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SUMMARY

Polychlorinated biphenyls (PCBs), DDT-related substances and hexachlorocyclohexane (HCH) isomers were analyzed in perch (*Perca fluviatilis*) from Estonian coastal waters depending of their age, sex, maturity of gonads and fishing ground. The profile (percent in mixture) of polychlorinated biphenyls and chlororganic pesticides concentrations in ng/g lipid in perch from the Baltic Sea (Estonian coastal waters) were examined by Principal Component Analysis.

The differences in hydrological features and the lack of information about perch migrations can make the situation more complicated than in freshwater. Alongside of perch`s age, lenght, weight, sex, fat percentage and degree of maturity, we recommend to bring forth the percentage of empty stomach and the content of different food in stomach as additional parameters. Increase in the percentage rate of empty stomachs of Baltic herring and sprat (important food for large perch), in the beginning of 1990s, may turn out to be one of the reasons for the decrease of persistent organic pollutants concentration in food for large perch, compared with the end of 1970s and the beginning of 1980s. For smaller perch, the reason for decrease of persistent organic pollutants concentrations in the beginning of 1990s, the proportion of empty stomachs was considerably higher in 1997 (34.4%) than in 1975 (8,8%). Some high contaminated specimens among the fish (from Pärnu and Matsalu Bays) may also be explained by an input of a PCB mixture with high content of the lower chlorinated congeners, such as the Russian PCB product Sovol from more contaminated parts of the southern part of the Gulf or Riga (Daugavgriva-Latvia) to the Pärnu and Matsalu Bays (Estonia). Of the Baltic perch samples taken from five regions of Estonian coastal waters, within the framework of the Estonian National Monitoring Programme, during the 1998-2001, the persistent organic pollutants content was below the internationally permitted threshold.

KEYWORDS:
persistent organic pollutants, Baltic Sea, fish.

INTRODUCTION

Perch (*Perca fluviatilis*) was chosen for the studies due to several reasons: it is the main target of commercial as well as recreational fishery in Estonian coastal areas. They are easy to obtain and relatively stationary. The Estonian total annual perch catch from the sea was in the middle of the nineties from 300 to 600 tonnes [1]. The main coastal fishing areas are Matsalu Bay, the Väinameri (Moonsund) Archipelago and Pärnu Bay in the Gulf of Riga.

The migration of perch has been studied in Matsalu Bay on the coast of Estonia between 1994 and 1999. The active migration area of perch seems to be relatively restricted. Therefore, 98.3% of the recaptures were made less than 20 km from the tagging place. Tagged perch were recaptured on the eastern side of the tagging place only within 0.5 – 1 km; on the western side, the longest distance from the tagging place was about 25 km [1].

Our knowledge on the presence, concentrations and temporal trends in the perch from the eastern part of the Baltic Sea is limited to only a few studies [2-6].

Proceeding from previous findings, the aim of the present study was firstly to compare the level of contaminants in perch from different geographical regions of the Estonian coastal waters - depending on the species' age, length, weight, catching area - and further, to give a better picture of the environmental situation concerning persistent organic pollutants in the Eastern part of the Baltic Sea, particularly in Estonia. Secondly, the objective of this paper was to examine the patterns of persistent organic pollutants in perch.

The differences in hydrological features and the presence of marine organisms can make the situation more complicated than in freshwater [7].

Consequently, it is essential for human health for all countries to monitor potential hazardous chemicals in their food supplies.

METHOD

Samples of fish were collected along the Estonian coast at five sampling sites. Perch, 86 female and 13 male, were caught between 1998 until 2001, from August to

December. They were caught from the eastern part of the Gulf of Finland (Narva Bay), western part of the Gulf of Finland (near Dirham), Central Baltic (around Vilsandi island), Väinameri (Matsalu) and Pärnu Bay (Table 1). This particular survey proceeds from the results obtained within the framework of the Estonian National Monitoring Program, "Monitoring of dangerous substances in the coastal sea", and several other research programs [4; 8]. The fish were frozen promptly before examination and selection. Description of sampling techniques as well as the analytical procedures can be found in Roots [4].

TABLE 1 - Description of the perch data.

S indicates the sites (see Fig. 1), the age of the fish is indicated by the number following the symbol. Male fish are in addition identified by the letter 'm'. 'A' and 'g' stand for α-hexachlorocyclohexane (α-HCH) and lindane respectively. DDE, DDD, and DDT are the respective p,p'- isomers, 28, 52, 101, 118,138,153, and 180 are IUPAC numbers of the measured chlorobiphenyls. Units refer to: length in mm, weight in g and concentrations of organochlorine compounds in ng/g lipid.

	S	mm	w	L%	a	g	DDE	DDD	DDT	28	52	101	118	138	153	180
1	M1	104	21	0.72	1	1	14	14	42	56	250	14	14	97	83	14
2	M1	103	21	2.88	3	3	45	375	417	1	1	24	24	35	17	17
3	M1	105	21	1.14	1	1	9	9	246	289	61	298	298	140	123	18
4	M1	111	24	1.21	1	1	1	1	397	1	1	66	66	99	58	50
5	M1	114	31	1.26	8	24	16	24	111	190	24	111	111	190	325	56
6	M1	106	26	0.99	1	1	20	1	121	354	1	81	81	101	293	61
7	M1	106	23	1.40	1	7	57	100	214	143	393	1	1	586	100	114
8	M1	108	25	1.99	1	5	35	85	292	1291	276	261	261	809	141	116
9	M1	108	24	1.70	24	9	100	71	429	147	288	147	147	394	735	135
10	M1	114	29	1.91	1	1	1	47	173	440	126	105	105	277	262	188
11	M1	105	19	1.73	29	35	358	81	173	1538	913	104	104	335	370	335
12	M1	113	22	1.34	37	45	52	60	216	813	575	515	515	910	851	358
13	M1	116	22	1.16	1	1	1	683	35	52	224	103	103	2422	250	362
14	M1	107	23	1.61	1	1	75	19	112	25	124	25	25	323	547	460
15	M4	191	231	0.46	2	3	5	8	16	4	6	19	19	24	29	7
16	M4	215	230	0.43	2	2	46	6	11	1	2	1	10	14	42	7
17	M4	191	205	0.57	1	1	1	1	3	2	5	7	11	101	15	8
18	M4	191	151	0.62	1	1	126	21	42	1	2	15	8	124	7	13
19	M4	214	187	0.67	1	1	4	3	3	2	5	21	13	138	33	13
20	M4	193	168	0.71	1	1	2	4	5	5	6	11	13	97	19	16
21	M4	211	205	0.47	1	4	38	10	15	4	3	23	11	20	46	24
22	M4	210	163	0.63	2	2	1	7	17	4	6	12	6	78	93	26
23	M4	205	178	0.60	4	16	132	14	38	7	10	25	34	108	73	27
24	M4	204	166	0.67	1	1	64	3	15	3	1	11	25	29	40	37
25	M4	201	184	0.38	1	2	7	8	26	2	5	16	20	69	62	41
26	M4	206	217	1.57	1	1	102	4	19	2	4	20	21	61	57	44
27	M4	201	192	0.71	1	1	42	11	24	8	6	46	22	54	21	45
28	M4	215	222	0.55	1	1	1	5	12	10	12	27	27	120	104	58
29	M4	199	184	0.51	2	7	84	4	20	3	20	56	11	61	79	84
30	M5	216	178	1.10	1	1	17	1	10	1	2	7	4	10	17	13
31	M5	226	304	0.53	1	6	22	10	31	3	8	51	32	63	127	37
32	M5	224	302	0.75	1	1	7	14	50	2	2	26	30	38	60	40
33	M5	238	255	0.70	1	2	9	2	30	3	3	38	16	75	99	43
34	N5	240	200	0.22	14	27	9	55	95	364	195	95	123	155	200	50
35	N5	240	215	0.24	8	42	225	67	71	363	142	92	188	179	242	58
36	N5	240	189	0.14	14	71	386	114	207	286	336	136	221	221	286	71
37	N5	240	230	0.07	14	86	357	100	186	29	200	43	286	300	357	86
38	N5	235	192	0.06	983	17	533	133	233	467	350	50	400	533	733	167
39	N5	240	210	0.02	150	450	1600	500	1100	2100	2050	1150	1700	1400	1900	500
40	N6	245	226	0.12	8	58	108	33	83	442	150	83	117	125	150	33
41	N6	245	258	0.46	2	65	57	15	85	2	252	39	178	159	135	35
42	N6	245	191	0.13	8	23	215	46	108	108	92	77	146	192	292	77
43	N6	250	264	0.14	7	29	286	86	114	293	129	100	221	250	321	93

