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Diversity and distribution of Bryozoa in Kongsfjorden, Svalbard

ABSTRACT: The species diversity of the Bryozoa in Kongsfjorden was determined based on quantitative, depth-stratified (0–30 m) samples collected by SCUBA divers (1996, 1998). One hundred and one species and 16 varieties of the three orders Cyclostomata, Ctenostomata, and Cheilostomata – are reported from Kongsfjorden. Ten species are presumably new. The bryozoan fauna of Svalbard is mainly represented by Arctic and boreal-Arctic species and varieties. The few amphiboreal and subtropical-boreal species found most likely reach their northern limit of distribution near Spitsbergen. The distribution of the Bryozoa within Kongsfjorden was determined by depth and location sampled. The number of taxa increased, generally, with depth and distance from tidal glaciers located in the inner fjord. Relative decreases in species number occurred at 15–20 m depth in the middle to outer fjord. This is most likely explained by a change of water mass properties, i.e. a transition from the surface water layer to deeper marine water.

Key words: Arctic, Svalbard, Bryozoa, biogeography, Kongsfjorden.

Introduction

The Bryozoa are the most common lophophorate animals; this phylum comprises almost 6000 living species. Bryozoans are generally sessile aquatic colonial animals, and their colonies are composed of zooids, often less than 0.5 mm in length. The colony (zoarium) is most often firmly attached to the substratum and can be ramified, lobed, fan-shaped, or appear as a crust covering the substratum. The colony size varies from several millimetres to several decimetres, and there is

a large variation in colonial shape as well as in the external morphology of the individual zooid. Many bryozoan species are probably yet undescribed.

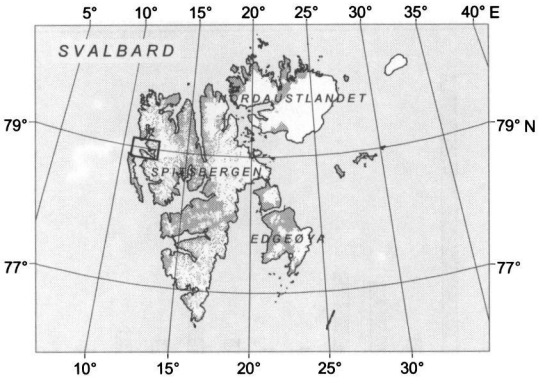
Bryozoans often constitute a major part of marine bottom biocenoses. Because of their large species diversity and wide habitat distribution, bryozoans are potential indicators of environmental factors and changes. The majority of bryozoans inhabit rocky substrata, but some species are more tolerant of sedimentation and may live on soft bottom (Kvitek 1989). In our study we determined how the species (or taxon's) diversity of bryozoans on hard substrata changed with depth and distance from tidal glaciers in Kongsfjorden on Svalbard.

Kongsfjorden is a broad, glacial fjord which is located on the west coast of Spitsbergen, Svalbard at 79°N (Fig. 1). Because it is an open fjord with no sill, it is influenced by both Arctic and Atlantic water masses (Svendsen *et al.*, unpubl.). The benthic fauna of the fjord is therefore composed of a mixture of Arctic and boreal species. Tidal glaciers discharge a large amount of freshwater and suspended sediments (0.5 km^3) annually into the inner and middle part of Kongsfjorden (Beszczyńska-Møller *et al.* 1997, Lefauconnier *et al.* 1999). Reduced salinity characterises the surface water, with a drop to 30 PSU in the middle fjord and less than 28 PSU in the inner basin near the glaciers where the brackish layer may constitute several meters (Svendsen *et al.*, unpubl.). The concentration of suspended solids and the extent of the sedimentation processes in the different parts of the fjord have a direct influence on both the physical and biological characteristics of the fjord system. This includes both the extent of the euphotic zone (Eilertsen *et al.* 1989) and the accumulation of sediments and ice-rafted material on hard surfaces (Jørgensen and Gulliksen 2001). The strong environmental gradients in sediments and freshwater input tend to structure the biological diversity in Kongsfjorden, particularly the benthic diversity (Wlodarska-Kowalczuk *et al.* 1998).

There have been some studies on bryozoans in Kongsfjorden, particularly on species that are associated with different macroalgae (Lippert 1998, Lippert *et al.* 2001) and species that live in the deeper parts of the fjord (Kukliński, unpubl.). Previous bryozoan records from the Svalbard area (Bidenkap 1897, 1900a, b, Nordgaard 1900, 1918, Kluge 1906) have been included in the fauna database for Svalbard waters (Gulliksen *et al.* 1999). Our study is the first to determine the biogeographical composition of the bryozoan fauna in the shallow water (0–30 m) of Kongsfjorden, from the inner to the outer part of the fjord.

Material and methods

The collections of benthic fauna from different parts of Kongsfjorden took place in August–September 1996 and 1998 (Fig. 1). Samples were collected from five transects of hard substrata from the inner to the outer fjord at different locations and distances (km) from the glacier front of Kongsbreen: Ossian Sars (1) ,



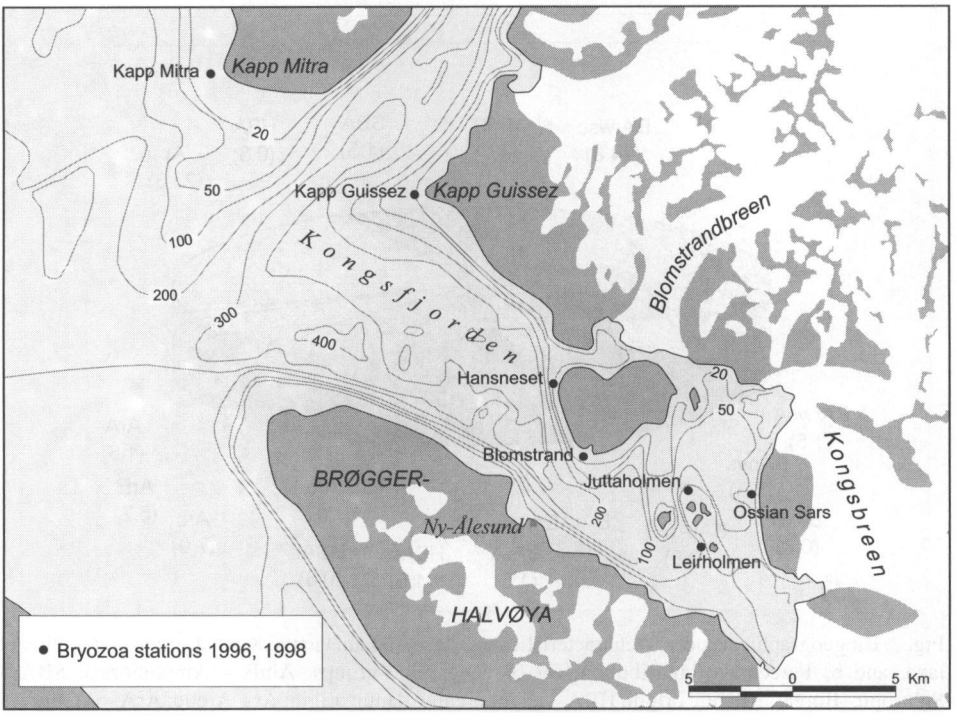


Fig. 1. Map of the Kongsfjorden with sampling stations for Bryozoa, 1996 and 1998.

