RESEARCH/REVIEW ARTICLE

Persistent organic pollutants in biota samples collected during the Ymer-80 expedition to the Arctic

Henrik Kylin,[1,2,3] Johan Hammar,[4,5] Jacques Mowrer,[1] Henk Bouwman,[6] Carl Edelstam,[5] Mats Olsson[5] & Sören Jensen[1]

[1] Department of Environmental Science and Analytical Chemistry, Stockholm University, SE-106 91 Stockholm, Sweden
[2] Norwegian Institute for Air Research, Fram Centre, NO-9296 Tromsø, Norway
[3] Department of Thematic Studies—Environmental Change, Linköping University, SE-581 83 Linköping, Sweden
[4] Institute of Freshwater Research, Department for Aquatic Resources, Swedish University of Agricultural Sciences, SE-178 93 Drottningholm, Sweden
[5] Natural History Museum, P.O. Box 50007, SE-104 05 Stockholm, Sweden
[6] Research Unit: Environmental Sciences and Development, North-West University, P. Bag X6001, Potchefstroom 2520, South Africa

Keywords
Polar bear; ringed seal; glaucous gull; Brünnich's guillemot; common eider; Arctic char.

Correspondence
Henrik Kylin, Department of Thematic Studies—Environmental Change, Linköping University, SE-581 83 Linköping, Sweden. E-mail: henrik.kylin@liu.se

Abstract

During the 1980 expedition to the Arctic with the icebreaker *Ymer*, a number of vertebrate species were sampled for determination of persistent organic pollutants. Samples of Arctic char (*Salvelinus alpinus*, $n=34$), glaucous gull (*Larus hyperboreus*, $n=8$), common eider (*Somateria mollissima*, $n=10$), Brünnich's guillemot (*Uria lomvia*, $n=9$), ringed seal (*Pusa hispida*, $n=2$) and polar bear (*Ursus maritimus*, $n=2$) were collected. With the exception of Brünnich's guillemot, there was a marked contamination difference of birds from western as compared to eastern/northern Svalbard. Samples in the west contained a larger number of polychlorinated biphenyl (PCB) congeners and also polychlorinated terphenyls, indicating local sources. Brünnich's guillemots had similar pollutant concentrations in the west and east/north; possibly younger birds were sampled in the west. In Arctic char, pollutant profiles from lake Linnévatn ($n=5$), the lake closest to the main economic activities in Svalbard, were similar to profiles in Arctic char from the Shetland Islands ($n=5$), but differed from lakes to the north and east in Svalbard ($n=30$). Arctic char samples had higher concentrations of hexachlorocyclohexanes (HCHs) than the marine species of birds and mammals, possibly due to accumulation via snowmelt. Compared to the Baltic Sea, comparable species collected in Svalbard had lower concentrations of PCB and dichlorodiphenyltrichloroethane (DDT), but similar concentrations indicating long-range transport of hexachlorobenzene, HCHs and cyclodiene pesticides. In samples collected in Svalbard in 1971, the concentrations of PCB and DDT in Brünnich's guillemot ($n=7$), glaucous gull ($n=2$) and polar bear ($n=2$) were similar to the concentrations found in 1980.

To access the supplementary material for this article, please see supplementary files under Article Tools online.

Contamination of the Arctic with persistent organic pollutants (POPs) gained interest in the 1980s when it was realized that northern indigenous peoples may carry high body burdens of these anthropogenic contaminants (Dewailly et al. 1989; de March et al. 1998). This triggered research to measure various POPs in biotic and abiotic samples from the Arctic with the aim to understand and model their global transport and fate (Wania & Mackay 1996). As a consequence, the Arctic Monitoring and Assessment Programme, an international working

Citation: *Polar Research* 2015, *34*, 21129, http://dx.doi.org/10.3402/polar.v34.21129

group under the Arctic Council, was established in 1991 to aid policymakers and implement the Arctic Environmental Protection Strategy (AMAP 2011).

In 1980, prior to the increased interest in organic contaminants in the Arctic, the Swedish icebreaker HMS *Ymer* performed an expedition to the eastern Arctic Ocean, the Ymer-80 expedition (Schytt 1983; Hoppe et al. 1987). The broad research programme included sampling of wildlife for the Swedish Museum of Natural History (SMNH). SMNH was, and is, a hub for the Swedish national environmental monitoring programme (SNEMP) for POPs in biota. The SNEMP for POPs was initiated at the end of the 1960s and includes, for example, sampling of fish in the sub-Arctic lakes of northern Sweden and fish and guillemot eggs from the central Baltic Sea. Consequently, some samples collected during Ymer-80 were analysed for the presence of POPs to compare the contaminant concentrations in the Arctic with Swedish limnic and marine environments. However, the results of this early investigation of the contamination situation at Svalbard were never published except as a popular science cruise report in Swedish (Edelstam et al. 1987), presenting only partial data. Here we present the complete data set, as far as it has been possible to reconstruct, of POP concentrations in the samples collected during Ymer-80 and complementary samples collected in 1971, 1979 and 1981. We also present data from seal samples collected in 1983–84, which have not been properly published. It is outside the scope of this paper to analyse time trends for all the species included and space would not allow it. Such time-trend analyses will be the subject of subsequent papers.

Material and methods

Muscle samples of Arctic char (*Salvelinus alpinus*; anadromous, resident and landlocked populations), common eider (*Somateria mollissima*), Brünnich's guillemot (*Uria lomvia*), glaucous gull (*Larus hyperboreus*) and polar bear (*Ursus maritimus*), and blubber samples of ringed seal (*Pusa hispida*) were obtained from specimens collected for the SMNH during the Ymer-80. Muscle samples of Brünnich's guillemots and polar bears from 1971 were donated by Norwegian authorities. Sampling locations are shown in Fig. 1 and sample details are given in Supplementary Tables S1 and S2.

The total list of analytes include hexachlorobenzene (HCB); α-, β-, γ- and δ- hexachlorocyclohexane (HCH); *p,p′*- dichlorodiphenyltrichloroethane (DDT); *o,p′*-DDT; *p,p′*- dichlorodiphenyldichloroethane (DDD); *o,p′*-DDD; *p,p′*-dichlorodiphenyldichloroethylene (DDE);

Fig. 1 Sampling sites in Svalbard. Arctic char (*Salvelinus alpinus*) were sampled in the lakes indicated on the map. In western Svalbard, glaucous gull (*Larus hyperboreus*) and common eider (*Somateria mollissima)* were sampled in Isfjorden, mainly around Kapp Linné, and Brünnich's guillemot (*Uria lomvia*) on Prins Karls Forland. In the north and east, eiders were sampled around Kinnvika on Nordaustlandet, gulls at Kinnvika and Kongsøya, and guillemots on Kongsøya and Hopen.

o,p′-DDE; methoxychlor; toxaphene; aldrin; dieldrin; endrin; oxy-, α- and γ-chlordane; α- and γ-chlordene; *cis*- and *trans*-nonachlor; heptachlor; heptachlor epoxide; polychlorinated biphenyl (PCB) and polychlorinated terphenyls (PCT). For formal chemical names see Supplementary Table S3.

Analyses were performed in 1983–84 at which time data were recorded in hand-written files. The data sets were digitalized in 2008–2012. As far as possible, missing data were recalculated based on saved chromatograms and integrator data. Limits of detection (LOD) and quantification (LOQ) were not possible to reconstruct in detail. For simplicity, the LOQ was set to 0.01 μg g^{-1} lipid for all analytes and the LOD to 0.003 μg g^{-1} lipid.

The analytical procedure (see the Supplementary file for a brief description), including quality control/quality assurance, was state-of-the-art at the time of analysis. The quantifications were performed by fused-silica capillary column gas chromatography with either electron capture detector or mass spectrometer to quantify individual compounds and congeners. Most of the results presented here should be comparable to more recent investigations. However, PCT and toxaphene data should be treated with caution. Individual PCT or toxaphene congeners were not available as standards. The data are included here to evaluate the spatial trends within the Svalbard Archipelago, not for comparison with other studies.

For comparison between data from 1971 and 1980 (Supplementary Table S8), the 1980 data were recalculated based on intercalibration of different quantification methods used over time in the SNEMP. Additional unpublished data from samples collected 1983 and 1984 in an investigation commissioned by the Norwegian Environmental Protection Agency are included for comparison (Supplementary Table S9). See further discussion in the Supplementary file for details.

Principal component analysis (PCA) was used for pollutant pattern comparisons between samples and groups of samples, using MjM Software PC-ORD version 6.07. Details of data treatment are given in the Supplementary file.

Results and discussion

The sampling programme of Ymer-80 was planned both to obtain information on POP contamination where few previous sampling campaigns had taken place and to gain information from a "pristine background area" useful for comparisons with SNEMP data from the Swedish environment (Edelstam et al. 1987). The vertebrates targeted for sampling, therefore, either occur or have close relatives in Sweden. Arctic char, common eider and ringed seal all occur in Sweden, while the Brünnich's guillemot of Svalbard is closely related to the common guillemot (*Uria aalge*) in the Baltic. As complement to these species, specimens of glaucous gull and polar bear were collected as representing the high trophic levels in the Arctic.

The sampling was also intended to distinguish difference between western and northern/eastern Svalbard. Economic activities in Svalbard were and are concentrated chiefly around Isfjorden and Van Mijenfjorden in the west, and the west potentially also is more exposed to contaminants arriving with ocean currents. The hypothesis was, therefore, that western Svalbard should have higher contamination levels than northern/eastern Svalbard.

Data are presented below and in the Supplementary file on a lipid mass basis. Information enabling conversion to a fresh mass basis is given in Supplementary Table S1.

Birds

Summary data on the contaminant concentrations are given in Table 1, with details in Supplementary Table S4. The contaminant concentrations were distinctly different in birds from western compared to northern/eastern Svalbard. In common eider and glaucous gull, perhaps the most obvious difference was the presence of PCT in samples from western Svalbard. PCT are three-ringed analogues to PCB (which has two rings). The two had similar uses, but PCT formulations were generally used at higher temperatures (de Boer 2000). Data on PCT contamination is scanty worldwide, the presence of PCT in only one area of Svalbard indicates that western Svalbard was subject to contamination from local economic activities. All samples with PCT residues were collected on or close to Kapp Linné, with both mining operations (Barentsburg) and a main telecommunications facility. However, exactly which activities in the area required the use of PCT is impossible to say. Nor is it possible to know if any PCT was still used at the time of sampling, or if the PCT residues were due to historical use. We cannot exclude that the birds also picked up contaminants in their wintering areas, but the number of species (including Arctic char, see below) contaminated with PCT in western Svalbard makes it unlikely that the main source of PCT was the wintering areas.

In common eider, the concentrations of ΣPCB were higher and the congener pattern more complex in western than in northern/eastern Svalbard, which strengthens the suspicion of a local source of contaminants. Mehlum & Daelemans (1995), too, suggested the presence of a local

Table 1 Summary of organochlorine concentrations (μg g^{-1} lipid) in birds and mammals collected during the Ymer-80 expedition in the northern and eastern (N/E) and western (W) parts of Svalbard. Concentrations of individual analytes in individual samples are presented in Supplementary Tables S4a and S4b.

		HCB Mean Median Range	Σ31PCB Mean Median Range	Σ6PCB[a] Mean Median Range	ΣPCT Mean Median Range	Oxychlordane Mean Median Range	*p,p′*-DDE Mean Median Range	ΣDDT[b] Mean Median Range	Lipid% Mean Median Range
Brünnich's guillemot	N/E (*n* = 4)	1.1	11	7.9	ND[c]	0.28	6.6	6.7	3.0
		0.55	10	7.0	—	0.13	5.8	5.8	2.7
		0.35–3.0	4.7–20	3.2–14	—	0.11–0.28	3.1–12	3.1–12	2.0–4.6
	W (*n* = 5)	0.39	3.0	2.2	ND	0.14	1.8	1.8	2.8
		0.24	1.4	1.2	—	0.15	1.4	1.4	2.9
		0.13–1.1	0.74–4.3	0.57–5.1	—	0.02–0.28	0.51–3.7	0.98–3.7	2.3–3.0
Glaucous gull	N/E (*n* = 2)	0.88	52	43	ND	0.92	15	15	3.7
		—	—	—	—	—	—	—	—
		0.50–1.3	5.5–98	4.0–83	—	0.29–1.6	3.1–27	3.2–27	3.1–4.4
	W (*n* = 6)[d]	2.7	78	64	23	1.9	29	30	6.7
		2.7	65	50	20	1.7	29	30	
		1.2–5.3	38–150	29–120	14–35	1.3–2.7	20–38	20–39	4.4–8.6
Common eider	N/E (*n* = 5)	0.11	1.0	0.75	ND	0.06	0.60	0.64	2.8
		0.11	0.80	0.58	—	0.05	0.46	0.49	3.0
		0.07–0.18	0.41–1.9	0.28–1.5	—	tr[e]–0.10	0.24–0.98	0.26–1.1	1.8–4.4
	W (*n* = 5)	0.10	3.1	1.1	17	0.75	0.44	0.48	2.8
		0.09	2.9	1.0	15	0.83	0.33	1.0	3.1
		0.06–0.15	2.3–4.3	0.65–2.0	8.0–29	0.10–1.4	0.17–1.0	0.20–1.1	2.0–3.4
Ringed seal	N/E (*n* = 2)	0.02	2.4	1.1	ND	0.22	0.07	0.8	93
		—	—	—	—	—	—	—	—
		0.01–0.02	1.6–3.2	0.65–1.6	—	0.09–0.34	0.06–0.08	0.61–0.99	90–96
Polar bear	N/E (*n* = 2)	—	140	130	ND	4.4	—	—	1.0
		—	—	—	—	—	—	—	—
		ND–0.06	3.5–280	3.2–260	—	0.11–8.6	M[f]–33	M–0.40	0.77–1.3

[a]Sum of CB-99, −118, −138, −153, −170 and −180. Provided here for comparisons with data on glaucous gulls in Verreault et al. (2010). [b]Sum of *o,p′*-DDE, *p,p′*-DDE, *o,p′*-DDD, *p,p′*-DDD, *o,p′*-DDT and *p,p′*-DDT. [c]ND - not detected. [d]*n* = 5 for ΣPCT, oxychlordane and lipid%. [e]tr - trace (0.003 μg g^{-1} lipid ≤ tr < 0.01 μg g^{-1} lipid). [f]M - missing data.

source of PCB in western Svalbard in the 1980s. However, the source is not necessarily activities on Kapp Linné only; activities in Longyearbyen and Sveagruva may also contribute contaminants to western Svalbard. For glaucous gull, the number of samples from the northern/eastern part of the archipelago is too low for any relevant comparison of PCB as the concentrations in these two samples vary with two orders of magnitude. It is noteworthy, though, that the glaucous gulls from western Svalbard contained substantially more chlordanes than those from the northern/eastern parts. But this is not reflected for common eider, in which the concentration differences may even be the opposite.

In contrast to the other two bird species, POP concentrations in Brünnich's guillemot did not differ much between western and northern and eastern Svalbard. This is somewhat surprising; more pronounced differences were expected as fish-eating guillemots feed at a higher trophic level than mussel-eating eider. Common and Brünnich's guillemots have similar feeding ecologies and it was expected that their body burdens relative to common eiders would be similar in any given area. In the Baltic, common guillemots generally had three to five times higher concentrations of PCB than common eiders (Edelstam et al. 1987), and a similar ratio was found between Brünnich's guillemots and common eiders in northern/eastern Svalbard, but not the western part. A possible explanation for the similar concentrations of POPs in guillemots and eiders from western Svalbard is that juvenile guillemots were sampled in the west. There was no way of ascertaining the age of the birds at the time of analysis as the collection of these samples was done separately by Norwegian staff and only the breast muscle was sent from the collector to the SMNH. An alternative explanation is that while common eider feed on locally contaminated stationary resources close to shore, guillemots forage on less contaminated pelagic fish (Edelstam et al. 1987). A third explanation is that the guillemots have different food choices in the western and northern/eastern

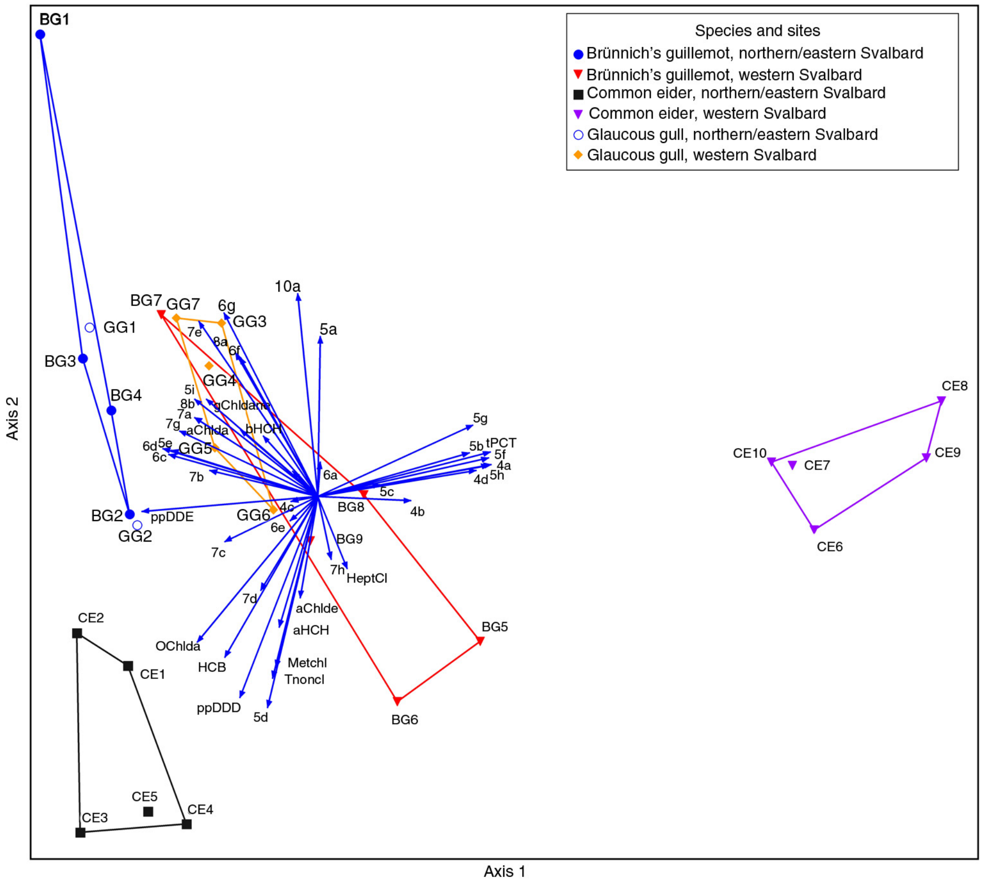


Fig. 2 Principal component analysis of relativized (see the Supplementary file for details) contaminant concentrations in birds. Vector numbers refer to individual polychlorinated biphenyl (PCB) congeners (see Supplementary Table S3). Axis 1 explains 76% and Axis 2 20% of the total variation. Vector numbers refer to individual PCB congeners; the numeral refers to the number of chlorines in the molecule, see Supplementary Table S3b for full explanation. Samples from different locations are presented by convex hulls. There were only two samples of glaucous gull from northern/eastern Svalbard and these are represented by their coordinate points only. Identities of individual samples are given in Supplementary Table S4.

parts of Svalbard. An investigation of the stomach content of some of the guillemots collected during Ymer-80 indicated large individual differences in food choice. Some individuals had fed on fish, while the stomach contents of others consisted of >99% crustaceans (amphipods and mysids, J. Hammar pers. obs.), suggesting that the differences in contaminant levels could be explained by individual guillemots feeding at different trophic levels. However, we cannot presently tie individual bird samples to specific a specific trophic level; determination of stable carbon and nitrogen isotope ratios (δ^{13}C and d^{15}N) would be helpful.