44	N6	245	209	0.09	56	567	267	78	422	3733	2100	1600	1911	1578	1300	233
45	N5m	235	207	0.13	8	31	362	100	108	331	146	138	177	300	346	100
46	N5m	235	220	0.06	17	100	950	267	333	1	350	317	417	583	817	233
47	N6m	245	237	0.30	20	303	317	100	153	167	203	130	237	243	373	97
48	N6m	270	251	0.07	14	43	500	86	257	243	200	171	400	500	800	200
49	P1	110	16	1.00	18	43	269	144	140	78	129	89	95	170	205	79
50	P2	150	37	0.60	24	66	294	139	208	158	240	100	71	135	168	25
51	P3	170	56	1.51	6	35	114	40	79	75	52	63	70	77	85	14
52	P4	210	69	0.70	16	63	503	220	232	132	116	135	92	190	204	91
53	P6	270	284	0.87	61	156	897	451	369	254	850	399	205	442	568	200
54	P7	300	407	0.32	26	70	955	392	308	166	609	179	201	456	574	153
55	P8	330	488	0.48	134	451	1309	411	912	762	1587	330	276	542	676	109
56	V5	225	165	1.08	5	2	76	5	26	1	5	18	32	49	43	10
57	V5	243	110	0.74	1	5	119	43	30	11	7	13	38	54	39	11
58	V6	250	203	0.53	1	17	81	51	50	39	8	28	45	56	49	10
59	V6	248	209	0.33	31	74	68	31	31	12	8	28	44	64	57	22
60	V4m	192	86	0.57	1	9	109	29	1	7	3	16	34	16	58	3
61	V4m	201	103	0.28	1	12	62	39	32	3	1	1	29	42	49	9
62	V4m	197	108	0.35	8	33	96	12	38	5	1	33	52	64	81	9
63	V5m	204	98	0.68	6	3	48	5	40	1	1	1	21	68	52	4
64	V6m	243	188	0.34	2	5	22	1	34	1	7	20	16	27	35	12
65	V7m	272	107	0.56	1	15	72	46	45	35	8	25	40	50	44	9
66	Va5	260	241	0.47	1	1	458	187	211	4	13	28	53	57	68	42
67	Va5	245	199	0.22	10	68	328	225	465	459	220	252	321	269	202	58
68	Va6	245	219	0.30	1	12	33	134	64	8	7	11	2	29	30	12
69	Va6	280	291	0.56	5	479	169	55	148	116	99	83	67	93	103	17
70	Va6	256	238	0.64	2	41	94	54	107	5	15	25	28	53	61	18
71	Va6	285	290	0.21	4	36	545	253	255	18	33	29	59	54	54	22
72	Va6	258	247	0.69	2	195	199	62	134	18	41	79	124	130	144	23
73	Va6	295	388	0.23	3	29	824	436	451	36	44	29	1	56	50	47
74	Va7	310	414	0.51	3	17	122	86	177	236	150	85	159	104	108	17
75	Va7	300	400	0.37	4	15	211	236	209	26	15	31	53	89	81	28
76	Va7	305	387	0.12	3	63	803	523	284	5	30	65	81	240	173	55
77	Va7	310	377	0.36	1	26	105	94	120	2	25	27	18	60	47	58
78	Va8	365	593	0.27	1	35	983	399	266	2	7	45	47	85	95	32
79	Va9	375	629	0.34	2	37	562	248	123	17	17	46	56	148	104	40
80	Va10	332	591	0.41	4	41	228	174	321	36	40	102	103	190	157	28
81	Va10	362	621	0.43	3	40	240	109	243	44	64	92	89	153	146	31
82	Va11	390	825	0.21	1	28	1466	638	282	7	20	59	47	194	197	67
83	Va6m	256	207	0.65	1	23	82	33	73	26	30	29	35	55	59	8
84	Va6m	248	173	0.68	2	16	152	44	104	11	33	48	70	100	102	21
85	Va7m	297	290	0.49	4	45	452	204	381	55	100	138	113	199	254	47
86	D5	221	129	1.08	31	61	126	122	115	74	247	118	138	131	152	39
87	D5	214	136	1.75	35	46	139	70	95	76	202	49	74	92	114	36
88	D4	212	131	1.45	33	57	99	46	76	65	171	45	63	25	23	27
89	D4	196	95	2.82	10	20	73	32	64	113	80	24	37	123	61	22
90	D4	204	103	1.57	49	95	382	92	159	146	242	111	140	195	173	36
91	D5	241	196	1.07	12	38	199	38	108	171	97	53	48	78	93	80
92	D5	283	285	1.04	6	20	242	83	159	87	100	184	79	134	283	51
93	D4	206	114	0.89	13	28	197	104	48	292	264	336	16	65	70	21
94	D6	248	207	1.13	12	25	197	40	63	48	133	22	58	73	70	19
95	D5	214	124	1.10	10	25	418	38	57	50	254	26	40	112	107	33
96	D5	217	130	1.02	10	23	194	23	40	54	115	19	57	76	110	44
97	D5	223	142	0.89	8	29	173	16	36	86	41	12	40	53	81	11
98	D4	202	113	1.03	10	34	109	50	46	125	124	162	32	54	51	10
99	D5	216	145	0.99	7	31	102	16	44	96	82	7	36	49	40	11

Persistent Organic Pollutants analysis took place in the Estonian Environmental Research Centre (EERC), which is an internationally accredited laboratory. The EERC is accredited by the German accreditation bureau Deutsches Akkreditierunssystem Prüfwesen GmbH (DAP), reg.-no. DAP-PO3. 131-00-97-01.

The concentrations of the polychlorinated biphenyls and of chlororganic pesticides in the muscle tissue of perch were scaled to the sum of 100; their concentrations in ng/g lipid weight were added as variables. The resulting data set was centered (mean of each variables was zero) and scaled (standard deviation of each variable was one). The set of data was then examined by Principal Component Analysis (e.g. see [9], by the program of Wise and Gallagher [10], running under Matlab 5.0 - The Math Works Inc., South Natick, MA 01760, USAB).

RESULTS AND DISCUSSION

In our earlier research [11], we examined by PCA the profile (percent in mixture) of chlorobiphenyls: 101, 118, 138, 153 and 180, and the sum of their concentrations in lipid in grey seals from the Baltic, Eastern and North-Eastern England and St. Lawrence Estuary (Canada). The patterns differed between juveniles and adult animals, but the gender of adults and geography did not appear to play a role.

Evaluation of bio-accumulation of toxic compounds into the organism of fish from Estonian coastal waters depends on the age, sex and maturity of gonads and on the fishing ground.

The data set contains age, length, weight, and the concentration of lipid, α-hexachlorocyclo-hexane (α -HCH), lindane (γ-HCH), p,p'-DDE, p,p'-DDD, p,p'-DDT and chlorobiphenyls 28, 52, 101, 118, 153, and 180 in 86 female and 13 male perch. The fish were collected from 5 sites from 1998 to 2001 and ranged in age from 1 to 11 years (Table 1). Their length and weight fit reasonably well on a single curve, except for 4-5 years-old female perch from Matsalu (Fig.1). The sizes of male perch lie also on the same curve, with one exception (V7m, Fig. 1 insert). The lipid content decreases with increasing length of the fish and often varies, particularly in the 1-year-old fish (Fig. 2).

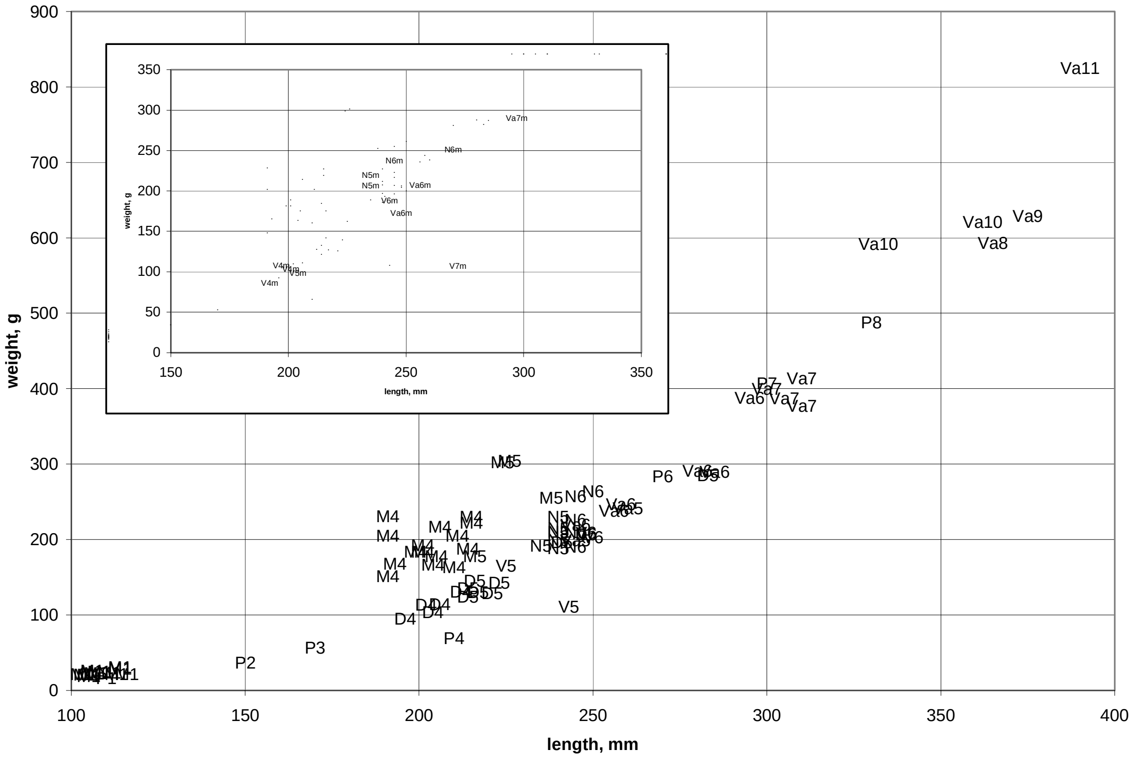

FIGURE 1
Length and weight of female and male (insert) perch. Letters indicate sites, numbers age.
The sites are Matsalu (M), Narva (N), Pärnu (P), Vilsandi (V), Väinameri (Va), and Dirhani (D).
The fish from these sites were collected in 1998, 2000, 2000, 1998, 1999, and 2001 respectively.

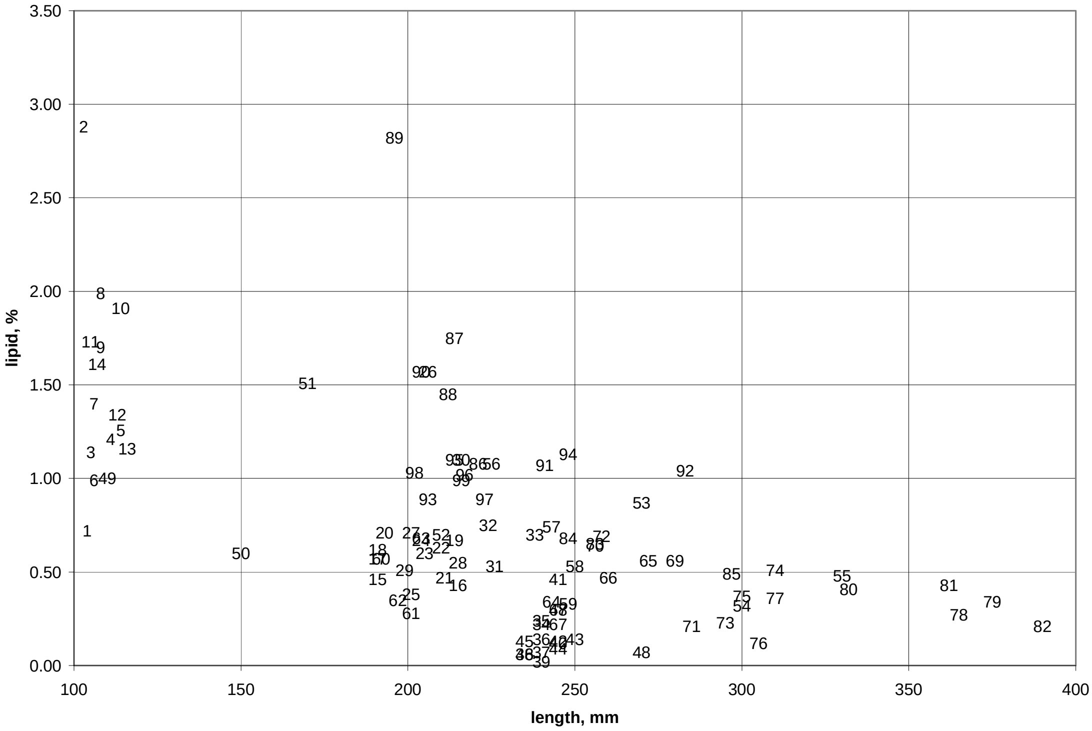

FIGURE 2 - Lipid content plotted against length of the fish. Numbers refer to fish identified in Table 1.

