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ECOLOGY

Relationship between biological characteristics of fish and their contamination with trace metals: a case study of perch *Perca fluviatilis* L. in the Baltic Sea

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Abstract. Biological characteristics of fish are expected to affect the bioaccumulation patterns of trace metals in aquatic organisms. Nonetheless, this topic is relatively unstudied among fish species. In this study we explored how biological characteristics such as sex, maturity, and age of perch affect the contamination of their liver and muscle tissue with mercury, cadmium, copper, and zinc. According to our analyses, the contamination of fish with trace metals was complex and depended on the one hand on the type of metal and on the other hand on the studied fish biological characteristics. In the presence of significant statistical differences the concentration of trace metals was higher in males than in females and in immature than in mature individuals. Mercury was the only trace metal that accumulated with age in the fish. However, no generic relationships between the studied variables were found, and this may hint at the lack of such a relationship.

Key words: perch, trace metal, tissue, sex, age, maturity, Baltic Sea.

INTRODUCTION

The trace metal loading into aquatic ecosystems increases with elevated industrial and traffic emissions and intensified land use practices. This may lead to severe ecological consequences, e.g. changes in growth, development, reproductive potential, and survival of fish (Sorensen, 1991; Szefer, 2002; Webb et al., 2006). Besides, some trace metals and their compounds are carcinogenic (Janssen et al., 2000; Diaconescu et al., 2008). Thus, the accumulation of trace metals in fish tissues does not affect only fish populations, but also has repercussion on their consumers, including humans. Considering the importance of fish in the human diet, consumption of contaminated fish poses a significant threat to human health (Schmitt et al., 2006; Klavins et al., 2009). Therefore, it is essential to better understand the trophic pathways of trace metals and their bioaccumulation in aquatic food webs.

The availability of ecologically clean food is becoming more problematic and expensive year by year. The pollution of seafood with trace metals is a challenging hygienic and eco-toxicological problem for several countries. Therefore, monitoring programmes of chemical pollutants including trace metals in fish, particularly in estuarine and semi-enclosed coastal areas, have been given priority by WHO, ICES, OSPAR, and HELCOM (e.g. Simm et al., 2006).

Aquatic organisms have been widely employed in assessing environmentally safe levels of trace metals in the ecosystem. Fish accumulate trace metals in the tissue selectively, mostly in the liver, kidney, muscle, and gills (Szefer et al., 2003; Webb et al., 2006; Idzelis et al., 2008; Frías-Espericueta et al., 2011; Ebrahimpour et al., 2011). Muscles and liver of fish are considered to be sensitive and selective bio-monitors of trace metals of the aquatic ecosystems (OSPAR, 2009; HELCOM, 2010; Bignert et al., 2011). In the Baltic Sea basin the content of trace metals has been well studied in many species such as cod, herring, sprat, and flounder (Vuori-

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nen et al., 1994, 1998; Simm and Kotta, 2000; Voigt, 2000, 2002, 2003) but also in perch (Voigt, 2001; Szefer, 2002; Szefer et al., 2003; Bignert et al., 2011). Nevertheless, the majority of studies just report values without giving deeper insight into how the accumulation of trace metals in fish tissues is related to fish biological characteristics.

Perch (*Perca fluviatilis* L.) is a widely distributed fish being native both in temperate fresh- and brackish-water ecosystems in the northern hemisphere except America. Its muscle tissue is lean and contains only about 1% fat (Bignert et al., 2011), which makes perch highly demanded as a diet food on markets. Perch is the most dominating commercial fish species in Estonian coastal fishery, particularly in the Pärnu Bay area (Järv, 1996; Kotta et al., 2008). As it is a relatively sedentary species (Kipling and Le Cren, 1984; Böhling and Lehtonen, 1985; Järv, 2000), the concentration of contaminants in perch reflects the water quality in the ambient environment. Therefore, perch was recommended as an indicator species to assess the biological effects of environmental pollution (HELCOM, 2011).

The present study describes how the contamination of different tissues with cadmium, copper, zinc, and mercury depends on the age, sex, and maturity of perch. Our hypotheses were as follows: (1) the content of trace metals differs among sexes, (2) the contamination of perch increases during the maturation process, and (3) the bioaccumulation of trace metals in perch tissues depends on their age.

