PRINCIPAL COMPONENT ANALYSIS OF POLYCHLORINATED BIPHENYLS AND POLYCYCLIC AROMATIC HYDROCARBONS IN SEALS

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(Accepted for publication November 12, 2002)

This report is a part of studies on toxic substances in the Baltic Sea. The study on polychlorinated biphenyls (PCB) and polycyclic aromatic hydrocarbons (PAH) in the Baltic grey seal (*Halichoerus grypus*) was carried out in the Eastern Baltic. According to the survey in the Estonian coastal waters during the annual molt period in May and June, the size of the grey seal stock is estimated to be of 1500–2000 individuals. This paper discusses reasons for the increase of the grey seal stock in the Baltic Sea. Data on the concentrations of PCB in the air, water and in the food chain of a grey seal are summarised. The impact of salinity and concentration of oxygen of the Baltic Sea on grey seal's food chain are pointed out as well. By our data, it is obvious that the PCB profiles in the muscle and in the kidney are different from those in the blubber.

Keywords: *the Baltic Sea, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, grey seal, food chain, salinity.*

Introduction

In 1970's, when seals became an object of research, it was soon noticed that there was an alarming decrease in their reproductive capacity in the Baltic Sea populations. Initially, this was thought to be caused by environmental toxins, primarily by the insecticide DDT and the industrial chemicals PCB, which were detected in high concentrations in the seals. Adult Baltic grey seals and ringed seals (*Phoca hispida*) suffer from a disease complex, interpreted as hyper-adrenocorticism, most probably caused by organochlorine compounds and especially by PCB. This disease complex includes uterine occlusions and, consequently, sterility [1].

The seals were chosen to be the subject of present research work because they live at the top of the food chain of the Baltic ecosystem, and accumulate many highly toxic compounds [2].

The results presented by HELCOM for seals from the Baltic indicate that the concentration of DDT in ringed seals has decreased considerably since the early 1970's, but there was no such a decrease in the concentration of PCB. In late 1970's, fewer than 2000 grey seals were registered in the Baltic Sea. Since then, the general population of grey seals in the Baltic has increased by 8–12% per year. The increase occurred particularly in the northern part of the Baltic Proper and in the Gulf of Bothnia. At the moment about 5300 individuals are counted in the northern Baltic as a whole [3].

The aim of the present study was to analyse contaminant distribution which might contribute to understanding the grey seal population changes.

Materials and methods

The samples originated from two sampling areas (Fig. 1), the Väinameri Sea and Vilsandi National Park (Table 1). The Väinameri Sea is the background station for organochlorine compounds in the Baltic Sea [2,4]. Both areas belong to the West-Estonian Archipelago Biosphere Reserve (WEABR). The WEABR is probably the best breeding area for seals in the Baltic.

The grey seal samples were analyzed as described in [4]. Briefly, the samples were frozen immediately after collection. All the solvents used were of the highest quality available.

The samples (10 g) were homogenized (IKA T25 homogenizer from Labassco AB, Pertille, Sweden), extracted according to [5], and the lipid content was determined. For the analyses of organic contaminants (PCB, PAH), approximately 0.1–0.2 g of lipids were taken. The polar lipids were separated from the sample by a silicagel column (10% water) and the eluate was divided into two parts. Dimethylformamide – water and cyclohexane were used to clean up the part used to measure the PAH. The detailed description of the clean-up procedures used

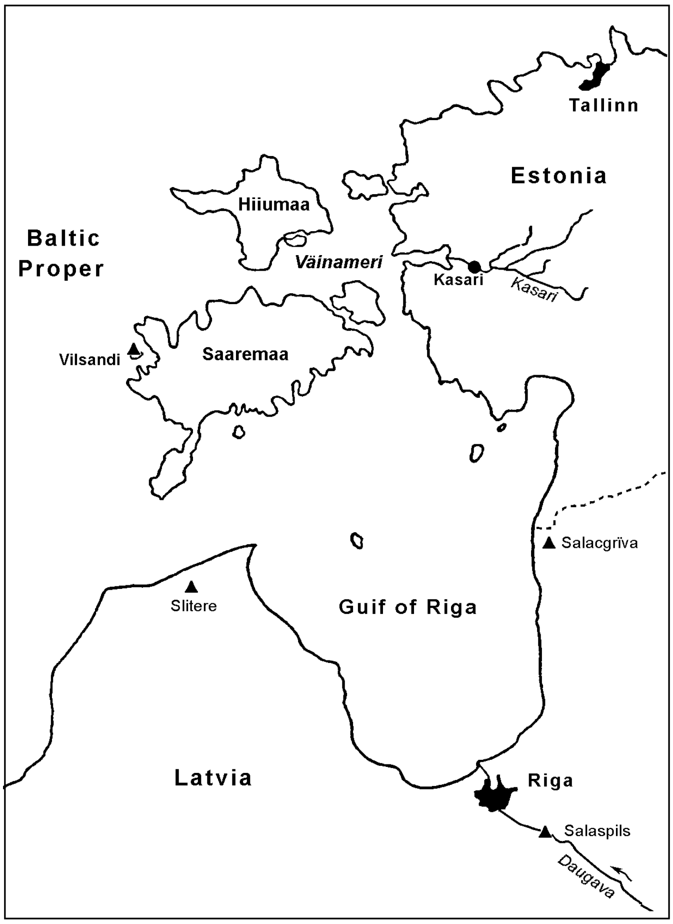

Fig. 1. The scheme of the sampling areas.