The differences in the pollution patterns between western and northern/eastern Svalbard are demonstrated by a PCA of the relativized data in all the bird species (Fig. 2). All the northern/eastern samples form convex hulls far to the left on the first axis (closely parallel with the *p,p'*-DDE vector), separating them from the samples from western Svalbard (closely paralleled with the vectors for ΣPCT and PCB congeners 44, 52, 92, 95, 97 and 101 [vector numbers 4b, 4a, 5b, 5a, 5f and 5d, respectively]). It is also noteworthy that in both geographical categories the eiders separate from the guillemots and gulls, which overlap with each other within each geographical category. Therefore, even if there is no obvious difference in the concentrations in eiders and guillemots, the fact that they feed at different trophic levels gives rise to different contaminant patterns. This is emphasized by the overlap of the guillemots and glaucous gulls in the PCA plot; both species are at least partially fish-eaters.

Glaucous gulls have been used to monitor bioaccumulating environmental pollutants in Svalbard (Verreault et al. 2010), and common eider and Brünnich's guillemots have been included occasionally (Mehlum & Daelemans 1995; Sagerup et al. 2009). To compare the Ymer-80 data with the data from other studies, we calculated a

Table 2 Summary of organochlorine concentrations (μg g^{-1} lipid) in Arctic char collected during the Ymer-80 expedition. Concentrations of individual analytes in individual samples are presented in Supplementary Table S5.

		HCB Mean Median Range	Σ31PCB Mean Median Range	ΣHCH Mean Median Range	*p,p′*-DDE Mean Median Range	Lipid% Mean Median Range
Linnévatn	Smolt (*n* = 3)	0.07	5.2	1.5	0.56	1.2
		0.07	4.2	1.3	0.38	1.0
		0.05–0.10	1.6–9.7	0.64–2.5	0.38–1.0	0.37–2.2
	Resident (*n* = 3)	0.04	0.71	1.9	0.08	1.6
		0.05	0.73	1.9	0.07	1.5
		0.02–0.05	0.47–0.94	1.4–2.5	0.04–0.11	0.99–2.4
	All (*n* = 6)	0.06	2.9	1.7	0.32	1.4
		0.05	1.27	1.6	0.21	1.3
		0.02–0.10	0.47–9.7	0.24–4.4	0.04–1.0	0.37–2.4
Diesetvatn	Anadromous (*n* = 2)	0.09	0.31	3.8	0.07	3.7
		—	—	—	—	—
		0.08–0.09	0.27–0.34	3.2–4.5	0.14–0.15	3.0–4.3
Jensenvatn	Resident (*n* = 6)	0.14	6.7	6.1	1.2	5.1
		0.13	7.0	5.3	1.2	4.4
		0.11–0.19	2.1–10	2.9–13	0.20–2.3	2.0–12
Annavatn	Resident (*n* = 5)	0.19	7.5	2.7	1.7	2.3
		0.19	7.4	2.7	1.5	2.4
		0.13–0.22	4.0–11	2.1–3.4	0.64–2.9	1.7–3.0
Wibjørnvatn	Resident (*n* = 7)	0.17	1.8	3.8	0.38	3.6
		0.17	1.5	4.0	0.30	3.8
		0.14–0.20	1.0–3.3	1.8–6.2	0.19–0.84	1.6–6.0
Arkvatn	Smolt? (*n* = 5)	0.20	1.3	2.9	2.6	2.5
		0.20	1.2	3.2	2.5	2.8
		0.16–0.22	0.85–1.9	2.0–3.6	1.1–4.1	1.7–3.2
	Resident? (*n* = 3)	0.18	0.59	4.0	0.43	3.6
		0.19	0.61	3.6	0.44	3.2
		0.15–0.20	0.54–0.61	3.5–5.0	0.19–0.66	3.1–4.6
	All (*n* = 8)	0.19	1.0	3.3	1.8	2.9
		0.20	0.93	3.3	1.5	2.9
		0.15–0.22	0.54–1.9	2.0–5.0	0.19–4.1	1.6–4.6
Girlsta Loch	Resident (*n* = 5)	0.09	4.7	1.1	1.4	0.88
		0.09	3.4	1.0	0.77	0.82
		0.08–0.09	2.1–9.6	1.0–1.2	0.37–3.5	0.78–1.0

Σ6PCB (Table 1). Generally, the contaminant concentrations from Ymer-80 compare well with concentrations reported for the respective species during the 1980s.

Samples from two specimens of common guillemot from the central Baltic Sea were included among the Svalbard samples as reference (Supplementary Table S7). The ΣPCB and ΣDDT concentrations were substantially higher in these samples than in samples of Brünnich's guillemot from Svalbard, while the concentrations of HCB, ΣHCH and oxychlordane are similar or even higher in Svalbard than in the Baltic. This suggests that local sources of PCB and DDT affected the Baltic more than Svalbard, but that the other contaminants may have reached both areas mainly by long-range atmospheric transport (Edelstam et al. 1987).

Other data on concentrations of POPs in birds from western Svalbard from the early 1980s have been published (Norheim & Kjos-Hanssen 1984; Carlberg & Bøler 1985), but the concentrations are difficult to compare with the concentration reported here for the Ymer-80 samples as the quantifications were done using an old packed-column gas chromatography method. See further discussion in the Supplementary file.

Mammals

Summary data on contaminant concentrations in ringed seals and polar bears are given in Table 1, with details in Supplementary Table S4. Too few specimens were analysed to allow far-reaching conclusions from this material alone; the data are presented here to allow comparisons with other studies.

Both polar bears were found north-east of Svalbard. As expected, an emaciated individual had the highest concentrations of all analytes (except HCB), but it is noteworthy that the number of PCB congeners detected was almost the same in both specimens. The additional congeners in the emaciated individual were present at much lower concentrations than the dominant congeners. Polar bears efficiently degrade most PCB congeners (Muir et al. 1988; Norstrom et al. 1988). The DDE and PCB concentrations in the non-emaciated specimen was similar to those reported for polar bears from many areas of the Arctic in the period 1996–2002 (Verreault et al. 2005), while the oxychlordane concentrations was slightly lower than reported for Svalbard in that study.

Both ringed seals were males. The contaminant patterns were fairly similar although the concentrations of PCBs and DDTs were about twice as high in the seal from north-eastern Svalbard than the seal from Kongsfjorden in western Svalbard, while the chlordane concentrations were about five times higher. The higher concentrations were accompanied by a larger number of detected congeners.

Additional data on five ringed seals and two bearded seals (*Erignathus barbatus*) were reported by Carlberg & Bøler (1985). These samples were analyses in the same laboratory, by the same staff, using the same methods as the Ymer-80 samples. However, for reasons unknown, the data were presented recalculated (see discussion in the Supplementary file). The original data, as far as it has been possible to reconstruct, are presented in Supplementary Table S9, with the caveat that quality assurance/control information is lacking and it was not possible to reconstruct the concentrations of the individual PCB congeners. The concentrations of various POPs are similar in ringed seals from northern Svalbard 1980 and ringed seals from Hornsund in 1984, whereas ringed seals from Kapp Linné seem to have higher concentrations; a similar pattern was observed for the bird samples in the Ymer-80 material.

Data on organochlorines in a ringed seal from Svalbard collected in 1980 is also presented by Andersson et al. (1988). However, as they used a different method of quantification, and presented only summary information of concentrations and samples, no relevant comparison of the results is possible. The cursory presentation of data by Andersson et al. (1988) is unfortunate; the only seal from Svalbard included in that paper is one of the Ymer-80 samples, and a detailed account of the results would have made a valuable comparison between methods possible.

Arctic char

Six different populations of Arctic char were sampled in Svalbard (Fig. 1), and one population on the east coast of Mainland, Shetland Islands. Summary data are given in Table 2, with details in Supplementary Table S5. The concentrations of toxaphene and individual cyclodiene pesticides were not possible to retrieve or reconstruct for individual fish, but the concentrations in pooled samples are given in Supplementary Table S6 for completeness.

In the anadromous populations of lakes Linnévatn, Diesetvatn and Arkvatn, some individuals reaching a certain size (or age) may spend a few summer weeks feeding in the sea or coastal lagoons (Hammar 1991). While the Arctic char collected from Diesetvatn were caught in a temporary, meromictic lagoon on Kapp Mitra, Kongsfjorden, away from their native freshwater system, the other individuals with an assumed partly marine feeding history had already returned to freshwater and amalgamated with the resident members of the populations. The Arctic char populations in the remaining lakes were landlocked, with such one-way obstructions in the outlets that return to their native freshwater, would be impossible.

Within some landlocked populations, such as in Annavatn and Wibjørnvatn, char of different size show very different feeding behaviour; small fish that feed mainly on zooplankton and insects grow slowly, while fish of above a certain size turn cannibalistic, which leads to faster growth, larger size, and accumulation of parasites (Hammar 2000). However, in these lakes with cannibalistic populations, during special events, for example, when chironomid or trichopteran pupae hatch, all sizes of Arctic char as well as both terrestrial and marine birds may feed on the insects. During these and other periods of the summer season, presence of bird droppings and remains of marine crustaceans and marine fish in char stomachs indicate a marine source of energy to landlocked Arctic char in the High Arctic (Skreslet 1973; Hammar 2000). A special case is Jensenvatn in which both small and large individuals foraged almost exclusively on the abundant amphipod *Gammaracanthus lacustris* (Hammar 2000). It is therefore not straightforward to compare the pollutant concentrations in these populations as their geography, ecology and life histories, including age, diet, growth and shifts of habitat, vary extensively both between and within the different populations and sampling sites (Hammar 1991, 2000). However, 31 individual PCB congeners and 10 pesticide compounds were determined in each sample, allowing a comparison of both contaminant concentrations and profiles with multivariate statistical methods.

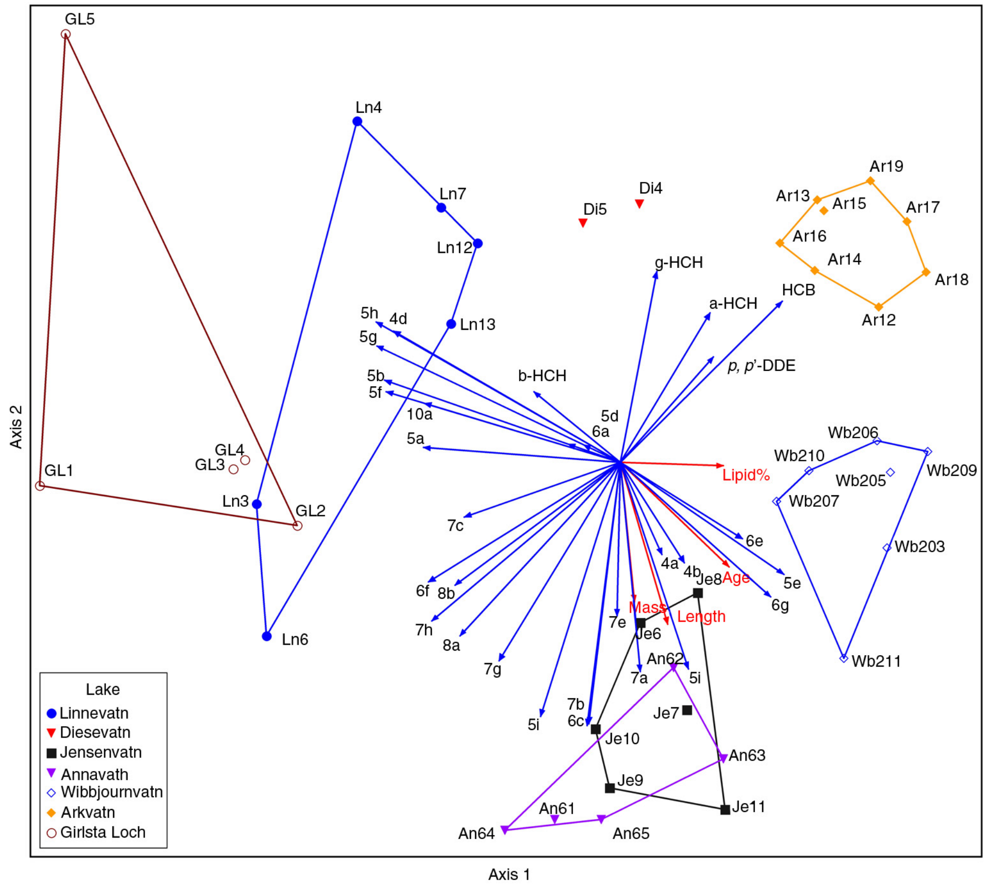


Fig. 3 Principal component analysis of relativized (see Supplementary file for details) contaminant concentrations in Arctic char with respect to lake. Axis 1 explains 50% and Axis 2 explains 22% of the total variation. Vector numbers refer to individual polychlorinated biphenyl (PCB) congeners; the numeral refers to the number of chlorines in the molecule, (see Supplementary Table S3b for full explanation). The samples from different lakes are presented as convex hulls. Lake Diesetvatn, with only two samples, is represented by the sample coordinates only. Identities of individual samples are given in Supplementary Table S5.

A PCA of the relativized data shows clear differences between the lakes (Fig. 3). The similarity between Linnévatn in Svalbard and Girlsta Loch in Shetland is remarkable given the lakes are located in different archipelagos. Note, though, that economic activity in Svalbard is centred close to Linnévatn, and Girlsta Loch is located close to main economic centres in Shetland. The similarity between the two lakes implies that proximity to human activities was a dominant factor determining their contaminant profiles. Further, lakes Jensenvatn and Annavatn, situated close together further up the west coast, show similar overlapping convex hulls (i.e., appear close together in the PCA plot), while lakes Arkvatn and Wibjørnvatn, situated to the east along the north coast of Nordaustlandet (Fig. 1), separate out discretely from the other lakes. The two samples from Diesetvatn also separate out from the other lakes.

PCAs to evaluate the effect of sex and fish age did not detect any significant influence of these factors because of overlapping convex hulls (Supplementary Figs. S2, S3); that is, the pollutant pattern differences between the lakes were larger than the pollutant pattern differences between individuals in the same lake irrespective of age or sex. Interestingly, in both lakes from which we have samples of both smolt and resident parr, the parr had consistently lower total concentrations of all contaminants. Although the total concentration of contaminants increased with age, the pattern of the contaminants in relation to each other is unaltered.

Although there were some differences between anadromous and landlocked populations, they are not sufficient to separate these two (Supplementary Fig. S4). However, we have only had access to samples from two clearly anadromous individuals, both from Diesetvatn, and both of these fall outside of the area spanned by the landlocked lake systems in the PCA plot. It is possible that if more sea-run individual fish had been available, the differences between the systems would have been more obvious.

With respect to contaminant concentrations (Table 2, Supplementary Table S5), with the exception of the anadromous fish from Diesetvatn that showed the lowest concentrations of all contaminants, Arctic char from the three other lakes along the west coast of Svalbard (and also Girlsta Loch) have higher concentrations of PCB than the lakes on the north coast of eastern Svalbard. There is also a shift in the congener profiles in the lakes with fewer congeners found in Arkvatn and Wibjørnvatn, and with a shift towards more volatile congeners.

Among the western Svalbard lakes, char from lakes Jensenvatn and Annavatn in the north-west showed a different PCB congener profile as well as an overall higher concentration of ΣPCB than the char in Linnévatn (Table 2, Supplementary Table S5a), and the differences increase if only the resident individuals are compared. However, comparing with other contaminants, such as the presence of PCT, the similarities with Girlsta Loch char (Fig. 3), and the larger number of congeners in Linnévatn indicates proximity to a source of technical PCB. Given its location close to one of the major settlements and a telecommunications facility, it is logical that Linnévatn is more influenced by human than the other lakes. The concentration differences between the lakes, on the other hand, reflect differences in how PCB is transferred in their food chains.

The PCB concentrations in char from lakes Jensenvatn and Annavatn are striking. As pointed out above, the food chains in these two closely located lakes differ substantially. In spite of this, the contaminant concentrations and profiles in the lakes are similar (Fig. 2), indicating that the source of the contaminants is more important than the food chain for the contaminants in the Arctic char in these lakes. While ice-free, both lakes are visited by seabirds to wash and to feed on hatching insects (Hammar 2000), and the droppings of the birds may transport POPs from the marine to the lake ecosystems (Evenset et al. 2004). These lakes are also located close to the shore and may receive sea spray or seawater intrusion; Jensenvatn seems to have salty bottom water.

In contrast to these western lakes, the easternmost lakes are ice-covered for a longer period, are not visited by birds to the same extent and do not receive sea spray or seawater intrusion. However, to fully evaluate differences in the contamination situations in the lakes, renewed sampling is necessary. The determination of stable carbon and nitrogen isotope ratios (δ^{13}C and δ^{15}N) would also help in identifying sea-run individuals from resident ones and would also make comparisons of the trophic levels of the fish in the lakes possible.

