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Community structure and species biodiversity in benthic fauna in the deeper Barents Sea

Michaela M. Aschan and Hilde C. Trannum

The community structure of the Barents Sea benthos is studied and species assemblages for the northern, eastern and southern Barents Sea are identified. The biogeography and the diversity of the benthos in the Barents Sea are described in relation to environmental variables. A novel method has been developed to effectively sample a large number of epifauna samples. A juvenile bag attached to a Campelen survey trawl at 125 stations in the Barents Sea. The stations covered the central part of the sea, with a depth range from 164 to 484 m. At 12 selected stations also infaunal samples were collected with the van Veen grab, to investigate the similarity between these sampling modes. In the epibenthic samples 197 taxa were recorded, where most were crustaceans (107 taxa). The species diversity is higher in the grab samples than in the bag samples although species number is only slightly higher in the grab samples. A Canonical correspondence analysis (CCA) revealed depth and temperature, which are correlated with longitude and latitude, as significant environmental variables (P=0.002) influencing the faunal distribution. 17 of the taxa were found to adequately represent the variation of the sampled communities, and are suggested as indicator species that can be used in monitoring effects of climate change.

Key words: Epibenthos, biodiversity, monitoring, ecology quality measures, indicator species, Barents Sea, climate change.

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INTRODUCTION

Topography of study area

The Barents Sea is a relatively shallow continental shelf sea with an average depth of 229 m and a volume of 322,000 km^2 (Zenkevich 1963). The shallowest area is the Svalbard Bank situated between the Bear Iceland and Hopen, with large areas shallower than 50 m. Depths below 400 m are rare, and are found in the western and northeastern part. The deepest area is the Bear Island Trench, having depths down to 500 m.

Since the Barents Sea is a shallow shelf sea, the bottom topography has large influence on the distribution and movement of the water masses (Figure 1).

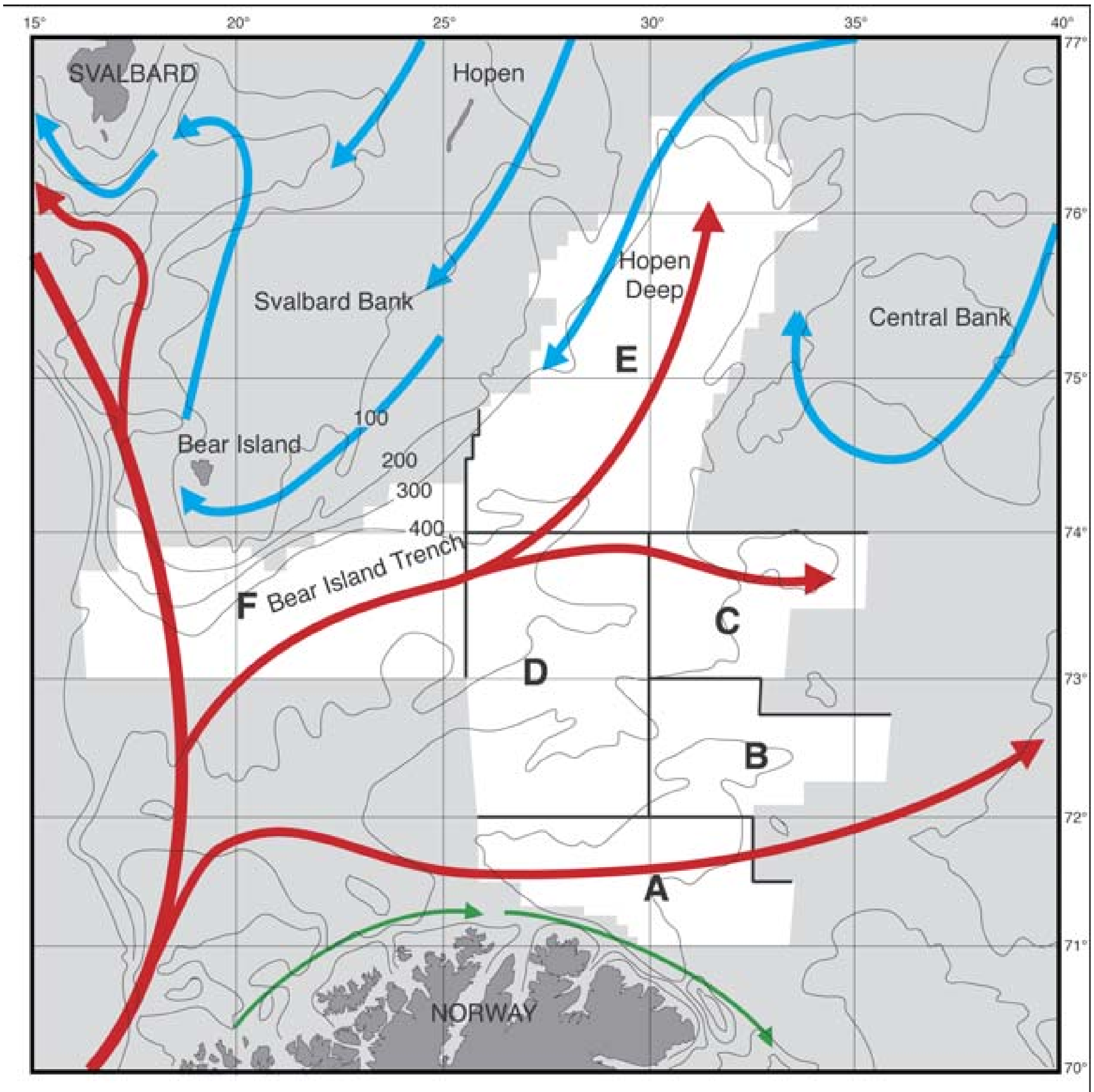


Figure 1. A schematic description of the circulation of the Barents Sea. Arrows show the current of Atlantic water (red) and Arctic water (blue). Main areas are East Finnmark (A), Tiddly Bank (B), Thor Iversen Bank (C), Bear IslandTrench (D), Hopen (E) and Bear Island (F).

Hydrography, water masses and ice

There are three main water masses in the Barents Sea; Atlantic water, Coastal water and Arctic water. The Atlantic water has a salinity higher than 35 ‰ and the temperature is higher than 3 ºC. Both the salinity and the temperature decrease towards the north and east as the water mass gradually mix with other water masses. The Coastal water has lower salinity than the Atlantic water, but approximately the same temperature (S < 34.7‰, T > 2 ºC). This water mass lies between the mainland and the heavier Atlantic water, and is deep and narrow during winter and shallower and broader during summer. Arctic water has a salinity of 34.4-34.6‰ and temperature below zero and occurs between 20 and 200 m in the northern part of the Barents Sea. The Atlantic water enters the Barents Sea from the south as the Norwegian Atlantic Current. The current divides into two main branches in the Bear Island Channel; one branch, the Murman Current, continues eastward parallel to the Norwegian Coastal Current. The other main branch turns north along the Hopen Trench and divides into smaller branches. Arctic water enters the Barents Sea between Spitsbergen and Franz Josef Land and, more importantly, between Franz Josef Land and Novaja Zemlya. There is considerable variation in the inflow of Atlantic water (Loeng et al. 1997; Ingvaldsen et al. 2002a), which in turn impacts the climatic conditions in the southern Barents Sea.

The Polar Front is formed where the Atlantic and the colder water masses meet. Its position follows the bottom topography and it runs from the west of Spitsbergen, south of the Bear Iceland northwards to the Great Bank and then to the southwest around the Central Bank. In the western part the Polar Front is well defined and stable, while it in the eastern part forms a broad and less defined transitional zone between the different water bodies.

In the Barents Sea there is mainly one-year ice, but there may also be small amounts of ice that has not melted during summer or multi-year ice drifting from the Polar Sea (Vinje 1994). The ice coverage is usually on its maximum in March-May and on its minimum in September-October. The maximal distribution of ice usually follows the position of the Polar Front, and thus the largest variations in ice covering are found in the eastern part of the sea, while the variation in the western parts are smaller.

Sediment and benthic fauna

The bottom sediment in the Barents Sea is very heterogeneous, ranging from fine mud in accumulation areas, to rock and stone in erosion areas (Elverhøi et al. 1989). There is a large area of mixed sediments south to southeast of Spitsbergen, while the remaining areas generally comprises fine-grained pelite material, with an admixture of sand (Fredriksen et al. 1994). In addition to this generalized picture, local variations are also expected.

The Barents Sea is one of the best studied shelf seas in the world, because of Russian, British and Norwegian expeditions in the beginning of the 20th century. Zenkevitch (1963) gave a huge review of available data up to that time. Blacker (1957) and Dyer and et al. (1984) presents benthic animlas as indicators of climate changes in Svalbard waters. After that there has been studies by e.g. Herman (1989), Piepenburg et al. (1995), Kendall (1996), Kiyko and Pogrebov (1979) and lately b Denisenko and Titov (2003) and Denisenko et al. (2003). Some data have also been published as reports, e.g. Cochrane et al. 1998; Dahle et al. (1995a, b). A new source of data is provided by the start-up of petroleum activities in the southern Barents Sea, where the operators have to perform environmental monitoring before the production starts and then every third year. The Norwegian research programme MAREANO started in 2005 and studies the physical, chemical and biological environment of the sea bottom (www.mareano.no).

The marine animals living in the near-bottom layers are associated with both the benthic and pelagic communities (Wishner 1980). According to their mode of life, these taxa are considered benthopelagic, nektobenthic or epibenthic (Wishner 1980; Petryashov 1990). The organisms play a significant role in the bentho-pelagic feedback system (Branth 1997). Benthic-pelagic coupling is supposed to play a key role in the structuring of benthic assemblages (Graf 1992). As the taxa in this zone are rarely caught by pelagic as well as benthic equipment, they have generally been less studied. The zone has been studied through sampling with different gears like sledges and trawls in Arctic waters (e.g. Piepenburg & Schmid 1996; Piepenburg et al. 1996; Sirenko et al. 1996; Brandt 1997); of these only the study of Piepenburg et al. (1996) covered a part of the Barents Sea. There is therefore a gap of knowledge regarding this ecologically important zone in the Barents Sea.

