHYHELMINTHES. The platyhelminths were only represented at loc. 1. Numbers are probably underestimated due to the sorting methods and the small overall size of members of this group (many belong to the meiofauna). This group will not be further analysed in this paper.

NEMATODA. The nematodes occurred scattered in samples from loc. 1 and 5. It appears that the nematodes had a higher occurrence in the lower part of the eulittoral zone at loc. 1. This may be due to a higher concentration of organic matter (food) at this site, and also a certain level of tolerance towards anaerobic conditions, which may prevail in the accumulated sediment.

Animal taxa. The classification follows Ruppert & Barnes (1994).
HYDROZOA
PLATYHELMINTHES
NEMATODA
OLIGOCHAETA
POLYCHAETA
Fabricia stellaris (Müller, 1774)
Polydora quadrilobata Jacobi, 1883
Spio filicornis (Müller, 1776)
Spio sp.
Pygospio elegans Claparède, 1863
Spirorbis spirorbis (Linné, 1758)
Eteone flava (Fabricius, 1780)
Capitella Blainville, 1828
Dysponetus pygmaeus Levinsen, 1879
ARACHNIDA Halacarida
Rhombognathinae
Rhombognathus sp.
Halacarinae
CRUSTACEA
Ostracoda
Cirripedia, *Semibalanus balanoides* (Linné, 1758)
Copepoda, Harpacticoida
Amphipoda, *Gammarus locusta* Linné, 1758
Isopoda, *Jaera* sp.
GASTROPODA
Littorina saxatilis Olivi, 1792 var. *groenlandica*
Margarites sp.
Margarites helicina (Phipps, 1774)
Natica sp.
Aclis sp.
BIVALVIA
Mytilus edulis Linné, 1758
Turtonia minuta (Fabricius, 1780)
Crenella faba Müller, 1776
Hiatella byssifera (Fabricius, 1780)
BRYOZOA
HOLOTHUROIDEA
PISCES

Algal taxa. The classification follows Hoek *et al.* (1995).
FLORIDEOPHYCEAE
Devaleraea ramentacea (L.) Guiry
Palmaria palmata (L.) Kuntze
Phycodrys rubens (L.) Batters
Ceramium sp.
Polysiphonia stricta (Dillwyn) Grev.
Polysiphonia arctica J.Agardh
Polysiphonia sp.
Ptilota serrata Kütz.
Rhodomela confervoides (Huds.) P.C.Silva
PHAEOPHYCEAE (FUCOPHYCEAE)
Ectocarpus siliculosus (Dillwyn) Lyngb.
Sphacelaria plumosa Lyngb.
Sphacelaria arctica Harv.
Scytosiphon lomentaria (Lyngb.) Link
Petalonia fascia (O.F.Müll.) Kuntze
Punctaria plantaginea (Roth) Grev.
Dictyosiphon foeniculaceus (Huds.) Grev.
Pilayella littoralis (L.) Kjellm.
Stictyosiphon tortilis (Rupr.) Reinke sensu Rosenv.
Elachista fucicola (Velley) Aresch
Chordaria flagelliformis (O.F.Müll.) C.Agardh
Desmarestia aculeata (L.) J.V.Lamour.
Chorda filum (L.) Stackh.
Fucus vesiculosus L.
Fucus evanescens C.Agardh
Agarum cribosum Bory
ULVOPHYCEAE
Ulothrix sp.1
Ulothrix sp.2
Urospora penicilliformis (Roth) Aresch.
Acrosiphonia arcta (Dillwyn) J.Agardh
CLADOPHOROPHYCEAE
Enteromorpha sp.
Blidingia minima (Nägeli ex.Kütz.) Kylin
Chaetomorpha melagonium (F.Weber & D.Mohr) Kütz.
Chaetomorpha capillaris (Kütz.) Børg.

Table 2. List of taxa found.

	Locality 1, sheltered		Locality 5, exposed		Locality 2, exposed and ice scoured	
Animal taxa	41	32/38	15	12/15	8	8/2/0
Average individuals per sample	863	881/844	205	205/204	0.8	2/0.5/0
Algae taxa	29		18		4	
Average biomass per sample (dry weight)	9.1 g		19.6 g		0.67 g	

Table 3. Comparison of localities.

ANNELIDA. (1) *OLIGOCHAETA*. The oligochaetes had the same pattern of distribution as the nematodes, with the exception of sample O4 (loc. 5) that had 115 individuals from one or more species, which can cope with exposure to fresh water (family: Enchytraeidae). Individuals present at the lower levels from loc. 1 probably represent genuinely marine species. (2) *POLYCHAETA*. The diversity of polychaetes was unexpected, both regarding numbers of species and individuals. A total of at least 14 taxa were found. Nine of these have been identified to species or genus level (Kirkegaard 1992, 1996). We estimate the species number to be approximately 20. See Table 4 for numbers and distribution. Most specimens belonged to *Fabricia stellaris* (Sabellidae) and *Polydora quadrilobata* (Spionidae), which are both colony forming taxa. They are tube builders and their tubes will at extreme low water protect them against desiccation. *Fabricia stellaris* is a common species found in shallow water between macroalgae in Denmark and also known from similar suitable localities in Greenland (Kirkegaard 1996). It is possible that *Polydora quadrilobata* is sometimes confused with *Polydora caulleryi* Mesnil, 1897, which is common at Disko (Kirkegaard 1996). Other members of the Spionidae found were *Pygospio elegans*, a tube builder which feeds on detritus and diatoms on sediment surfaces, and *Spio filicornis* and *Spio* sp., which are both suspension feeders. It was not possible to further identify *Spio* sp. which may in fact be a new species (see Worsaae 1999). *Capitella* sp. was common at loc. 1 (lower levels). The genus needs taxonomic revision. The forms encountered resembled oligochaetes with very small setae. They feed on organic matter from the surface layer. *Eteone flava* (Phyllodocidae), and some of the unidentified taxa, are predators (large, free living worms reminiscent of *Nereis*). They were found at loc. 1 (B1 and B2). *Dysponetus pygmaeus* is commonly found in the eulittoral zone in Greenland. It is approximately 2 mm long, white and with long, black setae in 2 bundles on each segment. *Spirorbis spirorbis* is common on *Fucus* in both temperate and arctic areas. However, it was found only at the lowest level of loc. 1. The majority of the polychaetes were found at loc. 1 (Table 4 and Fig. 2). The polychaetes are in fact the dominant animal group at the lower levels of loc. 1, while the Crustacea and Mollusca dominate the upper parts (Fig. 2). Only two taxa were found loc. 5: *Fabricia stellaris* (8 specimens scattered throughout the transects), and *Capitella* sp. (two specimens from the third level). Only one polychaete (*Fabricia stellaris)* was found at loc. 2.

ARTHROPODA. (1) *CHELICERATA*. Three unidentified sea spiders (Pycnogonida) were found at the lower levels of loc. 1. (2) *ARACHNIDA*, Halacarida, Marine water mites were fairly well represented in samples from loc. 1 and 5. The identification is based on Green & Macquitty (1987). A pale species (Indet. sp. 3 (pale) / Halacarinae), ca. 1.0 mm, dominated at the highly protected loc. 1 (rare at loc. 5). It was most frequent at the lower levels (A1, B1, A2, B2). A brown predator (Indet. sp. 2 (brown) / Halacarinae), ca. 1.3 mm, was found at A1 and A2. A small, ca. 0.4 mm long, green herbivore, *Rhombognathus* sp. (Rhombognathinae) was found scarcely at loc. 1, and more frequently at loc. 5. Three additional mites occurred in small numbers (Table 4). One of these, Indet. sp. 1, (Halacarinae), had very long palps and limbs. Loc. 1 and 5 differ significantly throughout the littoral zone (Fig. 2). At loc. 1 the frequency of mites decreases from 10 % (level 1) to 0 % (level 5), while at loc. 5 the frequency increases from 4% (level 1) to 38% (level 4).

CRUSTACEA. The crustaceans are a highly diverse group, and both sessile (class Cirripedia), and mobile forms occur. Their size spectrum includes both very small (class Ostracoda and Copepoda), and large specimens (Amphipoda and Isopoda / class Malacostraca). Crustaceans occured at all localities (except loc. 4). At localities with *Fucus* plants (loc. 1 and 5), they were found at every level throughout the littoral zone. (1) *OSTRACODA*. The ostracods were found at loc. 1 and 2 and most commonly at A1, A2, B1 and B2. They all looked very similar, which might indicate that only one species is in fact represented in the samples. (2) *CIRRIPEDIA*. This class was represented by a single species, *Semibalanus balanoides*. It occurred in relatively high numbers at loc. 1 upper levels. At loc. 5 it was present at the lower levels only. (3) *COPEPODA*. There were several species of copepods in the material, all belonging to the order Harpacticoida (Enckell 1980). Two main "types" were found, a large robust form which was clearly associated with the macroalgae, and a smaller, more slender form often encountered in the sediment. The copepods were found at all localities but were particularly numerous at loc. 5 where they were numerically dominant (Table 4). The tufted epiphyte, *Pilayella littoralis*, was a particularly popular place to live, and the plants contained high numbers of copepods. (4) *AMPHIPODA*. At least two species of gammarids (Amphipoda, suborder Gammaridea) were found. One is identified as *Gammarus locusta* using Enckell (1980) and Stephensen (1928), while the other forms remains unidentified. *G. locusta* was found at loc. 1 and 5, the unidentified species at loc. 2 and 5. None of the gammarids were found in high numbers. (6) *ISOPODA*. The isopods are represented by at least two species, one of which could be referred to the genus *Jaera* using Enckell (1980). They occurred scattered throughout the entire littoral zone, except for one sample (A4 with 426 individuals).

MOLLUSCA. (1) *GASTROPODA*. The gastropods identified comprised: *Littorina saxatilis* var. *groenlandica*, *Margarites helicina*, *Margarites* sp., *Natica* sp., and *Aclis* sp. The littorina snail was found at all localities (most frequent at loc. 1), and at loc. 1 and 5 throughout the littoral zone. The other gastropods were found at the two lowermost levels at loc. 1, where they will be exposed to very little desiccation. (2) *BIVALVIA*. The following species were present: *Mytilus edulis, Turtonia minuta, Crenella faba,* and *Hiatella byssifera.* They were all (except *Crenella faba*) found only at the lower levels of loc. 1. *Crenella faba* was also found in small numbers at loc. 5.

TENTACULATA. Bryozoans were found at loc. 1 at the lowermost levels, and both erect and disc shaped types were seen. The number of colonies was counted and is included in Table 4.

ECHINODERMATA. A few specimens (Holothuroidea) were found at loc. 1 (A1, B1).

CHORDATA. One juvenile Pisces was found at loc. 1 (B1).

Macrofauna - a summary

The frequency distribution (%) of major groups of animals at different levels throughout the littoral zone is shown in Fig. 2. Differences in fauna composition between a sheltered site and an exposed site can be deduced from this figure. Numbers of individuals and taxa are generally decreasing from the lower to the upper part of the littoral zone at the protected loc. 1 (Fig. 3), while almost constant throughout the littoral zone at the exposed loc. 5. Differences between the two sites are not evident at the uppermost levels. The average numbers are highest at loc. 1, 863 individuals per sample in average, and 35 taxa, while at loc. 5 the corresponding numbers are 205 and 15 (Table 3). Few animals, from the size range here investigated, were present at loc. 2 (0.8 specimens per sample / Table 3). No animals were found at loc. 4.

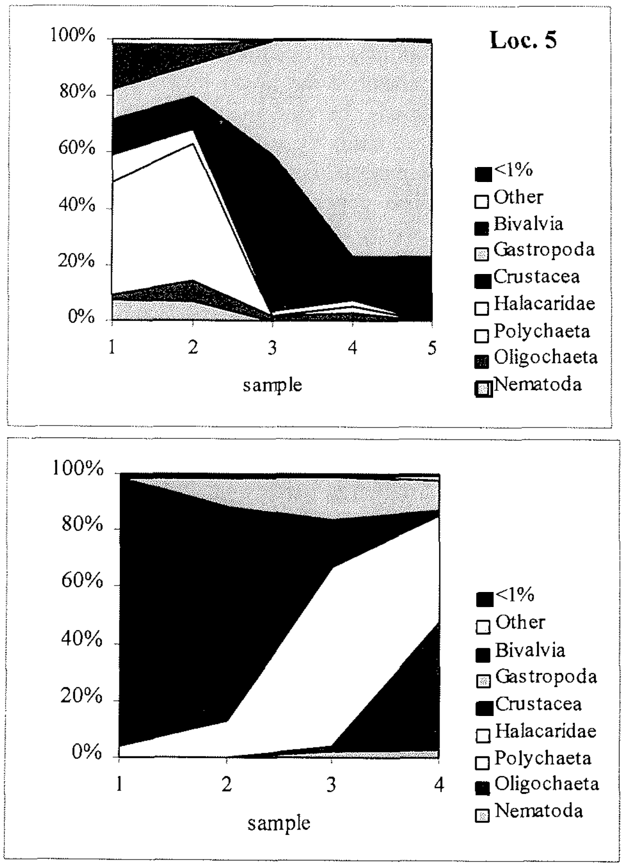
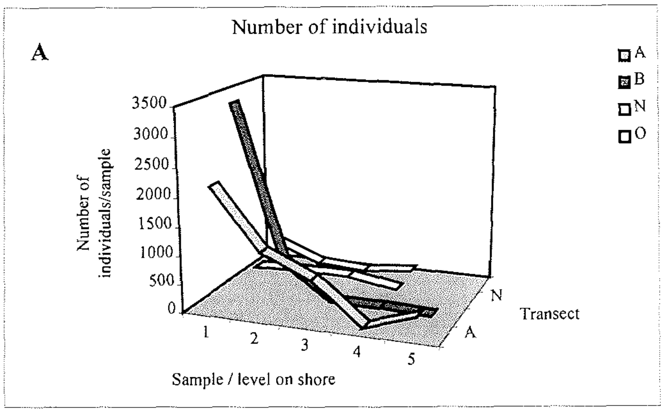


Fig. 2. Frequency distribution (%) of macrofaunal groups at two *Fucus* localities; loc. 1 (transect A, B); loc. 5 (transect N, O).



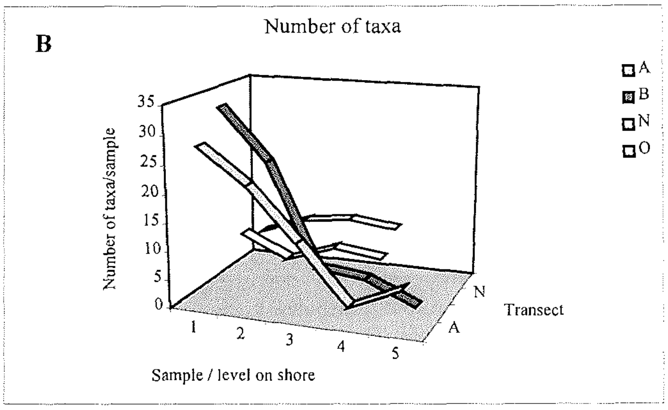


Fig. 3. Number of individuals (A) and taxa (B) in samples from two *Fucus* localities; loc. 1 (transect A, B); loc. 5 (transect N, O).

Macroalgae

The occurrence of species is shown in Table 5. The identification is based on Rueness (1977), and the nomenclature follows Nielsen et.al (1994).

Benthic macroalgae. *Fucus vesiculosus* was present in all samples from loc. 1 and 5. The morphology of the plants was very different at the two sites. Plants were small, (5 - 10 cm), dense and bushy at the exposed loc. 5, whereas they were taller (10 - 30 cm) and more slender at the lower part of the sheltered loc. 1. Plants from the uppermost levels at loc. 1 had the same overall size as plants from loc. 5, but maintained the same general morphology as other plants from this site. *Fucus evanescens* were only found in the lower levels at loc. 1. The biomass (averaged per site) of benthic algae (mostly *Fucus*) is highly variable. It was approximately twice as large at the exposed loc. 5 than at the sheltered loc. 1.

Other benthic algae include: *Devaleraea ramentacea, Phycodrys rubens, Chordaria flagelliformis, Petalonia fascia, Scytosiphon lomentaria, Chorda filum, Stictyosiphon tortilis, Enteromorpha sp., Chladophora rupestris, Urospora penicilliformis, Ulothrix* sp.1 and 2, *Blidingia minima. Devaleraea ramentacea* is a common red alga from the littoral zone at Disko Island and is found until 70°N in western Greenland. It was found in samples from loc. 5 (but was also observed near loc. 1 at moderately exposed sites). *Chordaria flagelliformis* was collected from the lowermost levels at loc. 1. This taxon contributes significantly to the algal biomass of sample B1.

Loc. 2 was dominated by filamentous green algae (Table 5), *Urospora penicilliformis*, (found in all samples) and *Blidingia minima* (E1). Two brown algae, *Petalonia fascia* and *Scytosiphon lomentaria*, contributed significantly to the biomass of sample D1. The biomass at loc. 2 was significantly lower than at loc. 1 and loc. 5 (Table 3).

Very few algae were found at loc. 4. The sample comprised three species: two *Ulothrix* spp. (forms distinguished by cell size) and *Chordaria flagelliformis* (juvenile specimen).

Our results indicate no general correlation between algal biomass and sampling level. This applies to all localities (Fig. 4A). However, the localities sampled differ significantly when average biomass per site is compared (Table 3). The biomass of benthic algae peaks at the exposed *Fucus* locality (loc. 5) and reaches the lowest values at the ice scoured loc. 2.

Epiphytic macroalgae. The most commonly occurring epiphytic alga was *Elachista fucicola*. As indicated by the name it normally grows on *Fucus* (especially on the receptacles). It was found on most *Fucus* plants and often on the conceptacles. However, specimens were smaller in comparison with material from Danish locations. In Greenland *E. fucicola* is growing also on several other species, e.g *Devaleraea ramentacea* (all specimens in this investigation). *Dictyosiphon foeniculaceus* was a common epiphyte on *Chordaria flagelliformis*. *Polysiphonia stricta* was associated with *Fucus*, and *Sphacelaria plumosa* was commonly found both epiphytic and in drifting material. *Pilayella littoralis* was found scattered throughout the littoral zone at loc. I and 5. It dominated in a sample from loc. 1 (B7), as an epiphyte on *Fucus vesiculosus*. The remaining epiphytes were found only in small quantities and scattered in the samples. There was no apparent correlation between epiphyte biomass and (1) sampling level within the littoral zone, or (2) degree of wave exposure (Fig. 4B).

Drifting algae. Drifting algae occurred in the samples as fragments among other algae. Most forms encountered are normally found in the sublittoral zone: *Palmaria palmata, Ptilota serrata, Sphacelaria plumosa, S. arctica, Desmarestia aculeata, Agarum cribosum*. They only contributed insignificantly to overall epiphyte biomass. The drifting algae are included in this investigation because they represent a food resource for benthic herbivores.

Chaetomorpha melagonium and *C. capillaris* were found free floating in our samples. This is a normal growth pattern for some species from the genus. *Chaetomorpha melagonium* most often grows attached to the substratum with a holdfast disc.

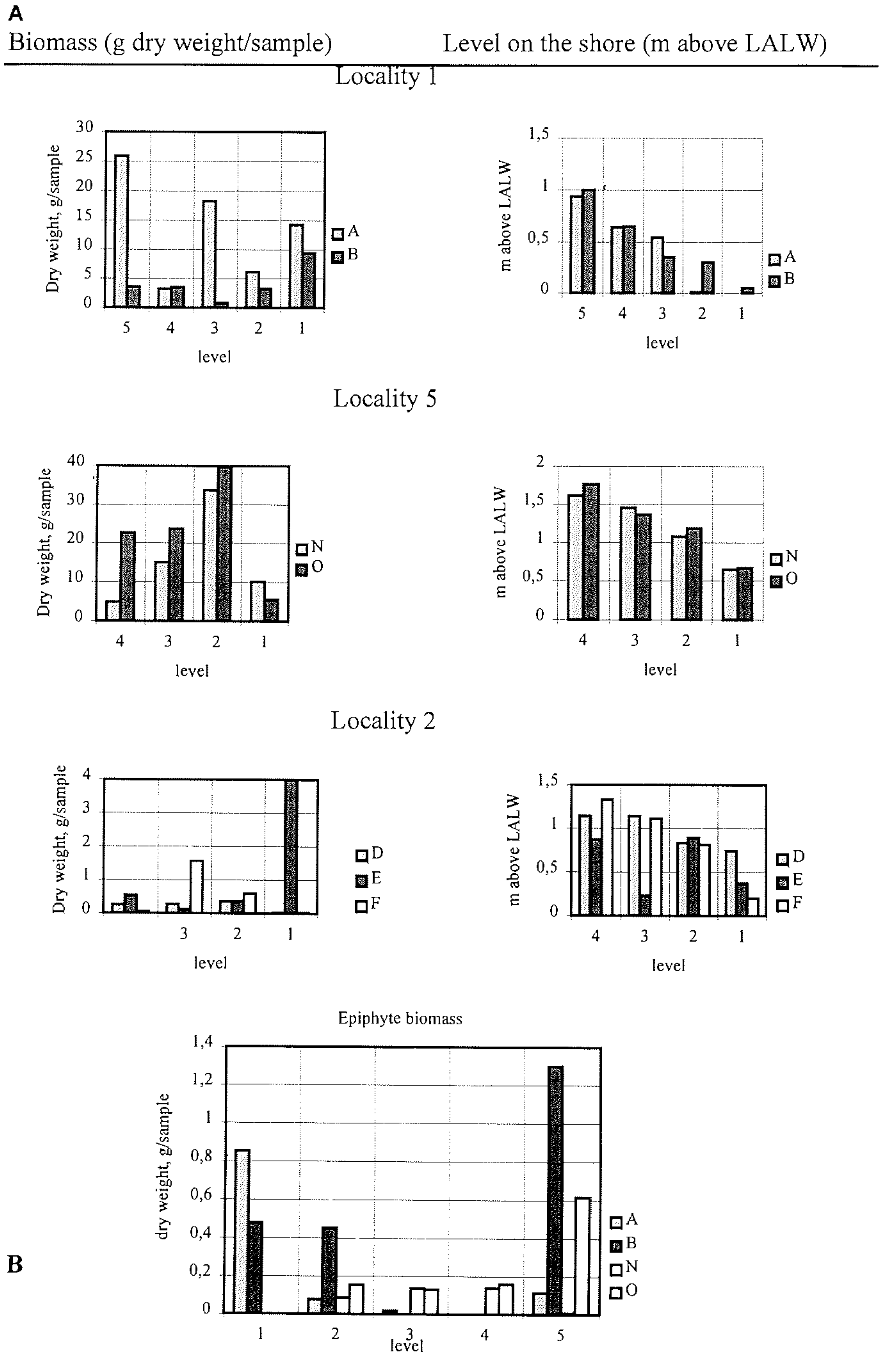


Fig. 4. (A) Biomass of benthic algae (dry weight: g/sample) and the height above LALW of each sample; (B) Biomass of the epiphytic algae (dry weight: g/sample) at loc. 1 (A, B) and loc. 5 (N,O).

Discussion

Macrofauna

POLYCHAETA. The lower part of loc. 1 can surprisingly be regarded as a small polychaete community reminiscent of that of soft bottom habitats. The water was almost stationary with accumulation of organic material between the stipes of the *Fucus* plants. The samples from the lower part of the eulittoral zone at loc. 1 were by coincident taken exactly where colonies of *Fabricia stellaris* and *Polydora quadrilobata* were established. The latter and closely related species are commonly found in shallow water and soft bottom localities (e.g. Ellis & Wilce 1961).

HALACARIDA. *Rhombognathus* sp. was relatively frequent at the exposed locality. It is apparently well adapted to this high energetic environment due to, e.g., well-developed claws that allow the animals to cling to the seaweeds, and also because of a relatively small size, which makes it easy to escape into small cavities. The contribution of halacarids to animal abundance (Fig. 2) was at loc. 1 decreasing from lower to higher levels. An opposite trend was evident at the exposed loc. 5 where it may be too turbulent for halacarids in the lower parts. The mites are likely to migrate to the upper part of the littoral zone, where the environment is more constant (longest time with the same degree of disturbance). At sheltered sites (e.g., loc. 1) the mites will probably prefer the most humid environments.

CRUSTACEA. (1) OSTRACODA. The number of ostracods was largest at the sheltered locality and towards the lowermost part of the transect. Most members of the ostracods, prefer a muddy/detrital substrate (Athersuch 1989). This type of substrate was only found at loc. 1. At low tide the environment is too dry for the ostracods in the upper part of the eulittoral zone. Although ostracods are mobile, their small size limits their possibility to migrate to a suitable microhabitat at low tide. The large number of specimens found in sample B1 (Table 4) may be due to a prevalence of *Chordaria flagelliformis* and *Dictyosiphon foeniculaceus*, which are possibly a better substrate and microhabitat than *Fucus* spp. (2) CIRRIPEDIA. *Semibalanus* spp. is a cosmopolitan intertidal taxon that can be used as an ecological indicator of vertical zonal patterns. Lewis (1964) uses this genus to identify the eu- and supralittoral zones. Dalby *et al.* (1978) incorporate the occurrence of *Semibalanus* in a biological characterisation of different degrees of exposure. On a scale from 0-9 (high exposure to ultimate shelter), the *Semibalanus* species are decreasing in abundance when approaching high numbers on the scale (compare loc. 1). At the very exposed loc. 5 the unexpected scarcity of *Semibalanus* is most likely due to a very irregular substrate. At loc. 2 ice scouring is most likely causing the absence of *Semibalanus*. (3) COPEPODA. The cause of the relatively large amount of copepods found at loc. 5 is difficult to explain. At loc. 1, the competition and predation may be the reason to the lower number. (4) AMPHIPODA. The scattered occurrence of amphipods in this investigation is not surprising. These animals are very mobile and will migrate and huddle together in the most humid areas at low tide. The number observed may be further biased because gammarids often escaped during sampling, in particular at loc. 5. (5) ISOPODA. The distribution of isopods indicates that they can not tolerate heavy exposure (only observed at loc. 1). This may be due to physical turbulence of the high energetic environment or lack of organic material, which is the main food source for many isopods. The large number of isopods found in sample A4 can be explained by their mobility and active search for the most favourable habitats on the shore.

MOLLUSCA. (1) GASTROPODA. The observed distribution of *Littorina saxatilis* var. *groenlandica* agrees with the exposure index characteristics of Dalby *et al.* (1978), i.e., abundant at the sheltered loc. 1 and rare or absent at the exposed loc. 2 and 5. There was no difference between loc. 1 and 2 in epiphyte biomass, which makes up the food source of these snails. The total number of *Littorina* snails is underestimated, because they are good migrators and tend to migrate downwards in the littoral zone at low tide. However, they are also found exposed to air with tighten closed operculae. Other gastropods observed have their primary habitat in the sublittoral zone. Only at ultimate sheltered sites are they sometimes to be found in the littoral zone (Madsen 1940, Petersen, pers. com.). (2) BIVALVIA. The species *Turtonia minuta, Crenella faba,* and *Hiatella byssifera* all have their primary habitat in the sublittoral zone. Only at ultimate sheltered sites are they to be found in the littoral zone. The presence of *Crenella faba* at loc. 5 can be explained by the occurrence of small crevices in the substrate, where this small bivalve can survive. *Mytilus edulis* is common in the littoral zone in the Arctic and in other climatic regions as well, at high levels in the littoral zone (e.g., Lewis 1964, Dalby *et al.* 1978). This general distributional pattern was evident only at loc. 2, where *M. edulis* was found in crevices (outside the sampling sites) throughout the eulittoral zone. Loc. 1 was too protected for this species, allowing only for a few relatively large specimens to be found.