Notably, the Arctic char from Linnévatn and Girlsta Loch had lower concentrations of HCB and the HCHs than the other lakes. The explanation could, perhaps, be that these two are ice-free for a longer time of the year than the other lakes, allowing these relatively volatile POPs to volatilize. It is also noteworthy that the Arctic char has generally higher concentrations of the HCHs than the birds and mammals. This may be due to species differences in metabolism, but also an effect of meltwater enrichment (Helm et al. 2002; Diamond et al. 2005), as meltwater can reach the lake ecosystems even if the lakes are covered by ice. Generally, in the early 1980s, HCHs were still being deposited in the Arctic (Li & Macdonald 2005), and the predicted concentrations for meltwater were higher than the predicted concentrations for seawater.

Comparison of data from 1971 and 1980

PCB and DDT data from three species, Brünnich's guillemot, glaucous gull and polar bear, sampled in 1971 were summarized by Edelstam et al. (1987). These and adjusted Ymer-80 data are compared in Supplementary Table S8. The PCB and DDT concentrations from 1971 and 1980 appear to be within the same range for each of the three species. Further, the concentrations of the only polar bear sample from Ymer-80 that is comparable with other studies fall within the range of the concentrations reported for archived samples from 1967 (Derocher et al. 2003). It would, therefore, seem that the PCB and DDT concentrations in Svalbard were fairly similar in the late 1960s and early 1980s. As far as it is possible to draw any conclusions from these few data, they suggest that the PCB and DDT concentrations culminated in the Svalbard environment some time during the 1970s. This is similar to other studies; PCB and DDT concentrations in sediment from lake Ellasjøen seem to peak around 1970 (Evenset et al. 2007), and the deposition flux of PCB to the glacier Lomonosovfonna also shows a peak in the 1970s (Garmash et al. 2013), although more recent fluxes also seem to be high. Peaking PCB and DDT concentrations in the Arctic during the 1970s is consistent with increased environmental awareness and successive bans in western countries during this time.

Acknowledgements

The Polar Research Committee, Swedish Royal Academy of Sciences organized Ymer-80. The Royal Swedish Navy operated the ship. Bjørn Kjos-Hanssen collected the 1980 bird samples, and Magnar Norderhaug made available the 1971 samples. Johan Hammar financed the 1979 and 1981 Arctic char sampling privately. Erna and Victor Hasselblad Foundation funded sample analyses. We thank a reviewer for substantial and constructive comments.

References

AMAP (Arctic Monitoring and Assessment Programme) 2011. *AMAP strategic framework 2010+. AMAP report 2010:8*. Oslo: Arctic Monitoring and Assessment Programme.

Andersson Ö., Linder C.E., Olsson M., Reutergårdh L., Uvemo U.B. & Wideqvist U. 1988. Spatial differences and temporal trends of organochlorine compounds in biota from the northwestern hemisphere. *Archives of Environmental Contamination and Toxicology 17*, 755–765.

Carlberg G.E. & Bøler J.B. 1985. *Determination of persistent chlorinated hydrocarbons and inorganic elements in samples from Svalbard. Report 83 11 01-1*. Oslo: Center for Industrial Research.

de Boer J. 2000. Polychlorinated terphenyls. In J. Paasivirta (ed.): *The handbook of environmental chemistry—new types of persistent halogenated compounds*. Pp. 44–59. Berlin: Springer.

de March B.G., de Wit C.A. & Muir D.C. 1998. Persistent organic pollutants. In S.J. Wilson et al. (eds.): *AMAP assessment report: Arctic pollution issues*. Pp. 183–372. Oslo: Arctic Monitoring and Assessment Programme.

Derocher A.E., Wolkers H., Colburn T., Schlabach M., Larsen T.S. & Wiig Ø. 2003. Contaminants in Svalbard polar bear samples archived since 1967 and possible population level effects. *Science of the Total Environment 301*, 163–174.

Dewailly E., Nantel A., Weber J.P. & Meyer F. 1989. High levels of PCBs in breast milk of Inuit women from Arctic Quebec. *Bulletin of Environmental Contamination and Toxicology 43*, 641–646.

Diamond M.L., Bhavsar S.P., Helm P.A., Stern G.A. & Alaee M. 2005. Fate of organochlorine contaminants in Arctic and Subarctic lakes estimated by mass balance modelling. *Science of the Total Environment 342*, 245–259.

Edelstam C., Hammar J., Jensen S., Mowrer J. & Olsson M. 1987. Miljögifter i Polarhavet. Analysresultat från Ymer-expeditionen 1980. (Environmental pollutants in the Polar Sea. Results from the Ymer expedition 1980.) In G. Hoppe et al. (eds.): *Expeditionen Ymer-80: en slutrapport. (Expedition Ymer-80: a final report.*) Pp. 174–182. Stockholm: Royal Academy of Sciences.

Evenset A., Christensen G.N., Carroll J., Zaborska A., Berger U., Herzke H. & Gregor D. 2007. Historical trend in persistent organic pollutants and metals recorded in sediment from lake Ellasjøen, Bjørnøya, Norwegian Arctic. *Environmental Pollution 146*, 196–205.

Evenset A., Christensen G.N., Skotvold T., Fjeld E., Schlabach M., Wartena E. & Gregor D. 2004. A comparison of organic contaminants in two High Arctic lake ecosystems, Bjørnøya (Bear Island), Norway. *Science of the Total Environment 318*, 125–141.

Garmash O., Hermanson M.H., Isaksson E., Schwikowski M., Divine D., Teixeira C. & Muir D.C.G. 2013. Deposition history of polychlorinated biphenyls to the Lomonosovfonna glacier, Svalbard: a 209 congener analysis. *Environmental Science & Technology 47*, 12064–12072.

Hammar J. 1991. Speciation processes in the High Arctic: hardly as simple as the environment might suggest. *International Society of Arctic Char Fanatics Information Series 5*, 73–88.

Hammar J. 2000. Cannibals and parasites: conflicting regulators of bimodality in high latitude Arctic char, *Salvelinus alpinus*. *Oikos 88*, 33–47.

Helm P.A., Diamond M.L., Semkin R., Strachan W.M.J., Teixeira C. & Gregor D. 2002. A mass balance model describing multiyear fate of organochlorine compounds in a High Arctic lake. *Environmental Science & Technology 36*, 996–1003.

Hoppe G., Björn-Rasmussen S. & Wiberg R.M. (eds.) 1987. *Expeditionen Ymer-80: en slutrapport. (Expedition Ymer-80: a final report.)* Stockholm: Swedish Royal Academy of Sciences.

Li Y.F. & Macdonald R.W. 2005. Sources and pathways of selected organochlorine pesticides to the Arctic and the effect of pathway divergence on HCH trends in biota: a review. *Science of the Total Environment 342*, 87–106.

Mehlum F. & Daelemans F.F. 1995. PCBs in Arctic seabirds from the Svalbard region. *Science of the Total Environment 160–161*, 441–446.

Muir D.C.G., Norstrom R.J. & Simon M. 1988. Organochlorine contaminants in Arctic marine food chains: accumulation of specific polychlorinated biphenyls and chlordane-related compounds. *Environmental Science & Technology 22*, 1071–1079.

Norheim G. & Kjos-Hanssen B. 1984. Persistent chlorinated hydrocarbons and mercury in birds caught off the west coast of Spitsbergen. *Environmental Pollution Series A 33*, 143–152.

Norstrom R.J., Simon M., Muir D.C.G. & Schweinsburg R.E. 1988. Organochlorine contaminants in Arctic marine food chains: identification, geographical distribution and temporal trends in polar bears. *Environmental Science & Technology 22*, 1063–1071.

Sagerup K., Savinov V., Savinova T., Kuklin V., Muir D.C.G. & Gabrielsen G.W. 2009. Persistent organic pollutants, heavy metals and parasites in the glaucous gull (*Larus hyperboreus*) on Spitsbergen. *Environmental Pollution 157*, 2282–2290.

Schytt V. 1983. Ymer-80: a Swedish expedition to the Arctic Ocean. *Geographical Journal 149*, 22–28.

Skreslet S. 1973. The ecosystem of the Arctic lake Nordlaguna, Jan Mayen Island. III. Ecology of Arctic char, *Salvelinus alpinus* (L.). *Astarte 6*, 43–54.

Verreault J., Gabrielsen G.W. & Bustnes J.O. 2010. The Svalbard glaucous gull as bioindicator species in the European Arctic: insight from 35 years of contaminants research. *Reviews of Environmental Contamination Toxicology 205*, 77–116.

Verreault J., Muir D.C.G., Norstrom R.J., Stirling I., Fisk A.T., Gabrielsen G.W., Derocher A.E., Evans T.J., Dietz R., Sonne C., Sandala G.M., Gebbink W., Riget F.F., Born E.W., Taylor M.K., Nagy J. & Letcher R.J. 2005. Chlorinated hydrocarbon contaminants and metabolites in polar bears (*Ursus maritimus*) from Alaska, Canada, East Greenland, and Svalbard: 1996–2002. *Science of the Total Environment 351*, 369–390.

Wania F. & Mackay D. 1996. Tracking the distribution of persistent organic pollutants. *Environmental Science & Technology 30*, 390A–396A.

Supplementary file for: Kylin H., Hammar J., Mowrer J., Bouwman H., Edelstam C., Olsson M. & Jensen S. 2015. Persistent organic pollutants in biota samples collected during the Ymer-80 expedition to the Arctic. *Polar Research 34.* Correspondence: Henrik Kylin, Henrik Kylin, Department of Thematic Studies—Environmental Change, Linköping University, SE-581 83 Linköping, Sweden. E-mail: henrik.kylin@liu.se

Supplementary material:

Additional information on material and methods

Sampling

Birds were shot with a narrow-gauge shotgun. In the west, except for one gull from Longyearbyen, eiders and gulls were taken at the mouth of Isfjorden around Kapp Linné, while guillemots were taken on Prins Karls Forland. In the north and east eiders were sampled around Kinnvika on Nordaustlandet, gulls at Kinnvika and Kongsøya and guillemots on Kongsøya and Hopen. The ringed seals were shot with rifles. One polar bear was found dead on the ice (emaciated with old skull injuries), the other drowned while under anaesthesia during sampling. Details of individual samples are kept on file at the Swedish Museum of Natural History (SMNH 2011) and summarized in Supplementary Table S1.

Indigenous populations of anadromous, resident and landlocked populations of Arctic char were sampled with gillnets of multiple mesh size in six lakes located along a gradient from Kapp Linné in the south-west, northwards along the west coast of Spitsbergen, the smaller islands of Danskøya and Amsterdamøya, and at Kinnvika and Prins Oscars Land on northern Nordaustlandet in the north-east (Fig. 1), using methods described by Hammar & Filipsson (1985). Supplementary samples of landlocked Arctic char were collected in 1981 from a Shetland loch as a southern and coastal reference in the North Atlantic Ocean. Detailed information on sampling strategies and sites are from Hammar (1982, 1991, 2000) and the field notes of Johan Hammar. Details for individual specimens are summarized in Supplementary Table S2.

Analysis

Extraction and analyses were performed as described by Jensen et al. (1983) with an additional fractionation step (Atuma et al. 1986). The extraction method was developed to extract similar amounts of lipid as the method of Bligh & Dyer (1959). In short: (1) extraction by macerating the samples in organic solvent; (2) determining lipid content; (3) removing lipids by treatment with either (i) concentrated sulphuric acid or (ii) potassium hydroxide (the latter allows determination of a wider range of cyclodienes); (4) separation after polarity using adsorption chromatography; (5) quantification by capillary column gas chromatography with electron capture detection (GC-ECD) using a Varian 3700 gas chromatograph (Varian, Mumbai, India), or, in the case of toxaphene and cyclodienes, by gas chromatography coupled to mass spectrometry (GC-MS) using a Finnigan 4500 spectrometer (Thermo Fisher Scientific, Waltham, MA, USA) using negative ion chemical ionization. GC-MS was also used to confirm results for other analytes if high backgrounds made quantification by GC-ECD difficult.

The analytical method and quality control/quality assurance followed the guidelines of the Swedish national environmental monitoring programme (SNEMP). The comparability of these data with other investigations is, therefore, similar to the comparability within the long environmental monitoring time series of SNEMP. Bignert et al. (1993) have analysed sources of variability in the SNEMP 1968-1990 time series for persistent organic pollutants (POPs) and can be referred to for information on the importance of biological variation vs. the variation in analytical chemical methods. Data from the intercalibration of different quantification methods used over time within the SNEMP time series was used to recalculate the 1980 data to become comparable to the 1971 data (Supplementary Table S8).

Specifically for polychlorinated biphenyl (PCB), 31 individual congeners were determined and the parameter ΣPCB was the sum of the concentrations of these 31 congeners. Standards of the individual organochlorine pesticides were from the US Environmental Protection Agency, while the individual PCB congeners were synthesized in-house (Sundström 1974).

To enable the determination of PCB and organochlorine pesticides in the presence of high concentrations of toxaphene, the extracts were fractionated on deactivated alumina (Atuma et al. 1986). This procedure yields three fractions containing approximately 5, 60 and 35% of the total toxaphene, respectively. Most of the other analytes elute to 100% within one of the three fractions, enabling identification and quantification by GC-ECD or GC-MS against a simplified toxaphene background. Supplementary Fig. S1 shows representative GC-MS chromatograms.

Polychlorinated terphenyls (PCT) were determined according to methods described by Renberg et al. (1978). The PCTs were determined as total-PCT (ΣPCT), the sum of *ortho*-, *meta*- and *para*-isomers of tetradecachloroterphenyl after perchlorination (isomer-specific data could not be reconstructed). For quantification the commercial product Aroclor 5460 was used as an external standard.

Note that detailed concentration data from one glaucous gull collected in 1979 and some other individual data have not been possible to recover. However, as these samples were analysed together with the other samples, the sum parameters should be comparable between all samples.

Principal component analysis

Principal component analyses (PCA) were used to compare pollutant patterns between samples and groups of samples, using MjM Software PC-ORD version 6.07 (www.pcord.com). PCA was done using correlation for the cross-products matrix, and a distance-based biplot was calculated for the response factors such as age and length. Compounds with no or few values above the limit of quantitation were excluded as they do not contribute towards co-occurrence from which patterns are inferred; the interest in the PCA is the patterns of co-occurrence of compounds, not the occurrence of rare compounds. Concentration data were relativized, i.e., the sum of the values per sample equals 1, and each value becomes a proportion of the sum of the total all concentrations of compounds in that sample. This allows comparisons of pollutant patterns between samples, the groups of samples represented by convex hulls in the Euclidean plane of the biplot. The data for polar bear and ringed seals were not included in the PCA because of few samples.

Other results of POPs in Svalbard biota from the early 1980s

Carlberg & Bøler (1985) report concentration data of some organochlorines and heavy metals in biota samples collected in western Svalbard in 1984. This investigation was done "In order to establish a background level of persistent chlorinated hydrocarbons and inorganic elements in biological material from Svalbard before a possible enhanced industrial activity in the area" (Carlberg & Bøler 1985, p. 2). Some of these samples (seals, fish, shrimps, ascidians) were analysed by Jacques Mowrer under the auspice of Sören Jensen, shortly after the Ymer-80 samples and using the same methods (Supplementary Table S9). Unfortunately, it is not possible to reconstruct the data at the same depth as for the Ymer-80 samples; critical documents on quality control/quality assurance (QA/QC) and chromatograms and integrator data are missing and it is not possible to reconstruct concentrations for individual PCB congeners.

A complication in interpreting the data is that, judging from saved hand-written result tables, Carlberg & Bøler (1985) do not present the original data; the data presented have been recalculated. The exact reason is not known, but it is noteworthy that Carlberg & Bøler (1985) also report data on POP concentrations in bird samples analysed in a different laboratory (Norheim & Kjos-Hanssen 1984). These data were produced with packed-column chromatography, and the quantification of PCB was based on one peak (CB153, 2,2',4,4',5,5'-hexachlorobiphenyl) only. It is possible, therefore, that the recalculations were done to make the data produced in the two laboratories comparable within the same report.

Direct comparison between the data from the Ymer-80 samples and the data presented by Carlberg & Bøler (1985) is meaningless. Although we cannot entirely vouch for the QA/QC procedures and that only the total PCB concentrations were determined, it is still worthwhile to present the original quantifications, i.e., the data before recalculation for the report by Carlberg & Bøler (1985). These "original" concentrations (Supplementary Table S9) should give a more relevant comparison with the Ymer-80 samples as well as other, more recently analysed samples. We also include data from two additional ringed seal samples that were not included by

Carlberg & Bøler (1985). However, we stress that critical information is missing and we cannot fully vouch for the accuracy of any of the data in Supplementary Table S9.

References

Atuma S.S., Jensen S., Mowrer J. & Örn U. 1986. Separation of lipophilic substances in environmental samples with special reference to toxaphene. *International Journal of Environmental Analytical Chemistry 24*, 213-225.

Bignert A., Göthberg A., Jensen S., Litzén K., Odsjö T., Olsson M., Reuthergårdh L. 1993. The need for adequate biological sampling in ecotoxicological investigation: a retrospective study of twenty years pollution monitoring. *Science of the Total Environment 128*, 121-139.

Bligh E.G., Dyer W.J. 1959. A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology* 37, 911-917

Carlberg G.E. & Bøler J.B. 1985. *Determination of persistent chlorinated hydrocarbons and inorganic elements in samples from Svalbard. Report 83 11 01-1.* Oslo: Centre for Industrial Research.

Edelstam C., Hammar J., Jensen S., Mowrer J. & Olsson M. 1987. Miljögifter i Polarhavet. Analysresultat från Ymer-expeditionen 1980. (Environmental pollutants in the Arctic Ocean. Results from the Ymer expedition 1980.) In G. Hoppe et al. (eds.): *Expeditionen Ymer-80: en slutrapport*. (*Expedition Ymer-80: a final report.)* Pp. 174-182. Stockholm: Swedish Royal Academy of Sciences.

Hammar J. 1982. Röding i Arktis. (Arctic char in the Arctic.) *Fauna och Flora 77,* 85-92.

Hammar J. 1991. Speciation processes in the High Arctic: hardly as simple as the environment might suggest. *International Society of Arctic Char Fanatics Information Series 5*, 73-88.

Hammar J. 2000. Cannibals and parasites: conflicting regulators of bimodality in high latitude Arctic char, *Salvelinus alpinus*. *Oikos 88*, 33-47.