Juttaholmen (5), Hansneset (12), Kapp Guissez (20) and Kapp Mitra (31). In addition, single samples were taken from Leirholmen (4) and Blomstrand (10), and a few bryozoan specimens were collected elsewhere. Animals, algae and parts of substrata were collected by SCUBA divers from 2 × square frames (0.25 m^2) placed at discrete depths (0–2.5–5–10–15–20–25–30 m). Macrobenthic organisms were picked and scraped off the underlying hard substrata with diver's knives and

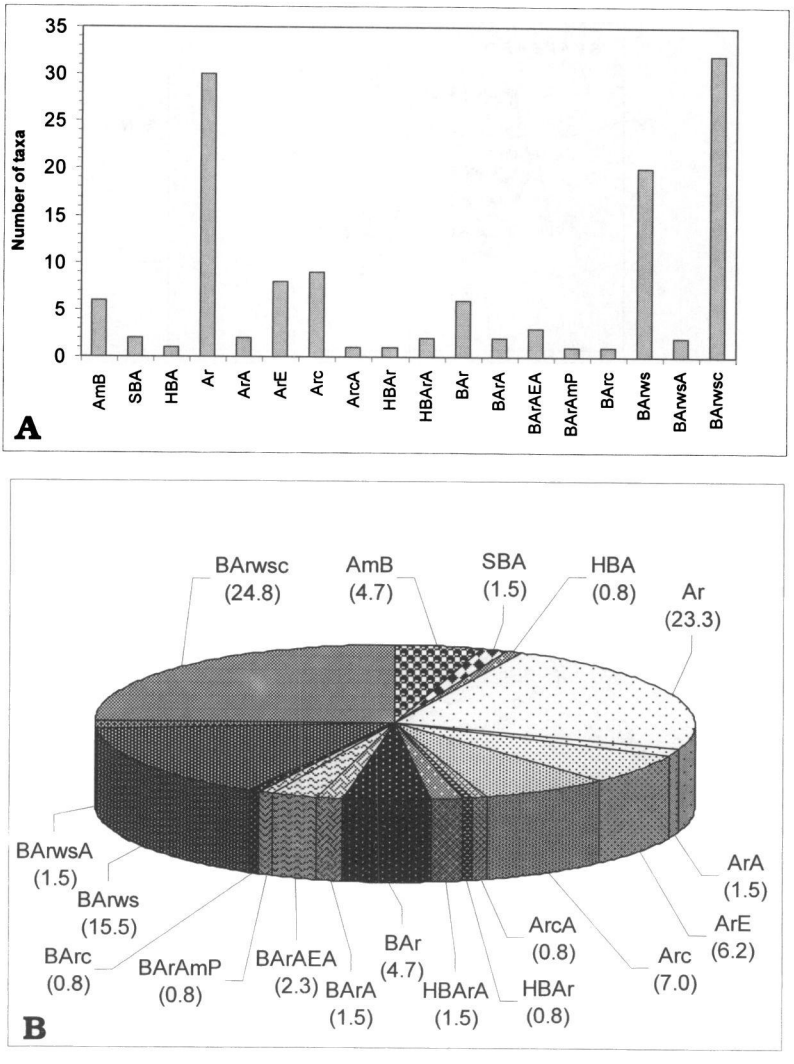


Fig. 2. Biogeographical species' characteristics of bryozoan fauna in the Kongsfjorden, a) Number of taxa, and b) Percentage contribution, for biogeographic groups: AmB – Amphiboreal; SBA – Subtropic–Boreal, Atlantic origin; HBA – Highboreal, Atlantic origin; Ar – Arctic; ArA – Arctic, Atlantic origin; ArE – Arctic, Euroasian; Arc – Arctic, circumpolar; ArcA – Arctic, circumpolar, Atlantic origin; HBAr – Highboreal-Arctic; HBArA – Highboreal-Arctic, Atlantic origin; BAr – Boreal-Arctic; BArA – Boreal-Arctic, Atlantic origin; BArAEA – Boreal-Arctic, Euroasian, Atlantic origin; BArAmP – Boreal-Arctic, Amerasian, Pacific origin; BArc – Boreal-Arctic, circumpolar; BArws – Boreal-Arctic, widespread; BArwsA – Boreal-Arctic, widespread, Atlantic origin; BArwsc – Boreal-Arctic, widespread, circumpolar.

put into plastic bags. The smallest sessile and motile animals were collected from frames using an electrical suction pump (Lønne 1988). A total of 65 quantitative samples were collected in the years 1996 and 1998. The branched and encrusted

bryozoan colonies, together with parts of substrata from samples, were preserved in 75% alcohol and transported to the Zoological Institute in Saint-Petersburg for identification.

Results

Bryozoan diversity in Kongsfjorden

The analysis of the quantitative collections of Bryozoa from seven locations in Kongsfjorden (Fig. 1) resulted in 101 species and 16 varieties (Table 1) of the three bryozoan orders: Cyclostomata, Ctenostomata and Cheilostomata (e.g., D'Hondt 1997, Taylor and Weedon 2000, Gordon 2001). This included 31 species and nine varieties recorded for the first time in Kongsfjorden. Additionally, 10 species are seemingly new, although these need to be described taxonomically. Some species could only be determined to the higher taxonomic level at a family (3) and genus (28) level.

Biogeographical composition

The bryozoan fauna of Kongsfjorden was represented mainly by boreal-Arctic species (54.3%) and species that are endemic to the Arctic (38.8%) (Fig. 2A, B). Boreal-Arctic species and varieties were represented in the fauna of Kongsfjorden by: widespread circumpolar boreal-Arctic (24.8%), widespread boreal-Arctic (17.1%) and boreal-Arctic (12.4%) biogeographic groups. Some of the Arctic species have circumpolar distribution, whereas others are generally found only in the Atlantic or Eurasian part of the Arctic. There were also some species that are generally not found in the Arctic waters, being amphiboreal, highboreal and subtropical-boreal species (7.0%) (Fig 2A, B). Amphiboreal and subtropical-boreal species do not play a significant role in the bryozoan fauna of Kongsfjorden. These eurybiontic species probably have their northern limit of distribution in Svalbard waters.

Distribution

The depth transects extended to 30 m at the outer stations, but were shallower at the two inner stations because of the limited availability of hard substrata. At Ossian Sars, near the Kongsbreen glacier, hard substrata at this relatively sheltered location was limited by a thick layer of silt below 5 m. The water masses were influenced by glacial melt water with low salinity (< 28 PSU) in the upper layer during summer (Svendsen *et al.*, unpubl.). The fauna of Bryozoa was represented by some eurybiontic species (Table 1). Their distribution showed an increase in the number of taxa with increasing depth down to 5 m (Fig. 3A).