Macrofauna - a summary

Crustacea and Mollusca dominate in the upper part of the littoral zone at loc. 1 (Fig. 2). Representatives from these groups are highly mobile species, which should frequent also the upper part of the shore. Polychaetes dominate (loc. 1) at the lower levels (Fig. 2). At the exposed loc. 5 with almost no polychaetes, the crustaceans dominate in the lower part (Fig. 2). We did not observe any tunicates or poriferans at any of the localities investigated. The results of this investigation indicate, apart from the differences in species occurring, that the number of individuals is clearly related to degree of exposure. The ultimately sheltered locality comprised four times as many individuals per sample as did the exposed locality (Table 3). This pattern is evident also from other investigations, e.g., Beckley & McLachlan (1980) who found, that the number of individuals at a sheltered locality was three times higher than at an exposed locality. The distribution of these individuals throughout the littoral zone also seems to be related to the degree of exposure. As seen in Fig. 3, the number changes dramatically at the sheltered site from the lower to the upper part of the transect, whereas no real changes were observed at the exposed site.

Macroalgae

Benthic macroalgae. The two *Fucus* localities differed with regard to the occurrence of morphotypes. The *Fucus* vegetation at loc. 5 was homogeneous throughout the littoral zone. Plants were morphologically intact and probably protected during winter from ice scouring by the ice foot. This homogeneity is also reflected in the distribution of macrofaunal elements at loc. 5. *Fucus* plants at loc. 1 differed markedly in size when comparing upper and lower levels.

The observed variability in algal biomass between sites and levels did not reveal very distinct patterns. However, the general picture is that the biomass is almost doubled at the exposed loc. 5 in comparison with the sheltered loc. 1. Loc. 2 differs significantly from the others in average biomass per area. Ephemeral vegetation is (when compared with perennial systems) not capable of building up that much biomass in only one year. This site was heavily affected by ice scouring and rafting preventing a general coverage of perennial algae. *Fucus* plants, and also specimens of *Mytilus* and *Semibalanus*, were only observed in cracks and crevices of the fairly smooth rocks. Many plants showed signs of morphological damage. The structure of the substrate is an important factor in settling success of *Fucus* plants and other perennial algae. However, in this case the ice scouring still seems to be the most important single factor in explaining the absence of perennial vegetation.

The *Fucus* species did not clearly display the expected zonation with *Fucus vesiculosus* occurring above *F. evanescens*. However, *Fucus evanescens* grew in the sublittoral zone at loc. 1 outside the transects analysed. The samples taken in the lower part of the eulittoral zone are in a transition zone, and they comprised only a few *F. evanescens* specimens. At this sheltered locality it appears as if *F. evanescens* is displaced sublittorally by its competitor *F. vesiculosus*. The absence of *F. evanescens* in samples from loc. 5 is most likely due to the effect of wave exposure impacting either the sampling process or the settling success of the algae.

Epiphytic macroalgae. There was no obvious correlation between the biomass of the epiphytes and the level of shore or the degree of exposure (Fig. 4B). It could have been expected that the fraction of epiphytes would affect the amount of macrofauna, but the degree of exposure surpasses this factor.

Comparison of localities

The four localities investigated are indeed very different, as was to be expected from variability in exposure, degree of ice scouring, and type of substratum. Especially loc. 4 deviated in type of substrate, and we consider this the main responsible factor for the very sparce macroalgae growth and the apparent absence of macrofaunal elements. The other three localities mainly differed in degree of exposure and ice scouring. The results reflect this difference (see Table 3). The average number of animal individuals was four times higher at the sheltered loc. 1 than at the exposed loc. 5. The number of taxa was correspondingly lower at loc. 5. Approximately 33 % of the animal taxa and 50 % of the algal taxa recorded from loc. 1 were retrieved at loc. 5. For a discussion of the station by station variability in average algal biomass see above.

Comparison with other similar investigations

The Arctic. As it is not possible to undertake a comprehensive comparison of Arctic investigations, we will here focus on the biodiversity of animals and algae in selected investigations (summarised in Table 6). It should be noted that in most of these the degree of exposure has not been taken into account. Only Ellis & Wilce (1961) and Wilce (1959) have accounted for the vertical distribution of macroalgae and macrofauna within zones of the littoral zone. Madsen (1940) listed 21 animal taxa from the NW Greenland littoral zone from ('Upernavik Harbour' and 'Prøven'). Nine of these were also found in this investigation. The northern location of sampling sites probably accounts for the overall much reduced animal diversity at these sites (number of animal taxa only 50 % of the number in this investigation. Madsen (1940) hypothesized that a reduced nutrition supply to coastal zone ecosystems might explain the scarcity of taxa observed. Ellis (1955) examined the littoral zone from Baffin Island sites (Arctic Canada). The species list comprised 34 faunal taxa of which eight genera are also recorded from Disko localities here examined. Wilce (1959) recorded 141 species of marine macroalgae at Labrador and NW Newfoundland sites. This investigation included collections from localities with different degrees of exposure and a range of substrates, as well as material from the sublittoral zone and rock pools. Wilce (1959) reported 33 macroalgae from the littoral zone of sites characterized by a bedrock substrate. Twenty-five of these taxa are also found during this investigation. Ellis & Wilce (1961) investigated the littoral zone at Baffin Island localities. They found 28 animal taxa (8 taxa also found here) and 39 algae (16). It should be noted that Ellis & Wilce (1961) include some laminarians from rock pools. Lee (1973) reports 14 algal genera from Arctic Canada, half of which were also represented in this investigation. Lee (1973) hypothesized that the limited algal biodiversity was a consequence of low nutrient supply at the localities investigated, and further, that this might generally account for the poor macroalgal growth in arctic areas, where the substrate is otherwise well suited for macroalgal growth. Hansen & Haugen (1989) recorded from Spitsbergen a relatively low number of taxa, 9 (5 taxa that also found at Disko Island sites) animals and 14 (10) algae. A low average temperature, heavy ice scouring, exposure to fresh water, and depletion of nutritents were used to explain the low biodiversity (Hansen & Haugen 1989). Hansen & Schlütter (1990) recorded 73 macroalgae from localities at Disko Island (Qeqertarsuaq), which is twice the number found in this investigation. This difference is due to several factors, the most important of which is the fact that Hansen & Schlütter's (1990) investigation is qualitive, where material was collected at different localities and including sublittoral species collected by diving and dredging from a boat.

The localities examined by Ellis & Wilce (1961), Wilce (1959), and Hansen & Schlütter (1990) are from a floristic point of view quite similar to those examined by us. As shown in Table 6, the number of animal taxa recorded as part of the above mentioned investigations is not any higher than reported by us. However, the number of taxa in common is quite low. These differences in faunal composition (few repetitions) can be explained by a more heterogeneous geographical distribution of animals (compared to algae) or it may relate to site specific differences that do not to the same extent impact algal diversity. Other possible explanations are small differences in sampling strategy, e.g., the use of different mesh sizes in the sieving process. However, an overall, preliminary conclusion based on the comparisons above is that the algal flora, in comparison with the associated animal community, is more homogeneous among Arctic sites.

Madsen (1940), Lee (1973), and Hansen & Haugen (1989) all explain the fairly low biodiversity of Arctic marine coastal flora and fauna by referring to a possible nutrient limitation of the coastal zone. However, this working hypothesis still needs to be critically tested in the field and in the laboratory.

	Latitude	Animal taxa		Algal taxa	
		Total	Shared	Total	Shared
Madsen (1940) LIT **AR**, G	72°N	21	9		
Ellis (1955) LIT **AR**, CAN	63–64°N	34	8		
Wilce (1959) LIT **AR**, CAN	48–68°N			33	25
Ellis & Wilce (1961) LIT **AR**, CAN	69–74°N	28	8	39	16
Lee (1973) LIT **AR**, CAN	60–69°N			14	7
Hansen & Haugen (1989) LIT **AR**, N	78–80°N	9	5	14	10
Hansen & Schlütter (1990) **AR**, G LIT + (SUBLIT)	60–69°N			73	32
This investigation (1998) LIT **AR**, G	69°N	41		32	

Table 6. Comparison of Arctic investigations - number of taxa found and taxa shared with the present study. (AR-Arctic / G-Greenland, CAN-Canada, N-Norway / LIT-littoral zone, SUBLIT-sublittoral zone)

Conclusion

In most places, the seashore can be regarded as a mosaic of numerous and different microhabitats, rendering it almost impossible to reveal a general pattern of organismal distribution and abundance. This investigation supports the statement and documents within a relatively small area great variability, only part of which can be explained by reference to environmental parameters such as degree of wave exposure and ice scouring.

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The Mellemfjord (Disko, West Greenland)
- hydrography and pelagic biology

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Abstract

This project is a brief introduction to Mellemfjord pelagic ecology. The data presented comprises hydrographic parameters (salinity, temperature, nutrients, and fluorescence) and biological core features with particular emphasis on protist plankton and mesozooplankton. Phytoplankton abundance seemed to be limited by a shortage of N and P. Organisms <20 µm (nanoplankton) contributed most to phytoplankton biomass Heterotrophic dinoflagellates constituted 30-75% of the total heterotrophic biomass in Mellemfjord. The mesozooplankton differed in composition from other Arctic sites. The meroplankton (larvae of echinoderms, brachyurans, gastropods, polychaetes, enteropneusts, and fish eggs) accounted for approximately 20% of the total mesozooplankton biomass. Copepod biomass peaked at approximately 80% of the mesozooplankton biomass and was found to be dominated by *Calanus* spp., copepod nauplii, and *Oithona* spp. Also *Acartia* spp. and *Centropages* spp. were represented in most samples. The small copepod taxa constituted approximately 50% of total copepod biomass, while in most other arctic environments it is generally the larger taxa that comprise the bulk of copepod biomass.

Introduction

The purpose of this project was to measure basic hydrographic and biological parametres of a West Greenland fiord ecosystem providing a snapshot picture of the pelagic system.

Material and methods

Area of investigation. The Mellemfjord (Fig. 1) is about 25 km long and 3-5 km wide. The approximate geographic coordinates are: 69°45 N / 54°37 W. The deepest area of the fiord (170 m) is located west of Enoks Harbour. Basic characteristics of the fiord system were published by Frische *et al.* (1995). These include (1) volume: 2.71 km^3, (2) surface area: 57.9 km^2, (3) average depth: 47 m, (4) freshwater inflow: 0.16 km^3 per year, and (5) water retention time: 10 months.

Transects and stations. Four transects, each comprising five approximately equidistant stations, were selected to represent the entire fiord (Fig. 1). Stations were numbered 1-5 in the south-north direction. Transect 6 comprised only one station.

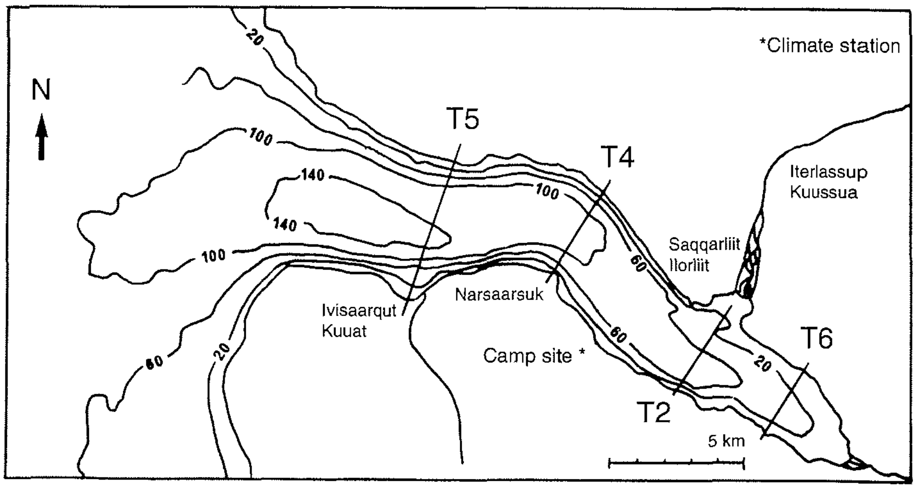

Fig. 1. Mellemfjord. Map showing bottom topography, transects and landmarks.

Dates of visits. This report presents data from three visits to the fiord. The first visit (2-3 July) comprised only a CTD profiling. Subsequent visits (20-21 and 27-29 July) included CTD profiling, net- and water sampling (Table 1).

2-3 July 1998					**20-21 July 1998**				**28 July 1998**			
	T5	T4	T2	T6	T5	T4	T2	T6	T5	T4	T2	T6
CTD	x	x	x	x	x	x	x	x	x	x	x	x
Phytoplankton net					x	x						
Hensen net					x							
WP2 net					x	x	x		x	x	x	
Bongo net									x			
Water samples					x	x			x	x		

Table 1. Sampling activities.

Hydrography. Profiling with a CTD (Seabird Sealogger 25) was performed at each station. The data sampling included pressure (depth), temperature, salinity, flourescense (algal biomass), light (PAR= "Photosynthetically Active Radiation"), and turbidity. The data were prepared for presentation using MS Word, MS Excel and the contour-plotting programme Surfer ver. 6.0 (Golden Software).

Water sampling. The water sampling programme (middle stations only) was based on the CTD profile und undertaken by means of a 10 l Niskin water bottle. The three depths sampled were: surface (2 m), chlorophyll maximum, and below chlorophyll maximum (typically 40-50 m depth). Subsamples were used for nutrient analyses, chlorophyll determination and quantification of algae and protists.

Water samples intended for nutrient analyses were taken from each sampling depth and immediately frozen. The samples were later analyzed at the National Environmental Research Institute (NERI).

Size-fractionated chlorophyll measurements (<20 μm, 20-45 μm, and total) were made using 2-4 l of seawater for each fraction. The GF/F filters were frozen immediately after filtration. The subsequent treatment took place at the Arctic Station laboratory. Extraction of pigments was in ethanol and lasted approximately 24 hours. Following whirlmixing and centrifuging the absorbance of the supernatant was measured spectrophotometrically at 480, 665, and 780 nm. The CTD fluorometer measurements were calibrated, based on a regression plot (Fig. 2) between corresponding values of pigment concentration (spectrophotometer versus fluorometer measurements).

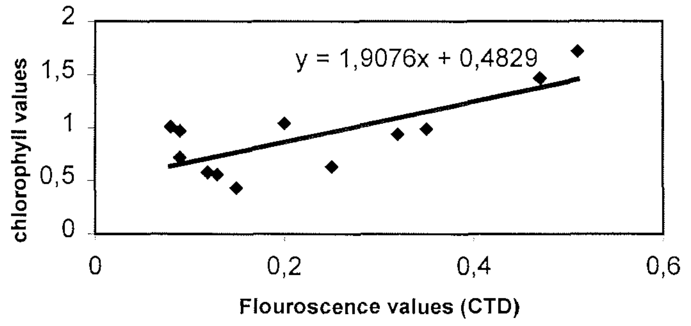

Fig 2. Plot of corresponding chlorophyll and CTD flourometer values, with superimposed regression line ($R^2 = 0.575$)

From each sampling depth 250 ml of seawater was fixed in Lugol's solution (final concentration 2%). This material was later used for the quantification of protist plankton using an inverted microscope (Uthermöhl 1956) and 50 ml sedimentation chambers. Whenever possible we counted 200-400 specimens of each group/taxon. The statistical confidence of the estimated cell density is then about ±15% (Kaas 1998). The cell volume was estimated based on cell measurements and the use of simple geometric models, and converted into carbon using the same factors as Thomsen (1992): 0.13 pg C μm^{-3} for dinoflagellates and 0.11 pg C μm^{-3} for other categories.

Phytoplankton net sampling. The net (mesh size 25 μm) was used to sample the upper 10 meters of the water column (see Table 1). Samples were fixed in Lugol's solution.

Copepoda	**Meroplankton**	**Others**
Copepod nauplii	Gastropoda larvae	Cnidaria
Calanus spp.	Polychaeta	Thecosomata
Acartia spp.	Brachyuran larvae	Decapoda
Centropages spp.	Echinoderm larvae	Amphipoda
Oithona spp.	Enteropneust larvae	Cladocera
Harpacticoid copepoda	Fish eggs	Fish larvae

Table 2. Zooplankton counting categories.

Group	**Regression**	**Reference**
Cnidaria	$W = 0.008 * r^{2.15}$	Båmstedt 1990
Gastropod larva	$W = 2.31 * 10^{-5} * L^{2.05}$	Hansen & Ockelmann 1991
Polychaete larva	$W = 1.58 * 10^{-4} * L^{1.38}$	Hansen 1998
Copepod nauplii	$W = 3.18 * 10^{-6} * L^{3.31}$	Berggreen *et al.* 1988
Calanus spp.	$W = 4.45 * 10^{-3} * (L * 10^{-3})^{3.38}$	Hansen 1998
Acartidea	$W = 1.11 * 10^{-5} * L^{2.92}$	Berggreen *et al.* 1988
Centropagidea	$W = 0.45 * (7.97 * 10^{-7} * L^{2.45})$	Breteler *et al.* 1982
Oithonidea	$W = 9.47 * 10^{-4} * L^{2.16}$	Sabatini & Kiørboe 1995
Harpacticoid copepod	$W = e^{(1.0275 * \ln L - 7.0703)}$	Satapoomin, Unpubl.
Fish egg	$W = \text{volume} * 0.14\ \text{pg/m}^3$	Kiørboe *et al.* 1985
Cladocera	$W = 10^{(4.15 * \text{LOG}(L) - 11.16)}$	Uye 1982
Echinoderm larva	$W = 3.06 * 10^{-8} * L^{2.88}$	Hansen 1998
Enteropneust larva	$W = 8.06 * 10^{-5} * L^{1.7}$	Hansen 1998

Tabel 3. Biomass estimates based on regressions, where L is body length, and W the weight in mgC/individual (based on a handout prepared by Benni Hansen, Roskilde Univ. Center, Denmark). The equation for *Calanus* spp. is from *C. finmarchius*. The equation for Cladocera refers to *Podon leuckarii*. The biomass of echinoderm larvae is based on an equation that applies to the second Bivalvia larval stage.

Zooplankton net sampling. The Hensen net (45 μm) was used once (Table 1). The diameter of the net was 55 cm. It was pulled vertically from 50 m depth giving a filtered water volume of 11.87 m^3. The WP2 net (200 μm) was used repeatedly (see Table 1). It was deployed similar to the Hensen net. The ring diameter was 57 cm. The volume filtered was thus 12.75 m^3 (50 m) and 15.30 m^3 (60 m). The Bongo net (500/1000 μm) was deployed while the ship sailed at a speed of approximately 3 knots. The net was lowered for 6 minutes and retrieved for another 6 minutes (22 m/min.), creating a V-shaped pull that was estimated to reach a depth of 50 m. The total distance of the pull was 1115.69 m and the diameter of the nets 60 cm. The volume filtered was thus about 315 m^3. All samples were initially fixed in formalin (4%).

Zooplankton analysis. The zooplankton samples were analysed for abundance (cells/m^3) and biomass (mg C/m^3) at RUC (Roskilde University Center). Samples were initially split into subsamples each comprising about 200 individuals. The taxonomic resolution is according to Table 2. An estimation of carbon content (mg C m^{-3}) was made based on the equations given in Table 3.

Results

Hydrography, algal biomass, and nutrients

Contourplots (transects and length profile of fiord) are shown in Figs. 3-8. (1) *Temperature* (Figs. 3-4). The surface temperature (5-10 m depth) was 5-8°C in all transects. There is a fairly steep, vertical temperature gradient in the surface water. The temperature at the bottom is <1°C. (2) *Salinity* (Figs. 5-6). All transects displayed the same pattern with horizontal isohalines and a fairly steep surface gradient. The salinity of the bottom water was approximately 33 ‰. The minimum surface salinity was 28 ‰. The upper 1-2 m of the water column is thus influenced by freshwater. Wind and tide effects are traceable down to about 10 m depth. (3) *Chlorophyll* (Figs. 7-8). A subsurface chlorophyll maximum layer at 15-30 meters depth was evident from all transects. A reduction in algal biomass took place during the sampling period. The maximum values measured during the three sampling periods were: 2.80 mg C/m^3, 1.60 mg C/m^3 and 1.30 mgC/m^3. (4) *Nutrients*. Table 4 summarizes measured values of phosphorus, nitrogen, and silicium. The detection limit for PO_4 is 0.09 µmol/l and for NO_3 0.06 µmol/l. The growth of diatoms is assumed to be limited at Si values <2.0 µmol/l (Egge and Aksnes 1992). The high NO_3 values measured during the second period (transect 4) are most likely caused by a contamination of the samples.

		PO4		NO3		**NO2**		**NH4**		**Si**	
		I	II	I	II	I	II	I	II	I	II
T4	Top	0.14	0.13	0.08	2.16	0.00	0.00	1.12	0.20	5.26	5.29
	Chl.max.	0.14	0.19	0.24	3.46	0.01	0.02	0.84	0.48	1.26	2.67
	Bottom	0.29	0.40	1.80	3.76	0.07	0.09	1.76	1.72	2.53	3.35
T5	Top	0.08	0.09	0.78	1.12	0.01	0.00	1.13	0.65	2.71	2.43
	Chl.max.	0.12	0.16	1.14	0.87	0.00	0.02	0.98	0.86	1.26	0.91
	Bottom	0.38	0.47	4.86	3.12	0.11	0.09	2.57	2.06	4.13	2.86

Table. 4. Nutrient concentrations (µmol/l); middle station of transects 4 & 5 on 20 July (I) and 28 July (II).