MATERIAL AND METHODS

The study was conducted in Pärnu Bay, located in the northeastern part of the Gulf of Riga, the Baltic Sea. The bay is shallow (4–5 m) and semi-exposed. It receives yearly 1.6 km^3 of fresh water from the Pärnu River; this amount corresponds approximately to the volume of the bay. Both agricultural and municipal pollution loads to Pärnu Bay are high and the bay is considered as one of the most polluted basins in the Baltic Sea range in terms of hazardous substances, including trace metals and numerous persistent organic pollutants such as polychlorinated biphenyls, DDT, dioxins, furans, etc. (HELCOM, 2001, 2010).

Perch were collected from commercial trap nets with a mesh size of 16−36 mm (bar length) at three stations in the northeastern part of Pärnu Bay adjacent to the mouth of the Pärnu River (Fig. 1, Appendix). The sampling was performed during October and November 2006 and in March 2007 in order to cover the main maturation periods of perch. Altogether 344 perch were analysed. Fish total length (TL, cm), weight (TW, g), sex, and maturity stage to a routine six-point macroscopic histological maturity scale (Anon., 2007) were estimated. The sampled fish were aged using the opercular bones according to Tesch (1971).

The analyses were performed at the Laboratory of Chemical Analyses, Tallinn University of Technology. The laboratory has accreditation No. L116 since 2003 by the Estonian Accreditation Centre for the analyses of the studied elements. The laboratory participates annually (and achieves satisfactory results) in an inter-laboratory comparison programme organized by QUASIMEME. The quality assurance for each series of analyses was provided by the parallel analysis of reference materials.

For the determination of trace metals fish were dissected and representative tissues, such as the liver and muscle, were weighed and two replicate sub-samples of each sample were then prepared (1–2 g of wet weight). Samples (n = 79) were processed in an Automatic Microwave Digestion System (AntonPaar Multiwave 3000) using concentrated HNO_3 Suprapur1 "Merck".

The concentration of zinc (Zn) and copper (Cu) were determined by the flame technique of Atomic Absorption Spectrophotometry (AAS) method (Spectra AA 220F; Varian, Australia). The concentration of cadmium (Cd) was determined using a flameless technique and the concentration of mercury (Hg) by cold vapour AAS. To check for contamination, blanks containing bi-distilled water were used after every five samples. The limits of detection for the analysis of Cu and Zn were 1.0 and 0.7 mg g^{-1} and of Cd and Hg 0.13 and 0.3 μg g^{-1}, respectively.

The general linear model (GLM) was used to seek tissue-specific (levels: liver, muscle) statistical relationship between trace metal concentrations, fish age, and maturity as well as to assess how the metal concentrations vary among sexes. For each metal and tissue two models were built: one model included sex and maturity as independent factors and metal concentrations as dependent variables; the other model included only mature individuals, and sex was as an independent

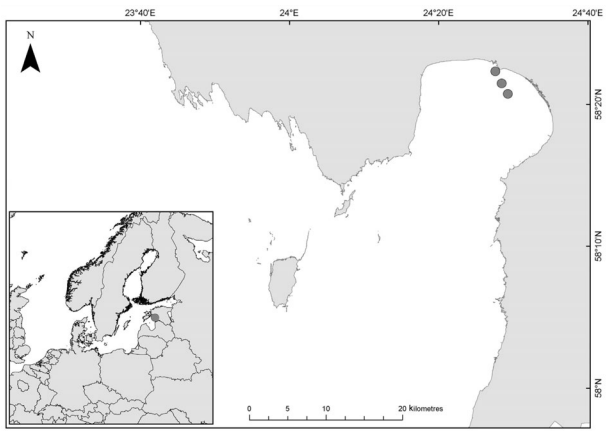

Fig. 1. Study area. Sampling sites are denoted by filled circles.

factor, age a covariate, and metal concentrations dependent variables. Linear regression analysis was used to visualize relationships between co-variants and dependent variables.

RESULTS

The studied perch ranged between 9 and 5 cm in total length, 7 and 506 g in weight, and 1 and 8 years in age. Both females and males contained immature (maturity stage II) and mature individuals (maturity stage III and IV). As a rule, the immature female perch were smaller and mature female larger than males of the same age. The average biological parameters are reported in Table 1.

