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Content of Selected Heavy Metals in the Organs of Fish from Żnin Duże Lake

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Fish species constituting the majority of the fish population of Żnin Duże Lake were selected for the investigations. They included: roach, white bream, common bream and perch. The largest amounts of detected metals accumulated in the liver and gills, and the lowest amounts occurred in muscle, except copper which had the lowest concentration in the gills. A bifactor analysis of variance revealed that the average concentrations of the elements in different organs differed significantly, but only in a few cases the average contents of mineral components in the same organ for different species differed significantly. The analysis of the dependence of the content of elements in different organs and the fish body length indicated a positive correlation for Cu, Fe and Ni, and a negative correlation for Zn and Mn in muscle. The analysis of the bioaccumulation coefficient revealed that the largest tendency to accumulate in muscle is displayed by zinc and iron, manganese and copper accumulate the least.

Key words: Heavy metals, biocumulation, fish, muscle, gill, liver.

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Lakes are important hydrological and landscape elements with very important tourist and recreational attractions. Unfortunately, during the last several decades a drastic decline in surface lakes in Poland from 316 972 ha (MAJDANOWSKI 1954) to 280 972 ha (CHOIŃSKI 1991) has taken place. The decrease of ground water and reckless melioralization has led not only to the decrease of the surfaces and capacities of lakes, but also to the decay of some lakes which now appear only on old maps (MASTYŃSKI 1999). Mineral components flow through the lithosphere, atmosphere and hydrosphere as a natural cycle of nature. They originate both from anthropogenic sources and natural processes. In the environment, trace metals occur as soluble and insoluble components contained in water**,** bottom sediments and tissues of organisms. Elements occurring in large concentrations in the water environment are accumulated in plants, fito- and zooplankton, waterfowl, and the predatory fowl which feed on them (SIEPEK & SOBCZYŃSKI 1992). Fish, which represent one of the last elements of the trophic chain of the water ecosystem can cumulate in their tissues (liver, bones, kidney, muscles and skin) large amounts of mineral components including elements very harmful for their health, such as lead, mercury and cadmium (ŁUCZYŃSKA *et al*. 2001; GOMMA *et al*. 1995). Therefore, they play a very important role in the elimination of mineral components from the water environment and are also a good index of pollution of the ecosystem in which they live. The metabolized metals can be removed from the fish body mainly through the gills, skin – during the exchange with other ions, with spawn and through intestines with excrement (MEINELT *et al*. 1995).

In the case of fish, metals are characterized by different degrees of toxicity. The ions of heavy metals are the most harmful, and the ions of sodium, potassium, magnesium and calcium are less harmful.

The lack of data on concentration of heavy metals in organs of fish from the Żnin Duże Lake has led to the undertaking of this research.

Material and Methods

156 fish including 131 non-predatory fishes (roach- *Rutilus rutilus*, white bream *Blicca bjoer-*

kna and common bream- *Abramis brama*) and 25 predatory fishes (perch- *Perca fluviatilis*) were studied. After transporting the fish to the laboratory, measurements of the mass of the fish body (g), body length (cm) and the total length (cm) were taken. After the preliminary measurements, the back muscle, liver and gills were collected from each fish in order to measure the concentrations of zinc, copper, iron, manganese and nickel.

Liofilization and mineralization

The collected tissues were crumbled and liofilizated in the liofilizator Lyovac GT2, Finn-Aqua. The liofilizated samples were mineralized in a microwave mineralizator Ethos plus, Milestone. For the purpose of mineralization, 0.2 g of the tissue was weighed and then HNO_3 and H_2O_2 were added in a ratio of 4:1. During the first 10 minutes, the temperature was increased to 190°C. During the next 10 minutes the temperature was kept at a level of 190°C±5°C. The mineralized samples have been carried quantitatively to the measuring-flasks with a capacity of 50 cm^3. These samples were analyzed for the purpose of determining the content of the mineral components using the ASA method (Solar 969, Unicam).

Statistical analysis

A bifactor analysis of variance was used in order to analyze the contents of metals in the muscle. A logarithmic transformation of data was performed in order to obtain a normal distribution and uniformity of variance. Tukey's test was used as a test of multiple comparisons. The dependence of fish body length and concentrations of particular metals in the organs were analysed and the bioaccumulation coefficient of metals in the muscle was calculated (k).