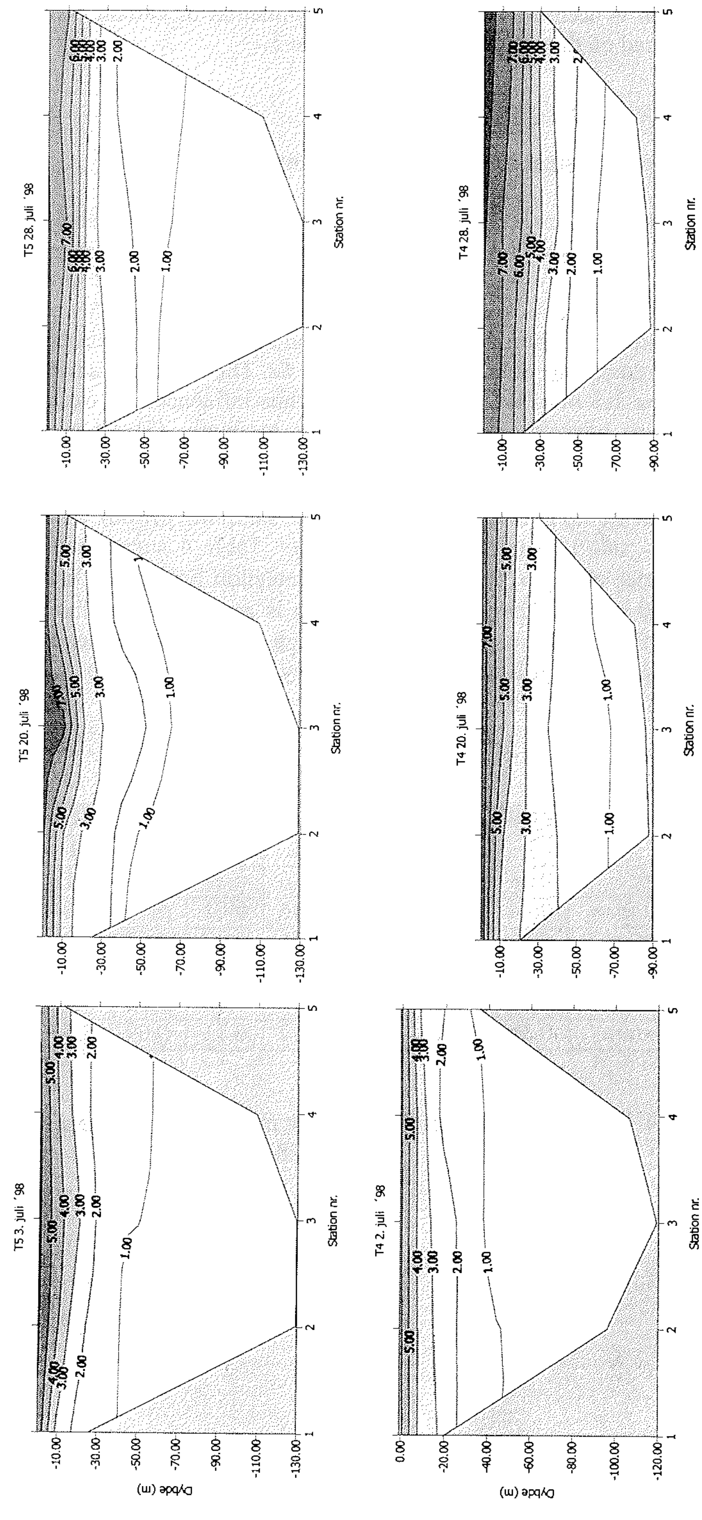

Fig. 3.
Temperature
T5 and T4

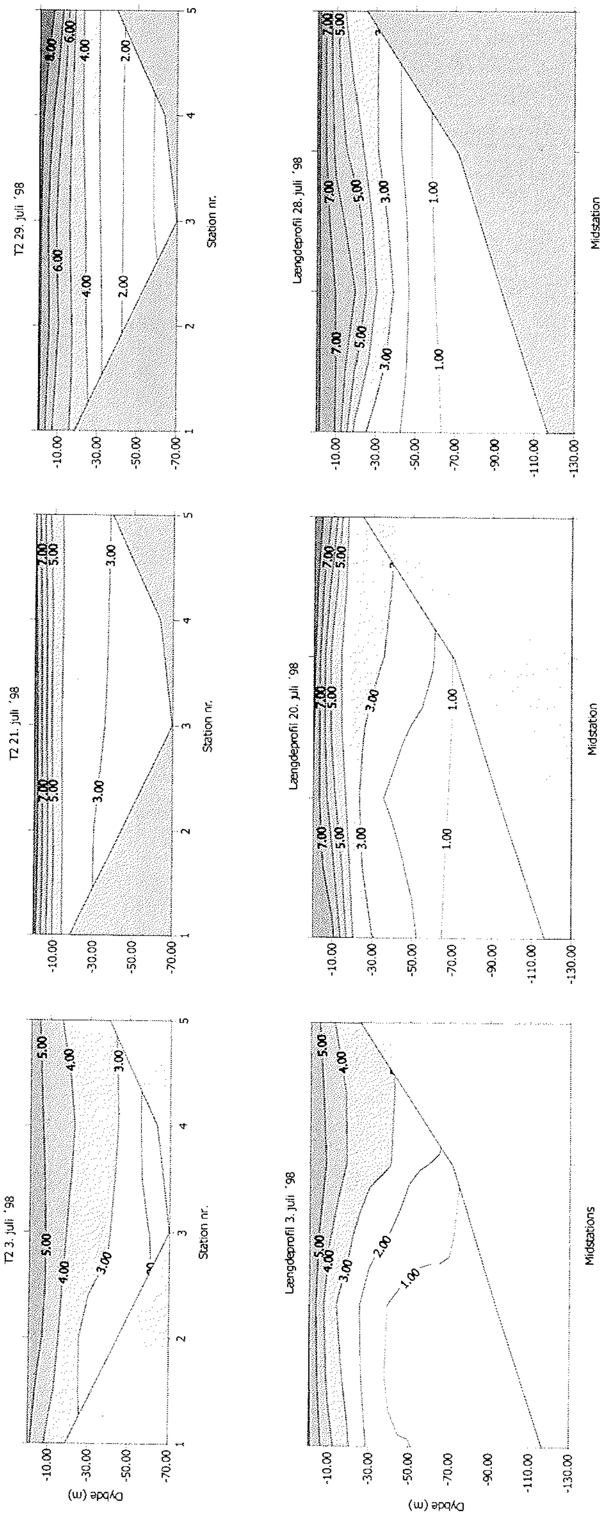

Fig. 4.
Temperature
T2 and length
profile

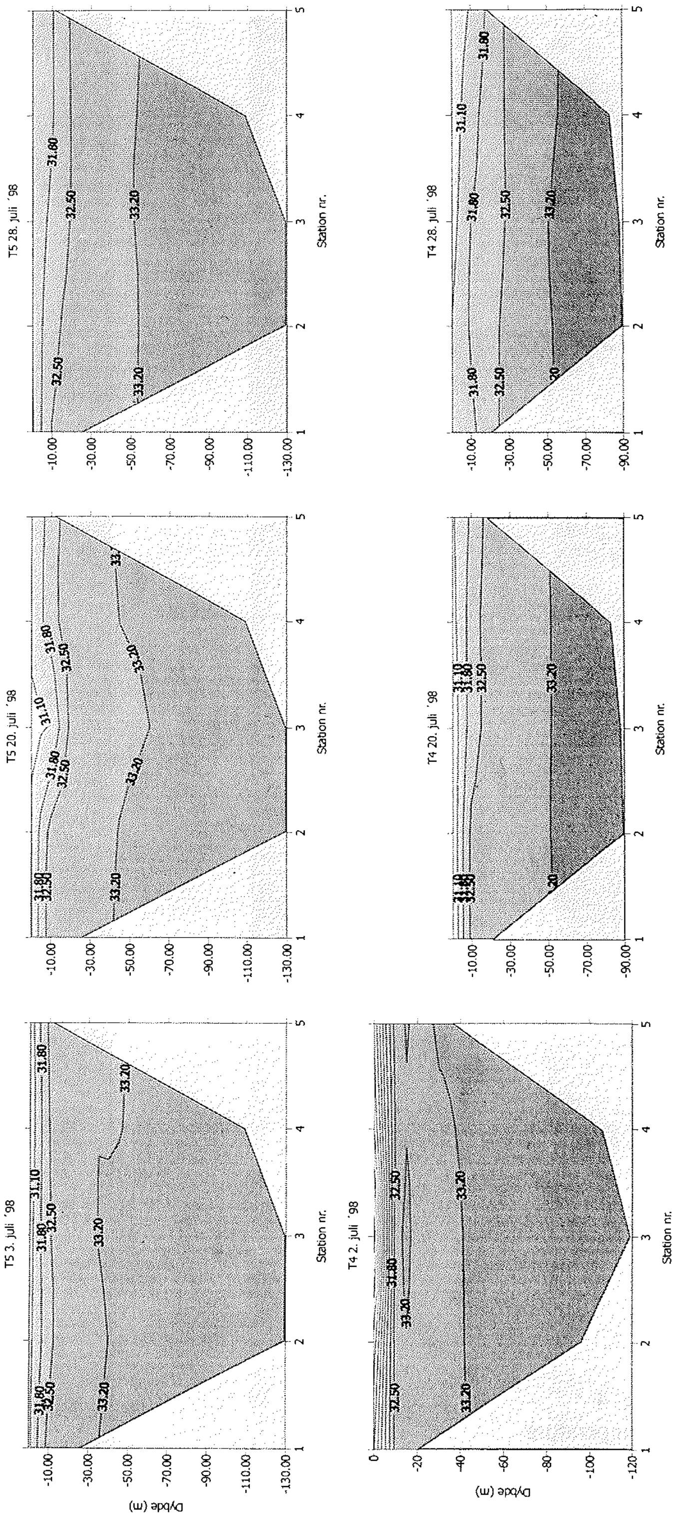

Fig. 5.
Salinity T5 and T4

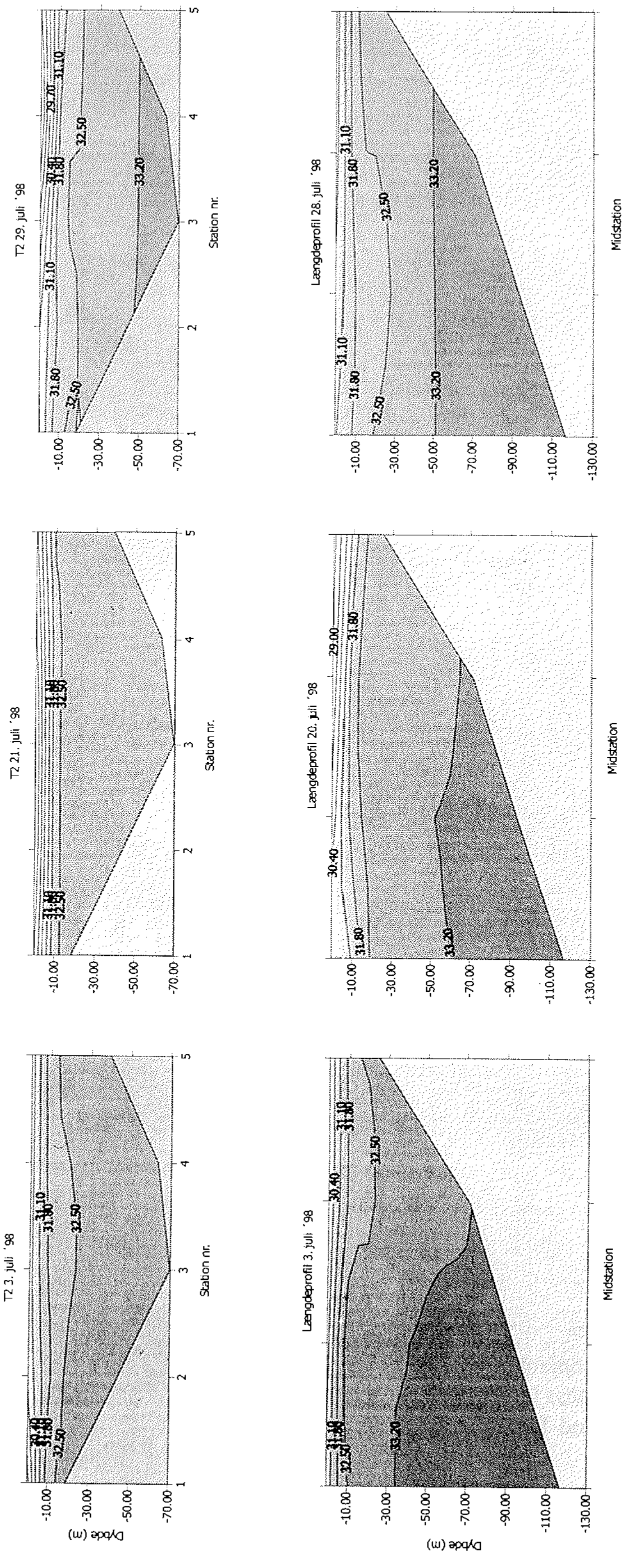

Fig. 6.
Salinity T2 and
length profile

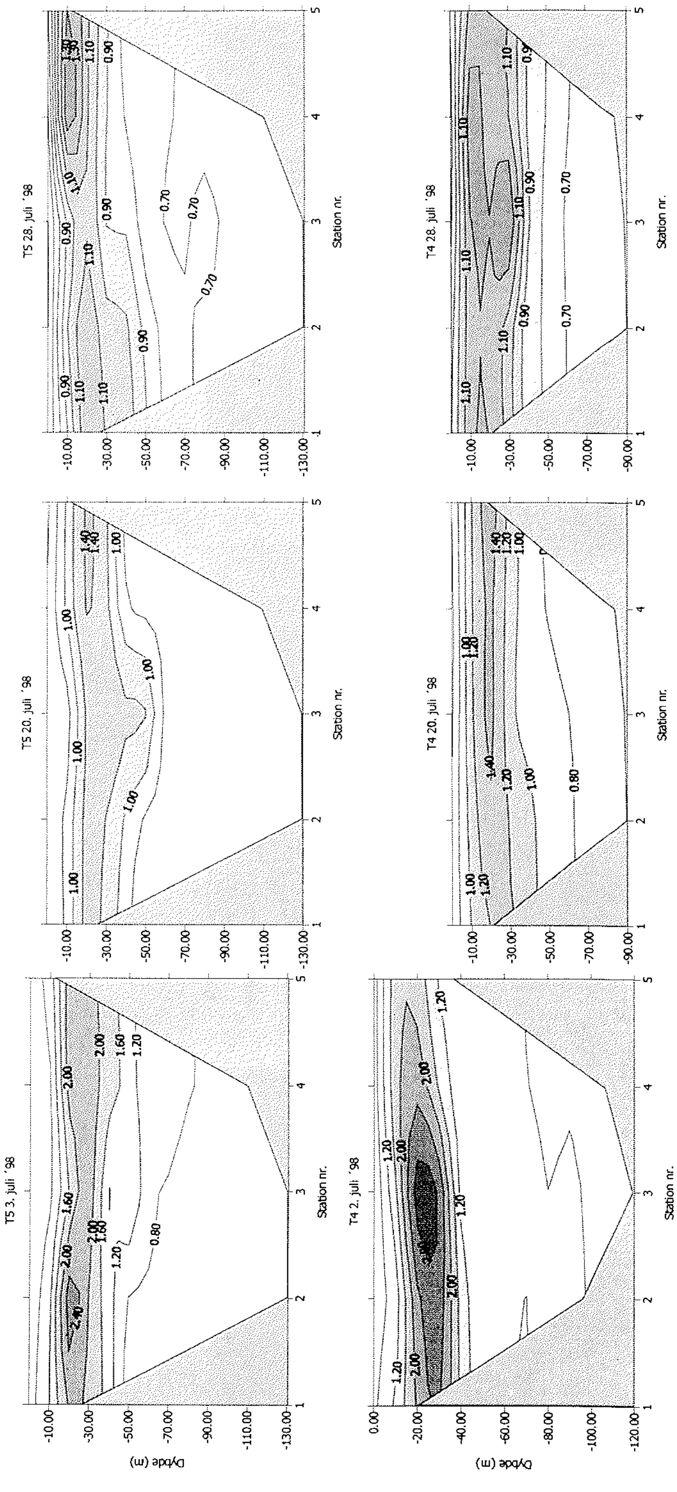

Fig. 7. Phytoplankton biomass (chl.). T5 and T4.

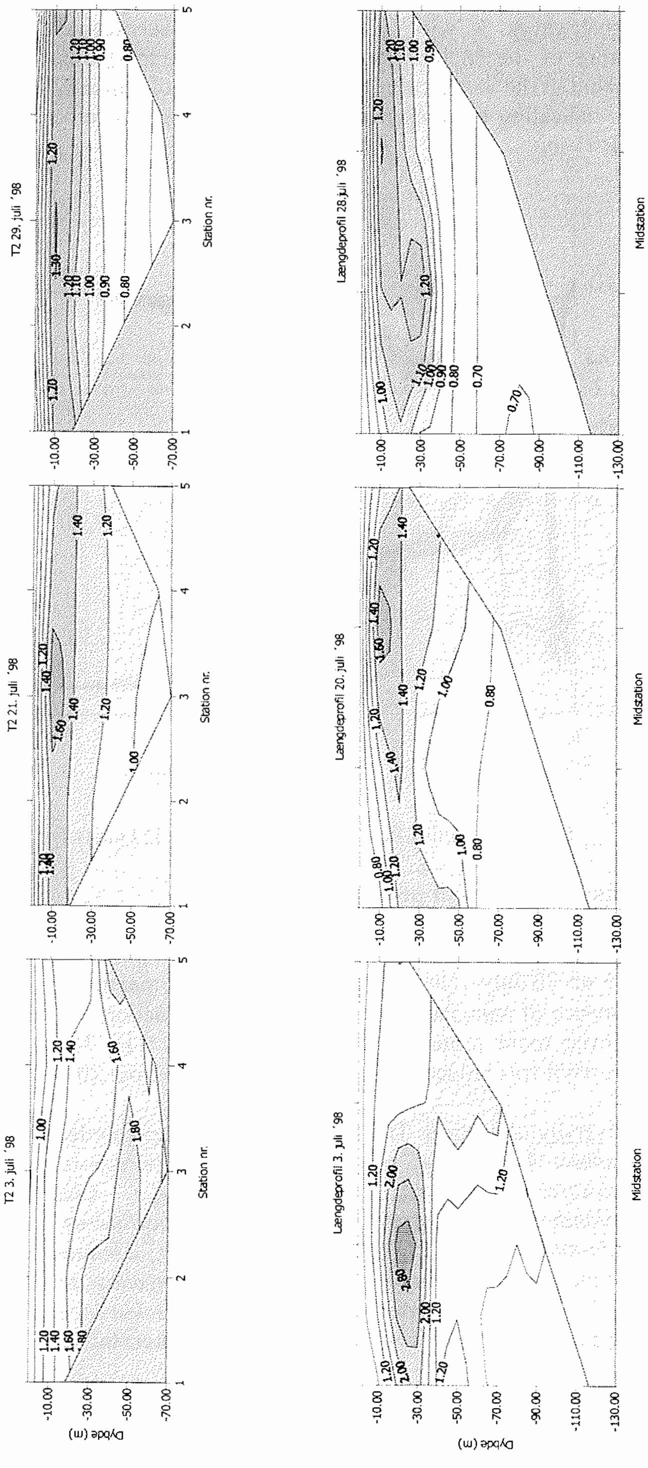

Fig. 8.
Phytoplankton biomass. T2 and length profile.

Internal waves. A 'yo-yo' CTD cast, i.e. five successive casts, was carried out at the entrance of the Mellemfjord in order to test for the presence of an internal wave structure in the water column. Fig. 9 is a plot of temperature and salinity from all five casts indicating the presence of a small internal wave structure with an amplitude of about 15 m.

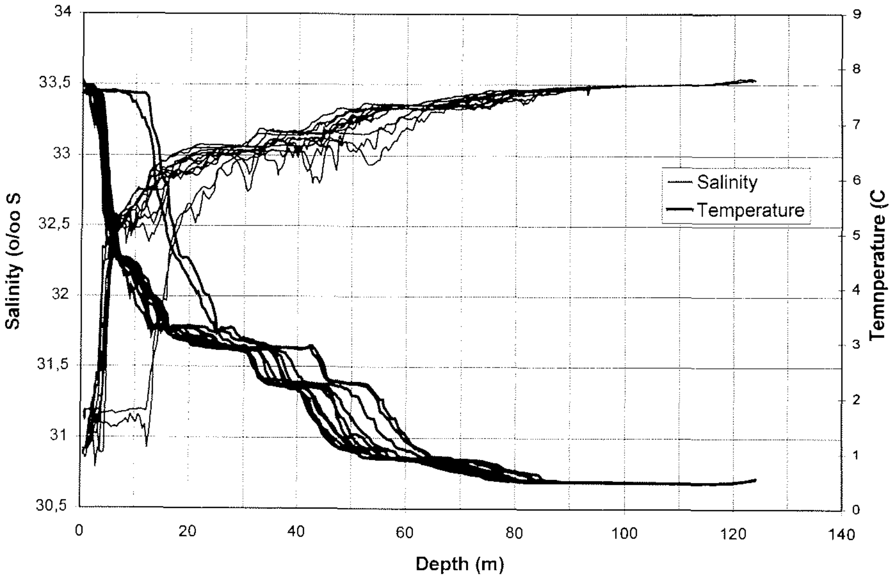

Fig. 9. Dataplot from five successive CTD casts from the Mellemfjord.

Biomass of algae and protists

Size-fractionated chlorophyll. Fig. 10 shows the results from midstations of transect 4 and 5 on 20 July. The subsurface chlorophyll maximum is evident as is also a clear dominance of nanoplankton, i.e., the <20μm fraction. The dominance of nanoplankton was even more pronounced on 28 July (Fig. 11). The algal biomass expressed as chlorophyll was reduced by approximately 40% from 20 to 28 July.

Biodiversity of protists. The following taxa were recorded from phytoplankton net tows at transect 4 (20 July). **Diatoms:** *Chaetoceros convolutus, Chaetoceros decipiens, Chaetoceros diadema, Chaetoceros socialis, Chaetoceros teres, Eucampia groenlandica, Leptocylindrus danicus, Leptocylindrus minimus, Proboscia alata, Pseudo-nitzschia* spp., *Skeletonema costatum, Thalassiosira* spp. **Dinoflagellates:** *Ceratium arctium, Dinophysis acuminata, Gonyaulax triacantha, Gymnodinium* spp., *Gyrodinium* spp., *Heterocapsa triquetra, Minuscula bipes, Protoceratium reticulatum.* **Crysophyceae:** *Dinobryon balticum.* **Protista incertae sedis:** *Ebria tripartita.*

Protist plankton - quantitative aspects. The results from the inverted microscopy counts are presented in Table 5 (cells/ml) and Fig. 12 (biomass μg C/l).

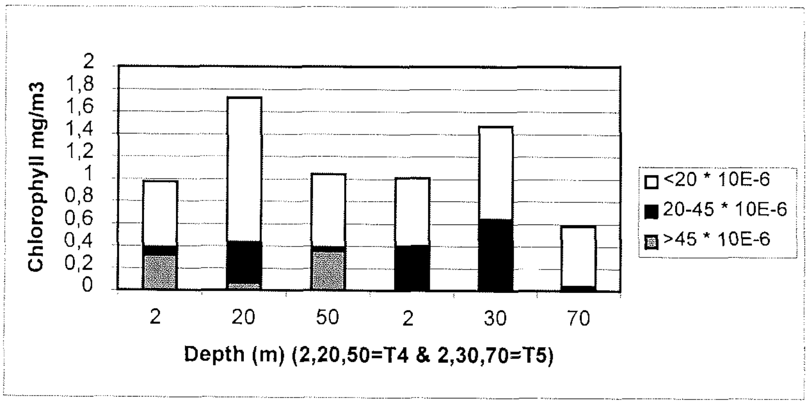

Fig. 10. Size fractionated chlorophyll (20 July 1998) / T4 and T5

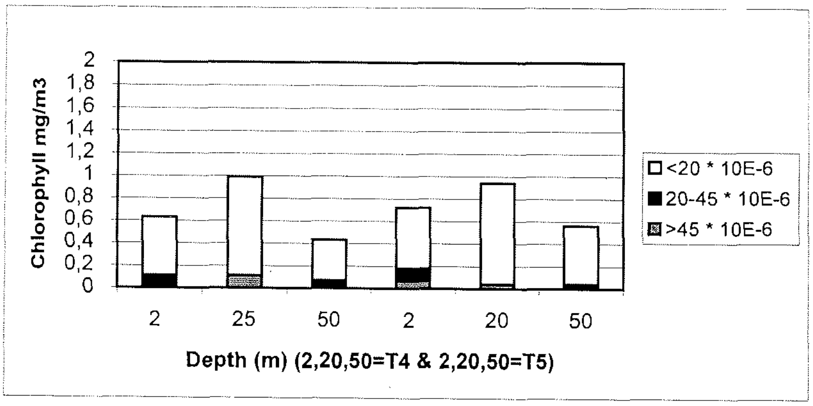

Fig. 11. Size fractionated chlorophyll (28 July 1998) / T4 and T5

Cells/ml	T4	T4	T4	T4	T5	T5
	Top	Chl. max.	Bottom	Chl. max.	Chl. max	Chl. max.
	20 July	20 July	20 July	28 July	20 July	28 July
Ciliates	19	20	3	4	12	2
Dinofl.	26	19	30	47	10	14
Cryptoph.	0	12	4	36	43	0
Diatoms	0	0	9	4	0	1
Chrysoph.	99	1	24	8	2	1

Table 5. Cell abundances (cells/ml) from selected samples.

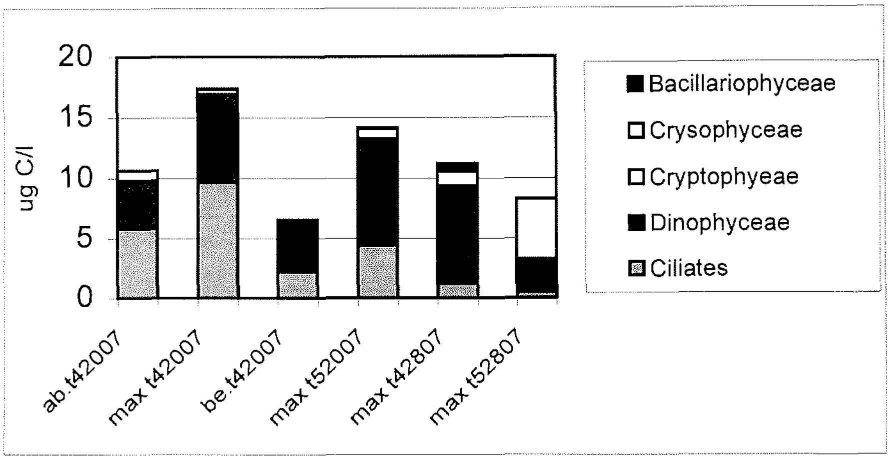

Fig. 12. Biomass contributions from major taxonomic groups (µg C/l); 'ab' = above chl. max. layer, 'max' = chlorophyll maximum layer, 'be' = below chl. max. layer, 't4' = transect 4, 't5' = transect 5, '2007' = collection date.

The biodiversity of ciliates was high. Tintinnids were found but were quantitatively insignificant. Dinoflagellates were the single most important group of organisms in terms of biomass. Many forms recognized were also found by Clausen *et al.* (1994). Most important were: *Gyrodinium spirale, Gymnodinium* spp. and *Ceratium* spp. Cryptophyceae were represented by a single morphotype. The cell was 6-8 µm long and with a characteristic curvature to the posterior cell end. The cells were well preserved by the fixative and the flagella were often intact. Crysophyceae were mostly represented by the colonial, mixotrophic *Dinobryon balticum*. Intact colonies comprising more than 100 cells were found in the net samples. In sedimented samples the colonies had disintegrated due to the rough handling of the organisms when shaking the sample prior to sedimentation. The diatoms were represented by numerous taxa. The quantitatively most important form was a small, pennate *Nitzschia*-like diatom. Only a few larger centric diatoms, i.e., *Thalassiosira* spp. and *Chaetoceros* spp. were found in the sedimented samples.

Mesozooplankton

Results of the mesozooplankton investigation using WP2 net (200 µm), Hensen net (45 µm), and Bongo nets (500/1000 µm) are summarized in Table 6 (numbers and average length (AVL) of the animals). Graphic analyses of the mesozooplankton data (animals/m^3 and mg C/m^3) are shown in Figs. 13-20.

20-21 July. The contribution of different categories of copepods is shown in Fig. 13 (average cell number approx. 700 animals/m^3). The nauplii, *Calanus* spp., and *Oithona* spp. were the most frequent taxonomic groups at all stations. The occurrence of meroplankton is shown in Fig. 14 (average cell number approx. 150 animals/m^3). Echinoderm and brachyuran larvae and fish eggs were the dominant groups of animals.

20-21 July 1998

Sampling tool Station Depth	WP2 T2 60m		WP2 T4a 50m		WP2 T5 50m		Hensen T5 50m	
	nos.	avl	nos.	avl	nos.	avl	nos.	avl
Cnidaria					64	700		
Gastropoda			64	650	32	200	4318	124
Polychaeta					512	950		
Copepod nauplii	2185	371	2944	509	1696	372	8128	217
Calanus spp.	1434	656	7424	1072	2816	861	508	350
Acartia spp.	785	689	64	500	736	596	508	225
Centropagidae			3008	614	96	600		
Oithona spp.	2185	386	1984	510	2304	492	2794	386
Harpacticoid spp.			64	500				
Copepoda (fragments)	683	345	768	875			508	
Copepoda (others)							508	575
Cladocera	68	475	64	500	480	523	508	500
Brachyura larvae	2355	1600	128	1650				
Echinoderm larvae	956	254	320	280	1280	249	762	233
Enteropneust larvae	102	1117			32	600		
Fish eggs	341	495			320	255	48768	103
Others	34	400						

27-29 July 1998

Sampling tool Station Mesh size	WP2 T2		WP2 T4a		WP2 T5		Bongo T5 500 µm		Bongo T5 1000 µm	
	nos.	avl	nos.	avl	nos.	avl	nos.	avl	nos.	avl
Cnidaria	32	300	256	550			64	12000	114	15214
Thecasomata							64	6000		
Gastropoda										
Polychaeta			32	450						
Decapoda									16	6000
Amphipoda							192	11667	65	12275
Copepod nauplii	1312	449	1984	473	2069	445				
Calanus spp.	1888	814	3008	795	1003	730	15616	1594	1154	3181
Acartia spp.	64	600	128	725						
Centropagidea										
Oithona spp.	1248	458	512	444					16	600
Copepod fragments	288		224							
Cladocera	192	567	128	813	107	550				
Brachyura larvae	64	1875	64	1650			1152	1719	2162	1615
Echinoderm larvae	128	300	128	313	85	325				
Enteropneust larvae	96	533			21	650	64	750		
Fish eggs	288	311	64	450	85	375				
Fish larvae							128	12500		

Table 6. Mesozooplankton results, total catch and average length (AVL).

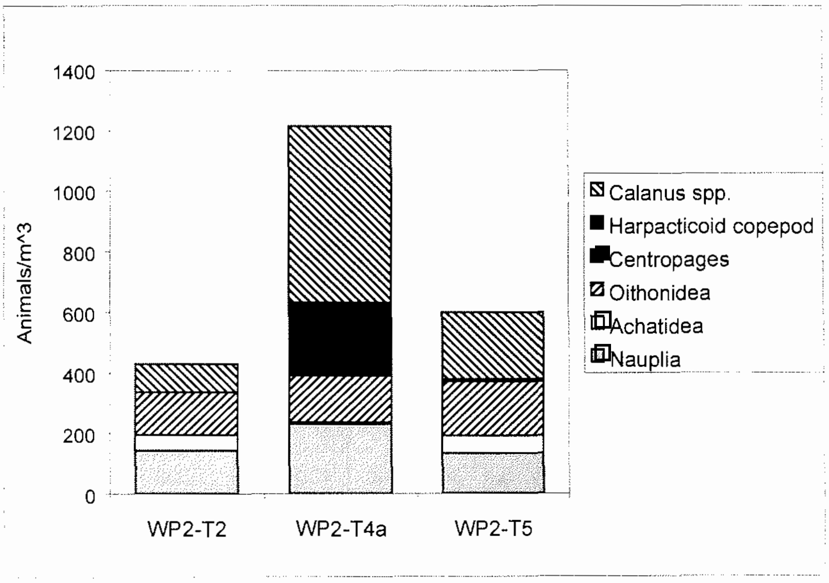

Fig. 13. Copepods (animals/m^3) / WP2 net / 20-21 July

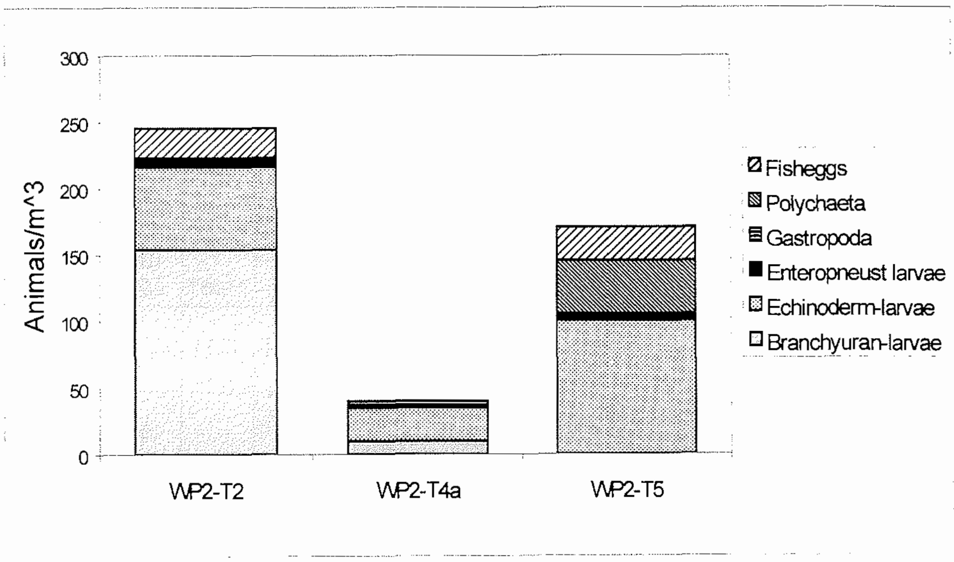

Fig. 14. Meroplankton (animals/m^3) / WP2 net / 20-21 July.