The second transect station was at Juttaholmen, located about 5 km west of the glacier front in the inner basin of Kongsfjorden. The conditions were semi-exposed

Table 1

Bryozoa in collected samples from Kongsfjorden, Svalbard, 1996 and 1998 (biogeographic groupes are listed in Fig. 2).

Location (distance from inner glacial front, km)		Ossian Sars (1)			Leirh.(4)	Juttaholmen (5)					Blom.(10)	Hansneset (12)								Kapp Guissez (20)								Kapp Mitra (31)							Others
Depth (m)		0	2,5	5	5	0	3	5	10	15	5	0	3	5	10	15	20	25	30	0	3	5	10	15	20	25	30	3	5	10	15	20	25	30	
No. of samples (0.25 m2)		2	2	2	1	2	2	3	2	1	1	3	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
Species	Biogeogr.																																		
Phylum Bryozoa																																			
Bryozoa g. sp.																																			
Class Stenolaemata																																			
Order Cyclostomata																																			
Suborder Tubuliporina																																			
Family Tubuliporidae																																			
Genus *Oncousoecia* Canu, 1918																																			
Oncousoecia canadensis Osburn, 1933	Arc																									+									
Oncousoecia diastoporoides (Norman, 1869)	BArwsA							+					+			+			+							+	+					+	+	+	
Oncousoecia polygonalis (Kluge, 1915)	Arc																									+	+					+		+	
Oncousoecia sp.					+														+			+				+							+		
Genus *Tubulipora* Lamarck, 1816																																			
Tubulipora soluta Kluge, 1946	ArE							+						+	+				+														+		
Tubulipora sp.							+	+	+	+			+	+	+	+	+	+	+		+	+	+	+	+	+		+			+	+	+	+	
Tubulipora uniformis Gostilovskaja, 1955	BArEA							+																											
Tubuliporidae g. sp.	ArE																															+		+	
Cyclostomatida g. sp.				+			+																			+									
Family Diastoporidae																																			
Genus *Diplosolen* Canu, 1918																																			
Diplosolen obelia (Johnston, 1838)	SBA																	+																	
Diplosolen sp. n.	ArA																	+																	
Diastoporidae g. sp.															+	+		+					+							+		+		
Genus *Desmeplagioecia*																																			
Desmeplagioecia sp.	ArA							+																											
Suborder Articulata																																			
Family Crisiidae																																			
Genus *Filicrisia* d'Orbigny, 1853																																			
Filicrisia geniculata (Milne-Edwards, 1838)	AmB													+							+														
Filicrisia smitti (Kluge, 1946)	BArAmP										+																								
Filicrisia sp.						+																													
Genus *Crisia* Lamouroux, 1812																																			
Crisia denticulata (Lamarck, 1816)	BArws										+																								
Crisia eburnea (Linnaeus, 1758)	BArws							+																											
Crisia sp.							+	+	+	+	+		+	+	+	+		+	+			+	+						+						
Crisiidae gen. sp.																																+			
Genus *Crisiella* Borg, 1924																																			
Crisiella diversa (Kluge, 1955)	ArE	+									+		+					+																	
Crisiella producta (Smitt, 1865)	BArAmP			+								+																							
Crisiella sp.			+	+	+	+	+	+	+		+	+	+	+	+		+		+		+	+		+			+		+	+	+			
Suborder Cerioporina																																			
Family Cerioporidae																																			
Genus *Borgella* Kluge, 1955																																			
Borgella tumulosa Kluge, 1955	ArE																	+																+	
Suborder Rectangulata																																			
Family Lichenoporidae																																			
Genus *Disporella*																																			
Disporella sp.			+	+	+		+	+	+	+	+		+	+	+	+	+	+	+		+	+	+	+	+	+	+		+	+	+	+	+	+	+
Disporella sp. 2	ArE																																		

Table 1 – continued.

Lichenoporidae g. sp.	ArE		+																		+	+								+		+	+	
Class Gymnolaemata																																		
Order Ctenostomata																																		
Suborder Stoloniferina																																		
Family Vesiculariidae																																		
Genus *Bowerbankia* Farre, 1837																																		
Bowerbankia imbricata (Adams, 1800)	SBA					+				+												+				+								
Bowerbankia sp.					+					+																								
Suborder Alcyonidiina																																		
Family Alcyonidiidae																																		
Genus *Alcyonidium* Lamouroux, 1813																																		
Alcyonidium gelatinosum (Linnaeus, 1767)	BArws	+				+						+			+	+		+		+										+				
Alcyonidium gelatinosum var. *andersoni* Abrikossov, 1932	ArE							+																										
Alcyonidium mytili Dalyell, 1847	BArws									+				+		+															+			
Alcyonidium irregulare Kluge, 1961	HBArA											+																						+
Alcyonidium disciforme Smitt, 1872	Arc		+																															
Alcyonidium sp.						+		+	+	+			+			+		+	+		+		+	+				+	+					
Suborder Flustrellidrina																																		
Family Flustrellidridae																																		
Genus *Flustrellidra* Bassler, 1953																																		
Flustrellidra corniculata (Smitt, 1872)	BArwsc										+	+								+							+							
Order Cheilostomata																																		
Suborder Scruparina																																		
Superfamily Scruparioidea																																		
Family Eucrateidae																																		
Genus *Eucratea* Lamouroux, 1812																																		
Eucratea loricata (Linnaeus, 1758)	BArws	+	+	+	+	+	+	+	+	+	+	+	+	+		+				+	+	+	+			+	+	+	+	+	+			
Suborder Malacostega																																		
Superfamily Membraniporoidea																																		
Family Electridae																																		
Genus *Electra* Lamouroux, 1816																																		
Electra crustulenta arctica Borg, 1931	BArws	+	+			+	+	+		+	+	+	+			+	+	+	+	+	+	+	+	+	+	+	+		+			+	+	
Electra sp.																					+													
Suborder Flustrina																																		
Superfamily Calloporidea																																		
Family Calloporidae																																		
Genus *Tegella* Levinsen, 1909																																		
Tegella amissavicularis (Kluge, 1952)	Ar																														+			
Tegella arctica (D'Orbigny, 1850-1852)	BArws			+		+	+	+	+	+		+	+	+	+	+	+	+		+	+	+	+	+	+	+		+	+	+	+	+	+	+
Tegella arctica retroversa Kluge, 1952	BAr			+			+	+						+	+	+	+	+			+	+	+		+	+			+	+	+	+	+	
Tegella armifera (Hincks, 1880)	Barwsc		+	+		+	+	+				+	+	+	+	+	+	+		+	+	+	+			+		+	+	+	+	+	+	
Tegella armiferoides Kluge, 1955	Ar					+																								+	+	+		
Tegella inermis Kluge, 1952	Ar														+						+									+				
Tegella nigrans (Hincks, 1882)	BArwsc							+																						+				
Tegella spitzbergensis (Bidenkap, 1897)	BArEA						+	+																										
Tegella sp.							+					+	+	+		+		+			+			+	+	+	+	+	+	+	+	+	+	
Tegella sp. n. (?)	Ar					+								+	+								+								+			
Tegella unicornis (Fleming, 1828)	AmB											+	+	+			+															+		
Genus *Callopora* Gray, 1848																																		
Callopora craticula (Alder, 1857)	BArwsc						+					+		+	+	+	+	+			+	+	+		+	+		+	+	+	+	+	+	
Callopora craticula sedovi Kluge, 1961	Ar							+						+	+	+											+							
Callopora lata (Kluge, 1907)	Ar		+			+	+	+				+	+	+	+	+	+	+			+	+	+			+		+	+	+	+	+	+	
Callopora lineata (Linnaeus, 1767)	BArwsc	+		+		+	+	+				+		+		+	+			+	+		+				+	+	+		+			
Callopora smitti Kluge, 1946	Ar														+	+	+	+															+	
Callopora sp.		+	+			+	+	+		+		+		+	+	+	+	+		+	+	+	+	+	+	+		+	+	+	+	+		
Callopora sp. n.																+		+																
Callopora whiteavesi (Norman, 1903)	Arc	+				+	+	+		+				+		+	+	+			+		+		+	+			+		+	+	+	
Genus *Cauloramphus* Norman, 1903																																		
Cauloramphus cymbaeformis (Hincks, 1877)	BArws																															+		

