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The Norwegian Polar Institute is Norway's main institution for research and topographic mapping in the Norwegian polar regions. The Institute also advises the Norwegian authorities on matters concerning polar environmental management.

Norsk Polarinstitutt 2001

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Preface

The governmental white paper number 22 (1994-95), Environmental conservation in Svalbard (Miljøverndepartementet 1995), states that Svalbard should be one of the best managed wilderness areas of the word. Proper environmental management includes investigations of waste management from settlements and the spread of contaminants in the environment.

The Governor of Svalbard has mapped both old and existing garbage dumps in Svalbard (Hansen *et al.* 1998) and measured contaminants at some sites (Sørlie *et al.* 1999 a, b, c, d). The pollutant reports conclude that new surveys should be done in selected areas. In this survey we examined the marine biota near urban settlements in five fjords in Svalbard. Sampling was done in the vicinity of old garbage dumps and sewage outlets. The sampling was done at different distances from settlements, including remotely located stations at the mouths of Isfjorden and Kongsfjorden. Polyaromatic hydrocarbon (PAH), hexachlorobenzene (HCB), and polychlorinated biphenyl (PCB) concentrations were measured in seven species of macro-benthos and fish in the five fjords on Spitsbergen. We evaluated whether elevated contaminant levels originated from local sources or from long-range transport.

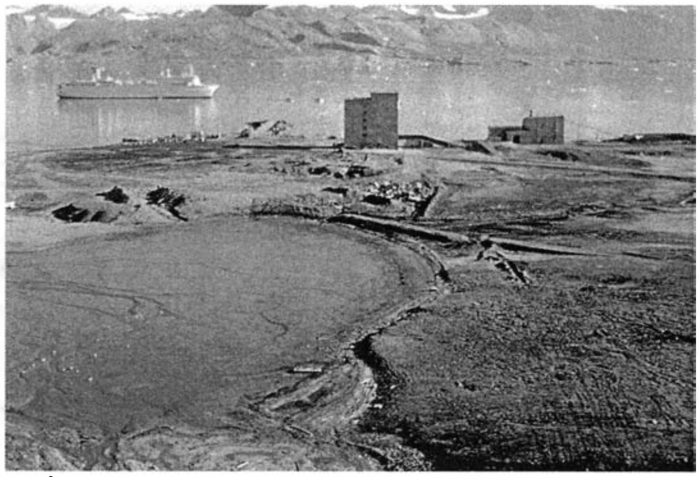
The Norwegian Polar Institute (NPI) performed the survey reported here, whereas a co-ordinated project was undertaken by Akvaplan-niva (Apn) (Cochrane *et al.* 2001). The Norwegian Institute for Air Research (NILU) performed the analyses of environmental pollutants and the Institute for Energy Technology, Kjeller, analysed for stable isotopes.

Tromsø, 1 Sept., 2001
Haakon Hop
project leader

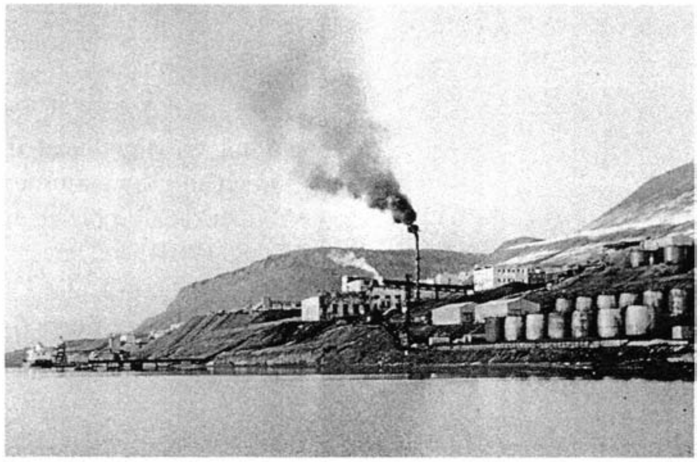
Abstract

The contribution of local sources of pollution to the contaminant concentrations in macro-benthos was evaluated for different fjords on Spitsbergen (Svalbard). Samples were collected at various distances from suspected point sources in: Billefjorden and Grønfjorden, with respective Russian towns Pyramiden and Barentsburg; Adventfjorden and Kongsfjorden, with respective Norwegian towns Longyearbyen and Ny-Ålesund; and the mouths of Isfjorden and Kongsfjorden as control stations. Seven species of invertebrates and fish were analysed for persistent organic pollutants of polyaromatic hydrocarbon (PAHs), hexachlorobenzene (HCB) and polychlorinated biphenyl (PCBs), as well as stable isotopes of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) to quantify trophic levels.

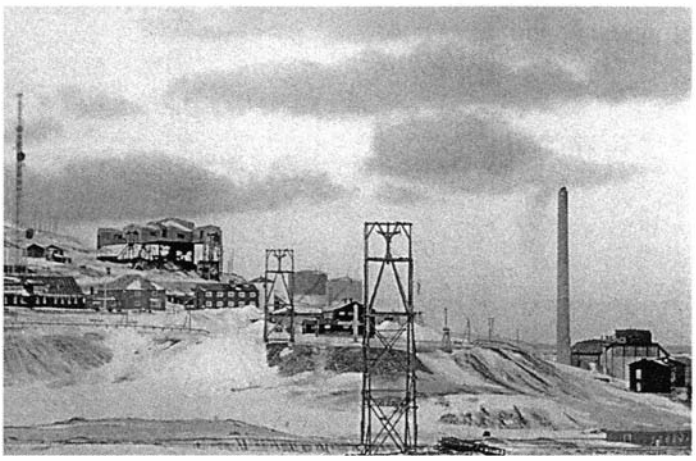
Local input of both PAHs and PCBs seemed to be present for the Isfjord system (Billefjorden, Grønfjorden, Adventfjorden and outer Isfjorden) and to a lesser degree for Kongsfjorden. There were no indications that HCB has local sources, since the concentrations measured were close to background levels. The concentrations of PAHs and PCBs were higher close to the settlements in Billefjorden, Grønfjorden, Adventfjorden, and Kongsfjorden. The distribution of some of the PCB congeners differed between fjords, in that Billefjorden and Grønfjorden were significantly different from Adventfjorden, Isfjorden, and Kongsfjorden. The most important differences were between fjords with Russian versus Norwegian settlement, and the characteristic congener profiles probably arise because of local pollution from these settlements.



Ny-Ålesund



Barentsburg



Longyearbyen

Pyramiden

Introduction

The objective of this study was to evaluate the contribution of local sources of pollution to the contaminant concentrations in the marine biota near urban settlements in Svalbard. The study constituted a contaminant survey of marine macro-benthos in fjords on Spitsbergen, including: Billefjorden and Grønfjorden, which have Russian settlements; Adventfjorden and Kongsfjorden, with Norwegian settlements; and the mouths of Isfjorden and Kongsfjorden as control stations. This is the first study that includes measurements of contaminants in marine macro-benthos and fish near these settlements.

Sampling stations were placed near known garbage dumps, sewage outlets, and harbours. Samples were collected at increasing distance from suspected point sources. Seven species of invertebrates and fish were analysed for persistent organic pollutants of polyaromatic hydrocarbons (PAHs), hexachlorobenzene (HCB) and polychlorinated biphenyls (PCBs), as well as stable isotopes of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) to quantify trophic levels.

Contaminants found in Arctic sediments and biota originate from two types of sources, remote and local. Our knowledge of contaminant sources has increased during the last 10-15 years. Most of the contaminants found in the high Arctic come from the denser populated and industrialised areas of the word, i.e. at lower latitudes (AMAP 1998). The contaminants are distributed globally and are transported to the Arctic by air, ocean currents and sea ice (Oehme 1991; Ballschmiter 1992; Iwata *et al.* 1993; Pfirman *et al.* 1995). The Persistent Organic Pollutants (POPs) described have low water solubility but high vapour pressure, which make them suitable for bonding to particles and for air transport (Oehme 1991; Ballschmiter 1992). The atmospheric transport can be sub-divided into singe and multi-hop pathways. The multi-hop pathway involves repeated entering into of the atmosphere with redeposition back to land; it is also known as global distillation. It applies to most organochlorines (OCs) and many polyaromatic hydrocarbon (PAH) components (AMAP 1998). Cold condensation and fallout from cold Arctic air masses is thought to be the most important input-pathway of these compounds to Arctic environments (Wania & Mackay 1993).

Since the early 1980s, indications for atmospheric long-range transport events of semi-volatile organic compounds (SOC) have been described for the Svalbard region (Oehme 1991; Oehme *et al.* 1996a, b). Elevated levels of PCBs and chlordane have been observed, but in later years the concentrations of airborne organochlorines have been relatively stable, indicating a continuous but low input of these chemicals to the atmosphere in the Arctic. However, every year several atmospheric long-range transport events are reported, showing that under favourable meteorological and temperature conditions, the atmospheric transport of large amounts of pollutants can take place within a few days from the central European source areas into the Arctic (AMAP 1998).

The local input of contaminants to the marine environment presumably originates from the mining industry, garbage dumps, or from sewage outlets. Seepage from garbage dumps can cause local contamination of land and marine sediments, depending on the type of waste deposited. Old and existing landfills represent potential point sources for both PCBs and PAHs (Skei 1993; Hansen *et al.* 1998), but there are no known point sources for HCB. There are reported some small amounts of PCBs in the ground around a landfill in Kongsfjorden, at the helicopter base in Grønfjorden, and at the fire training area in Adventfjorden (Sørlie *et al.* 1999a, b, c, d). In the past, transformers filled with PCB-containing oil were used, and it is likely that some of these transformers were dumped on landfills (Kovacs 1996). In marine sediments outside the harbour area in Kongsfjorden, moderate PCB levels have been found (Olsson *et al.* 1998).

Potential point sources of PAHs are the coal-fired power plants located in Longyearbyen, Barentsburg, Kapp Heer, and Pyramiden, combustion products from engines (such as large diesel generators) as well as oil spills. Elevated levels of PAHs were found in marine sediments near the Ny-Ålesund depot, and these were mainly attributed to oil contamination, most likely due to leakage from oil tanks or damaged pipes (Skei 1993).

Most of these contaminants are lipid soluble and become strongly bound to lipids in organisms. Arctic marine organisms generally contain large amounts of lipids, which represent seasonally stored energy (Falk-Petersen *et al.* 1990). The biotic transport of lipid-bound contaminants may be important on local scales and even on more regional scales for migratory animals (Ballschmiter 1992).

Town settlements in Svalbard

The town settlements in Svalbard were established during the first half of the 20-century when intensified coal mining started (Hisdal 1998). The coal production reached about 300 000 tonnes annually during the period of 1925-1929. The overwintering human population was then about 600 (Hisdal 1998). The production of coal has been variable during the last century with a peak in the mid-1980s when the total production from Russian and Norwegian mining reached about 1 million tonnes. The total production of coal was in 1998 about 500 000 tonnes.

The overwintering human population has varied with the coal production, although the Norwegian population has remained stable in spite of reduced coal production during later years. This is connected to an increase in other activities such as tourism, school and university activities, and scientific research. The Norwegian population was about 1300 (90 % in Longyearbyen) during the winter of 1998 (Hisdal 1998). The Russian activities and resident population have recently been declining. The schools and day-cares were closed in 1994 resulting in an exit of women and children from the societies. The Russian population counted about 800 in Barentsburg and 600 in Pyramiden during the winter of 1998 (Hisdal 1998). Pyramiden was closed in March 1998, and there is currently no mining activity in this town (Governor of Svalbard Office, pers. comm.).

Persistent organic pollutants

Persistent organic pollutants (POPs) are organic chemicals that degrade slowly in the environment. They include both industrial chemicals, such as polychlorinated biphenyls (PCBs), hexachlorobenzene (HCB), chlorinated pesticides (such as DDT, chlordanes, hexachloro-cyclohexanes [HCHs], aldrin/dieldrin, polychlorinated bornanes [toxaphene]) and industrial by-products such as polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), polybrominated biphenyls (PBBs) and polybrominated diphenyl ethers (PBDEs) (Muir *et al.* 1992). Most of these contaminants were developed and put into production more than 50 years ago. The highest production and use of most of these contaminants was during the late 1960s and early 1970s (AMAP 1998). However, the use of environmentally hazardous chemicals in the Svalbard industries or society is not listed in any overview. The production and use of most chlorinated compounds listed above were stopped in Europe and North America in the 1980s and 1990s. Some pesticides (such as DDT and toxaphene) are still being produced and used in Asia, Africa, South America and in some eastern European countries (AMAP 1998).

The presence of anthropogenic chlorinated contaminants in the Arctic, especially in the marine environment, has been documented in the literature since the 1970s (AMAP 1998). POPs were then reported in several Arctic species of marine mammals and seabirds, such as seals (Holden 1972), polar bears *Ursus maritimus* (Bowes & Jonkel 1975) and glaucous gulls *Larus hyperboreus* (Bogan & Bourne 1972; Bourne & Bogan 1972). The concern about levels of pollutants in the Arctic increased with the comprehensive surveys performed in the 1980s and 1990s (AMAP 1998). Organochlorines have also recently been measured in several marine organisms from the Svalbard area, but mostly in the upper trophic levels; seabirds, seals, and whales (Daelemans *et al.* 1993; Savinova *et al.* 1995; Andersen *et al.* 2001).

Since many of the organochlorines are highly lipophilic and persistent, they tend to bioaccumulate in lipid-rich tissues of organisms. Marine invertebrates and fishes tend to take up these pollutants directly from seawater or particles in seawater (bioconcentration), but they also get them from their food sources when OCs are transferred from prey to predator (biomagnification).

The term PAH generally includes all aromatic hydrocarbons that contain three or more benzene rings, but di-aromatic compounds are often also included (AMAP 1998). PAHs are generally formed during high-temperature burning of organic material, low to moderate temperature transformation of organic sediment to fossil fuels, and by direct biosynthesis by plants, bacteria, and fungi. PAHs enter the air mostly as releases from volcanoes, forest fires, and the burning of fossil fuels. It has low water solubility and is often attached to dust particles in air.

Biological effects from PAHs are dependent upon size and structure of the molecules. The 2-3-cyclic PAHs can cause acute toxicity for aquatic organisms. The 4-7-cyclic PAHs have no acute toxicity, but some are carcinogenic. Greater than 7-cyclic PAHs generally show neither acute toxicity nor carcinogenic activity (AMAP 1998). PAHs tend to bioaccumulate, but they generally do not biomagnify in food chains. Most vertebrates have some capacity to metabolise PAHs, and fish tend to have lower concentrations of PAHs than their invertebrate prey species. However, the metabolites are generally more dangerous than the mother compound, and they may have carcinogenic or mutagenic effects (AMAP 1998).

HCB has been used as a fungicide and is also a by-product from industrial processes. It is known to be persistent, carcinogenic, and acutely toxic to marine organisms. The concentration of HCB is lowest at the lowest trophic levels, and it increases up through the food chain, although to a lesser extent than PCBs.

PCBs are mixtures of chlorinated hydrocarbons that have been extensively used since 1930 for many industrial purposes such as dielectric fluids in transformers and large capacitors, heat exchange fluids, flame retardants, paint additives, and as compounds in carbonless copy paper and plastics (Fisher 1999). There are 209 possible PCB congeners, of which about 100 have been found in biological samples (McFarland & Clarke 1989). Sediments are known to be a sink for PCBs, which may be resuspended in the water column and transported to different areas by currents. PCBs are known to bioaccumulate and biomagnify strongly in marine food chains, and high concentrations have been found in top-predators such as the polar bear (e.g. Bernhoft *et al.* 1997). PCBs have been linked to impaired reproduction and immunosuppression.

Material and methods

Sampling area

Sampling was performed at different distances from known old dumping sites and sewage outlets. In each fjord, sampling locations were chosen at different distances from expected sources: near the source (50-100 m), intermediate (2-5 km), and remote from the source (10-100 km). The remote stations were at the mouth of Isfjorden (I1) and at the mouth of Kongsfjorden (K2) (Figs. 1, 2). These stations functioned as reference stations, and were assumed to have background levels of organic pollutants. Both these stations were hard-bottom locations, with sloping, terraced bedrocks covered with kelp. There were rocks and boulders, which served as hiding places for fish, and some areas of pebbles and softer sediments.

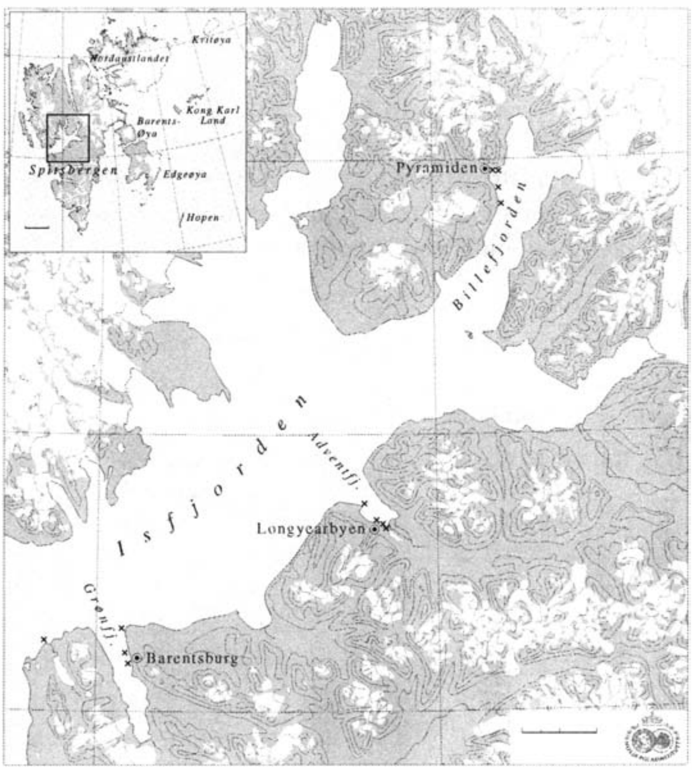


Figure 1. Sampling stations in Adventfjorden (A1-4), Billefjorden (B1-4), Grønfjorden (G1-3) and Isfjorden (I1) on Spitsbergen (Svalbard).

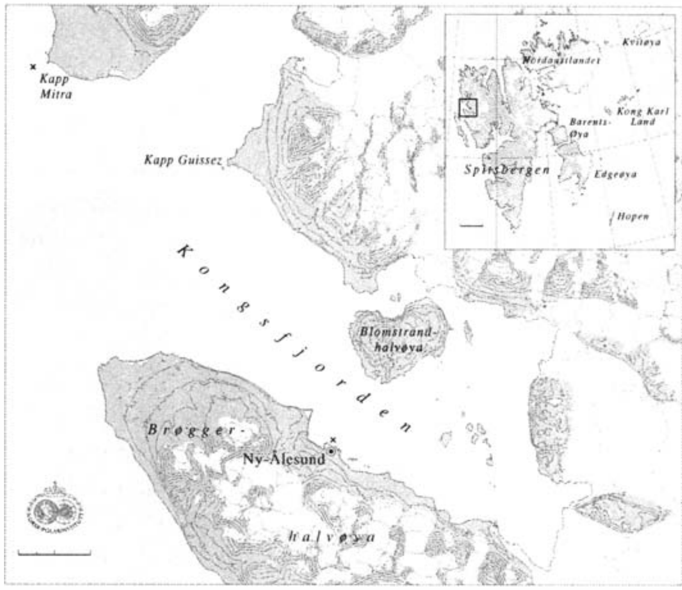


Figure 2. Sampling stations in Kongsfjorden (K1-2) on Spitsbergen (Svalbard).

In Adventfjorden (Fig. 1), a station was located near the old garbage dump in Longyearbyen (A2), near the existing sewage outlet (A4), near the new dock and the power plant (A1), and at some distance from the settlement near Adventpynten (A3). The bottom near the old garbage dump as well as near the existing sewage outlet consisted of soft sediments. The main sewer pipe was crossed, but organisms attached to the pipe itself were not collected. The area in the vicinity of the power plant also consisted of soft fine sediments, but the pipeline to the power plant functioned as a substrate for hard-bottom fauna, which was collected. The bottom near Adventpynten dropped steeply from the shore and there was a weak tidal current going into the bay. The bottom substrate was medium-fine sediments over pebbles and there were areas of kelp, although most seemed to be drifted and not attached to the substrate.

In Billefjorden (Fig. 1), one station was placed at the dock (B3), close to the power plant (B2), near the garbage dump of Pyramiden settlement (B1), and one station near the bay at Yggdrasil (B4). The dock in Pyramiden is built of logs, which functioned as a hard substrate for organisms. The main harbour between the power plant dock and the main dock was covered by soft sediments, and drifting kelp was present in depressions. The location near the garbage dump (about 300 m from it) was covered by very fine reddish-brown sediments, mainly because of riverine input of glacial sediments from Mimerelva. The station near the bay, below Yggdrasilkampen, consisted of a sloping bottom with terraces. There were some large depressions and ridges of bedrock, which supported some kelp and tunicates. The bottom substrate was generally soft or silty sediments over pebbles.