is given in [6]. Further cleanup of the part for the measurement of PCB was performed by two methods [5].

The quantitative analyses were done by gas chromatography using a mass-selective detector (Fisons 800 MD) and DB-5 capillary (30 m) column. ^{13}C-labelled standards of the chlorobiphenyls with IUPAC numbers 52, 101, 105, 118, 138, 153 and 180 were used as internal standards in PCB analyses. A standard consisting of 20 PAH with 3–7 rings was used in the determination of PAH. D_{10} perylene was used as the internal standard [6].

Principal Component Analysis (PCA) of the PCB and PAH "profiles" (concentrations scaled to a sum of 100) was performed by PLS Tool 2.0 (Eigenvector Research Inc., Madison WA 98831, USA), running under Matlab 6.1 (The MathWorks Inc., Natick, MA 01760, USA). The data were centered (mean = 0) and scaled (std = 1) before the analysis.

Results and discussion

Grey seals are the largest of the seal species in the Baltic Sea region. Large groups of grey seals are found mainly in the Swedish, Finnish and Estonian Archipelago areas. Small numbers are present also in the Kattegat-Skagerrak area. The Estonian coastal waters serve as the south-eastern boundary of the regular distribution of grey and ringed seals in the Baltic Sea.

Comparing the PCB concentrations (Table 2) in the blubber of the grey seals from Väinameri Sea and Vilsandi, it appears that the PCB concentration in grey seals from Vilsandi may be higher the that from the Väinameri Sea, but comparable or slightly lower than the PCB concentration in the grey seals from the open Baltic Sea [1,7].

Very low fat content in the blubber of 6–8 year-old male grey seals aroused interest (Table 2, seals No. 6 and 7). Only individuals with a poor nutritional status (thin layer of blubber and/or low content of extractable fat in blubber) had significantly higher concentrations of pollutants than other groups [7]. This is probably due to the fact that they had used the fat as a source of energy without being able to metabolise or excrete the pollutants at the same rate. On the other hand, it appears that the PAH profiles in the blubber of the seals No. 6 and 7 are not very different from those in the other seals (Table 3).

In general, it seems that the concentrations of the total PCB are considerably higher than the total PAH concentrations. In addition to the fact that mam-

Table 1

Grey seal sampling areas along the Estonian coast, 1994

Samples	Age of seals	Sampling	
		Area	Time
1–5	2–3	Väinameri Sea	October
6,7	6–8	Vilsandi National Park	July
8	3–4	Väinameri Sea	September
9–12	5–6	Väinameri Sea	September

mals are able to faster metabolise PAH than PCB, other factors, such as higher atmospheric fall-out, river discharge, and foodchain magnification, may contribute to the higher concentrations of PCB in grey seals.

Possible food chain effects. An adult grey seal consumes 7 kg fish per day [8]. Seals, fed contaminated Baltic fish (herring), developed significant body burdens of potentially immunotoxic organochlorines and displayed impaired immune responses as demonstrated by suppression of natural killer cell activity and specific T-cell responses. The results demonstrated that chronic exposure of environmental contaminants, accumulated through the food chain, affects immune function in seals, whereas short-term fasting periods do not seem to pose an additional risk [9].

The food intake reaches its highest level in late autumn when seals build up blubber for winter and is the lowest in the pupping and breeding seasons and during the molt period. In the beginning of the 1970's, the diet of grey seals, mainly in the Baltic Proper, contained 23.5% of herring, 21% of cod, 12.5% of salmon, 7% of sea trout, 5.6% of eel and flounder, 4.9% of perch and other fish in smaller proportions [8].

The Baltic salmon is important food for grey seals. Salmon is a pelagic feeder and preys mainly on herring in the open Baltic Sea. The few analyses performed on the Baltic salmon indicate levels of persistent pollutants at least two orders of magnitude than those found in cod, which contains smaller amounts of fat. A high fat content is often correlated with long spawning or feeding migrations in which the fat is used for gonadal growth or as an energy source. A large proportion of salmon in the Baltic Sea originates from compensatory hatcheries, where adult fish are caught in the river and used for breeding. During 1992, the mortality of fry was 45–90% in different hatcheries. The high mortality of fry originates from individual females, where all the fry die. Persistent pollutants were indicated to as the cause of mortality. High mortality rate of salmon fry was recorded at a PCB concentration of 9 ppm [10,11].