Table 1 – continued.

Cauloramphus intermedius Kluge, 1961	Ar	+				+	+	+		+		+	+	+	+	+	+	+	+	+	+	+	+				+	+	+	+	+		+	
Cauloramphus spiniferum (Johnston, 1832)	AmB									+											+													
Cauloramphus sp.		+					+	+				+	+	+							+	+				+		+	+					
Genus *Amphiblestrum* Gray, 1848																																		
Amphiblestrum trifolium quadrata (Hincks, 1880)	BArA															+																	+	
Genus *Doryporella* Worman, 1903																																		
Doryporella spathulifera (Smitt, 1868)	BArc													+	+	+	+	+					+	+		+				+		+	+	
Doryporella sp. n.	Ar																+																	
Superfamily Buguloidea																																		
Family Bugulidae																																		
Genus *Dendrobeania* Levinsen, 1909																																		
Dendrobeania fruticosa (Packard, 1863)	BArwsc					+	+	+						+	+	+	+	+			+			+										
Dendrobeania fruticosa var. *quadridentata* (Loven, 1834)	BArwsc															+		+			+		+						+	+				
Dendrobeania murrayana (Johnston, 1847)	BArws						+				+	+	+	+					+	+	+	+	+			+		+	+					
Dendrobeania levinseni (Kluge, 1929)	ArE						+									+	+					+												
Dendrobeania pseudolevinseni Kluge, 1952	Ar						+			+			+		+						+													
Dendrobeania pseudomurrayana fessa (Kluge, 1955)	BAr						+						+								+	+	+					+	+					
Dendrobeania sp.										+			+		+	+	+	+				+	+						+					
Family Candidae																																		
Genus *Bugulopsis* Verrill, 1879																																		
Bugulopsis peachii (Busk, 1851)	BArwsc					+																												
Genus *Tricellaria* Fleming, 1828																																		
Tricellaria gracilis inermis Kluge, 1961	Ar						+	+						+							+								+					
Tricellaria ternata (Ellis et Solander, 1786)	BArwsc		+		+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+		+	+	+	+	+	+	+			
Tricellaria sp.																																+		
Genus *Scrupocellaria* van Beneden ,1845																																		
Scrupocellaria arctica (Busk, 1855)	BArwsc						+							+	+	+	+	+			+	+	+					+	+					
Scrupocellaria scabra (van Beneden, 1848)	BArwsc							+						+	+	+	+	+					+											
Scrupocellaria scabra paenulata Norman, 1903	BArwsc							+																										
Scrupocellaria sp.																	+					+				+				+				
Suborder Ascophora																																		
Infraorder Acanthostega																																		
Superfamily Cribrilinoidea																																		
Family Cribrilinidae																																		
Genus *Cribrilina* Gray, 1848																																		
Cribrilina annulata (Fabricius,1780)	BArwsc	+	+	+		+	+	+	+	+		+	+	+	+	+	+	+		+	+	+	+	+		+		+	+	+		+		
Infraorder Hippothoomorpha																																		
Superfamily Hippothooidea																																		
Family Hippothoidae																																		
Genus *Hippothoa* Lamouroux, 1821																																		
Hippothoa divaricata arctica Kluge, 1906	Arc							+							+		+	+					+		+	+						+	+	
Hippothoa expansa Dawson, 1859	BArwsc																				+		+											
Hippothoa hyalina (Linnaeus, 1767)	BArwsc	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+
Infraorder Umbonulomorpha																																		
Superfamily Lepralielloidea																																		
Family Bryocryptellidae																																		
Genus *Porella* Gray, 1848																																		
Porella acutirostris Smitt, 1868	BArwsc															+	+	+								+						+	+	
Porella concinna (Busk, 1854)	BArwsc													+		+		+								+				+	+		+	
Porella concinna belli (Dawson, 1859)	BArwsc																									+								
Porella minuta Norman, 1869	BArA									+						+	+	+							+	+						+	+	
Porella sp. n.	Ar																	+																
Porella smitti Kluge, 1907	HBAr							+																										
Genus *Cystisella* Canu et Bassler, 1917																																		
Cystisella saccata subsp. n.	Ar																	+																
Genus *Rhamphostomella* Lorenz, 1886																																		
Rhamphostomella bilaminata (Hincks, 1877)	Arc					+				+			+	+		+	+				+	+	+					+	+	+	+	+	+	
Rhamphostomella bilaminata sibirica Kluge, 1929	BArwsc									+																								

Table 1 – continued.