The stations in Grønfjorden were placed close to Barentsburg (Fig. 1). One station was located near the garbage dump (G2), one near the sewage outlet (G3), and one at some distance from Barentsburg near the abandoned helicopter base at Kapp Heer (G1). The fjord area in the vicinity of the garbage dump dropped gently and consisted of soft sediments, and some areas with drifted kelp. The sea bottom by the sewage outlet dropped steeply and consisted of coarser sediments, and some areas were covered by debris of decaying kelp. The sea bottom off Kapp Heer dropped steeply from about 10 m depth, and consisted of soft sediments with some isolated rocks (dropstones) that supported kelp, tunicates and barnacles.

In Kongsfjorden (Fig. 2), one station was placed close to the old dock (K1), whereas the second station was a reference station located near the mouth of the fjord near Kapp Mitra (K2). Most organisms were sampled from hard substrates (bedrock and rocks). By the old dock there was wooden debris on top of soft sediments, and the wooden dock itself also functioned as hard substrate for organisms.

Sampling

Scuba divers collected the animals from 10-20 m depth at each station by hand or with nets. The diving was performed in mid-September 1998 in Kongsfjorden and Grønfjorden and in mid-September 1999 in Adventfjorden, Billefjorden, and Grønfjorden. The organisms sampled included the following species (Norwegian common name): Shorthorn sculpin *Myoxocephalus scorpius* (ulke), Arctic shorthorn sculpin *Gymnacanthus tricuspis* (glattulke), great spider crab *Hyas araneus* (sandpyntekrabbe), the clam *Mya truncata* (butt sandskjell), the gastropods *Buccinum undatum* (kongesnegl) and *Buccinum glaciale* (uspesifisert snegl), and green sea urchin *Strongylocentrotus droebachiensis* (kråkebolle) (Table 1).

The divers' nets were placed directly into Coleman coolers until the animals were sorted, back on the support vessel. Each individual was wrapped in tin foil and organisms were frozen in food-quality plastic bags at -20 °C. They were not thawed until sample preparation, done at the Norwegian Polar Institute laboratory.

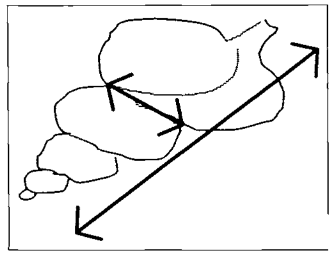


Figure 3. Size measurements taken on the snails *Buccinum undatum* and *B. glaciale.*

Preparation prior to analysis

Fish were weighed before livers were dissected for later analyses of organic pollutants. Skeletal muscle was sampled for determination of stable isotopes. Crabs were weighed and measured for carapace length. The digestive gland was used for analyses of organic pollutants and muscle from the claw for stable isotopes. Bivalves were weighed whole and without shell. The maximum dorsal length was measured in both longitudinal and transverse sections. Closing muscle and siphon were used for stable isotopes, whereas the remaining parts of the animal were used for organic pollutant analysis. Snails were length measured (Fig. 3) and weighed whole and without shell. The lower part of the foot was used for stable isotope analyses, whereas the reminder of the animal was used for analyses of organic pollutants. Sea urchins were weighed and measured, as diameter without spines. Gonads were used both for organic pollutant and stable isotope analyses.

Chemical analyses

PCBs and PAHs

Clean-up

About 1 to 40 g of sample was homogenised with sodium sulphate. An aliquot of the sample was used for determination of the fat content. The mixture was filled into a glass column and eluted with dichloromethane.

Table 1. Macro-benthos collected from sampling stations in fjords on Spitsbergen (Svalbard).

	Adventfjorden				Billefjorden				Grønfjorden			Isfj.	Kongsfj.		
Species	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**B3**	**B4**	**G1**	**G2**	**G3**	**I1**	**K1**	**K2**	**Species/ samples total**
Strongylocentrotus dro.				2			2					2			6
Mya truncata	2	1	3					1	3	2		3			15
Buccinum glaciale										3		3			6
Hyas araneus	3	3	3	3	2	3		3	3	3	3	3	3	3	38
Buccinum undatum	3	3	3	3	3			3	3		3	3	3	3	33
Gymnaranthus tricuspis	1					1				1		1			4
Myoxocephalus scorpius				1		1	2	1		2		3	2	1	13
Station total	9	7	9	9	5	5	4	8	9	11	6	18	8	7	115

The solvent was evaporated at 110 °C and the residue weighed in order to determine the fat content. The mixture was filled into a glass column and an intenal standard containing ^{13}C-labelled HCB and PCB and deuterated PAHs was added on top of the column. The lipophilic compounds were eluted by a slow flow of cyclohexane. Lipids were removed by gel permeation chromatography (GPC) on 50 g biobeads SX-3 with cyclohexane:ethylacetate (50:50 by volume). The PCB/PAH fraction was cleaned additionally on a column filled with potassium treated silica. Before quantification, a recovery standard (1,2,3,4-tetrachloro-naphthalene and deuterated biphenyl, fluoranthene and perylene) was added.

Quantification

The separation of the compounds was performed by high-resolution gas chromatography (HRGC) on a Hewlett-Packard HP6980 or HP5890 II with splitless injection of 1 ml aliquot of the sample extract and helium as carrier gas. A Hewlett-Packard HP5973 MSD low-resolution mass spectrometer (LRMS) was used for detection and quantification of the PAH compounds. A Micromass AutoSpec (formerly VG Analytical AutoSpec) high-resolution mass spectrometer (HRMS), with resolution > 10000, was used for detection and quantification of the PCB congeners.

The detection limit for each compound was very low and compound concentrations lower than the detection limits were treated as non-existent. This border for signal-to-noise level was set to 3:1.

Quality control

A rigorous quality control concept was adopted based on the recommendations of the Arctic Monitoring and Assessment Programme (AMAP) and on the requirements in the European quality norm EN 45001.

The quality of the methods used is verified regularly in international inter-calibrations between participating institutions. Particular attention was given to sample storage and transport including continuous freeze storage from sampling location to the laboratory. The use of isotopically labelled internal standards for quantification and the frequent control of complete method blank values insured a high quality of the analytical results. Blank values were not subtracted. The measurement uncertainties of the analytical methods are estimated to be ±15 to ± 20%.

The quality of the chemical analyses was found to be good according to the laboratory's accredited criteria. However, the recovery of the ^{13}C marked internal standard in 7 of the 115 PCB analyses and in 10 of the 115 PAH analyses indicated that the uncertainty of the results from analyses of these particular samples could be greater than ± 25%. The PAHs in these samples had a shift in retention time. In addition, the 9-methylphenanthrene dominated and could hide a small amount of 2-methylanthracene. Some noise from other non-PAH compounds was also detected. We decided to not exclude them from the results, because of already small sample sizes and large variation in contaminant concentrations.

Compounds analysed

The following compounds were determined in all samples: The PAH component naphthalene, 2-methylnaphthalene, 1-methylnaphthalene, biphenyl, acenaphthylene, acenaphthene, dibenzofuran, fluorene, dibenzothiophene, phenanthrene*, anthracene*, 3-methylphenanthrene, 2-methylphenanthrene, 2-methylanthracene, 9-methylphenanthrene, 1-methylphenanthrene, fluoranthene*, pyrene*, benzo[a]fluorene*, retene, benzo[b]fluorene*, benzo[ghi]fluoranthene, cyclopenta[cd]pyrene, benz[a]anthracene*, chrysene*/triphenylene*, benzo[b*/j/k*]fluoranthene, benzo[a]fluoranthene, benzo[e]pyrene*, benzo[a]pyrene*, perylene, indeno[1,2,3-cd]pyrene*, dibenzo[ac/ah*]anthracene, benzo[ghi]perylene*, anthanthrene, coronene, dibenz[a,e]pyrene*, dibenz[a,i]pyrene*, and dibenz[a,h]pyrene*.

* = EPA 16

In addition, hexachlorobenzene (HCB) and 28 PCB congeners were analysed. The PCB congeners had following International Union of Pure and Applied Chemistry (IUPAC) numbers: 18, 28, 31, 33, 37, 47, 52, 60, 66, 74, 99, 101, 105, 114, 118, 122, 123, 128, 138, 141, 149, 153, 156, 157, 167, 170, 180, 183, 187, 189, 194, 206, and 209 (Table 2).

Stable isotopes

The aim of the analysis of stable isotopes was to quantify the ratios (δ) of stable carbon ($^{13}C/^{12}C$) and stable nitrogen ($^{15}N/^{14}N$) in muscle, and - in sea urchin - gonads. About 1 g of tissue was prepared for analyses by cutting it into small pieces and drying it on filter paper before weighing. Then, the samples were dried for 24 hours at 70 °C and cooled in a desiccator. The dried samples were homogenised with mortar and pestle. Because individuals may vary in proportions of isotopically lighter lipids in samples (Sholto-Douglas *et al.* 1991), lipids were removed by Soxhlet extraction for two hours with dichloromethane (DCM) added with 7% of methanol. The samples were then dried at 80 ºC before they were rinsed with 2N HCl for 5 minutes in order to remove possible carbonates. All samples were thoroughly rinsed with distilled water and dried at 80 ºC before combustion in the elemental analyser.

For the determination of $\delta^{15}N$ and $\delta^{13}C$, a minimum of 1.0 mg sample material was weighed and put into small Sn-capsules. The samples were combusted with O_2 and Cr_2O_3 at about 1700 ºC in a Carlo Erba NCS Elemental Analyser. NO_x were reduced with Cu at 650 ºC. The combustion products N_2, CO_2 and H_2O were separated on a Poraplot Q column and the $^{15}N/^{14}N$ and $^{13}C/^{12}C$ isotopic ratios were determined on a Micromass Optima mass

Table 2. PCB congeners analysed in the present study.

Number	IUPAC-Nomenclature[a]
18	2,2',5-Trichlorobiphenyl
28	2,4,4'-Trichlorobiphenyl
31	2,4',5-Trichlorobiphenyl
33	2',3,4-Trichlorobiphenyl
37	3,4,4'-Trichlorobiphenyl
47	2,2',4,4'-Tetrachlorobiphenyl
52	2,2',5,5'-Tetrachlorobiphenyl
60	2,3,4,4'-Tetrachlorobiphenyl
66	2,3',4,4'-Tetrachlorobiphenyl
74	2,4,4',5-Tetrachlorobiphenyl
99	2,2',4,4',5-Pentachlorobiphenyl
101	2,2',4,5,5'-Pentachlorobiphenyl
105	2,3,3',4,4'-Pentachlorobiphenyl
114	2,3,4,4',5-Pentachlorobiphenyl
118	2,3',4,4',5-Pentachlorobiphenyl
122	2'3,3',4,5-Pentachlorobiphenyl
123	2',3,4,4',5-Pentachlorobiphenyl
128	2,2',3,3',4,4'-Hexachlorobiphenyl
138	2,2',3,4,4',5'-Hexachlorobiphenyl
141	2,2',3,4,5,5'-Hexachlorobiphenyl
149	2,2',3,4',5',6-Hexachlorobiphenyl
153	2,2',4,4',5,5'-Hexachlorobiphenyl
156	2,3,3',4,4',5-Hexachlorobiphenyl
157	2,3,3',4,4',5'-Hexachlorobiphenyl
167	2,3',4,4',5,5'-Hexachlorobiphenyl
170	2,2',3,3',4,4',5-Heptachlorobiphenyl
180	2,2',3,4,4',5,5'-Heptachlorobiphenyl
183	2,2',3,4,4',5',6-Heptachlorobiphenyl
187	2,2',3,4',5,5',6-Heptachlorobiphenyl
189	2,3,3',4,4',5,5'-Heptachlorobiphenyl
194	2,2',3,3',4,4',5,5'-Octachlorobiphenyl
206	2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl
209	2,2',3,3',4,4',5,5',6,6'-Decachlorobiphenyl

[a] According to Ballschmiter & Zell (1980).

spectrometer. The isotopic ratios were measured from a standard as defined by the following equation:
$\delta X = [(R_{sample}/R_{standard}) - 1] * 1000$.

Here, X is the ^{13}C or ^{15}N and R is the corresponding ratio $^{13}C/^{12}C$ or $^{15}N/^{14}N$. Atmospheric nitrogen (for $\delta^{15}N$) and Pee Dee Belemnite Limestone (for $\delta^{13}C$) were used as standards.

Trophic level (TL) has been described by the relationship $TL = 1 + [(Dm - 4.9) / 3.8]$ in the food web of Northeast Water Polynya (Hobson *et al.* 1995). Particulate organic matters were placed as TL = 1. The $\delta^{15}N$ value of the consumer's muscle tissue is D*m*, the $\delta^{15}N$-ratio (‰) for particulate organic matter was 4.9, and the fractionation factor between each trophic level was 3.8 (‰) (Hobson *et al.* 1995). The same trophic enrichment factor was used to calculate TL among the species in our survey.

Data treatments and statistics

Levels of contaminants were compared within and between fjords. The distribution of the PAHs, PCBs, and HCB was non-normal when testing $\log_{10}$ transformed data for each species. However, for the species with highest sample size the $\log_{10}$ transformed data appeared to be normally distributed. We therefore assume that the pooled data from all species are approximately normally distributed when $\log_{10}$ transformed and adjusted for trophic level differences. We therefore used non-parametrics statistics for each species and parametric statistics when analysing pooled data.

Due to the required 10 g of tissue for analysis of OCs, some organisms needed to be pooled prior to analysis. The total number of individual animals used was 183, whereas 115 samples are reported. Pooling of samples may have strengthened the conclusions with regard to differences between areas, since including more organisms in each sample would tend to make them more representative for each area. The sample sizes for each species from each fjord were small (Table 1), although two species (*B. undatum* and *H. araneus*) had sufficient sample sizes to be analysed statistically at the species level. To compare within and between fjords, all sample data were adjusted for trophic level (quantified by $\delta^{15}N$) and pooled before an ANCOVA model was used in the statistical analysis. To reduce the number of confounding factors we only analysed retene, HCB, and the sum (Σ) of PAHs and PCBs when comparing the stations within each fjord. Multiple comparisons were done with ANCOVA LSD post hoc test of the mean values (equivalent to the t-test).

Outliers were evaluated with regard to low sample sizes and high variance in this type of data. We had to exclude one extreme outlier from Grønfjorden. This sample was a *M. scorpius* with Σ 38 PAH concentration of 48 088 ng g^{-1} wet weight, compared to the mean of 60.9 ng g^{-1} wet weight for the remaining samples. The diver who sampled this fish could see in the water that the fish was not well; it appeared lethargic and had skin lesions and fin erosion.

Results

Persistent organic pollutants

The amount of PAHs varied from non-detectable to a maximum of 2320 ng g^{-1} wet weight for anthanthrene in one sample (Table 3). HCB was found in all samples with a maximum concentration of 3676 pg g^{-1} wet weight (Table 4). The PCB concentrations also varied, from non-detectable to a maximum of 12 921 pg g^{-1} wet weight of PCB 153 (Table 4).

The most abundant PAH was the methylphenanthrene group > pyrene > anthanthrene > benzofluorene group > retene (Table 3). The most abundant chlorinated compounds were PCB-153 > PCB-138 > PCB-118 > HCB > PCB-99 (Table 4). However, there was a large variation between samples and it was evident that the pollutants were not equally distributed between fjords and organisms. There were also large differences between

Table 3. PAH concentrations (ng g^{-1} wet weight) for samples of macro-benthos from fjords on Spitsbergen (Svalbard). The valid *n*-number vary since some of the samples had concentrations lower than the detection limit (signal:noise = 3:1).

Name	Valid *n*	Mean	Minimum	Maximum	SD
Naphthalene	114	3.09	0.12	21.43	3.16
2-Methylnaphthalene	114	2.65	0.19	21	3.1
1-Methylnaphthalene	114	1.81	0.11	9.1	1.62
Biphenyl	114	1.02	0.07	7.75	1.05
Acenaphthylene	114	0.23	0.02	1.29	0.23
Acenaphthene	114	0.29	0.02	2.54	0.34
Dibenzofuran	114	0.75	0.07	4.46	0.59
Fluorene	114	0.67	0.08	5.41	0.67
Dibenzothiophene	114	0.15	0.02	0.92	0.16
Phenanthrene*	114	2.19	0.18	15.73	2.19
Anthracene*	99	0.14	0.01	1.88	0.22
3-Methylphenanthrene	105	2.89	0.06	195.38	19.28
2-Methylphenanthrene	113	5.26	0.07	366.35	34.88
2-Methylanthracene	45	1.41	0.01	35.56	5.51
9-Methylphenanthrene	111	21.53	0.06	299.78	52.2
1-Methylphenanthrene	114	3.65	0.06	195.89	18.49
Fluoranthene*	113	1.42	0.03	63.49	6.14
Pyrene *	114	7.36	0.07	367.43	39.95
Benzo[a]fluorene*	113	1.90	0.01	138.83	13.47
Retene	113	4.57	0.04	116.8	13.77
Benzo[b]fluorene*	112	1.34	0.01	52.17	6.46
Benzo[ghi]fluoranthene	103	0.20	0.01	7.41	0.73
Cyclopenta[cd]pyrene	48	0.49	0.01	22	3.17
Benz[a]anthracene*	102	0.18	0.01	6.6	0.67
Chrysene*/Triphenylene*	109	0.99	0.08	22.2	3.01
Benzo[b*/j/k*]fluoranthene	108	0.35	0.03	3.13	0.45
Benzo[a]fluoranthene	59	0.09	0.01	0.7	0.11
Benzo[e]pyrene*	110	0.31	0.02	1.61	0.32
Benzo[a]pyrene*	87	0.12	0.01	1.46	0.18
Perylene	69	0.14	0.01	0.65	0.15
Indeno[1,2,3-cd]pyrene*	69	8.50	0.04	549.88	66.13
Dibenzo[ac/ah*]anthracene	53	0.17	0.02	3.01	0.41
Benzo[ghi]perylene*	97	0.78	0.07	13.27	1.42
Anthanthrene	106	27.71	0.02	2320	225.18
Coronene	70	0.24	0.01	2.71	0.39
Dibenz[a,e]pyrene*	77	0.58	0.01	9.67	1.4
Dibenz[a,i]pyrene*	5	0.48	0.01	1.04	0.42
Dibenz[a,h]pyrene*	7	0.11	0.01	0.27	0.09
Σ 16 US EPA PAH*	114	22.42	0.78	667.78	84.56
Σ bicyclic PAH	114	8.57	0.56	56.71	8.33
Σ 3-7 cyclic PAH	114	88.50	1.70	2902.52	317.85
Σ 38 PAH	114	97.07	2.27	2930.02	319.32

*Member of the 16 EPA group

PAH and PCB distribution. For example, *B. undatum* had higher concentration of Σ 38 PAH than *H. araneus*, but lower concentration of Σ 33 PCB (Tables 5, 6). For detailed listing of measurements, see Appendices 1 and 2.

Stable isotopes

All animals in this survey belonged to the lower trophic levels in the marine coastal food web. The clam is a filter feeder on phytoplankton. The sea urchin is a predator/grazer mainly on sessile macro-algae and the two species of snails are grazers and omnivores, which means that they also ingest animal remains. The crab and the two fishes are predators. The low trophic levels of the animals are further confirmed by the stable isotope analysis (Table 7). The seven species studied occupied trophic levels from 1.3 to 3.1 calculated based on the equation in Hobson *et al.* (1995). The sea urchin occupied the lowest trophic level and the shorthorn sculpin the highest (Table 7).

The stable nitrogen isotope ($\delta^{15}N$) was positively correlated ($p < 0.05$) to 15 of the 38 PAHs, Σ bicyclic PAH, Σ 3-7 cyclic PAH, and Σ 38 PAH. The strongest correlations were found for biphenyl and anthanthrene (Spearman's $r_s > 0.5$, $p < 0.01$). There were also positive

Table 4. HCB and PCB concentrations (pg g^{-1} wet weight) for samples of macro-benthos from fjords on Spitsbergen (Svalbard). The valid *n*-number vary since some of the samples had concentrations lower than the detection limit (signal:noise = 3:1).