Results and Disscusion

The bifactor analysis of variance revealed that the average concentrations of the analyzed elements differed significantly between organs, and only in a few cases did the average concentrations of metals for particular organs differ significantly between fish species (Table 1). The average concentrations of zinc detected in roach differed significantly from the content of this element in the remaining fish species in all three organs. In case of copper, differences occurred in the liver. As for manganese, statistically significant differences were established for the muscle. No statistically significant differences in the concentrations of iron and nickel for particular organs between fish species were found. The analyzed elements have mainly accumulated in the gills and liver, while the lowest amounts occurred in the muscle except for copper which was detected in the lowest amount in the gill (Fig. 1).

Investigations of muscles and livers of roach, carp, pike, perch and tench from the Dzierżno Duże Lake (Upper Silesia Industrial District) have shown that the mechanism of the excretion of heavy metals from the muscles and their accumulation in the liver, an organ which plays the role of

Table 1

The average concentrations of metals in fish organs – logarithmic values (log)

Organs	Species	The average concentrations of elements (mg/kg)				
		Zn	Cu	Fe	Mn	Ni
Muscle	common bream	1.516^{A}±0.127	0.889±0.290	1.704±0.250	0.807^{A}±0.203	0.710±0.337
	white bream	1.547^{B}±0.075	0.982±0.433	1.675±0.230	0.997^{AB}±0.126	0.201±0.352
	roach	1.761^{ABC}±0.084	0.659±0.110	1.519±0.514	0.996±0.131	0.409±0.948
	perch	1.546^{C}±0.094	0.980±0.360	1.572±0.165	0.768^{B}±0.112	0.376±0.262
Gill	common bream	1.937^{D}±0.085	0.650±0.206	2.436±0.093	1.745±0.119	0.839±0.225
	white bream	1.960^{E}±0.091	0.860±0.252	2.420±0.142	1.735±0.168	0.864±0.428
	roach	3.030^{DEF}±0.042	0.956±0.317	2.364±0.151	1.632±0.119	0.932±0.361
	perch	1.945^{F}±0.071	0.663±0.238	2.212±0.062	1.680±0.159	0.733±0.314
Liver	common bream	2.098^{G}±0.141	1.755±0.218	2.436±0.124	1.143±0.137	0.815±0.281
	white bream	2.137^{H}±0.062	1.743±0.136	2.638±0.052	1.201±0.120	0.340±0.801
	roach	2.382^{GHI}±0.162	2.169^{A}±0.332	2.631±0.185	1.405±0.381	0.903±0.079
	perch	2.012^{I}±0.143	1.395^{A}±0.253	2.358±0.110	1.143±0.149	0.988±0.258

The values in columns denoted by the same letters vary significantly for P<0.0

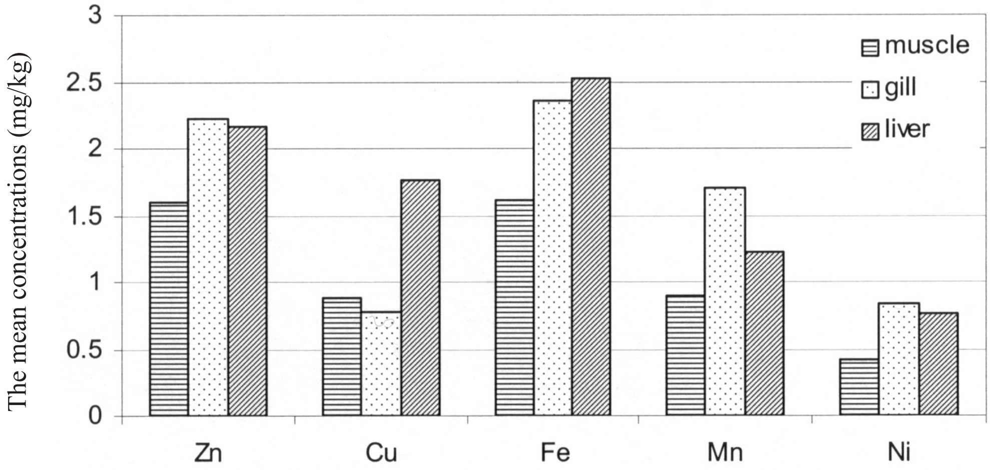

Fig. 1. The average concentrations of metals in fish organs (logarithmic values).