Hammar J. & Filipsson O. 1985. Ecological test fishing with the Lundgren gillnets of multiple mesh size: the Drottningholm technique modified for Newfoundland Arctic char populations. *Institute of Freshwater Research, Drottningholm, Report 62,* 12-35.

Jensen S., Reutergårdh L. & Jansson B. 1983. Analytical methods for measuring organochlorines and methyl mercury by gas chromatography. *FAO Fisheries Technical Paper 212*, 21-33.

Norheim G. & Kjos-Hanssen B. 1984. Persistent chlorinated hydrocarbons and mercury in birds caught off the west coast of Spitsbergen. *Environmental Pollution Series A 33*, 143- 152.

Renberg L., Sundström G. & Reutergårdh L. 1978. Polychlorinated terphenyls (PCT) in Swedish white-tailed eagles and in grey seals—a preliminary study. *Chemosphere 7*, 477- 482.

SMNH 2011. Swedish Museum of Natural History, environmental specimen bank. Accessed on the internet at http://www.nrm.se/english/researchandcollections/environmentalresearchandmonitoring/environmentalspecimenbank.9000848_en.html visited on 4 October 2015.

Sundström G. 1974. *Studies on the synthesis of* ^{14}*C-labelled and unlabelled chlorobiphenyls: identification of chlorobiphenyls present in technical PCB mixtures and in human adipose tissue*. PhD thesis, Stockholm University.

Supplementary Table S1. Sample information for birds and mammals.

Sample No.	Sample code in specimen bank	Species	Sampling location[a]	Body mass (g)	Sex	Tissue	Sample mass (g)	Lipid mass (mg)	Lipid (%)
1	A80/6422	Brünnich's guillemot	Svalbard, Tømmerneset, Kongsøya	920	Male	Muscle	9.93	194.5	1.96
2	A80/6424	Brünnich's guillemot	Svalbard, Kinnvika	890	Male	Muscle	9.98	274.6	2.75
3	A80/6426	Brünnich's guillemot	N 80° 34’ 56” E 41° 34’ 10”	980	Female	Muscle	10.02	271.3	2.71
4	A80/6427	Brünnich's guillemot	Hopen, Beisaren, Hermanseuskardet	920	Male	Muscle	9.93	456.0	4.59
5	A80/6401	Glaucous gull	Svalbard, Kapp Koburg, Kongsøya	1880	Missing	Muscle	9.98	434.1	4.35
6	A80/6454	Glaucous gull	Svalbard, Kinnvika, Claravågen	1605	Missing	Muscle	9.93	310.7	3.13
7	A80/5117 (MA2)	Polar bear[b]	N 81° 00’ E 30° 00’	95000	Male	Muscle	9.96	76.5	0.77
8	MA3	Polar bear[c]	N 80° 09’ E 30° 00’	470000	Male	Muscle	9.99	132.7	1.33
9	A80/6428	Common eider	Svalbard, Kinnvika	2135	Female	Muscle	10.00	303.9	3.04
10	A80/6429	Common eider	Svalbard, Kinnvika	1662	Female	Muscle	9.99	176.4	1.77
11	A80/6430	Common eider	Svalbard, Kinnvika	1955	Female	Muscle	10.21	310.0	3.04
12	A806431	Common eider	Svalbard, Kinnvika	2300	Female	Muscle	9.87	435.0	4.41
13	A80/6432	Common eider	Svalbard, Kinnvika	1875	Female	Muscle	9.96	187.0	1.88
14	C82/6150	Brünnich's guillemot	Svalbard, Prins Karls Forland	Missing	Missing	Muscle	4.89	141.5	2.89
15	C82/6151	Brünnich's guillemot	Svalbard, Prins Karls Forland	Missing	Missing	Muscle	2.03	61.2	3.01
16	C82/6152	Brünnich's guillemot	Svalbard, Prins Karls Forland	Missing	Missing	Muscle	3.71	85.1	2.29
17	C82/6253	Brünnich's guillemot	Svalbard, Prins Karls Forland	Missing	Missing	Muscle	3.14	90.4	2.88
18	C82/6154	Brünnich's guillemot	Svalbard, Prins Karls Forland	Missing	Missing	Muscle	3.78	102.8	2.72
19	C82/6155	Common eider	Svalbard, Kapp Linné	Missing	Missing	Muscle	4.06	138.5	3.41
20	C82/6156	Common eider	Svalbard, Kapp Linné	Missing	Missing	Muscle	5.42	176.4	3.25
21	C82/6157	Common eider	Svalbard, Kapp Linné	Missing	Missing	Muscle	4.06	125.9	3.10
22	C82/6158	Common eider	Svalbard, Kapp Linné	Missing	Missing	Muscle	4.15	102.4	2.47
23	C82/6159	Common eider	Svalbard, Kapp Linné	Missing	Missing	Muscle	5.45	109.6	2.01
24	C82/6160	Glaucous gull	Svalbard, Kapp Linné	Missing	Missing	Muscle	3.17	142.4	4.49
25	C82/6161	Glaucous gull	Svalbard, Kapp Linné	Missing	Missing	Muscle	2.97	226.6	7.63
26	C82/6162	Glaucous gull	Svalbard, Kapp Linné	Missing	Missing	Muscle	4.30	371.5	8.64
27	C82/6163	Glaucous gull	Svalbard, Kapp Linné	Missing	Missing	Muscle	4.30	361.5	8.41
28	C82/6164	Glaucous gull	Svalbard, Kapp Linné	Missing	Missing	Muscle	2.90	127.2	4.39
29	Missing	Glaucous gull[d]	Svalbard, Longyearbyen	Missing	Missing	Muscle	Missing	Missing	Missing
30	C81/6011	Common guillemot[e]	Stora Karlsö, C Baltic	940	Female	Muscle	10.07	337.1	3.35
31	C81/6012	Common guillemot[e]	Stora Karlsö, C Baltic	920	Male	Muscle	10.34	319.0	3.09
32	A81/5012	Ringed seal	Svalbard, N 81° 50’ E 26° 33’	28000	Male	Blubber	5.00	4786.6	95.73
33	C81/5101	Ringed seal	Svalbard, Kongsfjorden	58000	Male	Blubber	5.01	4521.2	90.24

[a] Location as given in the files of the Swedish Natural History Museum. [b] Found dead with skull injuries. Probably starved to death. [c] Drowned at sampling. [d] Sample collected 1979. [e] Samples 30 and 31 were included in the survey for comparison with the Arctic samples. [f] Sample collected 1981.

Supplementary Table S2. Sample information for Arctic char.

Sample no.	Lake	Longitude	Latitude	General System	Date	Individual life history	Length (cm)	Mass (g)	Sex	Age	Lipid (%)
Svalbard											
3	Linnévatn	78° 05’ 17” N	13° 51’ 20” E	Anadromous	1980-09-09	Smolt	24.6	95	M	12	1.04
4	Linnévatn	78° 05’ 17” N	13° 51’ 20” E	Anadromous	1980-09-09	Smolt	26.2	137	F	7	2.18
6	Linnévatn	78° 05’ 17” N	13° 51’ 20” E	Anadromous	1980-09-09	Smolt	20.0	56	M	11	0.372
7	Linnévatn	78° 05’ 17” N	13° 51’ 20” E	Anadromous	1980-09-09	Resident	14.6	19	F	9	2.35
12	Linnévatn	78° 05’ 17” N	13° 51’ 20” E	Anadromous	1980-09-09	Resident	13.8	17	F	7	1.5
13	Linnévatn	78° 05’ 17” N	13° 51’ 20” E	Anadromous	1980-09-09	Resident	13.6	13	M	7	0.987
4	Diesetvatn	79° 06’ 34” N	11° 25’ 59” E	Anadromous	1979-07-22	Anadromous	48.8	Missing	F	9	2.99
5	Diesetvatn	79° 06’ 34” N	11° 25’ 59” E	Anadromous	1979-07-22	Anadromous	42.7	Missing	F	8	4.34
6	Jensenvatn	79° 42’ 20” N	10° 51’ 10” E	Landlocked	1979-07-29	Resident	51.0	1260	M	13	5.19
7	Jensenvatn	79° 42’ 20” N	10° 51’ 10” E	Landlocked	1979-07-29	Resident	44.0	980	F	11	5.65
8	Jensenvatn	79° 42’ 20” N	10° 51’ 10” E	Landlocked	1979-07-29	Resident	38.4	590	M	7	11.6
9	Jensenvatn	79° 42’ 20” N	10° 51’ 10” E	Landlocked	1979-07-29	Resident	57.5	1910	M	17	1.99
10	Jensenvatn	79° 42’ 20” N	10° 51’ 10” E	Landlocked	1979-07-29	Resident	58.3	1990	M	16	3.69
11	Jensenvatn	79° 42’ 20” N	10° 51’ 10” E	Landlocked	1979-07-29	Resident	59.0	1800	M	19	2.27
61	Annavatn	79° 45’ 43” N	10° 43’ 26” E	Landlocked	1981-08-23	Resident	39.2	490	F	22	2.82
62	Annavatn	79° 45’ 43” N	10° 43’ 26” E	Landlocked	1981-08-23	Resident	39.0	462	F	21	1.71
63	Annavatn	79° 45’ 43” N	10° 43’ 26” E	Landlocked	1981-08-23	Resident	39.6	562	M	19	2.38
64	Annavatn	79° 45’ 43” N	10° 43’ 26” E	Landlocked	1981-08-23	Resident	34.9	364	F	21	3.03
65	Annavatn	79° 45’ 43” N	10° 43’ 26” E	Landlocked	1981-08-23	Resident	40.6	512	M	19	1.76
203	Wibjørnvatn	80° 03’ 44” N	18° 15’ 39” E	Landlocked	1980-08-20	Resident	43.3	500	M	21	2.79
205	Wibjørnvatn	80° 03’ 44” N	18° 15’ 39” E	Landlocked	1980-08-20	Resident	42.2	520	M	19	6.03
206	Wibjørnvatn	80° 03’ 44” N	18° 15’ 39” E	Landlocked	1980-08-20	Resident	41.1	440	M	26	3.75
207	Wibjørnvatn	80° 03’ 44” N	18° 15’ 39” E	Landlocked	1980-08-20	Resident	38.5	370	M	20	2.96
209	Wibjørnvatn	80° 03’ 44” N	18° 15’ 39” E	Landlocked	1980-08-20	Resident	39.4	410	F	18	3.84
210	Wibjørnvatn	80° 03’ 44” N	18° 15’ 39” E	Landlocked	1980-08-20	Resident	36.6	300	M	19	4.05
211	Wibjørnvatn	80° 03’ 44” N	18° 15’ 39” E	Landlocked	1980-08-20	Resident	41.7	340	M	22	1.6
12	Arkvatn	80° 28’ 32” N	22° 49’ 42” E	Anadromous	1980-08-16	Smolt?	28.8	160	M	16	3.2
13	Arkvatn	80° 28’ 32” N	22° 49’ 42” E	Anadromous	1980-08-16	Smolt?	28.9	156	F	19	2.79
14	Arkvatn	80° 28’ 32” N	22° 49’ 42” E	Anadromous	1980-08-16	Smolt?	28.4	150	F	16	2.8
15	Arkvatn	80° 28’ 32” N	22° 49’ 42” E	Anadromous	1980-08-16	Smolt?	29.6	198	M	18	2.27
16	Arkvatn	80° 28’ 32” N	22° 49’ 42” E	Anadromous	1980-08-16	Smolt?	29.5	150	M	15	1.65
17	Arkvatn	80° 28’ 32” N	22° 49’ 42” E	Anadromous	1980-08-16	Resident?	18.9	54	M	11	3.22
18	Arkvatn	80° 28’ 32” N	22° 49’ 42” E	Anadromous	1980-08-16	Resident?	12.8	14	M	7	4.59
19	Arkvatn	80° 28’ 32” N	22° 49’ 42” E	Anadromous	1980-08-16	Resident?	15.4	25	F	13	3.09
Shetland											
1	Girlsta Loch	60° 15’ N	01° 13’ W	Landlocked	1981-04-29	Resident	21.7	70	F	5	0.99
2	Girlsta Loch	60° 15’ N	01° 13’ W	Landlocked	1981-04-29	Resident	25.5	102	M	9	0.78
3	Girlsta Loch	60° 15’ N	01° 13’ W	Landlocked	1981-04-29	Resident	22.7	84	M	6	0.82
4	Girlsta Loch	60° 15’ N	01° 13’ W	Landlocked	1981-04-29	Resident	22.6	78	F	6	0.79
5	Girlsta Loch	60° 15’ N	01° 13’ W	Landlocked	1981-04-29	Resident	21.7	74	F	5	1.00

Supplementary Table S3a. Scientific names of the analytes.

Common name / abbreviation	Systematic name	CAS no.
Aldrin	(1*R*,4*S*,4a*S*,5*S*,8*R*,8a*R*)-1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4:5,8-dimethanonaphthalene	309-00-2
α-Chlordane	1-Exo,2-exo,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene	5103-71-9
γ-Chlordane	1-Exo,2-endo,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-4,7-methanoindene	5566-34-7
α-Chlordene	1,2,3,5,7,8-hexachloro-1,3a,4,5,6,6a hexahydro-, (1α,3aα,4β,5α,6aα)-1,4-ethenopentalene	56534-02-2
γ-Chlordene	2,3,3a,4,5,8-hexachloro-3a,6,7,7a-tetrahydro-(1α,3aβ,6α,7aβ,8*R**)-1,6-methano-1H-indene	97906-34-8
o,p'-DDD	1,1-dichloro-2-(2-chlorophenyl)-2-(4-chlorophenyl)ethane	53-19-0
p,p'-DDD	1,1-dichloro-2,2-bis(4-chlorophenyl)ethane	72-54-8
o,p'-DDE	1,1-dichloro-2-(2-chlorophenyl)-2-(4-chlorophenyl)ethene	3424-82-9
p,p'-DDE	1,1-dichloro-2,2-bis(4-chlorophenyl)ethene	72-55-9
o,p'-DDT	1,1,1-trichloro-2-(2-chlorophenyl)-2-(4 chlorophenyl)ethane	789-02-6
p,p'-DDT	1,1,1-trichloro-2,2-bis(4-chlorophenyl)ethane	50-29-3
Dieldrin	(1*R*,4*S*,4a*S*,5*R*,6*R*,7*S*,8*S*,8a*R*)-1,2,3,4,10,10-hexachloro-1,4,4a,5,6,7,8,8a-octahydro- 6,7-epoxy-1,4:5,8-dimethanonaphthalene	60-57-1
Endrin	(1*R*,4*S*,4a*S*,5*S*,6*S*,7*R*,8*R*,8a*R*)-1,2,3,4,10,10-hexachloro-1,4,4a,5,6,7,8,8a-octahydro-6,7-epoxy-1,4:5,8-dimethanonaphthalene	72-20-8
HCB	Hexachlorobenzene	118-74-1
α-HCH	1α,2α,3β,4α,5β,6β-hexachlorocyclohexane	319-84-6
β-HCH	1α,2β,3α,4β,5α,6β-hexachlorocyclohexane	319-85-7
γ-HCH (lindane)	1α,2α,3β,4α,5α,6β-hexachlorocyclohexane	58-89-9
δ-HCH	1α,2α,3α,4α,5α,6β-hexachlorocyclohexane	319-86-8
Heptachlor	1,4,5,6,7,8,8-Heptachloro-3a,4,7,7a-tetrahydro-4,7-methano-1*H*-indene	76-44-8
Heptachlor-epoxide	2,3,4,5,6,7,7-heptachloro-1a,1b,5,5a,6,6a-hexahydro-(1aα,1bβ,2α,5α,5aβ,6β,6aα)-2,5-methano-2H-indeno [1,2-b]oxirene	1024-57-3
Methoxychlor	1,1,1-trichloro-2,2-bis(4-methoxyphenyl)ethane	72-43-5
Mirex	1,1a,2,2,3,3a,4,5,5,5a,5b,6-dodecachlorooctahydro-1H-1,3,4-(methanetriyl)cyclobuta[cd]pentalene	2385-85-5
PCB	Polychlorinated biphenyls [a]	
PCT	Polychlorinated terphenyls [b]	
Toxaphene	Polychlorinated camphene [b]	
Trans-nonachlor	1,2,3,4,5,6,7,8,8-nonachloro-2,3,3a,4,7,7a-hexahydro-4,7-methano-1H-indene	39765-80-5

[a] The structure of the individual congeners quantified are given in Supplementary Table S3b. [b] Individual congeners were not analysed, concentrations are given based on a technical standard. See Renberg et al. 1978 (PCT) and Atuma et al. 1986 (toxaphene).

Supplementary Table S3b. Structures of individual PCB congeners included in this study.

Congener no.	Structure	CAS no.	Vector in PCA plots
CB44	2,2′3,5′-Tetrachlorobiphenyl,	41464-39	4b
CB52	2,2',5,5'-Tetrachlorobiphenyl	35693-99-3	4a
CB64	2,3,4',6-Tetrachlorobiphenyl	52663-58-8	4c
CB70	2,3',4',5-Tetrachlorobiphenyl	32598-11-1	4d
CB84	2,2',3,3',6-Pentachlorobiphenyl	52663-60-2	5c
CB87	2,2',3,4,5'-Pentachlorobiphenyl	38380-02-8	5g
CB92	2,2',3,5,5'-Pentachlorobiphenyl	52663-61-3	5b
CB95	2,2',3,5',6-Pentachlorobiphenyl	38379-99-6	5a
CB97	2,2'3',4,5-Pentachlorobiphenyl	41464-51-1	5f
CB99	2,2',4,4',5-Pentachlorobiphenyl	38380-01-7	5e
CB101	2,2',4,5,5'-Pentachlorobiphenyl	37680-73-2	5d
CB105	2,3,3',4,4'-Pentachlorobiphenyl	32598-14-4	5j
CB110	2,3,3',4',6-Pentachlorobiphenyl	38380-03-9	5h
CB118	2,3',4,4',5-Pentachlorobiphenyl	31508-00-6	5i
CB128	2,2',3,3',4,4'-Hexachlorobiphenyl	38380-07-3	6e
CB135	2,2',3,3',5,6'-Hexachlorobiphenyl	52744-13-5	6a
CB138	2,2',3,4,4',5'-Hexachlorobiphenyl	35065-28-2	6d
CB149	2,2',3,4',5',6-Hexachlorobiphenyl	38380-04-0	6b
CB153	2,2',4,4',5,5'-Hexachlorobiphenyl	35065-27-1	6c
CB156	2,3,3',4,4',5-Hexachlorobiphenyl	38380-08-4	6g
CB167	2,3',4,4',5,5'-Hexachlorobiphenyl	52663-72-6	6f
CB170	2,2',3,3',4,4',5-Heptachlorobiphenyl	35065-30-6	7g
CB171	2,2', 3,3',4,4',6-Heptachlorobiphenyl	52663-71-5	7d
CB172	2,2',3,3',4,5,5'-Heptachlorobiphenyl	52663-74-8	7e
CB177	2,2',3,3',4,5',6'-Heptachlorobiphenyl	52663-70-4	7c
CB180	2,2',3,4,4',5,5'-Heptachlorobiphenyl	35065-29-3	7f
CB183	2,2',3,4,4',5',6-Heptachlorobiphenyl	52663-69-1	7b
CB187	2,2',3,4',5,5',6-Heptachlorobiphenyl	52663-68-0	7a
CB196	2,2',3,3',4,4',5,6'-Octachlorobiphenyl	42740-50-1	8b
CB199	2,2',3,3',4,5,5',6'-Octachlorobiphenyl	52663-75-9	8a
CB209	Decachlorobiphenyl	2051-24-3	10a

Supplementary Table S4a. Concentrations (μg g^{-1} lipid) of HCB, individual PCB congeners and PCT in birds and mammals. PCB congeners are listed in elution order. "PCA id" refers to sample identification in Fig. 2.

