NEW ENVIRONMENTAL CONTAMINANTS IN SEABIRDS FROM THE SEVEN ISLANDS ARCHIPELAGO (BARENTS SEA, RUSSIA)

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Abstract
Polychlorinated dibenzo-p-dioxins and furans (PCDD/Fs), polybrominated diphenyl ethers (PBDEs), and dioxin-like polychlorinated biphenyls (PCBs) were measured in seabirds from the Russian Arctic. Black-legged kittiwakes, razorbills, Atlantic puffins, common guillemots, and Brünnich's guillemots were collected in 2002 on the Seven Islands Archipelago in the eastern Barents Sea. Detectable hepatic concentrations of PCDD/Fs, PBDEs, and PCBs were found in all samples analyzed. The highest concentrations of PCDD/Fs and non- and mono-ortho PCBs were found in the Atlantic puffin. PBDE levels were the highest in the razorbill (average total PBDE concentration of 19,422 pg/g wet wt). These data represent some of the first measurements of PCBs and PBDEs in seabirds from this area. While levels of these contaminants in the tested species currently appear to fall below critical values, continued monitoring is warranted for these compounds, especially for *Alcidae* species.

Introduction
Worldwide contamination by dioxin-related compounds, such as polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibezofurans (PCDFs), coplanar polychlorinated biphenyls (coplanar PCBs), and brominated flame retardants (including polybrominated diphenyl ethers or PBDEs), is of great concern due to the persistence, bioaccumulative nature, and toxicity of these compounds. Arctic birds tend to accumulate high concentration of organochlorine contaminants.[1] However, data on contaminant levels in seabirds from the Russian Arctic are limited, and no information exists regarding levels of new or emerging contaminants like PBDEs. The objective of the present study was to determine the concentrations and accumulation of dioxin-like contaminants in hepatic tissues of five species of the Barents Sea marine birds that breed at the Seven Islands Archipelago (Kandalaksha State Nature Reserve) in the eastern Barents Sea (*Figure 1*).

Materials and Methods
Seabirds were sampled with the permission of the environmental authorities in the Seven Islands Archipelago (68° 45 N; 37° 25 E) in July 2002 (*Figure 1*). The following species were collected: *Laridae* family: black-legged kittiwake, *Rissa tridactyla; Alcidae* family: razorbill, *Alca torda;* Atlantic puffin, *Fratercula arctica;* common guillemot, *Uria aalge;* and Brünnich's guillemot, *Uria lomvia.*

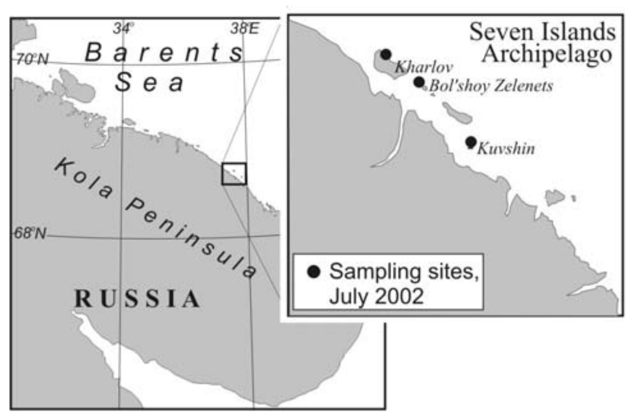

Figure 1. Map of the Seven Islands Archipelago and sampling site locations.

Liver samples were frozen until analysis. Hepatic concentrations of dioxins/furans (PCDD/PCDF); polybrominated diphenyl ethers (PBDEs); non- and mono-*ortho* polychlorinated biphenyls (PCBs, IUPAC #77, 81, 105, 114, 118, 123, 126, 156, 157, 167, 169, 170, 189) were determined at the Centre for Environmental Chemistry SPA "Typhoon." This laboratory has national accreditation and has successfully participated in interlaboratory exercises coordinated by the USA, Sweden, Italy and elsewhere. The method is described in the Arctic Assessment and Monitoring Programme report[2] and Stapleton *et al*[3].