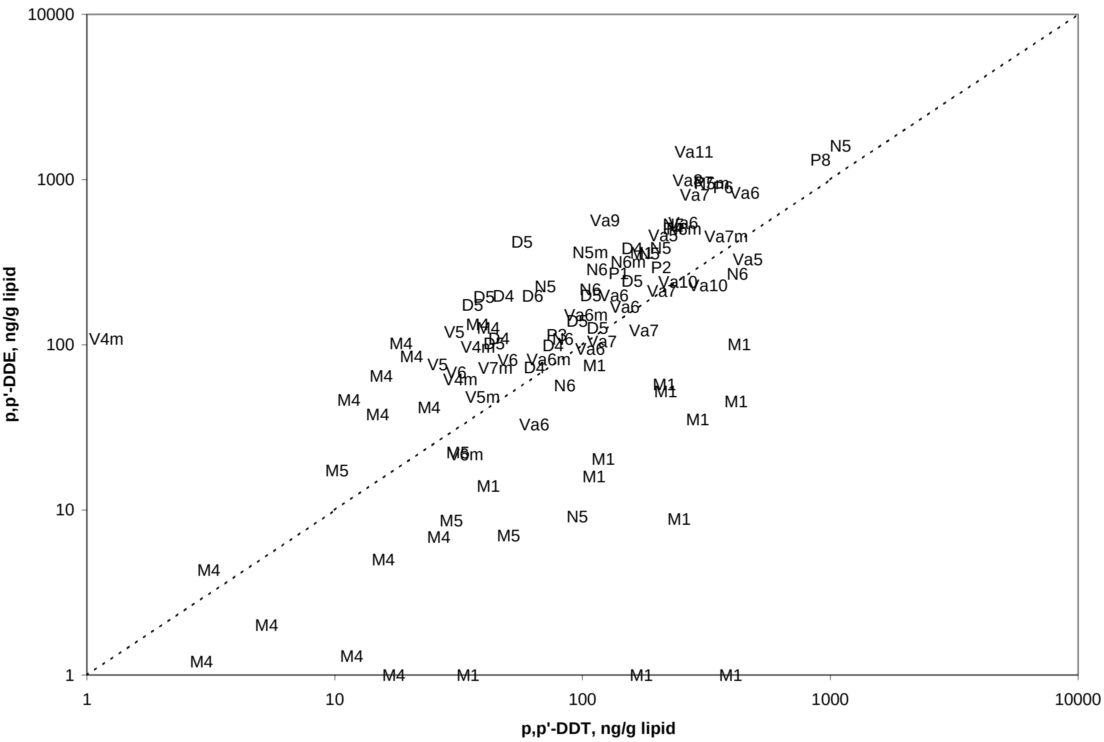

FIGURE 3 - Concentration of p,p'-DDE (ng/g lipid) plotted against the concentration of p,p'-DDT. Letters indicate site, numbers age, and 'm' male fish.

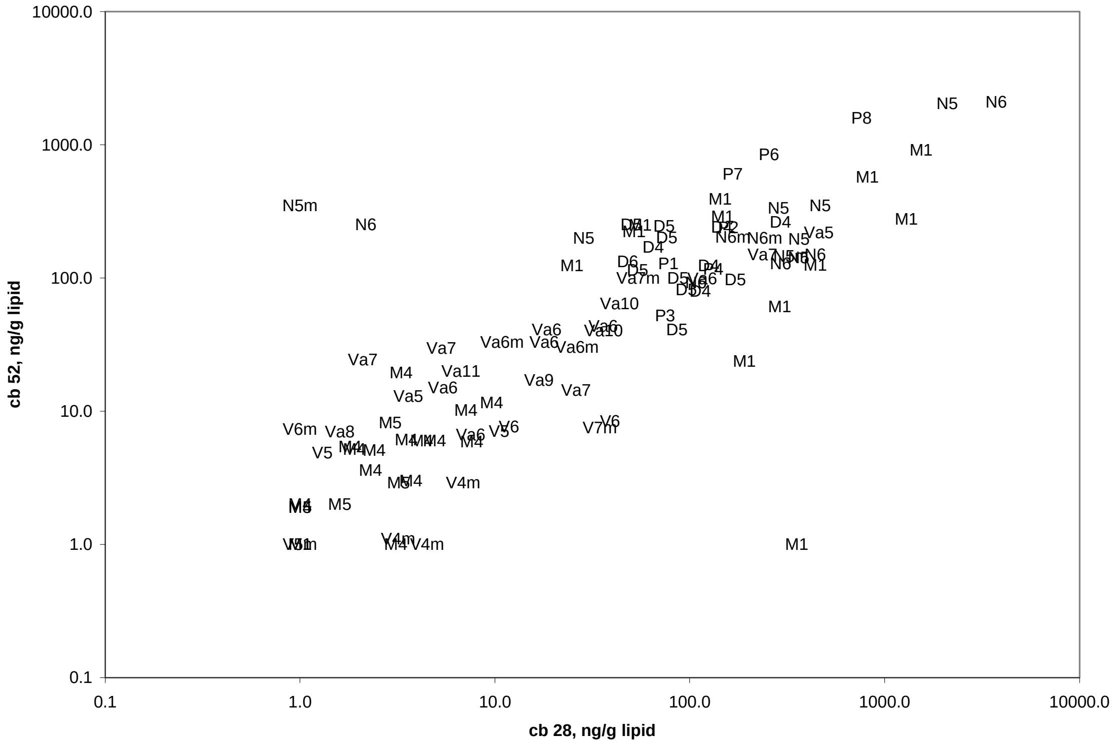

FIGURE 4 - Concentration of the chlorobiphenyl 52 (ng/g lipid) plotted against the concentration of the chlorobiphenyl 28. For additional details see Fig. 3.

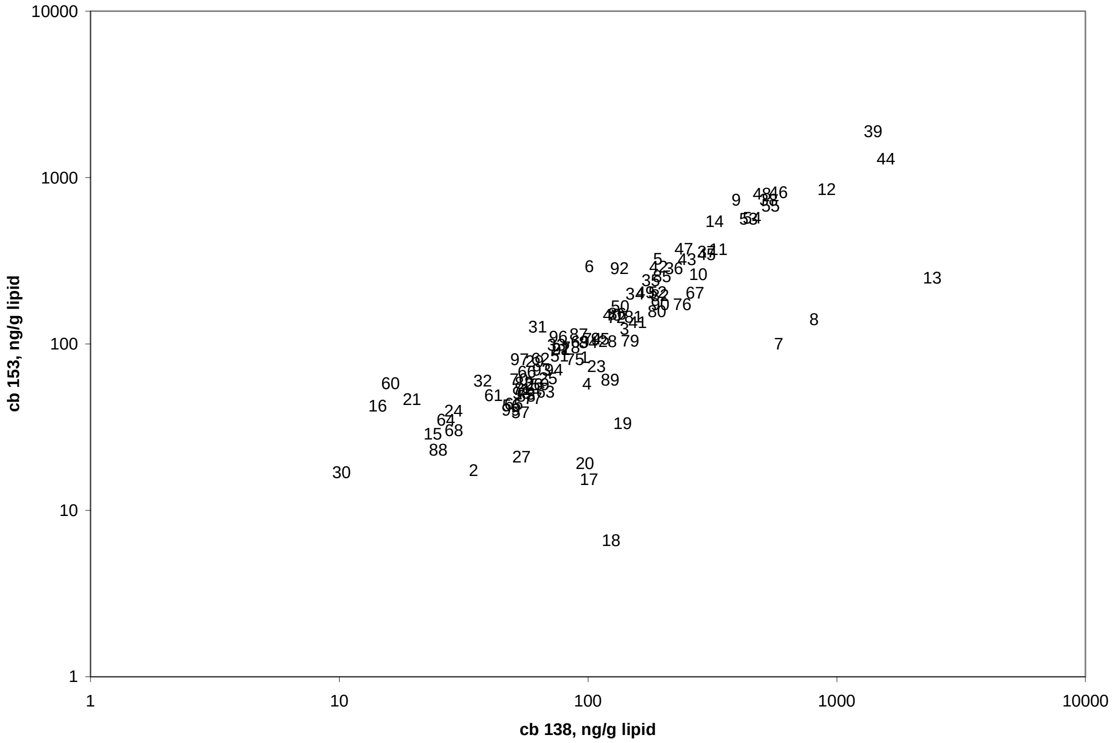

FIGURE 5 - Concentration of chlorobiphenyl 153 (ng/g lipid) plotted against the concentration of the chlorobiphenyl 138. For additional details see Fig. 3.

As Table 1 and Fig. 3 show, many 1year-old fish from Matsalu contain higher concentrations of p,p'-DDT than of p,p'-DDE. This is very unusual and might be a sign of a recent use of p,p'-DDT. The results in a previous study [3] indicate, that HCH and DDT have been recently used or discharged from Latvian and/or closely adjacent territories.

On the other hand, in most 4- and 5-years-old perch from Matsalu, the situation is reversed. It is worth noting that the concentrations of both, p,p'-DDT and p,p'-DDE span three orders of magnitude. In addition, the older fish from Matsalu also contain much lower concentrations of α-HCH and lindane than fish from other sites. The same is true for the 1-year-old fish, but there are four exceptions.

The concentrations of the tri- and tetrachloro-biphenyls (chlorobiphenyls 28 and 52) span four (Fig. 4), and the concentrations of the hexachlorobiphenyls (chlorobiphenyls 138 and 153), three orders of magnitude (Fig. 5). Such large concentration ranges do not allow a summarization of the data by means and standard deviations and require a further detailed analysis.

To this end, the concentrations of the organochlorine compounds in fish from all sites were, after centering (mean=0) and scaling (std=1), analyzed by principal component analysis (PCA). The projections of the data on the plane of the principal components 1 and 2, and 2 and 3 are presented in Figs. 6 and 7. For an easier identification of the individual fish, the values of the principal components are summarized in Table 2.

As can be seen from Fig. 6, two highly contaminated specimens are among the fish from Narva (the two points on the right-hand side of Fig. 6, corresponding to fish number 39 and 44 - Table 2). This may be a result of perch migration from more contaminated parts of the Gulf of Finland. The longest migrations reported earlier in the Baltic Sea are 180 km from the tagging place in the western part of the Gulf of Finland to the Estonian coast and 165 km in the Archipelogo Sea. In the Estonian coastal waters, the longest migration was observed in autumn 1994 when three perch were recaptured in Pärnu Bay, Gulf of Riga, over 160 km from the tagging site [1].

Figs. 6 and 7 also show three groups of fish from Matsalu. For the 4- and 5-years old fish, the concentrations of the organochlorine compounds are projected into an unresolved group of points on the left-hand side of Fig. 6 and in the center of Fig. 7. The 1-year-old fish (Fig. 6 insert and Fig. 7) form two groups (fish 3-7, 9, 10, 14, and fish 8, 11, 12), one much more contaminated than the other (Table 3). There are also two outliers: fish 2 and 13, which contain an unusually high concentration of p,p'-DDD. The profile of organochlorine compounds in fish no. 1 is similar to the profile observed in 4- and 5-years old Matsalu fish.

The fish from Pärnu is the most heterogeneous group, because of different ages. Several groups can be also seen among the fish from Väinameri and Narva (Figs. 6, 7).