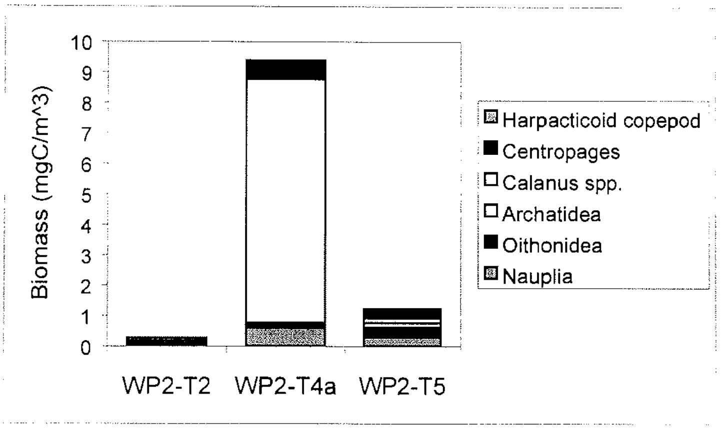

Fig. 15. Copepoda biomass / WP2 net / 20-21 July.

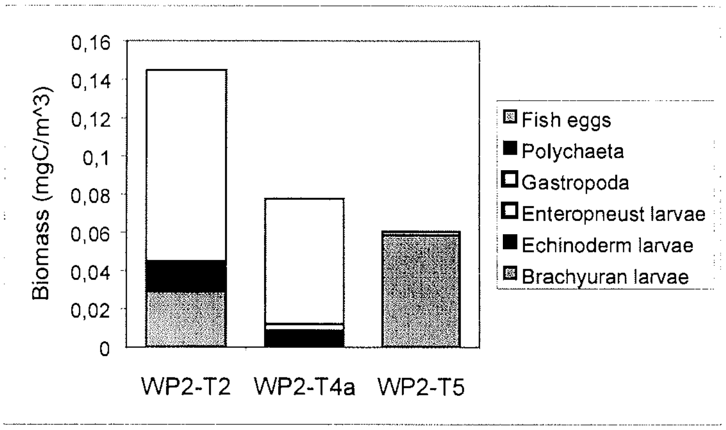

Fig. 16. Meroplankton and fish egg biomass / WP2 / 20-21 July.

Biomass contributions of copepoda and meroplankton are shown in Figs. 15-16. The average mesozooplankton biomass is 4 mg C/ m^3. *Calanus* spp. account for 8 mg C/ m^3 at station T4a. The average biomass of nauplii is 0.4 mg C/ m^3 and for *Oithona* spp. 0.2 mg C/ m^3.

27 – 29 July. The average number of animals is 360 specimens/m^3. The dominating groups are still the nauplii and *Calanus* spp. (Figs. 17, 19). *Oithona* spp. were present in small numbers. The overall diversity, as well as the total biomass, was much lower than during the previous sampling period (Figs. 13-16). Data on meroplankton (cell abundances and biomass) are shown in Figs. 18, 20. The average cell abundance is approximately 55 individuals/ m^3.

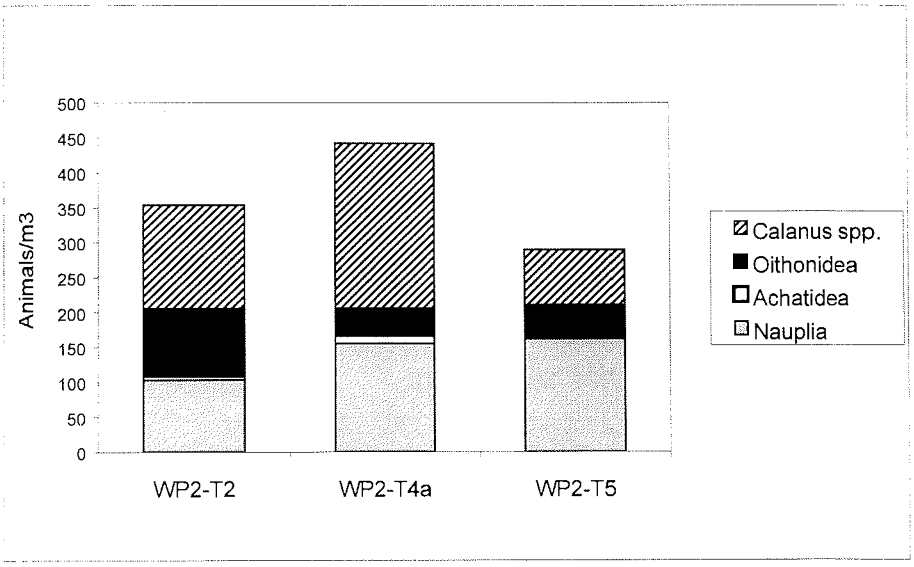

Fig. 17. Copepoda (animals/m^3) / WP2 net / 27-29 July.

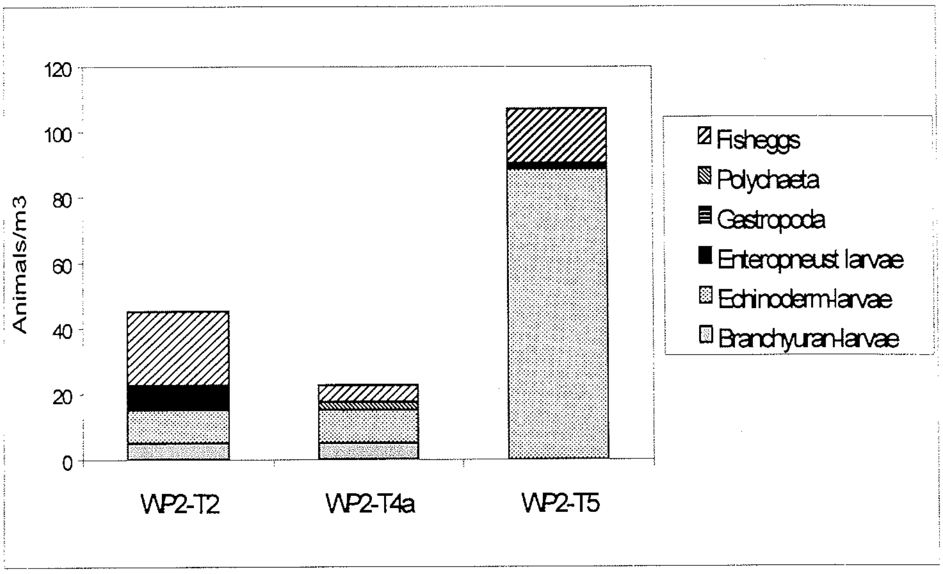

Fig. 18. Meroplankton and fish eggs (numbers/m^3) / WP2 net / 25-27 July.

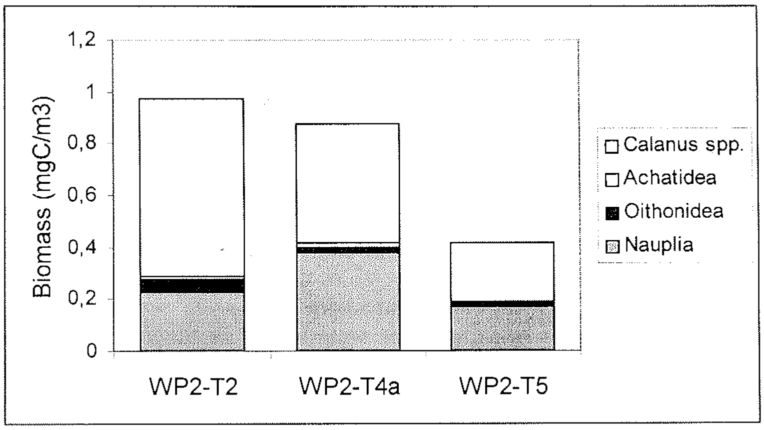

Fig. 19. Copepoda biomass / WP2 net / 25-27 July.

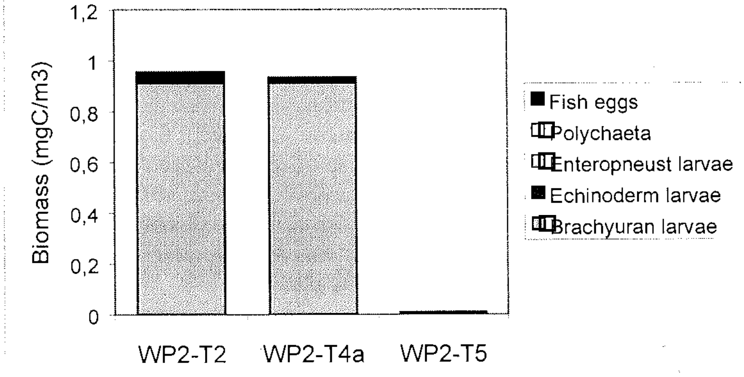

Fig. 20. Meroplankton and fish egg biomass / WP2 net / 25-27 July .

Discussion

Hydrography (incl. nutrients). The hydrography along the west coast of Greenland is above all influenced by the West Greenland current which flows northwards along the coast. This current originates from the mixing of the cold East Greenland current and the warm north Atlantic Irminger current. Part of the Davis Strait is under the influence of the Labrador current which is a genuine polar water flow. The West Greenland current can be found in bottom waters of the Disko Bay. It is characterized by a temperature of 2°C and a salinity of approximately 34 $^0/_{00}$.

During summer the Disko Bay encompasses three distinct layers of water including the remnants of the West Greenland current (Buch 1995) The surface water (upper 20-30 m) has a temperature of 3-10°C and the salinity, characterized by a significant vertical gradient, will usually be less than 33‰. Horizontal differences in salinity caused by freshwater outflows and melting icebergs is a common phenomenon in particular in the vicinity of the Jakobshavn Glacier. A fairly homogeneous water column (100-150 m) is a conspicuous midwater feature of the Disko Bay charaterized by temperatures <0.5°C. This water mass is found throughout the entire Disko Bay and also in coastal areas north and south of the bay proper (Buch 1995). The salinity increases slowly with depth. Vertical convection as a result of winter-cooling, in combination with ice formation in Disko Bay, seems to best explain the origin of this cold intermediate layer (Buch 1995).

Disko Bay has a complicated bottom topography. In the southwestern part, deepwater troughs render possible a certain inflow of deep water into the Bay. The general circulation within the Bay is counterclockwise. Outgoing water masses pass by Qeqertarsuaq/Arctic Station making their way to the northwest through a trough ('Godhavn Rende').

Only two of the three water masses described above for Disko Bay were found again in Mellemfjord (Akulliit). The bottom layer (the West Greenland current) is missing due in particular to the presence of shallow water areas outside the Mellemfjord that simply prevents the bottom waters from entering.

Nutrients. The upper water column and the chlorophyll maximum layer appear to be nutrient limited (N and P). A similar summer situation is known from Disko Bay (H.A. Thomsen, unpublished) and other West Greenland localities as reported by e.g. Trier (1998). The surface water nutrient limitation is consistent with the observed nanoplankton dominance of Mellemfjord waters. However, the Mellemfjord differs significantly from other sites examined because of the measured high values of Si in allmost all nutrient samples. A Si level >2.0 µmol/l is assumed to be a prerequisite to diatom growth (Egge & Aksnes 1992). This critical value is easily met by the majority of our samples. The small contribution of diatoms to phytoplankton biomass must be due to either N and P scarcity or a heavy grazing pressure.

Biomass of protist plankton. (1) *Phytoplankton.* The most significant part of an Arctic annual cycle of phytoplankton is the spring bloom. Fig. 21 shows data from an annual examination (May 1996 to July 1997) of protistplankton at a permanent station outside the Arctic Station (Thomsen, unpublished). The very conspicuous spring bloom starts in late May. A small, secondary bloom is evident in August. The phytoplankton biomass averages 10 µg C/l outside bloom incidents. Data from Disko Bay (Thomsen, unpublished) indicates a carbon:chlorophyll relationship which is close to 10:1

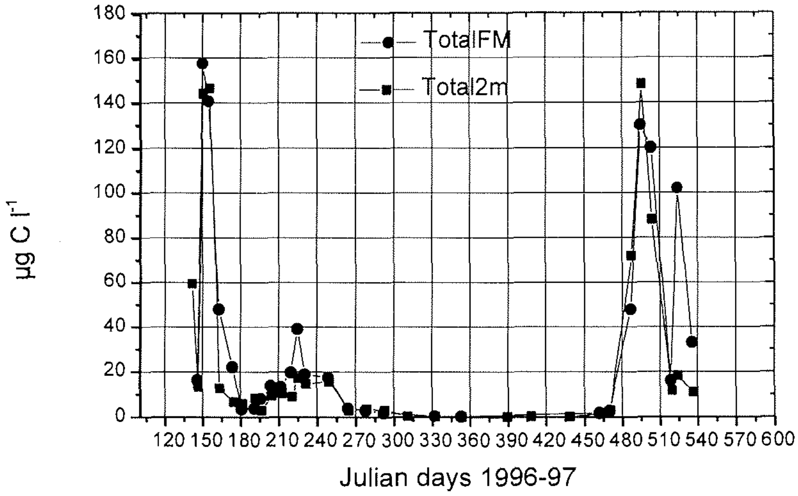

Fig. 21. Annual succession of protistplankton biomass at a permanent station ouside the Arctic Station, Qeqertarsuaq (Thomsen, unpubl. results).

At the time of our investigation the spring bloom must have come to an end, although a Mellemfjord delay of 2-4 weeks could be expected in comparison with the Disko Bay proper (due to in particular a prolonged ice coverage of the Mellemfjord area). During the investigation the chlorophyll maximum values decreased from 2.8 to 1.3 μg chlorophyll/l corresponding to 28 and 13 μg C/l using the correlation from Disko Bay. The latter value (13 μg C/l) is in good agreement with summer values from the Disko Bay (see. Fig. 21).

Heterotrophic Dinoflagellates. Our findings in terms of biomass level are consistent with comparable investigations from other marine environments (Table 7).

Locality	**min. μg C/l**	**max. μg C/l**	**Reference**
Kiel Bight	<1	25	Smetacek 1981
Kattegat, DK	<1	163	Hansen 1991
Disko Bay	<2	>8	Nielsen & Hansen 1995
Bisko Bay	2.5	53.4	Clausen *et al.* 1994
Barents Sea	<2	35	B. Hansen, unpubl.
Mellemfjord	0.9	4.4	This investigation

Table 7. Biomass contributions of heterotrophic dinoflagellates from north Atlantic localities.

Heterotrophic dinoflagellates (about 50% of all dinoflagellates) comprise 30-75% of the total Mellemfjord protist biomass. Clausen *et al* (1994) found a similar range (30-86%) in material from Disko Bay,

Ciliates. Ciliates varied in numbers from 2.000 to19.000 cells/l. The biomass values are within the same range as previously recorded from other north Atlantic sites (Table 8).

Locality	min. µg C/l	max. µg C/l	Reference
Disko Bay	<5	>20	Nielsen & Hansen 1995
Disko Bay	1	28	Clausen *et al.* 1994
Barents Sea	<1	22	B. Hansen, unpubl.
Mellemfjord	0.5	9.6	This investigation

Table 8. Biomass contributions of ciliates from Northatlantic localities.

Zooplankton – quantitative and qualitative data

Table 9 summarizes data from the WP2 net. It is obvious that major changes occurred just within the timespan of one week that separates the two sampling events. The overall abundance of Copepoda was reduced by almost 50%, and meroplankton by a significantly larger percentage.

In the Disko Bay proper the copepod mesozooplankton is totally dominating in June-July (Nielsen & Hansen 1995). This is also the case in most other Arctic environments, i.e., the Barents Sea (Hansen *et al.* 1996). The Mellemfjord plankton differs in several respects. There is an unusually large contribution of meroplankton, and the species composition of Copepoda is somewhat different. Fifty to seventy percent of the Copepoda are small taxa (incl. nauplii). In Disko Bay *Calanus* spp. make up 95% of all Copepoda (Nielsen & Hansen 1995). Investigations of mesozooplankton from the Nuuk area (SW Greenland) indicate a dominance of Copepoda but also a significant contribution of other Crustacea (Smidt 1979). The meroplankton is present from April to October and peaks during the month of July (33% of all mesozooplankton). The meroplankton has also been studied in the "Jørgen Brønlund Fjord" (North Greenland). The diversity was

Abundance (animals/m3)	20-21 July	25-27 July
COPEPODA		
Total	653	338
Nauplii	178	135
Calanus spp.	305	141
Oithona spp.	169	62
MEROPLANKTON		
Total	149	77
Brachyuran larvae	65	26
Echinoderm larvae	67	36
Fish eggs	17	15

Table 9. Abundances of Copepoda and meroplankton in Mellemfjord. Average values per sampling event.

very high (42 species) with a dominance of bivalves, polychaetes and echinoderm larvae (Andersen 1984).

Acknowledgements

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Comparative analysis of three sampling gear types for marine macrobenthos

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Abstract

The Mellemfjord on Disko Island in West Greenland is a relatively biologically unchartered region. Initial studies focussed on examining the abundance and diversity of Peracarida; in addition comparisons of three sampling gear types, mini van Veen grab, triangle dredge and Rauschert dredge were conducted. Twelve locations of the Mellemfjord, with three determined depths at four set locations leading from the mouth to the end of the fjord, were sampled.
Our studies revealed Amphipoda to be the most abundant taxon of Peracarida sampled, followed by Tanaidacea and Cumacea. Within the three gear types the mini van Veen grab collected the most animals in all Peracarida species per area calculated. The triangle dredge and the Rauschert dredge, both towed gear types, were less effected by patchiness and sediment structure than the mini van Veen grab. However, in optimal conditions the latter yielded an order of magnitude more Peracarida. This study demonstrates once again the difficulties concerning spacial scale presented to ecologists in deciding which gear type is most appropriate when sampling for research.

1. Introduction

During the field course in July-August 1998 we explored the Mellemfjord. The western side of Disko Island is characterized by three fjords. From north to south these are the Nordfjord, the Mellemfjord, and the Diskofjord. Several investigations were conducted in the Diskofjord until now (e.g. Nielsen and Hansen 1995, Schmid and Piepenburg 1993). First geological data were obtained in Mellemfjord during a field course (Gilbert et al. 1998), but hitherto no biological investigations were ever made. We went there with RV PORSILD and established our camp at the south coast near a small glacial meltwater stream (Fig. 1).

The **benthic biology** was divided into four main projects:

1. the present paper *Comparative analysis of three sampling gear types for marine macrobenthos*
2. *On the taxonomy of Spio filicornis (Spionidae, Polychaeta) from off Nipissat, Disko, Greenland*
3. *The diversity of Polychaeta, and their feeding habits related to types of sediment in Mellemfjord, Disko, Greenland* and
4. *Distribution and composition of meiofauna in the Mellemfjord.*

The Peracarida consist of seven orders, five of these occur in the Arctic (Amphipoda, Cumacea, Isopoda, Mysidacea, and Tanaidacea) and are supposed to play an important role in the food web of the Arctic seas (Dayton 1990).

Hitherto several gears, such as van Veen grab, box corer, and epibenthic sledge, have been employed in comparable investigations (e.g. Brandt and Schnack 1999; Schmid and Piepenburg 1993; Rauschert 1991) and yielded a fairly variable amount of animals.

It is generally accepted that the conventional van Veen grab (0.1 m^2) does not catch predominantly vagile animals, like Mysidacea, and also washes a lot of sediment away due to its bow wave (e.g., Schwoerbel 1980; Eleftheriou and Holme 1984). The disadvantage of dragged gear is, however, that it does not catch deeper buried inbenthic animals effectively. Therefore we took our samples in Mellemfjord with three different types of gear: A mini van Veen grab (MVVG), a triangle dredge (TAD) (both after R. M. Kristensen, Copenhagen) and a Rauschert dredge (RD) (after M. Rauschert, Berlin) and aimed to compare these gears in terms of effectivity, quantity, and quality of individuals sampled.

2. Material and Methods

2.1 Locality

The Mellemfjord lies at the western coast of Disko Island (West Greenland). Between the outermost and the innermost transect it is 22 km long and about 5 km wide (innermost transect Saqardlit: 3 km). The fjord gets freshwater from several glacier streams and adjacent 700 m high mountains. We took our samples between the 19th and 27th of July 1998. Positions and abiotic parameters of all stations are summarized in Table 1.

Names of the four transects:
I - Ivisarqut, **N** - Narssarssuk, **C** - Camp Site, **S** - Sarqardlit

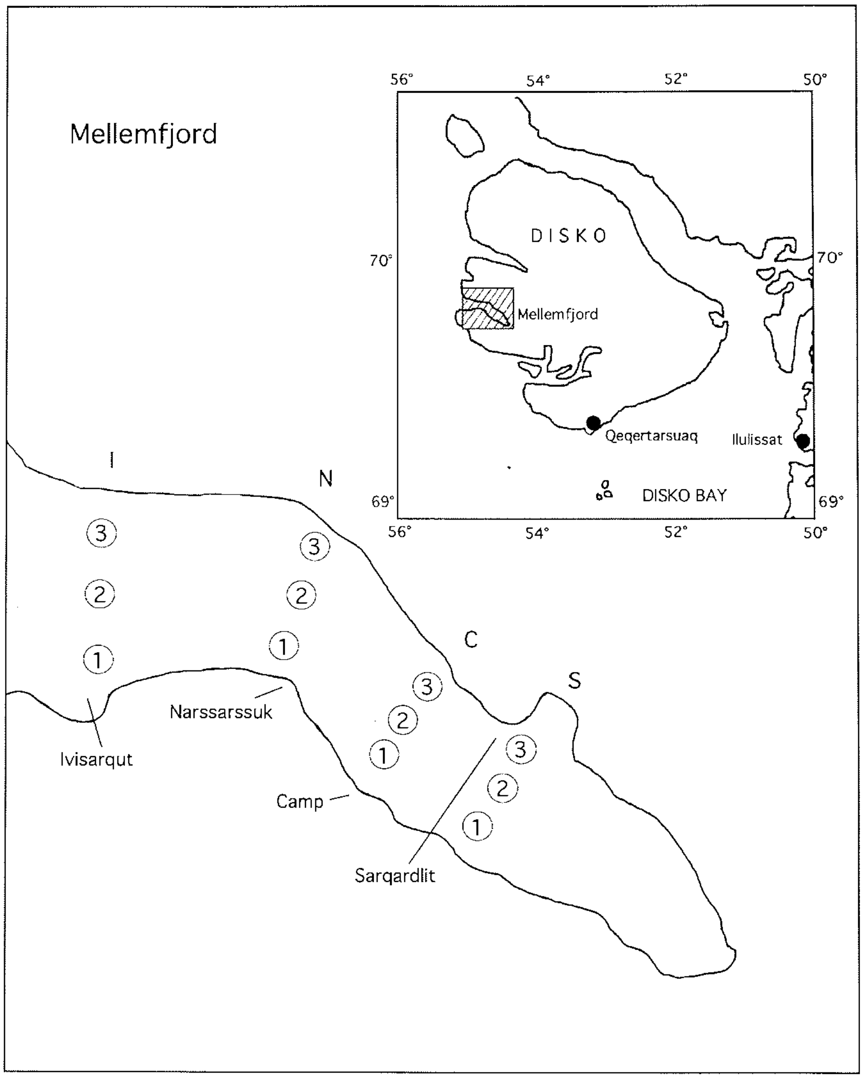


Fig. 1. Location of the study area

Table 1. Positions and abiotic parameters of all stations

Station	gear	date (all	time (UTC)	position start	position stop	temp °C	salinity ‰	depth m
I-1 a-c	MVVG	22.7.	1413	69.44.40 N - 054.47.50		8	37	30
I-1	RD	23.7.	2334	69.44.63 N - 054.47.39	69.44.78 N - 054.46.22	8	35	35
I-1	TAD	23.7.	2323	69.44.63 N - 054.47.38	69.44.65 N -054.47.56	8	35	30-40
I-2 a-c	MVVG	21.7.	0038	69.45.94 N - 054.47.05		7.8	33	135
I-2	RD	21.7.	0100	69.45.92 N - 054.46.92	69.45.87 N - 054.47.61	7.8	33	134
I-2	TAD	21.7.	0013	69.45.90 N - 054.47.15	69.45.90 N - 054.47.09	7.9	33	138
I-3 a-c	MVVG	22.7.	1330	69.46.44 N - 054.47.00		8	35	65
I-3	RD	23.7.	0020	69.46.68 N - 054.46.75	69.46.57 N - 054.45.68	7.6	35	60-80
I-3	TAD	23.7.	0050	69.46.61 N - 054.45.82	69.46.67 N - 054.46.38	6.9	35	60
N-1 a-c	MVVG	20.7.	1724	69.44.39 N - 054.39.31		7.5	32	60
N-1	RD	19.7.	2008	69.44.54 N - 054.39.21	69.44.81 N - 054.39.75	7.5	32	55
N-1	TAD	19.7.	2237	69.44.63 N - 054.39.28	69.44.57 N - 054.39.19	7.5	32	60
N-2 a-c	MVVG	20.7.	0027	69.44.88 N - 054.37.31		7.3	no data	90
N-2	RD	20.7.	0107	69.44.94 N - 054.37.69	69.45.18 N - 054.38.56	7.3	no data	97-112
N-2	TAD	20.7.	0052	69.44.91 N - 054.37.72	69.44.92 N - 054.37.82	7.3	no data	125
N-3 a-c	MVVG	20.7.	1756	69.45.07 N - 054.36.23		6.9	35	70
N-3	RD	20.7.	2302	69.45.35 N - 054.35.00	69.45.62 N - 054.36.60	6.9	35	60
N-3	TAD	20.7.	2334	69.45.61 N - 054.36.60	69.45.58 N - 054.36.70	6.9	35	60
C-1 a-c	MVVG	21.7.	2032	69.42.53 N - 054.35.04		9	34	50
C-1	RD	24.7.	1722	69.42.99 N - 054.35.68	69.42.69 N - 054.34.78	9.2	31	50-58
C-1	TAD	24.7.	1710	69.43.05 N - 054.35.70	69.43.07 N - 045.35.74	9.2	31	45-66
C-2 a-c	MVVG	27.7.	2145	69.43.44 N - 054.34.10		7.9	34	80
C-2	RD	24.7.	1806	69.43.36 N - 054.34.22	69.43.60 N - 054.34.77	8.2	34	75-82
C-2	TAD	24.7.	1839	69.43.40 N - 054.34.25	69.43.33 N - 054.34.11	8	34	82
C-3 a-c	MVVG	27.7.	2220	69.43.94 N - 054.33.18		7.2	34	60
C-3	RD	24.7.	2008	69.43.44 N - 054.33.33	69.43.13 N - 054.32.55	7.7	34	55-60
C-3	TAD	24.7.	1956	69.43.51 N - 054.33.69	69.43.47 N - 054.33.80	7.6	33	62-68
S-1 a-c	MVVG	23.7.	0005	69.42.08 N - 054.31.58		8	35	50
S-1	RD	24.7.	1342	69.42.21 N - 054.32.30	69.42.38 N - 054.33.33	9.4	no data	55
S-1	TAD	24.7.	1626	69.42.22 N - 054.32.40	69.42.29 N - 054.32.51	9.5	no data	60
S-2 a-c	MVVG	23.7.	0050	69.42.68 N - 054.31.58		8	35	70
S-2	RD	24.7.	1240	69.42.65 N - 054.31.83	69.42.84 N - 054.32.28	8.9	39	79
S-2	TAD	24.7.	1313	69.42.80 N - 054.32.10	69.42.81 N - 054.32.51	9,1	no data	73
S-3 a-c	MVVG	23.7.	0135	69.43.27 N - 054.30.99		8	35	30
S-3	RD	24.7.	1355	69.43.02 N - 054.30.90	69.43.21 N - 054.31.74	8.6	34	36
S-3	TAD	24.7.	1344	69.43.14 N - 054.30.90	69.43.03 N - 054.31.01	8.5	34	30

2.2 Description of the gear

For comparison of different methods to collect Peracarida we used the following gear:

I The Rauschert dredge (**RD**)
II The mini van Veen grab (**MVVG**)
III The triangle dredge (**TAD**)

I The Rauschert dredge (RD)

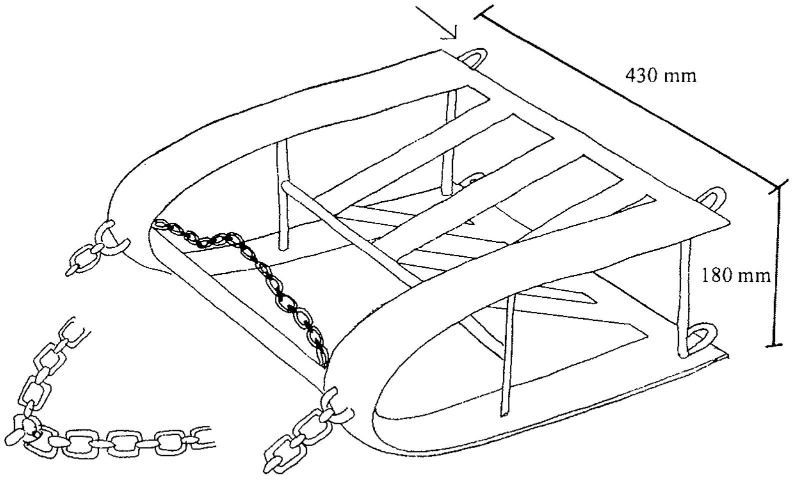


Fig. 2. The Rauschert dredge (RD)

The RD is a dredge consisting of three different nets. The main collecting net has a mesh size of 1.5 mm. For the protection of this net, it is covered by a second net with a wider diameter. The third net is the innermost net that collects megafauna (1.5 cm).
All three nets are fastened at four points (see arrow in fig. 2). A chain occasionally swirls up epifauna, which is then collected with the net.