Cod is a suitable indicator for examining water pollution by bioaccumulative organochlorine compounds, by being a higher ranking predator in the food chain and because of its reasonably sedentary life style. Cod liver is rich in lipid (50–85%) and hence is used as a raw material in the production of cod-liver oil. Most of the organochlorine compounds,

Table 2

Concentration of chlorobiphenyls in grey seal along the Estonian coast

Sample*	Organ	Fat, %	Sex	Concentration of chlorobiphenyls, $\mu g \cdot kg^{-1}$						
				52	101	118	105	138	153	180
1	Blubber	88.2	Female	27	77	60	12	2767	3607	2323
2	Muscle	1.40	Male	88	153	93	27	2828	3917	2284
3	Liver	2.30	Male	40	86	54	13	1867	2483	1253
4	Liver	2.00	Male	15	30	24	10	549	697	324
5	Blubber	88.8	Male	40	150	80	30	4105	5152	2317
6	Blubber	58.7	Male	525	924	419	132	25541	44020	23939
7	Blubber	58.7	Male	554	1138	409	122	15430	18382	20804
8	Blubber	87.5	Male	46	102	78	23	2288	2878	1505
9	Muscle	5.10	Male	17	40	49	17	340	431	180
10	Kidney	3.70	Male	59	83	44	13	827	110	486
11	Liver	4.70	Male	38	78	44	15	1825	1894	832
12	Blubber	91.5	Male	56	116	57	25	3053	4266	2138

* Sample number see Table 1.

Table 3

Concentrations of PAH in lipids of grey seals along the Estonian coast

Compound	Abbreviation	Concentration of PAH in sample*, µg·(kg lipid)$^{-1}$										
		1	2	3	4	5	6 and 7	8	9	10	11	12
Fluorene	Fen	13.6	13.8	1.1	12.1	96.3	44.5	9.4	39.3	1.8	6.9	11.6
Phenanthrene	Phe	134.3	551.9	20.8	118.9	1341.6	156.3	32.6	263.7	33.9	88.6	81.5
Anthracene	Ant	22.3	61.3	2.1	11.2	246.4	9.5	6.4	15.8	0.0	18.0	0.0
3-mePhenanthrene	3MPh	7.6	2484.8	2.6	20.0	60.1	38.1	7.1	62.3	6.6	9.5	5.5
1-mePhenanthrene	1MPh	0.0	285.3	0.0	0.0	77.2	124.3	0.0	612.0	3.3	0.0	0.0
Fluoranthene	Flu	13.3	55.1	10.7	26.5	88.4	19.2	14.6	136.3	10.5	17.3	20.1
Pyrene	Pyr	11.3	42.6	8.0	17.6	54.7	18.3	8.8	88.6	6.4	13.8	189.2
2-mePyrene	2Mpy	3.0	12.9	1.1	1.9	26.1	9.4	2.1	38.1	0.7	2.1	9.3
1-mePyrene	1Mpy	1.4	20.8	1.0	2.0	37.5	1.6	2.0	56.9	0.6	1.9	14.8
Benzo(ghi)fluoranthene	ghiF	2.8	9.8	1.9	4.5	18.6	0.9	2.6	64.7	1.7	3.6	78.2
Cyclopenta(cd)pyrene	cd	0.7	2.2	0.9	1.6	6.1	1.7	1.5	11.2	0.3	1.0	1.6
Benz(a)anthracene	BaA	1.7	6.9	1.8	3.6	23.6	6.7	2.8	43.2	1.3	2.6	4.8
Chrysene	Chr	9.8	37.7	7.8	16.7	64.2	17.2	8.0	314.4	8.2	14.5	51.7
Benzo(k)flouranthene	BkF	2.4	10.1	2.3	6.8	30.6	1.9	3.1	45.9	1.9	3.5	6.6
Benzo(e)pyrene	BeP	3.4	21.5	3.9	9.7	59.0	4.2	3.3	9.0	3.0	5.7	11.4
Benzo(a)pyrene	BaP	6.1	4.6	1.7	2.4	17.5	0.8	4.1	4.5	0.4	1.4	9.3
Perylene	Per	0.0	20.5	2.5	3.8	92.6	8.7	13.3	5.1	0.5	1.2	8.7
Indeno(1,2,3-cd)pyrene	IcdP	2.9	29.0	4.6	13.8	97.1	2.6	3.6	52.4	3.1	4.2	8.6
Benzo(ghi)perylene	ghiP	0.0	62.3	9.9	9.1	67.1	12.7	13.9	60.2	10.8	9.7	24.5
Coronene	Cor	3.7	30.5	2.1	7.1	16.8	2.0	2.6	37.5	2.1	3.0	0.0
Σ PAH		239.4	3768.8	86.2	289.3	2500.5	480.6	141.8	1961.1	97.1	208.5	637.4