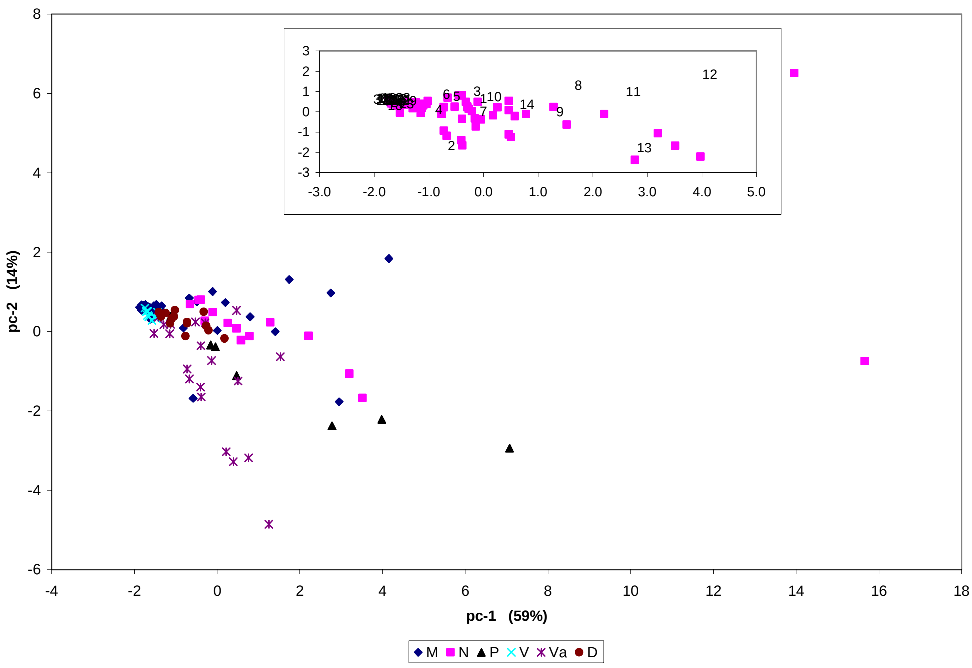

FIGURE 6 - Projection of the concentrations of organochlorine compounds on the plane of the principal components 1 and 2. The amount of the original variance accounted for, is indicated on the axes. For the identification of the sites see Fig. 1. Insert: Fish from Matsalu, indicated by numbers (see Table 1).

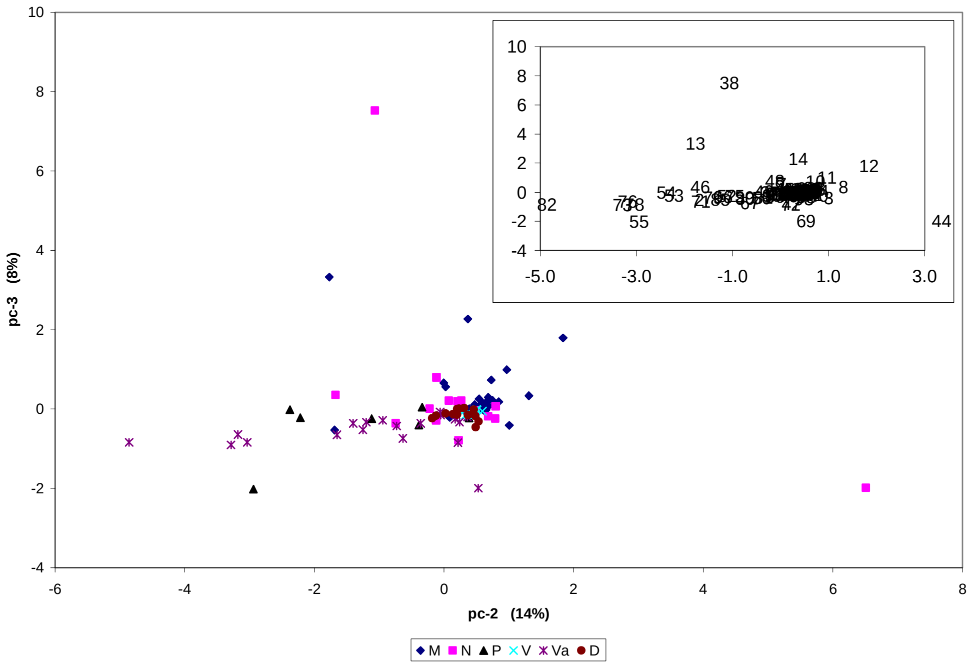

FIGURE 7 - Projection of the concentrations of organochlorine compounds on the plane of the principal components 2 and 3. For additional details see Fig. 1 and Fig. 3. Insert: samples identified by numbers (see Table 1).

TABLE 2 - Values of principal components: 1,2 and 3, obtained by principal component analysis (PCA) of centered (mean = 0) and scaled (std = 1) concentrations of organochlorine compounds. See also Figs. 6 and 7.

	S	pc-1	pc-2	pc-3		S	pc-1	pc-2	pc-3
1	M1	-1.34	0.65	-0.02	52	P4	0.47	-1.12	-0.24
2	M1	-0.58	-1.69	-0.53	53	P6	3.98	-2.22	-0.22
3	M1	-0.11	1.01	-0.41	54	P7	2.78	-2.38	-0.02
4	M1	-0.82	0.09	-0.21	55	P8	7.07	-2.94	-2.02
5	M1	-0.49	0.75	0.21	56	V5	-1.68	0.51	-0.02
6	M1	-0.68	0.84	0.18	57	V5	-1.58	0.28	-0.09
7	M1	0.00	0.02	0.56	58	V6	-1.47	0.33	-0.16
8	M1	1.74	1.31	0.34	59	V6	-1.30	0.47	-0.06
9	M1	1.40	0.00	0.66	60	V4m	-1.68	0.41	-0.12
10	M1	0.20	0.73	0.73	61	V4m	-1.65	0.37	-0.09
11	M1	2.75	0.97	0.99	62	V4m	-1.44	0.49	-0.13
12	M1	4.15	1.84	1.79	63	V5m	-1.71	0.50	-0.01
13	M1	2.95	-1.77	3.33	64	V6m	-1.75	0.59	-0.05
14	M1	0.80	0.37	2.27	65	V7m	-1.52	0.36	-0.15
15	M4	-1.81	0.62	-0.05	66	Va5	-0.67	-1.20	-0.33
16	M4	-1.83	0.54	-0.04	67	Va5	1.53	-0.64	-0.74
17	M4	-1.83	0.67	0.04	68	Va6	-1.53	-0.05	-0.15
18	M4	-1.62	0.31	-0.03	69	Va6	0.47	0.53	-1.99
19	M4	-1.73	0.68	0.10	70	Va6	-1.29	0.17	-0.26
20	M4	-1.78	0.66	0.07	71	Va6	-0.38	-1.65	-0.65
21	M4	-1.72	0.56	0.00	72	Va6	-0.29	0.22	-0.85
22	M4	-1.66	0.62	0.13	73	Va6	0.39	-3.29	-0.90
23	M4	-1.41	0.39	0.01	74	Va7	-0.52	0.24	-0.33
24	M4	-1.68	0.54	0.07	75	Va7	-0.73	-0.95	-0.28

25	M4	-1.62	0.60	0.14	76	Va7	0.76	-3.18	-0.64
26	M4	-1.57	0.47	0.11	77	Va7	-1.15	-0.06	-0.07
27	M4	-1.59	0.57	0.09	78	Va8	0.22	-3.04	-0.84
28	M4	-1.47	0.68	0.29	79	Va9	-0.40	-1.40	-0.36
29	M4	-1.35	0.54	0.25	80	Va10	-0.14	-0.73	-0.43
30	M5	-1.88	0.61	-0.02	81	Va10	-0.39	-0.36	-0.36
31	M5	-1.45	0.62	0.10	82	Va11	1.25	-4.86	-0.84
32	M5	-1.58	0.55	0.08	83	Va6m	-1.42	0.36	-0.20
33	M5	-1.53	0.64	0.16	84	Va6m	-1.12	0.18	-0.14
34	N5	-0.39	0.80	0.07	85	Va7m	0.51	-1.25	-0.52
35	N5	-0.10	0.48	-0.03	86	D5	-0.27	0.14	-0.13
36	N5	0.78	-0.12	-0.29	87	D5	-0.72	0.21	0.00
37	N5	0.58	-0.22	0.00	88	D4	-1.04	0.37	-0.15
38	N5	3.20	-1.07	7.52	89	D4	-1.24	0.46	-0.02
39	N5	15.65	-0.74	-0.36	90	D4	0.18	-0.18	-0.24
40	N6	-0.45	0.79	-0.24	91	D5	-0.72	0.24	0.01
41	N6	-0.66	0.69	-0.19	92	D5	-0.21	0.02	-0.11
42	N6	-0.30	0.27	0.21	93	D4	-0.32	0.49	-0.46
43	N6	0.26	0.21	0.19	94	D6	-1.13	0.20	-0.14
44	N6	13.95	6.51	-1.99	95	D5	-0.76	-0.12	-0.17
45	N5m	0.47	0.08	0.21	96	D5	-1.10	0.31	0.02
46	N5m	3.51	-1.67	0.35	97	D5	-1.35	0.37	-0.15
47	N6m	1.29	0.23	-0.79	98	D4	-1.02	0.54	-0.31
48	N6m	2.21	-0.11	0.79	99	D5	-1.41	0.49	-0.18
49	P1	-0.16	-0.34	0.05					
50	P2	-0.04	-0.39	-0.41					
51	P3	-1.12	0.38	-0.22					

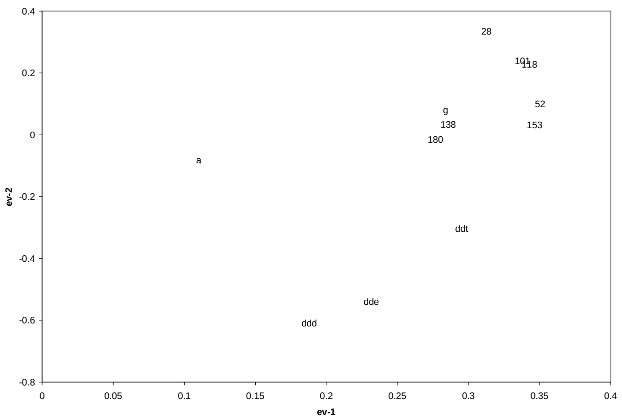

FIGURE 8
Effect of organochlorine compounds on the principal components pc-1 (ev-1) and pc-2 (ev-2). See Table 1 for symbols.

The principal component 1 (pc-1) is affected primarily by the concentration of the organochlorine compounds (Fig. 8, ev-1), since the concentrations were not scaled before centering (mean of the concentration of each organochlorine compound set to zero). The principal component 2 (pc-2, Fig. 8 or Fig. 9, ev-2) separates the DDT group from the other organochlorine compounds. Thus, for example, fish 82 (Fig. 7, insert) contains a very high concentration of p,p'-DDE. The principal component 3 (pc-3, Fig. 9, ev-3) separates α-HCH from lindane, and, to some extent, the less chlorinated chlorobiphenyls from the more chlorinated ones. The fish 38 (Fig. 7, insert) contains a very high concentration of α-HCH.