II The mini van Veen grab (MVVG)

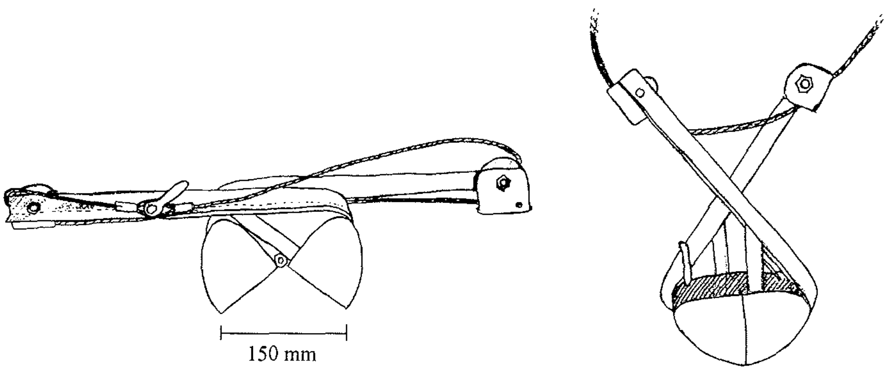


Fig. 3. The mini van Veen grab (MVVG)

The MVVG was originally modified by Reinhardt Kristensen. It samples a surface area diameter (0.0225 m^2) than the typical van Veen grab (0.1 m^2). The MVVG is streched by hand, at the same time the two shovels are opened. In this state the MVVG is deployed into the water. As soon as it contacts the seafloor, a special mechanism releases the shovels, and they dig into the sediment while closing totally. Afterwards the MVVG with the collected sediment is lifted back on deck. For logistic reasons we deployed the MVVG partly by hand, especially of station C (Camp Site), where we took all the samples from a Zodiak. At all other stations the MVVG was deployed from the RV PORSILD.

III The triangle dredge (TAD)

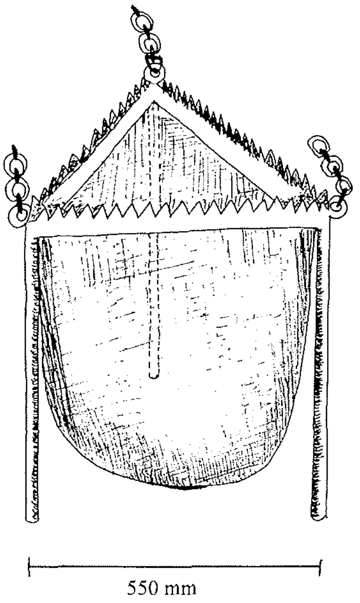


Fig. 4. The triangle dredge (TAD)

The TAD is a trawl which is suitable also for hardbottom, because of its metal frame. The frame is equipped with a serrated edge. This part of the sampler almost functions as a knife on seafloor, but also buries itself deeply into soft sediment. Only one net with a mesh size of 1 mm collects both infauna and epifauna. In addition, three long metal sticks attached to the frame protect the net and guide it on the bottom.

The three types of gear differed considerably in their sample size not only due to their opening size, but also due to different haul lengths. The TAD was towed for 3 minutes with a speed of 1 kn and covered an area of approximately 55 m^2. The RD was towed 20 min over the seafloor with the same speed and covered an area of about 160 m^2. The smallest sample was taken by the MVVG with exactly 0.0225 m^2 . To compare these different sizes, we calculate all numbers to the nearest 100 m^2.

2.3 Processing of samples

Samples were brought from the vessel to the camp site via the Zodiak, and sieved immediately in seawater through 300 µm mesh size. Subsequently, samples were fixed in 4 % buffered formalin solution. Beside the selected taxa of the macrofauna, megafauna was collected and preserved.

After about one week, samples were washed and transferred into 70 % ethanol. For this analysis Peracarida were determined to order level.

3. Results

A total of 2606 Peracarida were caught at the four transects. They belong to four orders, which occured in different abundance.

Amphipoda (72 %) were most abundant in most samples, followed by Tanaidacea (17.6 %), Cumacea (8.8 %) and Isopoda (1.6 %), respectively.

Isopoda were rare in the Mellemfjord samples. They were found at the innermost and outermost transects and collected with the MVVG.
Amphipoda occurred made up 83 % of all peracerids at the C-transect, 76 % at the S-transect, and 68 % and 63 % at the I- and N-transects, respectively.
The order Amphipoda was predominated by the family Lysianassidae in the Mellemfjord. Our preliminary determination revealed a high abundance of *Paratryphosites abyssi* and *Hippomedon propinquus*. The following four families were also present in considerable high numbers of specimens: Stenothoidae, Phoxocephalidae, Ampeliscidae (most abundant species: *Haploops laevis*) and Melitidae (most abundant species: *Melita dentata*).

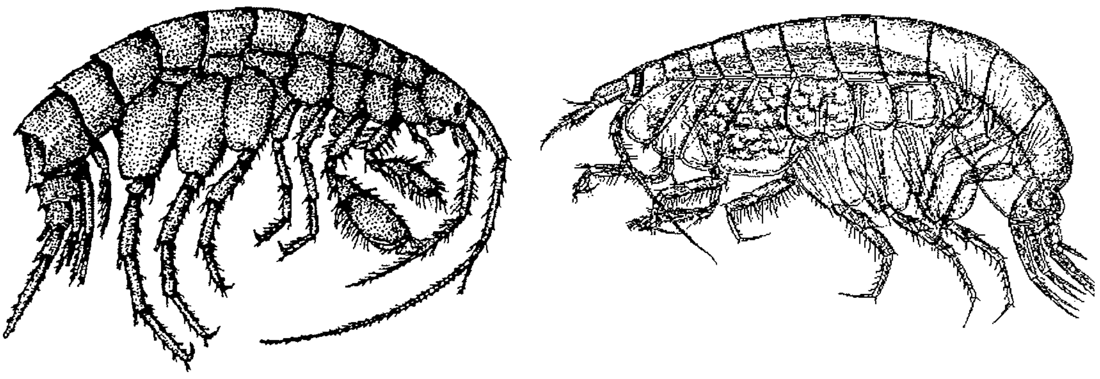


Fig. 5. *Melita dentata* (after Klelowski and Weslawski) and *Hippomedon propinquus* (after Sars)

Within the Cumacea we determined two families: Diastylidae (abundant genera: *Diastylis* and *Leptostylis*) and Leuconidae (abundant genera: *Eudorella*, *Eudorellopsis* and *Leucon*).

All Tanaidacea caught belong to the families Anarthuridae or Thyphlotanaidae.
On closer examination and comparison of the single transects, we counted most Peracarida at the innermost (S-28 % of all individuals) and outermost transects (I-35 %). The percentage of all Peracarida found was smaller at C- and N-transect, with 19 % and 18 %, respectively (Fig. 6).

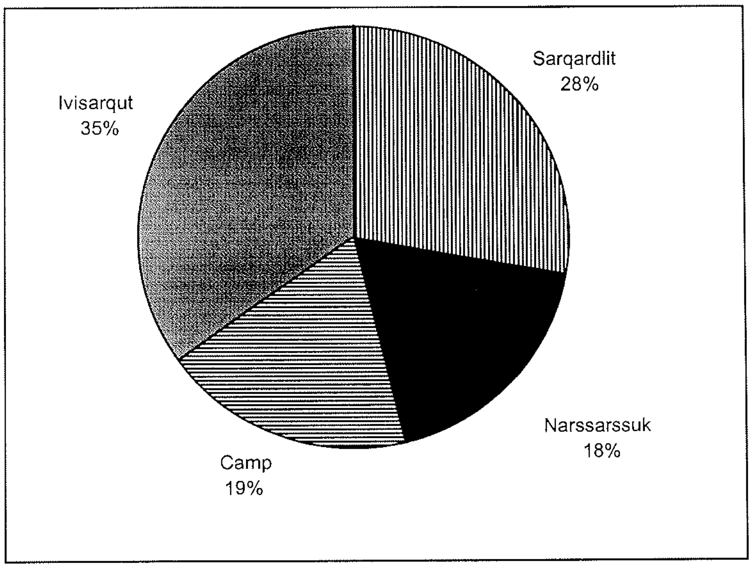


Fig. 6. Percentage of all Peracarida sampled at each transect

At all transects we observed, the highest amount of Peracarida per area calculated was taken by MVVG. The smallest number of specimens per 100 meter square was taken with the RD (Fig. 7). Exact numbers of all peracarids caught are listed in Table 2 (see appendix).

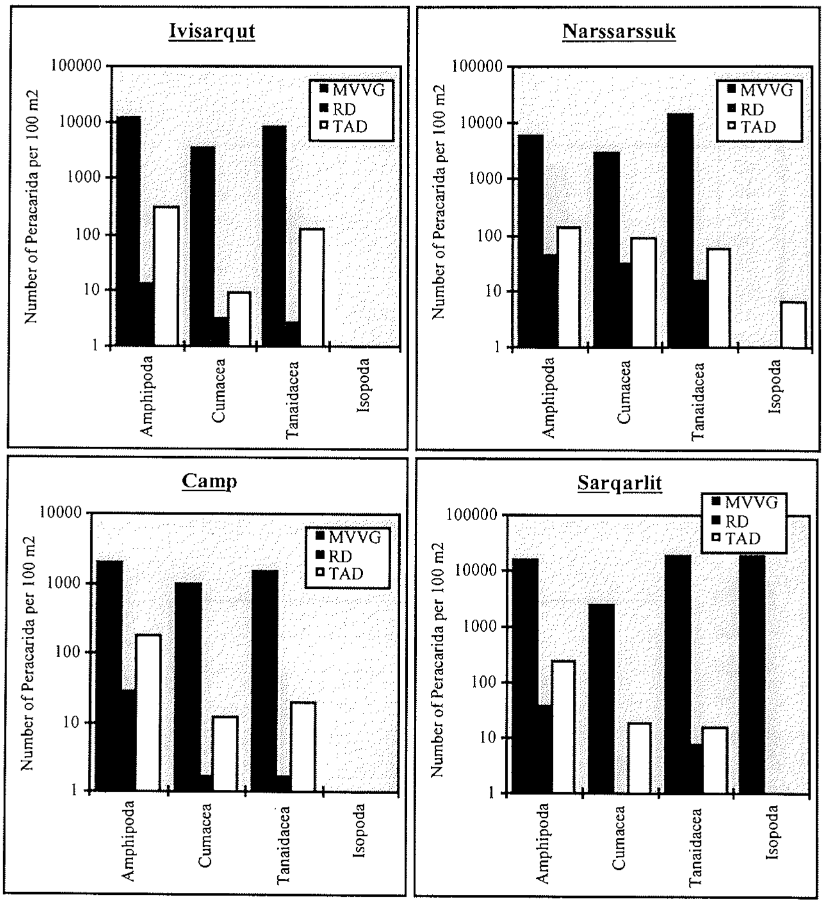
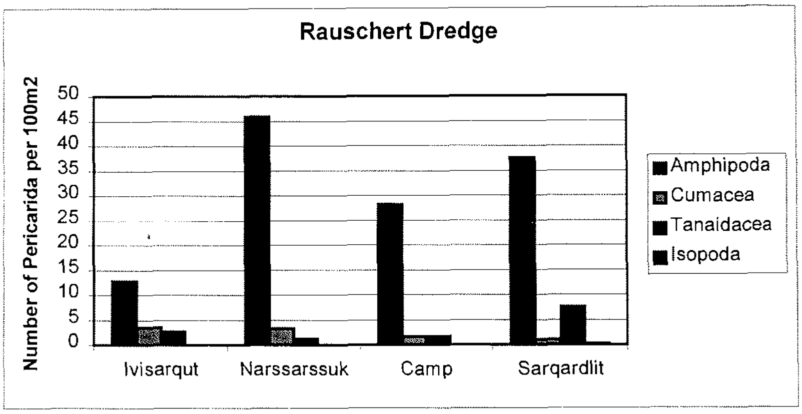


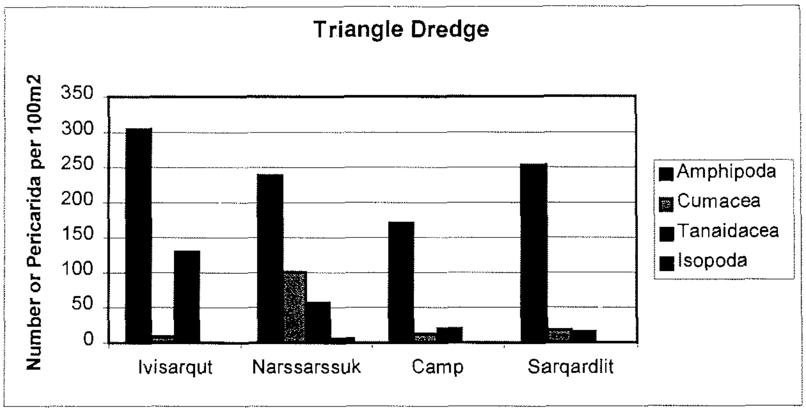
Fig. 7. Sampling efficiency of the three gear types along four vertical (MVVG= mini van Veen grab, RD = Rauschert Dredge, TAD= Triangle Dredge).

The distribution of Peracarida, taken by TAD at the different stations, shows that even though there is a higher number of Amphipoda at the Ivisarqut transect, the evenness is higher along the Narssarssuk-transect (Fig. 8).

Of the three kinds of gear types used, the MVVG collected the most even composition of peracarid orders at all stations.

Comparing the northern-, middle- and southern transects (Fig. 9), the RD samples show the lowest number of animals. The two dredges show a similar relative abundance of the Peracarida taxa to each other, but the TAD yielded nearly an order of magnitude more organisms.





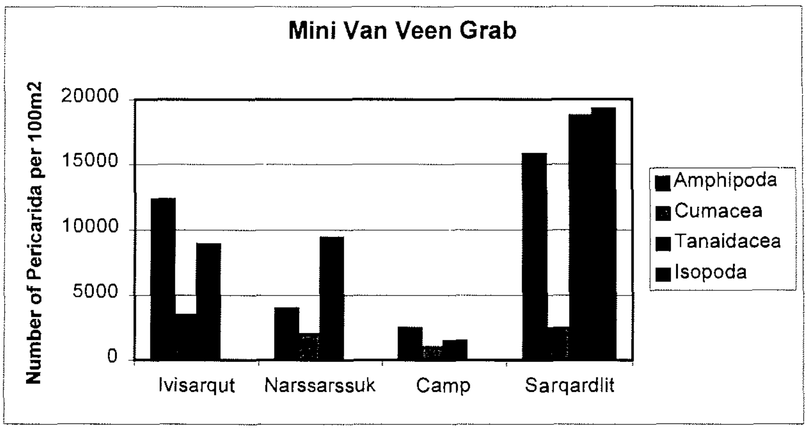
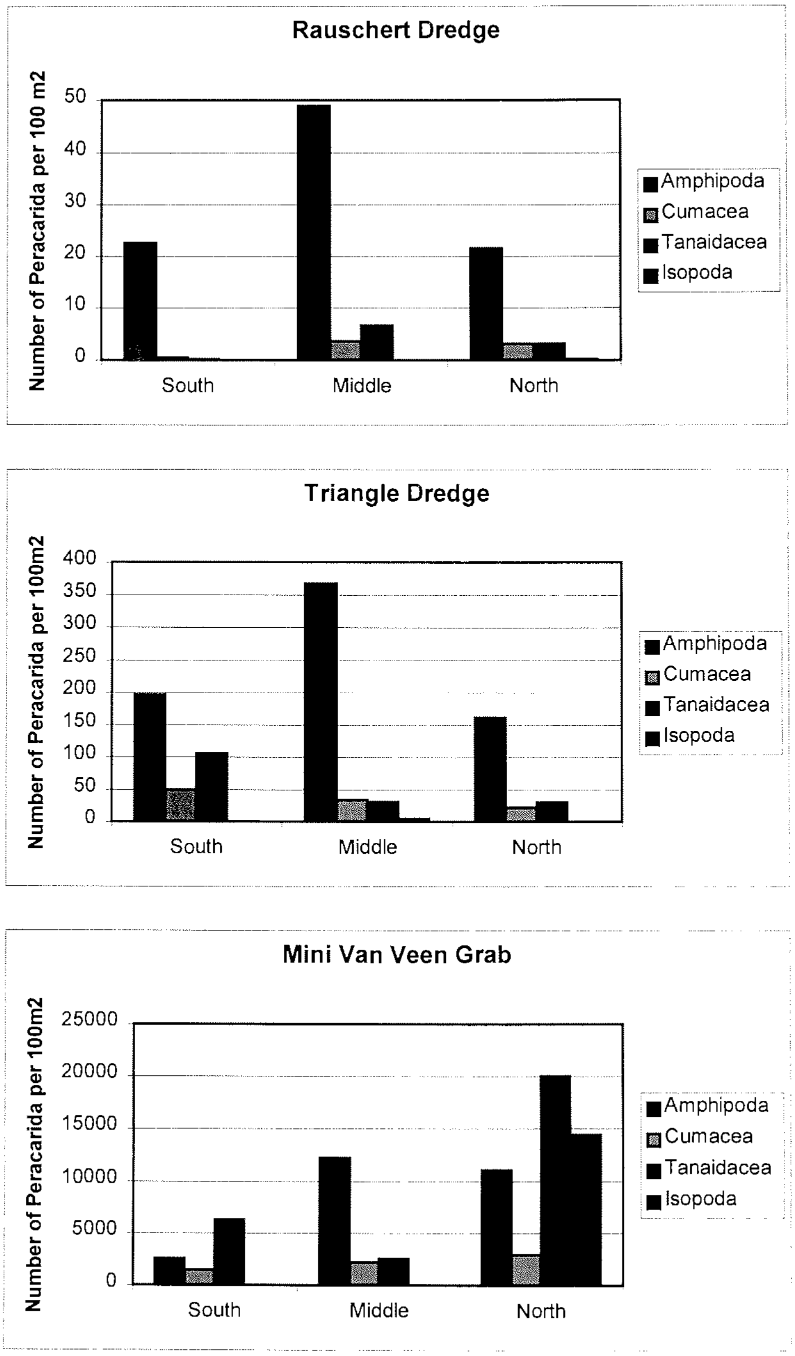


Fig. 8. A comparison of the different numbers of Peracarida gathered from the outermost to innermost transect using the three different gear types: Rauschert dredge, triangle dredge and mini van Veen grab.



Rauschert Dredge

Triangle Dredge

Mini Van Veen Grab

Fig. 9. A comparison of numbers of Peracarida gathered from the South, Middle and North transects using the three gear types: Rauschert dredge, triangle dredge and mini van Veen grab.

4. Discussion

Petersen and Curtis (1980) reported that the biomass is very high in East Greenlandic fjords in general and that it decreases with increasing distance from the open sea. When we counted the number of Peracarida from the different stations in the fjord, we did not find a difference in the numbers of these animals comparing the transects at the end and the mouth of the Mellemfjord. However, the Mellemfjord is very small compared with East Greenlandic fjords, e.g., the large Scoresbysund or Kejser-Franz Joseph Fjord. In many fjords, sedimentation decreases rapidly with increasing distance from the source, which is normally at the head (Gilbert et al. 1993). Gilbert et al. (1998) discovered that a different pattern in Akulliit (Mellemfjord) occurs. Two distinct sedimentary environments were recorded in the cores from Akulliit. The area of the fjord head, where the largest streams enter the fjord, is dominated by a medium dark brown sandy-silt with discontinuous stringers of fine sand and larger clasts of coarse sand and fine gravel. This contrasts strongly with sediment near the mouth of the fjord, where the water content is far higher, the clay content is more than twice as high as at the head and the bulk density is very low (Gilbert et al. 1998). They suggest two reasons for this unusual pattern:

1. "Because the drainage basin is relatively small (446 km^2) the input of water is small."
2."Even the head of the fjord is exposed to a moderately high energy wave environment".

The latter refers to an effective fetch of 40 km, except along the south shore. The exposure of the fjord results in a potentially high-energy environment to at least several tens of meters depth, even at the head. This and the relatively small inflow of freshwater reduces the stability of the surface water, and allows mixing of the nearly homogeneous conditions of temperature and salinity (Hansen and Schmidt, this issue). Since the highest abundance of peracarids occurs in the deepest part of the Mellemfjord, as shown in Fig. 9, we assume the most stable environmental conditions are in this area of the fjord. The entire shelf and much of the outer fjord may be subject to erosion (Gilbert et al. 1998). It also should be considered that icebergs scouring on the bottom of the fjord may have an impact on the benthic community. During our stay at the Mellemfjord in July 1997 an iceberg, of approximately 12 m height above the surface, probably stuck to the ground, stayed for more than one week close to station C 1. As determined for the Diskofjord, the nearest larger fjord south of the Mellemfjord, the first sea ice usually appears in October, and does not disappear until July (Petersen 1964).

In attempting to compare the efficiency of three gears in sampling Peracarida, we calculated the animals sampled per 100 m^2. The MVVG is a modification of the very common 0.1-m^2 van Veen grab by R. Kristensen (pers. comm.). This instrument obtained by far the highest output of specimens per sampled area. At every station in the fjord each order of peracarids was caught at the highest density by the MVVG. The MVVG caught all animals living endobenthically. Another explanation for the phenomenon that the MVVG caught the peracarids most numerous is the fact, that one MVVG sample is based on 225 cm^2 only. To get the number per 100 m^2 we multiplied the number of animals from the original sample. To receive the number of animals per 100 m^2 caught by the TAD and RD the numbers were divided. It is still surprising that the TAD being dragged for three minutes only caught so few peracarids. The TAD was also developed by R. Kristensen, but no descriptions of the two gear types are published yet.

The TAD yielded a higher number of peracarids per meter square than the RD. The TAD penetrates several cm into soft bottom while hauled, but the density of Peracarida from each order caught was higher than of those caught with the RD, independently from the composition of the sediment.

When comparing the three gear types the time spent sampling has to be considered as well. The MVVG theoretically works faster than the dragged equipment, but many unsuccessful attempts, for example caused by a stone which got stuck between the closing jaws, lead to time consuming repetitions. Another problem for replicate grab samples is the large sampling variation between replicates (Lie and Pamatant 1965). Due to patchiness of the peracarid crustaceans the MVVG, even if repeated samples are analysed, is not as representative (especially for vagile taxa) as the RD and the TAD, which integrate a longer distance. The area covered by the MVVG is very small and therefore benthic macrofaunal patchiness has a stronger effect on the MVVG than on the RD or TAD samples. It is notable that Isopoda were rarely sampled by the MVVG: Only at the station S 3 and only in two replicates were the isopods caught. This is clear evidence of the patchiness of their distribution. Mysidacea certainly will never be caught using this type of gear due to the bow wave effect. The bow wave in front of the instrument pushes many animals aside, especially the lighter ones.

As noted by Eleftheriou and Holme (1984), the choice of a sampler must necessarily be a compromise, based on requirements of the survey, working conditions, and the availability of suitable gear. The deck of RV Porsild is very small, which caused a few logistical problems. Neither is it possible to use gear of several meters width, nor can different gear types, e.g. from multiple teams be used at the same time. Choice may often be restricted by weight and the heavier equipment can only be used from large research vessels which have the necessary lifting equipment. The TAD and the RD were much heavier than the MVVG. A benefit of the MVVG was the possibility to handle it from a rubber Zodiak. Another advantage of the MVVG was the probability to sample through a hole in the ice in winter (Kristensen pers. comm.). Many of the lighter samplers have serious limitations and are less quantitative. The penetration into the sediment is limited when substrate is too hard. (Eleftheriou and Holme 1984). All benefits aside, it must be taken into consideration that from about 2.600 peracarids caught in total, only 200 peracarids were sampled by the MVVG.

The TAD sampled most animals in total, but the sieving and sorting of the samples required a long time, especially for those from a muddy bottom. Dredges with teeth are very effective and the use of inclined steel diving plates help to maintain contact with the bottom (Eleftheriou and Holme 1984). These different gears were constructed to sample different lifestyles of the benthic macrofauna. The MVVG and the TAD are not only able to collect epibenthic animals, but also to sample inbenthic animals more efficiently. The RD is used to sample highly mobile and suprabenthic animals, such as Amphipoda or Mysidacea, and it is thought to be less efficient catching endobenthic taxa (Brattegard and Fosså 1991; Rothlishberg and Pearcy 1977). However, looking at the composition of the RD samples we found many animals of burrowing taxa as well.

