Macro-epibenthic communities and diversity of Arctic Kongsforden, Svalbard, in relation to depth and substrate

Ricardo Sahade[1*], Alexia Stellfeldt[1], Marcos Tatián[1] and Jürgen Laudien[2]

1 Ecología Marina Universidad de Córdoba, Av. Vélez Sársfield 299. CP 5000. Córdoba, Argentina.

2 Alfred Wegener Institute for Polar and Marine Research, 27515 Bremerhaven, Germany.

*E-mail: rsahade@efn.uncor.edu

Introduction

Low and relatively constant temperatures, seasonal pulses of primary production, changes in ice cover, siltation and salinity are the main characteristics of polar marine ecosystems. Shallow coastal systems are especially affected by ice as a disruptive factor, which has a huge effect in structuring the established benthic communities, both in the Antarctic (Dayton 1990, Clarke 1996a, Grebmeier & Barry 1991, Sahade *et al*. 1998, Gutt 2001, Gutt & Piepenburg 2003) and the Arctic (Laudien *et al*., this issue). Despite these similarities the two polar ecosystems differ considerably in their evolutionary histories. While the Antarctic has been evolving isolated the last 20 million years, the Arctic Holocene history only reaches back some 10 thousand years (Clarke & Crame 1992, Dunton 1992, Dayton *et al*. 1994). These differences are reflected in the recent biota with the Arctic being impoverished in respect to the Antarctic in terms of species richness, diversity and abundance of organisms (Poore & Wilson 1993, Rex *et al*. 1993, Clarke 1996a,b, Arntz *et al*. 1997, Gray 2002). However, at small-scale these differences are not evident and several Arctic benthic communities exhibiting high abundance and diversity have been described (e.g., Grebmeier *et al*. 1989, Kendall 1996, Sejr *et al*. 2000). The major difficulties in comparing both polar ecosystems are due to the use of different methods, depth ranges, scales, and analytical procedures.

Photo-transects allow the quantitative analysis of communities, providing information about the habitat, abundances, percentage cover, species associations of epibenthic assemblages and a fast data acquisition in the field. Although this method underestimates abundances of small, cryptic and highly mobile individuals (Barthel *et al*. 1991, Roberts *et al*. 1994, Jørgensen & Gulliksen 2001), it has been successfully used to define polar benthic assemblages (Dayton *et al*. 1974, Barthel *et al*. 1991, Barthel & Gutt 1992, Jørgensen & Gulliksen 2001, Teixído *et al*. 2002).

The present study is a preliminary analysis of epi-macrobenthic community structures in relation to substrate types and depth in the Arctic Kongsfjorden. The application of the same methods (photo-transects), environmental variables (depth and substrate) and analytical procedures as in Antarctic Potter Cove (Sahade 1999) will allow to further establish valid comparisons between both polar benthic systems.

Material and methods

Study area

The study area was the Arctic glacial Kongsfjorden located on the western coast of Spitsbergen (79°N, 12°E). The fjord is 20km long and 4 to 10km wide and has a maximum depth close to 350m. It is directly connected to the North Atlantic Ocean via the Kongsfjord-Renna trough (Bluhm *et al.* 2001, Jørgensen & Gulliksen 2001, Svendsen *et al.* 2002). For a detailed review of environmental characteristics and a description of the marine ecosystem see Svendsen *et al*. (2002) and Hop *et al*. (2002). Three stations with different substrate types were selected, Prins Heinrichøya (S1), mainly composed of a sand-clay mixture with occasional ice-rafted stones, Hansneset (S2), rocky bottoms interspersed with sediment pools and Kongsfjordneset (S3) pure bedrock (Fig. 1).

Sampling

Sampling was carried out during the boreal summer 2001 by means of photo-transects taken by SCUBA-divers with a Nikonos V camera, a 15-mm lens and a Nikonos SB-104 strobe, mounted on an aluminium frame (50 x 50cm) at particular depth profiles 15, 20, 25 and 30m (Kühne 1992, Sahade *et al*. 1998). Percentage cover of the main taxonomic groups was obtained from the slides taken at each of the three stations. Thereafter data were analysed to access diversity and community structure. In order to compare diversity patterns for both the different stations and the depth gradient, K-dominance curves were plotted. Multivariate analysis as classification (clustering) and ordination MDS (non-metric multidimensional analysis) followed to evaluate community structures using *PRIMER v5* (Clarke & Gorley 2001).

