

Comparison of level and pattern of PDBE in four spatially separated populations of Atlantic salmon (*Salmon salar*) from Scandinavia.

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Introduction

Since the early 1980s brominated flame retardants have been found worldwide in biota, even in remote areas like the Arctic. A number of studies have demonstrated the presence of PBDEs in marine animals, such as fish, birds and marine mammals (Burreau et al. 2004, Ikonomou et al. 2002, Luross et al. 2002). PBDEs have been shown to biomagnify and bioaccumulate, and results on the accumulation of the specific congeners in fish have been presented (Burreau et al. 2004). To assess the concentrations and patterns of brominated flame retardants in Atlantic salmon (*Salmo salar*) from Scandinavia, a top predator, that lives in fresh and salt water environments, samples from four spatially separated populations of salmon were collected and analyzed for PBDEs. Two of the populations live in freshwater, in isolated lake environments, while the two other populations spend the first part of their lives in freshwater before migrating to the marine environment.

Owing to the long migration and starvation periods of the salmon, the lipid content is known to vary significantly during the life of the salmon (Fleming 1996). This study presents some preliminary results on how this difference in lipid content affects the concentration of PDBEs, by comparing the levels in liver and muscle.

Materials and Methods

5-7 salmon were collected from each of the following locations: Lake Vänern and Lake Vättern in Sweden (both October/November 2004), the Baltic Sea in the area between Simrishamn (S) and the island of Bornholm (DK) (April 2004) and in River Imsa, a small river in the south-western part of Norway (October 2005). The fish from Lake Vättern, Lake Vänern, and The Baltic Sea were caught using rods and line, and killed immediately after capture, while salmon from River Imsa were caught in a fish trap situated 100 m upstream of the river mouth controlling the ascent and descent of salmon. A muscle sample from the dorsal anterior part and the liver were removed from each fish and stored in separate annealed glass containers at – 20 °C until analysis.

As indicated by the removed adipose fin, all salmon from Lake Vänern and Lake Vättern were from hatchery origin (Öberg et al. 2003). The history of the fish from the Baltic Sea is unknown, however, based on their size they had spent at least one year in the marine environment. All salmon from River Imsa were tagged and measured prior to release as smolt and had spent approximately 1½ year in the sea (Data from NINA- Norwegian Institute for Nature Research).

The samples were analysed as described previously for black guillemot samples (Vorkamp et al. 2004). Briefly, the samples were homogenised, Soxhlet extracted with n-hexane:acetone (4:1) and purified on a multi-layered glass columns. After elution with n-hexane, the extracts were concentrated and kept in iso-octane. BDE-71 was used as a syringe standard for quantification, and BDE-77 was added prior to extraction to assess the recovery. Analysis of PBDEs was performed by GC-MS with negative chemical ionisation (NCI). Details on the QA/QC procedure are given in Asmund et al. (2004).

PBDE concentrations were log-transformed prior to statistical tests, owing to the skewed distributions of the values. Single-factor ANOVA and Turkey's test were used to compare levels between the different locations, while paired t-tests were used to test for differences in \sum PBDE between salmon liver and muscle. Principal component analysis (PCA) was chosen to analyze how the PBDEs co-varied among the samples, regarding PBDE intercorrelation, and if there was a structure in the variance that could be explained by species identity or sampling area. Only PBDE congeners quantified in all species were included in PCA. Further information on the specific PCA procedure can be found in Svendsen et al. (subm).

Results and discussion

Figure 1 shows concentrations of PDBEs in salmon from the four locations. Levels in Lake Vänern, Lake Vättern and the Baltic Sea are similar. The concentrations in the salmon from River Imsa are significantly lower ($p < 0.05$), but these salmon are also smaller in size and have been feeding in the Northern Atlantic. Lower levels in salmon from the Northern Atlantic compared to the Baltic Sea have previously been reported (Burreau et al. 2006).