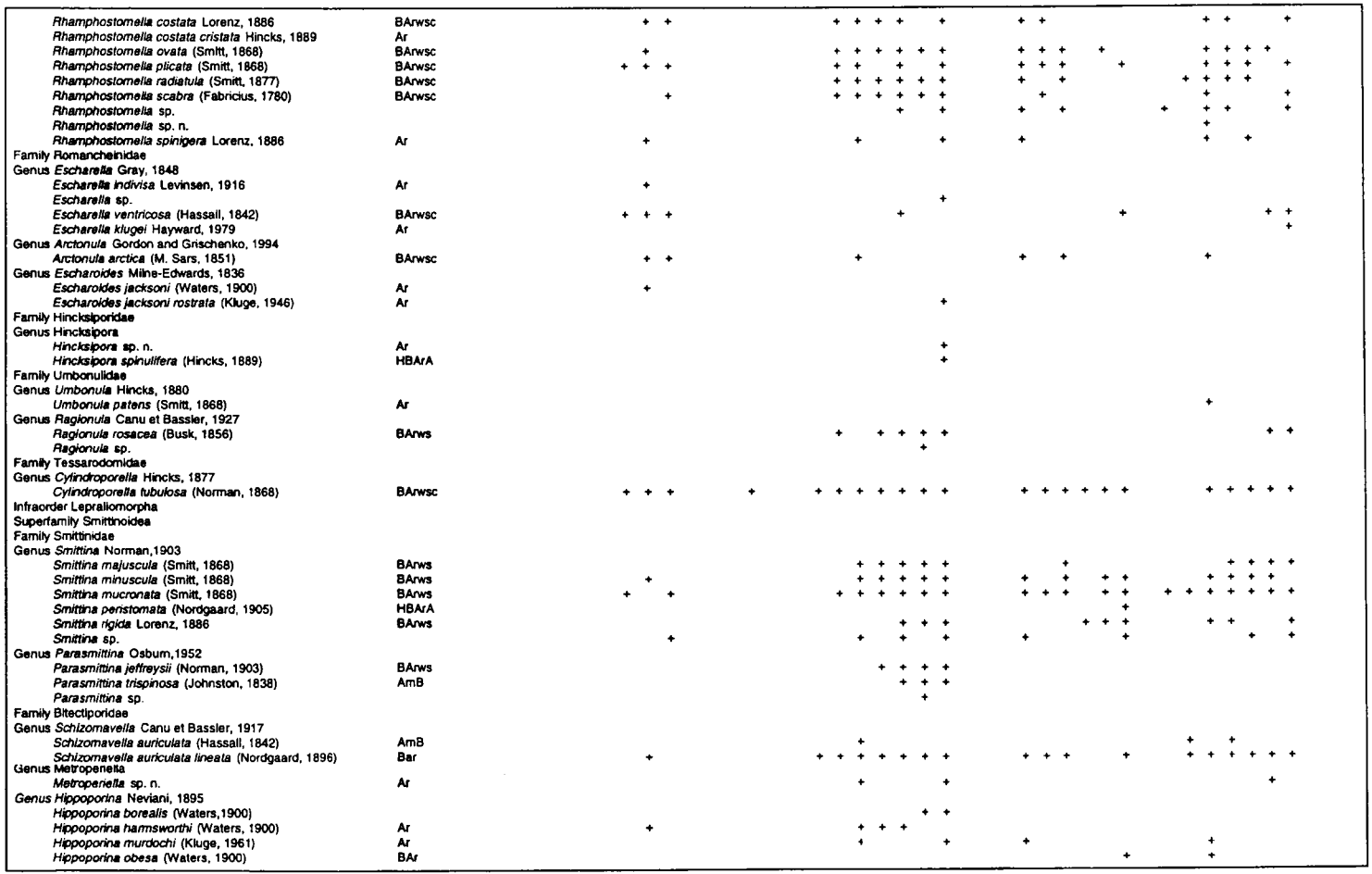


Table 1 – continued.

Hippoporina propinqua (Smitt, 1868)	Bar																												+	+						
Hippoporina reticulatopunctata (Hincks, 1877)	BArwsc								+					+	+		+	+				+		+						+	+	+	+		
Hippoporina ussowi (Kluge, 1908)	Arc							+					+	+	+	+	+	+	+			+		+	+				+	+	+	+	+	+	
Hippoporina sp.																							+												
Hippoporina sp. n.	Ar																																	+	
Superfamily Schizoporelloidea																																			
Family Schizoporellidae																																			
Genus *Schizobrachiella* Canu et Bassler, 1920																																			
Schizobrachiella sp.																+																			
Schizobrachiella stylifera (Levinsen, 1887)	BArwsc																																	+	
Genus *Schizoporella* Hincks, 1877																																			
Schizoporella costata Kluge, 1961	Bar																+	+	+								+							+	
Schizoporella porifera (Smitt, 1868)	Arc														+	+	+	+	+											+	+		+		
Schizoporella sp.														+		+		+	+												+		+		
Schizoporella sp. 1	Ar								+																									+	
Schizoporella sp. 2	Ar																																	+	
Family Stomachetosellidae																																			
Genus *Stomachetosella* Canu et Bassler, 1917																																			
Stomachetosella cruenta (Busk, 1860)	BArws							+	+				+	+	+		+	+	+			+	+	+	+	+	+			+	+	+		+	
Stomachetosella magniporata Nordgaard, 1906	BArws																																		
Stomachetosella sinuosa (Busk, 1860)	BArws																																	+	
Stomachetosella pachystega (Kluge, 1929)	BArws																		+															+	
Stomachetosella limbata Lorenz, 1886	BArws																																		
Stomachetosella sp.							+						+	+				+				+											+		
Stomachetosella sp. 1	Ar						+																												
Family Myriaporidae																																			
Genus *Myriozoella* Levinsen, 1909																																			
Myriozoella crustacea (Smitt, 1868)	BArwsc																+	+	+															+	
Family Cheiloporinidae																																			
Genus *Cheiloporina* Canu et Bassler, 1923																																			
Cheiloporina sincera (Smitt, 1868)	BArwsc								+						+			+	+											+					
Cheiloporina sincera praelucida (Hincks, 1888)	Ar																	+	+																
Family Cryptosulidae																																			
Genus *Harmeria* Norman, 1903																																			
Harmeria scutulata (Busk, 1855)	ArA		+	+	+		+	+	+	+	+	+	+	+	+						+	+	+	+		+	+		+		+				
Family Microporellidae																																			
Genus *Microporella* Hincks, 1877																																			
Microporella ciliata (Pallas, 1766)	AmB								+				+					+	+		+	+	+	+		+	+		+	+	+	+	+	+	
Microporella ciliata arctica Norman, 1903	Ar																										+								
Microporella sp. n.	Ar																					+							+	+					
Superfamily Celleporoidea																																			
Family Celleporidae																																			
Genus *Cellepora* Linnaeus, 1767																																			
Cellepora sp.																																			
Genus *Celleporina* Gray, 1848																																			
Celleporina surcularis (Packard, 1863)	BArwsc																		+																
Celleporina ventricosa (Lorenz, 1886)	BArwsc																																	+	
Celleporina sp.																			+														+	+	
Family Hippoporidridae																																			
Genus *Hippoporella* Canu 1917																																			
Hippoporella hippopus (Smitt, 1868)	BArwsc																	+	+			+				+						+	+	+	
Hippoporella parva Androsova, 1958																										+	+								
Family Phidoloporidae																																			
Genus *Reteporella* Busk,1884																																			
Reteporella cellulosa (Linnaeus, 1758)	BArEA																		+																
Sum taxa		1	13	15	11	5	32	48	43	10	27	9	30	39	55	44	61	62	74	5	19	56	38	45	15	26	44	13	31	53	45	39	44	52	4