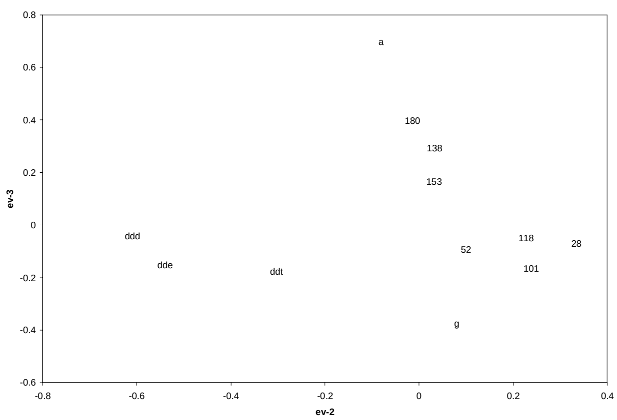

FIGURE 9
Effect of organochlorine compounds on the principal components pc-2 (ev-2) and pc-3 (ev-3). See Table 1 for symbols.

TABLE 3 - Medians of length, weight, and lipid content; concentrations of organochlorine compounds for groups of fish singled out by Principal Component Analysis (PCA), see Figs. 6-7. Numbers following the site symbols refer to fish numbers in Table 1. P and D refer to all fish from these sites. For additional details see Table 1.

Group/Fish	mm	w	L%	a	g	DDE	DDD	DDT	28	52	101	118	138	153	180
M3-7,9	107	24	1.24	1.0	4.1	18	16.3	230	169	42.6	96	96	165	208	58
M8,10-12,14	108	23	1.73	1.0	5.0	52.2	59.7	173	813	276	105	105	335	370	335
M1	104	21	0.72	1.0	1.0	14	14	42	56	250	14	14	97	83	14
M2	103	21	2.88	3.5	3.5	45	375	417	1.0	1.0	24	24	35	17	17
M13	116	22	1.16	1.0	1.0	1.0	683	35	52	224	103	103	2422	250	362
M15-29	204	187	0.60	1.1	1.4	38	6.3	16	3.3	5.4	19	13	69	42	26
M30-33	225	279	0.73	1.0	1.4	13	6.2	30	2.3	2.5	32	23	50	79	38
N38	235	192	0.06	983	17	533	133	233	467	350	50	400	533	733	215
N46-48	245	237	0.07	17	100	500	100	257	167	203	171	400	500	800	200
N34-47,40-43,45	240	215	0.14	8	42	225	67	108	293	150	92	178	192	286	71
N39	240	210	0.02	150	450	1600	500	1100	2100	2050	1150	1700	1400	1900	500
N44	245	209	0.09	56	567	267	78	422	3733	2100	1600	1911	1578	1300	233
V56-65	234	109	0.55	2	11	74	30	33	6	6	19	36	52	49	10
Va66,71.75,79	240	209	0.09	56	450	267	78	422	2100	2050	1150	1700	1400	1300	233
Va 73,76,78	293	345	0.36	3	26	501	242	210	17	16	30	55	73	75	34
Va82	390	825	0.21	1	28	1466	638	282	7	20	59	47	194	197	67
Va rest	280	290	0.51	2	40	152	86	134	26	40	79	70	100	103	21
Va67	245	199	0.22	10	68	328	225	465	459	220	252	321	269	202	58
D	215	130	1.08	11	30	184	43	64	87	129	47	53	77	87	30

The medians of sizes, lipid content and concentrations of organochlorine compounds from groups of perch, or of the individual 'outliers' identified by PCA, are presented in Table 3. The grouped data provide a better insight in the differences among the perch than a summary of the data by means and standard deviations.

It is possible, that many of these 'unusual' concentrations are analytical artifacts. A good practice would require the identification of such cases in 'real time'. Extracts yielding anomalous concentration should be reanalyzed and, if needed, the whole analysis, including the extraction, should be repeated.

The concentrations of the organochlorine compounds in the 1-year-old fish from Matsalu are very different from those in the older Matsalu fish. This difference may be caused by a different feed, or in the tissues analyzed. Another interesting point is the high concentration of p,p'-DDT relative to p,p'-DDE in these fish. Was the former used recently in Matsalu? If so, why there are no relatively elevated concentrations of p,p'-DDT in the older fish?

One would expect the concentrations of organochlorine compounds to be increased with age of the fish. This trend can be seen in fish from Pärnu, but not in fish from the other locations. Maybe this is due to the fact that sufficient information about age ranges were not available. The length of the Pärnu fish practically increases linearly with age, whereas their weight appears to have increased more rapidly after four years (Fig. 10). The concentration of lipid appears to decrease with age (Fig. 10 insert). The concentrations of α-HCH and lindane do not change very much with age (Fig. 11, upper graph). The very high concentration of lindane in the 8-years-old perch may be an artifact. On the other hand, this fish also contains elevated concentrations of p,p'-DDE and p,p'-DDT, and the concentration of the former fits the trend of the p,p'-DDE concentrations with age of the fish (Fig. 11, lower graph).

The pattern of the increased concentrations of hexachlorobiphenyls 138 and 153 with the age of fish is similar to that of p,p'-DDE and p,p'-DDT (Fig. 12). This is not surprising since both of these chlorobiphenyls are highly persistent. The heptachlorobiphenyl 180 is very likely to be less bioavailable and its concentration does not change very much with age of the perch. The accumulation of the pentachlorobiphenyls 101 and 118 with age assumes an intermediate position. On the other hand, the marked increase of the concentration of trichlorobiphenyl 28 (Fig. 11) and tetrachlorobiphenyl 52 (Fig. 12 insert) between the ages of 7 and 8 years, may indicate an increased recent input of less chlorinated PCBs into the Pärnu area. These chlorobiphenyls are considerably less persistent and very likely metabolized by the fish.

By the data [12], the station in Latvia (Salaspils), near the Gulf of Riga, showed the highest values of PCBs and DDTs in air, with medians of 454 pg/m3 of PCBs and 12 pg/m3 of DDTs. These levels, which are about eight and six times higher than the median concentrations of all

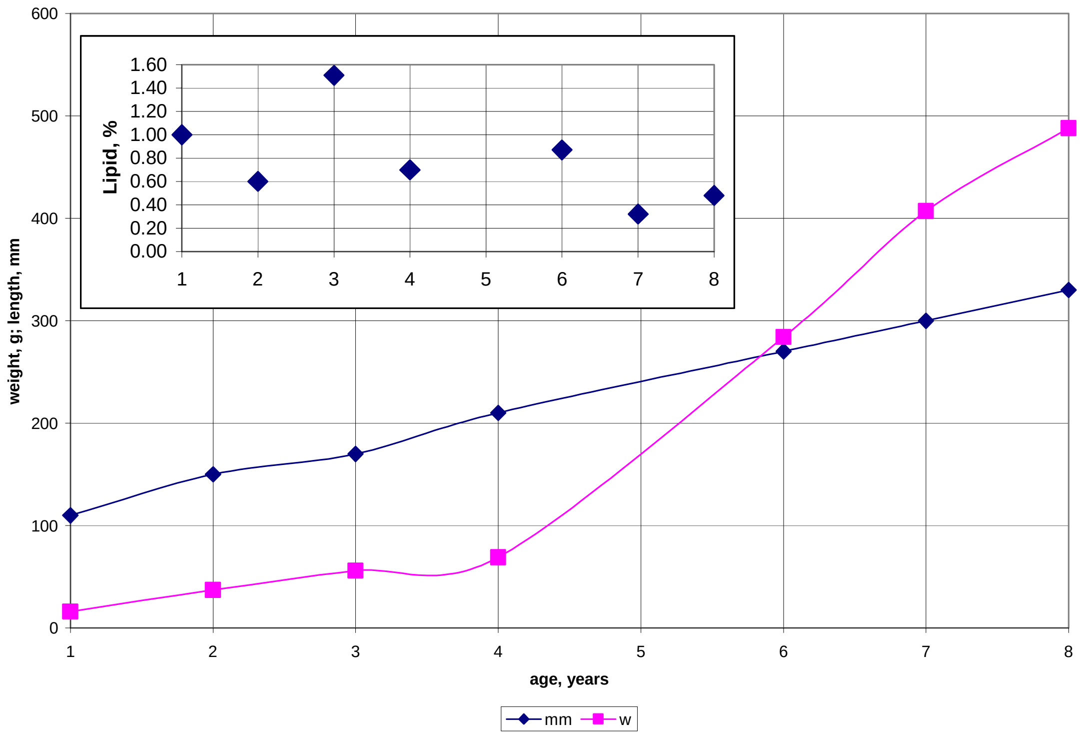

FIGURE 10
Length, weight and lipid content (insert) of perch from Parnu, plotted against their age.

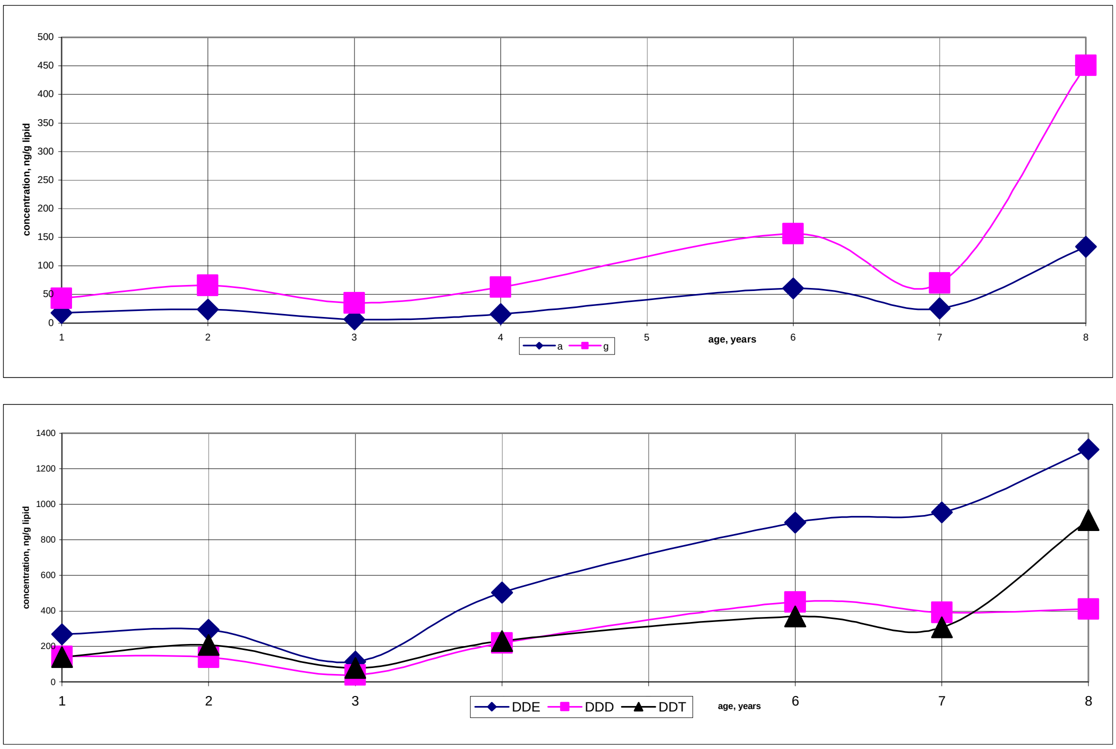

FIGURE 11 - The concentration of α-HCH and lindane in ng/g lipid (upper graph), and of the DDT group in perch from Pärnu (lower graph), plotted against their age.