* Sample number see Table 1.

except Σ DDT in cod-liver oil from the southern Baltic Proper (1971–1989), tended to decline at a very slow rate and, in some cases, a steady state was observed. Since 1982, the use of Baltic cod-liver oil for medical purposes in Poland has been restricted due to its higher organochlorine contamination: the concentration of PCB exceeded the tolerance limit (2.0 µg·g^{-1} for edible parts of fishery products). PCB in the cod contain significant residue levels of toxic coplanar PCB [12,13].

As a result, the cod and salmon caught from the southern part of the Baltic Sea and also Baltic herring, may be dangerous for grey seals, to consume [14].

The mean weight of herring has been decreasing not only in the Gulf of Finland but almost in all regions of the Baltic Sea [15]. Growth processes depend largely on feeding. The share of starving fish and the prey composition reflect the feeding conditions for herring. Lumberg and Ojaveer [16] analysed the dynamics of zooplankton abundance and biomass in the Gulf of Finland during the last 30 years. The decreased salinity has caused both, changes in the species composition of zooplankton and a decrease in its abundance. Young herring lives mainly on zooplankton and its average weight is in significant correlation with the copepod abundance in the growth period ($r = 0.61$; $P < 0.05$). It can be supposed that after 1982 herring had to utilise food organisms of generally poorer quality than during the five-year period before.

The studies concerning the feeding of herring and sprat that were carried out during the years 1982–1992 in north-eastern part of the Baltic Sea showed changes in the diet of the fish and also the rising number of fish with an empty stomach. The average body weight of herring, which had been relatively stable during 1940–1960, started to increase in most regions of the Baltic Sea in the late 1970's. High average values of body weight and length

Table 4

Indices of the experimental catches in the monitoring sites of Hiiumaa islets (Väinameri) and the Bay of Küdema [17]

Species*	Catches, %	Mean length, cm
	Hiiumaa islets	
Roach	47	16.2
Perch	36	20.2
Baltic herring	8.5	17.6
Ruff	4.2	13.5
	Bay of Küdema	
Baltic herring	59.1	23.2
Flounder	28.8	18.6
Cod	7.7	35.3

* Species which percentage of catches exceeded 2.0

were observed in all age groups of herring until the second half of the 1980's, when they started to fall unexpectedly. In the 1990's, also a drop in the average body weight of sprat occurred. Hydrological conditions are at least partially responsible for the rapid decrease in the growth of sprat and (especially) herring [2,15,16].

In addition, the fish species proportions in the Bay of Küdema and in the Sea of Väinameri (Table 4) are different. We found mostly thermophilic fresh-water fish in the shelf of the Väinameri Sea and quite a lot frostphilic marine fish in the Bay of Küdema. The content of fish species in these two areas has remained stable in last 4–5 years, the number of main species has not changed very much either [17].

When comparing Table 4 and control catches carried out in 1976–1978 and 1988–1990, one can notice that proportion of cod has decreased considerably. The average number of cod caught in one hour of experimental trawling depth zones (5–40 m) in the Gulf of Riga in the summers of 1976–1978 was 380 fish, and in the summers of 1988–1990 it was one fish, per hour [18].

Thus, the food chain of grey seal has changed leaving an essential part out (in Väinameri) or reducing it (in the open sea at Vilsandi). According to Table 4, the number of fat fish (salmon, sea trout etc.) is small in these areas. The control catches in different years also consisted of some sea trout in the Bay of Küdema [17].

Hereafter we pay attention to the grey seals at Vilsandi because the grey seal in Väinameri probably feed on Baltic herring, perch etc. The concentration of organochloirne compounds in these is one of the lowest in the Baltic Sea [2,4,19]. The remaining explanation is that the relatively elevated PCB concentrations in grey seals at Vilsandi, obtained by food are higher, but not as high as those, encountered in the 1970's [20,21].

The food chain of grey seals in the open sea at the beginning of the 1970's [8]. is different from the species content in the spring of 1995 (Table 4). One can thus assume that grey seals caught the Vilsandi monitoring site in the spring of 1995 could not have consumed as much cod, salmon, and sea trout as seals at the end of the 1970's and during the beginning and middle of the 1980's.

Long-range transport of PCB. At the present time, long-range transport of PCB from southern sources outside Estonia dominates [22]. This is reflected in a decreasing south-to-north gradient of compounds in atmospheric deposition [22] and in fish [2,4,21].