Until now, the Barents Sea has been considered a pristine sea. However, the fishery, organochlorine as well as nuclear contaminants are believed to effect the benthic fauna (Borgå 2002). Oil and gas activities are increasing in both the Norwegian and the Russian sector. Even though the Norwegian activity will be performed with zero discharges to the sea, there is a risk of acute discharges from the production wells. The activity will lead to increased ship traffic, and thereby increase the risk of oil spills and the introduction of alien organisms.

The effects of the increasing stock of the king crab (*Paralithodes camtschaticus*) also require monitoring of the benthos. The king crab was introduced by Russian scientists several times in the Murman area in the 60ies, and has since then spread successfully. It is now established in the easternmost fjords in Norway but is also recorded at the Goose Bank in the south of the Barents Sea and in the vicinity of the Bear Island. The crab has a social behaviour, and is often found in flocks of several hundred (Sundet 1999). Presently, it is not known how the crab influences benthic communities. Possible effects may be related to both grazing and physical disturbances.

Climatic change represents another potential source of change of the benthos. Climate models predict that global climatic changes will be most pronounced in polar regions (IPCC 1998). The impact of warming may be amplified in the Arctic due to the combined effects of sea ice retreat and stable atmospheric stratification (e.g. Manabe & Stouffer 1994; Rind et al. 1995; Weller & Lange 1999). Several lines of evidence indicate that significant environmental change is already occurring in terrestrial and marine Arctic and sub-Arctic environments (Serreze et al. 2000; Grebmeier & Dunton 2000; Morison et al. 2000). South of the Polar Front the spring phytoplankton bloom results in a seasonal pulse of short duration, but high magnitude, of organic matter to the seabed, which favours benthic production relatively to pelagic production (e.g. Peterson & Curtis 1980; Sakshaug & Skjoldal 1989; Wassmann et al. 1996). In ice-covered areas, where ice algae dominate the primary production, the benthic communities may be further favoured relatively to the pelagic communities as ice algae are not so easily grazed by herbivorous zooplankton (Carroll & Carroll 2003). However, the digestibility of ice algae is yet not clear. As the location of the ice edge in the Barents Sea can vary by hundreds of kilometres from year to year (Gloersen et al. 1992), the benthic fauna may experience large variations in the amount of available food and show large variations in structure. If climatic changes induce a shift in the distribution of the Atlantic and Arctic water masses, a permanent change in the benthic structure can thus be expected.

The above discussion shows that the benthic ecosystem in the Barents Sea can be subject to changes caused by several factors in the future. In order to monitor these changes it is important to have sufficient knowledge about the present structure of the ecosystem and also about the scale of natural variation. Here we describe variation in species diversity and community structure in epibenthic communities and propose indicator species.

MATERIAL AND METHODS

Sampling

The epibenthic sampling was conducted during the annual Norwegian shrimp survey in the Barents Sea 15.04-02.05.2002. The survey area is divided into six main areas mainly covering areas deeper than 200 m (Figure 2). In the Barents Sea the distance between trawl positions generally has been 28 nautical miles, except for the Hopen area (E) where sampling density of 20 nautical miles is maintained due to a combination of high shrimp biomass and heterogeneity. Harbitz *et al.* (1998) evaluated the accuracy and precision of the estimates obtained by such a sampling strategy. A Campelen 1800 survey trawl was used and a mesh bag of nylon (0.8 mm) with a 1 m^2 opening, the juvenile shrimp bag, was attached to the under belly (Figure 3). The juvenile shrimp bag samples a sub sample of small organisms, including juvenile shrimp and fish as well as benthic fauna, that flow into the trawl but escape through the meshes of the survey trawl. At each station the trawl with the attached juvenile bag was hauled for 20 minutes with a speed of 3 knots making 1 nautical mile. Aschan & Sunnanå (1997) gave a detailed description of the shrimp surveys.

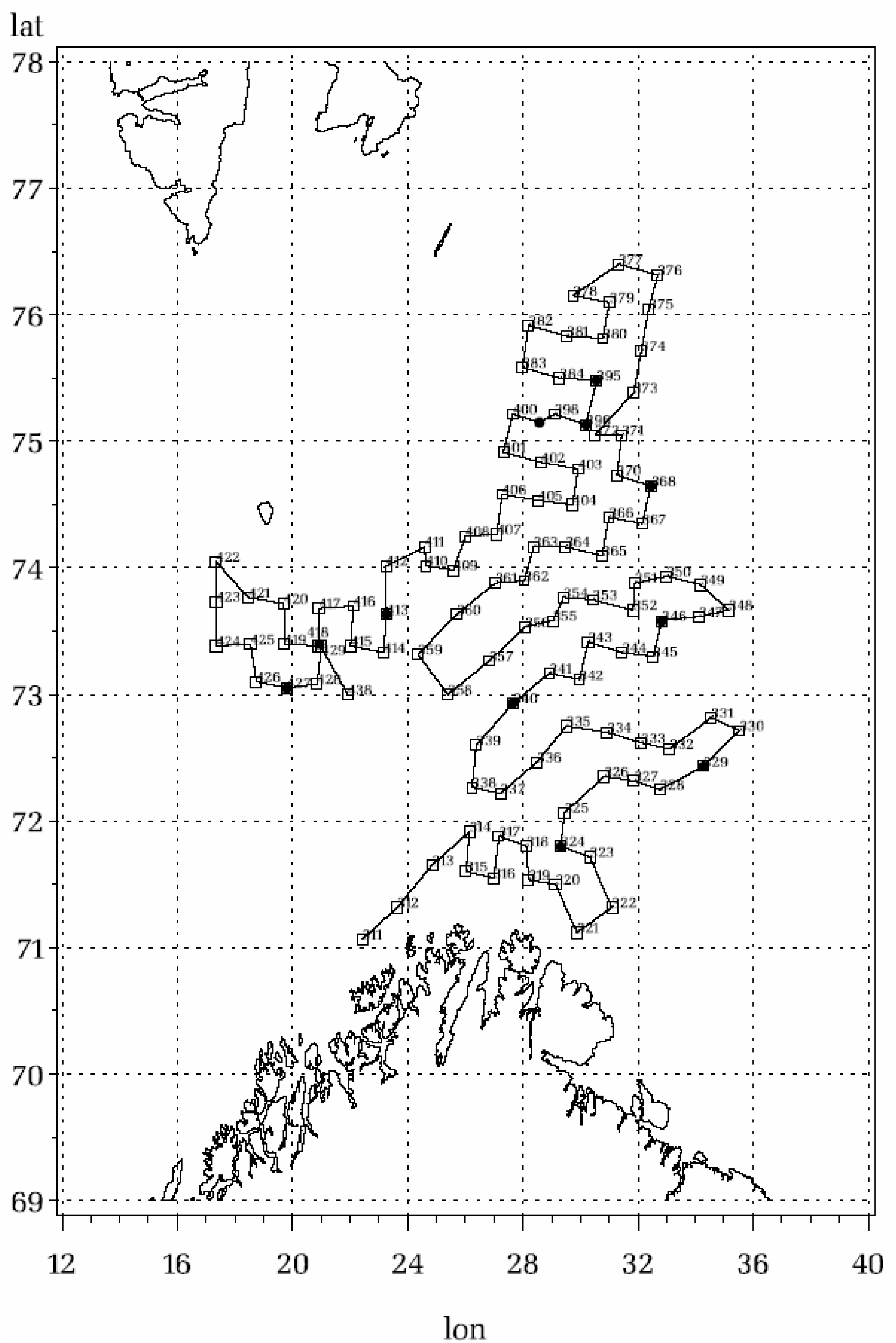


Figure 2. Overview of station grid. Square = Trawl station with sample from juvenile bag and filled circle = Van Veen grab sample.

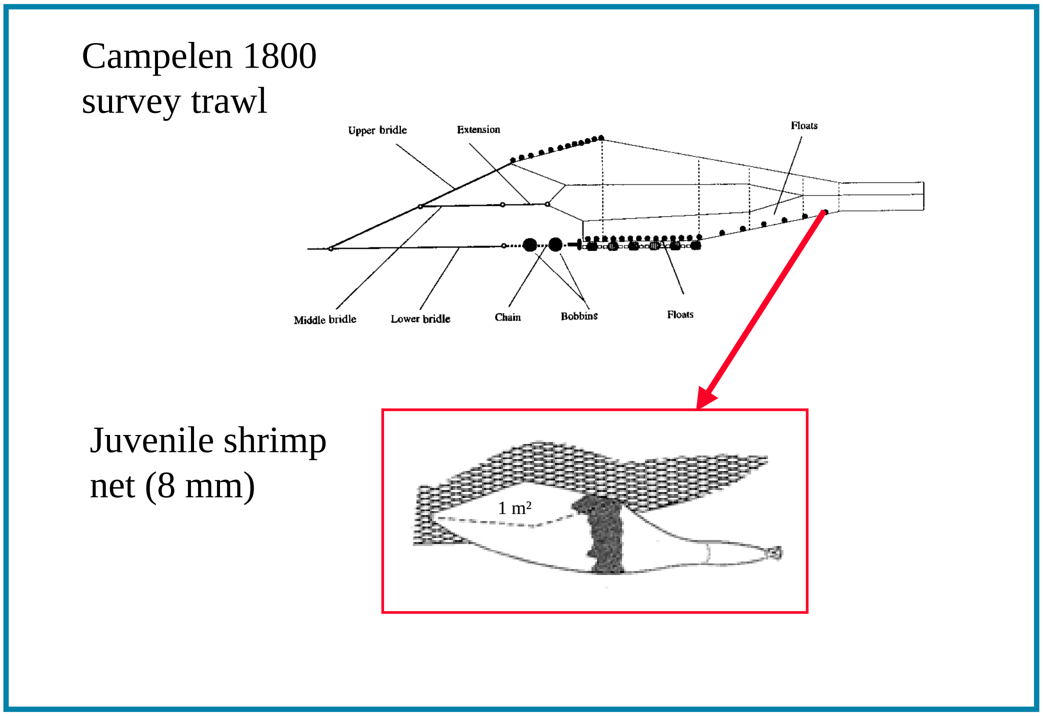


Figure 3. A schematic illustration of the Campelen 1800 survey trawl and the juvenile shrimp bag.