In liver tissue the concentrations (mg g^{-1}) of the studied metals decreased in the order Zn (min: 7.18, avg: 89.75, max: 137.57) > Cu (min: 2.24, avg: 21.40, max: 47.82) >> Cd (min: 0.002, avg: 0.23, max: 1.96) > Hg (min: 0.05, avg: 0.16, max: 0.43). In muscle tissue the concentrations of the studied metals decreased in the order Zn (min: 4.77, avg: 26.01, max: 93.97) >> Cu (min: 0.17, avg: 1.73, max: 6.44) > Hg (min: 0.01, avg: 0.32, max: 0.66) > Cd (min: 0.001, avg: 0.03, max: 0.49). Liver tissue had higher concentrations of Cd, Zn, and Cu compared to muscle tissue and muscle tissue had a higher concentration of Hg than liver tissue. The mean content of trace metals in male perch was always higher than in female perch.

The first set of GLM analyses on the effects of sex and maturity on the concentration of trace metals in fish showed that largely half of the studied metals were independent of fish sex and maturity. However, sex, maturity, and their interaction explained the variability of Cd in both liver and muscle tissues. Besides, only sex explained the variability of Cu in muscle tissue (Table 2). In the presence of significant statistical differences the concentration of trace metals was higher in males than in females. As for Cd, such differences were due to immature individuals as there was no statistical difference between sexes among mature individuals (Figs 2 and 3).

The other set of GLM analyses on the effects of sex and age on the concentration of trace metals in fish showed that the accumulation of trace metals into fish tissues was independent of fish age. As the only exception the concentration of Hg in muscle tissue increased with fish age (Table 3, Fig. 4).

Table 1. Mean biological characteristics of different perch length classes analysed in 2006–2007. Abbreviations: F – females, M – males, TL – total length, TW – total weight

Parameter	<15 cm		15–20 cm		>20 cm	
	F	M	F	M	F	M
Mean TL, cm	13.0	13.4	16.9	16.9	26.7	22.7
Mean TW, g	20.2	22.4	57.4	48.1	248.4	122.0
Age, yrs	1–2	1–2	2–4	3–5	5–8	5–6
Maturity	II	II–III	II–IV	II–III	II–IV	II–III

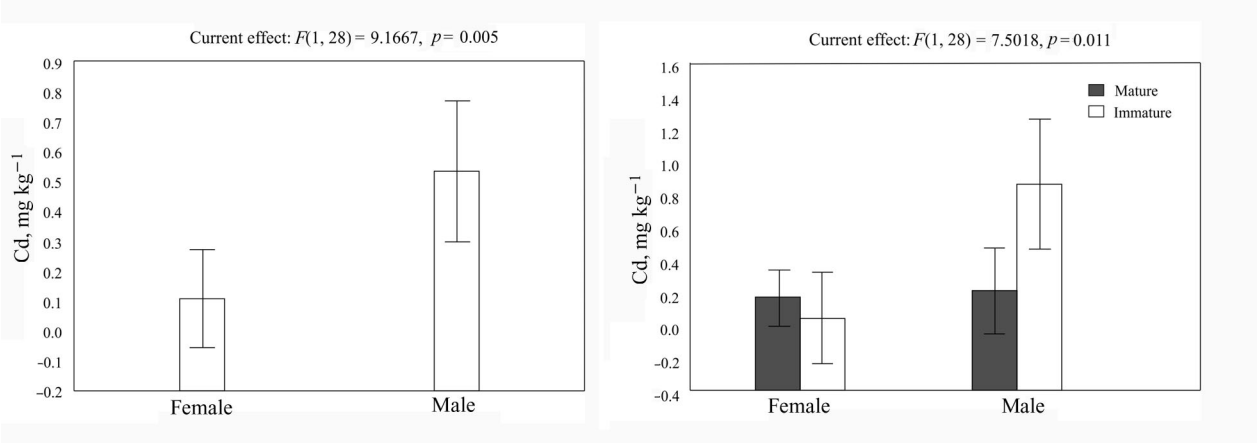

Fig. 2. GLM analysis on the effect of sex and maturity on the content of cadmium in liver tissue (means and 95% confidence intervals).