Tanaidacea and Cumacea are probably stirred up by the tickler chain in front of the sledge. The samples of the RD have collected the highest number of Peracarida. A metal shackle prevents larger animals from getting into the net. Small dredges with runners have been extensively employed for sampling epifauna on the continental shelf (Eleftheriou and Holme 1984).

The Mellemfjord on Disko Island inhabits an interesting composition of four peracarid taxa: Amphipoda, Cumacea, Isopoda and Tanaidacea. No Mysidacea were caught at the 12 stations with any of the three gear types. Most Mysidacea have a pelagial lifestyle (Zimmer 1932) and they have a great ability to escape quickly (Gruner 1993). Nonetheless, Mysidacea are often caught in great numbers with, e.g., an epibenthic sledge, a gear type similar to the RD used (e.g. Brandt and Schnack 1998). We therefore suggest that benthic Mysidacea are not present in the Mellemfjord. Probably food is the limiting factor. Mysidacea would be in strong competition for phytoplankton with ascidians, and the latter are very numerous in some parts of the Mellemfjord.

The highest percentage of amphipods from all peracarids of the gear compared is caught by the RD. The lowest percentage of amphipods is caught by the MVVG. Amphipoda are vagile animals which live rather epibenthically or suprabenthically than inbenthically. The TAD sampled most Cumacea per 100 m^2 in the Mellemfjord. While the MVVG sampled only about 2/3 of the Cumacea per 100 m^2 when compared with the TAD, the RD sampled even less, probably due to the fact that Cumacea live rather buried in the sediment (e.g. Mühlenhardt-Siegel 1996; Schminke 1996; Zimmer 1941). Isopoda were more or less sampled only by the MVVG. Most Tanaidacea per 100 m^2 were caught with the MVVG. The smallest number of Tanaidacea per 100 m^2 was sampled with the RD. The meshsize of the nets must also be considered. While the TAD had a meshwidth of 1 mm, the mesh of the RD measured 1.5 mm. Tanaidacea sampled in the Mellemfjord were generally longer than 1 mm, but much slimmer, so it could be expected that they escape through the net. During several deployments, parts of the nets were clogged rapidly with sediment. This may have led to the assumption that a soft bottom enables the dragged gear to catch more Tanaidacea, but the comparison of samples from stations with different bottom composition does not support this idea. Our samples allow the assumption that some areas of the fjord are covered by brittle stars, others inhabit so many ascidians on hard bottom that sediment was barely sampled. Ascidians live on stone, which supports the discovery of Gilbert et al. (1998) that the Mellemfjord is characterized by relatively little sediment.

The results of the comparative employment of the MVVG, the RD and the TAD reveal that the employment of all gear result in a different sample efficiency of the peracarid crustaceans. Three criteria are usually used in order to compare the efficiency of sampling devices (Eleftheriou and Holme 1984):

I digging characteristics of the sampler
II efficiency of capture in order to give a representative picture of the density and distribution of the fauna
III technical characteristics of the sample

While the TAD and the MVVG penetrate deeper into the sediment than the RD, the TAD catches by far the largest volume of sediment. The degree of disturbance of the environment is lowest using the MVVG. The RD is constructed to catch epibenthic animals, but it also caught several burrowing taxa, such as Tanaidacea and Cumacea. The MVVG and the TAD trapped several mobile taxa, e.g., Amphipoda. It is still very surprising that so few Isopoda were caught. Very many Isopoda living on algae were found at Godhavn in the tidal zone (Hansen and Johanse, this issue). Normally many Isopoda occur even in higher latitudes, and the deeper the sample is taken the more Isopoda are found (e.g., Hessler and Sanders 1967). This seems not to be true for the Mellemfjord. We do not know whether Peracarida composition of any gear closely resembles the Peracarida composition living on the ground of the Mellemfjord. In general the MVVG captured more peracarid crustaceans per 100 m^2, but the RD and the TAD caught far more animals per sample. The light weight of the MVVG is an advantage of handling this gear. Due to the low amount of sediment in a sample of the RD, it was quickly sorted when compared to the other gear. Our investigation has shown different qualities of sampling. While the MVVG is more able to point out patchines, since it samples a small area the dragged gear catches more animals and thus it is more suitable for morphological studies. The MVVG mainly caught inbenthic animals while the TAD also caught many vagile forms.

The results from the employment of the MVVG, the TAD and the RD samples off the West Greenlandic Mellemfjord show that each gear type has different sampling results and ideally all three types should be used for comparative qualitative and quantitative benthic studies.

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7. Appendix

Table 2. Amount of Peracarida

	Amphipoda	Cumacea	Tanaidacea	Isopoda	specimen
I-1 MVVG	3		15		18
I-2 MVVG	16	2	1		19
I-3 MVVG	6	5	2		13
I-1 RD	2				2
I-2 RD	19	1	9		29
I-3 RD	40	19	6		65
I-1 TAD	190	4	208	1	403
I-2 TAD	342	2	3		347
I-3 TAD	21	12	5		38
total	**639**	**45**	**249**	**1**	**933**
%	68,40 %	4,83 %	26,70 %	0,11 %	100 %
N-1 MVVG					
N-2 MVVG	3	2	3		8
N-3 MVVG	5	2	12		19
N-1 RD	4	1			5
N-2 RD	117	12	6		135
N-1 TAD	91	89	24		204
N-2 TAD	38	3	3		44
N-3 TAD	28	4	9		41
	286	**113**	**57**		**456**
%	63%	25%	12,00%		100 %
C-1 MVVG	3	2	2		7
C-2 MVVG	1		1		2
C-3 MVVG					
C-1 RD	45	2	1		48
C-2 RD	15	3	6		24
C-3 RD	54	3	1		58
C-1 TAD	17	4			21
C-2 TAD	189	11	14		214
C-3 TAD	77	5	25		107
	401	**30**	**50**		**481**
%	83 %	6 %	11 %		100 %
S-1 MVVG	1	2			3
S-2 MVVG	13	2	2		17
S-3 MVVG	18	1	36	39	94
S-1 RD	94				94
S-2 RD	63	4	21		88
S-3 RD	23	1	15		39
S-1 TAD	65	5	5		75
S-2 TAD	218	13	21		252
S-3 TAD	65	4	3		72
	560	**32**	**103**	**39**	**734**
%	76 %	4 %	14 %	6 %	100 %
-all transects	**1886**	**220**	**459**	**40**	**2604**
%	72.4 %	8.4 %	17.7 %	1.5 %	100 %

The diversity of Polychaeta and their feeding habits related to types of sediment in Mellemfjord, Disko Island, West Greenland

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Abstract

At least 16 species of polychaetes belonging to 14 families were found in a benthic investigation of the Mellemfjord, Disko Island. Samples were taken from four stations along a 60-m isobath throughout the fjord. The composition of the sediment was estimated at each station and found to range from soft, muddy bottom to hard, rocky bottom. Dendrogrammes, based on Bray-Curtis similarity coefficients, show that the diversity of polychaetes among the stations is low. The feeding habits of the collected polychaetes agree well with their choice of sediment.

Introduction

Previous studies have shown that Polychaeta are the relatively most abundant and diverse group of invertebrates in benthic soft-bottom communities in West Greenland waters (Andersen & Hartmann 1992, Jørgensen & Schiøtt 1997). Furthermore, their abundance makes them an important group of animals in an ecological context (Fauchald & Jumars 1979). So far, few taxonomic, ecological and behavioural studies have been made on Greenlandic polychaetes. Wesenberg-Lund (1950) published taxonomic studies on polychaetes from West Greenland, based on existing literature and the polychaete specimens deposited in the collections of the Zoological Museum, University of Copenhagen, ZMUC. Blake & Dean (1973) extended the list of Greenlandic polychaetes, and Curtis (1977) analyzed polychaete samples collected by G.H. Petersen during 1958-60 at four localities near Godhavn, Disko Island (Petersen 1977). Other studies from the area include those of Schmid & Piepenburg (1993).

Most polychaetes live in benthic environments, either in tubes or free-living. They have different feeding habits: deposit feeders, filter feeders, predators, and scavengers. Many polychaetes have a clear preference as to the choice of sediment. Hence, it is often the type of sediment that determines the distribution of a certain species. Environments with mixed sediment, such as sand, gravel, stone, and shells, can contribute to the fact that polychaetes with different sediment preferences have the same area of distribution. Some polychaete species do not show particular sediment preferences and, therefore, tend to occur in all types of sediment (Marin ID 1978).

The purpose of this paper is (1) to describe the diversity of Polychaeta at selected stations along a 60-m depth isobath throughout Mellemfjord, Disko Island, and (2) to relate the feeding habits of the collected polychaetes to the types of sediment in which they occurred. There are no previous investigations of the polychaete fauna in Mellemfjord.

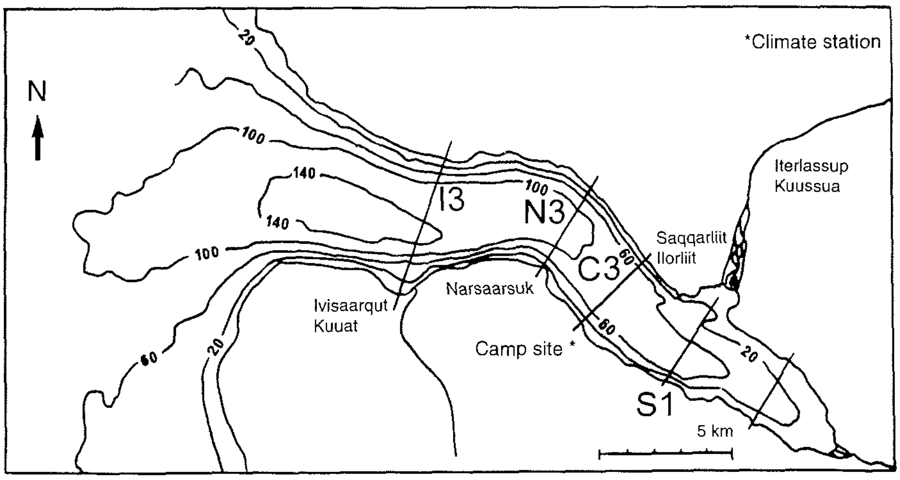
Material and Methods

Locality. The Mellemfjord, Disko Island, is about 25 km long and 5 km wide. The depth ranges from a few metres at the innermost part of the fjord to approximately 150 m where it opens into the southern part of Baffin Bay. The bottom salinity is ca. 33 ‰ throughout the fjord; surface-bottom range: 28-33 ‰. The bottom temperature is <1° C; surface-bottom range 8-1° C. It was decided to relate the sampling of polychaetes to only one parameter: type of sediment at a depth of approximately 60 m. A 60-m isobath stretches throughout a major part of the Mellemfjord, and samples taken along this line could not only provide a general picture of the polychaete diversity, but also indicate if diversity varied from station to station along with changes in substrate.

Transects. Four transects comprising a total of 12 stations were placed throughout Mellemfjord, see Lörz *et al.* (1999) and Fig. 1. Polychaetes were analyzed from 4 stations, named after landmarks on shore: Saqqarlit (S1); 69°42.08N, 54°31.58W, Camp (C3); 69°44.00N, 54°33.18W, Narsaarsuk (N3); 69°45.40N, 54°36.45W, and Ivisaarqut (I3); 69°46.44N, 54°47.00W.

Sampling. Sampling was either conducted from the Arctic Station research vessel 'Porsild', or from a Zodiac. A mini van Veen grab (modified by R. M. Kristensen), which covers an area of 0.15 m x 0.15 m, was used for sampling. Samples were accepted only when the grab was at least half full of sediment. Triplicate samples were taken at each station. The mini van Veen grab is a quantitative tool, gentle to the animals and easily operated by hand. However, to get an acceptable quantitative picture of the polychaete fauna at each station, it would have been nescessary to take more than three samples. This was not possible within the time limits of this project.

Fig. 1. (a) Mellemfjord and Disko Island; (b) Isobathes and stations in Mellemfjord



Processing of samples. Samples were stored in buckets until further processing could take place at the Mellemfjord camp site. Within 24 hours the samples were sieved in seawater through a 300 µm mesh and subsequently transferred to a 4% formaldehyde solution buffered with borax. A few days later the samples were washed several times in freshwater and transferred to 70% ethanol.

Sorting and identification. The animals sampled were initially sorted to major groups. Polychaeta were identified to family, genus or species level, using Kirkegaard (1992, 1996), Holthe (1996), Pleijel (1993), and Sigvaldadottir & Mackie (1993). Polychaete material is stored at ZMUC.

Types of sediment. The composition of the sediment was estimated from (1) sediment that remained in the samples after sieving, and (2) unsieved sediment samples taken with a triangular dredge. Samples from stations S1, C3, N3, and I3 were characterized as follows: **S1:** soft bottom with mud and detritus. **C3:** hard bottom (rocks and drop stone), probably with depressions containing deposits of detritus, sand, and gravel. The mini van Veen grab constantly hit hard bottom, only a few times did it contain sediment. **N3:** gravel and detritus. **I3:** soft bottom with mud and detritus. Sediment samples from each station are stored at ZMUC.

Data analysis. To illustrate similarities in polychaete species composition among stations, Bray-Curtis similarity coefficients were calculated and used to construct dendrogrammes (Jørgensen & Schiøtt 1997). The Bray-Curtis similarity coefficients were calculated in pairs for all samples. The dendrogrammes illustrate how the samples group proportional to each other. The coefficients were calculated from the following equation:

$$S_{jk} = 100(1 - \frac{\sum_{1=i}^{p} |y_{ij} - y_{ik}|}{\sum_{1=i}^{p} (y_{ij} + y_{ik})})$$

Yij = number of specimens of an identified species (i) in sample j, and Yik = number of specimens of an identified species (i) in sample k. P = total number of species. The similarity coefficients range from 0 (no similarity) to 100 (total similarity between species from two samples).

The two dendrogrammes illustrate the similarity among (1) all samples (Fig. 2), and (2) the four stations, with the triplicate samples from each station pooled (Fig. 3). All data are double-square-root average transformed. The transformation is made because the Bray-Curtis model is very sensitive to diverging values in a set of data, especially if the data set is extensive (Mitchie 1982). Data in this paper are not extensive, but diverging values do occur.

Appendix 1 shows the data set used to calculate the Bray-Curtis similarity coefficients, and Appendix 2 shows non-transformed Bray-Curtis similarity coefficients.

Results

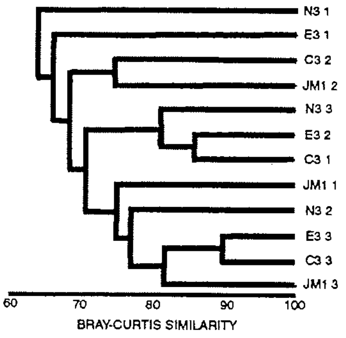
Table 1 shows: (1) the total number of polychaetes identified to family, genus, and species level, (2) sampling stations, (3) feeding habits according to Fauchald & Jumars (1979), and (4) the type of sediment they are reported to prefer. The triplicate samples from each station are pooled. For numbers of polychaetes found in each single sample (12) see Appendix 3.

Table 1. The occurrence of Polychaeta at stations S1, C3, N3, and I3 (S = soft bottom, m = mud, d = detritus, H = hard bottom, r = rocks, g = gravel), their feeding habits (DF = deposit feeders, P = predators, FF = filter feeders) according to Fauchald & Jumars (1979) = F&J 1979, and the type of sediment they are reported to prefer according to Holthe (1986) = H 1986, and Kirkegaard (1992, 1996) = K 1992, 1996.

Polychaeta collected from Mellemfjord	**S1** S (m+d)	**C3** H (r)	**N3** (g+d)	**I3** S (m+d)	**Feeding habits** (F+J 1979)	**Sediment preference** (H 1986, K 1992, 1996)
Ampharetidae						
Ampharetinae indet.	0	0	0	1	DF (detritus)	Mud or mixed substratum
Lysippe labiata	2	1	1	3		
Cirratulidae						
Chaetozone "setosa"	117	116	127	90	DF (detritus)	None
Maldanidae indet.	8	3	0	1	DF	Sand / mud
Nephtyidae						
Nephtys sp. (juv.)	55	35	27	40	P	None
Orbiniidae						
Scoloplos armiger	35	17	25	40	DF	Sand/mud
Paraonidae						
Aricidea suecica	1	0	0	0	DF	Sand/mud
Pholoidae						
Pholoe longa	11	0	2	1	P	Mud
Phyllodocidae						
Eteone longa	4	6	8	19	P	None
Phyllodoce groenlandica	0	0	1	0		
Pectinariidae						
Pectinaria hyperborea	0	0	1	0	DF (detritus)	Sand/mud
Polynoidae						
Gattyana cirrosa	3	0	0	1	P	Stone/shells
Sabellidae indet.	0	1	1	0	FF	Sand/mud
Scalibregmatidae						
Scalibregma inflatum	4	4	11	2	D	Mud or mixed substratum
Spionidae						
Prionospio steenstrupi	15	23	9	11	FF (detritus)	Sand/mud
Terebellidae						
Leaena ebranchiata	1	0	0	1	DF (detritus)	Soft mud/ stones and shells
Total no. of specimens	256	206	213	210		

Based on their feeding habits, the polychaetes in Table 1 can be classified as: (1) **deposit feeders**, consuming the organic matter in the sediment. They can be divided further into (a) **nonselective** deposit feeders that consume sand or mud directly by applying the mouth against the substratum where ingestion is generally facilitated by means of a simple, nonmuscular eversible pharynx, e.g., *Scoloplos armiger*, or (b) **selective** deposit feeders that lack a specialized pharynx; special head structures extend over or into the subtratum; deposited material adheres to mucous secretions on the surface of these feeding structures and is then conveyed to the mouth along ciliated tracts or grooves, e.g., *Lysippe labiata*, (2) **Filter feeders,** collecting detritus and plankton from the surrounding water aided by special feeding processes attached to the head. The particles adhere to the surface of the feeding structures, e.g., palps, and are then conveyed to the mouth along ciliated tracts, and (3) **Predators** which possess an eversible pharynx that commonly bears two or more jaws. Their prey consists of various small invertebrates, including other polychaetes. Predators also appear as scavengers (Marin ID 1978).

Two dendrogrammes illustrate the diversity of the polychaete communities investigated. Fig. 2 illustrates the similarity among all samples. Fig. 3 shows the similarity among pooled samples from the four stations.



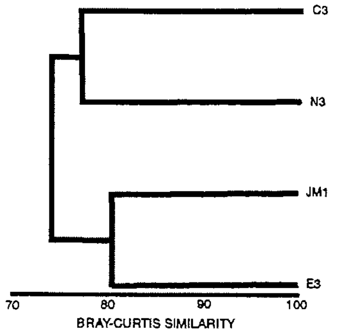


Fig. 2. Dendrogramme illustrating the hierarchical grouping of Bray-Curtis similarity coefficients for all samples. **Fig. 3.** Dendrogramme illustrating the hierarchical grouping of Bray-Curtis similarity coefficients for four stations. Notice change of prefixes: E=I, JM=S.

The following is a short description and a discussion of the feeding habits and distributions of the collected polychaetes. Earlier polychaete investigations from Disko Island are mentioned in the discussion in spite of differences in localities, sampling methods, and the subsequent treatment of collected polychaetes.

Ampharetidae: *Lysippe labiata* Malmgren, 1866

Lysippe labiata occurs in soft mud bottom and in mixed sediment. The worms live in thin clay tubes incrusted with a few grains of sand. The polychaete possesses retractable oral tentacles that are used for collecting organic matter from the surface of the bottom (Fauchald & Jumars 1979, Kirkegaard 1996). *Lysippe labiata* was found earlier from the Godhavn area by Curtis (1977) who reported 82 specimens from Lyngmarksbugt, near the entrance to Godhavn Harbour, 26-47 m from sediment consisting of "fine, black clay with stones, shells and a little sand" (Petersen 1977). In Mellemfjord, the species was collected from stations N3: gravel and detritus, and S1: soft bottom with mud and detritus.

Cirratulidae: *Chaetozone setosa* Malmgren, 1867

This species was for a long time considered cosmopolitan and present on all kinds of substrate. However, this appears to be an oversimplification with the species mainly occuring on muddy bottoms. The name *C. setosa* has been used for a number of species. The type material of the species has been reexamined and a detailed redescription is in preparation (M. E. Petersen, pers. comm.). Until published, all reports of the species should be considered provisional. *C.* "*setosa*" has two grooved palps on the back of the head and long filiform branchiae. The worms dig their way through mud or can be found among shells and pebbles and feed on detritus. Earlier investigations from Disko Island show that the species is very common and present at a considerable depth range (Curtis 1977; Madsen 1983; Andersen & Hartmann 1992; Jørgensen & Schiøtt 1997). *Chaetozone* "*setosa*" was found at all four Mellemfjord stations, suggesting that more than one species may be present, which was also the case with the material studied by Curtis (1977) (M. E. Petersen, pers.comm.).

Maldanidae indet.

Maldanidae, also referred to as 'bamboo worms', because the long segments and enlarged "joints" resemble bamboo, live in tubes made of bottom material cemented together by mucus from numerous cuticular glands. The tubes frequently stand perpendicular to the sediment surface, with the polychaetes living upside down. The 'bamboo worms' are able to renew their tubes throughout their lifetime and this gives them a certain motility. The worms feed by means of an eversible pharynx on organic matter in the sediment. Maldanidae can reach a considerable size and often dominate in soft mud bottom communities (Fauchald & Jumars 1979, Kirkegaard 1996). Maldanidae have been collected in limited numbers in earlier investigations from Disko (Curtis 1977; Jørgensen & Schiøtt 1997). In Mellemfjord, a few specimens were collected from stations S1: soft bottom; C3: hard bottom; and I3: soft bottom. Their presence at C3 could be explained with samples being taken from rocky depressions, containing muddy sediment.

Nephtyidae: *Nephtys* sp. (juveniles)

The Nephtyidae collected in Mellemfjord were juveniles which cannot be identified to species level. Nephtyidae possess big, eversible, and muscular pharynges containing a set of jaws. Mostly, they live buried in sand or mud where they dig their way through the sediment. They are also able to move around on the bottom surface using sinous movements. In addition they are fast swimmers. Nephtyidae are generally predators, but they also feed on detritus, diatoms, and sand (Fauchald & Jumars 1979, Kirkegaard 1996). Nephtyidae have been collected from Disko earlier, though in limited numbers (Curtis 1977; Jørgensen & Schiøtt 1997). In Mellemfjord they were collected in moderate numbers from all stations.

Orbiniidae: *Scoloplos armiger* O.F. Müller, 1776

Scoloplos armiger possesses characteristic, lancet-shaped gills which stretch out almost along the whole body. They have sac-like, eversible pharynges. *S. armiger* is very common at all depths, where it lives buried in sand, mixed sediment and clean soft, muddy bottom. Buried in the sediment the polychaete constantly produces long tube paths lined with mucus (Fauchald & Jumars 1979, Kirkegaard 1996). *S. armiger* feeds on organic matter in all different kinds of sediment and was earlier collected from Disko

Island (Madsen 1983, Andersen & Hartmann 1992, Jørgensen & Schiøtt 1997). Curtis (1977) reported the presence of *S. armiger* in moderate numbers at all localities. In Mellemfjord, *S. armiger* was collected from all stations.

Paraonidae: *Aricidea suecica* Eliason, 1920
Paraonidae possess short, eversible and sac-like pharynges. They are small and slender animals which live buried in sand or mud where they feed on organic matter. They appear to feed while screwing themselves down into the sediment; preserved paraonids often have curled-up bodies (Fauchald & Jumars 1979, Kirkegaard 1996). Curtis (1977) reported *A. suecica* to be common (89 specimens) at Lyngmarksbugten. In Mellemfjord, a single specimen was collected from station S1: soft muddy bottom and detritus.

Pectinariidae: *Pectinaria hyperborea* (Malmgren, 1866)
A single, very small specimen, probably referable to this species, was found in Mellemfjord at station N3: gravel and detritus. Curtis (1977) found this taxon in moderate numbers in Disko Fjord at Fangsthytten, 3-18 m (clay with a little sand and detritus), and Tut, 80-107 m (fine clay with larger stones and pebbles), both sheltered areas (Petersen 1977).

Pholoidae: *Pholoe longa* (O.F. Müller, 1776)
This genus has previously been referred to the Sigalionidae and was by Pettibone (1992) transferred to the Pholoidae. The species is redescribed and illustrated on the basis of material from Godhavn (Petersen 1998). The species was most common at S1 (soft muddy bottom and detritus) which is in good agreement with its distribution (Lyngmarksbugt) in material studied by Curtis (1977, as *P. minuta*, part) (M. E. Petersen, pers. comm.). Feeding biology of the closely related, perhaps identical, *P. baltica* Ørsted, 1843 (see Petersen 1998) has been studied by Pleijel (1983, as *P. minuta*), who found the species to be carnivorous.

Phyllodocidae: *Eteone longa* (Fabricius, 1780), *Phyllodoce groenlandica* Ørsted, 1843
Phyllodocids are fast animals that wriggle across the bottom with undulating movements. They possess an eversible pharynx lacking jaws but with papillae. The animals appear to be predators catching their prey with the pharynx. However, several investigations have shown that they may also behave as scavengers (Fauchald & Jumars 1979). The polychaetes inhabit different substrates such as reefs, shell banks, muddy bottom, and sandy bottom. *Eteone longa* prefers sandy bottom but can be found in sandy mud and among shells and stones. Earlier investigations from Disko Island show that the species is common here (Madsen 1983, Andersen & Hartmann 1992, Jørgensen & Schiøtt 1997). Furthermore, an investigation from Store Hellefiske Banke, Southwest Greenland (Marin ID 1978) shows that *Eteone longa* is very numerous there. In Mellemfjord, the species was found at all stations.

Phyllodoce groenlandica has been collected previously from the Godhavn Harbour area (Andersen & Hartmann 1992). In Mellemfjord, a single specimen was collected from station N3: gravel and detritus.

Polynoidae: *Gattyana cirrosa* (Pallas, 1766)
The polynoid scaleworms, equipped with characteristic scales on their backs, belong to the most species-rich families among the free-living polychaetes (Fauchald & Jumars 1979). Mostly, they crawl around in cracks and cavities in stones and shells. They can also be found in sandy or muddy bottom. The animals are fast swimmers using undulating movements. They possess an eversible pharynx with strong jaws. The majority are predators. *Gattyana cirrosa* is mostly found between stones on stone reefs, as a commensal in tubes of other polychaetes on sandy and muddy bottoms. They prey on other polynoids, crustaceans, echinoderms and molluscs (Curtis 1977, Kirkegaard 1992). The species is reported from Godhavn Harbour, Lyngmarksbugten, and Disko Fjord (Curtis 1977). Four specimens were collected in Mellemfjord from the stations S1 and I3: soft muddy bottom and detritus.

Sabellidae indet.
Sabellids belong to the tube-dwelling polychaetes. They live in cylindrical tubes incrusted with clay, sand or shells. The tubes are usually soft clay tubes attached to stones or shells. Small species are mobile with or without tubes. Larger species are usually found in shallow waters while small species occur in deeper waters (Kirkegaard 1996). The 2 specimens collected in Mellemfjord were only a few mm long. The anterior end of sabellids is modified into a tentacle crown which is used to filter plankton and detritus from the water (Kirkegaard 1996). However, some authors believe that the filtering behaviour is not by far the most important feeding behaviour in the family. Sabellids are able to turn their tentacle crown towards the sediment and search it for organic matter (Fauchald & Jumars 1979). Curtis (1977) found most sabellids at Godhavn Harbour and Lyngmarksbugt. Two small specimens were collected in Mellemfjord at station C3: hard bottom and N3: gravel and detritus.