Fieldwork and identification

At each station time, depth, bottom temperature (SCANMAR temperature sensor) and light at surface were registered. The juvenile bag was emptied into a bucket and then sorted carefully in the laboratory. The number of individuals of each species was registered. Most of the material was identified during the cruise. Unidentified individuals were delivered to specialists on the main taxonomic groups.

For some samples only 50%, or in very few cases 30% or 70%, of the collected material was identified due to the large volume sampled and time pressure. For these samples the abundances were multiplied to achieve an estimated value of 100%.

Some stations were also sampled with a 0.1 m^2 van Ven grab, which provides a direct comparison of the two sampling devices. One replicate at each station was processed, with the exception of one station, where three replicates were processed.

Analysis of grain size and TOC

An analysis of grain size and TOC of the sediment was carried out on the stations that were sampled with the van Veen grab. The samples were split into coarse (i.e. >0.063 mm) and fine (i.e. <0.063 mm) fractions by means of wet sieving, and dried in an drying chamber at approximately 60 °C (modified after Buchanan 1984).

To analyse TOC the samples are first dried in a drying chamber at 60 °C. Approximately 0.22 g (no more than 0.24 g) is weighted into porous crucible. The TOC-analysis is done one a Leco IR 212 carbon analyser. The instrument calculates the carbon content by measuring the CO_2 in the gas that is formed by a burning process.

Data analyses

Various univariate measures for faunal data were calculated for the bag samples and the grab samples, and included total number of taxa (S), total abundance (N), Shannon-Wiener diversity index (Shannon & Weaver 1963) calculated using $\log_2$ (H’), Pielou’s evenness (J’) (Pielou 1966) and Hurlbert’s diversity index (ES_{100}, Hurlbert 1971).

For both the epibenthic samples and the grab samples multivariate analyses were performed. MDS ordination was conducted using the PRIMER-package (Clarke 1993; Clarke & Warwick 1994). Similarity between samples was calculated using the Bray-Curtis similarity coefficient (Bray and Curtis 1957). The goodness of fit of the 2-dimensional MDS-plot was measured using Kruskal’s stress Formula 1 (Kruskal & Wish 1978).

Canonical correspondence analysis (CCA) was used to assess the relationship between species abundance and the measured environmental data, which were depth, temperature and time. The time factor was introduced to evaluate eventual effects of diurnal vertical migrations. The time was converted to a scale relating to sun elevation.

The principles of CCA are explained in Greenacre (1993), Jongman et al. (1995) and Fieler et al. (1994). Consider geometrically, each species can be considered as a point in the multidimensional space defined by the stations, and each species is given a weight, or “mass” proportional to the overall abundance of the species. Similarly, each station represents a point in the multidimensional space defined by the species and receives a mass proportional to the number of individuals counted at that station. Dispersion is defined as the weighted sum-of-squared distances of the species points (or, equivalently, of the station points) to their average. This dispersion is termed inertia, which is a measure of variance. Species with most inertia explained by the first two or three axes are considered to be most influenced in their distribution by the selected environmental variables. The CANOCO software package was used for CCA (ter Braak 2002).

RESULTS

Shrimp bag sampling

Dominant species and diversity

An overview of the most dominant species is presented in Table 4. Altogether 46567 individuals and 197 taxa were recorded in the shrimp bag. Of these, there were 107 taxa of crustaceans, 28 taxa of poychaetes, 26 taxa of echinoderms and 25 taxa of molluscs, while 11 taxa belong to other groups. Of the crustaceans, the amphipods dominated with 67 taxa, followed by 14 taxa of decapods, 9 taxa of isopods, 4 taxa of euphasids and 4 taxa of mysids. In each haul, the number of species varied from 11 (station 379) to 50 (station 402) and the number of individuals from 71 (station 314) to 1088 (station 366). Number of species (S), number of individuals (N), Shannon Wiener diversity (H'), Hurlbert's diversity (ES_{100}) and evenness (J') for each bag sample is given in Appendix 1.

Station groupings

The MDS ordination of the epibenthic communities is shown in Figure 4. It is evident that the south-north gradient in the dataset is much stronger than the east-west gradient. Furthermore, from the MDS ordination depth does not seem to have major importance on the structuring of the epibenthic communities as the stations not to a large extent are classified according to depth.

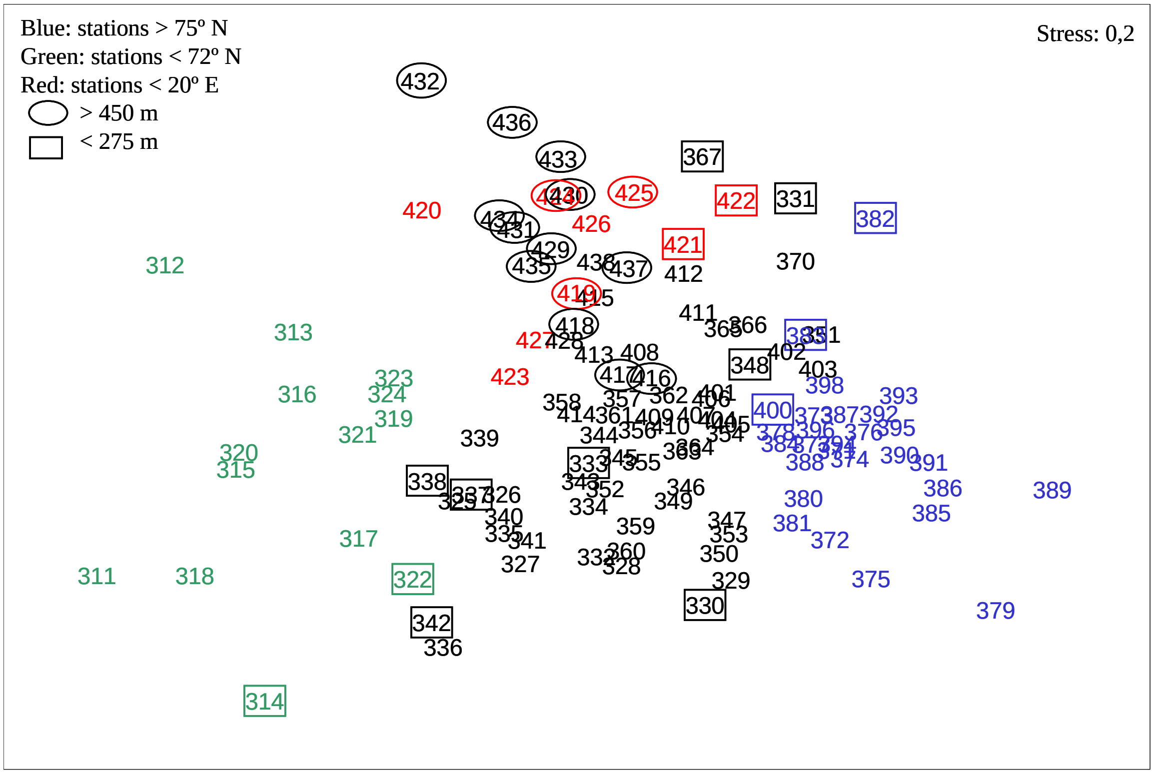
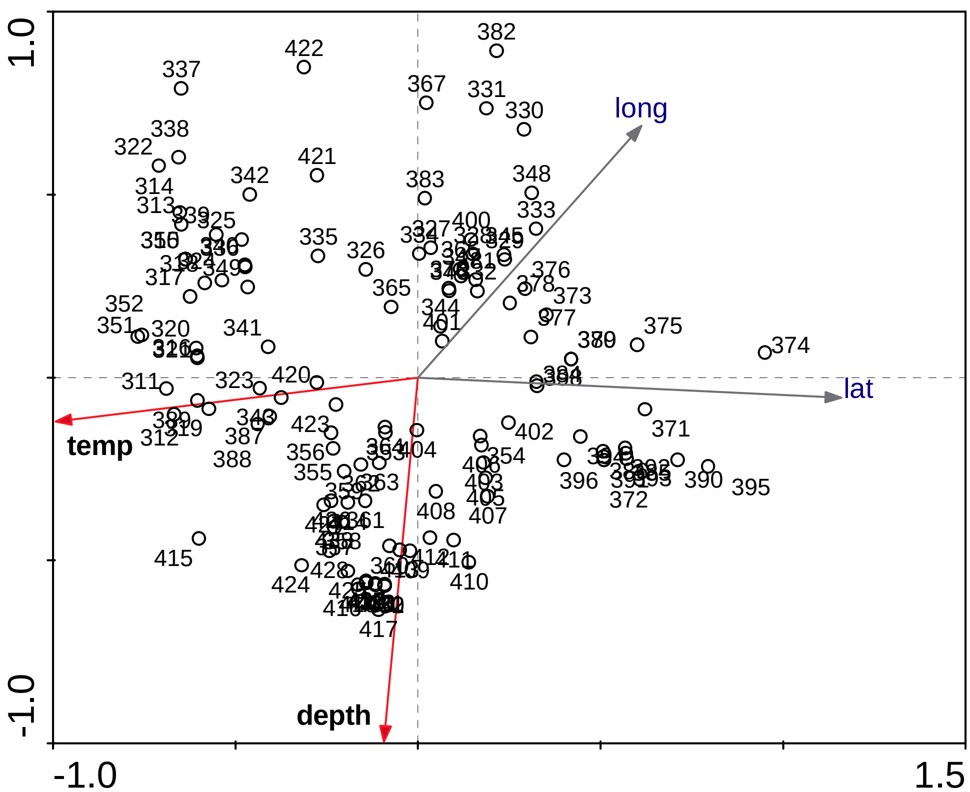


Figure 4. MDS ordination of epibenthos.