The hypothesis of normal distribution (Shapiro-Wilk's W test) was not rejected for log-transformed data. Lipid base log-transformed concentrations were used to determine the significant differences between group geometric means (Student-Newman-Keuls test). Null hypothesis (equality of means) was rejected at the 95% significance level ($p<0.05$). Statistically significant differences between mean organochlorine concentrations in male and female hepatic tissues were not found for any species, therefore, results shown below pool data among males and females.

Results and Discussion

The concentrations of compounds analyzed in hepatic tissue of birds are summarized in *Table 1*.

PBDEs. BDE-209 and other components of the industrial deca-formulation were not detected in bird tissues. BDE-47 was the most abundant congener and contributed between 40% (puffin) and 70% (common guillemot) of the sum of PBDEs, following by BDEs-99, 100, 154 and 153 (*Table 1)*. The arithmetic mean concentration of total PBDE (ΣPBDE) ranged from 512 pg/g wet wt in the Common guillemot to 19,422 pg/g wet wt in the razorbill. The highest concentration of ΣPBDE found in a razorbill sample, 38,600 pg/g wet wt, was comparable with the levels in Glaucous gull livers from Svalbard.[4] However, levels of ΣPBDEs in Kittiwakes (3008-9597 pg/g wet wt) and Brünnich's guillemot (129-2244 pg/g wet wt) from the Seven Islands Archipelago were low compared to those in the same species from the Canadian Arctic[1].

PCDD/Fs. Detectable concentrations of PCDD/Fs were found in all samples of the Barents Sea birds. Congener profiles of PCDD/Fs were characterized by a large proportion of PeCDD/Fs congeners, except for the puffin where the highest (33 pg/g wet wt) concentration of 2,3,7,8-TCDF were detected (*Table 1*). In birds, lower food consumption, lower body weight, and reproductive problems (fewer eggs, higher embryo death rates) have been reported as effects of dioxins and furans[5].

Dioxin-like PCBs. Among this group, PCB-126 was detected in only two of the five bird species analyzed (Brünnich's and Common guillemots), resulting in high levels of TEQ_{PCB} in tissues of these bird species (*Figure 2*). This is in good agreement with data from the Canadian Arctic.[1]

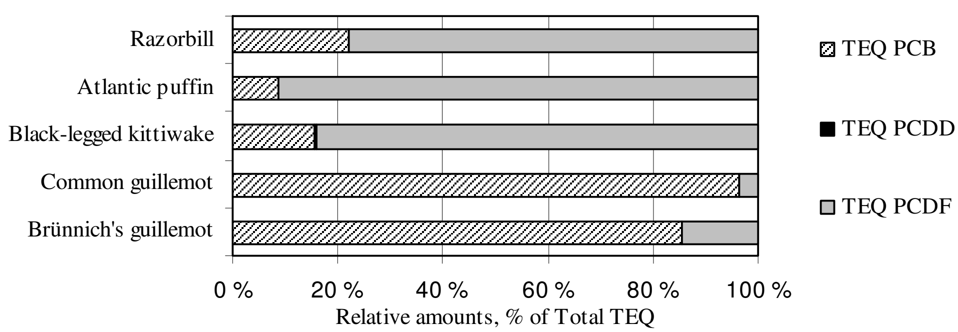

Figure 2. Contributions of PCDDs, PCDFs and dioxin-like PCBs into Total TEQ.

Razorbills accumulated the highest mean concentrations (95 ng/g wet wt) of dioxin-like PCBs following by puffins (82 ng/g wet wt), Kittiwake (68 ng/g wet wt), Brünnich's (50 ng/g wet wt), and common (50 ng/g wet wt) guillemots. Mono-*ortho* PCBs 118, 105, 156 and 170 were the prevalent congeners. The PCB congener profiles in bird livers were quite similar to pattern of the technical PCB mixture Aroclor 1254 (*Figure 3*).

Table 1. PBDEs (pg/g wet wt), PCDD/Fs (pg/g wet wt), sum of dioxin-like PCBs (ΣPCB) (ng/g wet wt) in hepatic tissues of birds and TEQs calculated for PCDD/Fs and PCBs (pg/gTEQ wet wt) according to [5]. Arithmetic means and standard deviation (S.D.). N = number of samples.