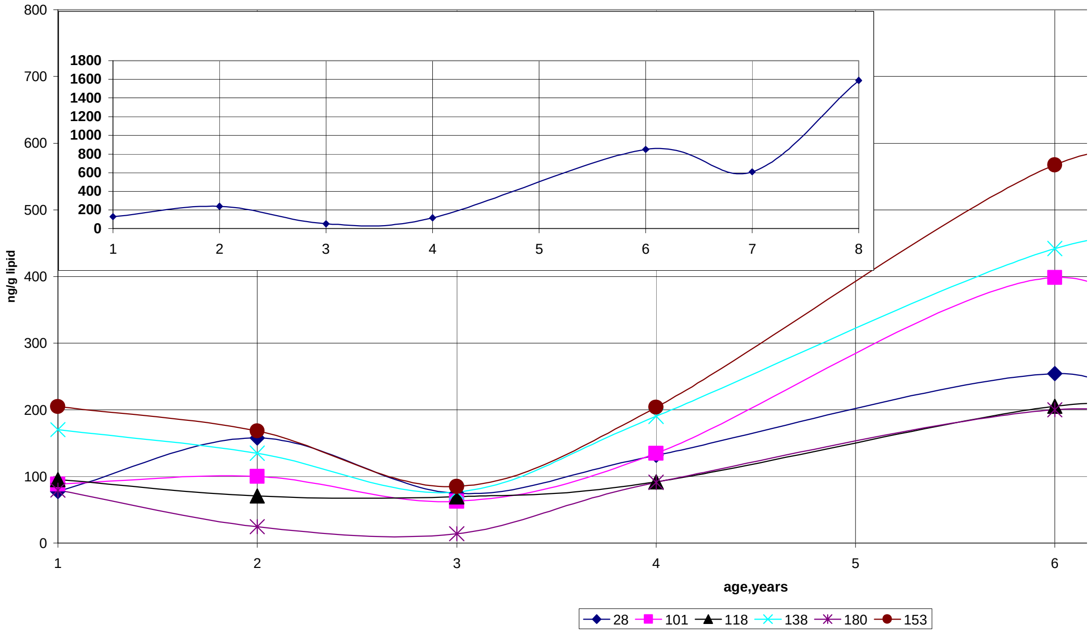

FIGURE 12 - Concentration (ng/g lipid) of chlorobiphenyls 28,101,118, 138, 180, 153, and 52 (insert) in perch form Pärnu, plotted against their age.

stations studied, are most likely the result of local sources. The results [13] show that the atmospheric PCB load decreases fast from the supposed source in Riga city to the outer Gulf of Riga regions. The results were further treated by principal component analysis (PCA), and it was showed that PCB in air samples near the city consisted of congeners present in the original industrial PCB mixture. The distribution (% of total PCB) of different congeners was similar to the composition found in transformer oils, indicating that the samples were taken close to the source(s). On the other hand, the levels of HCHs in Salaspils were similar to other stations in the vicinity (median of 39 pg/m3). By other data [3], the PCB composition at the Daugavgriva (Latvia) sampling location (10 km downstream of the City of Riga) showed a higher content of lower chlorinated CBs. This may be explained by an input of PCB with high content of lower chlorinated CBs, such as the Russian PCB product Sovol. Since the water exchange rate at this location is high, it is possible that this discharge may affect the Gulf of Riga and even the Baltic Proper. From April 1994 to April 1995, 72 kg of PCB were discharged into the Gulf of Riga by the River Daugava [13].

A closer look at the profiles of the chlorobiphenyls was carried out on the chlorobiphenyl concentrations scaled to a sum of 100 (Table 4), and analyzed further by PCA (Figs. 13-16).

As shown in Fig. 13 (ev-1), the principal component 1 (pc-1) separates the less chlorinated (28, 52) from the more chlorinated (138, 153, 180) biphenyls. The principal component 2 (pc-2) separates to some extent all chlorobiphenyls (Figs. 13, 14, ev-2). The principal component 3 (pc-3) separates particularly the chlorobiphenyls 101 and 118 (Fig. 11, ev-3).

The differences in the chlorobiphenyl profiles (Table 5) among the 1-year-old Matsalu perch are shown clearly in Fig. 15 (eight M1 points on the right-hand side of Fig. 15, and six on the left-hand side), the former with higher, the latter with lower concentration of the chlorobiphenyls 28 and 52. Chlorobiphenyl profiles of perch from all the other locations are much more homogeneous in comparison.

The differences in hydrological features can make the situation more complicated that in freshwater. Comparing the food chain of perch in the coastal waters of Finland (Table 6) in the middle of 1970 and species content during 1997, we can assume that nowadays the perch cannot have so much Amphipoda than in the middle of 1970. Mysidacea, Amphipoda and fish were the main food items for smaller perch, 12 – 20 cm in total length, and fish were important for larger fish. Larger perch, 24 cm and more, were fed mainly of fish, especially in 1997. Gobiidae accounted for approximately half of the fish diet of perch; other important species are herring and three-spined stickeback (Gasterosteus aculeatus) [14].

The proportion of empty stomach of smaller perch was higher in 1997 than in 1975, but among larger fish, the proportions were equal. Since the second half of the

TABLE 4
Concentrations of chlorobiphenyls, scaled to a sum of 100%.

	S	28	52	191	118	138	153	180
1	M1	10.6	47.3	2.7	2.7	18.4	15.7	2.7
2	M1	0.8	0.8	20.2	20.2	29.4	14.3	14.3
3	M1	23.6	5.0	24.3	24.3	11.4	10.0	1.5
4	M1	0.3	0.3	19.4	19.4	29.0	17.0	14.7
5	M1	18.9	2.4	11.0	11.0	18.9	32.3	5.6
6	M1	36.4	0.1	8.3	8.3	10.4	30.1	6.3
7	M1	10.7	29.4	0.1	0.1	43.8	7.5	8.5
8	M1	40.9	8.7	8.3	8.3	25.6	4.5	3.7
9	M1	7.4	14.5	7.4	7.4	19.8	36.9	6.8
10	M1	29.3	8.4	7.0	7.0	18.4	17.4	12.5
11	M1	41.6	24.7	2.8	2.8	9.1	10.0	9.1
12	M1	17.9	12.7	11.4	11.4	20.1	18.8	7.9
13	M1	1.5	6.4	2.9	2.9	68.9	7.1	10.3
14	M1	1.6	8.1	1.6	1.6	21.1	35.8	30.1
15	M4	3.7	5.6	17.6	17.6	22.2	26.9	6.5
16	M4	1.3	2.6	1.3	13.0	18.2	54.5	9.1
17	M4	1.3	3.4	4.7	7.4	67.8	10.1	5.4
18	M4	0.6	1.2	8.8	4.7	72.9	4.1	7.6
19	M4	0.9	2.2	9.3	5.8	61.3	14.7	5.8
20	M4	3.0	3.6	6.6	7.8	58.1	11.4	9.6
21	M4	3.1	2.3	17.6	8.4	15.3	35.1	18.3
22	M4	1.8	2.7	5.3	2.7	34.7	41.3	11.6
23	M4	2.5	3.5	8.8	12.0	38.0	25.7	9.5
24	M4	2.1	0.7	7.5	17.1	19.9	27.4	25.3
25	M4	0.9	2.3	7.4	9.3	32.1	28.8	19.1
26	M4	1.0	1.9	9.6	10.0	29.2	27.3	21.1
27	M4	4.0	3.0	22.8	10.9	26.7	10.4	22.3
28	M4	2.8	3.4	7.5	7.5	33.5	29.1	16.2
29	M4	1.0	6.4	17.8	3.5	19.4	25.2	26.8
30	M5	1.9	3.7	13.0	7.4	18.5	31.5	24.1
31	M5	0.9	2.5	15.9	10.0	19.6	39.6	11.5
32	M5	1.0	1.0	13.1	15.2	19.2	30.3	20.2
33	M5	1.1	1.1	13.7	5.8	27.1	35.7	15.5
34	N5	30.8	16.5	8.0	10.4	13.1	16.9	4.2
35	N5	28.7	11.2	7.3	14.9	14.2	19.1	4.6
36	N5	18.4	21.6	8.7	14.2	14.2	18.4	4.6
37	N5	2.2	15.4	3.3	22.0	23.1	27.4	6.6
38	N5	17.3	13.0	1.9	14.8	19.7	27.1	6.2
39	N5	19.4	19.0	10.6	15.7	13.0	17.6	4.6
40	N6	40.2	13.6	7.5	10.6	11.4	13.6	3.0
41	N6	0.3	31.5	4.9	22.3	19.9	16.9	4.4
42	N6	11.0	9.3	7.8	14.8	19.5	29.7	7.8
43	N6	20.8	9.2	7.1	15.7	17.8	22.8	6.6
44	N6	30.0	16.9	12.8	15.3	12.7	10.4	1.9
45	N5m	21.5	9.5	9.0	11.5	19.5	22.5	6.5
46	N5m	0.0	12.9	11.7	15.3	21.4	30.1	8.6
47	N6m	11.5	14.0	9.0	16.3	16.8	25.7	6.7
48	N6m	9.7	8.0	6.8	15.9	19.9	31.8	8.0
49	P1	9.2	15.3	10.5	11.2	20.1	24.3	9.3
50	P2	17.6	26.8	11.1	7.9	15.1	18.7	2.8
51	P3	17.2	11.9	14.4	16.1	17.7	19.5	3.2