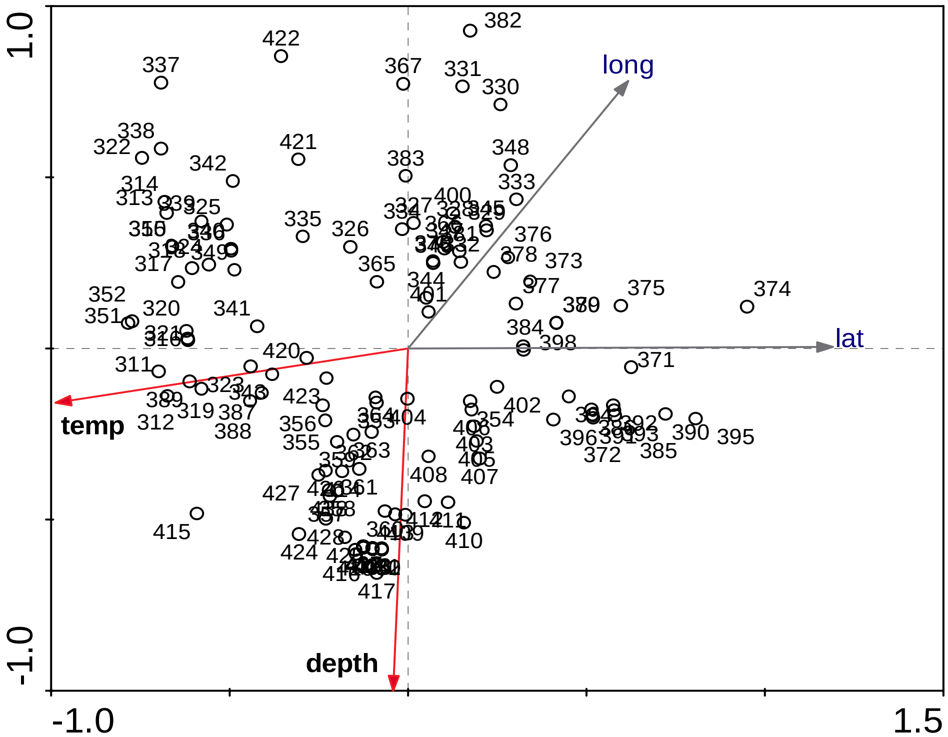
A CCA analysis was carried out to quantify the relative influence of the measured physical variables on the faunal distribution. The three environmental variables, depth, temperature and sun elevation were fitted to the environmental data, while the positions were treated as supplementary variables, which means that they are projected on the plot *a posteriori*. The analysis revealed depth and temperature significant (P=0.002), while the sun elevation was not significant. A biplot of the two first axes showing the stations and vectors for the environmental variables is shown in Figure 5a, while a biplot of selected species and environmental variables is shown in Figure 6. The criterion for the selection of the species was that they either should be among the 15 most dominating species or among the 15 species that contribute most to the biological variation. On this basis 19 species were selected. The four additional species that were included based on the explanation of variance, were *Ophiura sarsi*, *Halirages fulvocincta*, *Arca* sp. and *Arrhis* sp. *Arrhis* sp. was recorded by 137 individuals, while the other species were more abundant. The taxa that were only identified to order level or higher (Asellota indet., Polynoidae indet.), were excluded as they comprised more than one species, and then 17 species remained.

The first axis in the plot has a highly positive correlation with temperature, and shows a gradient with the northern station in the negative end and the southern stations in the positive end. The second axis has a highly negative correlation with depth, with the deep stations in the negative end and the shallow stations in the positive end. Only 9.1% of the biological variation is explained by the two first axes in the ordination.

In order to investigate whether the 17 species that were selected in the CCA analysis of the complete dataset had the potential to represent the whole community, a new CCA analysis was performed on only these species, see Figure 5b. As the plot shows, the analysis based on these 17 selected species to a very large extent gave the same result as the ordination based on the complete dataset. Furthermore, depth and temperature were significant variables (P = 0.002). Thus the 17 selected species are to a very large extent representative of the whole epibenthic communities. 13.0% of the biological variation is explained by the two first axes in the ordination space.



a)



b)

Figure 5. Biplot from the CCA analysis of the epibenthic communities, showing the stations and environmental variables. a) analysis based on all species. b) analysis based on 17 selected species.

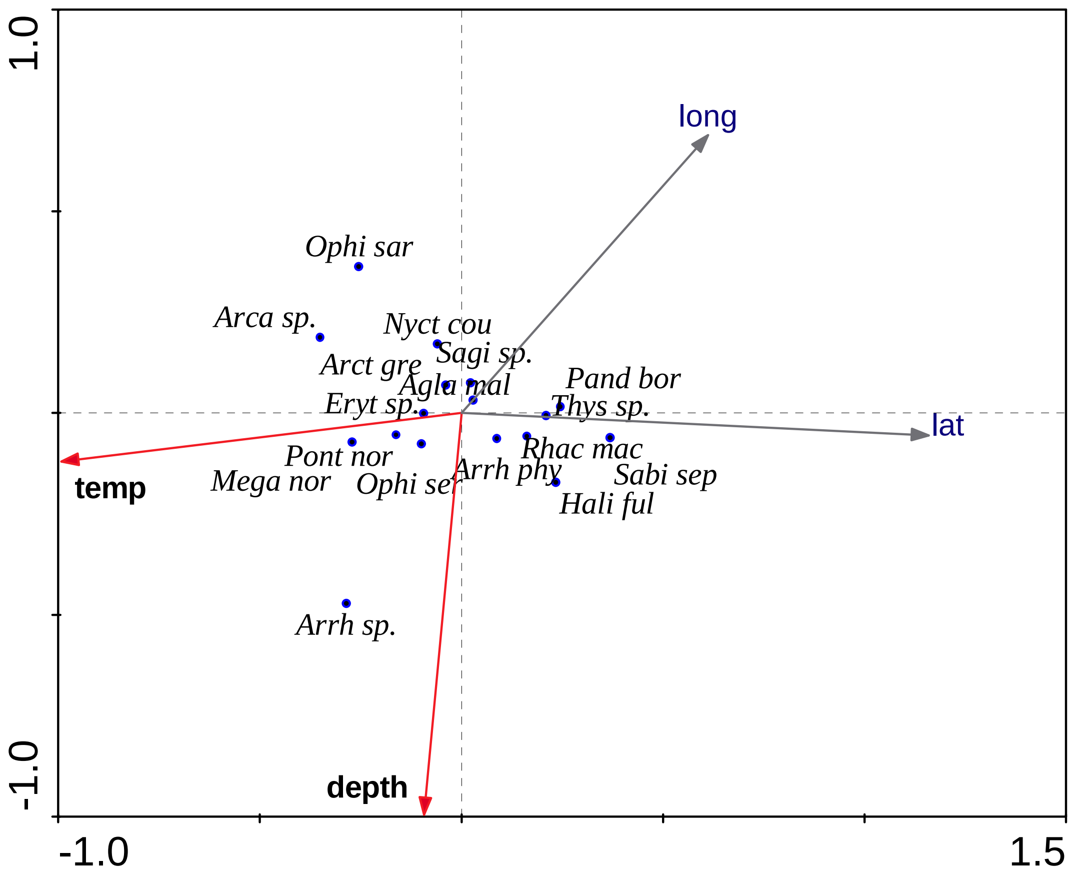


Figure 6. Biplot from the CCA analysis of the epibenthic communities, showing selected species and environmental variables.

Examples of distribution patterns for species belonging to the same taxonomic groups are given in Figure 7 and Figure 8 for decapods and Figure 9 and Figure 10 for euphausiids. For these taxa it is clearly evident that there is a shift in dominance pattern along a south-north gradient.