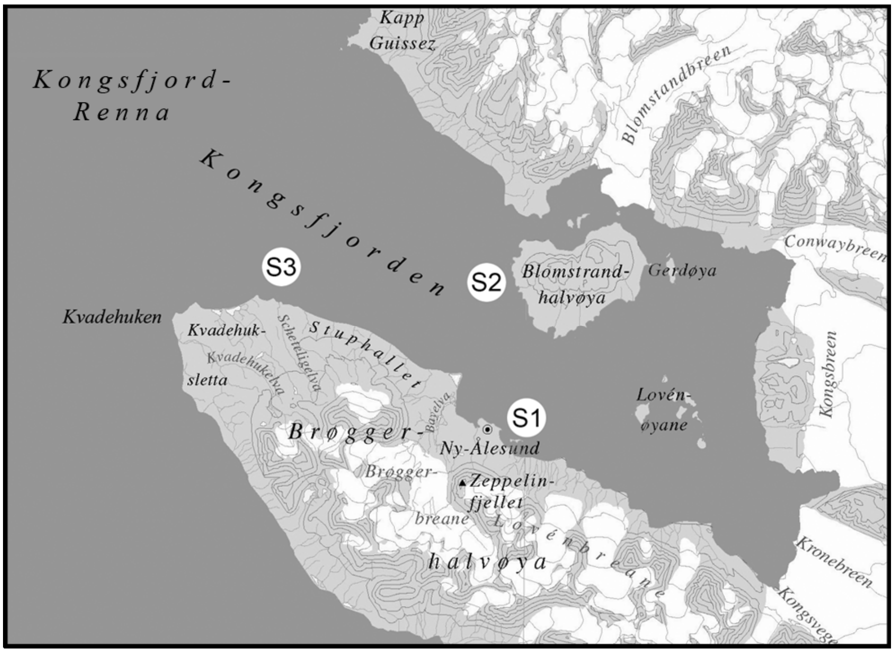

Fig. 1: Maps of the study area, sampling stations S1 (mainly soft bottom), S2 (mixed substrates) and S3 (bedrock) are indicated.

Results

A total of 47 species or morphospecies of 18 higher taxa (order to class) were identified. Table 1 list the species and their occurrences at the three stations.

Table 1: List of taxa identified, * indicates the presence of taxa at station S1 (mainly soft bottom), S2 (mixed substrates) and S3 (bedrock).

	Taxa	S1	S2	S3
Phaeophyta	*Laminaria* sp.	*		*
	Desmarestia aculeata	*		*
	Desmarestia viridis	*	*	*
	Acrosiphonia aff. *penicilliformis*	*		*
Rhodophyta	*Polysiphonia arctica*	*		*
	Phyllophora sp.	*		*
	Unidentified sp. 1	*		
Porifera	*Haliclona* sp.	*	*	
	Unidentified sp. 1		*	
	Unidentified sp. 2		*	
Anthozoa	*Urticina equees*	*	*	*
	Hormathia nodosa	*	*	
	Unidentified sp. 1		*	
Hydrozoa	*Eudendrium* sp.		*	
Polychaeta	*Thelepus* cf cincinnatus		*	
	Serpulidae		*	
	Sabellidae		*	
	Unidentified sp. 1		*	
	Unidentified sp. 2	*		
Gastropoda	*Buccinum* sp.	*		
	Neptunea sp.	*		
Bivalvia	*Mya truncata*	*	*	*
	Chlamys islandica	*	*	
	Hiatella artica	*	*	*
	Unidentified sp. 1	*		*
Polyplacophora	*Tonicella* sp.	*	*	
Cirripedia	*Balanus balanus*	*	*	*
Decapoda	*Lebbeus polaris*	*	*	
	Eupagurus sp.	*	*	*
	Unidentified sp. 1		*	
	Unidentified sp. 2	*	*	
Pycnogonida	Unidentified sp. 1			*
Bryozoa	*Reteporella beaniana*[1]		*	
	Crisia denticulata[1]	*	*	*
	Porella cf *compressa*		*	
	Unidentified sp. 1			*
	Unidentified sp. 2		*	
Asteroidea	*Crossaster papposus*		*	*
	Henricia sp.[1]		*	
	Pteraster sp.[1]		*	
Echinoidea	*Strongylocentrotus* sp.	*	*	*
Ophiuroidea	*Ophiopholis aculeata*	*	*	*
Ascidiacea	*Boltenia echinata*		*	
	Styela rustica		*	*
	Halocynthia pyriformis		*	*
	Unidentified sp. 1		*	*
Pisces	Unidentified sp. 1			*
Total	47	25	34	22