Table 2. Results of the general linear model analyses on the effect of sex and maturity on the content of trace metals in fish tissues. Significant effects and interactions are marked in bold

Model	Factors	SS	Df	MS	*F*	*p*
Cu in liver	Intercept	13 996	1	13 996	105.31	0.000
	Sex	144	1	144	1.09	0.306
	Maturity	526	1	526	3.96	0.057
	Sex × Maturity	95	1	95	0.71	0.406
	Error	3 722	28	133		
Cd in liver	Intercept	2.446	1	2.45	21.63	0.000
	Sex	1.036	1	1.04	9.17	**0.005**
	Maturity	0.393	1	0.39	3.47	0.073
	Sex × Maturity	0.848	1	0.85	7.50	**0.011**
	Error	3.166	28	0.11		
Zn in liver	Intercept	221 943	1	221 943	239.17	0.000
	Sex	2 894	1	2 894	3.12	0.088
	Maturity	2 476	1	2 476	2.67	0.114
	Sex × Maturity	82	1	82	0.09	0.769
	Error	25 984	28	928		
Hg in liver	Intercept	0.234	1	0.23	28.72	0.000
	Sex	0.001	1	0.00	0.11	0.747
	Maturity	0.019	1	0.02	2.37	0.152
	Sex × Maturity	0.000	1	0.00	0.00	0.994
	Error	0.090	11	0.01		
Cu in muscle	Intercept	115.03	1	115.03	119.20	0.000
	Sex	8.32	1	8.32	8.62	**0.005**
	Maturity	0.13	1	0.13	0.14	0.712
	Sex × Maturity	0.09	1	0.09	0.09	0.763
	Error	44.39	46	0.97		
Cd in muscle	Intercept	0.157	1	0.16	40.01	0.000
	Sex	0.102	1	0.10	26.00	**0.000**
	Maturity	0.068	1	0.07	17.30	**0.000**
	Sex × Maturity	0.057	1	0.06	14.49	**0.000**
	Error	0.185	47	0.00		
Zn in muscle	Intercept	18 223	1	18 223	94.65	0.000
	Sex	10	1	10	0.05	0.825
	Maturity	304	1	304	1.58	0.215
	Sex × Maturity	312	1	312	1.62	0.209
	Error	9 049	47	193		
Hg in muscle	Intercept	2.358	1	2.36	83.39	0.000
	Sex	0.014	1	0.01	0.51	0.481
	Maturity	0.000	1	0.00	0.01	0.918
	Sex × Maturity	0.026	1	0.03	0.91	0.350
	Error	0.707	25	0.03		

Table 3. Results of the general linear model analyses on the effect of sex and age on the content of trace metals in adult fish muscle tissue. Significant effect is marked in bold

Model	Factors	SS	Df	MS	*F*	*p*
Hg in muscle	Intercept	0.000	1	0.000	0.008	0.928
	Sex	0.019	1	0.019	0.994	0.336
	Age	0.131	1	0.131	7.003	**0.019**
	Sex × Age	0.003	1	0.003	0.169	0.687
	Error	0.262	14	0.019		

DISCUSSION

Our study only partly agreed with the first and second hypotheses as there were no generic relationships between fish sex and maturity and the content of trace metals in the fish tissues. Among the studied metals only Cd and Cu showed some sex dependence with males having higher metal concentrations compared to females. Just to name a few, membrane permeability, the nature of enzyme system and hormones, and the number of available binding sites in male and female fish may account for these differences (Heath, 1987;