Pontophilus norvegicus (M. Sars, 1861).

http://www.tmu.uit.no/crustikon/Index.htm

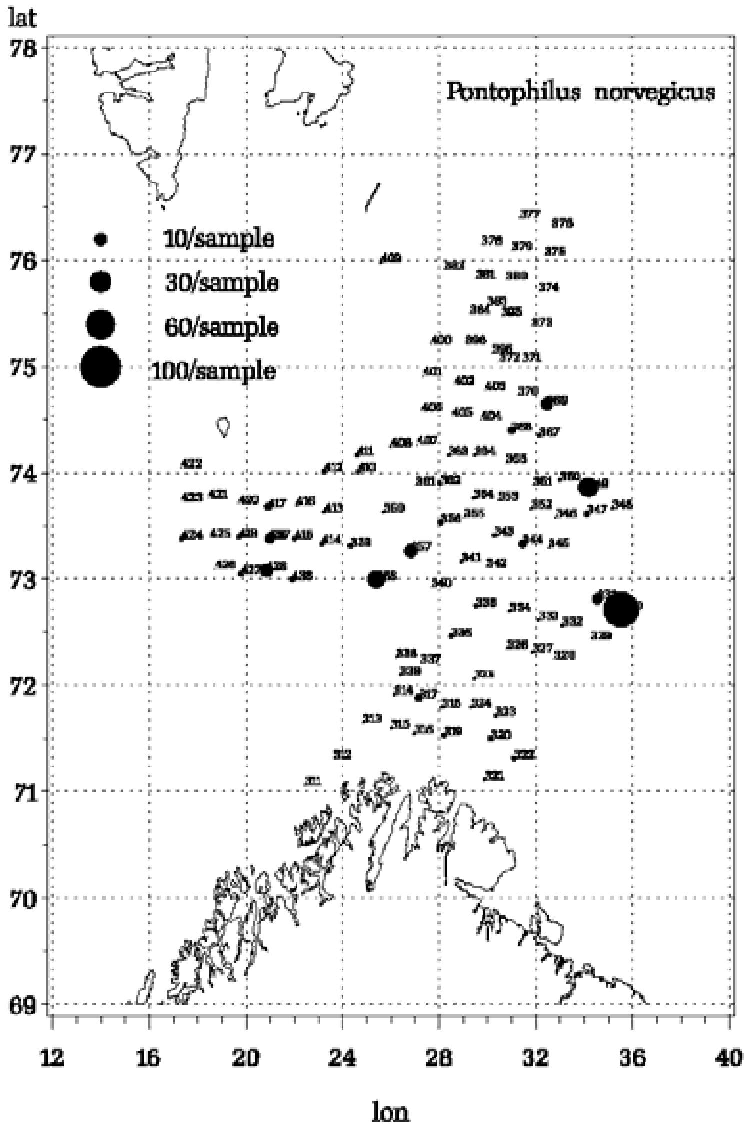


Figure 7. Distribution map of *Pontophilus norvegicus.*

Sabinea septemcarinata (Sabine, 1824)

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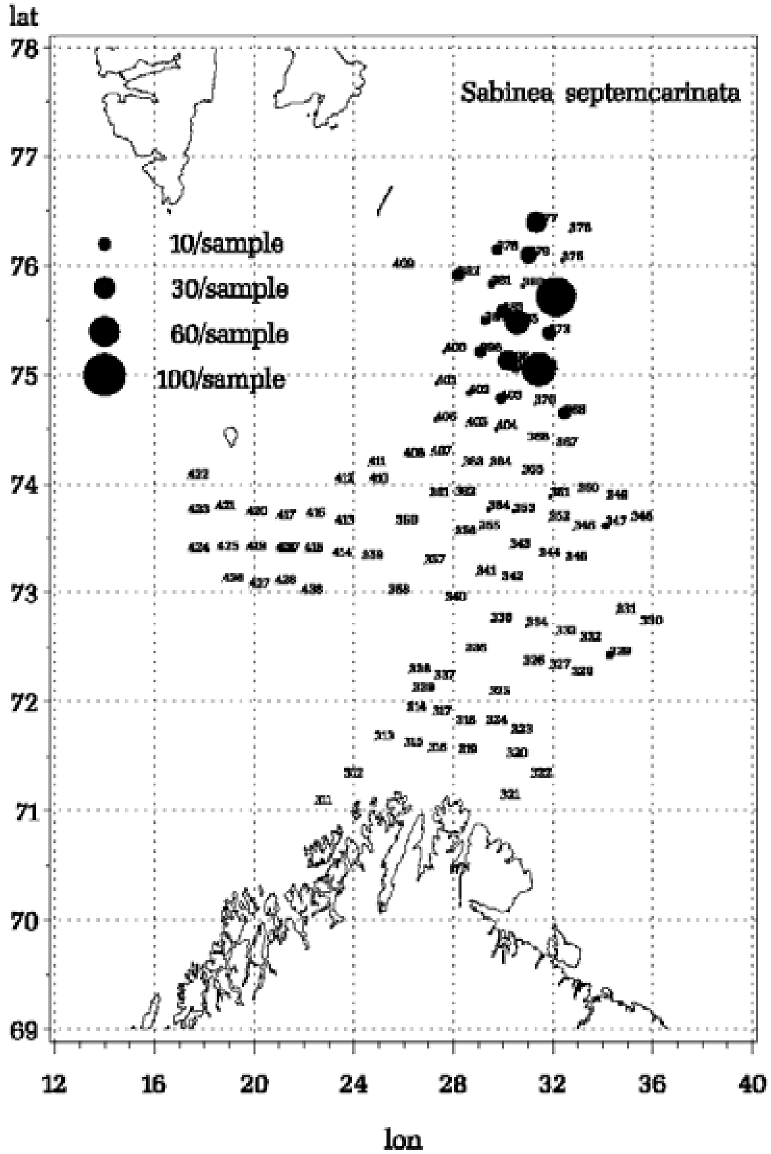

Figure 8. Distribution map of *Sabinea septemcarinata.*

Meganyctiphanes norvegica (M. Sars, 1856) (Northern krill)

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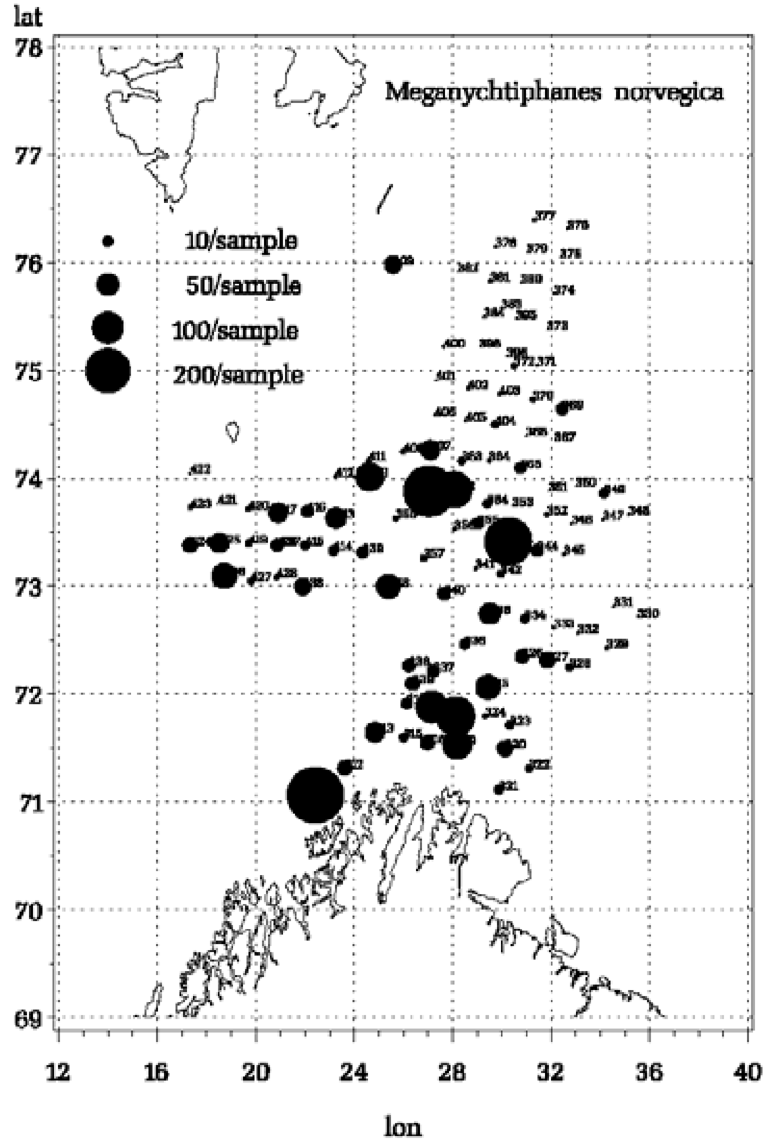

Figure 9. Distribution map of *Meganyctiphanes norvegica.*

Thysanoessa sp.

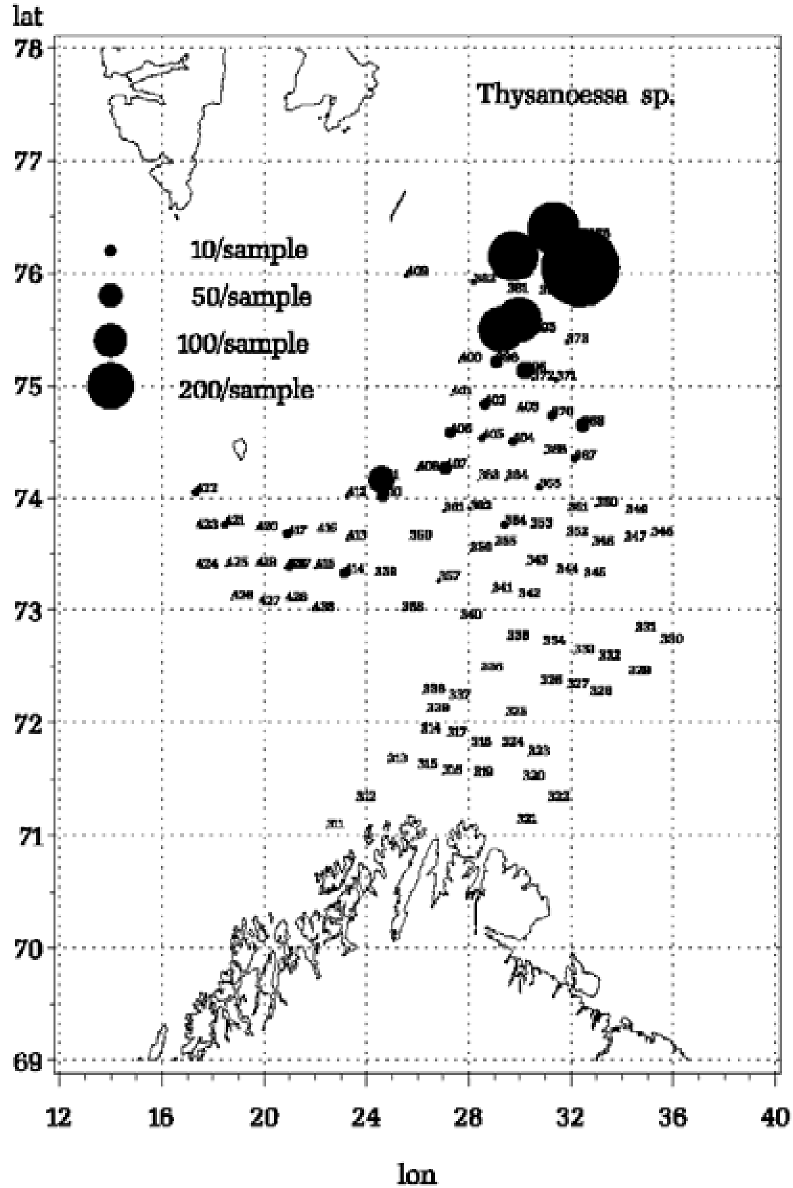

Figure 10. Distribution map of *Thysanoessa* sp.

