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Dynamics of PCDDs and PCDFs in the Pelagic Food Web of Lake Baikal

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Abstract

Polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) were determined in zooplankton, fish and seals (nerpa) from Lake Baikal. A large increase in TEQ values was found from macrozooplankton (0.19 pg/g wet weight) to seal (maximum 175 pg/g wet weight). 2,3,7,8-TeCDF, 1,2,3,7,8-PeCDF and 2,3,4,7,8-PeCDF were the dominant congeners in all species sampled with the exception of the seals, for which equally high concentrations of 2,3,7,8-TCDD and 1,2,3,7,8-PeCDD were measured. When expressed on a lipid weight basis the data indicated pronounced biomagnification of these two PCDD congeners through the food web. However, the lipid based levels of the PCDF congeners decreased in the seals in comparison to their primary food source, suggesting that the Baikal seal can metabolise these compounds. In seal females the average TEQ value (46 pg/g) was lower than that in males (60 pg/g wet weight). The increase in TEQ with age was very slight. The TEQ levels are comparable with those reported for ringed seal (*Phoca hispida*) living in Barrow Strait and Admiralty Inlet in the Canadian Arctic and in the Baltic Sea.

Introduction

In 1996 Lake Baikal was entered into the list of World Heritage Sites (Natural). It is the world's deepest lake (1637 m), contains the largest volume of water (one fifth of the world's surface fresh water reserves), and is geologically the most ancient (over 25 million years old).

The biota of the lake is also unique. The Baikal seal or nerpa, a freshwater form of seal, is at the top of Lake Baikal's food web. In 1987-1988 several thousand Baikal nerpa died as a result of infection by the morbillivirus¹⁾. It has been suggested that this epidemic may have been in part due to stress resulting from high levels of persistent organic pollutants in nerpa²⁾. High concentrations of DDT (4.9 - 160 µg/g), PCBs (3.5 - 64 µg/g on a lipid weight basis) and other organochlorine compounds have been found in the Baikal seal^{2,3)}. In a preliminary study we found high levels of PCDDs and PCDFs in three female seals (28, 73 and 93 pg TEQ/g fresh weight)^{4,5)}.

The present paper reports on the current status of our ongoing investigation into the levels of PCDDs and PCDFs in the pelagic food web of Lake Baikal.

LEVELS IN FOOD

Experimental Methods

The characteristics of the different samples analysed are given in Table 1. Baikal seals were collected during 1995. The age of the seals was estimated by dental examination. The fish and zooplankton samples were collected in the autumn of 1996. The age of *Coregonus* was estimated from scales. Samples were taken and stored at -20°C before being transported to Bayreuth for analysis.

Table 1: Characteristics of the biota samples from Lake Baikal

Sample	Time of sampling	Body weight (kg)	Body length (cm)	Age (yr)	Lipids (%)
<i>Epishura baikalensis</i> (zooplankton)	October 1996				3.5
<i>Macrohectopus branici</i> (macrozooplankton)	August 1996				2.3
<i>Commephorus dybovskii</i> (pelagic sculpin)	August 1996		11-13	3-5	4.1
<i>Cottocomephorus grewingki</i>	August 1996		9-12		7.2
<i>Paracottus kessleri</i>	November 1996		9-10		5.1
<i>Coregonus autumnalis</i> (<i>migratorius</i>) (omul)					
Female	November 1996	0.29	36	6	3.6
Male	November 1996	0.23	33	5	-
Female	November 1996	0.33	33	5	1.9
Roe (5 year old female)	November 1996				
<i>Phoca sibirica</i> (Baikal Seal)					
Male	28 May 1995	22.9	90	3 months	98
	28 May 1995	30.6	97	1	78
	29 May 1995	72.5	148	5	93
	24 May 1995	87.9	148	6	88
	25 May 1995	73.0	150	8	99
	25 May 1995	77.5	114	10	89
	31 May 1995	72.0	140	11	88
Female	29 May 1995	29.6	98	1	91
	29 May 1995	26.3	89	2	92
	30 May 1995	70.0	132	4	92
	28 May 1995	64.0	128	5	89
	24 May 1995	68.5	127	7	84
	25 May 1995	79.5	128	7	84
	31 May 1995	70.0	144	9	84