	S	28	52	191	118	138	153	180
52	P4	13.8	12.1	14.1	9.6	19.8	21.3	9.5
53	P6	8.7	29.1	13.7	7.0	15.1	19.5	6.9
54	P7	7.1	26.0	7.7	8.6	19.5	24.6	6.5
55	P8	17.8	37.1	7.7	6.4	12.7	15.8	2.5
56	V5	0.6	3.2	11.4	20.3	31.0	27.2	6.3
57	V5	6.4	4.0	7.5	22.0	31.2	22.5	6.4
58	V6	16.6	3.4	11.9	19.1	23.8	20.9	4.3
59	V6	5.1	3.4	11.9	18.7	27.2	24.3	9.4
60	V4m	5.1	2.2	11.7	24.8	11.7	42.3	2.2
61	V4m	2.2	0.7	0.7	21.6	31.3	36.6	6.7
62	V4m	2.0	0.4	13.5	21.2	26.1	33.1	3.7
63	V5m	0.7	0.7	0.7	14.2	45.9	35.1	2.7
64	V6m	0.8	5.9	16.9	13.6	22.9	29.7	10.2
65	V7m	16.6	3.8	11.8	19.0	23.7	20.9	4.3
66	Va5	1.5	4.9	10.6	20.0	21.5	25.7	15.8
67	Va5	25.8	12.4	14.1	18.0	15.1	11.3	3.3
68	Va6	8.1	7.1	11.1	2.0	29.3	30.3	12.1
69	Va6	20.1	17.1	14.4	11.6	16.1	17.8	2.9
70	Va6	2.4	7.3	12.2	13.7	25.9	29.8	8.8
71	Va6	6.7	12.3	10.8	21.9	20.1	20.1	8.2
72	Va6	3.2	7.3	14.1	22.2	23.3	25.8	4.1
73	Va6	13.7	16.7	11.0	0.4	21.3	19.0	17.9
74	Va7	27.5	17.5	9.9	18.5	12.1	12.6	2.0
75	Va7	8.0	4.6	9.6	16.4	27.6	25.1	8.7
76	Va7	0.8	4.6	10.0	12.5	37.0	26.7	8.5
77	Va7	0.8	10.5	11.4	7.6	25.3	19.8	24.5
78	Va8	0.6	2.2	14.4	15.0	27.2	30.4	10.2
79	Va9	4.0	4.0	10.7	13.1	34.6	24.3	9.3
80	Va10	5.5	6.1	15.5	15.7	29.0	23.9	4.3
81	Va10	7.1	10.3	14.9	14.4	24.7	23.6	5.0
82	Va11	1.2	3.4	10.0	8.0	32.8	33.3	11.3
83	Va6m	10.7	12.4	12.0	14.5	22.7	24.4	3.3
84	Va6m	2.9	8.6	12.5	18.2	26.0	26.5	5.5
85	Va7m	6.1	11.0	15.2	12.5	22.0	28.0	5.2
86	D5	8.2	27.5	13.1	15.4	14.6	16.9	4.3
87	D5	11.8	31.4	7.6	11.5	14.3	17.7	5.6
88	D4	15.5	40.8	10.7	15.0	6.0	5.5	6.4
89	D4	24.6	17.4	5.2	8.0	26.7	13.3	4.8
90	D4	14.0	23.2	10.6	13.4	18.7	16.6	3.5
91	D5	27.6	15.6	8.5	7.7	12.6	15.0	12.9
92	D5	9.5	10.9	20.0	8.6	14.6	30.8	5.6
93	D4	27.4	24.8	31.6	1.5	6.1	6.6	2.0
94	D6	11.3	31.4	5.2	13.7	17.3	16.5	4.5
95	D5	8.0	40.8	4.2	6.4	18.0	17.2	5.3
96	D5	11.4	24.2	4.0	12.0	16.0	23.2	9.3
97	D5	26.5	12.7	3.7	12.3	16.4	25.0	3.4
98	D4	22.4	22.2	29.0	5.7	9.7	9.1	1.8
99	D5	29.9	25.5	2.2	11.2	15.3	12.5	3.4

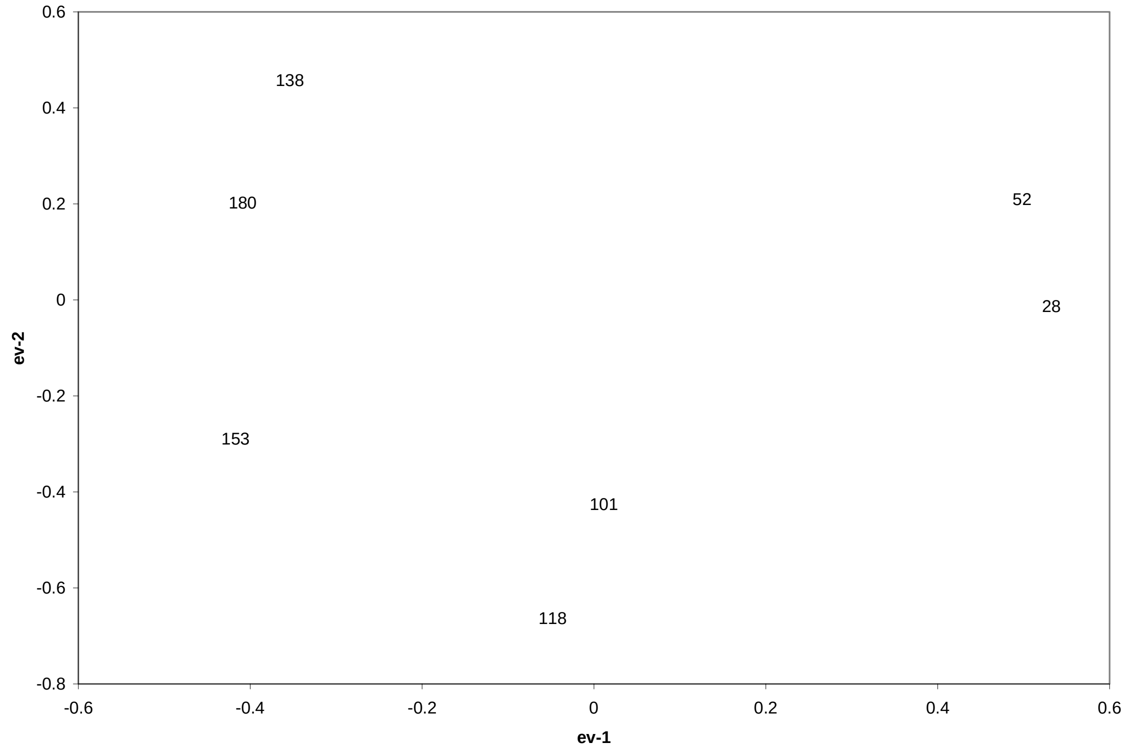

FIGURE 13 - The effect of scaled (sum = 100) chlorobiphenyl concentrations on the principal components 1 and 2.

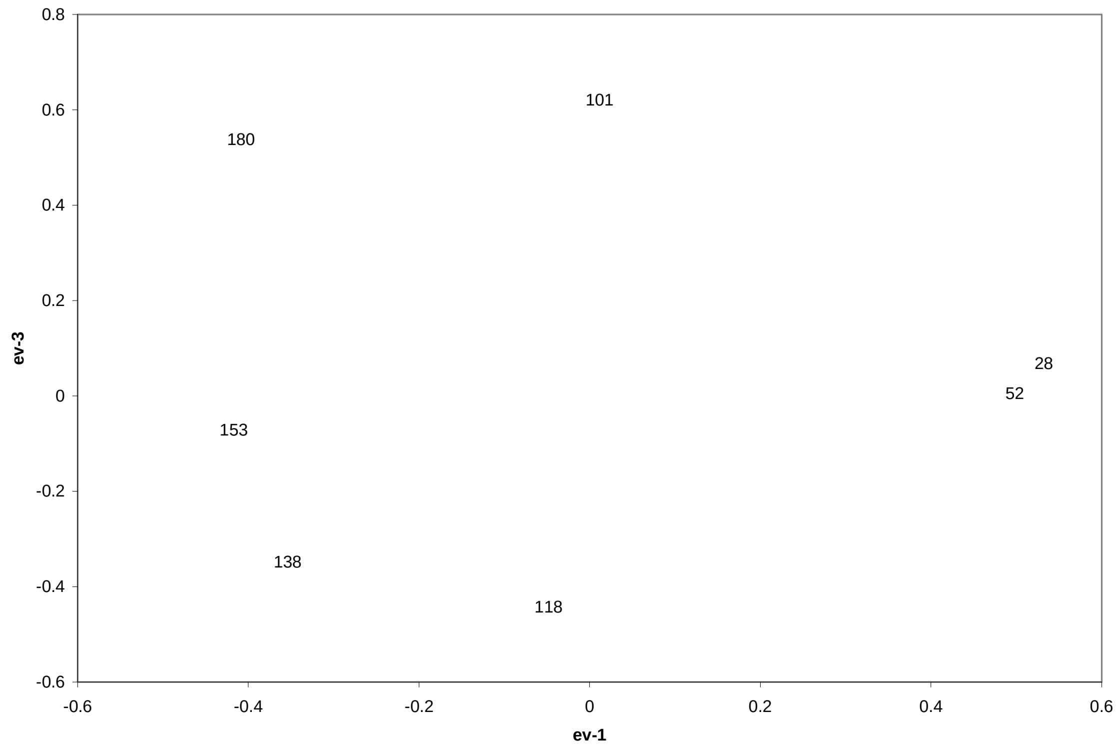

FIGURE 14
The effect of scaled (sum=100) chlorobiphenyl concentrations on the principal components 1 and 3.

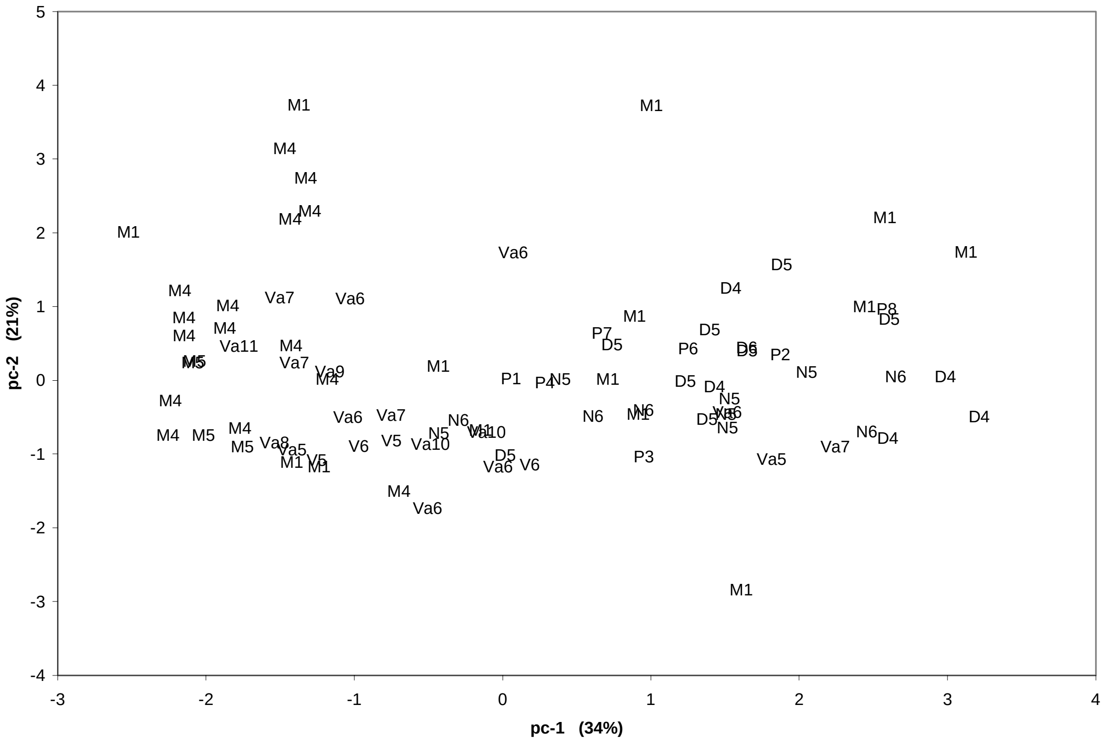

FIGURE 15 - The projection of scaled chlorobiphenyl concentrations on the plane of the principal components 1 and 2.