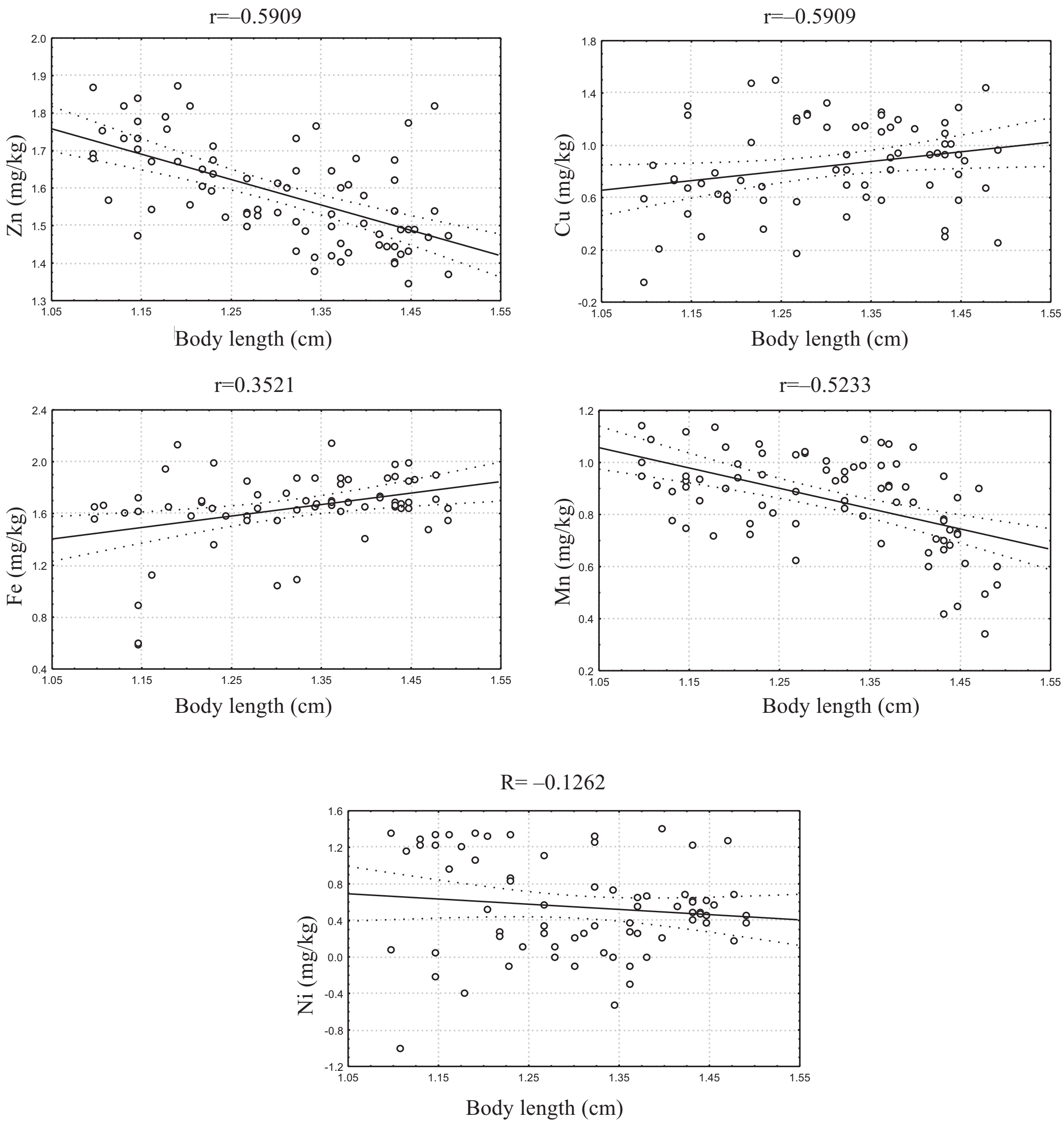

Fig. 2. The dependence of the content of metals in the fish muscle (mg/kg d.w.) and body length (cm).

Table 2

The average concentrations of selected metals in water (mg/dm^3) and in the back muscle of the fish (mg/kg of fresh product) from Żnin Duże Lake and the cumulation coefficient of these metals (k)

Fish species	Zn	k	Cu	k
common bream	6.862±2.276	275.58	1.974±1.833	47.11
white bream	7.148±1.274	287.11	2.571±1.353	61.36
roach	11.720±2.030	470.68	0.940±0.391	22.43
perch	7.188±2.035	288.67	2.532±1.877	60.43
Water	0.0249±0.033		0.0419±0.025	
Fish species	Fe	k	Mn	k
common bream	11.751±6.955	147.81	1.450±0.903	53.11
white bream	10.710±5.834	134.72	2.047±0.421	74.76
roach	10.050±7.566	126.42	2.056±0.493	75.31
perch	7.895±2.309	99.31	1.206±0.324	44.18
Water	0.0795±0.043		0.0273±0.013	

k – coefficient of cumulation (ratio of the average concentration of the metal in fish muscle and the average content of this element in water)
No data available on the concentration of Ni in water of Żnin Duże Lake.

a filter (KOSTECKI 2000; ŁYSAK *et al*. 1990), has been developed in these animals. The studies of tissues of spring-trout and stream-trout have also indicated the largest amounts of heavy metals in the liver and muscles, especially in case of Zn (162.8 mg/kg d.w. for spring-trout and 123.9 mg/kg d.w. for stream-trout) and Cu (69.3 mg/kg d.w. for spring-trout and 138.0 mg/kg for stream-trout) (PALUSZKIEWICZ-MACH 1997). Research on carp from the ponds in Lower Silesia has confirmed the ability to accumulate mineral component to the lowest extent in the muscle tissue (DOBICKI *et al.* 1990).