K-dominance curves indicated that diversity was lower at the station mainly composed of soft bottom (S1) than at stations dominated by hard substrate elements (S2 and S3) (Fig. 2). Diversity increased with depths at all three stations. This pattern was more evident at station S1, which showed a constant increase. At station S2 and S3 the differences were clear between 15m and 30m, but species composition was more similar at 20m and 25m (Fig. 2).

Multivariate analysis of classification and ordination (MDS) clearly separated the samples in first term by location, substrate type and later by depth (Figs. 3 and 4). Three communities were separated according to the sampling stations. The two sites with significant hard bottom occurrences (S2 and S3) were further grouped and separated from S1. Not one single sample was included among the samples of another station. Additionally, there was a distinction following the bathymetric gradient at each station.

All stations showed a change from macroalgal dominance in shallow waters to faunal communities in deeper waters. This pattern was especially clear at stations S1 and S2, while at S3 macroalgae were less abundant (even at 15m).

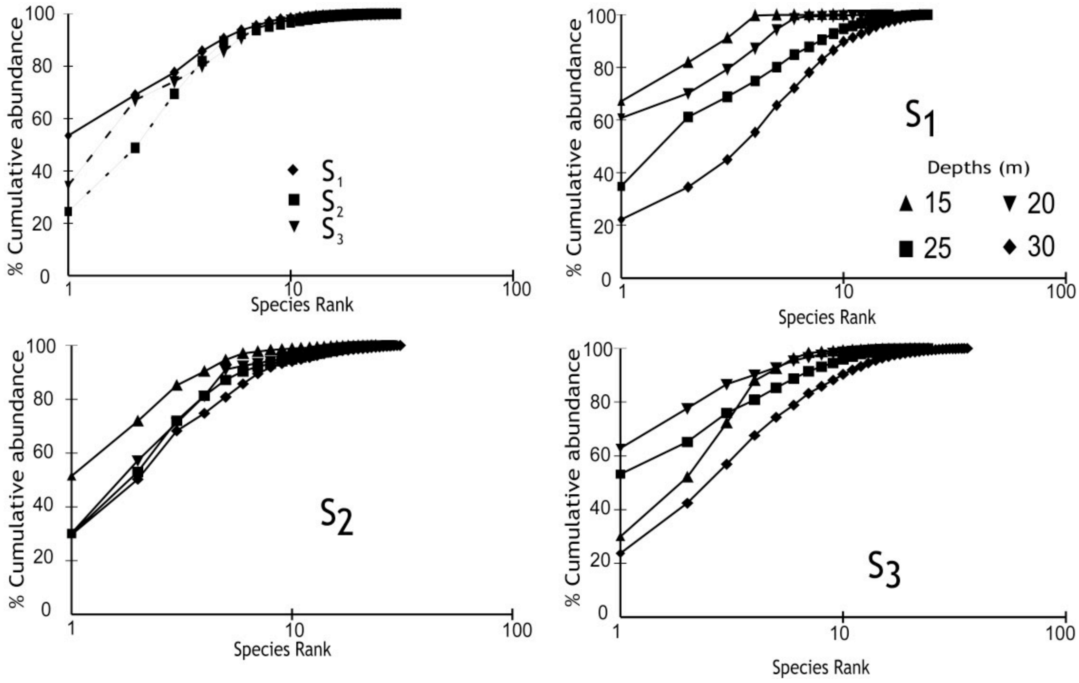

Fig. 2: K-dominance curves showing cumulative ranked abundances plotted against log species rank (following Lambshead *et al*. 1983). a: The most elevated curve (mainly soft bottom S1) shows a lower diversity than the two lower ones (S2 and S3). b-d: At all three stations cline of increasing diversity with depth was observed.