In Bayreuth the samples were mixed with Na₂SO₄ and Solxhlet extracted in hexane/acetone for 16 hours. Prior to extraction a mixture of 12 ¹³C-labelled 2,3,7,8-substituted PCDD and PCDF isomers was added to the solvent. The extract was cleaned up using a mixed H₂SO₄-silica gel/NaOH-silica gel column and an alox column. The HRGC/HRMS analyses were conducted using an HP-5890 gas chromatograph coupled to a VG-Autospec Ultima mass spectrometer operating in EI mode at a resolution of 10,000. A 60 m x 0.25 mm RTX 2330 (Restek) column with a film thickness of 0.10 µm was employed.

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Results and Discussion

Figure 1 shows the TEQ levels (in pg/g wet weight) along the food web. The increase in TEQ from *Macrohectopus* (3.8 pg/g) to nerpa (a maximum of 175 pg/g) is striking. However, when expressed on a lipid weight basis (see Table 1 for the lipid fractions) the concentrations throughout the food web are similar (see Figure 2). The high TEQ level found in *Epishura baikalensis* is possibly due to the fact that the samples of zooplankton were taken not far from Baikalsk where a pulp plant is in operation.

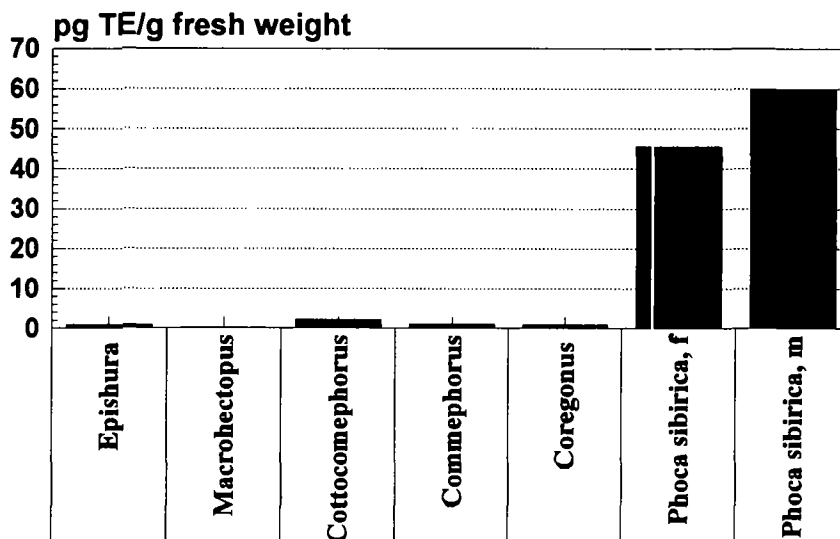


Figure 1: PCDD/F fresh weight concentrations in the pelagic food web of Lake Baikal