Species Sample no. / PCA id.	Region	HCB	52	44	64	70	95	92	84	101	99	97	87	110	135	149	118	153	105	138	187	183	128	167	177	171	156	172	180	170	199	196	209	ΣPCB	ΣPCT
Brünnich's guillemot																																			
1 / BG1	N/E	0.70	–[b]	–	–	–	0.77	–	–	tr	0.46	–	–	–	–	–	1.5	2.8	–	2.1	1.5	0.23	–	0.22	–	–	0.43	0.45	2.1	0.71	0.81	0.56	0.13	15	–
2 / BG2		0.35	–	–	–	–	–	–	–	0.09	0.32	–	–	–	–	–	0.78	1.3	–	1.2	0.46	0.05	–	0.06	0.04	0.13	–	0.06	0.59	0.18	0.07	0.05	tr	5.4	–
3 / BG3		0.40	–	–	–	–	0.46	–	–	0.09	0.31	–	–	–	–	–	0.63	1.0	–	0.53	0.4	0.10	–	0.07	0.04	–	0.11	0.06	0.49	0.17	0.09	0.07	tr	4.7	–
4 / BG4		3.0	–	–	–	–	2.2	–	–	0.50	1.3	–	–	–	0.05	–	3.2	4.1	–	3.6	1.3	0.14	–	0.17	0.16	–	0.39	0.19	1.5	0.48	0.18	0.14	tr	20	–
14 / BG5	W	0.24	–	–	–	–	0.15	–	–	0.05	0.11	–	–	–	–	–	0.16	0.29	–	0.24	0.07	–	–	0.01	–	–	–	0.01	0.12	0.04	0.01	0.01	–	1.3	–
15 / BG6		0.27	–	–	–	–	tr	–	–	0.07	0.14	–	–	–	–	–	0.18	0.36	–	0.32	0.11	–	–	–	–	–	–	–	0.15	0.06	0.02	–	–	1.4	–
16 / BG7		0.23	tr[c]	–	–	–	0.79	–	–	0.10	0.38	–	–	–	0.01	–	1.0	1.5	–	1.2	0.67	0.13	–	0.10	0.05	–	0.14	0.11	0.68	0.24	0.14	0.10	0.02	7.4	–
17 / BG8		0.13	–	–	–	–	tr	–	–	tr	0.06	–	–	–	–	–	0.06	0.18	–	0.15	0.07	0.02	–	0.02	–	–	0.02	0.01	0.09	0.03	0.02	0.01	–	0.74	–
18 / BG9		1.1	tr	–	–	–	0.5	–	–	0.07	0.29	–	0.03	–	–	–	0.60	0.86	–	0.80	0.23	0.30	–	0.04	0.03	–	0.07	0.03	0.32	0.1	0.04	0.03	–	4.3	–
Glaucous gull																																			
5 / GG1	N/E	1.3	tr	–	0.36	–	–	–	–	1.5	5.0	–	0.34	–	0.39	–	8.6	25	–	19	3.9	2.8	0.32	–	0.26	–	1.8	0.92	20	5.3	0.83	1.8	0.25	98	–
6 / GG2		0.50	tr	–	0.34	–	0.3	–	–	0.24	0.30	–	0.03	–	0.03	–	0.55	1.4	–	0.92		0.13	0.09	–	0.02	–	0.10	0.05	0.70	0.18	0.07	0.1	0.01	5.5	–
24 / GG3	W	3.1	tr	–	–	–	3.9	–	–	1.8	4.1	–	0.41	–	0.23	–	11	25	–	18	2.5	2.6	tr	0.79	tr	–	2.4	0.67	23	5.3	0.90	2.6	0.42	110	35
25 / GG4		2.3	tr	–	–	–	2.5	–	–	1.9	3.0	–	0.33	–	0.23	–	6.1	15	–	12	3.8	1.0	0.30	0.28	0.31	–	1.3	0.81	10	2.8	1.1	1.2	0.23	65	20
26 / GG5		1.2	tr	–	–	–	1.7	–	–	1.0	2.1	–	–	–	0.18	–	3.6	9.3	–	6.9	1.5	1.0	0.69	–	tr	–	0.77	0.42	5.9	1.6	0.50	0.75	tr	38	14
27 / GG6		1.4	tr	–	–	–	2.4	–	–	1.1	2.7	–	0.25	–	0.26	–	5.0	10	–	8.2	1.6	0.58	1.0	–	tr	–	0.85	0.34	5.1	1.6	0.30	0.52	tr	42	29
28 / GG7		5.3	tr	–	–	–	12	0.49	–	4.8	11	0.34	1.2	–	0.38	–	31	27	–	29	5.2	2.0	1.3	1.5	0.49	–	3.0	0.99	13	4.0	1.1	1.2	0.18	150	17
29		3.2	M[d]	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	65	M
Common eider																																			
9 / CE1	N/E	0.09	–	–	–	–	0.08	–	–	0.11	0.09	–	–	–	0.01	–	0.22	–	–	0.37	0.11	–	–	0.01	0.02	0.04	–	0.02	0.22	0.07	0.02	0.02	–	1.4	–
10 / CE2		0.12	–	–	–	–	–	–	–	0.14	0.05	–	–	–	0.01	–	0.04	0.66	–	0.23	–	0.08	–	0.03	0.02	0.03	–	0.02	0.44	0.09	0.03	0.05	–	1.9	–
11 / CE3		0.18	–	–	–	–	–	–	–	0.08	0.04	–	–	–	–	–	0.07	0.19	–	0.13	0.05	0.02	–	–	0.01	0.01	–	0.01	0.11	0.04	0.02	0.02	–	0.80	–
12 / CE4		0.07	–	–	–	–	–	–	–	0.06	0.03	–	–	–	–	–	0.07	0.15	–	0.11	0.04	0.01	–	–	–	–	0.01	–	0.05	0.01	–	0.01	–	0.55	–
13 / CE5		0.11	–	–	–	–	–	–	–	0.05	0.02	–	–	–	–	–	0.03	0.11	–	0.06	0.03	0.01	0.01	–	–	–	0.01	–	0.05	0.01	0.01	0.01	–	0.41	–
19 / CE6	W	0.15	0.12	0.08	–	0.13	0.60	0.07	–	0.33	0.11	0.09	0.13	0.26	0.03	–	0.41	0.67	–	0.48	0.15	0.07	0.03	0.04	0.03	–	0.05	0.01	0.27	0.06	0.03	0.03	tr	4.3	12
20 / CE7		0.14	0.16	0.09	–	0.15	0.71	0.11	–	0.27	0.15	0.10	0.16	0.3	0.02	–	0.34	0.35	–	0.33	0.08	0.03	0.06	–	0.02	–	0.04	0.01	0.12	0.04	0.04	0.05	0.10	3.8	29
21 / CE8		0.09	0.12	–	–	0.10	0.52	0.07	–	0.19	0.09	0.08	0.11	0.22	0.02	–	0.18	0.15	–	0.18	0.04	0.01	0.02	–	tr	–	0.02	0.01	0.05	–	0.08	0.07	tr	2.3	8.0
22 / CE9		0.06	0.16	–	–	0.16	tr	0.09	–	0.26	0.14	0.12	0.18	0.32	0.04	–	tr	0.21	–	0.28	0.06	0.01	tr	–	tr	–	0.05	–	0.07	0.03	0.11	0.07	tr	2.4	15
23 / CE10		0.08	0.15	–	–	tr	0.72	–	0.07	0.25	0.09	0.10	0.15	0.18	0.02	–	0.28	0.25	–	0.25	0.06	0.02	tr	0.03	tr	–	0.04	0.01	0.10	0.04	0.04	0.03	0.03	2.9	21
Ringed seal																																			
32	N/E	0.02	0.12	–	0.26	–	0.07	–	0.06	0.76	0.21	0.01	0.01	–	0.02	–	0.07	0.61	–	0.42	0.14	0.05	–	–	0.02	0.01	–	0.01	0.25	0.01	0.02	0.02	–	3.2	–
33		0.01	0.07	–	0.33	–	0.04	–	0.04	0.33	–	–	0.01	–	–	–	0.08	0.31	–	0.16	0.06	0.02	–	0.01	0.01	0.01	–	0.01	0.10	–	0.01	0.01	–	1.6	–
Polar bear																																			
7[a]	N/E		–	–	–	–	–	–	–	14	17	–	–	–	1.1	–	–	110	–	9.7	–	0.93	–	–	–	–	–	–	89	39	–	–	0.68	280	–
8		0.06	–	–	–	–	–	–	–	0.26	0.20	–	–	–	0.01	–	–	1.2	–	0.04	–	–	–	–	–	–	–	–	1.0	0.62	–	–	–	3.5	–

[a] Found dead and emaciated with skull injuries. [b] – Concentration below the limit of detection (≤ 0.003 μg g^{-1} lipid). [c] tr – trace amounts, i.e., between the limit of detection and limit of quantification (0.003 μg g^{-1} lipid ≤ tr < 0.01 μg g^{-1} lipid).
[d] M – missing data.

Supplementary Table S4b. Concentrations (µg g^{-1} lipid) of chlorinated pesticides in birds and mammals. "PCA id" refers to sample identification numbers in Fig. 2.

Species	Region	HCH				Dieldrin	Endrin	Aldrin	Heptachlor	Heptachlor	Chlordene		Chlordane			*Trans-*	ΣChlor-	Methoxy-	DDE		DDD		DDT		ΣDDT	Mirex	Toxaphene
Sample no / PCA id		α-	β-	γ-	δ-					epoxide	α-	γ-	Oxy-	γ-	α-	Nonachlor	danes	chlor	*o,p'-*	*p,p'-*	*o,p'-*	*p,p'-*	*o,p'-*	*p,p'-*			
Brünnich's guillemot																											
1 / BG1	N/E	–[b]	0.02	0.01	–	NQ[d]	NQ	–	–	NQ	–	–	0.11	0.01	–	0.01	0.13	0.03	–	8.0	–	–	–	0.02	8.1	–	M
2 / BG2		–	tr	–	–	NQ	NQ	–	–	NQ	–	–	0.12	–	–	0.03	0.15	–	–	3.5	–	0.05	–	–	3.5	–	M
3 / BG3		0.02	tr	–	–	NQ	NQ	–	–	NQ	–	–	0.14	0.02	0.03	0.04	0.23	–	–	3.1	–	0.04	–	–	3.1	–	M
4 / BG4		0.03	0.15	–	–	NQ	NQ	–	–	NQ	–	0.03	0.73	0.08	0.06	0.20	1.1	0.08	–	12	–	–	–	–	12	0.02	M
14 / BG5	W	0.02	–	–	–	NQ	NQ	–	–	NQ	0.02	–	0.10	–	0.02	0.02	0.16	–	–	0.98	–	–	–	–	0.98	–	M
15 / BG6		0.03	–	–	–	NQ	NQ	–	–	NQ	0.13	–	0.15	–	–	–	0.28	–	–	1.4	–	–	–	–	1.4	–	M
16 / BG7		–	–	–	–	NQ	NQ	–	–	NQ	–	–	0.28	–	–	–	0.28	–	–	3.7	–	–	–	–	3.7	–	M
17 / BG8		–	–	–	–	NQ	NQ	–	–	NQ	–	–	0.02	–	–	–	0.02	–	–	0.51	–	–	–	–	0.51	–	M
18 / BG9		–	–	–	–	NQ	NQ	–	–	NQ	–	–	0.15	–	–	–	0.15	–	–	2.3	–	0.05	–	–	2.4	–	M
Glaucous gull																											
5 / GG1	N/E	–	0.13	–	–	NQ	NQ	–	tr	NQ	tr	–	1.6	0.14	–	0.25	1.9	0.03	–	27	–	0.41	–	tr	27	–	M
6 / GG2		–	0.04	–	–	NQ	NQ	–	tr	NQ	0.07	–	0.29	–	–	0.06	0.42	–	–	3.1	–	0.11	–	tr	3.2	–	M
24 / GG3	W	–	tr	–	–	1.6	tr	–	0.56	2.1	0.02	0.03	1.7	0.06	–	0.12	4.6	0.07	–	34	–	0.24	–	0.09	34	–	M
25 / GG4		–	0.09	–	–	0.73	–	–	0.23	1.1	tr	–	1.5	0.08	0.03	–	2.9	–	–	33	–	0.52	–	tr	33	–	M
26 / GG5		–	tr	–	–	tr	–	–	0.12	1.5	tr	–	1.3	0.08	–	0.31	3.4	–	–	20	–	0.18	–	tr	20	–	M
27 / GG6		–	0.20	–	–	tr	–	–	tr	1.8	0.08	–	2.1	0.20	–	0.88	5.0	–	–	24	–	0.84	–	0.12	25	–	M
28 / GG7		0.01	0.24	–	–	1.8	tr	–	0.42	2.3	tr	–	2.7	0.30	–	0.90	6.7	–	–	38	–	1.1	–	0.11	39	0.04	M
29		0.75	4.2	–	–	M[e]	M	M	M	M	M	M	M	M	M	M	M	M	–	26	–	–	–	0.12	26	M	M
Common eider																											
9 / CE1	N/E	–	–	–	–	NQ	NQ	–	–	NQ	0.05	–	tr	–	–	0.02	0.07	–	–	0.98	–	0.07	–	–	1.1	–	M
10 / CE2		0.04	–	–	–	NQ	NQ	–	–	NQ	0.01	–	0.10	0.01	–	0.02	0.14	–	–	0.94	–	0.03	–	–	0.97	–	M
11 / CE3		0.06	–	–	–	NQ	NQ	–	–	NQ	–	–	0.06	–	–	0.02	0.08	–	–	0.46	–	0.03	–	–	0.49	–	M
12 / CE4		–	–	–	–	NQ	NQ	–	–	NQ	–	–	0.03	–	–	0.02	0.05	–	–	0.38	–	0.03	–	–	0.41	–	M
13 / CE5		–	–	–	–	NQ	NQ	–	–	NQ	–	–	0.03	–	–	0.01	0.04	–	–	0.24	–	0.02	–	–	0.26	–	M
19 / CE6	W	tr[c]	tr	–	–	tr	–	–	0.12	0.34	–	–	0.10	–	–	0.25	0.81	0.07	–	1.0	–	0.05	–	0.01	1.1	–	M
20 / CE7		0.05	tr	–	–	0.02	–	–	0.12	1.1	0.18	0.27	0.83	0.21	0.01	0.32	3.0	0.16	–	0.47	–	0.04	–	0.02	0.53	–	M
21 / CE8		–	–	–	–	0.06	–	–	0.06	1.5	0.12	0.19	1.4	0.08	0.01	0.01	3.4	–	–	0.18	–	0.02	–	0.02	0.22	–	M
22 / CE9		–	–	–	–	tr	–	–	0.03	0.82	0.04	–	0.92	0.03	–	0.04	1.9	0.17	–	0.17	–	0.03	–	tr	0.20	–	M
23 / CE10		–	tr	–	–	tr	–	–	0.01	0.23	–	–	0.48	–	–	0.02	0.74	0.10	–	0.33	–	0.03	–	tr	0.36	–	M
Ringed seal																											
32	N/E	0.06	–	–	–	NQ	NQ	–	–	NQ	–	–	0.34	0.03	0.09	0.88	1.3	–	–	0.08	–	–	–	0.91	0.99	–	M
33		0.03	–	–	–	NQ	NQ	–	–	NQ	–	–	0.09	–	–	0.11	0.20	–	–	0.06	–	0.26	–	0.29	0.61	–	M
Polar bear																											
7[a]	N/E	–	–	–	–	16	–	–	0.66	10	–	–	8.6	0.58	–	–	20	–	M	M	M	M	M	M	–	–	M
8		0.02	–	–	–	NQ	NQ	–	–	NQ	0.06	–	0.11	0.01	–	0.05	0.23	–	–	0.33	–	0.04	–	0.03	0.40	–	M

[a] Found dead and emaciated with skull injuries. [b] – Concentration below the limit of detection (≤ 0.003 µg g^{-1} lipid). [c] tr – trace amounts, i.e., between the limit of detection and limit of quantification (0.003 µg g^{-1} lipid ≤ tr < 0.01 µg g^{-1} lipid).
[d] NQ – not quantified. [e] M – missing data.

Supplementary Table S5a. Concentrations (µg g^{-1} lipid) of individual PCB congeners in Arctic char samples. The congeners are listed in elution order. "PCA id" refers to sample identification numbers in Fig. 3 and Supplementary Figs. S2, S3 and S4.