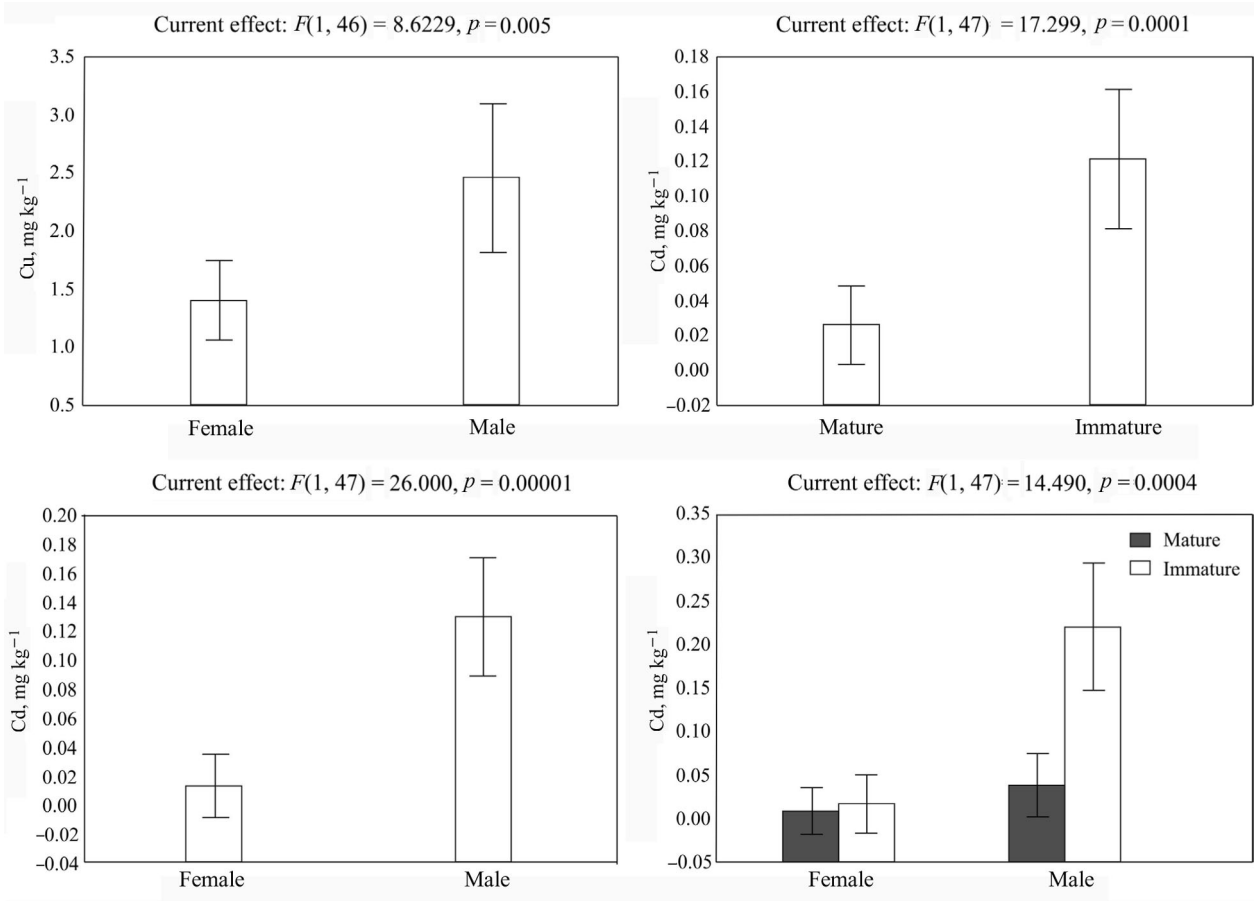

Fig. 3. GLM analysis on the effect of sex and maturity on the content of cadmium and copper in muscle tissue (means and 95% confidence intervals).

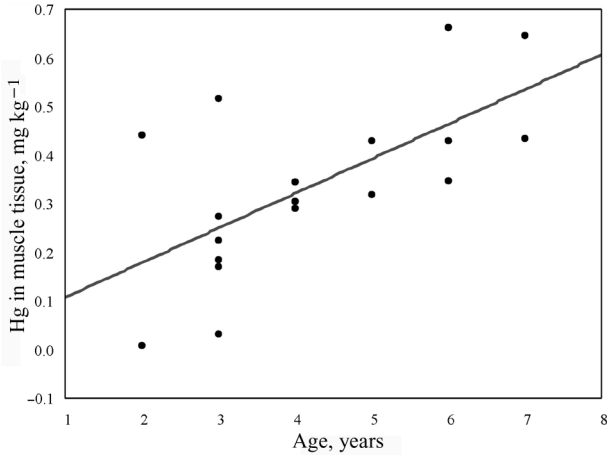

Fig. 4. Linear regression analysis to visualize the relationships between fish age and content of mercury in muscle tissue.

Jørgensen and Pedersen, 1994; Madenijan et al., 2011). Besides, Cu and Zn tend to accumulate to a greater extent than other trace metals, which increases the statistical probability that there are significant differences among sexes (Heath, 1987). In general, the concentrations of the studied trace metals were higher in liver than in muscle conforming to the earlier idea that metals primarily accumulate into tissues that are metabolically more active (Berninger and Pennanen, 1995; Klavins et al., 2009).

According to Pihu et al. (2003), the asymptotic growth of female perch is always faster compared with males in both fresh- and brackish-water environments, which means that the females of a given size category are younger than the males of the same length. Thus, provided no variability in fish size, males are expected to have higher metal concentrations than females. Besides, the lower trace metals content in female perch may be a consequence of their stronger immune system (Zeeman and Brindley, 1981; Dautremepuits et al., 2009).