Discussion

The epibenthic community structures analysed in Kongsfjorden are coincident with previous studies of the area (Jørgensen & Gulliksen 2001, Lippert *et al*. 2001, Hop *et al*. 2002). However, communities showed marked differences in relation to substrate type and depth. Higher diversities of organisms were found in habitats mainly composed of hard bottoms (S2 and S3), while epifauna and –flora of habitats dominated by soft bottoms were less diverse. This observation reflects that most of the organisms inhabiting hard substrates are epifaunic, while the epifauna of soft bottoms in Kongsfjorden is a rather small proportion of the total soft bottom inhabitants, which are mainly infaunal species. Therefore, the macro-epibenthic communities of soft habitats may be less diverse than the communities of hard substrates, as only a special group is using the surface of the sediment. Correspondingly, Jørgensen and Gulliksen (2001) state that the infauna was underestimated by their photographic method. However, this non-destructive sampling provides reliable information about differences of larger epibenthic taxa between locations and along the bathymetric gradient.

The comparison of the present results with those achieved from a soft-bottom study of macrobenthos, which was located at Brandal, approximately 5km down-fjord (north-west) of our study location (Laudien *et al.*, this issue), revealed significant differences in species composition. The present species list includes rare, large species like the anthozoan *Hormathia nodosa*, the gastropods