A separate CCA analysis was performed on the stations where data on the grain size and content of normalised organic carbon (norm. TOC) were available, i.e. at the stations that also were sampled with the van Veen grab, see Figure 11. As station 369 highly differed from the other stations, it was excluded from the analysis, despite of the fact that this station also was sampled with a grab. Again latitude and longitude were treated as supplementary variables. The plot of the analysis is not shown, but the result was that the amount of depth (P = 0.010) and pelite (P = 0.018) were significant variables. Temperature was excluded from the analysis as it was highly correlated with other variables (negatively correlated with the amount of pelite). 37.6% of the biological variation is explained by the two first axes in the ordination.

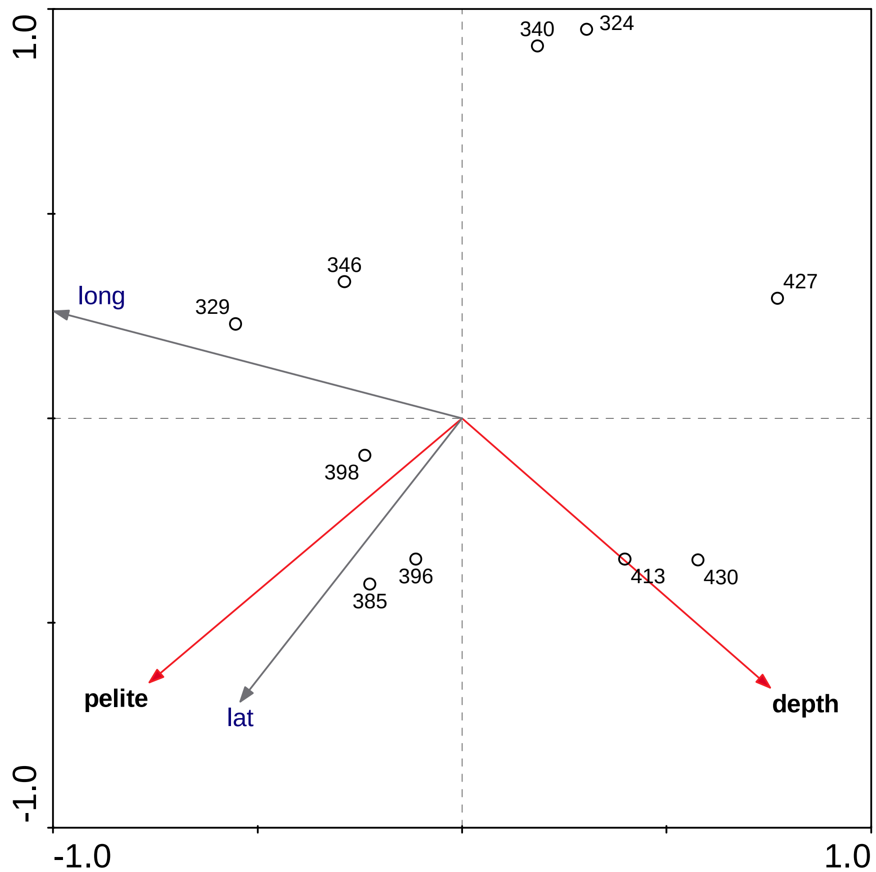

Figure 11. Biplot from the CCA analysis of the epibenthic communities at the stations that also were sampled with the grab, showing the stations and environmental variables.

Grab sampling

The environmental characteristics of the stations that also were sampled with a van Veen grab are shown in Table 1. The depth ranged from 164 m (st. 369) to 466 m (st. 430) and the amount of pelite from 20% (st. 369) to 96% (385). The content of total organic carbon ranged from 0.6% (st. 324 and 340) to 2.1% (st. 385) and the normalised organic carbon from 12.5 mg/kg (st. 340) to 32.5 mg/kg (st. 369). The temperature varied from -1.1 ˚C (st. 369) to 3.7 ˚C (st. 324).

Table 1. Depth, temperature, amount of pelite (<0.063 mm) and content of TOC/norm. TOC at the grab stations. The maximum and minimums values are indicated with bold.

Station	Depth (m)	% pelite	% TOC	Norm. TOC (mg/kg)[a]	Temperature (˚C)
324	298	62.24	**0.62**	13.00	**3.7**
329	277	90.78	1.57	17.36	0.7
340	290	64.77	**0.62**	**12.54**	3.3
346	293	82.90	1.19	14.98	1.1
369	**164**	**20.42**	1.82	**32.52**	**-1.1**
385	367	**95.78**	**2.08**	21.56	0.2
396	374	91.81	1.88	20.27	0.5
399	335	89.74	1.89	20.75	0.6

413	440	80.52	1.28	16.31	1.8
427	415	63.66	0.89	15.44	2.6
430	**466**	76.93	1.21	16.25	2.0

[a] Norm. TOC = TOC + 18(1 – F), where TOC and F represent the measured TOC and the proportion of pelite in the sample, respectively (Aure et al. 1993).

The biological characteristics of the grab samples are shown in Table 2. The number of species ranged from 31 (st. 346) to 59 (st. 324) and the abundance from 91 (st. 413) to 236 (st. 324. The Shannon-Wiener diversity and Hurlbert's diversity ranged from 3.2 (st. 346) to 5.0 (st. 324) and from 21 (st. 385) to 39 (st. 324), respectively, while the evenness ranged from 0.64 (st. 346) to 0.91 (st. 413 and 427). The samples from station 430 showed very similar values for the Shannon-Wiener diversity and Hurlbert's diversity.

Table 2. Number of species (S), number of individuals (N), Shannon Wiener diversity (H'), Hurlbert's diversity (ES_{100}) and evenness (J') of the grab samples (0.1 m^2). The maximum and minimums values are indicated with bold.

St.	S	N	H'	ES_{100}	J'
324_01	**59**	**236**	**5.0**	**39**	0.85
329_01	36	167	4.2	28	0.81
340_01	45	108	4.9	43	0.89
346_01	**31**	153	**3.2**	25	**0.64**
369_01	52	206	4.8	36	0.84
385_01	34	280	3.5	**21**	0.69
396_01	35	128	4.1	31	0.80
399_01	40	234	3.9	27	0.73
413_01	34	**91**	4.6	34	**0.91**
427_01	42	93	4.9	42	**0.91**
430_01	43	156	4.5	34	0.83
430_02	53	223	4.4	33	0.77
430_03	40	170	4.3	33	0.80

A MDS-ordination of the grab samples is given in Figure 12. There was no clear classification of samples, with the exception of the samples from station 430, which showed a very large degree of similarity. The large similarity between these samples indicates that one sample in this case will be representative of a larger sampling area.

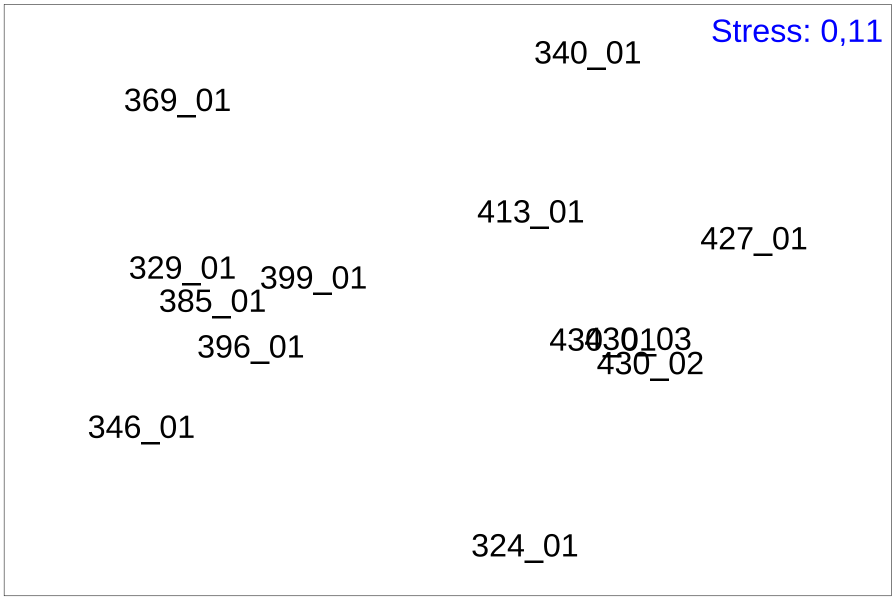

Figure 12. MDS ordination of grab-samples including tree replicates from station 430.