Our study also showed that such sex dependence was stronger in immature than mature individuals with immature males accumulating trace metals at significantly higher rates than immature females. The maturation process requires enhanced energy levels, i.e. increases feeding rates. This results in the elevated metabolic rate and, thus, the raised metal accumulation of fish (Bobori and Economidis, 1996). Although

differences in trace metal accumulation among males and females may persist at mature developmental stages, spawning seems to be the mechanism that helps the elimination of toxic substances from the body (Simm and Kotta, 2000; Szefer, 2002; Roots et al., 2004). Consequently, for mature individuals the differences in the concentration of trace metals among sexes decrease down to the level that is not detectable by statistical models.

There exists a large regional variability in the accumulation of trace metals in perch tissues. Earlier studies demonstrated higher metal concentrations either in males (Szefer et al., 2003; Voigt, 2003; Tulonen et al., 2006) or females (Berninger and Pennanen, 1995; Klavins et al., 2009). We believe that the among-study differences are not caused by sex-specific differences in foraging behaviour (Järv et al., 2011). Instead, the spatial differences in fish metabolism may result in the spatially varying sex-specific metal accumulation.

Our study also partly agreed with the third hypothesis as Hg was the only trace metal that accumulated with age in the fish. In general fish, especially predators, have a natural tendency to concentrate Hg in their bodies, often in the form of methylmercury, a highly toxic organic compound of Hg. Since fish are less efficient at depurating than accumulating methylmercury, the concentration of Hg in fish tissues is expected to increase with fish age (Janssen et al., 2000; Tulonen et al., 2006; Klavins et al., 2009; Gewurtz et al., 2011; Lepom et al., 2012).

CONCLUSIONS

To conclude, our analyses identified that the contamination of fish with trace metals is complex and depends on the one hand on the type of metal and on the other hand on fish biological characteristics such as tissue, sex, maturity, and age. However, no generic relationships between the studied variables were found either due to the lack of such relationships or potentially due to confounding environmental variables not identified in this study. Thus, experimental studies are needed to quantify the relationship between metal concentrations in the environment (including fish prey), fish biological characteristics, and the accumulation of trace metals in fish tissues.

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APPENDIX

Biological characteristics of perch and the concentration (mg kg wet weight^{-1}) of trace metals in their liver and muscle tissue. F – female, M – male

Year	Month	*n*	Age, yrs	TL, cm	TW, g	Sex	Maturity	Tissue	Dry matter, %	Cu	Cd	Zn
2006	Oct	82	0.2	8.8	6.8	F	2	Liver	20.8	9.280	0.0005	25.08
2006	Oct	14	1.0	12.9	21.3	M	3	Liver	21.9	2.750	0.0005	21.09
2006	Oct	8	0.5	9.3	7.8	F	2	Muscle	22.6	0.312	0.0005	4.83
2006	Oct	5	1.0	12.9	21.0	M	3	Muscle	21.3	0.415	0.0017	4.90
2006	Oct	12	0.8	12.9	20.8	F	2	Liver	21.5	5.704	0.0005	23.68
2006	Oct	5	0.4	12.5	18.0	F	2	Muscle	23.7	0.279	0.0005	6.65
2006	Oct	1	7.0	32.0	395.9	F	3	Liver	25.2	0.796	0.0047	1.81
2006	Oct	1	7.0	32.0	395.9	F	3	Muscle	23.3	0.321	0.0005	3.97
2006	Oct	3	6.0	26.1	200.3	F	3	Liver	22.8	2.489	0.2159	24.60
2006	Oct	1	6.0	26.2	211.5	F	3	Muscle	22.0	0.952	0.0009	4.95
2006	Oct	1	8.0	35.3	506.1	F	3	Liver	22.4	5.960	0.0005	23.31
2006	Oct	2	5.0	23.4	152.1	F	3	Liver	22.3	5.405	0.0518	23.60
2006	Oct	1	5.0	23.2	145.3	F	3	Muscle	23.2	3.934	0.0046	5.27
2006	Oct	3	5.0	23.5	146.2	M	3	Liver	24.2	4.966	0.0005	23.38
2006	Oct	1	5.0	23.1	132.8	M	3	Muscle	21.8	0.234	0.0232	5.22
2006	Oct	1	4.0	21.5	104.1	F	3	Muscle	23.3	0.201	0.0016	4.35
2006	Oct	4	4.0	21.5	114.7	F	3	Liver	23.4	2.518	0.0005	22.06
2006	Oct	4	4.3	22.0	113.4	M	3	Liver	24.9	3.532	0.0963	23.69
2006	Oct	1	8.0	35.3	506.1	F	3	Muscle	21.5	0.197	0.0011	3.78