Scalibregmatidae: *Scalibregma inflatum* Rathke, 1843
Scalibregmatids are deposit feeders. They dig their way through the sediment, while they swallow bottom material using their large eversible pharynx. The animals usually inhabit soft muddy bottom (Kirkegaard 1996). *Scalibregma inflatum* is mostly found buried at 30 to 60 cm in soft muddy sediment. The species also occurs in mixed sediment among stones and shells. The animals feed above and below the bottom surface (Fauchald & Jumars 1979). In Mellemfjord, the species was collected from all the stations but was not really abundant anywhere. As the mini van Veen grab does not penetrate deeply into the sediment (approximately 9 cm) it is likely that the collected animals have been feeding close to the bottom surface. The species has been reported from Lyngmarksbugt and Tut (Curtis 1977, Andersen & Hartmann 1992).

Spionidae: *Prionospio steenstrupi* Malmgren, 1867
Spionidae usually are infaunal animals living in tubes made of bottom material held together by mucus.The animals feed on organic matter in the sediment which they collect with their long palps. Spionids are very common and often occur in high numbers, especially in level bottoms (Kirkegaard 1996). In Mellemfjord the species was collected at all stations. *P. steenstrupi* has been reported as abundant at Lyngmarksbugt by Curtis (1977, as *P. malmgreni*, pers. comm. M.E. Petersen) and in small numbers from the Disko Bay area by Jørgensen & Schiøtt (1997).

Terebellidae: *Leaena ebranchiata* (M. Sars, 1865)

Terebellidae live in thick- or thin-walled clay tubes often with different material incrusted in the tubes. The tubes can also consist of sand or shell fragments. The animals are often found in soft, muddy bottom, but can also occur among stones and shells. They possess non retractable feeding tentacles. The tentacles are thick, with ciliated grooves and can be extended very far. Using their tentacles the animals are able to cover a considerable area of the bottom surface, and plankton or organic matter is moved from the ciliated grooves in the tentacles to the mouth (Kirkegaard 1996). Curtis (1977) reported 200 specimens of *L. ebranchiata* from Lyngmarksbugten. In Mellemfjord 2 specimens were taken from stations S1 and I3: soft bottom.

Table 2. An overview of polychaete investigations referred to in the discussion with information on taxonomic details (*M.E. Petersen, pers. comm., **Blake 1996), localities, year of investigation (1996: Jørgensen & Schiøtt (1997), 1990: Andersen & Hartmann (1992), 1982: Madsen (1983), and 1958-60: Curtis (1977)), sampling depths, and types of sediment (mx = mixed, m = mud, g = gravel, s = stones) . It should be mentioned, that only polychaetes relevant to the present investigation are listed in Table 2 (+ = species identical to the one collected from Mellemfjord, - = species not found.

Mellemfjord 1998 60 m mx	**Nipisat/ Ungussivik** 1996 3 m m + g	**Godhavn Harbour Nipisat/Satut** 1990 6-40 m m + s	**Nipisat/ Maligiaq** 1982 shallow water m + s + g	**Godhavn area** (4 localities) 1958-60 > 107 m mx
Ampharetidae Ampharetinae indet. *Lysippe labiata*	- -	*Ampharetinae sp.* *Ampharete acutifrons* *A. finmarchica*	- -	*Ampharete goesi* + *Asabellides sibirica* *Glyphanostomum pallescens*
Cirratulidae *Chaetozone setosa*	+	+	Cirratulidae indet.	+ *Cirratulus cirratus* = *C.* cf. *incertus**
Maldanidae indet.	+	-	-	+ *Maldane sarsi* *Praxillella praetermissa*
Nephtyidae *Nephtys* sp. (juv.)	*Nephtys caeca*	+	-	*Micronephthys minuta* *Nephtys caeca*
Orbiniidae *Scoloplos armiger*	+	+	+	+
Paraonidae *Aricidea suecica*	*Aricidea cerruti* *A. minuta*	-	-	+
Pectinariidae *Pectinaria hyperborea*	*Petta pusilla*	*Pectinaria granulata*	*Pectinaria granulata*	*Pectinaria granulata* *P. hyperborea*
Pholoidae *Pholoe longa*	*Pholoe longa* (as *P. inornata*)	-	*Pholoe longa* (as *P. inornata*)*	*Pholoe minuta* *P. longa* (*both* as *P. minuta*)
Phyllodocidae *Eteone longa* *Phyllodoce groenlandi*	+ -	+ +	+ *Phyllodoce maculata*	*Eteone flava* *Phyllodoce mucosa*

Polynoidae *Gattyana cirrosa*	-	-	Polynoidae indet.	+ *Harmothoe imbricata* *Antinoella sarsi* *Hartmania moorei*
Sabellidae indet.	*Euchone analis* *Fabricia stellaris*	*Chone duneri* *Euchone papillosa*	*Fabricia sabella* *Euchone analis*	*Chone duneri* *Euchone analis* *Potamilla neglecta* *Sabella crassicornis*
Scalibregmidae *Scalibregma inflatum*	-	+	-	+
Spionidae *Prionospio steenstrupi*	+ *Pygospio elegans* *Polydora quadrilobata*	*Spio filicornis* *Prionospio fallax*	*Pygospio elegans* *Microspio theeli* *Polydora quadrilobata*	*Prionospio steenstrupi* *Laonice cirrata* *Dipolydora quadrilobata* (as *Polydora caulleryi*) *, ** *Spio filicornis*
Terebellidae *Leaena ebranchiata*	-	*Amphitrite cirrata*	*Amphitrite cirrata*	*Terebellides stroemi* *Leaena ebranchiata* *Amphitrite cirrata* *Nicolea zostericola* *Trichobranchus glacialis*

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Appendix 1. Bray-Curtis similarity index

	I3-1	I3-2	I3-3	N3-1	N3-2	N3-3	C3-1	C3-2	C3-3	S1-1	S1-2	S1-3
I3-1	-	71	58	51	54	39	62	64	56	66	63	62
I3-2	-	-	63	70	56	49	83	81	63	69	71	62
I3-3			-	51	54	39	62	64	56	66	63	62
N3-1				-	69	30	70	74	74	76	71	75
N3-2					-	51	61	65	78	68	66	69
N3-3						-	41	41	31	29	32	26
C3-1							-	82	74	70	77	69
C3-2								-	72	77	83	68
C3-3									-	69	76	77
S1-1										-	73	74
S1-2											-	77
S1-3												-

Appendix 2. Bray-Curtis similarity index; pooled samples

	S1	C3	N3	I3
S1	-	84	81	80
C3		-	86	78
N3			-	77
I3				-

Appendix 3. Total number of Polychaeta from stations: pooled (S1,C3,N3, I3) and non-pooled (the rest).

	S1	**C3**	**N3**	**I3**	**I3 1**	**I3 2**	**I3 3**	**N3 1**	**N3 2**	**N3 3**	**C3 1**	**C3 2**	**C3 3**	**S1 1**	**S1 2**	**S1 3**
Amphritetinae indet.	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Aricidea suecica	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Chaetozone setosa	117	116	127	90	17	25	48	45	76	6	31	34	51	36	37	44
Eteone longa	4	6	8	19	7	2	10	0	7	1	2	0	4	9	0	5
Gattyana cirrosa	3	0	0	1	0	0	1	0	0	0	0	0	0	0	2	1
Leaena ebranchiata	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0
Lysippe labiata	2	1	1	3	0	0	0	1	0	0	0	0	0	2	0	0
Maldanidae indet.	8	3	0	1	0	0	1	0	0	0	0	1	2	1	6	1
Nephtys sp.(juv.)	55	35	27	40	18	9	13	9	13	5	9	12	14	11	15	29
Pectinaria hyperborea	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Pholoe longa	11	0	2	1	1	0	0	0	2	0	0	0	0	6	2	3
Phyllodoce groenlandica	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Prionospio steenstrupi	15	23	9	11	0	3	8	3	4	2	12	2	9	0	7	8
Sabellidae indet.	0	1	1	0	0	0	0	0	1	0	0	1	0	0	0	0
Scalibregma inflatum	4	4	11	2	1	0	1	7	4	0	1	0	3	3	0	1
Scoloplos armiger	35	17	25	40	8	9	23	16	7	2	7	7	3	13	8	14

On the taxonomy of *Spio filicornis* (Spionidae, Polychaeta) - Nipisat, Disko, Greenland.

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Abstract

Spio filicornis (Müller, 1776) is the type species of the genus *Spio* Fabricius, 1785 and was originally described and later redescribed from Greenland. Subsequent authors mistakenly referred to Denmark as the type locality. New information on the uncertain taxonomy of *S. filicornis* is presented here in a preliminary redescription based upon collections from off Nipisat, Disko Island, Greenland. *Spio filicornis* and *Spio theeli* (Söderström, 1920) are the only species of the genus previously reported from Greenland waters. During the present investigation three species of *Spio* were found off Nipisat: *S. filicornis*, *S. theeli* and an undescribed species of *Spio*. *Spio filicornis* differs from the others by the ringed palps and the appearance of hooded hooks from setiger 11 (exceptionally 10 or 12).

Introduction

Spio filicornis (Müller, 1776), was first found by Otto Fabricius. He functioned as a missionary to the Frederikshaab/Paamiut colony in Greenland from 1768 to 1773, where he studied various animals, later treated in his comprehensive work *Fauna Groenlandica* (1780). His former teacher, Otto Friderich Müller, gave a description of the species in *Zoologiae Danicae Prodromus*, based upon notes on Greenlandic animals by Fabricius (Müller 1776). This appears to be the reason why the type locality of *S. filicornis* was mistakenly noted as Denmark by Hartman (1959) and Maciolek (1990). It has not been possible to assign an exact type locality, but sampling and observations most likely took place in the area near Frederikshaab/Paamiut (62°N).

The first detailed description of *S. filicornis* (as *Nereis filicornis*) was given in *Fauna Groenlandica* (Fabricius 1780), but Fabricius (1785) also gave a second description and illustrated the species (Fig.1) when he established the genus *Spio*. In these works the following important characters were mentioned: General appearance long and thick; up to 48 setigers; a pair of long white palps with black rings; branchiae starting from setiger 1 or 2 (not quite clear on the drawing from 1785) and grey colour frontally and abdominally. The grey colour frontally is most likely dark pigmentation and the grey colour abdominally could be the gut. The middle part of the body is coloured yellow-red on the drawings (Fabricius 1785), possibly caused by a combination of white sexual products and red gills.

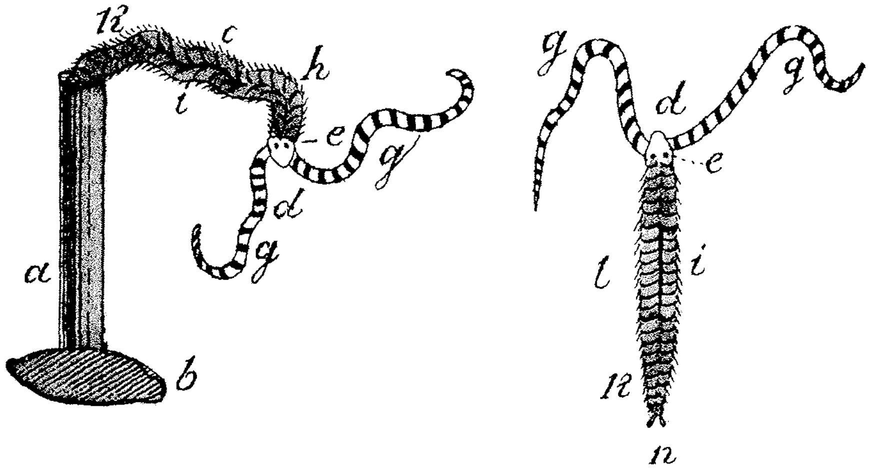

Fig. 1. Illustrations of *Spio filicornis* (Müller, 1776) by Fabricius (1785). **Left:** Stretching, as much as possible by free will, out of the tube. **Right:** Out of tube seen from dorsal side. a: tube, b: sea floor, c: the worm in swaying movement, d: prostomium, e: eyes, g: palps, h: first dark setigers, i: middle yellow-red setigers, k: posterior dark setigers, l: gut, n: anal cirri.

In recent decades *S. filicornis* has been reported from West Greenland by several authors: Wesenberg-Lund (1950) from all of the western coast of Greenland up to Upernavik, 73°N (12-380 m); Curtis (1977) from the area near Godhavn, Disko (3-107 m); Marin ID. (1978) from 63°N to 68°N (34-535 m); Andersen & Hartmann (1992) from Sâtut, Disko (20 m) and Nipisat Bay, Disko (20 m); Jørgensen & Schiött (1997) from Ungusivik, Disko (3 m). The only other species of *Spio* formerly reported from Greenland is *S. theeli* (Söderström, 1920) (Madsen 1983). *Spio filicornis*, *S. theeli* and an undescribed species of *Spio* were found in this investigation.

S. filicornis has most recently been redescribed by Maciolek (1990), but she did not include material from Greenland and the morphology of the palps was not described. The European distribution of *S. filicornis* is still unclear (Dauvin 1989; pers. comm. M.E. Petersen) and a conspecific relationship between the populations in Greenland and those in eastern North America and Europe, respectively, cannot be properly determined until material from Greenland has been examined. For this reason this investigation deals with animals from Greenland. It was not possible to collect material near Frederikshaab in this investigation and no preserved material exists from that area. Observations on live and fixed specimens were instead made on material collected almost 8° north of Frederikshaab. New information on the uncertain taxonomy of *S. filicornis* is presented here in a preliminary short redescription. A more general treatment (in Danish) of *Spio* from West Greenland was given by Worsaae (1999). A description of the new species, a redescription of *S. theeli* and a more thorough redescription of *S. filicornis* will be published elsewhere.

Methods

Samples were taken from a zodiac in Ungusivik Bay, off Nipisat (Disko Island, Greenland) with a mini van Veen grab (surface area = 0.0225 m^2) at 1.5 m depth. High densities of specimens were found when sampling in or near faecal casts of *Arenicola marina* (Linné, 1758). The sediment consisted of sandy mud. Samples were sieved through a 500 µm sieve, specimens sorted out alive, fixed in 4% formalin buffered with borax, rinsed in fresh water, transferred to 20% ethanol and dehydrated through a series to 80% ethanol. A few live specimens were recorded on videotape for later observations on pigmentation. Specimens used for SEM were further dehydrated to100 % ethanol, transferred to 100% acetone, critical-point dried, sputter coated with gold and photographed in a Jeol JSM-840 scanning electron microscope. All measurements and drawings were made on fixed specimens. Drawings were made using a camera lucida attached to a Wild M5 microscope. Material is kept at the Zoological Museum, University of Copenhagen.

Taxonomy

Spio Fabricius, 1785 (see Maciolek 1990 for synonymy).
Type species: *Nereis filicornis* Müller, 1776 (No type material exists).
Spio filicornis (Müller, 1776). Figs. 1-3.

Material examined: Ungusivik Bay, off Nipisat, Disko Island, Greenland (69°26.23'N, 54°13.70'W, 1.5 m), 25 July 1998. 13 specimens examined: 11 adults, 2 juveniles.

Description: Length up to 12 mm for 48 setigers, width excluding setae up to 1.4 mm; average width/length ratio 0.13 (n = 8). Juveniles in sample up to 3.3 mm long with up to 29 setigers (n = 2).

Prostomium anteriorly rounded, with slight medial incision (n = 13) (Fig. 3). Posterior part of prostomium raised (n = 13). Eyes 2-6 (n = 13) (Fig. 2A). Peristomial palps with ciliated median groove. Small groups of cilia on latero-frontal side of palp, lining median groove (n = 3) (Fig. 3).

Branchiae from setiger 1 (n = 13) (Fig. 2A). Last 6-10 setigers without branchiae (n = 8). Branchiae of setiger 1 almost as long as those of setiger 2 (never less than half their length) (n = 13). Branchiae on anterior setigers fused basally with notopodial postsetal lamellae (Fig. 2A, Fig. 3), gradually becoming separated further back (n = 11). Notopodial postsetal lamellae small, round on setiger 1, oval on setigers 2 to 11, gradually lengthening on posterior setigers, becoming leaf-shaped on last 10-15 setigers (coinciding with the disappearance of branchiae). Neuropodial postsetal lamellae rounded on first and last setigers, on setigers 11 to 20 narrower, elongated towards notopodial postsetal lamellae (n = 11).

Neuropodial hooded hooks bidentate, generally starting on setiger 11 (exceptionally on setiger 10 or 12) (n = 13), 6-10 per neuropodium (up to 3 in juveniles) (n = 11). Neuropodium with up to 3 sabre setae, gradually starting from setiger 11-13, disappearing near the pygidium. Pygidium with 4 (or rarely 3) leaf-shaped anal cirri of

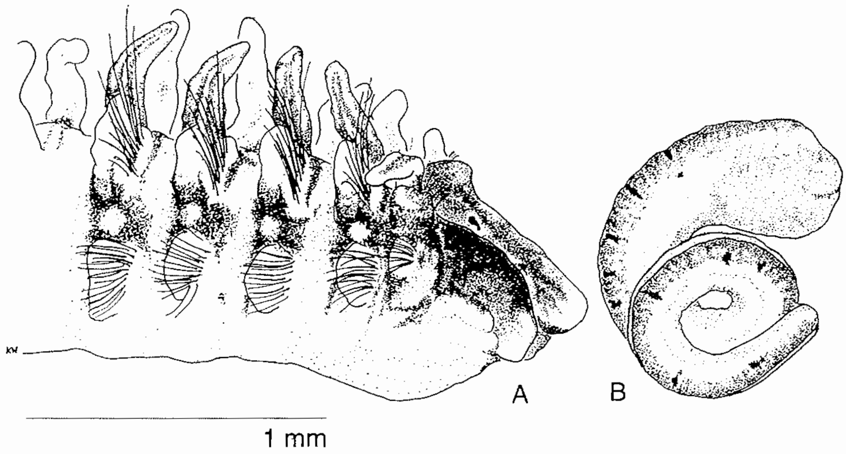

Fig.2. *Spio filicornis* (Müller, 1776). **A**: Anterior end in lateral view, without palps. **B**: Isolated palp. The illustrations are made from material in formalin, thereby showing a naturally pigmented head and body, but faded palps that no longer appear ringed, only spotted.

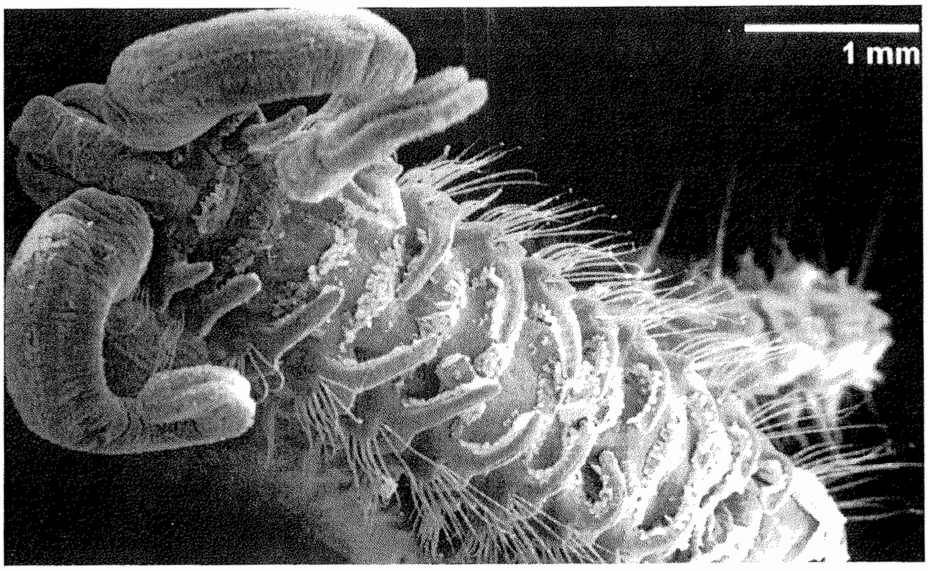

Fig. 3. SEM picture of *Spio filicornis* (Müller, 1776).

almost same size (n = 11). Subepidermal, opaque, round glands on anterior ventral half of body, 6-10 per setiger (n = 4).

Live and fixed specimens with dark pigmentation on prostomium and lateral sides of peristomium, on setigers 1 to 9 midventrally, on setigers 1-10 dorsally at base of branchiae, on branchiae and laterally between and around noto- and neuropodial lamellae (n = 11) (Fig. 2A). Large dark spots of pigment on palps of live animals (n = 2). Spots located on each side of median groove, forming up to 13 pairs (n = 6), giving palps a ringed appearance. Pigmentation fades in formalin and almost disappears in ethanol (Fig. 2B). Reflecting whitish spots occasionally seen between black spots on palps of live animals.

Reproductive biology: Four specimens contained white spermatophores laterally in setigers 10-14. Sexually mature females were not found..

Discussion

Spio filicornis and *S. theeli* are the only species of *Spio* formerly reported from Greenland (Madsen 1983, Wesenberg-Lund 1950). Most of the characters mentioned by Fabricius (1780, 1785) for *S. filicornis* could also apply to *S. theeli* and the undescribed species of *Spio*. An exception is the ringed palps, illustrated by Fabricius in 1785 (Figs. 1, 2), which are not found on *S. theeli* or the new species.

S. filicornis is further separated from *S. theeli* and the undescribed species by the first appearance of hooded hooks, starting on setiger 11 (exceptionally 10 or 12) in *S. filicornis* versus setiger 18-22 and setiger 18-24 in *S. theeli* and the new species, respectively (Worsaae, unpublished data).
Pigmented palps are described from only one other western Atlantic species of *Spio*, namely *S. setosa* Verrill, 1873 (Maciolek 1990). This species has been reported from the western North Atlantic (Maciolek 1990), but never from Greenland. *Spio setosa*, however, lacks pigmentation on the anterior part of the body and further differs from *S. filicornis* by having hooded hooks starting on setiger 13-15 (Maciolek 1990).

The preliminary description of *S. filicornis* given here strongly resembles the description given by Maciolek (1990), except that she does not mention ringed palps and finds the dorsal pair of anal cirri to be larger than the ventral pair (this study found the 4 anal cirri to be of similar size). As the pigmentation of the palps faded remarkably in alcohol, if palps were present, this could explain why Maciolek did not mention this character. More material should be examined to reveal if the differences of the anal cirri are just a matter of variability.

Based on the preliminary results from this investigation, there is no reason to suspect the populations from off Nipisat, Disko, Greenland and the populations from eastern North America not to be conspecific. The importance of examining live material or at least material not transferred to alcohol, when describing a species, should, however, be emphasised.

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Distribution and Composition of Meiofauna with special attention to the Kinorhyncha in the Mellemfjord, Disko Island (West Greenland)

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Introduction

The aim of our project was the investigation of the distribution of meiofauna with special attention to the Kinorhyncha in the Mellemfjord (Disko Island / West Greenland), a High Arctic ecosystem.

Due to the tremendous biodiversity of the meiofauna, samples were treated on a high taxon level. Furthermore some taxa were very difficult to identify, for example the Nematoda.

Although this community is not very well investigated in Arctic areas, earlier studies on Kinorhyncha on the west coast of Disko Island (Diskofjord) were done by R. P. Higgins and R. M. Kristensen. In correspondence with Kristensen we decided to focus on the phylum Kinorhyncha. Some striking Kinorhyncha are identified to species level.

The phylum Kinorhyncha consists of two orders, the Cyclorhagida and the Homalorhagida. In our investigation these were represented as one family each:

Kinorhyncha

- Cyclorhagida
    - Echinoderidae
        - *Echinoderes*
- Homalorhagida
    - Pycnophyidae
        - *Pycnophyes*

The individuals which belong to the *Echinoderes* species can easily be distinguished from those of *Pycnophyes* by their habitus. Usually the *Echinoderes* species are smaller and the cross section of their body is more or less circular while that of *Pycnophyes* is more triangular. Figure 1 shows a schematic view of *Echinoderes* morphology.

Material and methods

During our survey, four transects were sampled in the Mellemfjord (see Lörz et al., this volume), each with three stations, with the northernmost station taken in approximately 60 m depth. At these stations macrofauna samples (especially for the collection of Polychaeta and Peracarida) were also taken. For our investigation we used two transects: the N-transect as a cross-section through the fjord and lengthwise the northernmost stations of each transect.

The sampling gear used for meiofauna samples was a triangle dredge (TAD), and a

mini van Veen grab (MVVG) (for explanation see Lörz et al., this volume).
From the triangle-dredge samples we always transferred approximately 300 cm^3 of sediment into a bucket in order to minimise possible artefacts arising from the sampling method. The mini van Veen grab contained less sediment, therefore we could treat the whole sample.

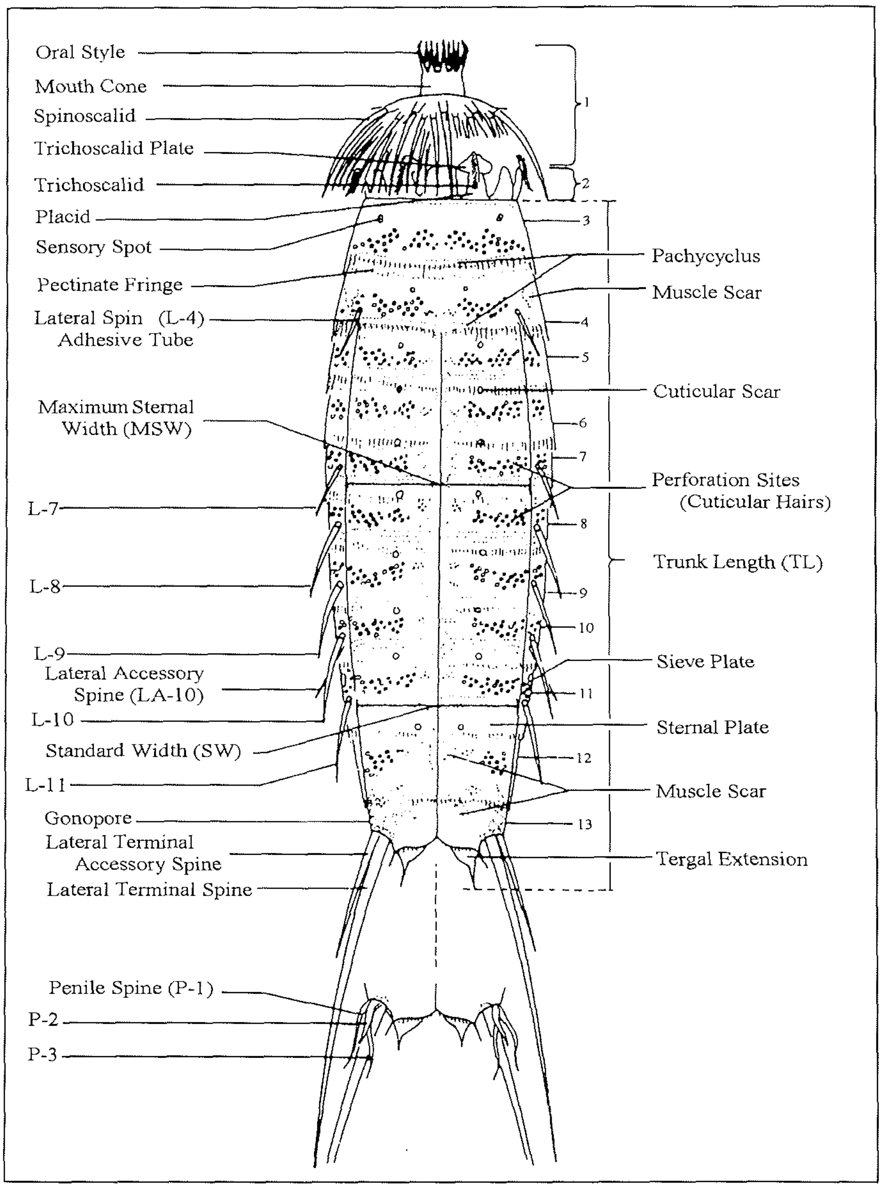


Figure 1: ***Echinoderes*** **morphology; ventral view, female and ventral view of terminal segment, male (after Higgins, 1983)**

For further examinations we took three different kinds of subsamples:

Quantitative subsamples

For quantitative subsamples we filled a modified syringe (a corer) with sediment by pressing it into the mud. The resulting 30-ml subsamples were transferred into small glass vials and fixed with about 30 ml formalin (8%). These were stored for future studies.