One of the most important indices of PCB concentrations is annual amount of precipitation. For instance, precipitation may influence the PCB concentrations in the Baltic Sea ecosystem during the following year [2], since the transition of PCB components from organisms, the so-called clearance half-lives vary from ten days for 2,5-dichlorophenyl, to sixty days for 2, 3', 4', 5-tetrachlorobiphenyl, which is correlated with the decreasing aqueous solubilities of the compounds [23]. One may assume that the clearance half-lives of penta-, hexa- and heptachlorobiphenyls are considerably higher. The potential dependence of PCB concentration in the cod liver upon the amount of the previous year precipitation is shown in our earlier studies [24].

There are no local pollution sources in the research sites, the Väinameri Sea and Vilsandi [25]. In spite of that long-range transport of air pollution still exists. Calculations of back trajectories identified different parts of Central Europe as source areas. According to Oehme et al. [26] an increased level of PCB was observed during a period of air transport from the Kola Peninsula.

According to Agrell et al. [22] the deposition load of PCB in fifteen stations around the Baltic Sea ranged from 1.2 to 17.9 $ng{\cdot}m^{-2}$ a day (median 2.7 $ng{\cdot}m^{-2}$ a day). The depositions of PCB at the Estonian EMEP stations, Vilsandi and Lahemaa (northern part of Estonia, 70 km to east from Tallinn) were 2.2 and 1.8 $ng{\cdot}m^{-2}$ a day, correspondingly. The loads could be considered as background for the Baltic Sea. The highest deposition of PCB was observed at the Salaspils station near the city Riga, Latvia.

The Väinameri Sea is a recipient for one river — River Kasari (in 1994 the inflow of PCB into the Väinameri Sea did not exceed 0.3

kg), but there are no rivers at Vilsandi.

Consequently, the higher PCB concentrations in grey seals at Vilsandi in comparison to those from the Väinameri Sea, cannot be caused by higher atmospheric and fluvial input. As for the latter, the amount of PCB carried by all rivers into the Baltic Sea is almost the same as the amount deposited by rain — 500 kg every year [27].

At present, the discharge of large amounts of PCB by rivers continues. The investigations have been carried out on the pollution caused by organic substances in the cross-section near the mouth of River Vistula, the longest river in Poland and a second to none estuary of the Baltic Sea. Total DDT and PCB loads from the Vistula River in 1983 were 580 and 206 kg, in 1984 —450 and 190 kg, respectively [28]. During 1991–1992, Johansson [27] studied the transport of PCB into the Baltic Sea via River Vistula (1991 — 14.5 kg and 1992 — 17.3 kg) and River Oder (1991 — 9.4 kg and 1992 — 15.4 kg). Consequently, the pollution of PCB in the southern part of the Baltic Sea is continuing.

Changes of salinity and oxygen concentration in the Baltic Sea. The inflow of brackish oxygen rich water from the North Sea during the winter of 1993–1994 might have caused cod to move northwards. At the time, the salinity in the Gotland Deep rose to 12.5 psu. First time after 1955, the oxygen concentration in the Gotland Deep exceeded 3 $ml \cdot l^{-1}$. By 1995 it had dropped to 1 $ml \cdot l^{-1}$ [29].

Only the strongest of major inflows can renew the deep water of the Eastern Gotland Basin.

New research indicates that the level of salinity is also of major importance for cod reproduction, and that the M74 syndrome could possibly also affect cod, salmon and sea trout.

Swedish scientists at the Stockholm University have demonstrated in experiments that the Baltic cod needs a salinity of 13–15 psu, instead of 10–11 psu as previously claimed. The salinity requirement may also vary between different female cod. Older females seem to tolerate a lower salinity. Scientists have also demonstrated that in order to survive, the newly hatched cod larvae require oxygen concentrations of 2 $ml \cdot l^{-1}$ of seawater, which is twice as much as has been assumed [30].

In stagnation periods, the emigration rate of cod from the northern part of its distribution area to the southern and south-western spawning grounds was the highest [31]. As the southern Baltic is far away from the Gulf of Riga, only a very limited number of young as well as adult cod find their way into the Gulf of Riga.

It can be assumed that the Gotland Deep has changed into a natural-neutral zone. Cod reproduces in the south (Bornholm Bay) but cannot spawn in the Gotland Deep which has low salinity and low oxygen concentration. Also, an adult seal would not go to the Gotland Deep because there is neither cod nor a suitable pupping ground. A low salinity and oxygen concentration became a factor affecting the evolution of grey seal as well as salmon and cod main food — Baltic herring and sprat.

Increase in the percentage rate of empty stomachs of Baltic herring and sprat in the beginning of 1990's may turn out to be one of the reasons for the decrease of PCB concentration in food, comparing with the end of 1970's and the beginning of 1980's.