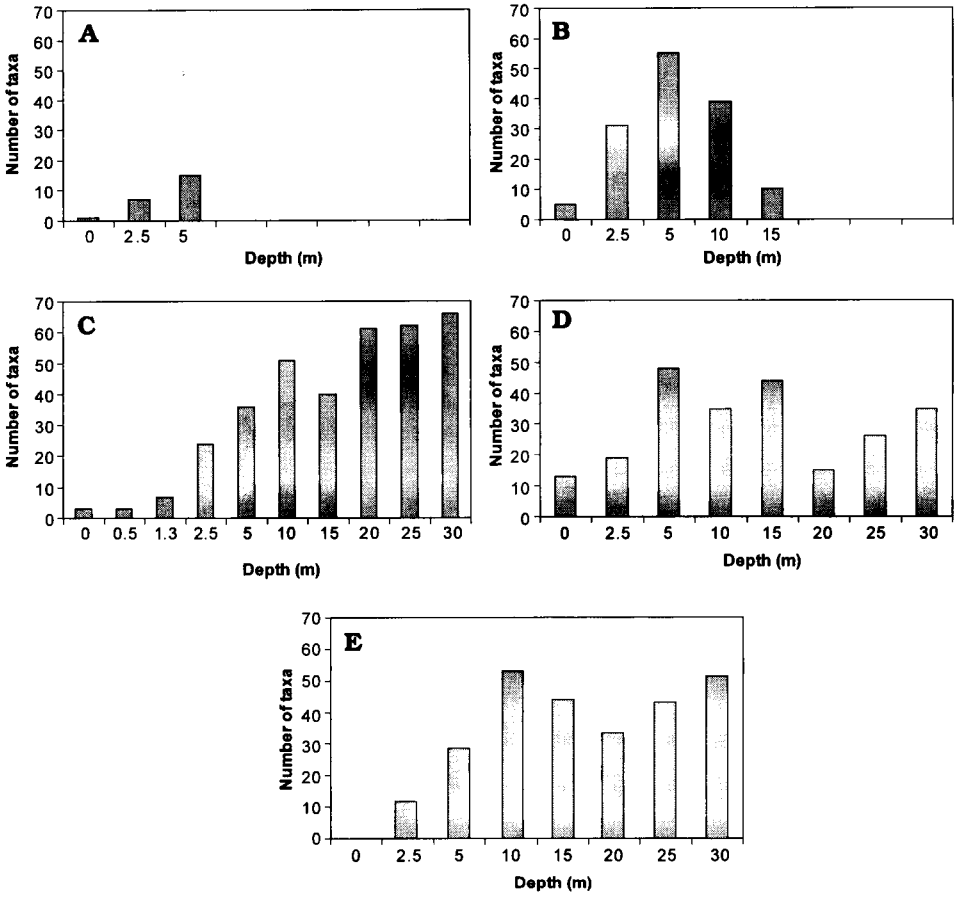


Fig. 3. Number of taxa at different depth transects in the Kongsfjorden: Ossian Sars (A), Juttaholmen (B), Hansneset (C), Kapp Guissez (D) and Kapp Mitra (E).

in the upper 5 m, and the more sheltered areas deeper than 10 m contained a thick silt cover over gravel substratum. The number of bryozoan taxa increased with depth to reach their maximum at 5 m, but then declined below this depth (Fig. 3B).

Two single-sample stations at 5 m depth near Leirholmen and Blomstrand demonstrated that the species occurrence closer to the glacier is limited by similar conditions as in Ossian Sars (Table 1). The location near Blomstrand Island was situated about 10 km away from the glacial front. It was more exposed with less silt, and higher salinity in the surface waters (32–33 PSU). This location contained more than twice the number of taxa compared to Leirholmen (Table 1).

Hansneset was located in the middle of the fjord, about 12 km from the glacial front in the inner fjord and 5 km from the glacial front of Blomstrandbreen in the middle of Kongsfjorden (Fig. 1). This location was exposed to the depth 15–20 m,

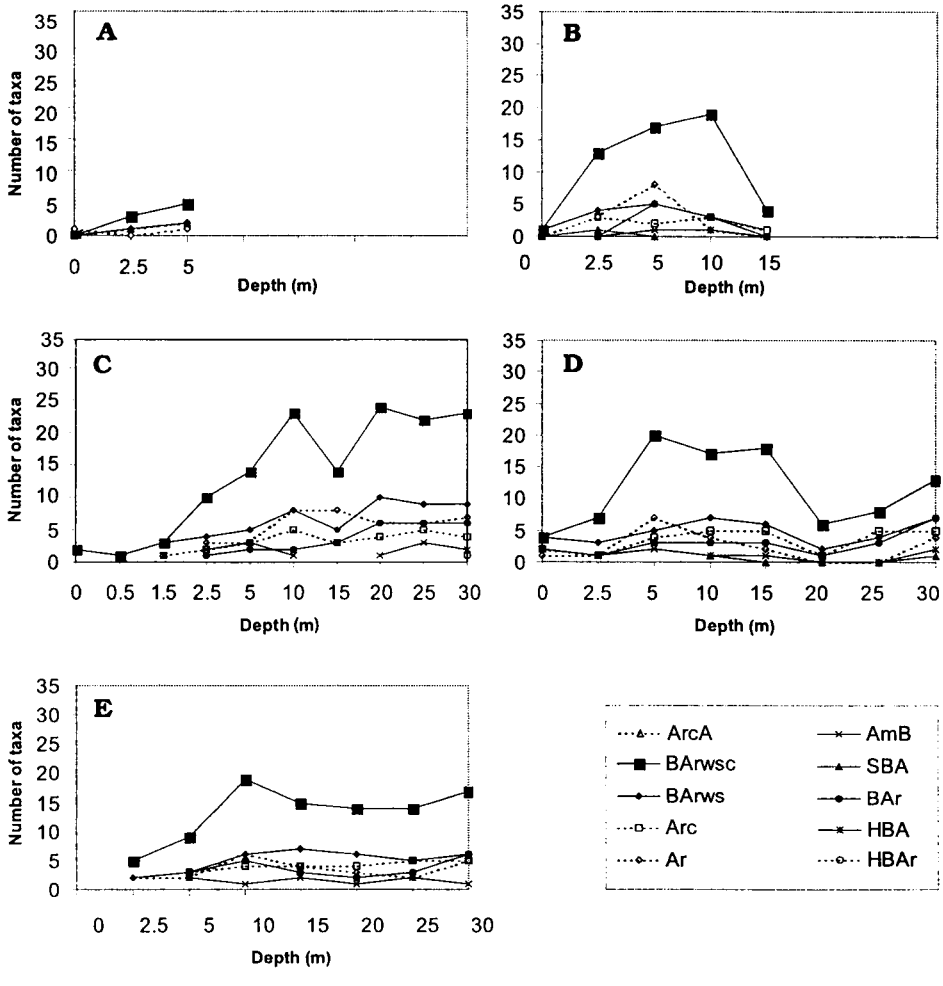


Fig. 4. Number of taxa in biogeographical groups at different depth transects in the Kongsfjorden: Ossian Sars (A), Juttaholmen (B), Hansneset (C), Kapp Guissez (D), Kapp Mitra (E) (Biogeographic groups are those listed in Fig. 2).

but sheltered below that depth. There was a thin flocculent layer of silt on boulders and pebbles below 15 m. The number of bryozoan taxa generally increased from 0 to 30 m depth, although there was a drop in number at 15 m (Fig. 3C).