Lake Sample no / PCA id	52	44	64	70	95	92	84	101	99	97	87	110	135	149	118	153	105	138	187	183	128	167	177	171	156	172	180	170	199	196	209	ΣPCB
Linnévatn																																
3 S[a] / Ln3	0.14	0.09	–	0.13	0.61	0.08	–	0.32	0.14	0.07	0.15	0.28	0.01	–	0.41	0.66	–	0.50	0.13	0.05	0.02	0.05	0.03	–	0.04	–	0.23	0.03	0.01	0.02	–	4.2
4 S / Ln4	0.12	–[d)]	–	0.08	0.28	0.03	–	0.19	0.04	–	0.11	0.22	–	–	0.15	0.11	–	0.16	0.02		0.01	–	–	–	–	0.01	0.05	0.02	–	–	–	1.6
6 S / Ln6	0.72	0.16	–	0.26	1.2	0.14	–	0.66	0.27	0.18	0.26	0.52	0.08	–	0.82	1.5	–	0.96	0.30	0.14	0.09	0.08	0.06	–	0.20	0.06	0.64	0.24	0.06	0.05	0.05	9.7
7 R[b] / Ln7	0.03	0.01	–	0.01	0.07	0.01	–	0.03	0.01	–	0.02	0.04	–	–	0.05	0.08	–	0.06	0.01	–	–	–		–	–	–	0.03	0.01	–	–	–	0.47
12 R / Ln12	0.05	–	–	0.01	0.10	0.02	–	0.07	–	0.01	0.01	0.06	–	–	0.04	0.18	–	0.10	0.02	0.01	–	–	0.01	–	0.01	–	0.03	–	–	–	–	0.73
13 R / Ln13	0.07	0.01	–	0.03	0.12	0.01	–	0.07	0.03	0.02	0.03	0.05	0.01	–	0.08	0.15	–	0.10	0.03	0.01	–	–	0.01	–	0.02	0.01	0.06	0.02	–	–	–	0.94
Diesetvatn																																
4 A[c] / Di4	0.01	0.01	–	0.01	0.04	–	–	0.02	0.01	–	0.01	0.02	–	–	0.03	0.04	–	0.03	0.01	–	–	–	–	–	–	–	0.02	0.01	–	–	–	0.27
5 A / Di5	0.04	–	–	0.01	0.04	–	–	0.02	0.01	0.01	0.01	0.04	–	–	0.03	0.05	–	0.03	0.02	–	–	–	–	–	–	–	0.02	0.01	–	–	–	0.34
Jensenvatn																																
6 R / Je6	0.23	–	–	–	0.38	0.01	–	0.15	0.34	–	0.04	–	0.01	–	1.0	0.85	–	0.85	0.14	0.06	0.04	0.04	0.01	–	0.09	0.02	0.33	0.09	0.01	0.01	–	4.7
7 R / Je7	0.18	0.02	–	–	0.17	–	–	0.37	0.41	–	–	–	0.02	–	0.79	0.93	–	0.69	0.25	0.10	0.07	–	–	–	0.08	0.05	0.29	0.10	0.05	0.03	–	4.6
8 R / Je8	0.13	0.03	–	–	0.09	–	–	0.10	0.21	–	–	–	0.01	–	0.24	0.46	–	0.35	0.12	0.05	0.03	–	–	–	0.04	0.02	0.14	0.05	0.02	0.01	–	2.1
9 R / Je9	0.46	0.04	–	–	0.48	–	–	0.21	0.45	–	0.04	–	0.02	–	2.3	2.7	–	1.7	0.25	0.26	–	0.07	–	–	0.24	0.05	0.35	0.20	0.09	0.09	–	10
10 R / Je10	0.28	0.06	–	–	0.87	0.03	–	0.36	0.69	0.03	0.08	–	0.02	–	1.9	1.7	–	1.8	0.33	0.12	0.08	0.09	0.03	–	0.16	0.06	0.72	0.15	0.03	0.01	–	9.6
11 R / Je11	0.36	–	–	–	0.28		–	0.84	0.90	–	–	–	–	–	1.6	1.9	–	1.4	0.50	0.20	0.19	–	–	–	0.16	0.20	0.56	0.10	0.05	0.06	–	9.3
Annavatn																																
61 R /An61	0.69	0.06	–	–	0.40	–	–	0.18	0.37	–	0.04	–	–	–	1.1	2.3	–	2.1	0.25	0.26	–	0.09	–	–	0.24	0.03	1.3	0.26	0.09	0.04	–	9.8
62 R / An62	0.37	0.15	–	–	0.13	–	–	0.20	0.31	–	–	–	0.02	–	0.45	0.81	–	0.68	0.25	0.04	0.03	–	0.04	–	0.08	0.01	0.29	0.09	0.05	–	–	4.0
63 R / An63	0.94	0.38	0.07	–	0.24	0.02	–	0.11	0.27	–	0.03	–	0.03	–	0.50	1.0	–	0.8	0.16	0.06	0.10	–	0.01	–	0.09	0.03	0.34	0.10	–	0.02	–	5.3
64 R / An64	0.70	0.19	–	–	0.16	0.09	–	0.19	0.30	–	0.06	–	0.01	–	0.61	1.6	–	1.2	0.33	0.14	0.03	0.04	0.03	–	0.13	0.08	1.1	0.28	0.11	0.02	–	7.4
65 R / An65	0.99	0.32	0.09	–	0.87	0.03	–	0.33	0.76	0.02	0.09	–	0.03	–	2.1	1.8	–	1.9	0.37	0.14	0.09	0.10	0.03	–	0.21	0.07	0.32	0.18	0.08	0.08	–	11
Wibjørnvatn																																
203 R / Wb203	0.19	0.05	–	–	0.10	–	–	0.29	0.31	–	–	–	0.01	–	0.34	0.28	–	0.20	0.07	0.03	0.07	–	–	–	0.08	–	0.05	0.03	–	–	–	2.1
205 R / Wb205	0.13	0.02	–	–	0.08	–	–	0.06	0.09	–	–	–	–	–	0.18	0.16	–	0.12	0.05	0.01	0.02	–	–	–	0.04	–	0.04		–	–	–	1.0
206 R / Wb206	0.14	0.03	–	–	0.07	–	–	0.21	0.20	–	–	–	–	–	0.30	0.21	–	0.14	0.05	–	0.04	–	–	–	0.05	–	0.04	0.02	–	–	–	1.5
207 R / Wb207	0.12	0.04	–	–	0.17	–	–	0.10	0.15	–	0.01	–	0.05	–	0.30	0.33	–	0.22	0.05	0.01	0.01	–	–	–	0.07	–	0.05	0.02	–	–	–	1.7
209 R / Wb209	0.13	0.03	–	–	0.07	–	–	0.21	0.23	–	–	–	–	–	0.30	0.20	–	0.14	0.05	–	0.04	–	–	–	0.06	–	0.04	–	–	–	–	1.5
210 R / Wb210	0.13	–	–	–	0.11	–	–	0.06	0.12	–	0.01	–	0.01	–	0.26	0.22	–	0.13	0.06	0.01	–	–	–	–	0.04	–	0.04	–	–	–	–	1.2
211 R / Wb211	0.25	0.10	–	–	0.14	–	–	0.43	0.40	–	–	0.02	0.02	–	0.40	0.55	–	0.39	0.25	0.06	0.07	–	–	–	0.11	–	0.09	0.02	–	–	–	3.3
Arkvatn																																
12 S? / Ar12	0.13	0.04	–	–	0.07	–	–	0.23	0.27	–	–	–	0.01	–	0.26	0.21	–	0.14	0.05	0.02	0.05	–	–	–	0.06	0.02	0.04	–	–	–	–	1.6
13 S? / Ar13	0.14	–	–	–	0.12	–	–	0.05	0.11	–	0.01	–	–	–	0.22	0.20	–	0.15	0.06	–	0.03	–	–	–	0.06	–	0.03	0.02	–	–	–	1.2
14 S? / Ar14	0.17	0.02	–	–	0.09	–	–	0.05	0.08	–	–	–	0.03	–	0.15	0.17	–	0.11	0.05	0.01	0.01	–	–	–	0.03	–	0.03	0.01	–	–	–	1.0
15 S? / Ar15	0.07	–	–	–	0.04	–	–	0.09	0.13	–	–	–	–	–	0.12	0.11	–	0.10	0.06	0.02	0.02	–	–	–	0.03	–	0.05	0.01	–	–	–	0.85
16 S? / Ar16	0.15	0.04	–	–	0.30	–	–	0.12	0.28	–	0.03	–	0.02	–	0.28	0.23	–	0.22	0.06	0.01	0.03	0.02	–	–	0.05	0.02	0.04	–	–	–	–	1.9
17 R? / Ar17	0.09	0.03	–	–	0.05	–	–	0.02	0.05	–	–	–	0.01	–	0.11	0.10	–	0.05	0.03	–	0.02	–	–	–	0.03	–	0.02	–	–	–	–	Σ0.61
18 R? / Ar18	0.06	0.01	–	–	0.03	–	–	0.07	0.09	–	–	–	–	–	0.12	0.08	–	0.06	0.02	–	0.02	–	–	–	0.02	0.01	0.02	–	–	–	–	0.61
19 R? / Ar19	0.06	0.03	–	–	0.05	–	–	0.02	0.04	–	–	–	–	–	0.11	0.08	–	0.07	0.02	0.01	0.01	–	–	–	0.02	–	0.02	–	–	–	–	0.54

Supplementary Table S5a. Continued.

Lake Sample no / PCA id	52	44	64	70	95	92	84	101	99	97	87	110	135	149	118	153	105	138	187	183	128	167	177	171	156	172	180	170	199	196	209	ΣPCB
Girlsta Loch																																
1 R / GL1	0.13	–	–	0.08	0.58	0.07	–	0.15	0.08	0.10	0.11	0.26	0.01	–	0.27	0.18	–	0.35	0.10	0.01	0.06	0.06	0.02	–	0.02	0.01	0.12	0.08	0.05	0.07	0.03	3.0
2 R / GL2	0.36	0.07	–	0.22	0.88	0.07	0.06	0.84	0.46	0.30	0.13	0.65	0.12	–	1.1	1.3	0.02	0.88	0.37	0.14	0.07	0.09	0.10	–	0.13	0.01	0.64	0.28	0.09	0.03	0.19	9.6
3 R / GL3	0.36	0.09	–	0.15	0.88	0.11	–	0.33	0.18	0.08	0.16	0.41	0.02	–	0.47	0.68	–	0.40	0.13	0.09	0.06	0.05	0.02	–	0.06	0.01	0.23	0.14	0.07	0.09	0.13	5.4
4 R / GL4	0.19	–	–	–	0.52	–	0.07	0.25	0.09	0.11	0.16	0.19	0.02	–	0.58	0.35	–	0.25	0.09	0.02	–	0.05	–	–	0.04	–	0.16	0.09	0.06	0.02	0.09	3.4
5 R / GL5	0.13	–	–	0.14	–	0.09	–	0.22	0.13	0.12	0.18	0.30	0.04	–	0.00	0.21	–	0.27	0.04	–	–	–	–	–	0.03	–	0.09	0.03	–	–	0.08	2.1

[a] S – smolt. [b] R – resident. [c] A – anadromous. [d] – Concentration below the limit of detection (≤ 0.003 μg g^{-1} lipid).

Supplementary Table S5b. Concentrations of (µg g^{-1} lipid) of HCB, PCT, HCHs and DDT compounds in Arctic char samples.

Lake	HCB	ΣPCT	HCH				ΣHCH	DDE		DDD		DDT	
Sample no / PCA id			α-	β-	γ	δ-		*o,p'*-	*p,p'*-	*o,p'*-	*p,p'*-	*o,p'*-	*p,p'*-
Linnévatn													
3 S[a] / Ln3	0.07	0.83	0.18	0.06	0.01	–	0.25	–	0.38	–	–	–	NQ[f]
4 S / Ln4	0.05	0.28	0.27	0.05	0.04	–	0.36	–	0.31	–	–	–	NQ
6 S / Ln6	0.10	1.1	0.15	0.10	0.02	–	0.27	–	1.0	–	–	–	NQ
7 R[b] / Ln7	0.02	–[d]	0.14	0.04	0.02	–	0.20	–	0.04	–	–	–	NQ
12 R / Ln12	0.05	–	0.32	0.04	0.03	–	0.40	–	0.07	–	–	–	NQ
13 R / Ln13	0.05	–	0.32	0.06	0.03	–	0.42	–	0.11	–	–	–	NQ
Diesetvatn													
4 A[c] / Di4	0.08	–	0.19	–	–	–	0.19	–	0.06	–	–	–	–
5 A / Di5	0.09	–	0.15	–	–	–	0.15	–	0.08	–	–	–	–
Jensenvatn													
6 R / Je6	0.15	–	1.0	0.08	0.06	–	1.1	–	0.61	–	–	–	0.03
7 R / Je7	0.19	–	1.1	0.07	0.06	–	1.2	–	0.56	–	–	–	0.03
8 R / Je8	0.11	–	0.99	0.12	0.03	–	1.1	–	0.20	–	–	–	0.02
9 R / Je9	0.13	–	0.75	0.07	0.05	–	0.87	–	2.3	–	–	–	0.02
10 R / Je10	0.13	–	0.62	0.02	0.03	–	0.67	–	1.8	–	–	–	0.03
11 R / Je11	0.13	–	0.81	0.05	0.05	–	0.91	–	1.9	–	–	–	0.03
Annavatn													
61 R /An61	0.19	NQ[e]	0.37	–	0.04	–	0.41	–	2.9	–	–	–	NQ
62 R / An62	0.22	NQ	0.35	–	0.04	–	0.39	–	1.5	–	–	–	NQ
63 R / An63	0.13	NQ	0.31	–	0.04	–	0.35	–	0.64	–	–	–	NQ
64 R / An64	0.22	NQ	0.34	–	0.04	–	0.38	–	2.2	–	–	–	NQ
65 R / An65	0.17	NQ	0.31	–	0.04	–	0.35	–	1.3	–	–	–	NQ
Wibjørnvatn													
203 R / Wb203	0.20	NQ	0.21	0.03	0.02	–	0.26	–	0.46	–	–	–	–
205 R / Wb205	0.16	NQ	0.18	–	0.03	–	0.21	–	0.21	–	–	–	–
206 R / Wb206	0.17	NQ	0.21	0.03	0.03	–	0.27	–	0.38	–	–	–	–
207 R / Wb207	0.18	NQ	0.20	0.03	0.02	–	0.25	–	0.30	–	–	–	–
209 R / Wb209	0.20	NQ	0.22	0.03	0.02	–	0.27	–	0.26	–	–	–	–
210 R / Wb210	0.16	NQ	0.19	0.04	0.02	–	0.25	–	0.19	–	–	–	–
211 R / Wb211	0.14	NQ	0.18	0.03	0.02	–	0.24	–	0.84	–	–	–	–
Arkvatn													
12 S? / Ar12	0.22	NQ	0.38	–	0.06	–	0.44	–	1.8	–	–	–	–
13 S? / Ar13	0.22	NQ	0.36	–	0.04	–	0.40	–	3.5	–	–	–	–
14 S? / Ar14	0.20	NQ	0.33	–	0.04	–	0.37	–	1.1	–	–	–	–
15 S? / Ar15	0.18	NQ	0.32	–	0.04	–	0.36	–	2.5	–	–	–	–
16 S? / Ar16	0.16	NQ	0.29	–	0.04	–	0.33	–	4.1	–	–	–	–
17 R? / Ar17	0.20	NQ	0.38	–	0.04	–	0.42	–	0.44	–	–	–	–
18 R? / Ar18	0.15	NQ	0.32	–	0.04	–	0.36	–	0.19	–	–	–	–
19 R? / Ar19	0.19	NQ	0.35	–	0.05	–	0.40	–	0.66	–	–	–	–

Supplementary Table S5b. Continued.

Lake Sample no / PCA id	HCB	ΣPCT	HCH α-	 β-	 γ	 δ-	ΣHCH	DDE *o,p'*-	 *p,p'*-	DDD *o,p'*-	 *p,p'*-	DDT *o,p'*-	 *p,p'*-
Girlsta Loch													
1 R / GL1	0.09	NQ	0.10	0.03	0.05	–	0.17	–	0.53	–	–	–	NQ
2 R / GL2	0.08	NQ	0.12	0.05	0.02	–	0.19	–	3.5	–	–	–	NQ
3 R / GL3	0.09	NQ	0.11	0.05	0.04	–	0.19	–	1.9	–	–	–	NQ
4 R / GL4	0.09	NQ	0.10	0.05	0.05	–	0.19	–	0.77	–	–	–	NQ
5 R / GL5	0.09	NQ	0.14	0.05	0.06	–	0.25	–	0.37	–	–	–	NQ

[a] S – smolt. [b] R – resident. [c] A – anadromous. [d] – Concentration below the limit of detection (≤ 0.003 μg g^{-1} lipid). [e] NQ – not quantified. [f] Not quantified because of co-elution with large toxaphene peak.

Supplementary Table S6. Concentrations (μg g^{-1} lipid) of PCT and selected pesticides in pooled samples of Arctic char.

Lake	PCT	Dieldrin	Endrin	Aldrin	Hepachlor	Heptachlor epoxide	*Trans*-nonachlor	Chlordene		Chlordane			ΣChlor-danes	Methoxy-chlor	DDE		DDD		DDT		ΣDDT	Mirex	Toxaphene fraction			ΣToxaphene
								α-	γ-	Oxy-	γ-	α-			*o,p'*-	*p,p'*-	*o,p'*-	*p,p'*-	*o,p'*-	*p,p'*-			1	2	3	
Jensenvatn	–[a]	0.22	0.01	–	0.09	0.07	0.04	–	–	0.07	0.02	0.02	0.30	–	–	0.20	–	tr[b]	–	0.01	0.21	–	tr	0.24	2.0	2.2
Annavatn	–	0.52	0.03	–	0.01	0.11	0.20	–	–	0.11	0.01	0.07	0.60	–	–	1.7	–	0.02	–	0.17	1.9	–	–	0.80	0.31	1.1
Arkvatn																										
Smolt?	–	0.50	0.04	–	0.11	0.13	0.40	–	–	0.13	0.02	0.10	0.89	–	–	2.0	–	0.06	–	0.40	2.5	–	–	1.6	0.31	1.9
Resident?	–	0.58	0.05	–	0.14	0.14	0.31	–	–	0.14	0.03	0.11	0.87	–	–	0.42	–	0.04	–	0.31	0.73	–	–	1.3	0.70	2.0

[a] – Concentration below the limit of detection (≤ 0.003 μg g^{-1} lipid). [b] tr – trace amounts, i.e., between the limit of detection and limit of quantification (0.003 μg g^{-1} lipid ≤ tr < 0.01 μg g^{-1} lipid).