Name	Valid *n*	Mean	Minimum	Maximum	SD
HCB	114	818	26	3676	863
PCB-18	113	17	2	182	20
PCB-28	114	39	2	266	43
PCB-31	114	33	2	177	35
PCB-33	114	10	1	99	11
PCB-37	110	5	1	32	5
Sum-TriCB	114	133	10	958	133
PCB-47	114	42	2	441	58
PCB-52	114	180	5	1815	275
PCB-60	114	24	1	301	37
PCB-66	114	134	3	1623	208
PCB-74	114	99	2	1368	161
Sum- TetraCB	114	836	22	8054	1216
PCB-99	114	562	6	6940	922
PCB-101	114	543	10	5618	885
PCB-105	114	361	3	4672	629
PCB-114	114	36	0	371	54
PCB-118	114	1110	10	11 536	1647
PCB-122	85	7	0	60	11
PCB-123	113	20	0	231	32
Sum- PentaCB	114	3762	40	34 716	5735
PCB-128	114	283	2	2714	415
PCB-138	114	1206	9	9405	1578
PCB-141	112	70	1	592	108
PCB-149	114	396	7	3370	602
PCB-153	114	1877	13	12 921	2331
PCB-156	114	130	1	1263	197
PCB-157	110	34	0	271	47
PCB-167	114	69	1	570	94
Sum- HexaCB	114	5164	42	34 123	6540
PCB-170	114	159	1	1445	211
PCB-180	114	450	2	5489	680
PCB-183	114	61	0	684	85
PCB-187	114	197	1	1808	271
PCB-189	93	10	1	95	12
Sum- HeptaCB	114	989	3	9380	1393
PCB-194	103	35	0	571	63
PCB-206	86	11	0	106	13
PCB-209	88	9	0	33	8
6 PC B (28,52, 101,138,153,180)	114	4295	42	28 210	5355
33 PCB	114	10 930	120	80 649	14 269

correlations ($p < 0.05$) to HCB, to 31 of the 33 PCB congeners and to Σ 33 PCB (Fig. 4). The strongest correlation was found to PCB-183 (Spearman's $r_s = 0.6$, and $p < 0.01$). However, $\delta^{15}N$ was not correlated with PCB-206 and PCB-209. These two congeners were found only in a few samples and then at very low concentrations.

Between fjords

The mean (n/ SD) levels of Σ 38 PAH for the fjords Isfjorden > Adventfjorden > Kongsfjorden were: 202.1 (18/ 398.1), 138.9 (26/ 569.7), 60.9 (21/ 84.3), 53.6 (34/ 72.3), 47.8 (15/ 45.3) ng g^{-1} wet weight, respectively. The ANCOVA post hoc test showed that Isfjorden had significantly more PAHs ($p < 0.02$) than the other fjords, which were not significantly different from each other. The same pattern in PAH concentrations between fjords was also found for *H. araneus* and *B. undatum*, although the differences between fjords were not significant at the species level.

The mean (n/ SD) levels of HCB for the fjords Kongsfjorden > Isfjorden > Billefjorden > Grønfjorden > Adventfjorden were: 1289 (15/ 988), 1153 (18/ 1240), 1061 (21/ 951), 661 (26/ 629), 404 (34/ 318) pg g^{-1}

Table 5. The overall PAH levels (ng g^{-1} wet weight) of the eight most abundant PAHs and Σ 38 PAH in *Buccinum undatum* and *Hyas araneus* from fjords on Spitsbergen (Svalbard).

	Buccium undatum			*Hyas araneus*		
PAH	***n***	**mean**	**SD**	***n***	**mean**	**SD**
Naphthalene	33	2.1	1.1	38	3.9	2.9
2-Methylphenanthrene	33	0.9	1.2	38	1.8	5.2
9-Methylphenanthrene	33	29.8	76.7	38	22.2	39.3
1-Methylphenanthrene	33	2.1	3.1	38	2.1	3.5
Pyrene *	33	0.7	0.8	38	6.4	32.9
Retene	32	5.4	12.6	38	5.2	18.8
Indeno[1.2.3-cd]pyrene*	19	29.6	126.0	30	0.6	0.4
Anthanthrene	31	91.9	414.1	38	0.9	1.0
Σ 38 PAH	33	158.3	507.4	38	58.9	71.4

*Member of the 16 EPA group

Table 6. The overall levels (pg g^{-1} wet weight) of HCB, the eight most abundant PCB congeners and Σ 33 PCB in *Buccinum undatum* and *Hyas araneus* from fjords on Spitsbergen (Svalbard).

	Buccium undatum			*Hyas araneus*		
Chlorinated compound	***n***	**mean**	**SD**	***n***	**mean**	**SD**
HCB	33	250	127	38	1406	839
PCB 99	33	283	401	38	684	742
PCB 101	33	239	453	38	994	1197
PCB 105	33	164	260	38	526	568
PCB 118	33	631	853	38	1559	1603
PCB 138	33	704	819	38	1662	1676
PCB 149	33	241	280	38	686	728
PCB 153	33	1039	1118	38	2677	2536
PCB 180	33	216	204	38	726	933
Σ 33 PCB	33	5718	6520	38	16 592	16 102

wet weight, respectively. The post hoc ANCOVA model showed that Kongsfjorden had significantly more HCB than Isfjorden and Adventfjorden. The other fjords were not significantly different from each other.

PCB congeners were highly intercorrelated. From a total of 528 possible correlations, 522 were statistically significant (Pearson's $r > 0.24$, $p < 0.05$). PCBs were therefore easier to handle than the PAHs since all congeners could be represented by Σ33PCB. The mean (n/SD) of Σ33PCB for the fjords Billefjorden > Grønfjorden > Kongsfjorden > Isfjorden > Adventfjorden were: 26 180 (21/ 18 243), 14 447 (26/ 16 006), 5760 (15/ 4557), 5284 (18/ 6973), 4093 (34/ 5665) pg g^{-1} wet weight, respectively. The most PCB-polluted fjord was Billefjorden, with significantly higher levels than the other fjords. Also, Grønfjorden and Kongsfjorden had significantly higher concentrations of PCBs than Adventfjorden and Isfjorden. The fjords could therefore be ranked as follows: Billefjorden > Grønfjorden and Kongsfjorden > Adventfjorden and Isfjorden. The results were similar for the species *H. araneus* and *B. undatum*, but Adventfjorden had significantly lower concentration of PCBs than the other fjords with regard to *H. araneus*.

The distribution of some of the PCB congeners differed between fjords. The apparently small differences in congener distribution between fjords were significant because of small variances (Appendix 4). Billefjorden and Grønfjorden were significantly different from Adventfjorden, Isfjorden, and Kongsfjorden with regard to PCB-118, 138, and 153 (Fig. 5). Thus, the most important differences were between fjords with Russian versus Norwegian settlement.

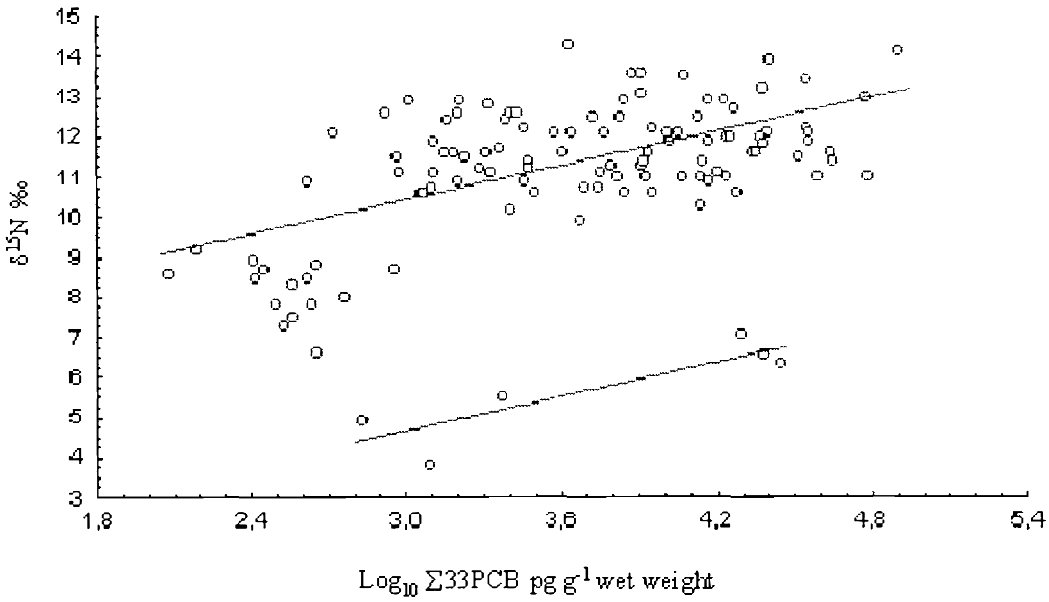


Figure 4. Relationships between Log_{10} Σ33 PCB (pg g^{-1} wet weight) and the stable isotope ($\delta^{15}N$). The upper regression line represents all species except the sea urchin (n = 108, Spearman's $r_s = 0.5$, $p < 0.01$), whereas the lower line represents the sea urchins (n = 6, Spearman's $r_s = 0.7$, $p = 0.1$).

Within fjords

Within fjord differences (revealed by ANCOVA post hoc test) were also found for the pollutants investigated in the benthic food web. These differences were based on combined samples, since species comparisons could not be performed due to low sample sizes. The macro-benthos in the vicinity of the power plant (A1) in Longyearbyen had significantly higher concentrations of Σ 38 PAH than the station near Adventpynten (A3) and the station by the sewage outlet (A4) ($p < 0.05$, n = 34). Furthermore, stations A1 and A4 had significantly higher concentration of Σ 33 PCB than station A3 ($p < 0.03$, n = 34).

The concentrations of PCBs were higher close to Pyramiden in inner Billefjorden than in outer Billefjorden. The station close to the power plant (B2) and the dock (B3) had higher concentrations of Σ 33 PCB than the outermost station (B4) ($p < 0.02$, n = 21). There were no differences between stations for Σ 38 PAH.

The concentrations of retene, Σ 38 PAH, HCB, and Σ 33 PCB were elevated close to Barentsburg in Grønfjorden ($p < 0.01$, n = 26). The station near the sewage outlet (G3) was the highest contaminated with respect to all four pollutants. The station near the garbage dump was more contaminated than the station at Kapp Heer (G1) with respect to PCBs and HCB ($p < 0.01$, n = 26), but less contaminated than the sewage outlet with respect to Σ 38 PAH.

Even though Kongsfjorden was the most HCB-polluted fjord, given the generally low levels of HCB, we were not able to detect any differences between the old dock and the mouth of Kongsfjorden. A similar result was found for Σ 38 PAH and Σ 33 PCB. Only retene (in PAHs) of the four statistically treated samples had higher concentration at the old dock station than at the mouth of Kongsfjorden station ($p = 0.04$, n = 15). Because the retene concentration differed between stations, whereas Σ 38 PAH did not, and because PAHs are not highly inter-correlated, we investigated the other PAH components further. There were higher concentrations for 12 of the 38 PAHs at the old dock station compared to the mouth of Kongsfjorden station (Table 8). In addition, the Σ 16 US EPA PAH (which includes 8 of the 12 PAHs) had significantly higher concentrations at the old dock station.

Table 7. Stable isotope ratios and trophic levels (TL), calculated from the relationship in Hobson *et al.* (1995), for macro-benthic organisms sampled from fjords on Spitsbergen (Svalbard).

Species	*n*	**mean $\delta^{13}C$ (SD)**	**mean $\delta^{15}N$ (SD)**	**Mean TL (SD)**
Strongylocentrotus droebachiensis	6	-19.3 (1.2)	5.9 (1.2)	1.3 (0.3)
Mya truncata	15	-19.1 (0.4)	8.2 (0.7)	1.9 (0.2)
Buccinum glaciale	6	-16.9 (0.5)	11.0 (0.3)	2.6 (0.1)
Hyas araneus	38	-18.1 (0.6)	11.4 (0.7)	2.7 (0.2)
Buccinum undatum	33	-17.3 (0.7)	11.9 (0.8)	2.8 (0.2)
Gymnacanthus tricuspis	4	-18.9 (1.1)	12.4 (0.9)	3.0 (0.2)
Myoxocephalus scorpius	12	-18.7 (0.7)	13.0 (1.0)	3.1 (0.3)

Table 8. Differences between the old dock (K1) the mouth of Kongsfjorden (K2) for PAH components. F-values and significance levels are calculated by ANCOVA test controlled for $\delta^{15}N$.

PAH	Df Error	F	*p*-level	$p < 0.05$
Naphthalene	12	0.40	0.54	
2-Methylnaphthalene	12	0.44	0.52	
1-Methylnaphthalene	12	0.64	0.44	
Biphenyl	12	2.38	0.15	
Acenaphthylene	12	0.06	0.80	
Acenaphthene	12	1.18	0.30	
Dibenzofuran	12	0.12	0.73	
Fluorene	12	0.00	0.96	
Dibenzothiophene	12	4.86	0.05	**
Phenanthrene*	12	7.81	0.02	**
Anthracene*	9	1.48	0.26	
3-Methylphenanthrene	9	5.51	0.04	**
2-Methylphenanthrene	12	1.81	0.20	
2-Methylanthracene	1	0.55	0.59	
9-Methylphenanthrene	12	0.65	0.44	
1-Methylphenanthrene	12	2.48	0.14	
Fluoranthene*	12	9.37	0.01	**
Pyrene *	12	11.70	0.01	**
Benzo[a]fluorene*	12	13.36	0.00	**
Retene	11	5.38	0.04	**
Benzo[b]fluorene*	11	5.38	0.04	**
Benzo[ghi]fluoranthene	10	5.85	0.04	**
Cyclopenta[cd]pyrene	4	0.09	0.78	
Benz[a]anthracene*	11	5.13	0.04	**
Chrysene*/Triphenylene*	12	1.14	0.31	
Benzo[b*/j/k*]fluoranthene	11	4.34	0.06	
Benzo[a]fluoranthene	6	0.89	0.38	
Benzo[e]pyrene*	12	8.68	0.01	**
Benzo[a]pyrene*	12	9.03	0.01	**
Perylene				*na*
Indeno[1.2.3-cd]pyrene*	7	0.43	0.53	
Dibenzo[ac/ah*]anthracene				*na*
Benzo[ghi]perylene*	10	0.22	0.65	
Anthanthrene	11	1.63	0.23	
Coronene	7	0.03	0.86	
Dibenz[a.e]pyrene*	12	2.81	0.12	
Dibenz[a.i]pyrene*				*na*
Dibenz[a.h]pyrene*				*na*
Σ 16 US EPA PAH*	12	11.43	0.01	**
Σ bicyclic PAH	12	0.74	0.41	
Σ 3-7 cyclic PAH	12	0.80	0.39	
Σ 38 PAH	12	0.42	0.53	

na lower than detection limit
* Member of the 16 EPA group.
** $p < 0.05$

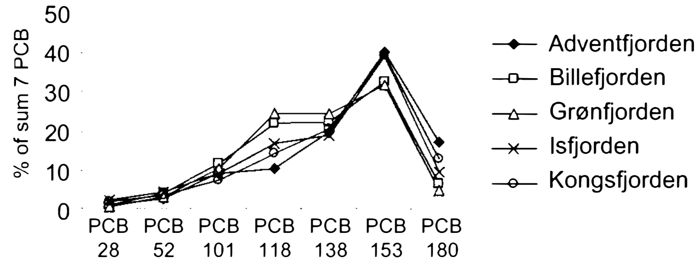


Figure 5. Mean distribution of 7 PCB congeners in five fjords on Spitsbergen (Svalbard).

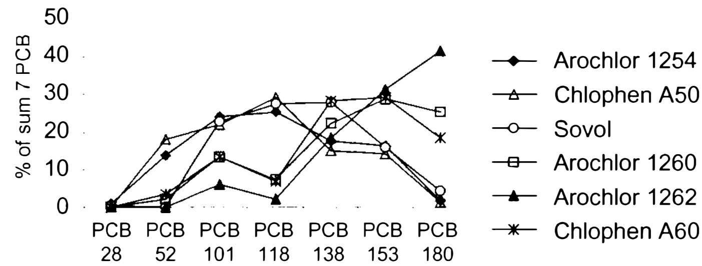


Figure 6. The distribution of 7 PCB congeners (those in Fig. 5) in technical mixture of PCB that may have been used in Svalbard.

Discussion

Organic pollutants in marine food chains

The concentrations of PAHs, HCB, and PCBs in the macro-benthos vary substantially in biological samples. Only few comparable studies involving these pollutants in macro-benthos were found (Tables 9, 10), and there were no studies of the same species and PAHs. Another bivalve, the blue mussel (*Mytilus edulis*), showed similar PAH concentrations as *M. truncata* in our study (Table 9). These blue mussel samples were collected from fjords in Norway where PAHs were elevated (Berge & Moy 2000).

The HCB concentration in macro-benthos from Svalbard fjords was not higher that what has been found in other Arctic areas. Comparing the fishes *G. tricuspis* and *M. scorpius* with the polar cod (*Boreogadus saida*) and Atlantic cod (*Gadus morhua*) from Bjørnøya revealed similar concentrations of HCB (Borgå 1997) (Table 9). The HCB concentration in *M. scorpius* from Greenland was on average 3 times higher than concentrations found in this study, and the concentration in livers of polar cod was even higher (Cleemann *et al.* 2000). The concentration of HCB in *H. araneus* from Bjørnøya was about 4.5 times higher than what was found in our study (Borgå 1997) (Table 9).

The PCB concentrations in macro-benthos from Svalbard fjords were considered as elevated, particularly when comparing with levels measured on Bjørnøya, which is known to have high background levels of PCBs (AMAP 1998) as well as high levels in seabirds (Savinova *et al.* 1995). The Σ 33 PCB concentration found in *H. araneus* was about 3.5 times higher in Svalbard than on Bjørnøya (Borgå 1997), and the fishes measured in this study also had much higher levels of PCBs than polar cod from

Bjørnøya (Table 10). However, higher levels have been measured elsewhere in the Arctic. Σ 6 PCB was about 2.5 times higher in *M. scorpius* from Greenland (for the same 6 PCB congeners; Table 10).

The stable isotope analysis confirmed that the selected animals belonged to the lower trophic levels. A trophic level less than 2.0 is not very likely for these species, since none of them are primary producers. The isotopic content of nitrogen in particulate organic matter (POM) in Svalbard fjords is not necessarily the same as in the Northeast Water Polynya of Greenland (Hobson *et al.* 1995). The constant assigning trophic level 1 may therefore be shifted, but the relative increase between animals up in the food chain should be similar since the same $\delta^{15}N$ trophic enrichment factor was applied (e.g., Hobson & Welch 1992; Hobson *et al.* 1995).

We conclude that all species surveyed in our study belong to the lower trophic levels and that the two fish species represent the top trophic level in this survey. The significant correlation between $\delta^{15}N$ and a majority of the organic pollutants implied that the mean concentration values could not be used without controlling for the trophic levels of the species measured. This was therefore done in all the ANCOVA tests.

Table 9. Mean PAH and HCB concentrations (ng g^{-1} wet weight) from this study and other comparable studies.

Species	Tissue	*n*	PAH (SD)	HCB (SD)	Reference
			Σ 38 PAH		
Strongylocentrotus droebachiensis	Gonad	6	21.32 (16.81)	0.06 (0.028)	This study
Mya truncata	Soft parts (except muscle)	15	134.87 (441.61)	0.196 (0.144)	This study
Buccinum glaciale	Upper soft parts	6	73.70 (121.64)	0.339 (0.318)	This study
Hyas araneus	Hepatopancreas	38	58.92 (71.37)	1.406 (0.839)	This study
Buccinum undatum	Upper soft parts	33	158.35 (507.44)	0.250 (0.127)	This study
Gymnacanthus tricuspis	Liver	4	79.46 (42.78)	1.392 (0.924)	This study
Myoxocephalus scorpius	Liver	12	57.59 (47.45)	1.725 (0.911)	This study
			Σ 24 PAH		
Myoxocephalus scorpius, Greenland	Liver	87		5.3 (2.9)	A
Boreogadus saida, Greenland	Liver	16		11 (1.4)	A
Mytilus edulis, Greenland	Soft tissue	44		0.07 (0.02)	A
Boreogadus saida, Bjørnøya	Whole organism	14		1.7	B
Gadus morhua, Bjørnøya	Whole organism	15		1.5	B
Hyas araneus, Bjørnøya	Hepatopancreas	15		6.5	B
Larus hyperboreus, Bjørnøya	Liver	15		24.5	B
Mytilus edulis, Larvik, Norway	Soft parts	pool	22.7 (5.5)[1]	0.06 (0.03)[1]	C
Mytilus edulis, Eidangerfjorden, N.	Soft parts	pool	198.6 (82.3)[2]	0.47 (0.04)[2]	D
			Σ PAH		
Mytilus edulis, Tromsø, Norway	Soft parts	?	58 (24)[3]	0.65 (052)[4]	E

[1] Mean from 5 stations in Larvik, Norway.
[2] Mean from 5 stations in Dalsbukta, Eidangerfjorden, Norway.
[3] Mean from 3 stations in Tromsøysund and Sandnessund in Tromsø, Norway
[4] Mean from 5 stations in Tromsøysund and Sandnessund in Tromsø, Norway

A: Cleemann *et al.* 2000
B: Borgå 1997
C: Berge 1999
D: Berge & Moy 2000
E: Holte *et al.* 1992

Environmental quality of the fjords

PAHs

PAHs in coal are strongly bound to the coal particles (Sørlie *et al.* 1999b), and it is therefore claimed that the PAHs from coal probably do not enter the biota (Luthy *et al.* 1997; Sørlie *et al.* 1999b). The Norwegian guide for classification of fjords has only the blue mussel in the reference list for PAHs (Molvær *et al.* 1997). If we - in spite of using different species - compare our mean results with this classification, then Isfjorden and Grønfjorden belong to Class II (of five), suggesting a moderately polluted environment. The reason for the higher levels in these fjords may be related to the location of the two coal-fired power plants near Grønfjorden, as well as extensive ship traffic in the outer part of Isfjorden. The other fjords belong to Class I, termed insignificantly polluted.