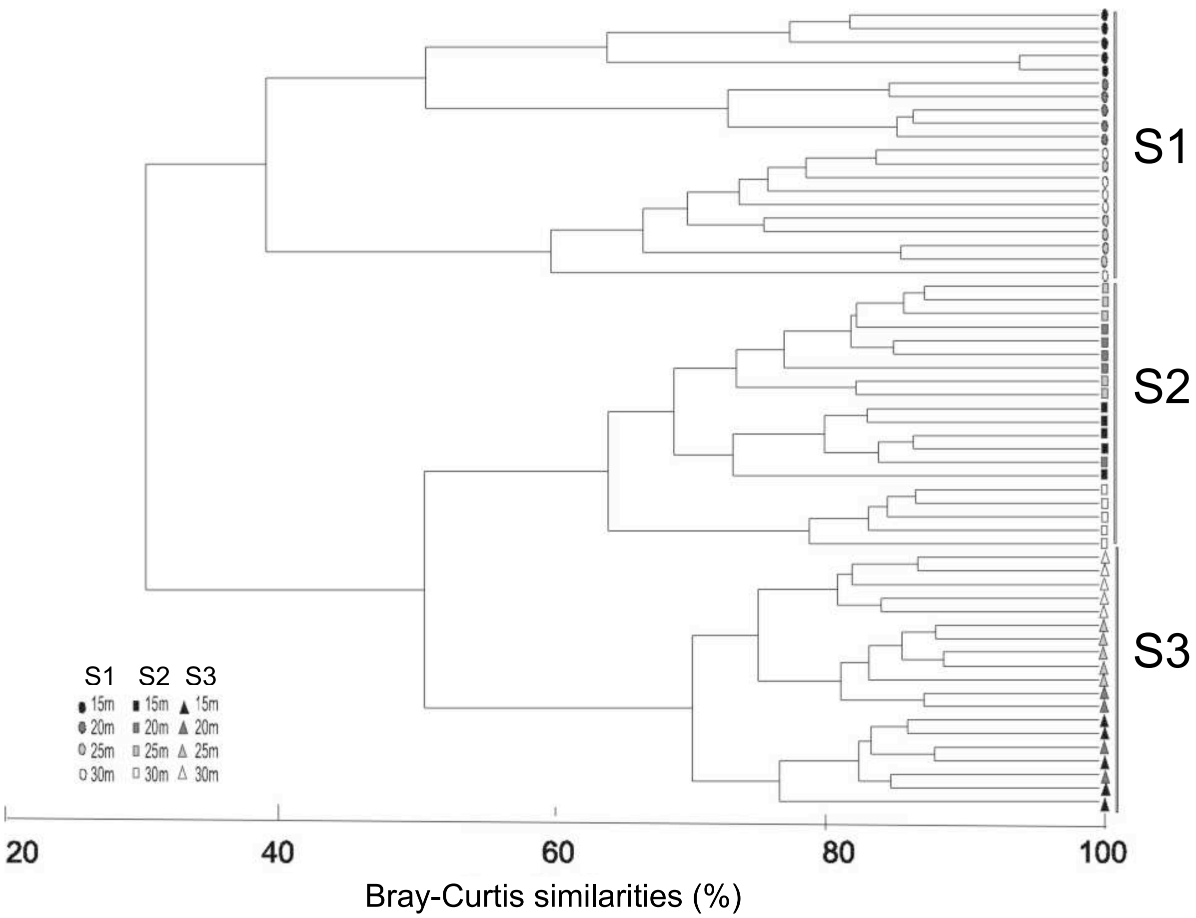

Fig. 3: Dendrogram resulting from classification analysis (Bray-Curtis similarities) of macroepibenthos from Kongsfjorden based on the UPGMA method. All samples are separated according to the stations (substrate type); the two communities inhabiting habitats dominated by hard bottom (S2 and S3) are more closely related and separated from the community inhabiting soft-bottom dominated habitats (S1).

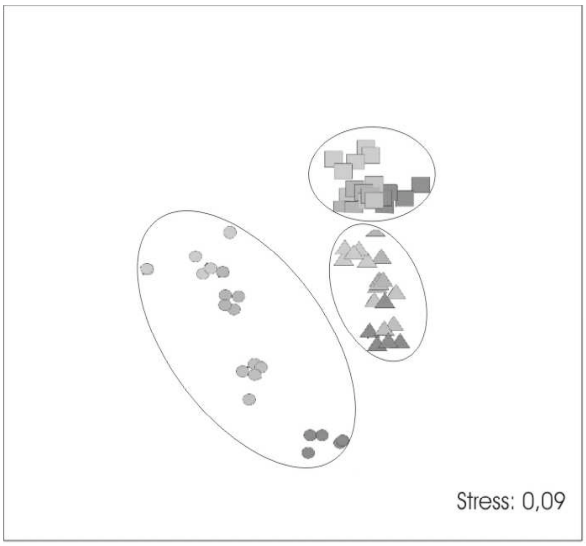

Fig. 4: MDS plot, circles are the superimposed results of the cluster analysis, ●: station with mainly soft bottom (S1), ■: station with mixed substrate (S2) and ▲: station with bedrock (S3). The shading of the sample symbols indicates depth, following the legend given in Figure 3.

Buccinum sp. and *Neptunea* sp., as well as highly mobile species like the decapods *Lebbeus polaris* and *Eupagurus* sp., which were not reported in the Brandal study. The latter sampled five replicates of a 20 × 20cm corer (surface: 0.2m^2) by means of a suction method, while the present study covered a much wider area of 59 photo quadrates of 50 × 50cm (surface: 14.75m^2). However, according to species-accumulation curves, the previous study already detected the majority of the total soft bottom fauna. Therefore both studies are contributing to a detailed description of the macrofauna of Kongsfjorden. Moreover, four species found in this study had been reported for Svalbard, but not for Kongsfjorden before (Gulliksen *et al*. 1999, Jørgensen & Gulliksen 2001) (Table 1).

Differences in species diversity might not only be substrate related, but also be correlated with environmental parameters (e.g., salinity, turbidity, temperature) following a gradient along the mayor axis of the fjord (for review: Svendsen *et al*. 2002). This explanation agrees well with the general trend that deposit feeding infauna (not quantitatively detectable with the applied photographic method) increases in dominance and filter feeders decrease in abundance – due to unfavourable conditions – with a decreasing distance from the glacier front (Farrow *et al*. 1983, Syvitsky *et al*. 1989, Holte *et al*. 1996, Wlodarska *et al*. 1996). Low species richness near the glacier fronts has also been related to the scarcity of food available to substrate detritivorous species as a consequence of low levels of primary production and the dilution of organic matter in the substrate by high sedimentation (Görlich *et al*. 1987). The same trend can be seen by comparing the two stations dominated by hard bottom substrates, where the station located down-fjords (S3, pure bedrock) showed a higher diversity than the intermittent station (S2). Under constant environmental conditions the opposite pattern would have been expected as the habitat heterogeneity of station S2 should result in a higher diversity (Gray 2001). Therefore, the environmental parameters could also have a strong effect in determining these communities. Both, this hypothesis and the explanation of substrates playing a major role in determining the benthic community structure will be analyzed in future studies.