APPENDIX. *Continued*

Year	Month	*n*	Age, yrs	TL, cm	TW, g	Sex	Maturity	Tissue	Dry matter, %	Cu	Cd	Zn
2006	Oct	1	4.0	22.3	111.7	M	3	Muscle	21.9	0.443	0.0097	4.01
2006	Oct	8	3.0	18.4	69.3	M	3	Liver	23.2	6.826	0.1353	23.92
2006	Oct	1	3.0	17.5	60.1	M	3	Muscle	20.7	0.332	0.0128	5.14
2006	Oct	6	3.2	19.1	79.5	F	2	Liver	20.7	2.761	0.0005	23.26
2006	Oct	1	3.0	20.0	91.6	F	3	Muscle	24.7	0.204	0.0050	3.58
2006	Oct	6	2.0	16.0	45.9	F	2	Liver	24.2	10.249	0.0005	22.79
2006	Oct	1	2.0	16.2	65.2	F	2	Muscle	23.5	0.375	0.0005	6.74
2006	Oct	1	2.0	15.0	35.1	M	2	Muscle	24.4	0.499	0.0403	4.35
2006	Oct	11	2.0	15.7	39.3	M	2	Liver	21.1	5.574	0.1304	22.83
2006	Nov	11	2.0	14.7	35.4	F	2	Liver	21.6	2.438	0.0305	16.11
2006	Nov	1	2.0	14.5	40.3	F	2	Muscle	21.8	0.449	0.0002	5.08
2006	Nov	1	2.0	15.0	34.7	F	2	Muscle	20.7	0.177	0.0004	4.23
2006	Nov	1	2.0	15.0	32.9	F	2	Muscle	19.8	0.183	0.0008	5.94
2006	Nov	8	3.0	17.1	56.1	F	3	Liver	22.5	3.488	0.0363	14.98
2006	Nov	1	3.0	17.8	70.4	F	3	Muscle	25.6	0.092	0.0003	1.22
2006	Nov	1	3.0	16.1	46.4	F	2	Muscle	23.2	0.527	0.0007	4.54
2006	Nov	1	3.0	16.3	51.5	F	2	Muscle	19.5	0.291	0.0007	4.75
2006	Nov	8	3.0	18.9	77.1	F	3	Liver	21.6	0.483	0.0493	4.05
2006	Nov	1	3.0	18.8	81.0	F	3	Muscle	20.4	0.184	0.0088	19.18
2006	Nov	1	3.0	18.5	72.1	F	2	Muscle	22.9	0.223	0.0002	5.74
2006	Nov	1	3.0	19.0	86.9	F	3	Muscle	23.8	0.251	0.0019	4.21
2006	Nov	1	4.0	22.0	130.0	F	3	Muscle	24.5	0.230	0.0004	4.58
2006	Nov	1	4.0	22.0	119.3	F	3	Muscle	20.1	0.177	0.0003	4.81
2006	Nov	1	4.0	22.1	129.1	F	3	Muscle	19.9	0.186	0.0007	4.23
2006	Nov	8	4.0	22.3	131.7	F	3	Liver	28.9	7.647	0.0382	19.87
2006	Nov	3	5.3	26.1	209.4	F	3	Liver	25.4	3.170	0.0212	18.15
2006	Nov	1	5.0	26.5	203.5	F	3	Muscle	18.7	0.198	0.0002	4.69
2006	Nov	1	5.0	25.3	207.3	F	3	Muscle	21.3	0.146	0.0003	5.16
2006	Nov	1	6.0	26.5	217.3	F	3	Muscle	23.1	0.167	0.0002	4.32
2006	Nov	1	6.0	28.5	327.8	F	3	Muscle	21.9	0.333	0.0005	4.07
2006	Nov	1	6.0	28.5	327.8	F	3	Liver	26.2	3.250	0.0138	16.82
2006	Nov	1	7.0	29.5	342.3	F	3	Muscle	23.6	0.159	0.0002	4.60
2006	Nov	1	7.0	29.5	342.3	F	3	Liver	25.8	1.817	0.0133	23.73
2006	Nov	1	8.0	31.5	361.8	F	3	Muscle	20.6	0.189	0.0002	7.45
2006	Nov	1	8.0	31.5	361.8	F	3	Liver	24.3	2.866	0.0129	8.37
2007	March	24	1.9	13.3	21.3	F	2	Liver	20.1	7.442	0.0339	17.74
2007	March	1	1.0	12.5	17.0	F	2	Muscle	20.4	0.465	0.0003	5.78
2007	March	1	2.0	14.1	24.0	F	2	Muscle	22.5	0.429	0.0122	4.89
2007	March	1	3.0	15.0	31.0	F	2	Muscle	20.4	0.035	0.0114	4.78
2007	March	1	3.0	14.6	29.0	F	2	Muscle	17.9	0.513	0.0116	6.47
2007	March	1	3.0	15.8	36.0	F	2	Muscle	21.0	0.384	0.0118	4.89
2007	March	5	4.0	18.5	67.6	F	4	Liver	21.4	4.642	0.0509	19.35
2007	March	1	4.0	18.3	75.0	F	4	Muscle	19.9	0.512	0.0035	5.18
2007	March	6	4.8	21.5	111.3	F	4	Liver	20.4	7.859	0.0368	24.16
2007	March	1	5.0	22.2	126.0	F	4	Muscle	20.5	0.266	0.0049	4.85
2007	March	2	6.0	25.3	190.0	F	4	Liver	21.7	4.487	0.0951	29.28
2007	March	1	6.0	25.5	208.0	F	4	Muscle	21.7	0.521	0.0107	8.23
2007	March	1	7.0	28.7	336.0	F	4	Liver	23.7	0.714	0.0006	6.15
2007	March	1	7.0	28.7	336.0	F	4	Muscle	19.3	0.453	0.0012	5.91
2007	March	24	2.0	13.6	23.3	M	3	Liver	18.6	6.036	0.0177	21.97
2007	March	1	2.0	13.5	21.0	M	3	Muscle	19.3	0.337	0.0002	6.40
2007	March	1	2.0	14.0	28.0	M	3	Muscle	21.2	0.427	0.0004	4.20
2007	March	1	2.0	13.2	21.0	M	3	Muscle	21.4	1.380	0.0489	16.72
2007	March	1	2.0	13.6	21.0	M	3	Muscle	18.4	0.580	0.0019	6.89
2007	March	12	2.8	15.8	36.2	M	3	Liver	19.0	9.100	0.0730	26.18
2007	March	1	3.0	17.5	50.0	M	3	Muscle	20.8	0.359	0.0005	5.06
2007	March	1	3.0	17.0	36.0	M	3	Muscle	19.9	0.502	0.0009	5.69
2007	March	8	3.9	19.2	74.8	M	3	Liver	21.3	3.248	0.0144	13.85
2007	March	1	3.0	14.8	32.0	M	3	Muscle	21.1	0.590	0.0012	5.19
2007	March	1	5.0	22.1	106.0	M	3	Muscle	24.1	0.650	0.0002	7.21