HCB

The HCB concentrations measured could not be readily compared with the values in the classification guide since none of the species were the same. Depending on the species or tissue we chose to compare with, the resulting

Table 10. Mean PCB concentrations (ng g^{-1} wet weight) from this study and other comparable studies.

Species	Tissue	*n*	PCB (SD)	PCB (SD)	Reference
			Σ 6 PCB	Σ 33 PCB	
Strongylocentrotus droebachiensis	Gonad	6	4.744 (4.989)	13.433 (13.416)	This study
Mya truncata	Soft parts (except muscle)	15	0.120 (0.055)	0.378 (0.188)	This study
Buccinum glaciale	Upper soft parts	6	2.586 (2.57)	5.689 (5.588)	This study
Hyas araneus	Hepatopancreas	38	6.388 (6.152)	16.592 (16.102)	This study
Buccinum undatum	Upper soft parts	33	2.292 (2.459)	5.718 (6.52)	This study
Gymnacanthus tricuspis	Liver	4	8.754 (4.526)	21.199 (11.4)	This study
Myoxocephalus scorpius	Liver	12	7.539 (7.647)	18.473 (22.39)	This study
			Σ PCB		
Amphipods (*Anonyx sarsi* and *Tmetonyx cicada*), Island	Fat	pool	1 600		A
Amphipods (*Anonyx sarsi* and *Tmetonyx cicada*), Island	Fat	pool	14 000		A
Boreogadus saida, Arctic Bay	Muscle	pool	1.9		B
Gadus morhua, Northern Finland	Whole	?	570		C
				Σ 29 PCB	
Boreogadus saida, Bjørnøya	Whole	14		2.9	D
Gadus morhua, Bjørnøya	Whole	15		2.5	D
Hyas araneus, Bjørnøya	Hepatopancreas	15		4.8	D
Larus hyperboreus, Bjørnøya	Liver	15		5295.7	D
			Σ 7 PCB	Σ 10 PCB	
Myoxocephalus scorpius, Greenland	Liver	87		25 (17)	E
Boreogadus saida, Greenland	Liver	16		37 (10)	E
Mytilus edulis, Greenland	Soft parts	44		0.95 (0.29)	E
Mytilus edulis, Larvik, Norway	Soft parts	pool	0.92 (0.28)[1]		F
Mytilus edulis, Eidangerfjorden, N.	Soft parts	pool	4.31 (0.86)[2]		G
Mytilus edulis, Tromsø, Norway	Soft parts	?	4.48 (1.1)[3]	0.65 (052)	H

[1] Mean from 5 stations in Larvik, Norway.
[2] Mean from 5 stations in Dalsbukta, Eidangerfjorden, Norway.
[3] Mean from 5 stations in Tromsøysund and Sandnessund in Tromsø, Norway

A: Bidleman *et al.* 1989
B: Muir *et al.* 1987
C: Paasivirta *et al.* 1991
D: Borgå 1997
E: Cleemann *et al.* 2000
F: Berge 1999
G: Berge & Moy 2000
H: Holte *et al.* 1992

classification ranged from I, insignificantly polluted, to class V, strongly polluted. However, if we assume that the most appropriate comparison was HCB in livers of benthic fishes (sculpins versus Atlantic cod), then all fjords in Svalbard belong to Class I, insignificantly polluted (Molvær *et al.* 1997). This is in agreement with our earlier conclusion that the HCB was not elevated in these fjords.

PCBs

As with HCB levels, the PCB concentrations could not be readily compared with the guide, because the species differed. If the benthic fish species used in the HCB comparison are also used with regard to PCBs, then all fjords were again classified to Class I, insignificantly polluted (Molvær *et al.* 1997). However, we question this classification because the PCB concentrations in these fjords were found to be higher than what has been measured on Bjørnøya (Borgå 1997). The classification scheme for fjords on mainland Norway may therefore not be directly applicable to fjords in the Arctic.

PCB profiles

The PCB congener profiles in our study were compared with known profiles of technical PCBs (Konieczny & Mouland 1997). We have complete information on seven PCB congeners in the technical mixture, and these could therefore be compared with the distribution we found in macro-benthos (Fig. 6). The lighter chlorinated samples from Grønfjorden and Billefjorden, with Russian settlements, could arise from Arochlor 1254, Chlophen A50, or the former Soviet Union produced Sovol. Adventfjorden and Kongsfjorden, which have Norwegian settlements, and to a lesser degree Isfjorden, could be influenced by heavier chlorinated mixtures such as Arochlor 1260, Arochlor 1262, or Chlophen A60. There is no reason why globally transported pollutants should give different congener structure in fjords closer than 150 km apart, especially not inside the Isfjord system where maximum distance between the fjord arms is 80 km. The congener profile of Isfjorden is intermediate to the profile measured outside Russian and Norwegian settlements (Fig. 5). The difference probably arises because of leakages from the Norwegian and Russian settlements. Local pollution, rather than long-range transport, therefore most likely cause the characteristic congener profiles.

Conclusions

PAH levels were quite variable both between and within fjords. The ranking based on Σ 38 PAH was: Isfjorden > Grønfjorden > Billefjorden > Adventfjorden > Kongsfjorden, but only the station at Isfjorden had a significantly higher level of PAHs. Applying the Norwegian guide for classification of fjords we suggest that Isfjorden and Grønfjorden are moderately polluted, whereas the other fjords are insignificantly polluted. The reason for the higher levels in these fjords may be related to the location of the two coal-fired power plants near Grønfjorden, as well as extensive ship traffic in the outer part of Isfjorden.

The mean level of HCB ranked the fjords as: Kongsfjorden > Isfjorden > Billefjorden > Grønfjorden > Adventfjorden. Kongsfjorden had significantly more HCB than Isfjorden and Adventfjorden, whereas the other fjords were not significantly different from each other. The HCB concentration in macro-benthos from the fjords was not higher than what has been found in other Arctic areas, and HCB levels in livers of fish were similar to those measured in fjords classified as insignificantly polluted. There are no indications that HCB has local sources, since the concentrations measured were close to background levels and no significant differences existed between stations in the most HCB polluted fjord.

PCB levels represented by Σ 33 PCB, ranked the fjords as: Billefjorden > Grønfjorden > Kongsfjorden > Isfjorden > Adventfjorden. The most PCB-polluted fjord was Billefjorden, with significantly higher concentrations in biota than the other fjords. Also, Grønfjorden and Kongsfjorden had significantly higher concentrations of PCBs than Adventfjorden and Isfjorden. If the benthic fish species used in the HCB comparison are also used with regard to PCBs, then all fjords can be classified as insignificantly polluted. However, we question this classification because the PCB concentrations were higher than what has been measured on Bjørnøya, which is known to have high background levels of PCBs.

Local input of both PAHs and PCBs seemed to be present for the Isfjord system and to a lesser degree for Kongsfjorden. The concentrations of PAHs and PCBs were higher close to the settlements in Adventfjorden, Billefjorden, Grønfjorden, and Kongsfjorden.

The distribution of some of the PCB congeners differed between fjords, in that Billefjorden and Grønfjorden were significantly different from Adventfjorden, Isfjorden, and Kongsfjorden. The most important differences were between fjords with Russian versus Norwegian settlements, and the characteristic congener profiles (i.e. lighter chlorinated vs. heavier chlorinated) probably arise because of local pollution from these settlements. Cleaning up of point sources will most likely be sufficient to stop the local input of these contaminants to the fjord system.

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Appendices

Appendix 1. PAH concentrations (ng g-1 wet weight) in samples from fjords on Spitsbergen (Svalbard): Adventfjorden (A), Billefjorden (B), Grønfjorden (G), and Kongsfjorden (K). The stations I1 (Isfjorden) and K2 (Kongsfjorden) are reference stations, with assumed background levels of organic pollutants. Concentrations are means (SD) for the following species (Norwegian common name): Shorthorn sculpin *Myoxocephalus scorpius* (ulke), Arctic shorthorn sculpin *Gymnacanthus tricuspis* (glattulke), great spider crab *Hyas araneus* (sandpyntekrabbe), the clam *Mya truncata* (butt sandskjell), the gastropods *Buccinum undatum* (kongesnegl) and *Buccinum glaciale* (uspesifisert snegl), and green sea urchin *Strongylocentrotus droebachiensis* (kråkebolle).

Station	**Species**	***n***	**Naphthalene**	**2-Methylene-naphthalene**	**1-Methylene-naphthalene**	**Biphenyl**	**Ace-naphthylene**	**Ace-naphthene**
A1	*B. undatum*	3	2.9 (1.3)	2.1 (0.4)	1.6 (0.4)	1.2 (0.3)	0.6 (0.5)	0.2 (0.1)
	H. araneus	3	2.6 (0.4)	2 (0.4)	1.7 (0.7)	1 (0.1)	0.4 (0.2)	0.2 (0)
	M. truncata	2	0.8 (0.1)	0.8 (0.1)	0.5 (0)	0.3 (0)	0.1 (0)	0.1 (0)
	G. tricuspis	1	7.9	6.3	4.6	1.7	0.6	0.4
A2	*B. undatum*	3	2.9 (0.2)	2.7 (0.6)	1.9 (0.4)	1 (0.1)	0.2 (0.1)	0.4 (0.1)
	H. araneus	3	5.7 (1.8)	4.4 (1)	2.3 (0.6)	1.7 (0.4)	0.4 (0.1)	0.5 (0.2)
	M. truncata	1	2.0	2.5	1.8	0.4	0.1	0.1
A3	*B. undatum*	3	2.1 (0.4)	2.4 (0.9)	1.8 (0.7)	0.7 (0.1)	0.2 (0.1)	0.2 (0.1)
	H. araneus	3	2.7 (1.2)	2.1 (1.2)	1.5 (0.9)	0.7 (0.2)	0.2 (0.1)	0.1 (0.1)
	M. truncata	3	1 (0.1)	1.1 (0.1)	0.7 (0.1)	0.4 (0.1)	0.1 (0)	0.1 (0)
A4	*B. undatum*	3	1.5 (0.3)	1.8 (0.3)	1.3 (0.4)	0.7 (0.1)	0.1 (0)	0.3 (0.1)
	H. araneus	3	2.8 (1.8)	2.5 (1)	1.6 (0.7)	0.8 (0.3)	0.2 (0.2)	0.3 (0.1)
	S. droebach.	2	1.8 (0.5)	1.6 (0.2)	1.8 (0)	0.6 (0.2)	0.1 (0)	0.1 (0)
	M. scorpius	1	3.0	2.8	1.6	1.0	0.2	0.3
B1	*B. undatum*	3	2.3 (0.7)	1.6 (0.4)	1.4 (0.6)	0.9 (0.3)	0.2 (0)	0.2 (0.1)
	H. araneus	2	3.4 (1.6)	1.8 (0.5)	1.1 (0.3)	1.1 (0.5)	0.4 (0.3)	0.5 (0.4)
B2	*H. araneus*	3	2.6 (0.7)	1.9 (0.6)	1.1 (0.3)	0.9 (0.1)	0.2 (0.1)	0.2 (0)
	G. tricuspis	1	6.8	0.2	3.1	1.9	0.4	1.0
	M. scorpius	1	2.5	2.2	1.3	0.9	0.3	0.2
B3	*S. droebach.*	2	1.6 (0.1)	1.7 (0.7)	1.4 (0.4)	0.4 (0)	0.1 (0)	0.1 (0)
	M. scorpius	1	5.0	4.9	2.8	2.6	0.4	0.4
B4	*B. undatum*	3	1.1 (0.2)	0.9 (0.1)	0.7 (0.2)	0.4 (0.1)	0.1 (0)	0.1 (0)
	H. araneus	3	3 (0.9)	1.9 (0.5)	1.4 (0.4)	0.9 (0.4)	0.1 (0.1)	0.3 (0.2)
	M. truncata	1	0.8	0.7	0.4	0.3	0.1	0.1
	M. scorpius	1	14.3	17.1	6.0	4.9	0.7	2.5
G1	*B. undatum*	3	1.1 (0.1)	1 (0.1)	0.8 (0.1)	0.5 (0.1)	0 (0)	0.1 (0)
	H. araneus	3	1.8 (0.7)	2.3 (1.9)	1.8 (1.6)	0.5 (0.2)	0.1 (0)	0.1 (0)
	M. truncata	3	0.2 (0)	0.2 (0)	0.2 (0)	0.1 (0)	0 (0)	0 (0)
G2	*H. araneus*	3	3.1 (0.8)	2.6 (0.8)	1.6 (0.4)	0.6 (0.1)	0.2 (0)	0.1 (0)
	M. truncata	2	0.8 (0.4)	1 (0.4)	0.8 (0.3)	0.3 (0.1)	0.1 (0)	0.1 (0)
	G. tricuspis	1	7.6	7.4	4.3	1.8	0.5	0.5
	B. glaciale	3	1.5 (0.2)	1.4 (0.2)	0.9 (0.1)	0.6 (0.1)	0.2 (0.1)	0.1 (0)
	M. scorpius	2	6.3 (6.2)	8.4 (8.4)	3.8 (3.5)	1.7 (1.2)	0.3 (0.1)	0.4 (0.3)
G3	*B. undatum*	3	3.4 (2)	6.2 (4.9)	4.6 (3.4)	1.4 (0.4)	0.2 (0)	0.3 (0)
	H. araneus	3	4 (1.6)	2.7 (0.6)	2 (0.3)	1.3 (0.6)	0.2 (0)	0.4 (0.1)
K1	*B. undatum*	3	2.8 (1.5)	2.7 (2.6)	2.4 (2.4)	0.8 (0.5)	0.1 (0)	0.5 (0.5)
	H. araneus	3	2.5 (2.5)	1.3 (1)	0.8 (0.6)	0.5 (0.4)	0.2 (0.1)	0.2 (0.1)
	M. scorpius	2	1.9 (0.3)	1.6 (0.1)	0.8 (0.1)	0.7 (0)	0.2 (0)	0.2 (0.1)
K2	*B. undatum*	3	1 (0.5)	0.7 (0.2)	0.5 (0.2)	0.4 (0.1)	0.1 (0)	0.1 (0)
	H. araneus	3	5 (1.7)	2.4 (1.1)	3.5 (2.5)	4.2 (3.5)	0.2 (0.1)	0.1 (0)
	M. scorpius	1	4.9	3.4	2.1	1.3	0.3	0.4
I1	*B. undatum*	3	2.4 (0.2)	1.9 (0.2)	1.7 (0.1)	0.9 (0.3)	0.3 (0.3)	0.2 (0)
	H. araneus	3	11.4 (4.3)	6.8 (2.9)	4.5 (1.3)	2 (0.8)	0.9 (0.4)	0.6 (0.2)
	S. droebach.	2	1.8 (0.3)	0.9 (0.1)	0.8 (0.1)	0.3 (0)	0.1 (0)	0.1 (0)
	M. truncata	3	1 (0.2)	0.7 (0.1)	0.4 (0.3)	0.3 (0.1)	0.1 (0)	0.1 (0.1)
	G. tricuspis	1	21.4	21.0	9.1	5.2	0.6	1.8
	B. glaciale	3	1.2 (0.1)	0.9 (0.1)	0.7 (0.2)	0.5 (0)	0.1 (0)	0.1 (0)
	M. scorpius	3	4.1 (3.5)	4.9 (1.5)	3.6 (1.2)	1.8 (0.2)	0.6 (0.1)	0.8 (0.5)

Appendix 1

Station	Species	*n*	Dibenzo-furan	Fluorene	Dibenzo-thiophene	Phenan-threne	Anthra-cene	3-Methylene-phenanthrene
A1	*B. undatum*	3	0.8 (0.2)	0.9 (0.2)	0.1 (0)	2.3 (0.4)	0.1 (0)	1 (1.1)
	H. araneus	3	1.1 (0.3)	0.9 (0.4)	0.1 (0)	2.5 (0.9)	0.1 (0.1)	0.6 (0.7)
	M. truncata	2	0.3 (0.1)	0.3 (0)	0.1 (0)	1.8 (0.5)	0 (0)	0.6 (0)
	G. tricuspis	1	1.3	1.4	0.2	2.2	0.2	0.3
A2	*B. undatum*	3	0.9 (0.2)	0.7 (0.1)	0.2 (0.1)	3.1 (1.5)	0.3 (0.2)	0.8 (0.9)
	H. araneus	3	1 (0.3)	0.8 (0.2)	0.1 (0.1)	1.9 (0.4)	0.1 (0)	0.3 (0.1)
	M. truncata	1	0.6	0.4	0.2	2.4	0.1	1.2
A3	*B. undatum*	3	0.7 (0.2)	0.6 (0)	0.1 (0)	1.8 (0.4)	0.1 (0)	0.3 (0.1)
	H. araneus	3	0.7 (0.3)	0.5 (0.2)	0.2 (0.1)	2.7 (2.1)	0.1 (0.1)	5.9 (9.5)
	M. truncata	3	0.5 (0.1)	0.5 (0.1)	0.1 (0)	1.8 (0.6)	0.1 (0.1)	0.4 (0.2)
A4	*B. undatum*	3	0.7 (0.1)	0.6 (0.2)	0.1 (0)	1.7 (0.7)	0.1 (0)	0.3 (0.2)
	H. araneus	3	0.8 (0.2)	0.6 (0.1)	0.1 (0)	1.4 (0.6)	0.1 (0.1)	0.3 (0.1)
	S. droebach.	2	0.9 (0.3)	0.3 (0.1)	0.1 (0)	1.4 (0.2)	0.1 (0)	0.3 (0.2)
	M. scorpius	1	0.7	0.7	0.1	1.3	0.1	0.1
B1	*B. undatum*	3	0.5 (0.1)	0.5 (0)	0.1 (0)	1.3 (0.4)	0.1 (0)	0.3 (0)
	H. araneus	2	1.4 (1.3)	0.6 (0.3)	0.1 (0)	2.3 (2.1)	0.1 (0.1)	0.2 (0.1)
B2	*H. araneus*	3	0.8 (0.2)	0.4 (0.1)	0.1 (0)	1.4 (0.3)	0 (0)	0.5 (0.6)
	G. tricuspis	1	1.4	1.2	0.3	4.4	0.1	13.3
	M. scorpius	1	0.5	0.5	0.1	1.1		0.1
B3	*S. droebach.*	2	0.5 (0.1)	0.3 (0)	0.1 (0)	1.3 (0.5)	0.1 (0.1)	0.3 (0.2)
	M. scorpius	1	0.8	0.7	0.2	2.1	0.0	12.4
B4	*B. undatum*	3	0.4 (0.1)	0.3 (0.1)	0 (0)	0.9 (0.2)	0.1 (0)	0.1 (0)
	H. araneus	3	0.8 (0.2)	0.9 (1)	0.3 (0.4)	2.4 (2.2)	0.1 (0)	0.2 (0.1)
	M. truncata	1	0.3	0.3	0.1	1.1	0.1	0.2
	M. scorpius	1	2.6	5.4	0.3	5.1	0.8	1.2
G1	*B. undatum*	3	0.3 (0.1)	0.4 (0)	0.1 (0)	1 (0.2)	0.1 (0)	0.3 (0.2)
	H. araneus	3	0.6 (0.5)	0.4 (0.3)	0.2 (0.2)	1.4 (0.9)	0 (0)	0.4 (0.4)
	M. truncata	3	0.1 (0)	0.1 (0)	0 (0)	0.2 (0)	0 (0)	0.1 (0)
G2	*H. araneus*	3	0.5 (0.2)	0.4 (0.1)	0.1 (0)	1.3 (0.3)	0.1 (0)	0.2 (0.1)
	M. truncata	2	0.4 (0.2)	0.4 (0.1)	0.2 (0.1)	2.2 (0.9)	0.1 (0)	0.4 (0.2)
	G. tricuspis	1	1.1	1.2	0.3	4.3		0.6
	B. glaciale	3	0.3 (0.1)	0.4 (0.1)	0.1 (0.1)	1.7 (0.8)	0.1 (0)	0.1 (0)
	M. scorpius	2	1.1 (0.9)	1.1 (0.9)	0.3 (0.3)	3.6 (3.9)	0 (0)	0.2 (0.2)
G3	*B. undatum*	3	1.1 (0.8)	1.1 (0.7)	0.5 (0.3)	3.5 (1.6)	0.2 (0)	0.6 (0.5)
	H. araneus	3	0.9 (0.2)	0.6 (0.1)	0.1 (0)	1.6 (0.3)	0.1 (0)	0.3 (0)
K1	*B. undatum*	3	1 (1.1)	0.9 (0.8)	0.3 (0.3)	4.5 (4.3)	0.7 (1)	1 (0.5)
	H. araneus	3	0.5 (0.1)	0.4 (0.1)	0.2 (0)	2.3 (0.8)	0.2 (0)	0.5 (0.6)
	M. scorpius	2	0.5 (0)	0.4 (0)	0.1 (0)	1.3 (0.1)	0.1 (0)	0.1 (0)
K2	*B. undatum*	3	0.3 (0.1)	0.2 (0)	0.1 (0)	0.8 (0.3)	0.2 (0.1)	0.2 (0.1)
	H. araneus	3	0.7 (0.4)	0.6 (0.2)	0.1 (0)	0.8 (0.1)	0 (0)	0.2 (0)
	M. scorpius	1	1.1	1.0	0.1	1.9	0.1	0.2
I1	*B. undatum*	3	0.4 (0.1)	0.5 (0.1)	0.1 (0)	1.5 (0.2)	0.1 (0)	0.3 (0)
	H. araneus	3	1.4 (0.4)	1.2 (0.4)	0.2 (0)	3.3 (0.9)	0.4 (0.1)	0.1 (0.1)
	S. droebach.	2	0.5 (0.1)	0.2 (0)	0 (0)	0.7 (0)	0.1 (0)	0.1 (0)
	M. truncata	3	0.4 (0.1)	0.3 (0.1)	0.3 (0.5)	5.9 (8.5)	0.1 (0)	65.3 (112.6)
	G. tricuspis	1	4.5	3.7	0.8	12.4	0.4	1.5
	B. glaciale	3	0.3 (0.1)	0.3 (0)	0.1 (0.1)	1.5 (1.1)	0.1 (0)	9 (15.4)
	M. scorpius	3	1.3 (0.5)	1.3 (0.7)	0.3 (0.2)	4.5 (3.2)	0.4 (0.3)	0.3 (0.3)