The transect near Kapp Guissez, a point between Kongsfjorden and Krossfjorden, was exposed down to a depth of about 20 m. A more sheltered zone without silt existed from 25 to 30 m, although a thin flocculent layer of silt was present on stones at 30 m depth. The limit for macroalgal vegetation and bedrock habitat was about 15 m depth. Below this depth, the substratum was composed of pebbles and rocks with encrusted corraline algae. The number of bryozoan taxa increased to about 5 m and fluctuated at depths below that, with a drop in number at 20 m (Fig. 3D).

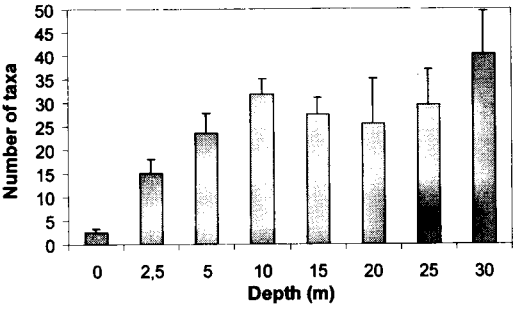


Fig. 5. Depth distribution of the Bryozoa (mean number of taxa ± SE) in Kongsfjorden, for all locations combined.

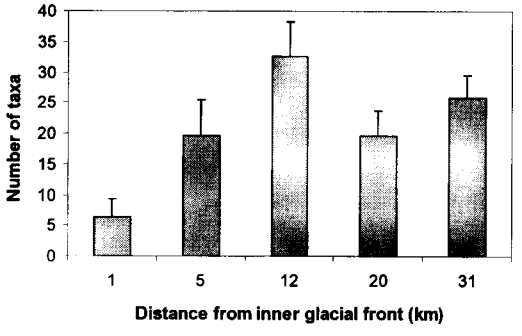


Fig. 6. Distribution of the Bryozoa along the length axis of Kongsfjorden, meassured from the inner glacial front (Kongsbreen). Mean numbers of taxa (± SE) are calculated for all depths combined.

The outer transect, near Kapp Mitra was at the exposed outer coast of the West Spitsbergen. The fully marine water at this location is influenced by the West Spitsbergen current (Svendsen *et al.*, unpubl.). The physical characteristics of this location and the distribution pattern of the Bryozoa were similar to that of Kapp Guissez. The number of taxa increased down to 10 m and fluctuated at depths below that (Fig. 3E). There was also a similar drop in number at 20 m.

The depth distribution of different biogeographic groups generally reflected the total number of taxa at these depths (Fig. 4A–E). However, the decline in species numbers at Hansneset at 15 m depth, and at Kapp Guissez and Kapp Mitra at 20 m depth was mainly caused by eurybiontic widespread boreal-Arctic and widespread circumpolar boreal-Arctic species (Fig. 4C–E).

The combined distribution pattern for Kongsfjorden showed an increase in mean number of taxa down to 10 m depth (Fig. 5). There was a drop in number down to 20 m depth and a subsequent increase to 30 m depth. The mean number of taxa increased from the inner glacial front of Kongsbreen to the middle of the fjord

(Fig. 6). There was a drop at the outer part of the fjord and a subsequent increase at the outer exposed coast of the West Spitsbergen.

Discussion

The bryozoan fauna of Kongsfjorden has not been extensively studied so far. Their ecological roles are poorly known and further studies tend to result in additional species recorded for the fjord. Four additional species and one variety were found in Kongsfjordrenna at 960 m depth by Gontar (1996). These included *Hornera lichenoides* (L., 1758), *Reteporella beaniana* (King, 1846), *R. beaniana* var. *watersi* (Nordgaard, 1907), *Smittina glaciata* (Waters, 1900) and *Porella minuta* (Norman, 1869). Twenty six species and two varieties were found by Lippert (1998) near Hansneset, Kongsfjorden. Kukliński (unpubl.) contributed substantially to the understanding of the bryozoan biodiversity in this region by identifying 111 species and 12 varieties in this area, including 85 species and 11 varieties that were new for the fauna of Kongsfjorden. He also determined 16 species at the genus and 3 at the family level. The bryozoan diversity of Kongsfjorden probably exceeds 147 species and 23 varieties; this constitutes more than half of all known bryozoans in Svalbard waters so far.

A total of 196 bryozoan species and varieties have been reported by Gulliksen *et al.* (1999) for Svalbard's marine coastal waters. This is the largest modern list of bryozoan species for this area, although it is not exhaustive, as shown by our list of 96 additional species recorded for Svalbard waters (Table 2). Gulliksen *et al.* (1999) most likely could not use records from Russian studies. Thirty species and varieties were recorded by Kluge (1962), 32 by Gostilovskaya (1964), 32 by Gontar, (1996), 22 by Denisenko (1998), 28 by Lippert (1998), and 123 by Kukliński (unpubl., pers. comm.). Finally, 117 species (and varieties) were identified in this study from the shallow waters of Kongsfjorden. The total number of Bryozoa (i.e. those that we could account for) in all Svalbard waters comprises 292 species and varieties.

The high bryozoan diversity in Kongsfjorden is most likely a result of the influence of both Arctic and Atlantic water masses to this fjord (Svendsen *et al.*, unpubl.). Within the fjord, the biogeographic composition and the depth distribution of organisms are largely dependent on physical factors. The depth distribution of bryozoan species in Kongsfjorden depended on their distance from the tidal glaciers, with their large influx of freshwater and sediments, as well as on the substratum availability and the hydrologic characteristics of the water masses. The low species numbers close to the surface probably reflect the relatively brackish surface waters (28–30 PSU) that are present in Kongsfjorden during the summer (Svendsen *et al.*, unpubl.). Since most marine bryozoans are stenohaline invertebrates, the brackish water will probably limit species colonization and survival of bryozoans at the shallow sites, particularly in the inner fjord.

Table 2

Species and varieties of Bryozoa recorded in Svalbard waters, in addition to the 196 listed in Gulliksen *et al.* (1999).