Besides substrate and/or the location, depth appears important in structuring epibenthic communities. We detected increasing diversity along the bathymetric gradient at each of the three stations. This trend is most obvious in the station mainly composed of soft bottom showing a constant increase of diversity from 15m to 30m. The communities were characterized by a dominance of macroalgae at 15m and a shift to faunal dominance at 20m, diversity was highest at 30m. As boulders colonised by a typical rocky community (barnacles, actinians, ascidians and sponges) were more frequent at 30m, again the substrate could explain increasing diversity with depths. The previous study conducted at Brandal (Laudien *et al*., this issue) revealed that species richness was lowest at 5m but highest at an intermittent depth of 10-15m; thereafter species richness steadily decreased (20, 25, 30m). This observation was explained according to the ‘intermediate disturbance hypothesis’ (Connell 1978): locations with minimal disturbance show reduced species richness because of competitive exclusion between species. With increasing intensity or frequency of iceberg scouring (more icebergs ground in shallower areas) competition is relaxed, reflected in increasing species richness; while at higher or more frequent levels of disturbance species start to be eliminated by stress. These findings appear to be true for homogeneous substrates as sampled in the Brandal study. However, the results of the present study indicate that such a trend may be masked by substrate heterogeneity, especially when the density of hard bottom elements increase with depths.

The up-fjord bedrock station (S3) showed considerably lower abundances of macroalgae than the other stations. This observation could be explained with high densities of the green sea urchin *Strongylocentrotus droebachiensis* foraging on macroalgae (H. Wessels, Univ. Bremen, unpubl. data). In the year previous to this study abundances of 80 ind. m^{-2} were observed at the same location (F. Beuchel and B. Gulliksen, Univ. Tromsø pers. comm. in Hop *et al*. 2002). Grazed areas are commonly populated by sessile organisms such as actinians, barnacles and bryozoans. At deeper waters from 20m to 30m the increase in diversity is less marked than at the other stations and the community is dominated by suspension feeders (barnacles, actinians, bryozoans and ascidians). These organisms are favoured by rich Atlantic waters entering into the fjord. However, in the central and inner part of Kongsfjorden filter feeders might be under permanent stress, as the high inorganic load (800 g m^{-2} d^{-1} at the glacier front, Svendsen *et al*. 2002) is likely to clog their filter organs (e.g., Moore 1977).

The comparison with Potter Cove (King George Island, Antarctica), although still preliminary, appears to be coincident with the general trend of Antarctic communities being more diverse than the Arctic ones. There are striking differences: In the Potter Cove the highest diversities were found on soft bottoms (Sahade 1999) with pennatulaceans, bivalves and ascidians as dominant organisms, while in Kongsfjorden hard bottom habitats were more diverse. Besides that, soft bottom communities at Potter Cove were dominated by suspension feeders, especially ascidians and sponges, which are characteristic for many Antarctic faunal communities, but rarely seen in other areas. Diversity patterns along the major axis of both fjords are also different. While diversity is lower at the outer station of Potter Cove (hard bottom) compared with inner stations, the opposite is the case for Kongsfjorden. Future work will focus on further comparisons of both polar systems.

Conclusions

Photo-transects (15, 20, 25 and 30m) of macro-epibenthic invertebrate communities and algae from Arctic glacial Kongsfjorden (Spitsbergen) revealed a species list comprising 47 taxa. Mean species richness (17-20 species) was similar at all three stations. K-dominance curves showed higher diversity in stations dominated by hard substrates than in habitats mainly composed of soft sediment. A bathymetric pattern was evident showing increasing diversity with depth, which is apparently related to increasing densities in hard bottom elements. The comparison with studies conducted in the Antarctic fjordic system Potter Cove, revealed major differences between the two polar systems.

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