Appendix 1

Station	Species	*n*	2-Methylene-phenanthrene	2-Methylene-anthracene	9-Methylene-phenanthrene	1-Methylene-phenanthrene	Fluoran-thene	Pyrene
A1	*B. undatum*	3	2.2 (2.9)	0.2 (0)	108.4 (166.1)	3.1 (2.8)	0.6 (0.3)	0.6 (0.3)
	H. araneus	3	1.7 (1.4)	0 (0)	112.3 (101.1)	4.8 (4.4)	0.3 (0.1)	0.6 (0.3)
	M. truncata	2	0.9 (0.1)	0.1 (0)	1 (0.1)	0.9 (0.2)	0.6 (0.1)	0.4 (0.1)
	G. tricuspis	1	1.2		10.8	1.0	0.8	0.9
A2	*B. undatum*	3	1.4 (1.8)	0.2 (0.1)	0.9 (0.9)	0.9 (1)	0.6 (0.5)	0.8 (0.9)
	H. araneus	3	0.5 (0.2)	0 (0)	5.1 (3.4)	0.6 (0.3)	0.5 (0.1)	1 (0.6)
	M. truncata	1	1.2		2.0	1.0	0.7	0.9
A3	*B. undatum*	3	0.4 (0.2)	0.5 (0.8)	1.4 (1.6)	0.6 (0.3)	0.3 (0.1)	0.3 (0.1)
	H. araneus	3	11.1 (18)	0.8 (1)	6.7 (7.8)	5.8 (8.5)	1.9 (2.5)	4.7 (7.5)
	M. truncata	3	0.6 (0.1)	0 (0)	9.8 (4.3)	0.8 (0.2)	0.6 (0.2)	0.4 (0.2)
A4	*B. undatum*	3	0.4 (0.2)	0 (0)	0.3 (0.2)	0.6 (0.3)	0.3 (0.1)	0.4 (0.2)
	H. araneus	3	0.6 (0.2)	0 (0)	13.8 (16.6)	1 (0.6)	0.4 (0.1)	0.5 (0.2)
	S. droebach.	2	0.5 (0.2)	0 (0)	0.5 (0.4)	1.1 (0.4)	0.3 (0.1)	0.4 (0.2)
	M. scorpius	1	0.3		0.3	0.3	0.3	0.3
B1	*B. undatum*	3	0.4 (0)	0.4 (0)	18 (6.7)	3.6 (3.3)	0.4 (0.2)	0.6 (0.1)
	H. araneus	2	0.5 (0.3)	0 (0)	22 (19.7)	0.9 (0.5)	0.4 (0.2)	0.5 (0.2)
B2	*H. araneus*	3	1.1 (1)	0.1 (0)	4.3 (6.1)	0.9 (0.5)	0.5 (0.3)	1.2 (1.2)
	G. tricuspis	1	25.6		14.1	10.9	5.3	20.7
	M. scorpius	1	0.3		4.0	0.3	0.4	0.6
B3	*S. droebach.*	2	0.5 (0.2)	0.2 (0)	0.5 (0.2)	0.6 (0)	0.6 (0.4)	16 (9.3)
	M. scorpius	1	23.1	0.0	10.9	10.5	6.2	45.7
B4	*B. undatum*	3	0.1 (0)	0 (0)	0.1 (0)	0.2 (0)	0.2 (0)	0.3 (0.1)
	H. araneus	3	2.9 (4.4)	0 (0)	2.7 (4.2)	2 (2.7)	0.4 (0.1)	68.1 (117)
	M. truncata	1	0.4		0.3	0.3	0.5	0.8
	M. scorpius	1	2.5		12.4	2.1	1.5	2.1
G1	*B. undatum*	3	0.2 (0.1)	0.1 (0)	0.1 (0)	0.3 (0.1)	0.2 (0.1)	0.2 (0)
	H. araneus	3	0.6 (0.5)	0.8 (0.4)	0.5 (0.5)	0.9 (0.9)	0.3 (0.1)	0.3 (0.1)
	M. truncata	3	0.1 (0)	0 (0)	0.1 (0)	0.1 (0)	0.1 (0)	0.1 (0)
G2	*H. araneus*	3	0.2 (0.1)	0 (0)	3.4 (5.5)	0.4 (0.3)	0.3 (0.2)	0.3 (0.2)
	M. truncata	2	0.6 (0.3)	0.1 (0)	0.5 (0.3)	0.6 (0.4)	0.8 (0.4)	0.5 (0.2)
	G. tricuspis	1	0.7	1.5	0.4	0.3	1.3	1.6
	B. glaciale	3	0.2 (0.1)	0 (0)	0.1 (0)	0.2 (0)	0.4 (0.2)	0.3 (0.1)
	M. scorpius	2	0.8 (0.9)	4.8 (6.5)	0 (0)	0.4 (0.3)	1 (0.9)	1 (0.7)
G3	*B. undatum*	3	1.2 (0.9)	0 (0)	0.9 (0.9)	1.5 (1.4)	0.6 (0.5)	0.7 (0.2)
	H. araneus	3	0.9 (0.4)	0 (0)	32.7 (23.7)	1.6 (1)	0.7 (0.1)	1 (0.3)
K1	*B. undatum*	3	1.7 (0.7)	0.3 (0.4)	1.4 (0.9)	3 (3.5)	2.5 (2.5)	2.7 (1.4)
	H. araneus	3	1.2 (0.8)	0 (0)	20.2 (29.7)	5.4 (7.9)	1 (0.5)	1.2 (0.6)
	M. scorpius	2	0.4 (0.1)	0 (0)	3.1 (4.3)	0.4 (0.1)	0.4 (0)	0.4 (0.1)
K2	*B. undatum*	3	0.3 (0.1)	0 (0)	0.7 (0.9)	0.2 (0.1)	0.3 (0.2)	0.3 (0.1)
	H. araneus	3	0.8 (0.4)	0 (0)	25.7 (14.2)	1 (0.1)	0.3 (0.1)	0.3 (0.1)
	M. scorpius	1	1.5		36.8	1.2	0.7	0.9
I1	*B. undatum*	3	2 (0.9)	0 (0)	195.4 (75.9)	9.6 (1.9)	0.3 (0.1)	0.9 (0.2)
	H. araneus	3	1 (0.4)	0 (0)	39.3 (10.5)	1.5 (0.8)	1.1 (0.3)	1.1 (0.3)
	S. droebach.	2	0.2 (0)	0 (0)	0.1 (0)	0.2 (0.1)	0.3 (0)	0.3 (0)
	M. truncata	3	122.6(211.1)	0 (0)	99.4 (102.9)	66 (112.5)	21.6(36.2)	122.8(211.9)
	G. tricuspis	1	2.7	0.2	1.5	1.7	2.3	2.5
	B. glaciale	3	17.6 (30.1)	4.1 (5.2)	17.2 (14.8)	7.7 (10.9)	5.4 (8.8)	27.8(47.3)
	M. scorpius	3	1.7 (0.4)	35.6 (0)	39 (2.3)	1.2 (0.3)	1.8 (1.4)	1.4 (0.5)

Appendix 1

Station	Species	*n*	Benzo[a] fluorine	Retene	Benzo[b] fluorene	Benzo [ghi] fluoran-thene	Cyclo penta[cd] pyrene	Benz[a]an -thracene
A1	*B. undatum*	3	0.2 (0.1)	1.5 (1.8)	0.2 (0.2)	0.3 (0.2)	0 (0)	0.1 (0.1)
	H. araneus	3	0.1 (0.1)	3.2 (3)	0.1 (0.1)	0 (0)	0 (0)	0.1 (0.1)
	M. truncata	2	0.2 (0)	1.9 (0.8)	0.1 (0)	0.1 (0)	0 (0)	0.1 (0)
	G. tricuspis	1	0.1	0.4	0.1	0.2		0.1
A2	*B. undatum*	3	0.2 (0.1)	1.7 (1.9)	0.3 (0.1)	0.2 (0.2)	0 (0)	0.2 (0)
	H. araneus	3	0.1 (0.1)	1.4 (0.7)	0.2 (0.2)	0.3 (0.2)	0.1 (0)	0.2 (0.1)
	M. truncata	1	0.5	0.9	0.3	0.2	0.0	0.2
A3	*B. undatum*	3	0.2 (0.1)	2.2 (2.1)	0.6 (0.2)	0.2 (0)	0 (0)	0.1 (0)
	H. araneus	3	0.6 (0.8)	2 (0.9)	0.6 (0.6)	0.1 (0)	0 (0)	0.2 (0.1)
	M. truncata	3	0.1 (0)	3.8 (1.2)	0.1 (0)	0.1 (0)	0 (0)	0 (0)
A4	*B. undatum*	3	0.2 (0.1)	3.1 (2.7)	0.1 (0)	0.1 (0.1)	0 (0)	0.1 (0)
	H. araneus	3	0.2 (0.1)	0.9 (0.7)	0.2 (0.1)	0.1 (0)	0 (0)	0.1 (0)
	S. droebach.	2	0.2 (0.1)	1.7 (0.2)	0.1 (0)	0.1 (0)	0 (0)	0.1 (0)
	M. scorpius	1	0.0	0.1	0.0	0.1	0.4	0.0
B1	*B. undatum*	3	0.1 (0.1)	5.4 (3.7)	0.1 (0)	0.2 (0.2)	0 (0)	0.1 (0)
	H. araneus	2	0.4 (0.5)	0.7 (0.8)	0.1 (0.1)	0.1 (0)	0 (0)	0.2 (0.2)
B2	*H. araneus*	3	0.2 (0.3)	0.3 (0.1)	0.2 (0.3)	0.1 (0)	0 (0)	0.1 (0)
	G. tricuspis	1	3.1	1.0	3.5			0.1
	M. scorpius	1	0.2	0.1	0.0	0.0		
B3	*S. droebach.*	2	0.3 (0.3)	8.8 (5)	0.1 (0.2)	0.1 (0)	0 (0)	0.2 (0.2)
	M. scorpius	1	19.8	6.4	19.1	0.2	0.0	0.2
B4	*B. undatum*	3	0 (0)	2.5 (0.6)	0.1 (0)	0.2 (0)	0 (0)	0 (0)
	H. araneus	3	0 (0)	39.2 (67.2)	5.5 (9.5)	0.2 (0.2)	0 (0)	0.1 (0.2)
	M. truncata	1	0.2	0.1	0.2	0.1	0.0	0.0
	M. scorpius	1	0.1	1.9		0.2		0.2
G1	*B. undatum*	3	0.2 (0)	4 (2.9)	0.7 (0.1)	0.1 (0)	0 (0)	0 (0)
	H. araneus	3	0.3 (0.4)	1.3 (1.2)	0.2 (0.1)	0 (0)	0 (0)	0 (0.1)
	M. truncata	3	0 (0)	0.7 (0.5)	0 (0)	0.1 (0.1)	0 (0)	0 (0)
G2	*H. araneus*	3	0.1 (0.1)	4.6 (7.1)	0.1 (0.1)	0.1 (0)	0 (0)	0.1 (0)
	M. truncata	2	0.2 (0.2)	3.2 (1.8)	0.1 (0.1)	0.2 (0.1)	0 (0)	0.1 (0)
	G. tricuspis	1	0.2	0.3	0.7			
	B. glaciale	3	0 (0)	0.7 (1)	0.1 (0)	0.1 (0)	0 (0)	0.1 (0.1)
	M. scorpius	2	0.1 (0.1)	0.2 (0.1)	0.2 (0.2)	0.1 (0.1)	0.1 (0)	0.1 (0)
G3	*B. undatum*	3	0.9 (0.7)	5.1 (0.8)	0.4 (0.3)	0.4 (0)	0 (0)	0.2 (0.1)
	H. araneus	3	0.3 (0.1)	3 (0.4)	0.4 (0.2)	0.1 (0)	0 (0)	0.2 (0)
K1	*B. undatum*	3	0.7 (0.5)	37.7 (48)	0.5 (0.5)	0.2 (0.2)	0 (0)	0.7 (1.1)
	H. araneus	3	0.2 (0.1)	6.3 (7.3)	0.2 (0.1)	0.2 (0)	0 (0)	0.2 (0)
	M. scorpius	2	0.1 (0)	0.4 (0.4)	0.1 (0)	0 (0)	0 (0)	0 (0)
K2	*B. undatum*	3	0 (0)	0.5 (0.7)	0 (0)	0 (0)	0 (0)	0 (0)
	H. araneus	3	0 (0)	0.7 (0.4)	0 (0)	0 (0)	0 (0)	0 (0)
	M. scorpius	1	0.1	0.1	0.1	0.1	0.0	0.1
I1	*B. undatum*	3	0.1 (0.1)	6.8 (9.9)	0.1 (0)	0.1 (0)	0 (0)	0.1 (0)
	H. araneus	3	0.1 (0)	2.6 (0.9)	0.1 (0)	0.1 (0)	0 (0)	0.1 (0.1)
	S. droebach.	2	0.1 (0)	0.2 (0.2)	0 (0)	0 (0)	0 (0)	0 (0)
	M. truncata	3	46.4 (80)	20.4 (29.8)	17.4 (30.1)	2.6 (4.2)	7.4 (12.7)	2.4 (3.7)
	G. tricuspis	1	0.2	1.2	0.2	0.2	0.1	0.1
	B. glaciale	3	10.8 (18.5)	7.3 (6.7)	12.8 (22)	0.2 (0.2)	0 (0)	0.2 (0.2)
	M. scorpius	3	0.1 (0)	0.2 (0.1)	0.1 (0)	0.1 (0)	0 (0)	0.1 (0)
								0.2

Appendix 1

Station	Species	*n*	Chrysene*/-Triphenylene	Benzo[b*/j/k*]-fluoranthene	Benzo[a]-fluoranthene	Benzo[e]-pyrene	Benzo[a]-pyrene	Perylene
A1	*B. undatum*	3	7.9 (12.4)	0.4 (0.2)	0.1 (0)	0.7 (0.7)	0.1 (0.1)	0.2 (0.3)
	H. araneus	3	1 (1)	0.3 (0.3)	0 (0)	0.3 (0.3)	0.1 (0)	0.1 (0.1)
	M. truncata	2	0.8 (0.1)	0.3 (0)	0 (0)	0.9 (0.1)	0 (0)	0 (0)
	G. tricuspis	1	0.4	0.3	0.1	0.2	0.1	0.2
A2	*B. undatum*	3	0.8 (0.4)	0.6 (0.6)	0.1 (0)	0.5 (0.5)	0 (0)	0.4 (0)
	H. araneus	3	0.6 (0.4)	1.4 (0.3)	0.2 (0.1)	0.9 (0.6)	0.3 (0.1)	0.4 (0.2)
	M. truncata	1	0.9	0.4	0.0	1.3	0.1	0.1
A3	*B. undatum*	3	0.5 (0.1)	0.2 (0.1)	0 (0)	0.2 (0.1)	0.1 (0)	0 (0)
	H. araneus	3	0.6 (0.6)	1 (0.5)	0.1 (0)	0.4 (0.5)	0.2 (0)	0.1 (0)
	M. truncata	3	0.6 (0.2)	0.3 (0)	0 (0)	0.4 (0.2)	0 (0)	0.1 (0)
A4	*B. undatum*	3	0.5 (0.2)	0.2 (0.2)	0 (0)	0.3 (0.2)	0.1 (0)	0.1 (0)
	H. araneus	3	0.4 (0.2)	0.4 (0.1)	0.1 (0)	0.3 (0.1)	0.2 (0.1)	0.1 (0.1)
	S. droebach.	2	0.6 (0.4)	0.4 (0.1)	0.1 (0)	0.4 (0.2)	0.1 (0.1)	0.2 (0)
	M. scorpius	1	0.1	0.2	0.1	0.2	0.1	0.2
B1	*B. undatum*	3	1.7 (1.3)	0.3 (0.1)	0 (0)	0.3 (0.1)	0 (0)	0 (0)
	H. araneus	2	1 (1.1)	1.3 (1.5)	0.1 (0.1)	0.4 (0.2)	0.2 (0)	0.4 (0)
B2	*H. araneus*	3	0.3 (0)	0.3 (0.1)	0.1 (0)	0.3 (0.1)	0.1 (0)	0.2 (0)
	G. tricuspis	1	0.2	0.2		0.2		0.2
	M. scorpius	1	0.1	0.1		0.0		
B3	*S. droebach.*	2	0.5 (0.2)	0.4 (0.5)	0.1 (0)	0.5 (0.3)	0.3 (0.2)	0.1 (0)
	M. scorpius	1	0.6	0.1	0.1	0.2	0.0	0.0
B4	*B. undatum*	3	0.3 (0)	0.1 (0)	0 (0)	0.1 (0)	0 (0)	0 (0)
	H. araneus	3	0.4 (0.2)	0.2 (0.1)	0.1 (0)	0.1 (0.1)	0.1 (0)	0.1 (0)
	M. truncata	1	0.4	0.1		0.2		
	M. scorpius	1	0.6	0.4	0.2	0.4		0.5
G1	*B. undatum*	3	0.3 (0.2)	0.2 (0)	0.1 (0)	0.1 (0.1)	0 (0)	0 (0)
	H. araneus	3	0.5 (0.4)	0.2 (0.2)	0 (0)	0.2 (0.3)	0.1 (0.1)	0 (0)
	M. truncata	3	0.1 (0)	0.1 (0)	0 (0)	0.1 (0)	0 (0)	0 (0)
G2	*H. araneus*	3	0.4 (0.4)	0.4 (0.3)	0 (0)	0.3 (0.3)	0.1 (0)	0.1 (0.1)
	M. truncata	2	0.5 (0.4)	0.3 (0.2)	0 (0)	0.7 (0.3)	0 (0)	0 (0)
	G. tricuspis	1	0.1	0.1		0.1		
	B. glaciale	3	0.2 (0.1)	0.2 (0)	0 (0)	0.1 (0)	0 (0)	0.1 (0)
	M. scorpius	2	0.3 (0.2)	0.7 (0.6)	0 (0)	0.7 (0.7)	0.1 (0)	0.4 (0.4)
G3	*B. undatum*	3	1 (0.7)	0.7 (0.6)	0.4 (0.5)	0.5 (0.3)	0.1 (0)	0.1 (0)
	H. araneus	3	0.6 (0.2)	0.4 (0.1)	0.1 (0)	0.3 (0.1)	0.2 (0.1)	0.2 (0.1)
K1	*B. undatum*	3	0.9 (1.1)	1.2 (1.7)	0.2 (0.2)	0.6 (0.7)	0.6 (0.8)	0.2 (0.2)
	H. araneus	3	0.6 (0.5)	0.5 (0)	0.1 (0)	0.3 (0.1)	0.2 (0.1)	0.2 (0.2)
	M. scorpius	2	0.1 (0)	0.2 (0.1)	0 (0)	0.2 (0)	0.1 (0)	0.1 (0)
K2	*B. undatum*	3	0.3 (0.3)	0.1 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	H. araneus	3	0.4 (0.2)	0.1 (0.1)	0.1 (0)	0.1 (0.1)	0 (0)	0 (0)
	M. scorpius	1	0.2	0.2	0.1	0.2	0.1	
I1	*B. undatum*	3	7.6 (0)	0.1 (0)	0 (0)	0.1 (0)	0 (0)	0 (0)
	H. araneus	3	0.8 (0.4)	0.3 (0.2)	0 (0)	0.1 (0.1)	0.1 (0)	0 (0)
	S. droebach.	2	0.2 (0.1)	0.1 (0)	0 (0)	0.1 (0)	0 (0)	0 (0)
	M. truncata	3	7.7 (12.3)	0.2 (0.1)	0 (0)	0.2 (0.1)	0.1 (0.1)	0 (0)
	G. tricuspis	1	0.4	0.3	0.2	0.4		
	B. glaciale	3	0.8 (0.7)	0.1 (0)	0 (0.1)	0 (0)	0 (0)	0 (0)
	M. scorpius	3	0.3 (0.1)	0.1 (0)	0.1 (0)	0.1 (0.1)	0.1 (0)	0.1 (0)