A CCA analysis was carried out to quantify the relative influence of the measured physical variables on the faunal distribution. As for the epibenthos samples, station 369 was excluded. Only the first replicate from station 430 was used. The five environmental variables, depth, pelite, normalised TOC, temperature and sun elevation were treated as primary environmental variables, while the positions were treated as supplementary variables. The values were transferred with ln(x+1). Temperature was excluded from the analysis as it was shown to be highly correlated with other variables (again the amount of pelite). The analysis then revealed pelite (P=0.006) and depth significant (0.046), while the other variables were not significant. This is the same result as for the CCA of the epibenthos from the grab stations. A biplot of the infaunal samples showing the stations and vectors for the environmental variables is given in Figure 13. 32.1% of the biological variation is explained by the two first axes of the plot.

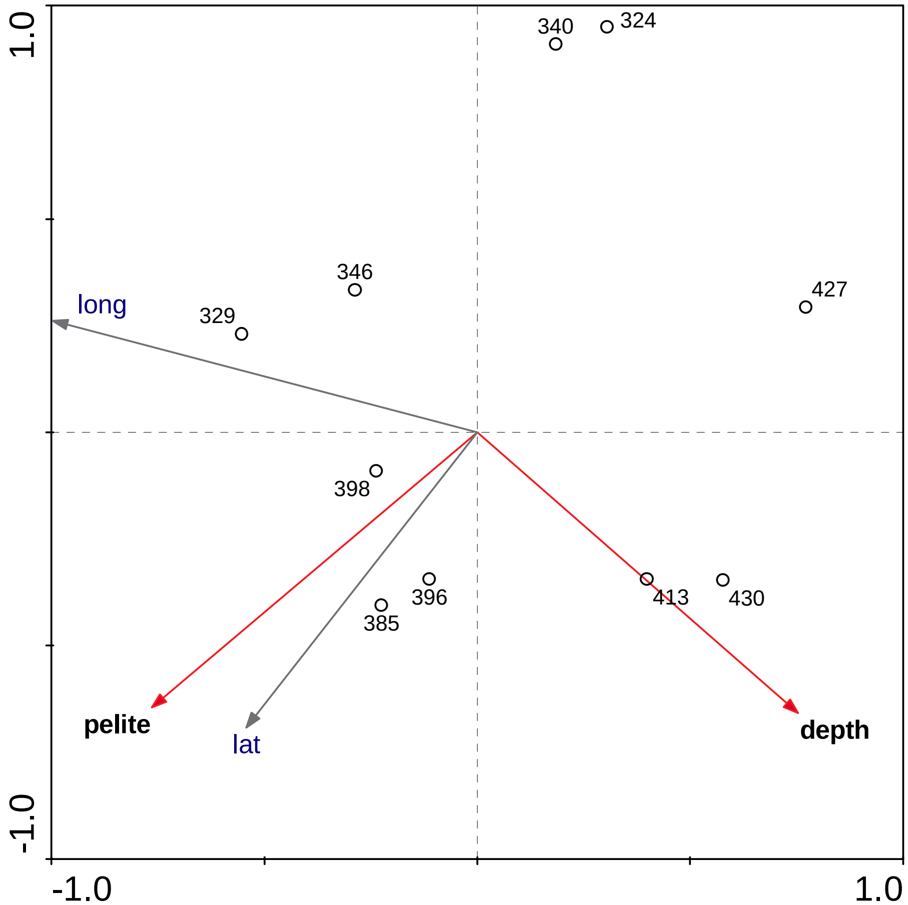

Figure 13. Biplot from CCA analysis of grab samples, showing stations and environmental variables.

Comparison of sampling with grab and shrimp bag

To compare the similarity in faunal composition between the grab- and epibenthic samples, a cluster-analysis was performed at the stations where both sampling devices were used (plot not shown). The similarity between these two sets of samples was less than 5%, clearly showing that the sampling devices collect completely different ecological zones. 21 taxa were sampled with both devices, see Table 3. However, only the polychaete *Aglaophamus malmgreni* was consequently found in both set of samples, while all the other taxa were only recorded with very few individuals in one or both sampling devices. The grab sampled by far more species of annelids than the shrimp bag. On the other hand, all crustacean groups were more represented in the shrimp bag than in the grab.

Table 3. Overview of taxa that were sampled with both the grab and the juvenile shrimp bag.

Species	sum grab	sum shrimp bag
Aglaophamus malmgreni	41	94
Ampharete finmarchica	2	1
Amphipoda indet.	1	29
Arca sp.	1	7
Arctinula greenlandica	3	793

Asellota indet.	3	39
Calathura brachiata	1	8
Cnidaria indet.	1	47
Ctenodiscus crispatus	5	14
Diastylis scorpioides	1	4
Diastylis sp.	4	1
Gammaridea indet.	2	2
Lysianassidae indet.	6	1
Nemertini indet.	37	2
Ophiopholis aculeata	1	6
Ophiura sarsii	1	25
Phascolion strombus	4	36
Pycnogonida indet.	1	23
Rhachotropis sp.	1	2
Spirorbidae indet.	1	8
Thyasira sp.	35	1

DISCUSSION

Dominant species in the juvenile shrimp bag

Ophiocten sericeum was by far the most dominant of the brittle stars, having the largest distribution in the central part of the sea. Dense assemblages of that species in the Barents Sea were also recorded by Piepenburg & Schmid (1996). However, they found that this species was rare or absent in deeper shelf habitats (>150 m), while no such trend was evident in our data. Starmans et al. (1999) reported that *Ophiocten sericeum* was most abundant in the transitional zone (62-186 m) between banks and troughs northeast of Greenland. *Ophiacantha bidentata* and *Ophiura sarsii* were also quite abundant in our study. Pipenburg & Schmid (1996) found that *O. bidentata* dominated the brittle star fauna in deeper habitats in the Barents Sea, while Starmans et al. (1999) found that it dominated in both banks and troughs northeast of Greenland. Neither these observations correspond with our findings.

Of the amphipods, *Rhachotropis macropus* was the most dominant species, followed by *Arrhis phyllonyx*. *R. macropus* had a north-eastern distribution and *A. phyllonyx* a north-central distribution. Regarding amphipods, a new species of the genus *Paramphithoe*, which is named *Paramphithoe buchholzi* , was recorded in the collected material (d'Udekem d'Acoz & Vader 2004).

Of the euphausiids *Nyctiphanes couchii*, *Meganyctiphanes norvegica* (northern krill) and *Thysanoessa* sp. were recorded in high densities. The distribution of *Meganyctiphanes norvegica* was mainly in the southern and central parts of the Barents Sea (see Figure 9). *Thysanoessa* sp., on the other hand, had a clearly northern distribution (see Figure 10). The abundance of *Nyctiphanes couchii* was less consistent than for the other euphausiids as it showed large densities both in the southern area and also further north.

The decapod *Pandalus borealis* was also very abundant. Most of the specimens of *Pandalus borealis* were juveniles. Sampling of juvenile *Pandalus borealis* was the original purpose of the sampling with the juvenile bag.

The decapods *Sabinea septemcarinata* and *Pontophilus norvegicus* had lower densities than the crustaceans mentioned above. Their distribution clearly varied across the sea, where *S. septemcarinata* had a northern distribution and *P. norvegicus* an eastern distribution (see Figure 7 and Figure 8, respectively). Both these species, in addition to *Sabinea sarsi*, are also recorded in the main trawl. In the 2004 cruise, *Sabinea sarsi* was captured in the main trawl in the northern areas. However, in the described study, it may have been mixed with *S. septemcarinata*.

The bivalve *Arctinula greenlandica* was recorded in very large densities all over the sampled area, with the largest density in the central parts of the sea. This species has been reported to have a broad distribution in Arctic and northern seas (Gulliksen et al. 1999; Sneli, pers. comm.).

Aglaophamus malmgreni was the most abundant of the polychaete species. Also in other surveys in the Barents Sea this species has been recorded in quite high densities (Cochrane et al. 1998; Gulliksen et al. 1999). As it was captured in high densities in the juvenile bag, it is assumed to live at the sediment surface.

Several stations were characterized by large quantities of empty tubes of the polychaete *Spiochaetopterus typicus*. The worm itself was not found, but the tube was often inhabited by the sipunculid *Phascolion strombus*. The tubes were not in a state of decaying, and as only the upper layer of the sediment was sampled, it is assumed that the worm itself was present deeper down in the sediment. Furthermore, the species had rather high abundance in some analysed grab-samples. The species is typical of muddy clay and is a characteristic species in the Barents Sea (Zenkevich 1963). Its close relative *S. oculatus* is capable of both surface deposit feeding and suspension feeding, depending on flow speed (Turner & Miller 1991), and *S. typicus* is assumed to have the same behaviour (Cochrane et al. 1998).

Generally, large densities of Bryozoa, belonging to different species, were recorded. This group was not identified, as specific skills on its taxonomy are needed. In a survey of 16 benthic stations in the central and eastern part of the Barents Sea as many as 122 taxa of bryozoans were recorded (Cochrane et al. 1998). There was also quite high density of Porifera, and neither this group was identified to species or order.

Abiotic factors influencing benthic community structure

Depth and temperature were both identified as significant variables for the faunal composition of the epibenthos from all stations. However, in the CCA of the epibenthic samples from the grab stations, where more environmental variables were available, depth and the amount of pelite came out as the significant variables. Temperature was excluded from the analysis as it showed a highly negative correlation with the amount of pelite ($R^2 = 0.95$). The reason for this correlation is not known, although relevant specialists were contacted. There was also a negative correlation between temperature and normalised TOC (R^2 = 0.77). Until more data is available, it is considered too early to conclude that there is causality between temperature and these sediment parameters. However, it is likely that the warm Atlantic Current has a higher velocity in the southern parts of the Barents Sea, decreasing its speed as it meets the cold Polar water. Thereby a connection between temperature, current and partcle size may be established.

Generally, depth is one of the most important environmental variables for the structuring of benthic communities. Depth was also identified as a significant variable for the composition of infauna in the Pechora Sea (Dahle et al. 1999) and the area surrounding Frans Joseph's land (Dahle et al *in press*).