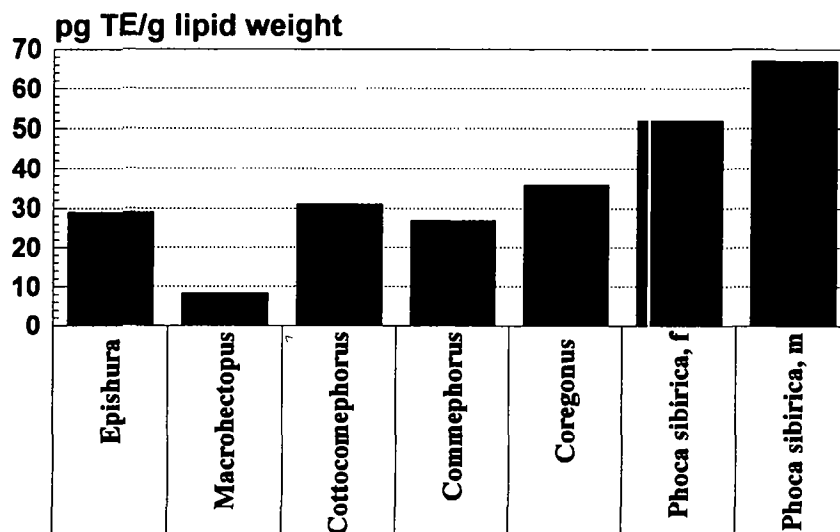


Figure 2: PCDD/F lipid based concentrations in the pelagic food web of Lake Baikal

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The congener composition in *Epishura baikalensis*, *Macrohectopus*, *Cottocomephorus grewingki*, *Commephorus dybovskii* and *Coregonus autumnalis (migratorius)* is dominated by 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF and 2,3,4,7,8-PeCDF (see Figure 3). The seal samples show a different pattern. In addition to the above mentioned furans, high levels of 2,3,7,8-TCDD, 1,2,3,7,8-PeCDD and hexachlorinated dioxins were measured. The primary food source for the Baikal seal is *Commephorus dybovskii*, which accounts for 64.2% of the diet⁶⁾. Expressed on a lipid weight basis, the concentrations of the furans in the seals are one to two orders of magnitude lower than in their primary food source, while the concentrations of the dioxins are higher. This suggests that there is biomagnification of the 2,3,7,8-TCDD and 1,2,3,7,8-PeCDD in Baikal seal on the one hand, accompanied by significant metabolism of 2,3,7,8-TCDF, 1,2,3,7,8-PeCDF and 2,3,4,7,8-PeCDF on the other. This is fortunate, because without this metabolism the TEQ levels in the seals would be much higher.

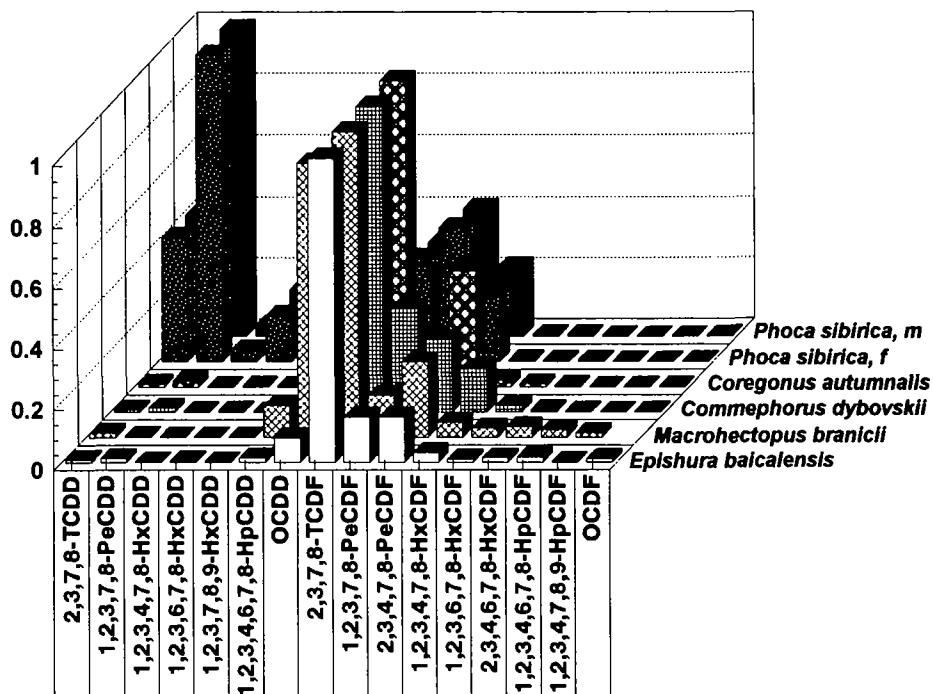


Figure 3: PCDD/F homologue profiles in different species in the pelagic food web of Lake Baikal