Appendix 1

Station	Species	*n*	Indeno-[1,2,3-cd]pyrene	Dibenzo-[ac/ah*]-anthracene	Benzo[ghi]-perylene	Anthan threne	Coronene	Dibenz[a,e]-pyrene
A1	*B. undatum*	3	0.3 (0.2)	0.2 (0.1)	0.8 (0.4)	11.2 (9.7)	0.1 (0)	0.1 (0)
	H. araneus	3	0.8 (0.8)	0.1 (0.1)	0.4 (0.4)	0.5 (0.3)	0.1 (0.1)	0.2 (0.1)
	M. truncata	2	0.2 (0)	0 (0)	0.7 (0)	0.1 (0)	0.1 (0)	0.1 (0)
	G. tricuspis	1		0.1	0.5	0.8	0.1	0.3
A2	*B. undatum*	3	0 (0)	0 (0)	1.5 (0)	28 (5.6)	0.5 (0)	0 (0)
	H. araneus	3	1.2 (0.3)	0.5 (0)	2.7 (0.3)	1.7 (0.9)	1.4 (0.1)	0 (0)
	M. truncata	1	1.7		0.8			
A3	*B. undatum*	3	1.5 (0)	0 (0)	0.4 (0)	9.6 (1.5)	0 (0)	0 (0)
	H. araneus	3	0.1 (0)	0.1 (0)	0.4 (0.3)	0.4 (0.2)	0.1 (0)	0.1 (0)
	M. truncata	3	0.1 (0.1)	0 (0)	0.5 (0.1)	0.1 (0)	0.1 (0)	0.1 (0)
A4	*B. undatum*	3	0.3 (0.2)	0 (0)	0.2 (0.1)	12.8 (8.3)	0.1 (0)	0.2 (0.1)
	H. araneus	3	0.4 (0.2)	0.1 (0)	0.8 (0.3)	0.6 (0.2)	0.3 (0.2)	0.2 (0)
	S. droebach.	2	0 (0)	0.1 (0)	0.5 (0)	0.2 (0)	0.1 (0)	0.1 (0)
	M. scorpius	1			0.3	2.4		
B1	*B. undatum*	3	0.6 (0.1)	0.1 (0)	0.5 (0.1)	11.2 (8.9)	0 (0)	0 (0)
	H. araneus	2	0.9 (0.2)	0 (0)	1.6 (1.1)	1.4 (0.8)	0.5 (0.2)	0 (0)
B2	*H. araneus*	3	0.4 (0.2)	0.2 (0.1)	0.8 (0.2)	0.6 (0.1)	0.3 (0.1)	0.2 (0)
	G. tricuspis	1			0.7	1.2		0.4
	M. scorpius	1			0.2	1.6	0.2	0.3
B3	*S. droebach.*	2	0.2 (0)	0.1 (0)	0.4 (0.3)	0.1 (0)	0.1 (0)	0.6 (0.2)
	M. scorpius	1	0.0	0.0	0.5	2.9	0.0	0.0
B4	*B. undatum*	3	0.5 (0.3)	0.1 (0)	0.3 (0)	8.2 (4.2)	0 (0)	0.1 (0.1)
	H. araneus	3	0.2 (0)	0.1 (0)	0.4 (0.1)	1 (1.4)	0.2 (0)	0.1 (0.1)
	M. truncata	1	0.3	0.0	0.4	0.0	0.1	0.1
	M. scorpius	1			1.5	1.4	0.5	0.8
G1	*B. undatum*	3	1.6 (0)	0 (0)	0 (0)	8.4 (3)	0 (0)	0 (0)
	H. araneus	3	0.2 (0)	0.1 (0)	0.3 (0.2)	0.7 (0.3)	0.1 (0)	0.2 (0)
	M. truncata	3	0.1 (0)	0 (0)	0.1 (0)	0.2 (0.2)	0 (0)	0 (0)
G2	*H. araneus*	3	0.4 (0)	0.1 (0.1)	0.9 (0.5)	0.3 (0)	0 (0)	0.5 (0.3)
	M. truncata	2	0.7 (0.4)	0 (0)	0.4 (0.1)	0 (0)	0 (0)	0.2 (0.3)
	G. tricuspis	1			0.5	1.0		1.4
	B. glaciale	3	0.5 (0.2)	0 (0)	0.4 (0.2)	10.4 (6.2)	0.1 (0)	0.3 (0.1)
	M. scorpius	2	0 (0)	0 (0)	1.3 (1.4)	1.4 (0)	0 (0)	0.3 (0)
G3	*B. undatum*	3	275.1(388.6)	0 (0)	0 (0)	785.3(1 329.1)	0.1 (0)	0.1 (0)
	H. araneus	3	0.6 (0.4)	0.1 (0)	1 (0.2)	1.7 (0.1)	0.4 (0.1)	0 (0)
K1	*B. undatum*	3	0.8 (0.5)	0.1 (0)	0.1 (0.1)	26.7 (13.1)	0.1 (0)	0.5 (0.2)
	H. araneus	3	0.8 (0.3)	0.1 (0)	0.7 (0.3)	2.2 (2.6)	0.3 (0.1)	3.6 (2.8)
	M. scorpius	2	0 (0)	0.1 (0)	0.3 (0)	1.3 (0.4)	0.2 (0)	2.6 (1.4)
K2	*B. undatum*	3	0.1 (0)	0 (0)	0.2 (0)	9 (1.1)	0.1 (0)	0.3 (0.1)
	H. araneus	3	0.7 (0.2)	0 (0)	0.5 (0.2)	0.3 (0)	0.2 (0.1)	0.6 (0.4)
	M. scorpius	1			0.7	0.8	0.2	0.8
I1	*B. undatum*	3	0.6 (0)	1.6 (2)	4.8 (7.3)	64 (79.2)	2.7 (0)	0 (0)
	H. araneus	3	0.4 (0.1)	0 (0)	0.7 (0.1)	0.6 (0.2)	0.3 (0)	0.4 (0.3)
	S. droebach.	2	0 (0)	0 (0)	0.2 (0)	0 (0)	0.1 (0)	0.3 (0)
	M. truncata	3	0.4 (0.2)	0 (0)	0.4 (0.1)	0.1 (0)	0.1 (0)	0.1 (0.1)
	G. tricuspis	1			3.1	0.7	0.5	9.7
	B. glaciale	3	0 (0)	0 (0)	0.2 (0.1)	0.5 (0.2)	0.1 (0)	0.1 (0)
	M. scorpius	3	0.1 (0)	0 (0)	0.4 (0.2)	0.6 (0.4)	0.2 (0.2)	0.2 (0.1)

Appendix 1

Station	Species	*n*	Dibenz-[a,i]-pyrene	Dibenz-[a,h]-pyrene	Σ 16 US EPA PAH	Σ bi-cyclic PAH	S 3-7 cyclic PAH	Σ 38 PAH
A1	*B. undatum*	3	0 (0)	0 (0)	14.4 (14.6)	7.8 (1.9)	145.3 (188)	153.1(187.6)
	H. araneus	3	0 (0)	0 (0)	6.7 (3.5)	7.4 (1.5)	132.8(113.5)	140.1(114.8)
	M. truncata	2	0(0)	0 (0)	6.2 (0.6)	2.3 (0.1)	12.8 (0.1)	15.1 (0.2)
	G. tricuspis	1			6.3	20.5	25.2	45.7
A2	*B. undatum*	3	0 (0)	0 (0)	7.5 (5.4)	8.5 (1.2)	44.3 (16.4)	52.8 (17.5)
	H. araneus	3	0 (0)	0 (0)	11.6 (3.1)	14.1 (3.6)	26 (4.9)	40.1 (6.5)
	M. truncata	1			10.2	6.7	18.2	24.9
A3	*B. undatum*	3	0 (0)	0 (0)	5.4 (0.8)	7.1 (2)	22.4 (0.4)	29.5 (2.4)
	H. araneus	3	0 (0)	0 (0)	12.9 (13.7)	6.9 (3.3)	47.2 (57.3)	54.2 (54.5)
	M. truncata	3	0.1 (0)	0 (0)	5.2 (1.5)	3.1 (0.4)	22.4 (7.2)	25.5 (7.6)
A4	*B. undatum*	3	0 (0)	0.1 (0)	4.4 (1.9)	5.2 (0.7)	23.9 (9.4)	29.2 (9.9)
	H. araneus	3	0 (0)	0 (0)	5.5 (1.3)	7.7 (3.7)	25 (18.7)	32.7 (22.4)
	S. droebach.	2	0 (0)	0 (0)	4.8 (1.5)	5.7 (0.5)	10.9 (2.5)	16.5 (2)
	M. scorpius	1			3.0	8.4	9.2	17.6
B1	*B. undatum*	3	0 (0)	0 (0)	5.6 (0.5)	6.2 (2)	46.3 (1.7)	52.5 (2.5)
	H. araneus	2	0 (0)	0 (0)	9.4 (7.7)	7.5 (3)	38.9 (33)	46.3 (35.9)
B2	*H. araneus*	3	0.8 (0.3)	0.2 (0.1)	7.1 (2.8)	6.5 (1.8)	16.9 (5.8)	23.4 (4.4)
	G. tricuspis	1			39.1	11.9	109.8	121.7
	M. scorpius	1			3.0	6.9	11.2	18.1
B3	*S. droebach.*	2	0 (0)	0.1 (0)	21.7(12.6)	5.1 (1.1)	34.1(18.3)	39.2(19.4)
	M. scorpius	1	0.0	0.0	94.5	15.3	163.6	178.9
B4	*B. undatum*	3	0 (0)	0 (0)	2.9 (0.2)	3.2 (0.5)	15.3 (3.7)	18.5 (3.2)
	H. araneus	3	0 (0)	0 (0)	77.8 (128.3)	7.1 (2.1)	128.5(209.9)	135.6(211.5)
	M. truncata	1			4.4	2.1	6.8	8.9
	M. scorpius	1			13.5	42.2	47.9	90.1
G1	*B. undatum*	3	0 (0)	0 (0)	3.5 (1.6)	3.4 (0.3)	18.1 (4.6)	21.5 (4.4)
	H. araneus	3	0 (0)	0 (0)	4.2 (2.9)	6.5 (4.4)	10.9 (7.4)	17.4 (11.8)
	M. truncata	3	0 (0)	0 (0)	1 (0.2)	0.7 (0.1)	2.6 (1)	3.3 (1.1)
G2	*H. araneus*	3	0 (0)	0 (0)	4.8 (2.6)	8 (1.9)	15.3 (15.9)	23.2 (17)
	M. truncata	2	0 (0)	0 (0)	6.9 (3.7)	2.8 (1.2)	13.6 (7.3)	16.4 (8.4)
	G. tricuspis	1			10.2	21.0	18.6	39.6
	B. glaciale	3	0 (0)	0 (0)	4.3 (1.6)	4.4 (0.5)	17.3 (7.4)	21.7 (7.4)
	M. scorpius	2	0 (0)	0 (0)	9 (8.5)	20.1 (19.3)	19.8 (18.4)	40 (37.7)
G3	*B. undatum*	3	0 (0)	0 (0)	191.2 (322.4)	15.6 (10.7)	989.4(1 656.8)	1 005(1 667.1)
	H. araneus	3	0 (0)	0 (0)	7.5 (0.5)	10 (3)	50.4 (24.6)	60.4 (26.8)
K1	*B. undatum*	3	0 (0)	0 (0)	17 (16)	8.7 (6.9)	79.4 (74.3)	88.2 (81.1)
	H. araneus	3	0 (0)	0 (0)	11.9 (4.5)	5.2 (4.4)	49.7 (40.5)	54.9 (44.9)
	M. scorpius	2	0 (0)	0 (0)	5.9 (1.2)	5 (0.5)	13.2 (3.6)	18.3 (4.1)
K2	*B. undatum*	3	0 (0)	0 (0)	2.3 (1)	2.6 (1.1)	11.1 (6.6)	13.7 (6)
	H. araneus	3	0 (0)	0 (0)	4 (1)	15 (8.3)	34.4 (15.3)	49.4 (22.6)
	M. scorpius	1			5.9	11.8	49.8	61.6
I1	*B. undatum*	3	0 (0)	0 (0)	12 (7.8)	7 (0.3)	271 (148.1)	277.9 (148)
	H. araneus	3	0 (0)	0 (0)	9 (2.6)	24.7 (9.3)	59.1 (15.8)	83.8 (23.3)
	S. droebach.	2	0 (0)	0 (0)	2.4 (0)	3.8 (0.5)	4.4 (0.2)	8.2 (0.7)
	M. truncata	3	0 (0)	0 (0)	225.6 (382.9)	2.4 (0.6)	610.8 (967.8)	613.2 (967.3)
	G. tricuspis	1			32.2	56.7	54.1	110.8
	B. glaciale	3	0 (0)	0 (0)	59.3 (98.6)	3.3 (0.4)	122.4 (169.5)	125.7 (169.8)
	M. scorpius	3	0 (0)	0 (0)	9.3 (5.8)	14.4 (1.9)	55.1 (11.3)	69.5 (10.9)

Appendix 2. HCB and PCB concentrations (wet weight pg g^{-1}) in samples from fjords on Spitsbergen (Svalbard): Respective fjords and species are listed in Appendix 1.

Station	Species	n	HCB	PCB 18	PCB 28	PCB 31	PCB 33
A1	*B. undatum*	3	219 (169)	24 (10)	26 (15)	19 (10)	10 (6)
	H. araneus	3	720 (112)	14 (3)	27 (6)	30 (5)	9 (2)
	M. truncata	2	170 (55)	10 (1)	9 (3)	8 (1)	6 (2)
	G. tricuspis	1	890	35	48	28	19
A2	*B. undatum*	3	126 (28)	18 (4)	17 (8)	12 (7)	8 (5)
	H. araneus	3	910 (240)	13 (5)	21 (6)	25 (7)	9 (2)
	M. truncata	1	51	6	7	6	4
A3	*B. undatum*	3	104 (31)	6 (1)	7 (1)	6 (1)	4 (1)
	H. araneus	3	674 (116)	10 (2)	23 (6)	25 (4)	8 (2)
	M. truncata	3	252 (158)	14 (6)	16 (7)	15 (7)	10 (5)
A4	*B. undatum*	3	238 (62)	13 (3)	14 (6)	6 (1)	4 (0)
	H. araneus	3	678 (120)	17 (17)	24 (10)	31 (19)	11 (10)
	S. droebach.	2	48 (31)	14 (10)	22 (14)	21 (14)	6 (4)
	M. scorpius	1	581	10	17	8	4
B1	*B. undatum*	3	202 (71)	11 (5)	19 (9)	9 (4)	4 (2)
	H. araneus	2	1 662 (1 012)	16 (8)	39 (19)	65 (27)	11 (6)
B2	*H. araneus*	3	1 984 (429)	20 (6)	58 (10)	99 (4)	14 (3)
	G. tricuspis	1	769	33	59	42	25
	M. scorpius	1	782	8	35	16	5
B3	*S. droebach.*	2	46 (20)	11 (5)	33 (7)	36 (12)	9 (5)
	M. scorpius	1	2 331	43	194	88	22
B4	*B. undatum*	3	227 (72)	11 (4)	24 (5)	8 (3)	3 (1)
	H. araneus	3	1 964 (916)	37 (31)	46 (9)	80 (10)	16 (7)
	M. truncata	1	191	12	10	10	7
	M. scorpius	1	1 667	73	139	65	59
G1	*B. undatum*	3	156 (35)	8 (3)	10 (4)	6 (2)	4 (1)
	H. araneus	3	514 (350)	6 (1)	31 (23)	31 (21)	5 (1)
	M. truncata	3	37 (12)	3 (0)	3 (1)	2 (1)	2 (0)
G2	*H. araneus*	3	1 011 (424)	12 (5)	73 (71)	81 (63)	9 (4)
	M. truncata	2	423 (153)	8 (6)	11 (8)	9 (7)	6 (4)
	G. tricuspis	1	1 151	40	60	39	23
	B. glaciale	3	357 (207)	9 (6)	17 (6)	7 (5)	4 (3)
	M. scorpius	2	1 461 (980)	28 (18)	96 (27)	33 (22)	15 (14)
G3	*B. undatum*	3	329 (7)	8 (1)	19 (3)	10 (2)	6 (1)
	H. araneus	3	1 686 (485)	23 (3)	77 (39)	99 (36)	16 (2)
K1	*B. undatum*	3	366 (161)	12 (2)	15 (3)	11 (3)	9 (2)
	H. araneus	3	1 768 (864)	14 (4)	64 (35)	64 (26)	12 (1)
	M. scorpius	2	1 202 (142)	20 (6)	80 (8)	29 (4)	11 (3)
K2	*B. undatum*	3	417 (108)	14 (7)	30 (8)	9 (5)	7 (6)
	H. araneus	3	1 905 (326)	14 (6)	47 (5)	76 (8)	8 (3)
	M. scorpius	1	3 570	31	196	55	25
I1	*B. undatum*	3	370 (83)	9 (2)	16 (2)	8 (2)	5 (1)
	H. araneus	3	2 893 (928)	26 (17)	66 (18)	82 (40)	24 (9)
	S. droebach.	2	85 (23)	24 (8)	29 (5)	24 (3)	8 (3)
	M. truncata	3	214 (8)	10 (1)	13 (3)	14 (3)	8 (2)
	G. tricuspis	1	2758	182	266	177	99
	B. glaciale	3	321 (62)	12 (3)	22 (4)	9 (1)	5 (1)
	M. scorpius	3	2 146 (691)	22 (9)	116 (15)	39 (5)	16 (3)