Sieved subsamples

These samples were gently stirred in buckets with seawater. This procedure causes the meiofaunal animals to float to the water surface. We then strained the surface water with a small hand net (mesh size 64 µm) with swift, circulating movements. We did not use a finer net because it could have been blocked by detritus. Afterwards we washed the meiofauna into a vial containing seawater. For conservation the sample was fixed in an 8% formalin solution. If the sediment was very coarse we placed stones and crushed shells into a bucket filled with fresh water in order to shock the adhesive meiofauna (osmotic shock). After a few minutes the fresh water was decanted through a sieve (mesh size 32 µm).

„Bubbling“ subsamples

This method is used to obtain the special meiofauna that has hydrophobic exocuticle. After slightly stirring up the sediment we used a bicycle pump with a „bubblestone“ (as used for aquaria) and pumped for a while. Kinorhyncha and other meiofauna were bubbled up and adhered to the surface film of the seawater. Thereafter we waited until the heavier particles had sunk again. The meiofauna was then collected with a piece of paper which was laid on the water surface. The adhering particles and animals were rinsed with seawater directly through a net (mesh size 32 µm).

Sorting of the samples

In the laboratory all samples were sorted. All organisms were identified to orders except for the Kinorhyncha. Some interesting and the most abundant Kinorhyncha were selected, mounted on slides, and then identified to species.

Calculation of the number of specimens per 10 cm^2 from the mini van Veen grab

The sides of the mini van Veen grab have a length of 15 cm, resulting in a surface area of 225 m^2. The numbers of specimens per sample were then divided by 22,5 and thus calculation yielded the number of specimens per 10 cm^2.

Results

Abundance of the organisms

Tables 1, 2 and 3 present the numbers of organisms per taxa that were counted at the different stations.

Table 1: Number of organisms per taxa of the "most important taxa"

Most important taxa								
Station	**Equipment**	**Depth**	Nematoda	Copepoda	*Echinoderes*	*Pygnophyes*	others	total
I3	TAD	60m	62	63	39	12	8	184
	MVVG	65m	49	64	91	84	10	298
N1	TAD	60m	1222	936	424	216	151	2949
	MVVG	60m	100	141	26	23	15	305
N2	TAD	125m	369	455	381	60	93	1358
	MVVG	93m	165	91	166	16	20	458
N3	TAD	60m	24	38	331	119	20	532
	MVVG	70m	29	41	207	110	7	394
C3	TAD	65m	58	27	83	29	1	198
	MVVG	60m	55	18	291	73	7	444
S3	TAD	30m	316	46	212	124	45	743
	MVVG	30m	503	39	102	9	44	697

Table 2: Number of organisms per taxa of the "Other Crustacea"

Other Crustacea								
Station	**Equipment**	**Depth**	Amphipoda	Cumacea	Isopoda	Tanaidacea	Mysidacea	Ostracoda
I3	TAD	60m	1	1	-	1	1	-
	MVVG	65m	4	-	-	1	-	3
N1	TAD	60m	26	4	-	1	1	9
	MVVG	60m	-	-	-	2	-	4
N2	TAD	125m	5	-	-	21	-	12
	MVVG	93m	1	-	-	6	-	6
N3	TAD	60m	2	-	-	13	2	2
	MVVG	70m	-	-	-	4	-	3
C3	TAD	~65m	1	-	-	-	-	-
	MVVG	60m	-	-	-	-	-	6
S3	TAD	30m	1	-	-	6	1	10
	MVVG	30m	1	-	1	10	-	-

The numbers of organisms within a taxon differ significantly at each station. Station N1 TAD turned out to be the sample with highest density (2789 individuals) and a high diversity (about 19 taxa). Station N2 TAD also contained a high number of organisms (1255 individuals) and the same number of taxa (19). At both stations the values of the MVVG were lower. The lowest number of organisms, however, was found at station I3 TAD (176 individuals).

Generally the TAD yields a higher number of specimens per catch than the MVVG, with the exception of stations I3 and C3.

Table 3: Number of organisms per taxa (partly morpha) of the "Other Groups"

Other Groups (*Morpha)								
Station	**Equipment**	**Depth**	Polychaeta	Acari	Protohydra	Polyps*	Medusae*	Hydrozoa
I3	TAD	60m	3	1	-	-	-	-
	MVVG	65m	1	1	-	-	-	-
N1	TAD	60m	80	5	9	1	-	3
	MVVG	60m	7	-	2	-	-	-
N2	TAD	125m	31	6	3	6	4	-
	MVVG	93m	3	-	1	-	-	-
N3	TAD	60m	-	-	-	-	-	-
	MVVG	70m	-	-	-	-	-	-
C3	TAD	~65m	-	-	-	-	-	-
	MVVG	60m	1	-	-	-	-	-
S3	TAD	30m	7	3	15	1	-	-
	MVVG	30m	18	1	11	1	-	-

Station	**Equipment**	**Depth**	Gastropoda	Holothuria juv.	Ophiuroidea	Ciliata	Foraminifera	Turbellaria
I3	TAD	60m	-	-	-	-	3	-
	MVVG	65m	1	-	-	-	-	-
N1	TAD	60m	-	-	4	1	35	4
	MVVG	60m	-	-	-	-	-	-
N2	TAD	125m	-	3	4	1	3	1
	MVVG	93m	-	-	-	-	8	-
N3	TAD	60m	-	-	-	-	-	-
	MVVG	70m	-	-	-	-	-	-
C3	TAD	~65m	-	-	-	-	-	-
	MVVG	60m	-	-	-	-	-	-
S3	TAD	30m	-	-	-	-	3	-
	MVVG	30m	-	-	-	-	10	-

Station	**Equipment**	**Depth**	Sipuncula	Priapulida juv.	Entoprocta	Nemertini	other Crustacea
I3	TAD	60m	-	-	-	-	4
	MVVG	65m	-	-	-	-	8
N1	TAD	60m	-	12	-	-	41
	MVVG	60m	-	-	-	-	6
N2	TAD	125m	-	4	-	1	38
	MVVG	93m	1	2	-	-	13
N3	TAD	60m	-	-	1	-	19
	MVVG	70m	-	-	-	-	7
C3	TAD	~65m	-	-	-	-	1
	MVVG	60m	-	-	-	-	6
S3	TAD	30m	-	1	-	-	18
	MVVG	30m	-	1	-	-	12

The C3 station (TAD + MVVG) and N3 MVVG sample are the only samples where almost no „other taxa" were found (organisms as well as taxa).

Tanaidacea, Amphipoda, Ostracoda, Polychaeta, Foraminifera, Cnidaria, Chelicerata, and Priapulida regularly appeared in the samples, but in varying numbers. The remaining taxa (e.g., Isopoda, Entoprocta, Turbellaria) were often single finds restricted to a few stations and were therefore neglected in the present study.

All analysed samples contained green, muddy sediment. In most of the samples we found Tintinnidae which had sedimented from the water column.

Percentage of the most common taxa

Figures 2 and 3 illustrate the percentage of the particular taxa at the different stations from triangle-dredge and mini van Veen grab samples.

All stations, except I3 and N2, were characterized by a pronounced dominance of one taxon with more than 40%. However, the dominant taxa differed from station to station. Station I3 represents the outermost and station N2 the deepest station of the investigated area.

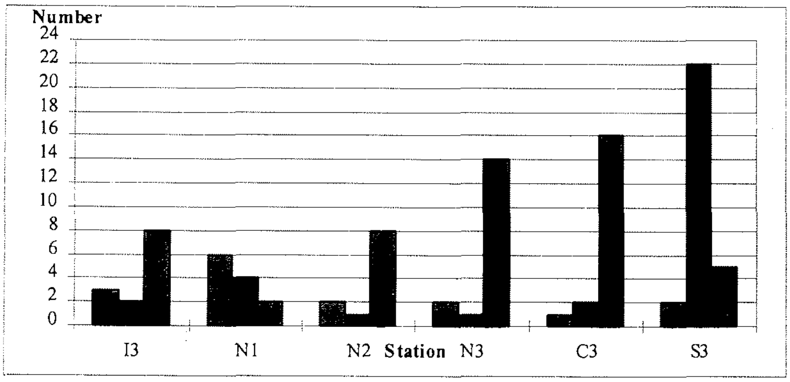
Number of specimens per 10 cm^2 of the mini van Veen grab

Table 4 and Figure 4 illustrate the number of specimens per 10 cm^2 of the mini van Veen grab:

Table 4: Number of specimens per 10 cm^2 of the MVVG

Station	Copepoda	Nematoda	Kinorhyncha
I3	3	2	8
N1	6	4	2
N2	2	1	8
N3	2	1	14
C3	1	2	16
S3	2	22	5
average	3	5	9

Figure 4: Number of specimens per 10 cm^2 of the MVVG



It is interesting to note that the Kinorhyncha have on average a higher number of specimens per 10 cm^2 than the Nematoda or Copepoda. An exception is station N1, where the Copepoda have the highest value with 6 specimens per 10 cm^2, and at station S3 the Nematoda were most numerous with 22 specimens per 10 cm^2. These 22 specimens of Nematoda represent the highest number of organisms per taxon sampled per 10 cm^2 of all mini van Veen grab catches.

Figure 2: Percentage of the most common taxa from the triangle-dredge samples

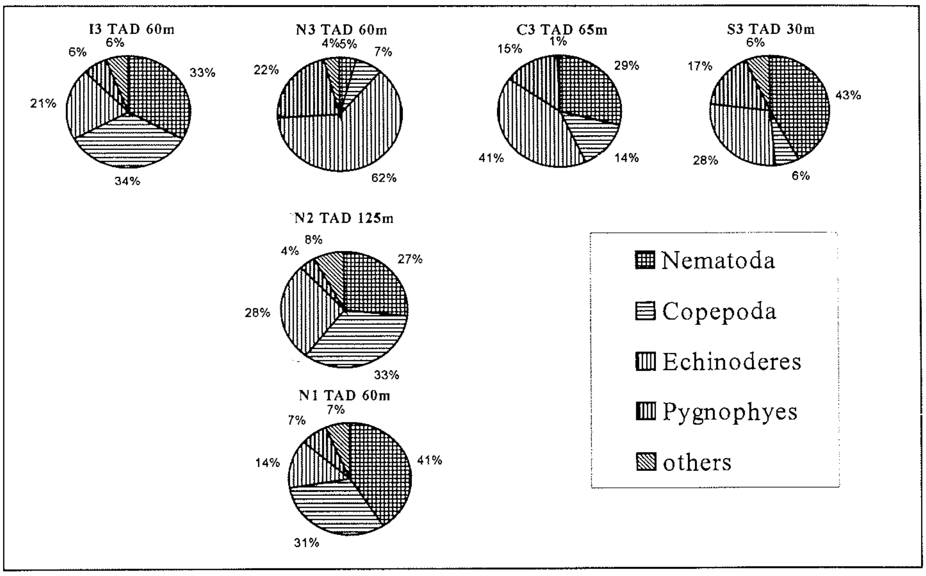
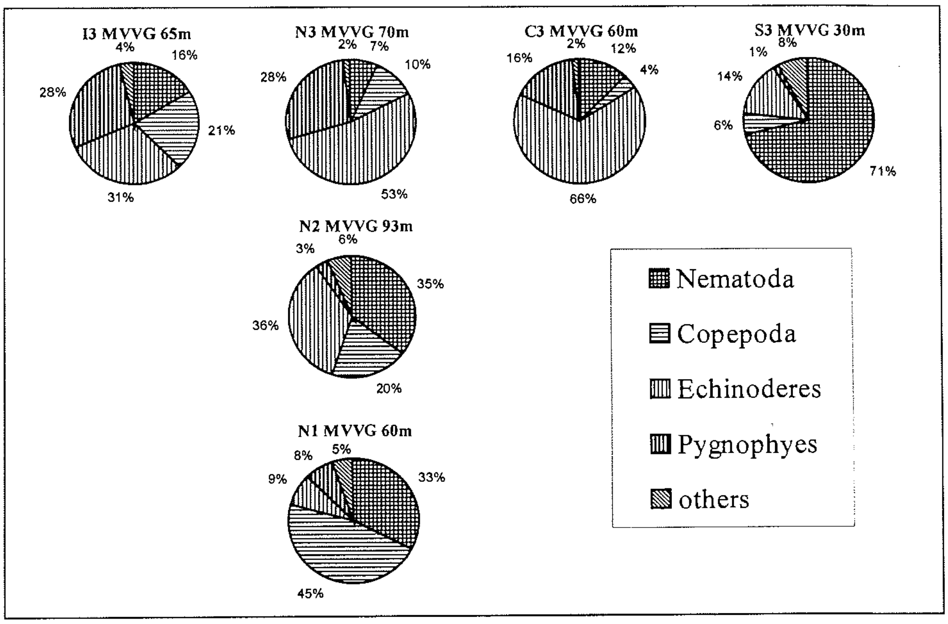


Figure 3: Percentage of the most common taxa from the mini vanVeen grab samples



Determination of the Kinorhyncha

Until now 45 specimens of the Kinorhyncha could be determined comprising six species:

Station N1 TAD

	adult	juvenile
Pycnophyes cryopygus	5	5
Pycnophyes greenlandicus	2	1
Pycnophyes spitzbergensis	3	
Echinoderes eximus		7
Echinoderes tubilak	1	
Echinoderes aquilonius	4	

Station N3 TAD

	adult	juvenile
Echinoderes eximus	1	

Station N1 MVVG

	adult	juvenile
Pycnophyes cryopygus	8	2
Echinoderes eximus		1

Station N3 MVVG

	adult	juvenile
Pycnophyes cryopygus	1	2
Pycnophyes greenlandicus	1	
Echinoderes aquilonius	1	

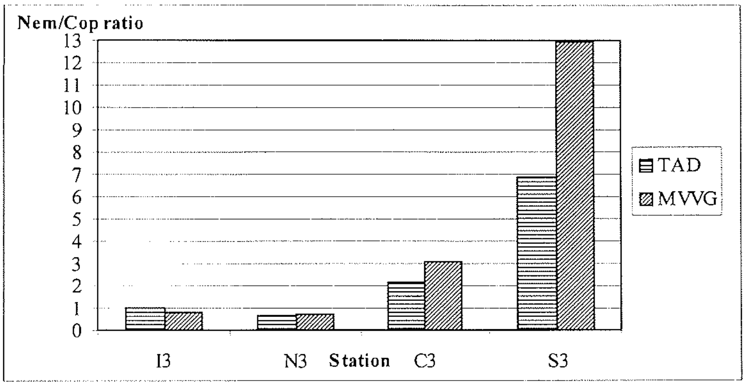
Nematoda/Copepoda ratio

The following Table 5 and Figure 5 show the Nematoda/Copepoda ratio and their distribution:

Table 5: Nem/Cop ratio at the different stations

Station	**Equipment**	Nematoda	Copepoda	Nem/Cop
I3	TAD	62	63	0,98
	MVVG	49	64	0,77
N1	TAD	1222	936	1,31
	MVVG	100	141	0,71
N2	TAD	369	455	0,81
	MVVG	165	91	1,81
N3	TAD	24	38	0,63
	MVVG	29	41	0,71
C3	TAD	58	27	2,15
	MVVG	55	18	3,06
S3	TAD	316	46	6,87
	MVVG	503	39	12,90

Figure 5: Nem/Cop ratio at the different stations



Interestingly an increase of the Nematoda/Copepoda ratio from the mouth towards the innermost part of the fjord could be noted.

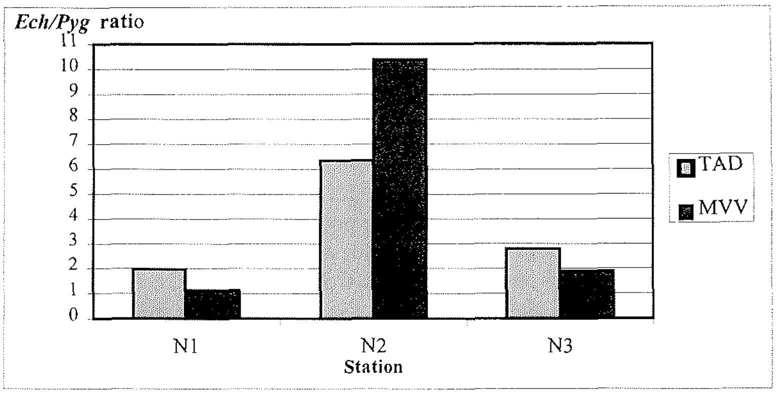
Echinoderes/Pycnophyes ratio

The following Table 6 and Figure 6 show the *Echinoderes/Pycnophyes* ratio correlated to depth.

Table 6: *Ech/Pyg* ratio at the different stations

Station	Equipment	Depth	*Echinoderes*	*Pygnophyes*	*Ech/Pyg*
I3	TAD	60m	39	12	3,25
	MVVG	65m	91	84	1,08
N1	TAD	60m	424	216	1,96
	MVVG	60m	26	23	1,13
N2	TAD	125m	381	60	6,35
	MVVG	93m	166	16	10,38
N3	TAD	60m	331	119	2,78
	MVVG	70m	207	110	1,88
C3	TAD	65m	83	29	2,86
	MVVG	60m	291	73	3,99
S3	TAD	30m	212	124	1,71
	MVVG	30m	102	9	11,33

Figure 6: *Ech/Pyg* ratio at the different stations



The values of the N-stations show a higher *Echinoderes/Pycnophyes* ratio at the deepest station (N2) in the middle of the fjord.

Discussion

The relatively high percentage of Kinorhyncha in the Mellemfjord is quite interesting. At every station we found that the Kinorhyncha represent at least the third highest percentage of all meiofaunal organisms. Often the Kinorhyncha even dominate the meiofauna (e.g.: C3 MVVG 83%; N3 MVVG 82%; N3 TAD 85%).

The Nematoda never reach values over 72% (S3 MVVG). Usually in other faunistic studies the Nematoda are known to be the dominant group with 90–95% of all organisms in meiofauna samples, followed by the Copepoda (Harpacticoidea) (Giere, 1993).

In the same work Giere (1993) refers to values for the Nematoda of up to 23 x 10^3 specimens per 10 cm^2 and for Harpacticoidea >1000 specimens per 10 cm^2. For the Kinorhyncha a value of 15 specimens per 10 cm^2 was found in muddy sediments. The average values of our calculations are lower (Nematoda: 5 per 10 cm^2; Copepoda: 3 per 10 cm^2). Although the percentage of Kinorhyncha per MVVG seemed very high at first view, this value of 9 specimens per 10 cm^2 is not so uncommon. In 1977 Dinet found in the Norwegian and the Greenland Sea an average of 1-8 Kinorhyncha per 10 cm^2. Other Arctic studies at Svalbard, however, recorded >250 specimen per 10 cm^2 (Pfannkuche and Thiel, 1987), and in Alaska 130 specimens per 10 cm^2 have been recorded (Giere, 1993). Carey and Montagna (1982), however, found a very low Kinorhyncha abundance of only 0.1 per 10 cm^2 in the Beaufort Sea.

We suppose that the high number of organisms at the N-transect might be a result of a mixing of different water layers due to a narrowing (the "Narssarssuk", see map) of the fjord in this area. This could also have resulted in an accumulation of nutrients. Because of the distance to this potential area of "disturbance", station N3 was possibly not affected.

The distinct enhancement of the Nematoda/Copepoda ratio towards the inner end of the fjord is interesting. A change of physical or biological factors might be the possible reason for this. In 1981 Raffaelli and Mason found that the abundance of Nematoda increases and Copepoda decrease as beaches become more polluted by sewage. This can be excluded in the Mellemfjord because it is unpopulated. It is also mentioned by Raffaelli and Mason (1987) that the Nem/Cop ratio is influenced by particle size, Nematoda usually increase and Copepoda decrease in abundance in finer sediments. Although these investigations are related to sandy sediments we found similar tendencies. At station S3 a stream flows into the Mellemfjord, transporting a high load of very fine, muddy sediment, while the sediment at the opening (I3 and N3) of the fjord is more coarse because of the tidal currents. The highest Nem/Cop ratio was found at station S3. Thus our results may support this hypothesis.

In his later paper Raffaelli (1987) presented more precise data and distinguished between the behaviour of epi- and mesobenthic Copepoda.

The N-stations showed that *the Echinoderes/Pycnophyes* ratio might also depend on depth. At a depth of around 100 m (N2) we have a strikingly higher *Ech/Pyg* ratio than at the other stations (N1 and N2) in approximately 60 m depth. In contradiction to this, the MVVG sample of the S3-station at 30 m showed the highest *Ech/Pyg* ratio of all samples, but this could not be verified by the TAD sample. We think that the 30 m MVVG sample might represent an example of patchiness.

We suspect that with our methods we did not catch all taxa of meiofauna with equal efficiency. The proportions of the taxa found were possibly influenced by the shape and the skin (hydrophobic exocuticle) of the organisms. Certainly the "bubbling method" increases the sampling efficiency of the Kinorhyncha and decreases that of the Nematoda. These effects were obviously lowered, however, by including the „sieving method“ whereby more Nematoda and less Kinorhyncha were caught. Generally two-thirds of the Nematoda and one-third of the Kinorhyncha per station were sampled using the "sieving method". The number of the Copepoda is the same using both methods.

Many of the soft-bodied meiofaunal animals were destroyed before they could be determined and could therefore not be counted. They just appeared as undefinable artefacts. This destruction is probably primarily due to the storage and the treatment of the sample while sieving and also while counting in aqua dest.

With regard to the sampling gear, a comparison of the numbers of individuals resulting from the mini van Veen grab (MVVG) and the triangle dredge (TAD) is interesting. Except for two stations (I3 and C3), the number of organisms are higher in the TAD samples. Possible explanations are the following:

- the amount of substrate taken from the TAD should be equal to the substrate taken from one MVVG. But in fact, a MVVG does not work with the same efficiency and depends on the composition of the substrate and how it reaches the ground. We only took samples when the MVVG was filled to a certain extent, but discrepancies could not be avoided. For the TAD one can never know where the substrate was taken. It could come from an oxygen and meiofauna rich surface sediment or from a deeper sediment layer depending on how deep the dredge was digging into the ground.
- a second explanation could be the horizontal distribution of the meiofauna. It is known that patchiness of meiofauna sometimes occurs within a radius of only a few (Giere, 1993). Tendencies of the distribution of meiofauna might be easier to recognise using the TAD because in these samples patchiness is covered well. The MVVG on the contrary only samples a little spot of the ground and therefore shows just a small aspect of the biodiversity.

The Kinorhyncha species determined are common for this area. All species were already found in the southern part of Disko Island (Higgins and Kristensen, 1988) with the exception of *Pycnophyes spitzbergensis* which was only found at Svalbard in 1995 by A. V. Adrianov. *Pycnophyes spitzbergensis* is therefore a new record for Greenland. Higgins and Kristensen (1988) found in their study two more species: *Echinoderes angustus* and *Echinoderes peterseni,* with *E. angustus* being the most eurytopic species. Possibly this species prefers the southern more Subarctic area of Disko Island, but it is also possible that we might find it in the remaining samples. *Echinodermes peterseni* appeared only at a single station and seemed to be associated with the encrusting red algae *Lithothamnium glaciale*.

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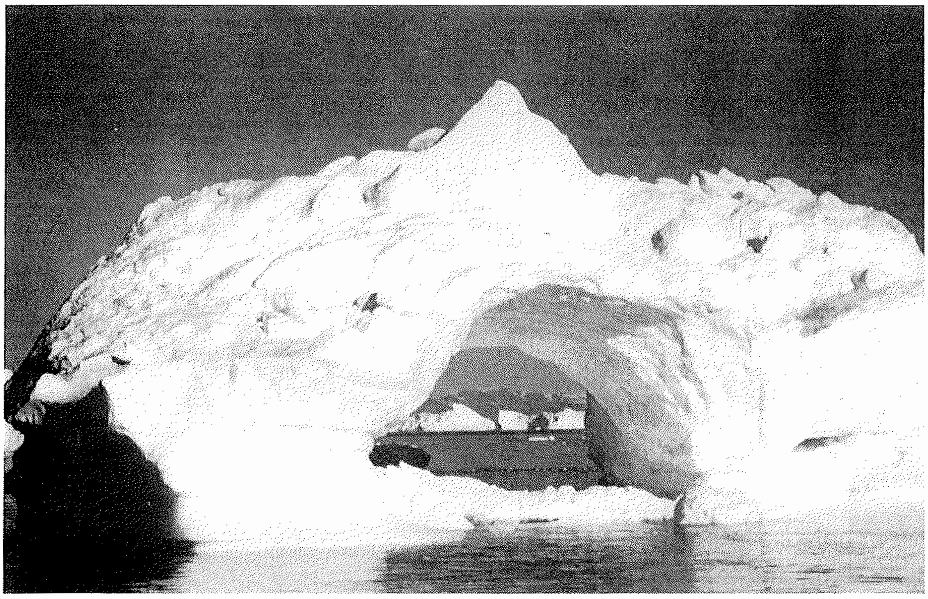
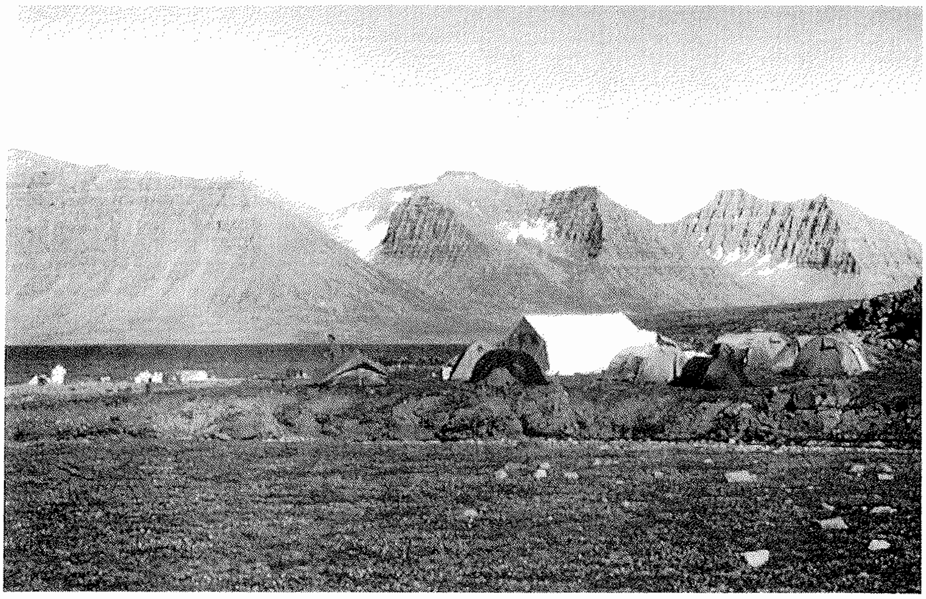
The Arctic Station Queqertarsuaq (Godhavn), Disko Island, West Greenland

Iceberg seen from the Arctic Station



Campsite in the Mellemfjord



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