In Figure 4 the TEQ concentrations in seal blubber are plotted as a function of age and sex. The levels are comparable with those that have been reported for ringed seal from Barrow Strait and Admiralty Inlet in the Canadian Arctic⁷⁾ and from the Baltic Sea⁸⁾. There is no apparent trend in the levels with age. Amongst the nerpa studied, the maximum TEQ value was found in a 6 year old male (175 pg/g wet weight) and a 7 year old female (120 pg/g wet weight). The former was caught near the Ushkany Islands in an area where pulp fiber had accumulated⁹⁾, and the latter was caught to the north of the Ushkany Islands. The average TEQ value for females is lower (46 pg/g) than for males (60 pg/g wet weight), which may be attributable to the passing on of PCDDs and PCDFs to the pups before birth and while feeding.

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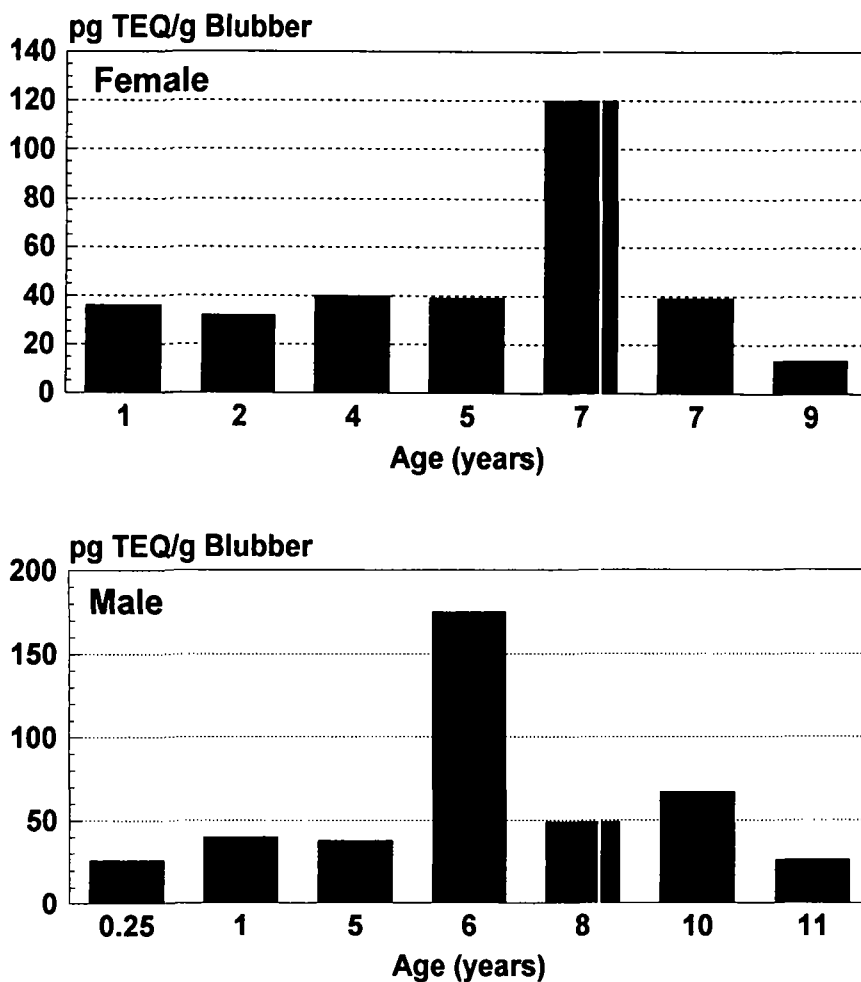


Figure 4: PCDD/F concentrations in seal blubber as a function of age and sex

Acknowledgements

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