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Raskmetallide sisalduse ja ahvena (*Perca fluviatilis* L.) bioloogiliste näitajate vahelised seosed Pärnu lahes

Leili Järv, Jonne Kotta ja Mart Simm

On alust arvata, et kala bioloogilised näitajad mõjutavad raskmetallide kogunemist tema organismi. Kahjuks on selliseid uuringuid tehtud vaid üksikute kalaliikide kohta. Käesolev uurimus püüabki näidata, kuidas ahvena bioloogilised näitajad, nagu sugu, suguküpsus ja vanus, mõjutavad elavhõbeda, kaadmiumi, vase ning tsingi kogunemist maksa- ja lihaskoesse. Selgus, et kalade saastumine raskmetallidega on keerukas nähtus, mis ühelt poolt sõltub sellest, millise metalliga on tegemist, ja teiselt poolt vaadeldavate bioloogiliste näitajate kompleksist, st kala bioloogilisest seisundist. Maksas oli kaadmiumi-, vase- ja tsingisisaldus suurem kui lihastes, elavhõbedasisaldus oli aga lihastes suurem kui maksas. Saastumist raskmetallidega mõjutas ka kala sugu. Reeglina olid raskmetallide sisaldused isastes ja mittesuguküpsetes ahvenates suuremad kui emastes ning suguküpsetes isendites. Ahvena vanuse kasvuga suurenes üksnes lihaste elavhõbedasisaldus.