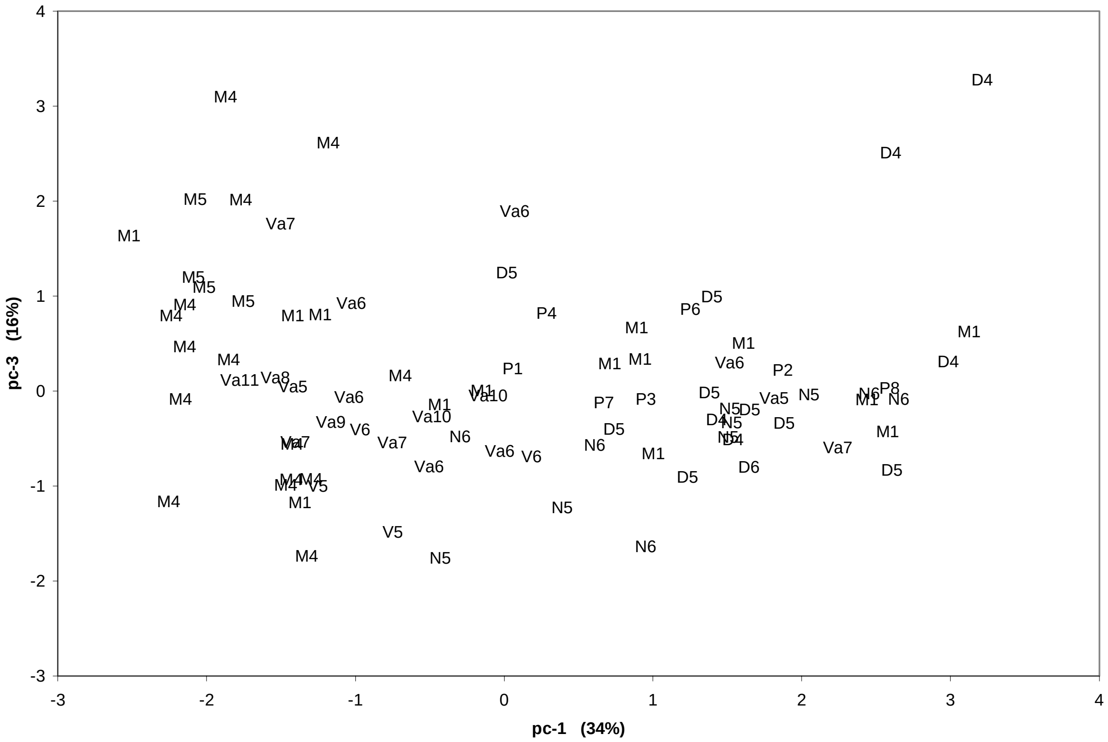

FIGURE 16 - The projection of the scaled chlorobiphenyl concentrrations on the plane of the principal components 2 and 3.

TABLE 5
Values of principal components 1, 2 and 3, obtained by principal component analysis (PCA) of centered (mean = 0) and scaled (std = 1) concentrations of chlorobiphenyls, scaled to a sum of 100 before the PCA, see also Figs. 15 and 16.

	S	pc-1	pc-2	pc-3
1	M1	2.58	2.21	-0.43
2	M1	-1.24	-1.17	0.81
3	M1	1.61	-2.84	0.50
4	M1	-1.42	-1.11	0.80
5	M1	-0.15	-0.67	0.00
6	M1	0.91	-0.45	0.34
7	M1	1.00	3.72	-0.66
8	M1	2.44	1.00	-0.09
9	M1	-0.43	0.20	-0.14
10	M1	0.89	0.87	0.67
11	M1	3.12	1.74	0.63
12	M1	0.71	0.01	0.29
13	M1	-1.37	3.73	-1.17
14	M1	-2.52	2.01	1.64
15	M4	-0.70	-1.51	0.16
16	M4	-2.26	-0.74	-1.16
17	M4	-1.33	2.74	-1.74
18	M4	-1.47	3.14	-0.99
19	M4	-1.43	2.19	-0.93
20	M4	-1.30	2.30	-0.92
21	M4	-1.77	-0.65	2.01
22	M4	-2.18	1.22	-0.08
23	M4	-1.43	0.47	-0.55
24	M4	-2.24	-0.27	0.80
25	M4	-2.15	0.85	0.47
26	M4	-2.15	0.61	0.91
27	M4	-1.18	0.01	2.62
28	M4	-1.85	1.01	0.33
29	M4	-1.87	0.71	3.10
30	M5	-2.08	0.26	2.02
31	M5	-1.75	-0.90	0.95
32	M5	-2.02	-0.75	1.10
33	M5	-2.09	0.24	1.20
34	N5	2.05	0.11	-0.03
35	N5	1.50	-0.46	-0.48
36	N5	1.53	-0.25	-0.33
37	N5	-0.43	-0.72	-1.76
38	N5	0.39	0.01	-1.22
39	N5	1.52	-0.64	-0.19
40	N6	2.65	0.05	-0.08
41	N6	0.95	-0.40	-1.64
42	N6	-0.30	-0.54	-0.48
43	N6	0.61	-0.49	-0.57
44	N6	2.46	-0.69	-0.03
45	N5m	0.67	-0.08	-0.10
46	N5m	-0.79	-0.72	-0.16
47	N6m	0.27	-0.72	-0.46
48	N6m	-0.55	-0.66	-0.70
49	P1	0.06	0.03	0.24
50	P2	1.87	0.35	0.22
51	P3	0.95	-1.03	-0.08

	S	pc-1	pc-2	pc-3
52	P4	0.29	-0.03	0.82
53	P6	1.25	0.43	0.86
54	P7	0.67	0.64	-0.12
55	P8	2.59	0.97	0.03
56	V5	-1.25	-1.08	-1.00
57	V5	-0.75	-0.82	-1.49
58	V6	0.18	-1.14	-0.69
59	V6	-0.97	-0.89	-0.41
60	V4m	-0.97	-2.96	-1.22
61	V4m	-1.78	-0.75	-2.31
62	V4m	-1.27	-1.85	-0.98
63	V5m	-1.88	0.55	-2.51
64	V6m	-1.18	-0.93	0.66
65	V7m	0.20	-1.11	-0.68
66	Va5	-1.42	-0.94	0.04
67	Va5	1.81	-1.07	-0.07
68	Va6	-1.03	1.11	0.92
69	Va6	1.51	-0.43	0.30
70	Va6	-1.04	-0.50	-0.06
71	Va6	-0.03	-1.17	-0.63
72	Va6	-0.51	-1.74	-0.79
73	Va6	0.07	1.73	1.89
74	Va7	2.24	-0.90	-0.60
75	Va7	-0.75	-0.47	-0.54
76	Va7	-1.40	0.24	-0.54
77	Va7	-1.50	1.12	1.76
78	Va8	-1.54	-0.84	0.15
79	Va9	-1.16	0.12	-0.32
80	Va10	-0.49	-0.86	-0.27
81	Va10	-0.11	-0.70	-0.05
82	Va11	-1.78	0.47	0.12
83	Va6m	0.29	-0.61	-0.44
84	Va6m	-0.64	-1.01	-0.64
85	Va7m	-0.25	-0.73	0.19
86	D5	1.38	-0.53	-0.02
87	D5	1.65	0.40	-0.20
88	D4	2.98	0.05	0.31
89	D4	1.54	1.25	-0.51
90	D4	1.43	-0.08	-0.30
91	D5	1.40	0.69	0.99
92	D5	0.02	-1.01	1.25
93	D4	3.21	-0.49	3.28
94	D6	1.65	0.44	-0.80
95	D5	1.88	1.57	-0.33
96	D5	0.74	0.49	-0.40
97	D5	1.23	-0.01	-0.91
98	D4	2.60	-0.78	2.51
99	D5	2.61	0.83	-0.83

TABLE 6
Composition of diet (% of total amount of fullness points) in Tvärminne (Gulf of Finland) in 1975 and 1997 [14].

Food item	12.0-15,9		16,0-19,9		20,0-23,9		24,0-27,9	
	1975	1997	1975	1997	1975	1997	1975	1997
Fish	18.3	19.0	26.1	22.8	33.0	61.8	40.0	93.9
Amphipoda	32.1	12.7	29.7	15.5	12.3	9.9	15.7	2.0
Mysidacea	23.1	37.0	13..3	35.1	9.4	17.5	1.7	1.2
Chironomidae	11.3	9.6	6.5	6.4	1.9	0.2	-	2.9
Isopoda	3.3	11.5	6.2	9.0	26.6	-	26.0	-
Trichoptera	2.4	3.0	2.1	3.4	0.6	-	-	-
Decapoda	2.3	-	3.4	0.7	4.9	1.8	3.3	-
Polychaeta	0.5	6.7	1.5	4.0	0.3	7.9	-	-
Mollusca	0.4	-	1.3	0.7	2.3	-	1.3	-
Odonata	0.2	-	0.6	-	1.0	0.9	2.3	-
Other	6.1	0.5	9.3	2.4	7.8	-	9.7	-
Number of perch	329	128	271	109	149	76	54	30
Empty (%)	8.8	34.4	19.6	33.0	36.9	34.2	37.0	40.0

1980s, the mean weight at age of the Baltic herring (second important food for large perch) began to decrease in most regions of the Baltic Sea. The results of feeding investigations conducted during 1982 – 1994 show in prey composition and increases in the share of fish with empty stomachs. These changes, probably inducted by hydrological conditions, are prevailing since the mid-1980s and could be at least partly responsible for drastic alternations in growth [7, 15].

This was probably the result of natural changes in last twenty years (decrease of salinity and oxygen concentration in the Baltic Sea). Increase in the percentage rate of empty stomachs of Baltic herrings and sprat, in the beginning of 1990s may turn out to be one of the reasons for the decrease of persistent organic pollutants concentration in food, compared with the end of 1970s and the beginning of 1980s [16].

CONCLUSIONS

The differences in hydrological features and the lack of information about perch migrations can make the situation more complicated than in freshwater.

Alongside of perch`s age, length, weight, sex, fat percentage and degree of maturity, we recommend to bring forth the percentage of empty stomach and the content of different food in stomach as additional parameters. Increase in the percentage rate of empty stomachs of Baltic herring in the beginning of the 1990s may turn out to be one of the reasons for the decrease of persistent organic pollutants concentration in perch (food). For smaller perch, the reason for decrease of persistent organic pollutants concentrations in the beginning of 1990s, the proportion of empty stomachs was considerably higher in 1997 than in 1975.

The reason why 1 year-old fish from Matsalu contain higher concentrations of persistent organic pollutants may indicate, that toxicants have recently been used, or discharged from closely joined territories. Especially the capital city Riga (Latvia) is likely to be a source of input of local toxicants.

High contaminated specimens among the fish from Narva Bay may be a result of perch migration from more contaminated parts of the Gulf of Finland.

Even the current levels of the investigated organochlorine compounds in fish do not represent a risk to humans; a continuing monitoring however is needed to document the effectiveness of the international ban of the selected persistent organic pollutants.

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