The author recommends that the percentage of empty stomachs (and the content of different food in stomach) should be considered in the future as additional parameters, in addition to age, length, weight, sex, fat percentage and degree of maturity. One can assume that the rising number of fish with an empty stomach has contributed to the stability of chlororganic compounds contents in herring organisms in the northern part of the Baltic Sea [2,25].

As a result, we have to pay more attention to the salinity and oxygen concentration in sea water, the annual amount of precipitation and its PCB concentrations. Tightening the cooperation between the Baltic Sea countries is necessary. First successful steps in this field were made in the beginning of 1990's already [22].

Some other factors that we have paid attention to in our earlier works [2]: direction and speed of wind and currents, amount of precipitation, amount and measurements of aerosols in the air, concentration and sedimentation rate of plankton in the water etc., have to be considered as well.

Grey seal migrations. Besides the above mentioned, the PCB concentrations in grey seals may also depend on migrations. There is quite little information about current migrations of grey seals. Recovery of tagged seals indicated that at least the pups leave the whelping areas and disperse. Probably most of such pups found on the shore or in fishing gears have been moving to the south. Seals born in the northern part of the Gulf of Riga were found mainly in the southern part of the Gulf, whereas seals born in the west coast of Saaremaa (Vilsandi) were found along the west coast of Latvia and Lithuania [32], in the southern Baltic and Danish Straits [33].

Especially dangerous is the migration of grey seals, younger than one year, to the southern part of the sea. The female grey seal's milk contains 60–80% fat and a large amount of lipid soluble contaminants are passed from mother to pup [19]. In the southern part of the sea, the food has higher PCB concentrations than in the northern part.

Grey seals in the Gulf of Bothnia and the Baltic Proper give birth to their pup in February – March. According to Hongell [34], the chromosome aberrations are probably caused by chemical pollutants. Blood samples were taken from 47 grey seal pups before weaning in March – April and from ten adult ringed seals in the end of April during 1988–1992. The types of aberrations found were chromosome and chromatid breaks, gaps and fragmentations. More complicated rearrangements were rare. The frequency of aberrations found in the adult Baltic ringed seals were lower than those found in the grey seal pups. The mean frequency of cells with chromosome aberrations from grey seals was 5.7% (SD ± 5.3), but some individuals have a considerably higher frequency of aberrations than the average. Some cells with several aberrations and fragmentation of the chromosomes were observed among the lymphocytes from these animals. It is necessary to continue studying the migrations along with food-chain. This research objects were males, since females excrete part of their PCB load during the feeding period of the pups. Female grey seals with high PCB concentrations do not only harm their off-springs. By some data [35], they may not only feed their own pups, which makes studies more complicated.

Principal component analysis (PCA)

The results of PCA are "score" plots (Fig. 2), in which the samples (the numbers correspond to Tables 1 and 2) are plotted in the principal component coordinates. Samples with similar profiles are located in close proximity. The amounts of the original variance captured by the principal components are indicated on the axes. The projection of the PCB profiles on the plane of the principal components 1 and 2 captures 88% of the original variance (63 + 25).

It is obvious that the PCB profiles in the muscle (No. 9) and in the kidneys (No. 10) are different from those in the blubber. The PCB profile in the sample No. 7 is different from the main cluster because of its unusually high relative level of the chlorobiphenyl 180. It is impossible to decide whether this is an analytical artifact or an indicator of a previous exposure to higher levels of more chlorinated PCB formulations.

The projection of the PCB profiles on the plane of the principal components 1 and 3 (Fig. 2-B) leads to similar conclusions. By viewing the projections in Figs. 2-A and 2-B together, one can get a feeling for the location of the samples in three dimensions and, at the same time, retain 98% of the original information.

"Loading" plots (Fig. 3) show how the original variables (the chlorobiphenyls) affect the principal components. In these plots, the symbols indicate the original variables, in this case the numbers are the IUPAC numbers of the chlorobiphenyls.

It can be seen from Fig. 3-A that the chlorobiphenyls 105 and 118 have a high loading on the ev-2. Consequently, samples with a high concentration of either one or both of these chlorobiphenyls will be located at high pc-2 values. This is the case for the muscle of seal 9. Similarly, the chlorobiphenyls 52, 101, and 138 have a high loading on ev-1 and that is the reason for sample No. 10 to be located to the far right in Fig. 2-A. The PCB profile of the seal No. 7 is located at the bottom of Fig. 2-A because of an unusually high concentration of the chlorobiphenyl 180, as mentioned earlier.

The PAH profiles also show that four profiles are different from the rest (Fig. 4-A). In general, the PAH profiles are more heterogeneous than those of the PCB (compare Fig. 4-B and Fig. 2-B).