The analysis of the dependence of the content of elements in particular organs and the body length of the fish from the Żnin Duże Lake indicated, in the case of muscle, a positive correlation for Cu, Fe and Ni, and a negative correlation for Zn and Mn (Fig. 2).

Similar results for zinc have been obtained from analyses of the muscle tissue of fish from Łańskie Lake (Mazurian Lakeland). In the case of roach and perch, more zinc has been found in small fish than in large fish. The calculated differences for common bream have not been significant (ŁUCZYŃSKA *et al*. 2000). The concentration of zinc in muscles of roaches from Dzierżno Duże Lake fluctuated between 32.5 and 121.2 mg/kg d.w., but there was a clear tendency to increase the level of zinc in the muscle tissue of roach as the body mass increased. The concentration of Cu in the muscle tissue of roach from Dzierżno Duże Lake was from 4.0 to 7.7 mg/kg d.w., whereas no tendency related to the content of this element and increasing mass was found (KOSTECKI 2000). The muscle tissue of roach and common bream from Łańskie Lake contained similar amounts of copper with a tendency for its content to increase in large fish (ŁUCZYŃSKA *et al*. 2000).

The dependence of the concentrations of heavy metals and the fish body length depends mainly on the availability of elements, i.e. their concentrations in the water environment (KLJAKOVIĆ *et al.* 2002). Investigations have shown that the biocumulation of heavy metals in tissues, i.e.: Cr, Mn, Ni and Pb, decreased as fish body length increased (negative correlation) (CANLI & ATLI 2003). The ability to metabolize metals by organisms is a very important factor which influences the degree of cumulation of these compounds in fish organs. The main explanation of the negative correlation between the concentration of metals and the size of fish is a difference in the ability to metabolize compounds, higher for young fish than for older fish. This dependence, however, is not observed in highly polluted waters. In this case, a positive correlation is usually found. The second explanation of this phenomenon is the fact that for young organisms, the mechanisms of the neutralization of harmful compounds are not developed sufficiently. Therefore, larger amounts of toxins can accumulate in their bodies (KLJAKOVIĆ *et al.* 2002). The fact that the rate of nutrition and daily food-ration of older fish decreases with size is also very important. Then, the risk that toxins can get into organisms with food decreases (FARKAS *et al.* 2003). The decreasing content of heavy metals in the organisms of older fish can also result from the fall of the content of proteins responsible for binding these compounds in tissues (ALLEN-GIL & MARTYNOV 1995).

From the analysis of the biocumulation coefficient, zinc and iron had the strongest tendency to accumulate in the fish muscle of the fish from the Żnin Duże Lake. Manganese and copper accumulated to the lowest extent (Table 2). The biocumulation coefficient is a measure of intensity of accumulation of an element in an organ and is inversely proportional to the concentration of the metal in water. This means that even very small concentrations of the element in the water environment may lead to dangerous amounts of the element accumulated in fish organs (SZULKOWSKA-WOJACZEK *et al*. 1992). The ability of fish to cumulate zinc in the muscle tissue has been confirmed by the studies of heavy metals in the fish of Wielkopolski National Park. The biocumulation coefficients of zinc have been from 203 for common bream to 426 for pike. Copper has lower values of the coefficients than zinc (from 52 for pike to 87 for common bream) (SOBCZYŃSKI *et al*. 1995). The biocumulation coefficient of zinc in the muscle of the fish from Żnin Duże Lake has the following values: 22 for roach, 47 for common bream, 60 for perch and 61 for white bream.

On the basis of the present study it may be inferred that the largest amounts of detected metals have accumulated in the liver and gills, and the lowest amounts occurred in muscle. The average concentrations of the elements in different organs have significantly differed , but only in a few cases did the average contents of mineral components in the same organ for different species differ significantly. The largest tendency to accumulate in the muscle was displayed by Zn and Fe. The analysis of the dependence of the fish body length and content of metals in different organs indicated a positive correlation for most metals in the case of muscle.

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