Supplementary Table S7 Concentrations of organochlorine contaminants (µg g^{-1} lipid) in common guillemot (*Uria aalge*) from the central Baltic Sea. These samples were analysed together with the samples from Ymer-80 for comparison. The data have not been presented in full elsewhere and are included here to present as complete a data set as possible from the Ymer-80 survey.

Sample no	52	44	64	70	95	92	84	101	99	97	87	110	135	149	118	153	105	138	187	183	128	167	177	171	156	172	180	170	199	196	209	ΣPCB	ΣPCT
30	–[a]	–	3.4	–	2.6	–	–	0.48	2.2	–	0.35	–	–	–	8.9	10	–	14	7.4	1.4	–	0.89	0.84	–	1.3	1.2	5.1	1.6	2.0	0.91	0.15	65	M[b]
31	–	–	2.2	–	1.1	–	–	0.46	1.1	–	0.26	–	–	–	4.1	–	–	7.5	6.1	1.1	–	0.55	1.2	–	0.70	1.1	3.2	1.2	1.7	0.92	0.27	35	M

Sample no	HCB	HCH				Dieldrin	Endrin	Aldrin	Hepachlor	Heptachlor	Chlordede		Chlordane			*Trans-*	Methoxy-	DDE		DDD		DDT		ΣDDT	Mirex	Toxaphene
		α-	β-	γ-	δ-					epoxide	α-	γ-	Oxy-	γ-	α-	nonachlor	chlor	*o,p'*-	*p,p'*-	*o,p'*-	*p,p'*-	*o,p'*-	*p,p'*-			
30	3.4	–	0.17	–	–	NQ[c]	NQ	–	–	NQ	–	–	0.18	–	–	–	–	–	19	–	0.13	–	–	19	–	M
31	2.5	–	–	–	–	NQ	NQ	–	–	NQ	–	–	0.02	–	–	–	–	–	13	–	–	–	–	13	–	M

[a] – Concentration below the limit of detection (≤ 0.003 µg g^{-1} lipid). [b] M – missing data. [c] NQ – not quantified.

Supplementary Table S8. Concentrations (µg g^{-1} lipid) of ΣPCB and ΣDDT in samples of Brünnich's guillemot and polar bears collected on Svalbard in 1971 and 1980. The data from the 1971 samples are from Edelstam et al. (1987) and included here for completeness. Note that the 1971 data were produced with an older analytical method using packed column GC-ECD and not comparable to data from capillary column GC-ECD. The Ymer-80 data in this table have, therefore, been recalculated based on an intercalibration of the methods to ensure consistency within SNEMP time series to make them comparable to the data from 1971.

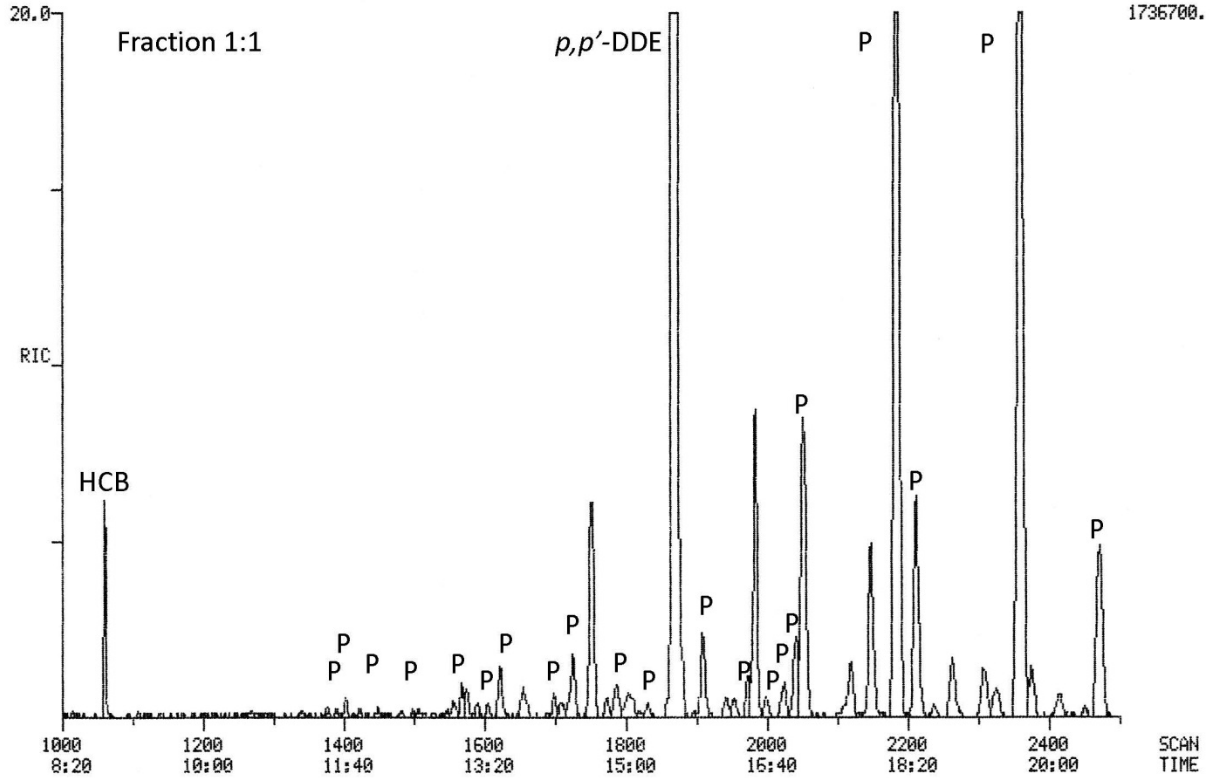
	ΣPCB Mean Range	ΣDDT Mean Range
Brünnich's guillemot		
1971		
Adults, W Svalbard (n = 7)	12 7.3-16	5.6 3.2-8.4
1980		
Adults, N/E Svalbard (n = 4)	18 7.0-33	5.2 2.4-9.4
Age unknown, W Svalbard (n = 5)	4.9 1.2-12	1.4 0.40-2.9
Glaucous gull		
1971		
Svalbard unspecified (n = 2)	130 61-200	34 30-38
1980		
N/E Svalbard (n = 2)	100 10-190	12 2.5-21
W Svalbard (n = 5)	150 75-270	24 16-27
Polar bear		
1971 (n = 2)	17 13-20	0.34 0.31-0.37
1980 (n = 1)	6.4	0.31

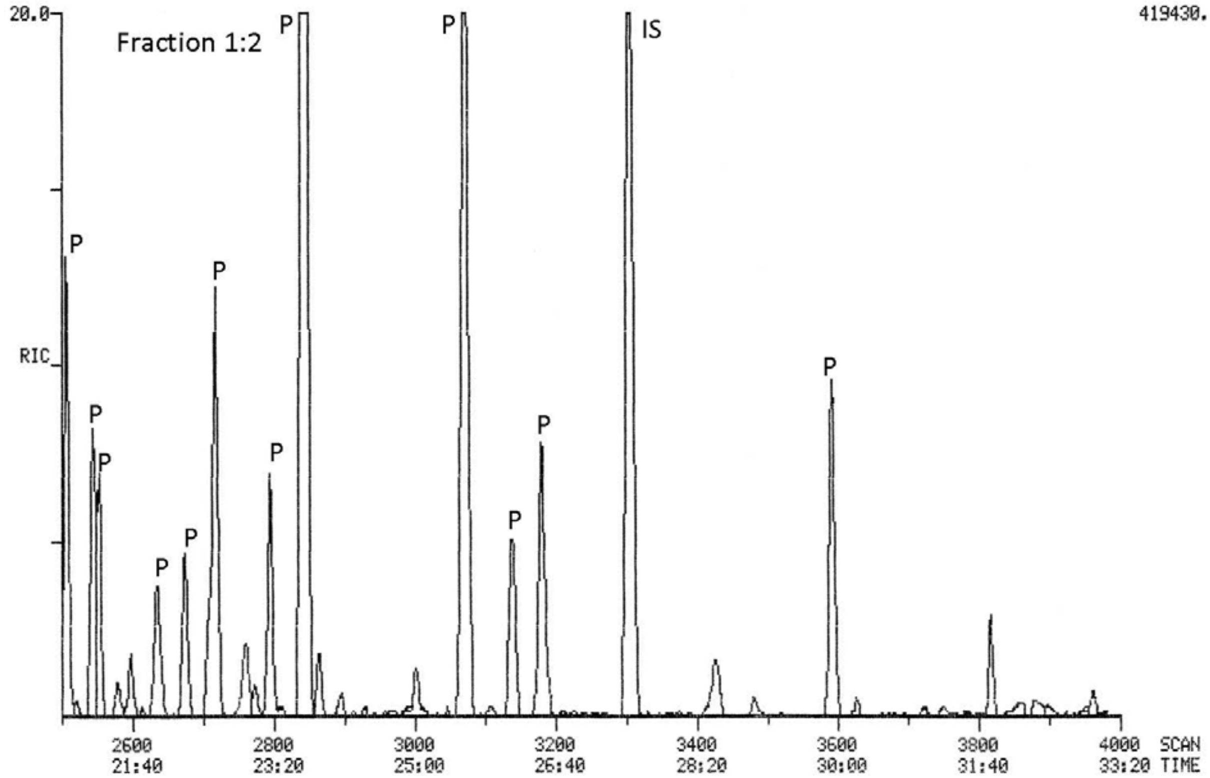
Supplementary Table S9. Concentrations (µg g^{-1} lipid) of POPs in seals, fish and other animals collected in western Svalbard in 1984. These samples were analysed in the same laboratory and with the same methods as, but slightly prior to, the Ymer-80 samples. Unfortunately, the documentation has not been possible to reconstruct in full. These are the original data. Data regarding these samples presented by Carlberg & Bøler (1985) were, for unknown reasons, recalculated (see discussion in text above).

Species	Lipid.	HCB	ΣPCB	HCH			Diel-	En-	Al-	Hepta	Heptachlor	Chlordene		Chlordane			Nonachlor		Methoxy-	DDE		DDD		DDT		ΣDDT	Mirex	Toxaphene
Date	%			α-	β-	γ-	drin	drin	drin	chlor	epoxide	α -	γ-	Oxy-	γ-	α-	*Trans-*	*Cis-*	chlor	*o,p'-*	*p,p'-*	*o,p'-*	*p,p'-*	*o,p'-*	*p,p'-*			
Ringed seal (*Pusa hispida*), liver, Hornsund																												
1984–09–13	3.3	0.02	0.76	0.05	–[c]	0.01	0.08	–	–	0.01	0.04	0.28		0.11	tr	tr	0.04	tr	–	0.02	0.48	–	0.06	–	0.06	0.29	–	NQ
1984–09–21	3.9	0.03	0.42	0.06	–	tr	0.10	–	–	0.01	0.04	0.28	–	0.11	tr	tr	0.04	tr	–	0.02	0.48	–	0.06	–	0.06	0.29	–	NQ
1984–09–28	3.2	0.03	0.45	0.04	–	tr	0.08	–	–	0.01	0.03	0.21	0.01	0.07	tr	tr	0.04	tr	–	0.01	0.26	–	0.02	–	0.01	0.14	–	NQ
1984–10–02	3.1	0.04	1.0	0.03	–	tr	0.11	–	–	0.02	0.03	0.16	–	0.12	tr	tr	0.07	tr	–	0.02	0.37	–	0.04	–	0.03	0.23	–	NQ
1984–10–03	2.6	0.03	0.66	0.07	–	tr	0.11	–	–	0.01	0.02	0.21	–	0.16	tr	tr	0.07	0.01	–	0.02	0.44	–	0.06	–	0.03	0.27	–	NQ
Kapp Linné[a]																												
1983?	3.2	0.03	7.2	0.04	tr[d]	0.01	NQ[e]	NQ	–	0.01	NQ	0.59	0.01	0.86	tr	0.01	0.02	tr	–	0.02	0.46	–	0.06	–	0.021	0.75	–	NQ
Ringed seal (*Pusa hispida*), blubber Hornsund																												
1984–09–13	82	0.02	1.6	0.07	tr	tr	tr	–	–	0.01	0.03	0.01	–	0.19	tr	tr	0.11	0.02	–	–	0.83	–	0.02	–	0.40	1.2	–	0.63
1984–09–21	90	0.01	0.84	0.14	tr	0.01	0.01	–	–	–	0.02	0.01	–	0.14	0.01	tr	0.16	0.04	–	–	0.67	–	0.04	–	0.31	1.0	–	1.1
1984–09–28	84	0.01	1.0	0.05	tr	tr	0.01	–	–	–	0.02	0.01	0.01	0.20	0.01	tr	0.18	0.03	–	–	0.89	–	0.02	–	0.44	1.4	–	0.96
1984–10–02	79	0.02	2.3	0.06	tr	tr	0.02	–	–	–	0.02	0.02	–	0.25	0.02	tr	0.26	0.06	–	–	0.94	–	0.04	–	0.52	1.5	–	0.51
1984–10–03	90	0.01	0.78	0.08	tr	tr	0.01	–	–	–	0.02	0.01	–	0.19	0.01	tr	0.1	0.02	–	–	0.77	–	0.04	–	0.42	1.2	–	0.36
Kapp Linné																												
1983?	84	0.04	4.6	0.26	0.01	0.02	NQ	NQ	–	0.02	NQ	0.01	–	0.13	0.01	0.01	0.15	0.03	–	–	0.92	–	0.03	tr	1.0	1.9	–	NQ
1983?	96	0.02	5.1	0.14	0.01	0.01	NQ	NQ	–	0.03	NQ	0.01	–	0.25	0.01	0.01	0.23	0.04	–	–	1.4	–	0.03	0.01	1.6	3.0	–	NQ
Bearded seal (*Erignathus barbatus*), liver, Hornsund																												
1984–09–21	3.5	0.48	4.3	0.05	tr	tr	0.01		–	0.01	0.04	0.20	–	0.12	tr	tr	0.12	tr	–	0.01	2.5	–	0.31	–	0.31	2.9	–	NQ
1984–10–01	2.9	0.30	3.5	0.04	–	–	0.01		–	0.01	0.05	–	–	0.11	tr	tr	0.11	tr	–	0.01	2.9	–	0.17	–	0.17	3.2	–	NQ
Bearded seal (*Erignathus barbatus*), blubber, Hornsund																												
1984–09–21	80	0.02	2.1	0.01	tr	tr	0.02	0.02	–	–	0.03	–	–	0.14	tr	tr	0.59	0.02	–	tr	1.4	–	0.01	–	0.01	1.8	–	M[f]
1984–10–01	77	0.02	2.2	0.01	tr	tr	0.02	0.03	–	0.02	0.01	–	–	0.13	tr	tr	0.29	0.02	–	–	1.5	–	0.01	–	0.01	1.9	–	0.47
Cod (?)[b], fillet, Kongsfjorden																												
1984–08–19	2.0	0.06	0.11	0.02	tr	tr	0.04	–	–	tr	0.01	–	–	tr	tr	tr	0.04	tr	–	–	0.06	–	0.02	–	0.02	0.10	–	M
Plaice (*Hippoglasoidus platesoidus*), fillet, Kongsfjorden																												
1984–08–19	0.11	55	0.04	tr	tr	0.05	0.01	–	–	tr	0.01	0.03	tr	0.12	0.05	0.01	0.08	0.04	–	0.01	0.15	–	0.01	–	0.07	0.24	–	M
Shrimps (*Pandalus*), Kongsfjorden																												
1984–08–19	0.01	34	0.02	–	0.01	–	–	–	–	0.01	–	–	0.01	–	tr	0.01	–	–	–	–	0.01	–	–	–	–	0.01	–	M
Ascidian (Ascidiacea), Kongsfjorden																												
1984–08–20	0.07	0.49	–	0.10	–	0.02	0.05	0.04	–	0.04	0.02	tr	–	tr	tr	0.01	0.02	–	–	0.02	0.03	–	–	–	0.01	0.06	–	0.22

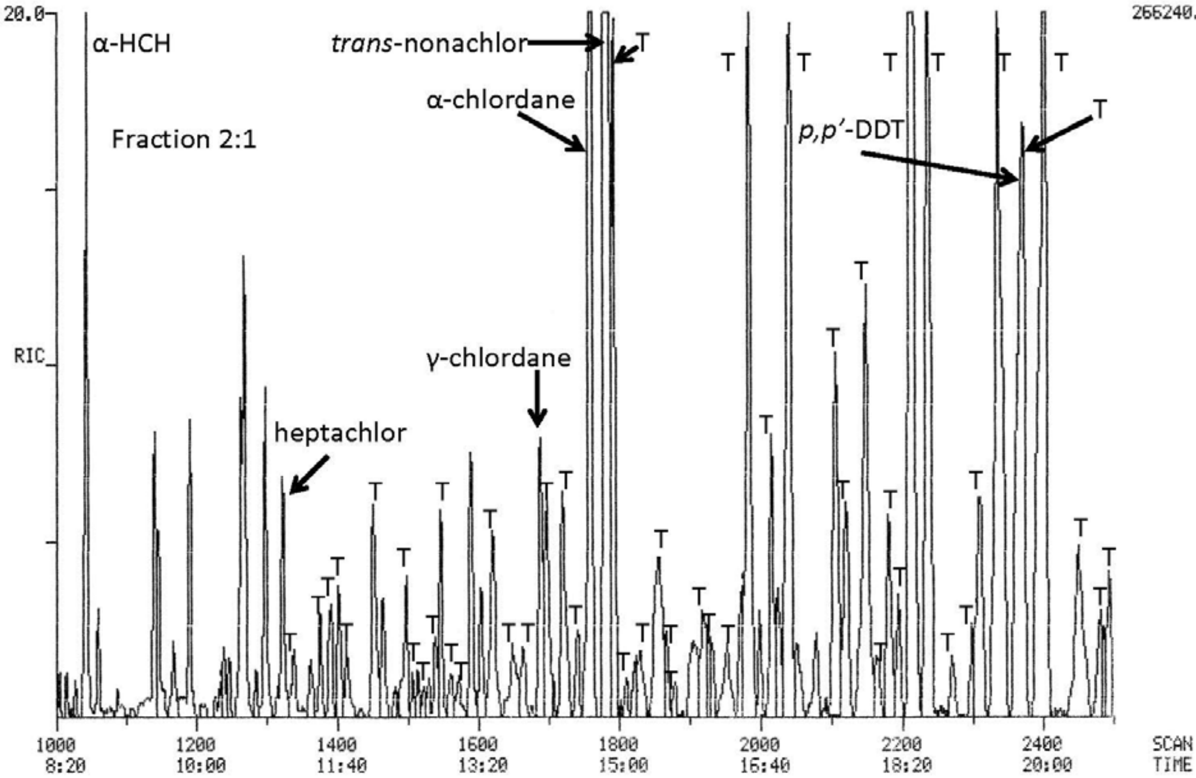
[a] The Kapp Linné samples are poorly documented, e.g., sampling date are lacking. These samples were provided from Norwegian authorities and analysed in the same sequence as the data report by Carlberg & Bøler (1985). However, for unknown reasons they were not included in that report. [b] Species unclear due to varying and strange usage of both common and scientific names in the background material. Either cod (*Gadus morhua*) or polar cod (*Boreogadus saida*), but most likely the latter. [c] – Concentration below the limit of detection (≤ 0.003 µg g^{-1} lipid). [d] tr – trace amounts, i.e., between the limit of detection and limit of quantification (0.003 µg g^{-1} lipid ≤ tr < 0.01 µg g^{-1} lipid). [e] NQ – not quantified. [f] M – missing data.