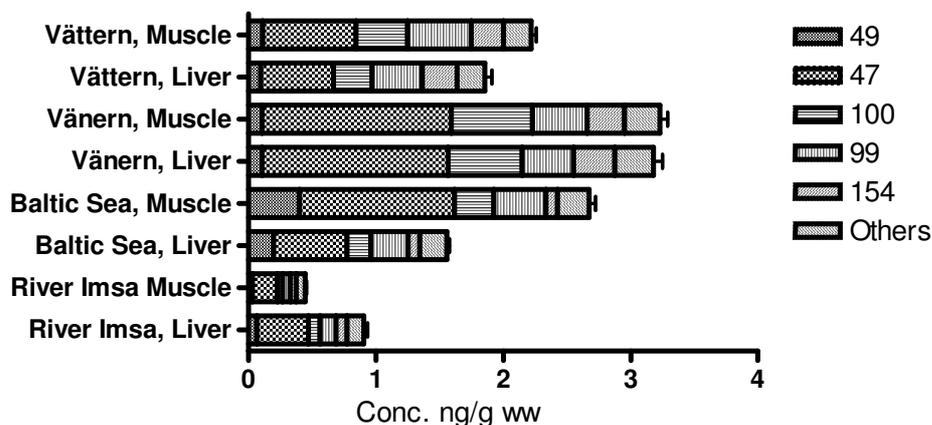


Figure 1: Levels of PDBEs in muscle and liver tissues of Atlantic salmon (*Salmo salar*) from four locations in Scandinavia.

The concentrations in the liver for the salmon from Lake Vänern, Lake Vättern and the Baltic Sea are lower or at the same level as in the muscle while the opposite is seen for the salmon from River Imsa. Here the concentration in the liver is almost twice as high as that in the muscle. The salmon from River Imsa are depleted in lipid, due to a long migration. This can lead to a very low concentration of lipid in the muscles, and thereby a low concentration of PBDEs on a wet weight basis. When relating the levels to lipid content, the concentration in the liver is significantly lower than in the muscle for salmon from Lake Vänern and River Imsa ($p < 0.05$) and especially the salmon from River Imsa stands out with more than five times higher concentrations in the muscle, indicating a faster depletion of lipid compared to the redistribution of PBDE to areas with higher lipid content. The difference between liver and muscle is not statistically significant for the salmon from Lake Vättern and the Baltic Sea (Fig. 2). Transformation processes in the liver may affect the PBDE concentrations. However, no significant differences have been observed between the PBDE composition in the liver and the muscle samples.

Little is known about movements of PBDEs between different organs and tissues of the fish. In the case of Atlantic salmon, the distribution of PBDEs within the fish may be even more complex, due to the large variation in lipid content during a year caused by periods of migration and starvation. From

these data it seems that depletion of lipids in the muscle tissue can lead to elevated concentration of PBDEs on a lipid weight basis compared to other compartments of the salmon body, as seen in the salmon from River Imsa, which is the group of salmon with the lowest lipid content of the four analyzed populations. Recent research on salmon from the Baltic Sea has revealed that the internal body variation of PCBs can be larger than the interspecies variation (Persson et al. 2007) When levels are compared to that found by Bureau et al. (2006), the levels of this study (ng/g lw) are higher. A possible explanation for the difference in the salmon from the Northern Atlantic is that the salmon investigated in this study is on spawning migration, and thereby depleted in lipids. This result in the PBDEs being concentrated in a smaller amount of lipids compared to the Atlantic salmon, which are not depleted in lipids. There is not a good and simple explanation for the elevated levels found in the salmon from the Baltic Sea.

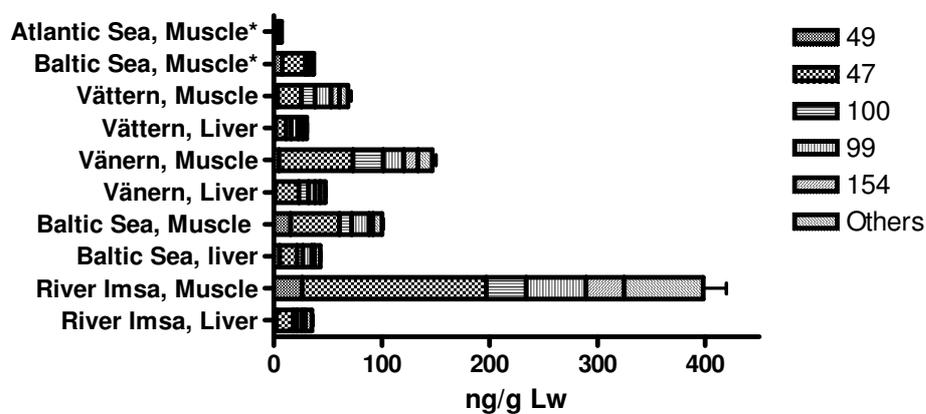


Figure 2: PBDE content of the different salmon populations, related to lipid content. Samples with * are from Bureau et al. 2006 for comparison.

BDE47 is the main congener, representing more than 25 % of the total PBDE burden in all fish, while BDE99 and BDE100 also is found in all samples, representing between 7-25 % of the total amount. However, PCA on normalized PBDE concentrations from the muscle samples revealed some differences in the PBDE pattern for the 4 locations (fig 3).