Appendix 2

Station	Species	*n*	PCB 37	∑-Tri-PCB	PCB 47	PCB 52	PCB 60	PCB 66
A1	*B. undatum*	3	7 (8)	108 (74)	20 (10)	68 (39)	8 (5)	44 (24)
	H. araneus	3	5 (1)	93 (12)	23 (6)	53 (17)	10 (3)	68 (31)
	M. truncata	2	2 (1)	41 (5)	5 (0)	16 (3)	1 (0)	7 (2)
	G. tricuspis	1	5	140	55	141	19	91
A2	*B. undatum*	3	3 (2)	78 (36)	11 (5)	29 (12)	2 (2)	11 (6)
	H. araneus	3	4 (1)	100 (27)	23 (5)	83 (17)	10 (1)	60 (7)
	M. truncata	1	2	33	5	10	1	5
A3	*B. undatum*	3	2 (1)	33 (5)	4 (2)	8 (2)	2 (1)	5 (2)
	H. araneus	3	4 (1)	89 (20)	18 (2)	44 (5)	7 (3)	41 (15)
	M. truncata	3	3 (2)	79 (41)	9 (3)	31 (16)	3 (1)	12 (3)
A4	*B. undatum*	3	1 (0)	48 (16)	22 (16)	82 (55)	8 (10)	39 (42)
	H. araneus	3	5 (4)	84 (24)	18 (8)	51 (27)	8 (4)	52 (26)
	S. droebach.	2	2 (1)	79 (45)	16 (8)	63 (25)	4 (2)	25 (11)
	M. scorpius	1	1	52	21	41	4	23
B1	*B. undatum*	3	3 (3)	75 (33)	49 (29)	279 (89)	30 (8)	192 (105)
	H. araneus	2	8 (5)	212 (106)	63 (39)	446 (232)	40 (12)	363 (221)
B2	*H. araneus*	3	10 (0)	220 (102)	121 (39)	897 (327)	71 (10)	534 (223)
	G. tricuspis	1	9	122	100	518	46	339
	M. scorpius	1	2	92	94	165	44	272
B3	*S. droebach.*	2	7 (3)	162 (64)	79 (26)	468 (215)	57 (17)	408 (162)
	M. scorpius	1	52	531	441	1 815	301	1 623
B4	*B. undatum*	3	3 (1)	71 (21)	37 (25)	146 (83)	24 (6)	152 (89)
	H. araneus	3	8 (0)	254 (41)	50 (27)	269 (29)	27 (8)	221 (57)
	M. truncata	1	3	54	7	23	2	10
	M. scorpius	1	13	257	122	226	46	193
G1	*B. undatum*	3	2 (1)	37 (9)	6 (4)	36 (37)	5 (3)	18 (20)
	H. araneus	3	5 (3)	104 (67)	31 (29)	125 (103)	21 (22)	149 (157)
	M. truncata	3	1 (0)	13 (2)	3 (1)	7 (2)	1 (0)	3 (1)
G2	*H. araneus*	3	11 (12)	277 (234)	59 (47)	494 (500)	54 (54)	292 (265)
	M. truncata	2	4 (3)	48 (35)	8 (5)	21 (11)	3 (2)	12 (8)
	G. tricuspis	1	7	225	75	294	37	205
	B. glaciale	3	2 (2)	52 (26)	12 (4)	47 (14)	4 (1)	22 (2)
	M. scorpius	2	5 (5)	251 (116)	167 (48)	546 (78)	116 (5)	436 (56)
G3	*B. undatum*	3	5 (1)	60 (23)	10 (2)	80 (25)	22 (4)	33 (4)
	H. araneus	3	17 (7)	326 (108)	77 (14)	677 (168)	67 (34)	422 (91)
K1	*B. undatum*	3	4 (1)	67 (20)	10 (5)	21 (2)	5 (2)	11 (2)
	H. araneus	3	11 (4)	221 (85)	47 (43)	130 (47)	34 (34)	160 (131)
	M. scorpius	2	3 (0)	130 (106)	94 (13)	154 (45)	56 (15)	168 (1)
K2	*B. undatum*	3	4 (3)	80 (37)	13 (4)	48 (22)	4 (2)	19 (7)
	H. araneus	3	9 (2)	194 (15)	40 (17)	156 (72)	25 (6)	137 (39)
	M. scorpius	1	6	386	88	135	22	135
I1	*B. undatum*	3	2 (0)	43 (10)	8 (2)	30 (5)	3 (1)	14 (4)
	H. araneus	3	12 (9)	276 (110)	64 (16)	316 (58)	35 (6)	199 (18)
	S. droebach.	2	3 (0)	108 (23)	17 (5)	53 (12)	4 (1)	23 (5)
	M. truncata	3	3 (0)	51 (23)	9 (3)	24 (3)	3 (1)	12 (3)
	G. tricuspis	1	32	958	276	566	93	359
	B. glaciale	3	2 (1)	58 (14)	10 (3)	36 (16)	3 (1)	13 (4)
	M. scorpius	3	4 (1)	242 (38)	73 (29)	81 (26)	38 (15)	126 (48)

Appendix 2

Station	Species	*n*	PCB 74	Σ-Tetra-PCB	PCB 99	PCB 101	PCB 105
A1	*B. undatum*	3	27 (14)	306 (182)	98 (32)	192 (71)	42 (14)
	H. araneus	3	33 (20)	335 (107)	183 (179)	194 (104)	91 (61)
	M. truncata	2	5 (2)	68 (11)	12 (5)	21 (7)	4 (1)
	G. tricuspis	1	69	643	346	370	137
A2	*B. undatum*	3	9 (4)	111 (55)	43 (12)	29 (9)	13 (4)
	H. araneus	3	40 (8)	328 (43)	225 (67)	205 (48)	140 (36)
	M. truncata	1	3	37	10	17	4
A3	*B. undatum*	3	10 (4)	39 (16)	18 (5)	11 (1)	8 (1)
	H. araneus	3	20 (11)	237 (20)	74 (30)	125 (36)	60 (19)
	M. truncata	3	8 (2)	114 (45)	17 (2)	33 (7)	8 (1)
A4	*B. undatum*	3	32 (26)	255 (219)	106 (58)	348 (447)	43 (33)
	H. araneus	3	29 (22)	262 (120)	133 (113)	222 (180)	78 (56)
	S. droebach.	2	18 (8)	245 (28)	83 (5)	796 (873)	50 (14)
	M. scorpius	1	17	157	196	40	51
B1	*B. undatum*	3	151 (34)	1 206 (532)	1 108 (498)	1 227 (789)	762 (258)
	H. araneus	2	209 (147)	2 234 (1 256)	1 569 (885)	838 (1 051)	1 235 (401)
B2	*H. araneus*	3	322 (160)	3 894 (1 407)	1 774 (768)	2 674 (756)	1 187 (408)
	G. tricuspis	1	250	2 451	2 098	2 342	1 106
	M. scorpius	1	219	1 308	2 239	305	1 051
B3	*S. droebach.*	2	298 (106)	2 556 (783)	1 648 (280)	1 841 (234)	1 078 (244)
	M. scorpius	1	1 368	8 054	6 940	1 846	4 672
B4	*B. undatum*	3	111 (30)	730 (394)	810 (326)	642 (525)	511 (165)
	H. araneus	3	103 (47)	1 392 (251)	899 (431)	1 601 (493)	781 (121)
	M. truncata	1	6	79	23	34	10
	M. scorpius	1	156	1097	884	324	348
G1	*B. undatum*	3	31 (13)	143 (113)	102 (50)	42 (54)	52 (42)
	H. araneus	3	80 (96)	925 (972)	406 (426)	740 (773)	322 (322)
	M. truncata	3	2 (1)	29 (9)	10 (5)	15 (5)	6 (4)
G2	*H. araneus*	3	164 (126)	2 096 (1 990)	1 163 (1 188)	2 453 (2 757)	1 035 (1 070)
	M. truncata	2	8 (4)	94 (53)	33 (14)	52 (24)	18 (11)
	G. tricuspis	1	152	1346	984	1527	545
	B. glaciale	3	55 (12)	207 (65)	483 (115)	63 (10)	55 (4)
	M. scorpius	2	446 (91)	2 380 (391)	2 673 (1 283)	764 (81)	1 799 (436)
G3	*B. undatum*	3	205 (97)	497 (155)	623 (232)	66 (25)	318 (37)
	H. araneus	3	246 (77)	2 893 (465)	1 712 (526)	1 936 (1 587)	1 369 (317)
K1	*B. undatum*	3	36 (17)	126 (28)	52 (25)	18 (1)	12 (8)
	H. araneus	3	67 (53)	754 (533)	235 (192)	381 (249)	176 (151)
	M. scorpius	2	157 (7)	778 (98)	435 (58)	137 (111)	212 (8)
K2	*B. undatum*	3	18 (8)	145 (61)	76 (18)	39 (21)	12 (4)
	H. araneus	3	57 (41)	755 (126)	223 (93)	516 (60)	166 (25)
	M. scorpius	1	104	603	401	168	226
I1	*B. undatum*	3	25 (7)	120 (28)	78 (42)	17 (3)	26 (13)
	H. araneus	3	103 (15)	1 341 (146)	591 (170)	986 (253)	430 (183)
	S. droebach.	2	14 (6)	198 (55)	39 (19)	80 (33)	13 (5)
	M. truncata	3	8 (2)	114 (23)	14 (1)	26 (5)	5 (0)
	G. tricuspis	1	337	2 300	1 848	1 088	444
	B. glaciale	3	13 (2)	112 (29)	50 (3)	33 (15)	8 (4)
	M. scorpius	3	113 (43)	579 (184)	398 (140)	76 (19)	208 (52)

Appendix 2

Station	Species	*n*	PCB 114	PCB 118	PCB 122	PCB 123	Σ-Penta-PCB
A1	*B. undatum*	3	6 (1)	164 (41)	1 (0)	3 (1)	690 (315)
	H. araneus	3	11 (8)	335 (243)	1 (0)	5 (2)	1 122 (797)
	M. truncata	2	0 (0)	16 (5)	0 (0)	0 (0)	86 (31)
	G. tricuspis	1	15	516	1	9	2052
A2	*B. undatum*	3	2 (1)	58 (12)	0 (0)	1 (0)	234 (54)
	H. araneus	3	18 (3)	533 (157)	1 (0)	8 (3)	1 457 (143)
	M. truncata	1	1	17		0	66
A3	*B. undatum*	3	2 (1)	62 (9)	1 (0)	1 (1)	124 (40)
	H. araneus	3	8 (2)	187 (60)	1 (0)	4 (1)	670 (217)
	M. truncata	3	1 (0)	26 (3)	0 (0)	1 (0)	139 (18)
A4	*B. undatum*	3	8 (6)	200 (121)	1 (0)	3 (2)	944 (961)
	H. araneus	3	13 (13)	354 (330)	1 (0)	7 (7)	1 190 (950)
	S. droebach.	2	13 (13)	325 (269)	1 (0)	2 (1)	2 299 (2 151)
	M. scorpius	1	5	158		4	700
B1	*B. undatum*	3	59 (12)	2 302 (483)	7 (3)	37 (15)	8 482 (3 024)
	H. araneus	2	107 (41)	3 455 (1 429)	17 (5)	73 (29)	13 953 (6 721)
B2	*H. araneus*	3	107 (48)	3 390 (1 503)	23 (6)	69 (24)	13 632 (4 064)
	G. tricuspis	1	101	3 274	14	60	13 608
	M. scorpius	1	81	2 736	3	46	9 239
B3	*S. droebach.*	2	69 (15)	2 904 (683)	39 (30)	61 (12)	10 928 (1 959)
	M. scorpius	1	371	11 536	20	231	34 716
B4	*B. undatum*	3	38 (7)	1 555 (421)	5 (1)	24 (12)	4 983 (2 359)
	H. araneus	3	73 (18)	2 068 (661)	11 (1)	46 (7)	7 729 (2 129)
	M. truncata	1	1	31	0	0	168
	M. scorpius	1	33	1 218		23	1 661
G1	*B. undatum*	3	9 (3)	256 (72)	1 (1)	3 (2)	609 (251)
	H. araneus	3	35 (34)	954 (940)	7 (6)	20 (17)	3 696 (3 841)
	M. truncata	3	1 (0)	14 (6)	0 (0)	1 (0)	65 (28)
G2	*H. araneus*	3	107 (109)	2 970 (2 821)	19 (23)	62 (66)	11 162 (12 050)
	M. truncata	2	1 (1)	45 (24)	1 (0)	1 (1)	241 (118)
	G. tricuspis	1	54	1 577	7	33	6 322
	B. glaciale	3	31 (9)	1 357 (202)	2 (1)	11 (2)	2 593 (586)
	M. scorpius	2	138 (42)	4 282 (1 503)	2 (0)	52 (12)	11 392 (3 850)
G3	*B. undatum*	3	64 (0)	1 986 (109)	5 (1)	10 (1)	3 161 (1 216)
	H. araneus	3	139 (39)	3 970 (1 116)	29 (18)	73 (11)	15 772 (3 694)
K1	*B. undatum*	3	6 (2)	143 (37)	1 (0)	1 (0)	313 (64)
	H. araneus	3	29 (23)	626 (482)	2 (2)	13 (12)	1 999 (1 456)
	M. scorpius	2	20 (1)	629 (14)	0 (0)	8 (1)	1 928 (237)
K2	*B. undatum*	3	4 (1)	105 (18)	0 (0)	2 (0)	305 (69)
	H. araneus	3	22 (5)	550 (133)	3 (0)	13 (2)	2 474 (461)
	M. scorpius	1	23	970		9	1 010
I1	*B. undatum*	3	4 (1)	109 (35)	1 (0)	1 (0)	293 (98)
	H. araneus	3	50 (11)	1 513 (612)	8 (2)	34 (15)	4 716 (1 053)
	S. droebach.	2	2 (1)	54 (22)	1 (0)	1 (1)	253 (109)
	M. truncata	3	1 (0)	17 (1)	0 (0)	0 (0)	91 (11)
	G. tricuspis	1	87	1556	13	36	5 494
	B. glaciale	3	3 (0)	69 (13)	0 (0)	1 (0)	204 (27)
	M. scorpius	3	20 (6)	649 (175)	0 (0)	9 (3)	1 701 (404)

Appendix 2

Station	Species	*n*	PCB 128	PCB 138	PCB 141	PCB 149	PCB 153
A1	*B. undatum*	3	59 (10)	364 (105)	60 (18)	214 (68)	619 (144)
	H. araneus	3	61 (30)	512 (448)	25 (15)	118 (36)	1 089 (910)
	M. truncata	2	4 (2)	18 (5)	3 (1)	14 (3)	27 (5)
	G. tricuspis	1	129	730	61	287	1 689
A2	*B. undatum*	3	21 (4)	118 (23)	5 (2)	96 (33)	237 (56)
	H. araneus	3	84 (16)	565 (121)	26 (7)	141 (36)	1 319 (552)
	M. truncata	1	4	17	3	16	30
A3	*B. undatum*	3	10 (3)	69 (18)	2 (1)	18 (7)	156 (53)
	H. araneus	3	40 (10)	216 (85)	11 (4)	80 (16)	375 (125)
	M. truncata	3	5 (1)	22 (4)	3 (0)	18 (3)	34 (4)
A4	*B. undatum*	3	88 (81)	719 (841)	44 (38)	412 (558)	1 410 (1 674)
	H. araneus	3	53 (31)	518 (528)	44 (47)	180 (165)	1 344 (1 486)
	S. droebach.	2	300 (374)	1 607 (2 044)	307 (404)	1 766 (2 269)	2 799 (3 508)
	M. scorpius	1	60	272	7	19	614
B1	*B. undatum*	3	569 (169)	1 920 (532)	133 (93)	580 (62)	3 083 (398)
	H. araneus	2	950 (359)	3 773 (1 193)	253 (146)	1 544 (781)	5 214 (1 455)
B2	*H. araneus*	3	823 (378)	3 763 (2 280)	240 (88)	1 409 (386)	6 621 (4 766)
	G. tricuspis	1	960	3 842	389	1 563	4 928
	M. scorpius	1	787	3 273	154	142	5 426
B3	*S. droebach.*	2	705 (20)	2 305 (208)	160 (27)	891 (3)	2 437 (149)
	M. scorpius	1	2 714	9 405	287	420	12 921
B4	*B. undatum*	3	433 (34)	1 630 (187)	79 (64)	332 (59)	2 003 (448)
	H. araneus	3	610 (183)	2 747 (1 260)	158 (33)	1 013 (519)	4 392 (2 449)
	M. truncata	1	7	26	4	18	43
	M. scorpius	1	300	1 502	47	148	2 417
G1	*B. undatum*	3	63 (19)	244 (55)	5 (6)	98 (42)	304 (77)
	H. araneus	3	195 (156)	742 (569)	44 (30)	359 (299)	1 007 (803)
	M. truncata	3	4 (3)	15 (10)	2 (1)	11 (6)	21 (11)
G2	*H. araneus*	3	647 (754)	2 628 (2 998)	204 (273)	1 350 (1 571)	3 434 (3 735)
	M. truncata	2	14 (9)	50 (29)	8 (4)	41 (22)	60 (33)
	G. tricuspis	1	480	1 578	205	841	2 262
	B. glaciale	3	465 (255)	1 813 (883)	5 (2)	261 (131)	2 417 (766)
	M. scorpius	2	1 318 (394)	4 336 (1 326)	163 (47)	182 (113)	5 987 (1 538)
G3	*B. undatum*	3	464 (76)	2 168 (245)	6 (4)	737 (184)	2 561 (266)
	H. araneus	3	914 (180)	3 759 (648)	253 (88)	1 711 (347)	5 004 (680)
K1	*B. undatum*	3	42 (10)	260 (80)	4 (1)	64 (40)	463 (171)
	H. araneus	3	144 (110)	947 (821)	61 (60)	335 (209)	1 816 (1 531)
	M. scorpius	2	162 (12)	1 059 (170)	40 (30)	56 (42)	1 790 (385)
K2	*B. undatum*	3	30 (9)	134 (49)	3 (1)	54 (14)	301 (18)
	H. araneus	3	135 (46)	692 (220)	37 (4)	345 (72)	1 570 (463)
	M. scorpius	1	182	1 226	40	69	1 967
I1	*B. undatum*	3	34 (16)	123 (32)	3 (0)	49 (18)	294 (113)
	H. araneus	3	266 (87)	1 446 (501)	68 (18)	618 (133)	2 457 (810)
	S. droebach.	2	13 (8)	55 (34)	7 (2)	53 (24)	117 (48)
	M. truncata	3	4 (0)	16 (2)	2 (0)	16 (2)	29 (3)
	G. tricuspis	1	418	2 151	96	404	6 746
	B. glaciale	3	29 (4)	110 (37)	3 (2)	42 (10)	231 (16)
	M. scorpius	3	155 (42)	777 (272)	23 (11)	37 (16)	1 423 (366)

Appendix 2

Station	Species	*n*	PCB 156	PCB 157	PCB 167	∑-Hexa-PCB	PCB 170
A1	*B. undatum*	3	36 (16)	6 (1)	18 (6)	1 907 (439)	162 (96)
	H. araneus	3	54 (40)	13 (9)	27 (14)	2 402 (1 866)	117 (106)
	M. truncata	2	2 (0)	0 (0)	1 (0)	91 (24)	3 (1)
	G. tricuspis	1	87	22	50	3 838	267
A2	*B. undatum*	3	11 (2)	2 (0)	6 (1)	652 (163)	36 (4)
	H. araneus	3	99 (74)	23 (15)	53 (36)	2 890 (701)	152 (92)
	M. truncata	1	2		2	99	3
A3	*B. undatum*	3	5 (3)	2 (1)	5 (1)	328 (97)	13 (6)
	H. araneus	3	23 (7)	6 (2)	12 (4)	1 022 (292)	40 (10)
	M. truncata	3	2 (0)	1 (0)	1 (0)	111 (26)	3 (1)
A4	*B. undatum*	3	59 (57)	7 (4)	24 (21)	3 746 (4 499)	144 (129)
	H. araneus	3	77 (85)	14 (14)	42 (48)	2 787 (2 879)	154 (160)
	S. droebach.	2	62 (77)	13 (16)	101 (129)	9 469 (12 064)	228 (291)
	M. scorpius	1	26	8	17	1 183	40
B1	*B. undatum*	3	196 (58)	53 (14)	104 (15)	8 547 (1 533)	203 (41)
	H. araneus	2	423 (123)	126 (39)	208 (81)	16 078 (5 767)	407 (97)
B2	*H. araneus*	3	479 (279)	114 (59)	255 (193)	17 505 (10 022)	712 (638)
	G. tricuspis	1	435	101	202	16 861	355
	M. scorpius	1	340	78	153	12 648	576
B3	*S. droebach.*	2	135 (13)	62 (9)	127 (17)	8 811 (506)	103 (1)
	M. scorpius	1	1 263	271	570	34 123	802
B4	*B. undatum*	3	149 (52)	46 (4)	81 (3)	5 218 (2 427)	160 (11)
	H. araneus	3	302 (37)	86 (16)	156 (35)	12 084 (5 564)	485 (324)
	M. truncata	1	2	1	2	126	3
	M. scorpius	1	112	41	72	5 086	142
G1	*B. undatum*	3	20 (10)	6 (2)	16 (4)	981 (245)	23 (6)
	H. araneus	3	103 (84)	24 (16)	42 (27)	3 253 (2 564)	55 (28)
	M. truncata	3	1 (1)	0 (0)	1 (1)	72 (41)	1 (1)
G2	*H. araneus*	3	326 (363)	80 (90)	152 (175)	11 731 (13 400)	190 (212)
	M. truncata	2	5 (3)	1 (1)	3 (1)	248 (134)	4 (1)
	G. tricuspis	1	219	50	107	8 088	110
	B. glaciale	3	103 (61)	29 (23)	102 (25)	6 576 (2 642)	173 (65)
	M. scorpius	2	609 (129)	140 (32)	220 (39)	16 036 (4 364)	506 (155)
G3	*B. undatum*	3	183 (30)	51 (14)	110 (28)	7 860 (982)	127 (44)
	H. araneus	3	489 (136)	120 (34)	226 (47)	16 379 (2 788)	360 (68)
K1	*B. undatum*	3	16 (4)	4 (1)	17 (5)	1 140 (386)	51 (21)
	H. araneus	3	91 (86)	21 (17)	62 (54)	4 545 (3 768)	208 (226)
	M. scorpius	2	95 (6)	19 (1)	48 (4)	3 901 (346)	254 (63)
K2	*B. undatum*	3	8 (3)	3 (1)	9 (2)	682 (114)	27 (5)
	H. araneus	3	56 (24)	18 (6)	46 (14)	3 735 (1 060)	106 (34)
	M. scorpius	1	87	23	47	4 430	102
I1	*B. undatum*	3	11 (4)	3 (1)	10 (4)	628 (176)	22 (8)
	H. araneus	3	143 (48)	34 (6)	93 (30)	6 217 (1 622)	184 (59)
	S. droebach.	2	3 (1)	1 (1)	4 (2)	334 (152)	5 (1)
	M. truncata	3	1 (0)	0 (0)	1 (0)	93 (16)	2 (0)
	G. tricuspis	1	207	59	77	12 345	595
	B. glaciale	3	7 (2)	2 (0)	9 (2)	544 (89)	21 (8)
	M. scorpius	3	79 (21)	21 (8)	39 (10)	3 016 (909)	114 (33)