The corresponding loading plots are presented in Fig. 5. The different PAH profile of the seal No. 2 is caused by an extremely high level of 3-methylphenanthrene. This is almost certainly a chemical-analytical artifact. Similarly, the combined extracts of seals No. 6,7 and 12 contain an unusually high level of 1-methylphenanthrene and pyrene, respectively. These, again, may be chemical-analytical artifacts. It could be expected that the PAH profile in the muscle (seal No. 9) will be different from that in the blubber. However, also in this case, the unusually high levels of 1-methylphenanthrene and chrysene suggest the possibility of chemical-analytical artifacts.

Conclusions

Over the past decades increased knowledge of the behaviour of pollutants in the aquatic environment and their effect on the ecosystem, as well as a tendency towards a more cost effective strategy for monitoring, has led to a growing interest in additional monitoring approaches. The integration of chemical and biological monitoring provides more comprehensive information on quality assessment and ecological functioning of aquatic ecosystems.

Comparing to the end of 1970's and the beginning of 1980's, at least the PCB concentrations obtained by food in grey seals in West-Estonian Archipelago Biosphere Reserve must have decreased. This is probably the result of natural changes in last twenty years (decrease in salinity and oxygen concentration in the Gotland Deep).

This research was supported from the Research and Writing Initiative of the Program on Global Security and Sustainability of the John D. and Catherine T. MacArthur Foundation.

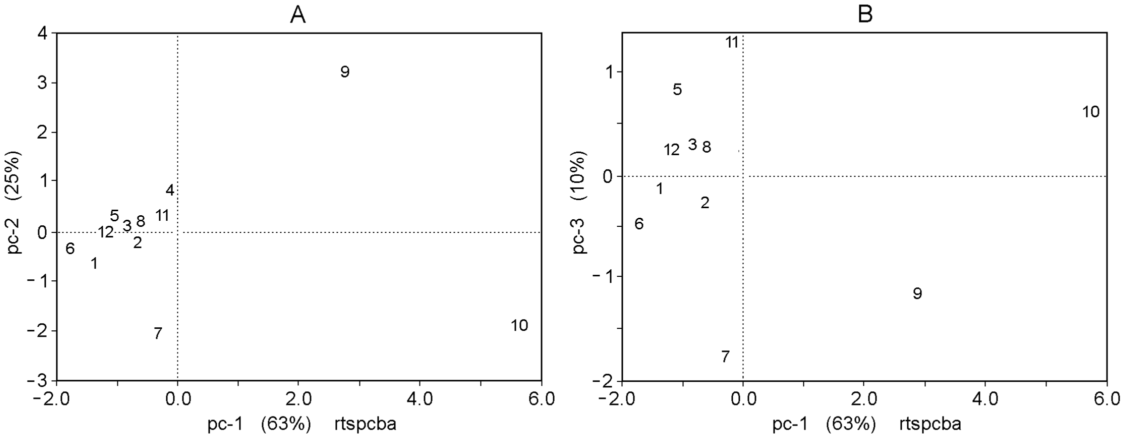

Fig. 2. The projection of the PCB profiles (chlorobiphenyl concentrations scaled to a sum of 100) on the plane of the principal components: A — the components 1 and 2, B — the components 1 and 3. Samples are marked by numbers used in the Tables 1 and 2.

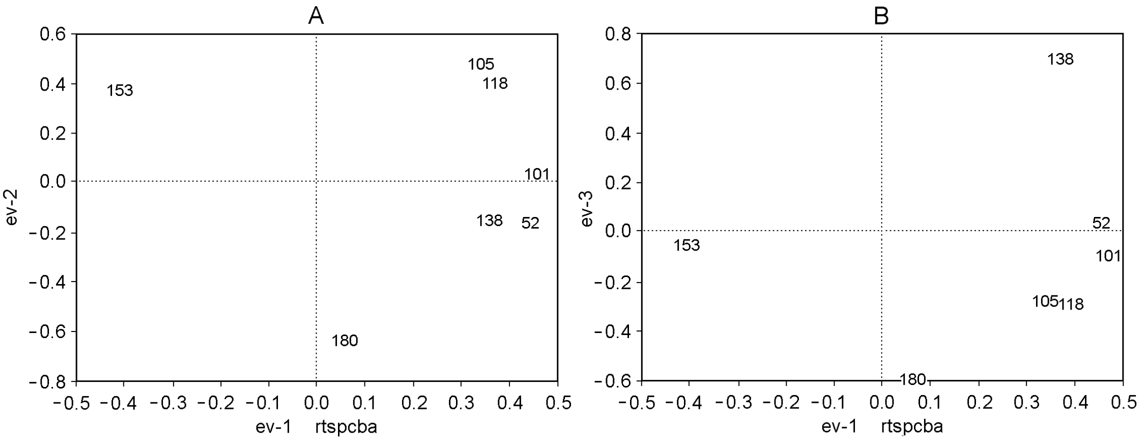

Fig. 3. The loading plots of the chloropbiphenyl profiles on the principal components: A — the components 1 and 2, B — the components 1 and 3. These plots show the effect of the original variables (the individual chlorobiphenyls) on the corresponding principal components. Numbers in the plots are the IUPAC numbers of the chlorobiphenyls.