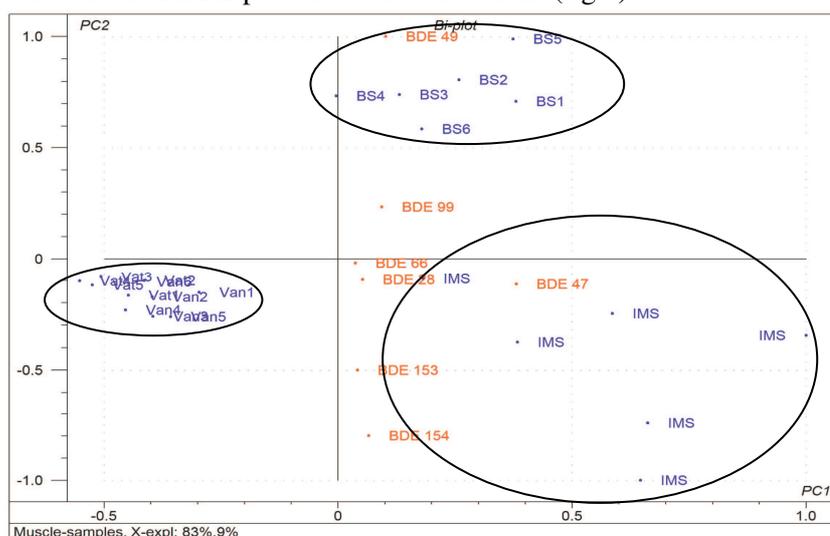


Figure 3. PCA on normalized PBDE concentrations for the four groups of salmon.

A combination of the score and the loading plot is presented in figure 3. Three groups can be separated in the scoreplot, a group consisting of the salmon from the two Swedish lakes, a group representing the Norwegian salmon and finally a group consisting of the Baltic salmon. The observed difference between the three groups can be ascribed to a location related difference in pollutant exposure and availability. Since this study is conducted on the same species and on fish of similar size the difference in PBDE level is probably not caused by principal differences in uptake mechanisms and metabolism, but rather by a difference in the PBDE content in their feed. The large variation within the Baltic Sea group was expected since salmon from the entire Baltic Sea feeds in the area where the salmon were caught and a similar variation has previously been seen for PCBs (Svendsen et al. *subm.*). The contribution of BDE49 to the total sum of PBDEs is significantly higher in the salmon from the Baltic Sea, compared to the salmon from the two Swedish lakes, which can also be seen from the PCA loading plot. BDE49 makes up less than 1% of the total PBDE in the penta-mixture and is not present in the octa-mixture. Therefore, the BDE49 present in the environment almost exclusively originates from degradation of higher brominated PBDEs (de Wit 2002), suggesting an older source for the Baltic Sea pollution of PBDEs. Both of the lakes are situated in industrialized areas, with discharge from wastewater treatment plants, possibly more recent sources of PBDEs than those in the Baltic Sea, leading to differences in PBDE concentrations and compositions.

References

- Asmund, G, Vorkamp, K, Backus, S, Comba, M. 2004. *Science of the Total Environment* 331:233-245
- Burreau, S, Zebuhr, Y, Broman, D, Ishaq, R. 2006. *Science of the Total Environment* 366:659-672
- Burreau, S, Zebuhr, Y, Broman, D, Ishaq, R. 2004. *Chemosphere* 55:1043-1052
- de Wit, CA. 2002. *Chemosphere* 46:583-624
- Fleming, IA. 1996. *Reviews in Fish Biology and Fisheries* 6:379-416
- Ikonomou, MG, Rayne, S, Addison, RF. 2002. *Environmental Science & Technology* 36:1886-1892
- Luross, JM, Alaei, M, Sergeant, DB, Cannon, CM, Whittle, DM, Solomon, KR, Muir, DCG. 2002. *Chemosphere* 46:665-672
- Persson, ME, Larson, P, Holmqvist, N, Stenroth, P. 2007. *Environmental Pollution* 145:131-137
- Svendsen, TC, Vorkamp, K, Rønsholdt, B, Frier, J-O. *subm. Canadian Journal of Fisheries and Aquatic Sciences*
- Vorkamp, K, Christensen, JH, Glasius, M, Riget, FF. 2004. *Marine Pollution Bulletin* 48:111-121
- Öberg, T, Darnerud, P-O, Hajslova, J. 2003. Report from Natur Vårds Verket, Sweden