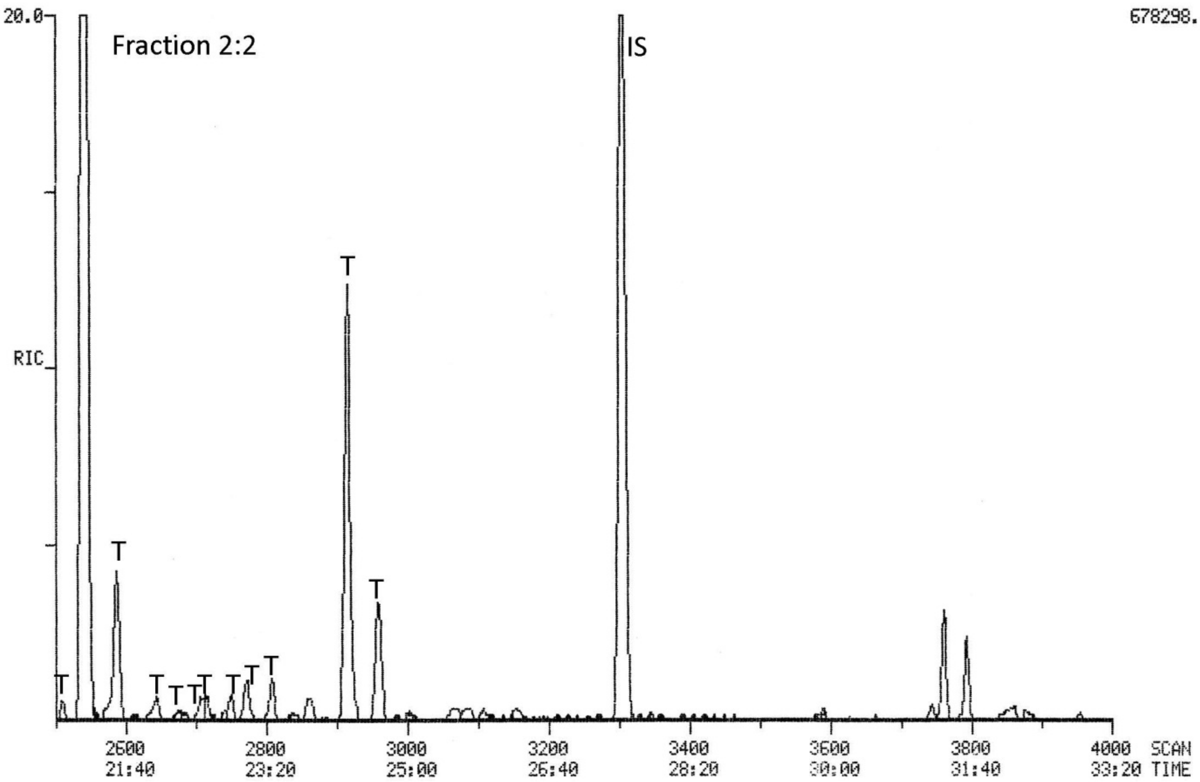
Supplementary Fig. S1. Representative chromatograms (full scan GC-MS) of the fractions obtained after fractionation on deactivated alumina of an Arctic char sample. Each chromatogram is presented in two panels. Peak identifications: P – PCB; T – toxaphene.



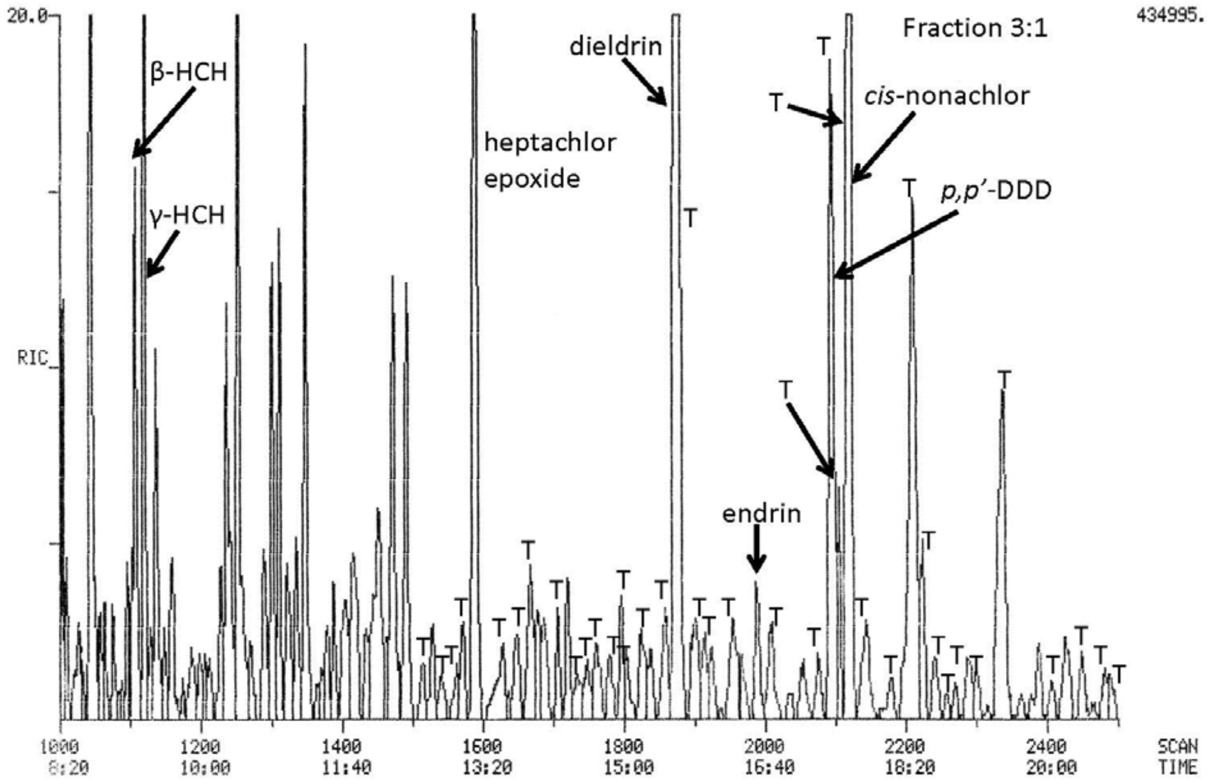


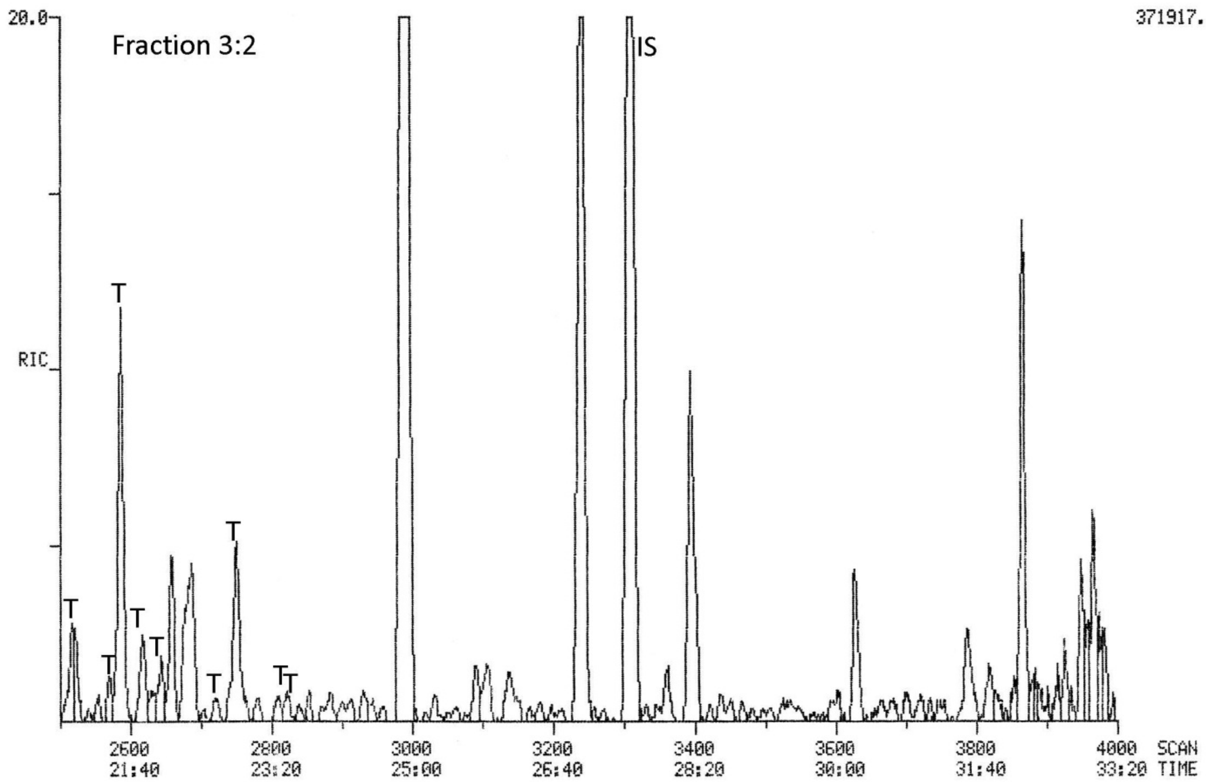
Supplementary Fig. S1. Continued.



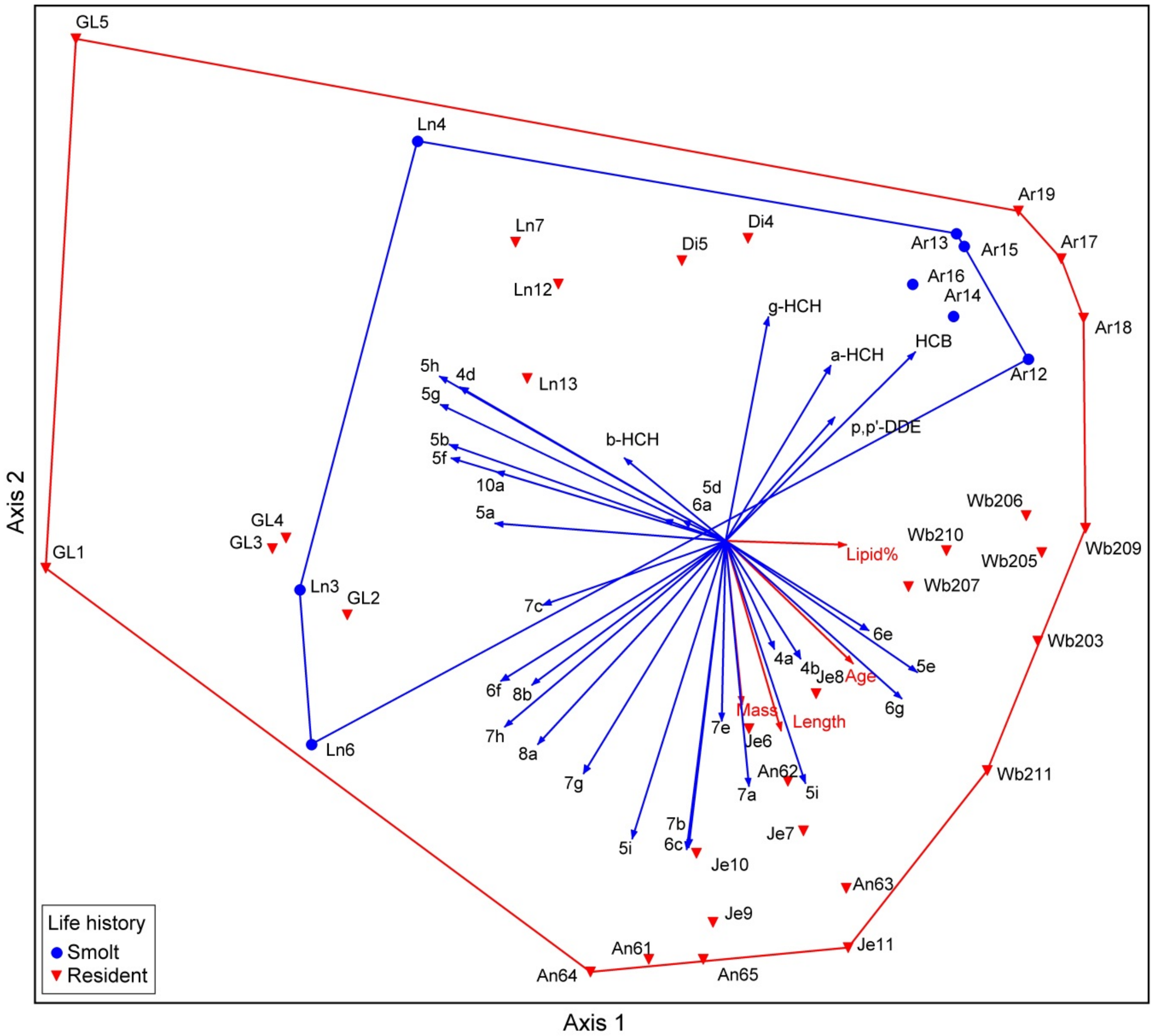


Supplementary Fig. S1. Continued.

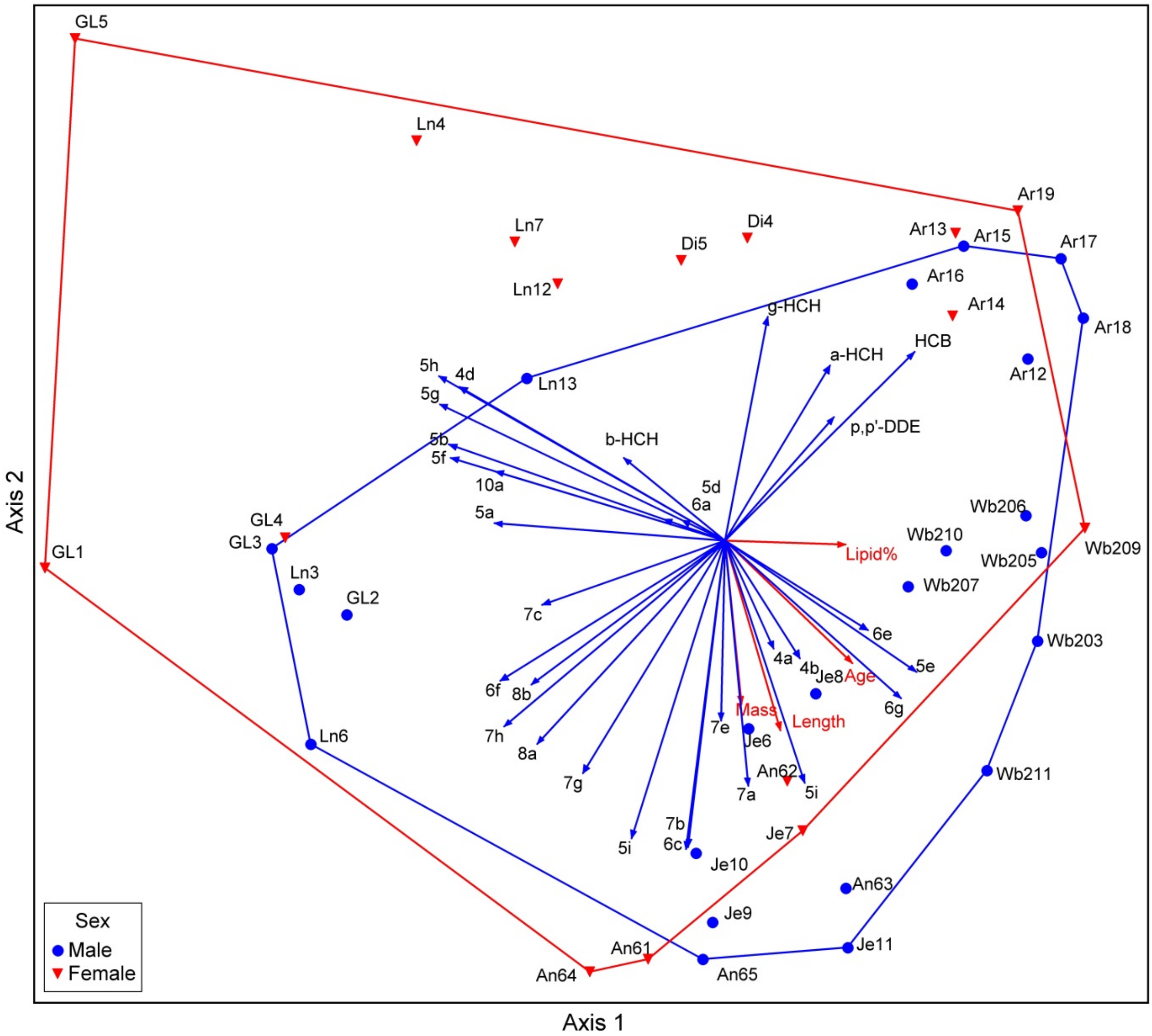




Supplementary Fig. S2. Principal component analysis of relativized contaminant concentrations in Arctic char. Vector numbers refer to individual PCB congeners, see Table S3b.



Supplementary Fig. S3. Principal component analysis of relativized contaminant concentrations in Arctic char. Vector numbers refer to individual PCB congeners, see Table S3b.



Supplementary Fig. S4. Principal component analysis of relativized contaminant concentrations in Arctic char. Vector numbers refer to individual PCB congeners, see Table S3b.