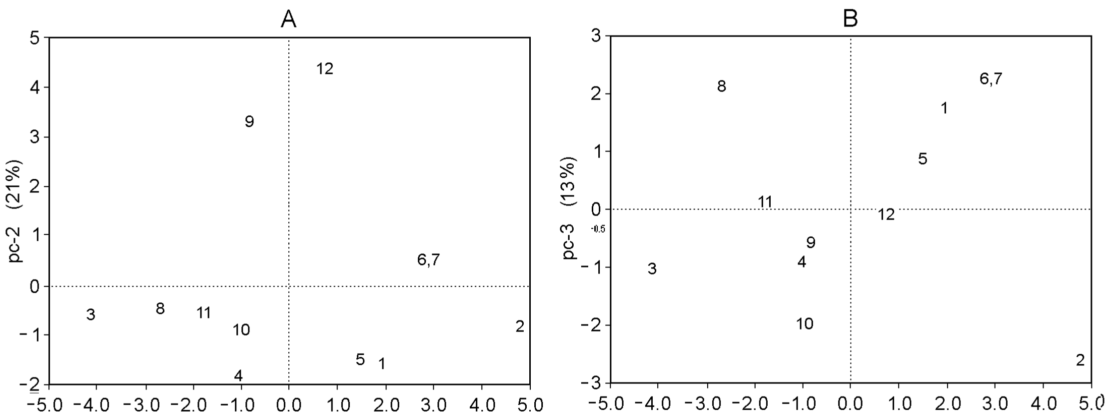

Fig. 4. The projection of the PAH profiles (PAH concentrations scaled to a sum of 100) on the plane of the principal components: A — the components 1 and 2, B — the components 1 and 3. Samples are marked by numbers used in the Tables 1 and 3.

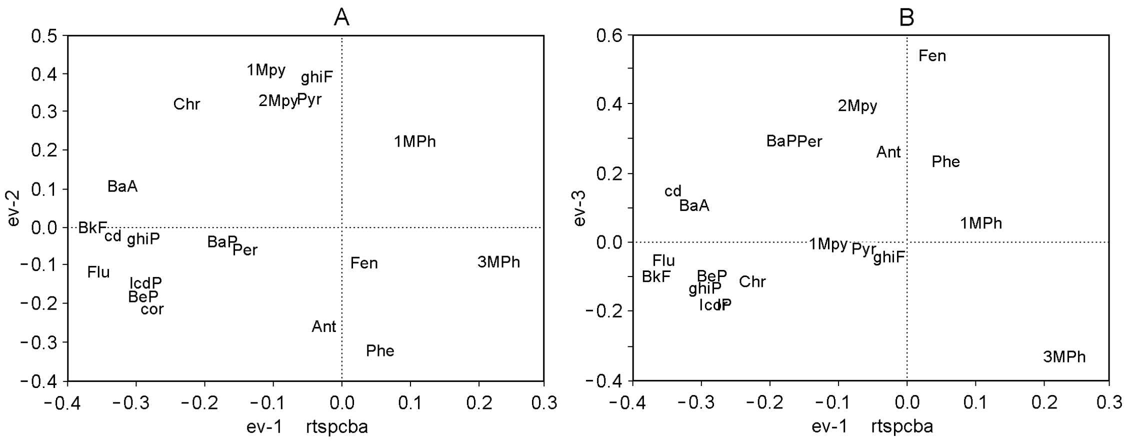

Fig. 5. The loading plots of the PAH profiles on the principal components: A — the components 1 and 2, B — the components 1 and 3. These plots show the effect of the original variables (the individual PAH) on the corresponding principal components. See Table 3 for the abbreviations.

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Применение метода анализа главных компонент к исследованию полихлорированных бифенилов и полициклических ароматических углеводородов в организме тюленей

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Статья является частью исследования токсических веществ в Балтийском море. Изучение полихлорированных бифенилов (ПХБ) и полициклических ароматических углеводородов (ПАУ) в организме серых балтийских тюленей (*Halichoerus grypus*) было выполнено в восточной части Балтики. Согласно наблюдениям, в прибрежных водах Эстонии ежегодно в мае и июне, в период линьки, популяция серых тюленей составляет 1500–2000 животных. В статье обсуждаются причины увеличения их популяции в Балтийском море. Обобщены сведения о содержании ПХБ в воздухе, воде и компонентах пищевой цепи серых тюленей. Изучено влияние солености и концентрации кислорода в воде Балтийского моря на пищевую цепь тюленей. Методом анализа главных компонент установлены отличия в характере накопления ПХБ в мышцах и почках от накопления в тюленьем жире.