Bryozoa taxon

Gostilovskaya (1964)

1. *Alcyonidium mamilatum* var. *erectum* Andersson, 1902
2. *Crisia eburneo-denticulata* (Smitt, 1865)
3. *Diplosolen obelia* var. *arctica* (Waters, 1904)
4. *Eucratea loricata* var. *arctica* (Kluge, 1915)
5. *Kinetoskias smitti* (Daniellsen, 1868)
6. *Lichenopora hispida* (Fleming, 1828)
7. *Palmicellaria skenei* var. *tridens* (Busk, 1856)
8. *Porella plana* Hincks, 1888
9. *Pseudoflustra anderssoni* Kluge, 1846
10. *Pseudoflustra sinuosa* (Andersson, 1902)
11. *Smittina majuscula* (Smitt, 1868)
12. *Smittina peristomata* (Nordgaard, 1905)
13. *Tessarodoma boreale* (Busk, 1860)
14. *Tubulipora ventricosa* Busk, 1875
15. *Turbicellepora canaliculata* (Busk, 1886)

Kluge (1962)

16. *Alcyonidium gelatinosum* var. *diaphanum* (Farre, 1837)
17. *Bugula tricuspis* Kluge, 1915
18. *Cauloramphus intermedius* Kluge, 1962
19. *Dendrobeania fruticosa* var. *frigida* (Waters, 1900)
20. *Electra crustulenta* var. *catenularia-similis* Kluge, 1962
21. *Escharella klugei* Hayward, 1979
22. *Escharelloides cancellatum* (Smitt, 1868)
23. *Filicrisia geniculata* (Milne-Edwards, 1838)
24. *Microporella impressa* (Audouin,1826)
25. *Reteporella beaniana* var. *watersi* (Nordgaard, 1907)
26. *Rhamphonotus minax* (Busk, 1860)
27. *Rhamphostomella costata* var. *cristata* Hincks, 1889
28. *Schizoporella elmwoodiae* var. *mammilata* Kluge, 1962
29. *Stigmatoechos* (*Stegohornera*) *violacea* (M. Sars, 1863)
30. *Tubulipora smitti* Kluge, 1962

Gontar (1996)

31. *Alcyonidium gelatinosum* var. *anderssoni* (Abrikossov, 1932)
32. *Hornera pseudlichenoides* Gontar, 1996
33. *Idmidronea atlantica* var. *gracillima* (Busk, 1875)
34. *Palmicellaria skenei* var. *bicornis* (Busk, 1859)
35. *Parasmittina jeffreysii* (Norman, 1903)
36. *Phylactella labiata* (Smitt, 1868)
37. *Securiflustra securifrons* (Pallas, 1766)
38. *Smittina glaciata* (Waters, 1900)

Denisenko (1998)

39. *Dendrobeania pseudomurrayana* var. *fessa* Kluge, 1955
40. *Dendrobeania pseudomurrayana* Kluge, 1955
41. *Escharoides bidenkapi* (Kluge, 1946)
42. *Reteporella septentrionalis* Harmer, 1933

Table 2 – continued.

Lippert (1998)
43. *Callopora aurita* (Hincks, 1877)
44. *Crisiella diversa* (Kluge, 1955)
45. *Hippothoa divaricata* var. *arctica* Kluge, 1906
46. *Schizomavella auriculata* var. *lineata* (Hassall, 1896)
47. *Scrupocellaria arctica* (Busk, 1855)

Kukliński (unpubl.)
48. *Amphiblestrum trifolium* (S. Wood, 1844)
49. *Celleporina ventricosa* (Lorenz, 1886)
50. *Crisiella producta* (Smitt, 1865)
51. *Desmeplagioecia* (Berenicea) *arctica* (Kluge, 1946)
52. *Electra crustulenta* var. *arctica* Borg, 1931
53. *Escharella latodonta* Kluge, 1962
54. *Escharelloides spinulifera* (Hincks, 1889)
55. *Hippoponella hippopus* (Smitt, 1868)
56. *Hippoporina murdochi* Kluge, 1962
57. *Hippoporina propinqua* (Smitt, 1868)
58. *Lichenopora sibirica* Kluge, 1955
59. *Membranipora membranacea* (Linnaeus, 1767)
60. *Microporella cilata* var. *arctica* Norman, 1903
61. *Palmiskenea faroensis* Hayward, 1994
62. *Porella concinna* var. *belli* (Dawson, 1859)
63. *Porella tumida* Kluge, 1955
64. *Proboscina major* (Johnston, 1847)
65. *Rhamphostomella bilaminata* (Hincks, 1877)
66. *Rhamphostomella ovata* (Smitt, 1868)
67. *Schizobrachiella stylifera* (Levinsen, 1887)
68. *Schizoporalla ortmanni* Kluge, 1955
69. *Schizoporella elmwoodiae* Waters, 1900
70. *Schizoporella hexagona* Nordgaard, 1905
71. *Smittina mucronata* (Smitt, 1868)
72. *Tegella arctica* var. *retroversa* Kluge, 1952
73. *Tubulipora dilatans* (Johnston, 1847)
74. *Tubulipora soluta* Kluge, 1946

Gontar, Hop, Voronkov (this paper)
75. *Alcyonidium irregulare* Kluge, 1962
76. *Amphiblestrum trifolium* var. *quadrata* (Hincks, 1880)
77. *Borgella tumulosa* Kluge, 1955
78. *Callopora craticula* var. *sedovi* Kluge, 1962
79. *Callopora whiteavesi* (Norman, 1903)
80. *Cauloramphus spiniferum* (Johnston, 1832)
81. *Cheiloporina sincera* var. *praelucida* (Hincks, 1888)
82. *Dendrobeania levinseni* (Kluge, 1929)
83. *Dendrobeania pseudolevinseni* Kluge, 1952
84. *Escharella indivisa* Levinsen, 1916
85. *Escharoides jacksoni* var. *rostrata* (Kluge, 1946)
86. *Filicrisia smitti* (Kluge, 1946)
87. *Oncousoecia polygonalis* (Kluge, 1915)
88. *Porella smitti* Kluge, 1907
89. *Reteporella cellulosa* (Linnaeus, 1758)

Table 2 – continued.

90. *Rhamphostomella bilaminata sibirica* Kluge, 1929
91. *Schizoporella porifera* (Smitt, 1868)
92. *Tegella amissavicularis* (Kluge, 1952)
93. *Tegella armiferoides* Kluge, 1955
94. *Tegella inermis* Kluge, 1952
95. *Tricellaria gracilis* var. *inermis* Kluge, 1962
96. *Tubulipora uniformis* Gostilovskaya, 1955

In the inner part of Kongsfjorden, the bryozoan depth distribution was also strictly limited by substratum because of thick layers of sediments below certain depths (i.e. 5 m at Ossian Sars and 10 m at Juttaholmen). At the station in the middle fjord, the drop in number of taxa at 15 m was probably mainly related to the water masses since it occurred in transitional water with salinity < 34.0 PSU (Svendsen *et al.*, unpubl.). The numbers increased in the deeper water, with salinity > 34.0 PSU (Svendsen *et al.*, unpubl.). At the two outer stations, the drop in number of taxa at 20 m may also be related to the water mass characteristics, and possibly to changes in habitat since it was the lower limit for macroalgae and the bedrock substratum. However, the latter may be less important since many bryozoans are attached to barnacles (*Balanus balanus*) and rocks at all depths.

We have shown that bryozoans constitute an important part of the marine bottom biocenoses since they represent a major portion of the overall species diversity in Kongsfjorden. We have also shown that their diversity changes with both depth and location in the fjord. However, it is evident that more research is needed to determine the direct effects of environmental factors on survival and the bryozoan distribution. It would be important to determine what kind of bryozoan species or communities are the most suitable environmental indicators.

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