Compounds	Brünnich's Guillemot, N=10	Common guillemot, N=10	Black-lagged kittiwake, N=10	Atlantic puffin, N=6	Razorbill, N=5
	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.	Mean ± S.D.
PBDE-17	16.0 ± 13.4	<0.1	63.2 ± 26.8	12.9 ± 9.1	73.6 ± 27.3
PBDE-28	77.6 ± 85.0	44.0 ± 32.7	165 ± 57.5	207 ± 105	259 ± 177
PBDE-49	<1.0	<1.0	<1.0	<1.0	<1.0
PBDE-71	122 ± 92.9	38.0 ± 23.1	125 ± 70.6	166 ± 94.7	301 ± 169
PBDE-47	1469 ± 1404	357 ± 224	3075 ± 1132	1638 ± 871	8954 ± 4816
PBDE-66	32.8 ± 31.9	9.1 ± 11.8	105 ± 29.2	144 ± 122	96.5 ± 101
PBDE-100	224.5 ± 207.6	5.5 ± 2.3	376 ± 149	493 ± 254	3074 ± 2291
PBDE-99	136.3 ± 142.1	26.8 ± 14.1	680 ± 287	638 ± 255	3523 ± 2378
PBDE-85	<3.0	<3.0	<3.0	<3.0	<3.0
PBDE-154	101 ± 120	11.6 ± 4.6	266 ± 125	523 ± 276	1225 ± 802
PBDE-153	38.7 ± 33.3	4.8 ± 3.7	598 ± 319	288 ± 94.9	1687 ± 1418
PBDE-138	<3.0 ± <3.0	0.3 ± 1.0	<3.0	<3.0	27.2 ± 46.3
PBDE-183	26.4 ± 14.3	13.7 ± 5.8	147 ± 106	58.0 ± 15.0	203 ± 136
PBDE-190	<5.0	1.6 ± 3.5	92.0 ± 72.0	<5.0	<5.0
PBDE-208	<10.0	<10.0	<10.0	<10.0	<10.0
PBDE-207	<10.0	<10.0	<10.0	<10.0	<10.0
PBDE-206	<10.0	<10.0	<10.0	<10.0	<10.0
PBDE-209	<10.0	<10.0	<10.0	<10.0	<10.0
ΣPBDE	2244 ± 2092	512 ± 298	5693 ± 2094	4167 ± 1963	19422 ± 11998
2,3,7,8-TCDD	<2.0	<2.0	<2.0	<2.0	<2.0
1,2,3,7,8-PeCDD	<0.2	<0.2	<0.2	<0.2	<0.2
1,2,3,4,7,8-HxCDD	<0.05	<0.05	<0.05	<0.05	<0.05
1,2,3,6,7,8- HxCDD	<0.05	<0.05	3.06 ± 2.05	0.42 ± 1.03	4.66 ± 3.15
1,2,3,7,8,9- HxCDD	<0.05	<0.05	0.12 ± 0.38	<0.05	<0.05
1,2,3,4,6,7,8-HpCDD	0.67 ± 0.59	0.22 ± 0.47	0.92 ± 0.87	<0.05	1.54 ± 1.45
OCDD	1.20 ± 0.98	0.92 ± 0.72	2.59 ± 0.32	1.01 ± 1.26	1.81 ± 1.04
2,3,7,8-TCDF	2.23 ± 1.44	1.54 ± 0.83	3.94 ± 7.99	24.0 ± 9.04	<0.10
1,2,3,7,8-PeCDF	1.28 ± 0.47	1.10 ± 0.28	2.10 ± 1.15	5.87 ± 2.21	1.91 ± 0.90
2,3,4,7,8-PeCDF	5.94 ± 2.38	9.12 ± 2.57	8.28 ± 4.29	9.08 ± 3.59	11.3 ± 6.84
1,2,3,4,7,8-HxCDF	0.41 ± 0.19	0.69 ± 0.17	0.67 ± 0.30	1.23 ± 0.29	2.25 ± 0.92
1,2,3,6,7,8- HxCDF	0.45 ± 0.18	0.68 ± 0.17	0.78 ± 0.32	0.82 ± 0.24	1.97 ± 0.61
2,3,4,6,7,8-HxCDF	0.41 ± 0.18	0.56 ± 0.19	0.68 ± 0.37	0.64 ± 0.23	1.15 ± 0.40
1,2,3,7,8,9-HxCDF	<0.05	<0.05	<0.05	<0.05	<0.05
1,2,3,4,6,7,8-HpCDF	<0.05	<0.05	<0.05	<0.05	0.55 ± 0.53
1,2,3,4,7,8,9-HpCDF	<0.05	<0.05	<0.05	<0.05	<0.05
OCDF	<0.05	<0.05	<0.05	<0.05	<0.05
ΣPCDD/F	12.6 ± 4.38	14.8 ± 3.31	23.1 ± 12.6	43.0 ± 14.2	27.1 ± 13.2
ΣPCB	49.8 ± 33.9	49.6 ± 12.2	67.7 ± 30.0	82.3 ± 31.7	95.0± 46.1
$TEQ_{PCDD/F}$	8.42 ± 3.67	11.0 ± 2.83	12.7 ± 10.1	33.9 ± 12.4	12.1 ± 7.11
TEQ_{PCB}	49.1 ± 151	279 ± 116	2.35 ± 1.01	3.19 ± 1.31	3.39± 1.53
Total TEQ	58.2 ± 153	290 ± 117	15.0 ± 10.6	37.1 ± 13.6	15.5± 8.56
Lipids, %	3.4 ± 1.6	2.5 ± 0.6	3.3 ± 0.9	2.2 ± 1.3	3.5± 0.8