Appendix 2

Station	Species	*n*	PCB 180	PCB 183	PCB 187	PCB 189	Σ-Hepta-PCB
A1	*B. undatum*	3	543 (341)	112 (78)	212 (134)	6 (3)	1 352 (845)
	H. araneus	3	443 (392)	62 (57)	103 (39)	6 (5)	834 (651)
	M. truncata	2	9 (1)	2 (0)	4 (1)	0 (0)	24 (3)
	G. tricuspis	1	803	117	261	11	1715
A2	*B. undatum*	3	98 (11)	23 (5)	71 (32)	2 (0)	317 (69)
	H. araneus	3	487 (282)	48 (22)	132 (31)	9 (6)	872 (289)
	M. truncata	1	9	1	7		20
A3	*B. undatum*	3	40 (17)	5 (3)	28 (4)	2 (0)	67 (68)
	H. araneus	3	135 (31)	15 (5)	110 (17)	2 (1)	246 (194)
	M. truncata	3	7 (1)	1 (0)	5 (1)	0 (0)	15 (4)
A4	*B. undatum*	3	361 (245)	88 (89)	419 (534)	7 (7)	1 374 (1 477)
	H. araneus	3	599 (659)	66 (70)	199 (213)	9 (11)	1 174 (1 261)
	S. droebach.	2	1 316 (1 706)	8 (4)	948 (1217)	0 (0)	4 012 (5 196)
	M. scorpius	1	133	13	11	2	201
B1	*B. undatum*	3	436 (49)	66 (7)	153 (42)	6 (3)	1 039 (56)
	H. araneus	2	1 009 (158)	159 (48)	399 (42)	21 (7)	1 807 (331)
B2	*H. araneus*	3	2 392 (2 684)	313 (321)	699 (505)	43 (45)	4 030 (4 694)
	G. tricuspis	1	787	170	274	16	2 191
	M. scorpius	1	1 182	135	126	23	582
B3	*S. droebach.*	2	192 (16)	19 (4)	139 (12)	3 (0)	689 (17)
	M. scorpius	1	1 764	224	198	23	3 127
B4	*B. undatum*	3	345 (11)	72 (12)	125 (55)	6 (1)	589 (350)
	H. araneus	3	1 292 (890)	169 (124)	570 (443)	22 (12)	2 963 (2 058)
	M. truncata	1	8	2	6		19
	M. scorpius	1	491	84	74		825
G1	*B. undatum*	3	44 (11)	8 (3)	26 (7)	1 (1)	121 (19)
	H. araneus	3	124 (44)	19 (8)	87 (61)	3 (2)	361 (187)
	M. truncata	3	3 (2)	1 (1)	3 (2)	0 (0)	7 (6)
G2	*H. araneus*	3	476 (541)	89 (105)	315 (324)	11 (13)	1 471 (1 670)
	M. truncata	2	9 (4)	2 (1)	8 (3)	0 (0)	28 (5)
	G. tricuspis	1	339	39	116	6	797
	B. glaciale	3	334 (121)	62 (24)	233 (78)	8 (2)	855 (483)
	M. scorpius	2	1 027 (259)	118 (48)	165 (11)	20 (6)	1 957 (546)
G3	*B. undatum*	3	220 (112)	60 (23)	203 (39)	7 (3)	833 (290)
	H. araneus	3	941 (341)	150 (35)	475 (59)	24 (9)	2 380 (473)
K1	*B. undatum*	3	137 (65)	21 (14)	100 (42)	4 (1)	389 (215)
	H. araneus	3	696 (756)	93 (96)	383 (320)	14 (15)	1 702 (1 716)
	M. scorpius	2	701 (150)	98 (2)	113 (79)	14 (2)	1 301 (90)
K2	*B. undatum*	3	87 (17)	14 (4)	77 (12)	2 (0)	238 (31)
	H. araneus	3	402 (144)	39 (12)	407 (34)	6 (1)	1 121 (185)
	M. scorpius	1	418	43	72	5	183
I1	*B. undatum*	3	64 (24)	11 (4)	35 (8)	1 (0)	162 (45)
	H. araneus	3	540 (127)	74 (19)	431 (132)	13 (6)	1 457 (343)
	S. droebach.	2	19 (3)	3 (1)	23 (12)	1 (0)	75 (33)
	M. truncata	3	6 (0)	1 (0)	6 (1)	0 (0)	17 (8)
	G. tricuspis	1	1 885	155	586	34	2 960
	B. glaciale	3	49 (2)	8 (3)	42 (10)	1 (0)	154 (40)
	M. scorpius	3	345 (72)	44 (20)	54 (14)	6 (2)	630 (202)

Appendix 2

Station	Species	*n*	PCB 194	PCB 206	PCB 209	Σ 6 PCB	Σ PCB
A1	*B. undatum*	3	61 (36)	11 (4)	3 (1)	1 812 (465)	4 438 (792)
	H. araneus	3	66 (64)	12 (7)	8 (3)	2 318 (1 857)	4 872 (3 460)
	M. truncata	2	1 (0)	0 (0)	0 (0)	100 (24)	311 (74)
	G. tricuspis	1	83	24	11	3 780	8 505
A2	*B. undatum*	3	12 (1)	3 (0)	3 (1)	528 (109)	1 409 (330)
	H. araneus	3	41 (25)	9 (3)	9 (3)	2 680 (855)	5 706 (1 099)
	M. truncata	1	1			90	256
A3	*B. undatum*	3	3 (2)	1 (0)	2 (0)	291 (87)	594 (222)
	H. araneus	3	13 (6)	4 (0)	5 (1)	918 (257)	2 285 (691)
	M. truncata	3	0 (0)	0 (0)	0 (0)	142 (26)	457 (109)
A4	*B. undatum*	3	27 (11)	5 (0)	3 (3)	2 934 (3 250)	6 400 (7 169)
	H. araneus	3	66 (70)	10 (8)	5 (3)	2 757 (2 880)	5 577 (5 307)
	S. droebach.	2	22 (24)	0 (0)	7 (0)	6 603 (8 093)	16 130 (19 357)
	M. scorpius	1	11	2	2	1 117	2 309
B1	*B. undatum*	3	11 (3)	5 (2)	3 (1)	6 963 (1 674)	19 366 (4 889)
	H. araneus	2	54 (4)	24 (11)	20 (9)	11 319 (2 005)	34 381 (13 544)
B2	*H. araneus*	3	217 (307)	47 (51)	21 (7)	16 405 (10 305)	39 566 (18 225)
	G. tricuspis	1	70	34	22	12 477	35 359
	M. scorpius	1	46	23	13	10 386	23 951
B3	*S. droebach.*	2	6 (1)	2 (0)	26 (5)	7 276 (797)	23 179 (3 291)
	M. scorpius	1	69	17	12	27 945	80 649
B4	*B. undatum*	3	12 (3)	5 (1)	3 (1)	4 790 (1 227)	11 609 (5 446)
	H. araneus	3	88 (53)	26 (6)	26 (3)	10 347 (5 075)	24 561 (10 021)
	M. truncata	1				144	447
	M. scorpius	1	27			5 099	8 952
G1	*B. undatum*	3	3 (1)	1 (0)	1 (0)	679 (183)	1 895 (613)
	H. araneus	3	9 (4)	4 (2)	5 (3)	2 768 (2 306)	8 357 (7 619)
	M. truncata	3	0 (0)	0 (0)	1 (0)	64 (30)	186 (86)
G2	*H. araneus*	3	20 (20)	9 (7)	8 (5)	9 558 (10 602)	26 773 (29 359)
	M. truncata	2	2 (1)	0 (0)	1 (0)	203 (109)	661 (346)
	G. tricuspis	1	1	0	0	6 058	16 779
	B. glaciale	3	13 (6)	4 (1)	3 (1)	4 691 (1 792)	10 302 (3 770)
	M. scorpius	2	59 (7)	17 (2)	11 (5)	12 756 (3 308)	32 103 (9 282)
G3	*B. undatum*	3	10 (6)	4 (1)	3 (1)	5 114 (612)	12 427 (2 214)
	H. araneus	3	53 (16)	14 (4)	12 (4)	12 395 (1 061)	37 829 (6 196)
K1	*B. undatum*	3	14 (11)	3 (1)	3 (2)	915 (306)	2 054 (626)
	H. araneus	3	63 (80)	16 (15)	9 (4)	4 032 (3 433)	9 309 (7 641)
	M. scorpius	2	79 (16)	19 (3)	7 (3)	3 921 (541)	8 142 (26)
K2	*B. undatum*	3	6 (2)	2 (1)	3 (1)	638 (36)	1 461 (209)
	H. araneus	3	25 (5)	10 (4)	12 (3)	3 383 (844)	8 326 (1 827)
	M. scorpius	1	39	11	7	4 109	6 668
I1	*B. undatum*	3	2 (1)	1 (0)	2 (0)	544 (178)	1 250 (336)
	H. araneus	3	37 (5)	17 (2)	22 (1)	5 810 (1 597)	14 084 (2 978)
	S. droebach.	2	3 (0)	4 (0)	33 (0)	352 (133)	989 (401)
	M. truncata	3	0 (0)	0 (0)	0 (0)	114 (15)	364 (74)
	G. tricuspis	1	97			12 702	24 154
	B. glaciale	3	3 (1)	1 (0)	1 (0)	481 (67)	1 076 (124)
	M. scorpius	3	32 (6)	9 (0)	11 (2)	2 818 (737)	6 220 (1 712)

Appendix 3. Stable isotope ratios of carbon and nitrogen in samples from fjords on Spitsbergen (Svalbard): Respective fjords and species are listed in Appendix 1.

Station	Species	*n*	$\delta^{13}C$	$\delta^{15}N$
A1	*B. undatum*	3	-17.1 (0.2)	12.2 (0.2)
	H. araneus	3	-18.4 (0.2)	11 (0.4)
	M. truncata	2	-19.1 (0.3)	8.4 (0.1)
	G. tricuspis	1	-17.4	11.6
A2	*B. undatum*	3	-18.7 (0.3)	12.8 (0.2)
	H. araneus	3	-18.4 (0.7)	10.5 (0.6)
	M. truncata	1	-18.9	8.9
A3	*B. undatum*	3	-17 (0.5)	11.9 (0.9)
	H. araneus	3	-19.2 (1.1)	11.3 (1)
	M. truncata	3	-19.4 (0.5)	7.8 (0.3)
A4	*B. undatum*	3	-17.3 (0.9)	12.4 (0.5)
	H. araneus	3	-18.1 (0.5)	11.1 (0.1)
	S. droebach.	2	-17.7 (0.3)	6.1 (0.6)
	M. scorpius	1	-18.5	11.7
B1	*B. undatum*	3	-18.1 (0.4)	11.2 (0.8)
	H. araneus	2	-18.5 (0.2)	11.9 (0.4)
B2	*H. araneus*	3	-18.5 (0.3)	12.4 (0.5)
	G. tricuspis	1	-19.1	13.4
	M. scorpius	1	-18.9	13.2
B3	*S. droebach.*	2	-20.1 (0.1)	7 (0.4)
	M. scorpius	1	-18.7	14.1
B4	*B. undatum*	3	-17.9 (0.6)	11.4 (0.9)
	H. araneus	3	-18.1 (0.3)	11.8 (1.1)
	M. truncata	1	-19.3	8.8
	M. scorpius	1	-18.8	12.2
G1	*B. undatum*	3	-16.7 (0.3)	11.9 (0.7)
	H. araneus	3	-18 (0.4)	10.8 (0.2)
	M. truncata	3	-18.7 (0.2)	8.8 (0.3)
G2	*H. araneus*	3	-17.4 (0.1)	11.1 (0.2)
	M. truncata	2	-18.9 (0.1)	8.6 (0.1)
	G. tricuspis	1	-18.9	12.9
	B. glaciale	3	-16.4 (0.2)	11.2 (0.3)
	M. scorpius	2	-19.5 (1.6)	12.5 (2.1)
G3	*B. undatum*	3	-16.5 (0.4)	12.8 (0.8)
	H. araneus	3	-17.6 (0.6)	11.6 (0.3)
K1	*B. undatum*	3	-16.8 (0.3)	12.2 (0.5)
	H. araneus	3	-18 (0.2)	11.9 (0.3)
	M. scorpius	2	-18.8 (0.1)	13.4 (0.4)
K2	*B. undatum*	3	-17.1 (0.3)	11.4 (0.3)
	H. araneus	3	-18 (0.3)	11.4 (0.6)
	M. scorpius	1	-18.7	12.5
I1	*B. undatum*	3	-17.5 (0.4)	11 (0.4)
	H. araneus	3	-17.9 (0.2)	11.8 (0.4)
	S. droebach.	2	-20 (0.3)	4.6 (0.8)
	M. truncata	3	-19.5 (0.2)	7.2 (0.6)
	G. tricuspis	1	-20.1	11.8
	B. glaciale	3	-17.4 (0.1)	10.8 (0.3)
	M. scorpius	3	-18.1 (0.6)	13.6 (0.7)

Appendix 4. The distribution of seven PCB congeners (ng g^{-1}) in samples from fjords on Spitsbergen (Svalbard). Mean levels (SD) and percentage contribution by individual congeners are listed.

Adventfjorden (*n* = 34)

PCB	Mean ng g^{-1}	SD ng g^{-1}	% of 7PCB	SD %
28	19.4	10.4	1.0	2.9
52	49.9	35.2	2.5	5.4
101	180.5	274.1	8.9	5.4
118	209.6	206.0	10.4	4.1
138	399.1	594.5	19.8	3.2
153	815.6	1140.6	40.4	8.1
180	345.2	505.0	17.1	6.7
Sum 7 PCB	2019.3	2637.6	100	0

Billefjorden (*n* = 21)

PCB	Mean ng g^{-1}	SD ng g^{-1}	% of 7PCB	SD %
28	48.7	43.3	0.7	1.3
52	445.3	423.6	3.8	2.6
101	1363.8	940.7	11.7	6.2
118	2831.3	2284.1	22.1	4.4
138	2875.2	2018.2	22.5	3.6
153	4254.0	3185.6	32.6	5.0
180	953.7	1172.6	6.6	3.4
Sum 7 PCB	12 772.1	9009.8	100	0

Grønfjorden (*n* = 26)

PCB	Mean ng g^{-1}	SD ng g^{-1}	% of 7PCB	SD %
28	36.9	40.4	0.5	1.4
52	224.0	293.2	3.2	2.8
101	734.8	1294.5	10.5	9.0
118	1721.2	1774.4	24.5	4.2
138	1709.8	174 2.4	24.4	4.7
153	2253.7	2276.6	32.1	5.4
180	340.1	401.7	4.8	1.3
Sum 7 PCB	7020.5	7350.6	100	0

Isfjorden (n = 18)

PCB	**Mean ng g^{-1}**	**SD ng g^{-1}**	**% of 7PCB**	**SD %**
28	56.8	64.9	2.0	3.2
52	118.6	155.2	4.1	5.9
101	258.8	424.3	9.1	7.5
118	485.1	650.0	17.0	3.5
138	537.7	696.8	18.8	4.5
153	1126.6	1696.0	39.4	8.6
180	274.2	453.5	9.6	2.6
Sum 7 PCB	2857.8	3965.3	100	0

Kongsfjorden (n = 15)

PCB	**Mean ng g^{-1}**	**SD ng g^{-1}**	**% of 7PCB**	**SD %**
28	54.9	47.0	1.8	1.3
52	100.3	67.6	3.3	2.3
101	220.4	227.0	7.3	4.8
118	433.3	337.6	14.3	2.0
138	629.6	512.4	20.8	3.8
153	1199.7	933.8	39.7	2.6
180	385.7	392.6	12.8	2.8
Sum 7 PCB	3023.8	2384.7	100	0

Appendix 5. Methods description of the PCB and PAH analysis from NILU (in Norwegian).

Bestemmelse av PCB (Metode: NILU-O-2) og PAH (Metode: NILU-O-3)

Biologisk materiale

- Akkreditert av Norsk Akkreditering i henhold til EN 45 001 -

Forbehandling:

Det veies inn en prøvemengde som tilsvarer omtrent 0 25 g fett. Prøvene tilsettes ^{13}C-merkete PCB-standarder og ^{2}D-merkete PAH-standarder for å kontrollere utbytte av ekstraksjon og opparbeidelse. De samme forbindelser brukes senere som intern standard ved kvantifiseringen. Dette medfører at prøveresultatene automatisk er korrigert for eventuelle tap under ekstraksjon og opparbeidelse.

Prøvene blir homogenisert med natriumsulfat kolonne-ekstrahert med sykloheksan/etylacetat 1/1 og neddampet til 5 ml.

Opparbeidelse:

Ekstraktet fraksjoneres ved hjelp av gelpermeasjonskromatografi (GPC) på Biobeads SX-3. Prøven oppkonsentreres og renses ytterligere via kromatografi på en kolonne fylt med kaliumhydroxid belagt silika. Prøven oppkonsentreres igjen tilsettes gjenvinningsstandarder og analyseres ved hjelp av GC/MS.

Identifisering og kvantifisering:

Bestemmelse av PCB-kongenerene utføres ved hjelp av gasskromatografi kombinert med høyoppløsende massespektrometri (GC/HRMS). Dette gir høy følsomhet og god selektivitet på de ulike komponenter. PAH-komponentene analyseres ved hjelp av gasskromatografi kombinert med lavoppløsende massespektrometri (GC/LRMS).

Kvalitetssikring:

Følgende kvalitetskriterier blir kontrollert:

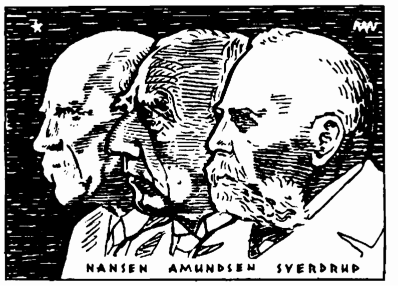
Rene uforstyrrete massefragmentogrammer
Korrekte retensjonstider i forhold til ^{13}C-merkete isomerer
Korrekt intensitetsforhold for M- og (M+2)-massefragmentogrammene (PCB)
Signal/støyforhold > 3:1
Gjenvinningen av de tilsatte internstandard komponenter ligger innenfor de gitte grenser:

NILU-O-2	HCB	10 - 100
	HCH og TriCB	20 - 130
	alle andre	40 - 130
NILU-O-3	3-ring PAH	10 - 130
	4-ring PAH	20 - 130
	5-ring PAH	30 - 130

Etter hver 15 prøveopparbeiding analyseres det en fullstendig metode-blindprøve. (Analyseresultater fra blindprøven skal være under deteksjonsgrensen eller en faktor 5-10 lavere enn måleresultatene.)
Analysekvaliteten blir regelmessig testet ved hjelp av kontrollprøver sertifiserte referanseprøver og ved deltakelse i interkalibreringer.

Appendix 6. The Norwegian - English translation of different PAHs.

English	Norwegian
Acenaphthene	acenaften
Acenaphthylene	acenaftylen
Anthanthrene	antantren
Anthracene	antracen
Benz[a]anthracene	benz(a)antracen
Benzo[a]fluoranthene	benzo(a)fluoranten
Benzo[a]fluorene	benzo(a)fluoren
Benzo[a]pyrene	benzo(a)pyren
Benzo[b/j/k]fluoranthene	benzo(b/j/k)fluorantener
Benzo[b]fluorene	benzo(b)fluoren
Benzo[e]pyrene	benzo(e)pyren
Benzo[ghi]fluoranthene	benzo(ghi)fluoranten
Benzo[ghi]perylene	benzo(ghi)perylen
Biphenyl	bifenyl
Chrysene/Triphenylene	krysen/trifenylen
Coronene	coronen
Cyclopenta[cd]pyrene	syklopenta(cd)pyren
Dibenz[a e]pyrene	dibenz(ae)pyren
Dibenz[a h]pyrene	dibenz(ah)pyren
Dibenz[a i]pyrene	dibenz(ai)pyren
Dibenzo[ac/ah]anthracene	dibenzo(ac/ah)antracen
Dibenzofuran	dibenzofuran
Dibenzothiophene	dibenzotiofen
Fluoranthene	fluoranten
Fluorene	fluoren
Indeno[1 2 3-cd]pyrene	inden(1 2 3-cd)pyren
Methylanthracene	2-metylantracen
Methylnaphthalene	2-metylnaftalen
Methylnaphthalene	1-metylnaftalen
Methylphenanthrene	3-metylfenantren
Methylphenanthrene	2-metylfenantren
Methylphenanthrene	9-metylfenantren
Methylphenanthrene	1-metylfenantren
Naphthalene	naftalen
Perylene	perylen
Phenanthrene	fenantren
Pyrene	pyren
Retene	reten


NANSEN AMUNDSEN SVERDRUP