Regarding the infaunal communities, depth and the amount of pelite were identified as significant variables. Thus the infaunal and epibenthic communities seem to be structured by the same environmental variables, where the sediment composition, which again is structured by depth, seems to be of most importance. The infauna is an important food source for the epibenthos, and the factors that structure the composition of the infauna may therefore also be the most important factors when it comes to the composition of the epibenthos.

In the CCA of the epibenthos, the significant variables (depth and temperature) only explained 9.1% of the biological variation, while in the CCA of the grab samples, the significant variables (depth and amount of pelite) explained 32% of the biological variation. Regarding biological communities, there will always be stochastical variation that cannot be explained by environmental variables. This variation is expected to be larger when the number of samples increases. However, the fact that only 8.2% of the variation in the epibenthic communities were explained by the significant variables, indicates that a large part of the underlying factors for the composition of the communities still remains obscure.

Evaluation of sampling methodology

In monitoring of benthic communities the grab is the most used sampling device (usually 0,1 m^2). Sampling with grab provides quantitative data from a specific point. It samples from the surface of the sediment down to approximately 15-25 cm, depending on the hardness of the sediment. However, it mainly samples relatively immobile species, and thus the results are not necessarily representative of the community structure. Crustaceans is one group that is often underrepresented when using grab. Large crustaceans have the ability to move away from the grab and small crustaceans may be displaced by the pressure wave that is in front of the grab on its way down. The shrimp bag samples the loose surface layer of the sediments, in addition to species living close to the sediment surface. The different sampling modes are very clear in our study as the similarity between the sampled communities were less than 5%.

Due to patchiness of macrofaunal species, grab samples will not be as representative as the survey trawl, which integrates over continuous distances. This is especially the case for rare species. The juvenile bag gives a subsample of all small invertebrates entering the survey trawl. It is considered to give a quantitative measure as an abundance index. This index is comparable by species in time and space.

The sampling with the juvenile bag has not been used for this purpose on a large scale earlier. In the present study, all the sampled specimen were identified. It was not possible to finish the identification during the cruise, and remaining specimen were identified on a later stage in the laboratory. Thus the processing was quite resource demanding. In order to perform the monitoring more cost-effective, which means that it may be implemented to perform it on e.g. a yearly basis, we propose to base it on only selected species. The study showed that the 17 species selected in the CCA analysis to a very large degree were representative of the communities, which means that one can focus on these species without much lack of information. A summary of the features of these species is given in Table 4.

Table 4. Summary of features of the candidates for a monitoring system. Recognition refers to a subjective scale from 1 to 5, where 5 represents the highest score and 1 the lowest. Level of magnification; eye (2), binocular (1).

Species	Total abundance	Variance in CCA (%)	Recognition	Level of magnification
Ophiocten sericeum	7990	31.3	4	1
Arctinula greenlandica	7863	3.1	5	2
Rhacotropis macropus	4569	4.8	5	2
Nyctiphanes couchii	3615	5.9	3	1
Pandalus borealis	3591	17.6	5	2
Meganyctiphanes norvegicus	3440	7.9	5	2
Arrhis phyllonyx	2731	1.9	5	2
Thysanoessa sp.	1640	1.8	3	1
Sabinea septemcarinata	1432	7.7	5	2
Pontophilus norvegicus	887	0.7	5	2
Aglaophamus malmgreni	809	0.04	2	1
Erythrops sp.	658	0.3	5	2
Sagitta sp.	611	0.1	5	2
Ophiura sarsi	370	1.3	4	1
Halirages fulvocincta	287	1.2	4	2
Arca sp.	227	1.1	5	2
Arrhis sp.	137	1.0	2	1

Some species naturally show high annual fluctuations in abundance from year to year. The present program will contribute to increase the knowledge on the population variation of the selected species. However, before the program is implemented, one should be sure that the selected species do not show annual variation in abundance that hides the variations that are caused by a shift in the environmental factors. We therefore propose to repeat the sampling for some years on a test basis.

Although the 17 selected species were found to adequately represent the communities, we recommend to analyse all the collected material regularly, e.g. every fifth year. This is to get information on number of taxa collected and to see if there are taxa showing large variations in number over time.

As the sampling is coupled with an already ongoing cruise, the sampling itself does not require any additional resources. Furthermore, as the monitoring is based on easily recognizable indicator taxa, the identification can be conducted on board on the ship. The personnel who carry out the identification will need some training, but does not need to be a specialist. However, most important is that the monitoring in our view will be sensitive enough to detect ecological changes in the system.

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Appendix 1. Number of species (S), number of individuals (N), Shannon Wiener diversity (H’) Hulberts diversity (ES) and eveness (J’).

St	S	N	H	ES	J'	St	S	N	H	ES	J'
311	12	228	**0,9**	9	0,38	374	26	540	2,3	17	0,70
312	12	93	1,6	12	0,65	375	16	542	1,5	**9**	0,53
313	20	202	2,1	15	0,69	376	26	124	2,6	24	0,79
314	13	**71**	1,6	13	0,63	377	23	429	1,8	12	0,58
315	16	108	2,3	16	0,82	378	26	491	2,2	15	0,67
316	17	167	1,9	14	0,65	379	**11**	234	1,5	9	0,64
317	23	271	2,2	18	0,69	380	24	214	2,1	17	0,66
318	15	191	1,5	13	0,55	381	27	550	2,3	17	0,69
319	19	449	2,0	12	0,67	382	43	838	2,7	24	0,71
320	13	143	1,9	12	0,74	383	32	866	2,5	20	0,71
321	17	213	2,3	14	0,80	384	19	708	2,2	13	0,76
322	27	237	2,3	19	0,69	385	20	338	1,9	13	0,63
323	19	226	2,0	15	0,70	386	19	528	2,0	13	0,68
324	19	184	1,6	15	0,56	387	22	528	2,1	15	0,67
325	17	248	1,5	11	0,53	388	23	296	2,3	16	0,74
326	24	306	2,0	16	0,62	389	19	343	1,8	13	0,61
327	22	345	2,1	16	0,69	390	18	251	1,9	14	0,67
328	22	325	2,0	15	0,63	391	19	295	1,9	13	0,64
329	23	374	2,2	15	0,72	392	27	578	2,0	15	0,62
330	26	353	2,4	17	0,75	393	29	646	2,2	18	0,66
331	38	404	**3,0**	**28**	**0,84**	394	29	475	2,3	17	0,69
332	12	309	1,8	10	0,74	395	25	324	2,1	16	0,65
333	27	535	2,0	14	0,62	396	32	555	2,5	17	0,71
334	21	237	2,1	16	0,69	398	33	704	2,5	19	0,71
335	25	305	2,1	16	0,64	400	27	321	2,6	19	0,78
336	24	335	1,7	15	0,55	401	34	328	2,5	21	0,70
337	24	143	2,3	20	0,72	402	**50**	560	2,9	25	0,74
338	17	128	2,1	16	0,74	403	32	658	2,5	20	0,73
339	22	165	2,2	17	0,71	404	29	351	2,5	18	0,73
340	17	145	1,9	14	0,69	405	27	216	2,4	20	0,72
341	21	160	2,4	19	0,79	406	34	294	2,8	24	0,78
342	19	246	1,4	12	0,46	407	33	469	2,6	20	0,75
343	18	373	1,8	13	0,62	408	29	206	2,6	21	0,76
344	34	451	2,2	17	0,63	409	20	246	2,2	15	0,73
345	26	205	2,4	20	0,72	410	24	589	2,3	16	0,73
346	25	434	2,1	17	0,65	411	23	296	2,2	17	0,72
347	27	943	2,1	16	0,63	412	23	286	1,7	16	0,55
348	33	724	2,3	18	0,66	413	24	210	2,2	18	0,70
349	24	1061	2,3	15	0,73	414	22	217	2,5	18	0,81
350	20	466	2,1	16	0,70	415	33	283	2,8	23	0,80
351	26	472	1,8	18	0,56	416	28	351	2,5	19	0,76
352	27	249	2,2	18	0,67	417	27	320	2,6	20	0,80
353	33	240	2,7	23	0,78	418	24	391	1,6	15	0,49
354	31	412	2,6	19	0,76	419	29	229	2,1	20	0,62
355	27	428	2,2	16	0,68	420	17	102	2,0	17	0,69
356	27	283	2,5	20	0,76	421	24	270	1,9	16	0,59
357	32	393	2,6	20	0,76	422	23	196	2,5	19	0,80
358	30	366	2,1	17	0,63	423	19	229	1,9	14	0,64
359	27	278	2,6	20	0,78	424	34	463	2,0	20	0,58
360	22	249	2,4	17	0,76	425	41	460	2,5	22	0,67
361	21	594	1,5	10	0,48	426	35	516	1,6	14	0,45
362	32	446	2,3	17	0,67	427	28	276	2,0	17	0,60
363	24	451	2,2	15	0,68	428	29	328	2,3	18	0,67
364	24	332	2,2	17	0,69	429	25	313	1,9	17	0,58
365	28	897	1,4	12	0,41	430	26	449	1,5	15	0,46
366	30	**1088**	1,6	14	0,48	431	22	323	1,3	13	0,42
367	30	543	1,2	14	**0,35**	432	15	184	1,2	12	0,45
368	25	418	1,7	14	0,51	433	33	340	1,7	18	0,50
370	31	507	1,9	18	0,57	434	18	269	1,4	13	0,50
371	27	559	2,7	21	0,81	435	22	237	1,7	17	0,54
372	22	268	2,4	18	0,77	436	19	227	1,7	14	0,57
373	33	746	2,1	19	0,61	437	25	198	2,2	21	0,69
						438	38	253	2,5	24	0,69