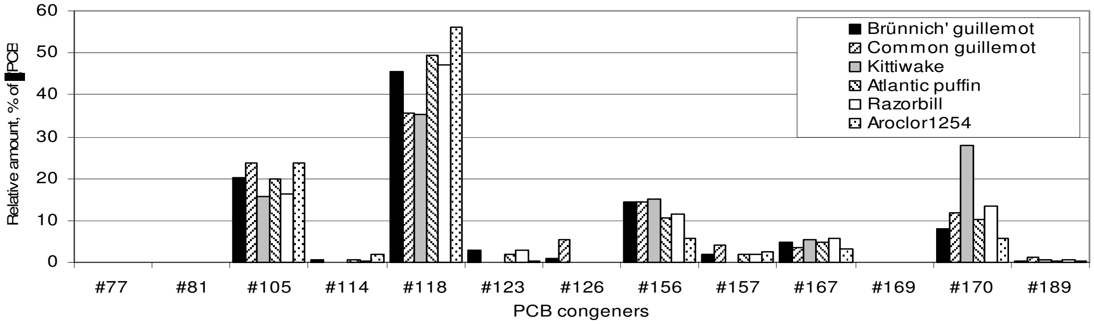

Figure 3. PCB composition of non-ortho and mono-ortho substituted PCB in technical mixture Aroclor 1254[6] and in hepatic tissues of seabirds.

Interspecies differences. The highest contaminant levels of non- and mono-*ortho* PCBs and ΣPCDD/Fs were found in livers of the Atlantic puffin. The geometric mean concentrations of ΣPCB and ΣPCDD/F in hepatic tissues of this species significantly differed from the four other species studied. ΣPBDE levels were the highest in the razorbill (*Table 2*). Difference in migration patterns, feeding habits and metabolic capacities may be the primary reasons for interspecies differences in the bioaccumulation of contaminants.

Table 2. Geometric mean (GM) concentrations of ΣPCB, ΣPCDD/F and ΣPBDE (ng/g lipid weight) in hepatic tissues of seabirds. Bars (│) indicate homogeneous groups according to Student-Newman-Keuls test

Species	ΣPCB		ΣPCDD/F	
	GM	Groups	GM	Groups
Brünnich's guillemot	1157		0.375	
Common guillemot	1935		0.584	
Kittiwake	1975		0.649	
Razorbill	2575		0.727	
Atlantic puffin	4240		2.265	

Species	ΣPBDE	
	GM	Groups
Common guillemot	16	
Brünnich's guillemot	48	
Kittiwake	168	
Atlantic puffin	212	
Razorbill	493	

TEQs calculated for Russian Arctic seabirds do not appear to be at critical levels with respect to literature values, however, continued monitoring for contaminants is warranted, including enzyme activity studies, particularly for *Alcidae* species.

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