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Ewa SZAREK-GWIAZDA

Karol Starmach Institute of Freshwater Biology, Polish Academy of Sciences,
Sławkowska Street 17, 31-016 Cracow, Poland, e-mail: szarek@zbw.pan.krakow.pl

HEAVY METAL CONTENTS IN STONE LOACH *NOEMACHEILUS BARBATULUS* (L.) (COBITIDAE) LIVING IN THE RIVER ABOVE AND BELOW DAM RESERVOIR (DOBCZYCE RESERVOIR, SOUTHERN POLAND)

ABSTRACT: The concentrations of Cd, Pb, Cu, Cr, Zn and Fe in tissues (liver, ovaries and muscle) of stone loach *Noemacheilus barbatulus* (L.) living in the Raba River above and below Dobczyce dam reservoir (southern Poland) was determined. The contents of the heavy metals in fish varied in the studied dates and tissues. The highest concentrations of metals were usually determined in liver and the lowest ones in muscle. The lower concentrations of Cr, Cd and Pb were stated in the stone loach from the Raba River below the reservoir, so the Dobczyce Reservoir was sink for these metals. The concentrations of Cu, Zn and Fe in the fish tissues from the Raba River above and below the reservoir had the same level.

KEY WORDS: dam reservoir, river, fish tissues, *Noemacheilus barbatulus* (L.), heavy metals.

1. INTRODUCTION

Dam reservoirs as a sink and source of contaminant heavy metals in aquatic system may influence metal pollution of rivers below them. The results of most studies, among the others of Pasternak and Gliński (1972), Imhoff and Koppe (1980), Harding *et al.* (1981), Reczyńska-Dutka (1985) showed that dam reservoirs may deposit a big part of heavy metals. On the other hand, some authors (Reczyńska-Dutka 1985, Szarek-Gwiazda unpubl.) pointed that under suitable conditions of the water near the bottom heavy metals may be released from the sediment, so the water of the river below the reservoir may have higher concentrations of heavy metals then of that above.

The contamination of an aquatic ecosystem by heavy metals can be confirmed in water, sediment and organisms. As aquatic organisms concentrate heavy metal pollutants to a marked degree over water layers, they may be used to estimate the level of heavy metal pollution (Förstner and Whittmann 1983).

Among water organisms fish were used in field studies of heavy metal pollution (Murphy *et al.* 1978, Salánki *et al.* 1982, Marek 1990, Amundsen *et al.* 1997). Individual organs of fish have a different affinities for heavy metals (Honda *et al.* 1983, Marek 1990, Mccoy *et al.* 1995, Yamazaki *et al.* 1996). For instance the increase of heavy metals in muscle tissue of contaminated fish is often much lower than in other organs (for instance liver). To determine heavy metal contamination of water environment a suitable part of the body should be chosen.

The aim of the present work was to study the concentrations of heavy metals in the tissues of stone loach *Noemacheilus barbatulus* (L.) living in the Raba River above and below of the eutrophic dam reservoir (Dobczyce Reservoir), typical for mountain foot part of the Polish Carpathians.

2. STUDY AREA, MATERIAL AND METHODS

Stone loach *Noemacheilus barbatulus* (L.) has a wide distribution throughout Europe. It lenght reaches 12–18 cm. It has small environmental requirement and can live even in very polluted water (Rolik and Rembiszewski 1987, Cihař 1992). It occupies mainly benthic habitats and feeds on small benthic organisms (chironomid larvae and pupae, ephemeropteran nymphs, trichopteran larvae (Frankiewicz 1994).

The study was conducted in the Raba River, located about 25 kilometres south of Cracow. The Raba River rises in the Carpathian belt of the Gorce Mountains. In the middle part of the Raba River (60 km of the river course, 270 m a.s.l.), Dobczyce dam reservoir (49° 52'N, 20° 02'E, alt. 270 m) was created in 1986. The capacity of Dobczyce Reservoir is 99.2 milion m^{-3}, lengh about 11 km and average frequency of water exchange is 3.6 times a year (Mazurkiewicz 1988).

There was no a large industry plant in the catchment basin of the Raba River. The river was mainly contaminated by municipal sewage from three small town: Rabka, Mszana Dolna (less than 10,000 of inhabitants) and Myślenice (17,800 of inhabitants) as well as by waste water from villages (without sewage system) laying in the surrounding of the Dobczyce Reservoir (Mazurkiewicz 1996). Atmospheric pollution in the surroundings of the Dobczyce Reservoir was mainly caused by emission from metallurgical industry (the Tadeusz Sendzimir Steel Works in Cracow) and two power plant (Manecki and Tarkowski 1993).

The study of heavy metal (Pb, Cu, Zn and Fe) contents in the water of the Raba River led in early 70-ties (Pasternak and Antoniewicz 1971) pointed to very small contamination of river's water. Their concentrations in the water were mainly influenced by physico-chemical features of catchment area.

The stone loach *Noemacheilus barbatulus* (L.) were collected by electrofishing from two sites on the Raba River in 2 October 1991 and 13 May 1992. Station 1 was located above and station 2 below the reservoir (Fig. 1). The width of the Raba River at these stations ranges from 20–50 m, maximum depth were: 1 m at Station 1 and 0.7 m at Station 2. The bottom of the river was stony. Every time 10 specimens of fish were collected from each station. Fish weight and lenght

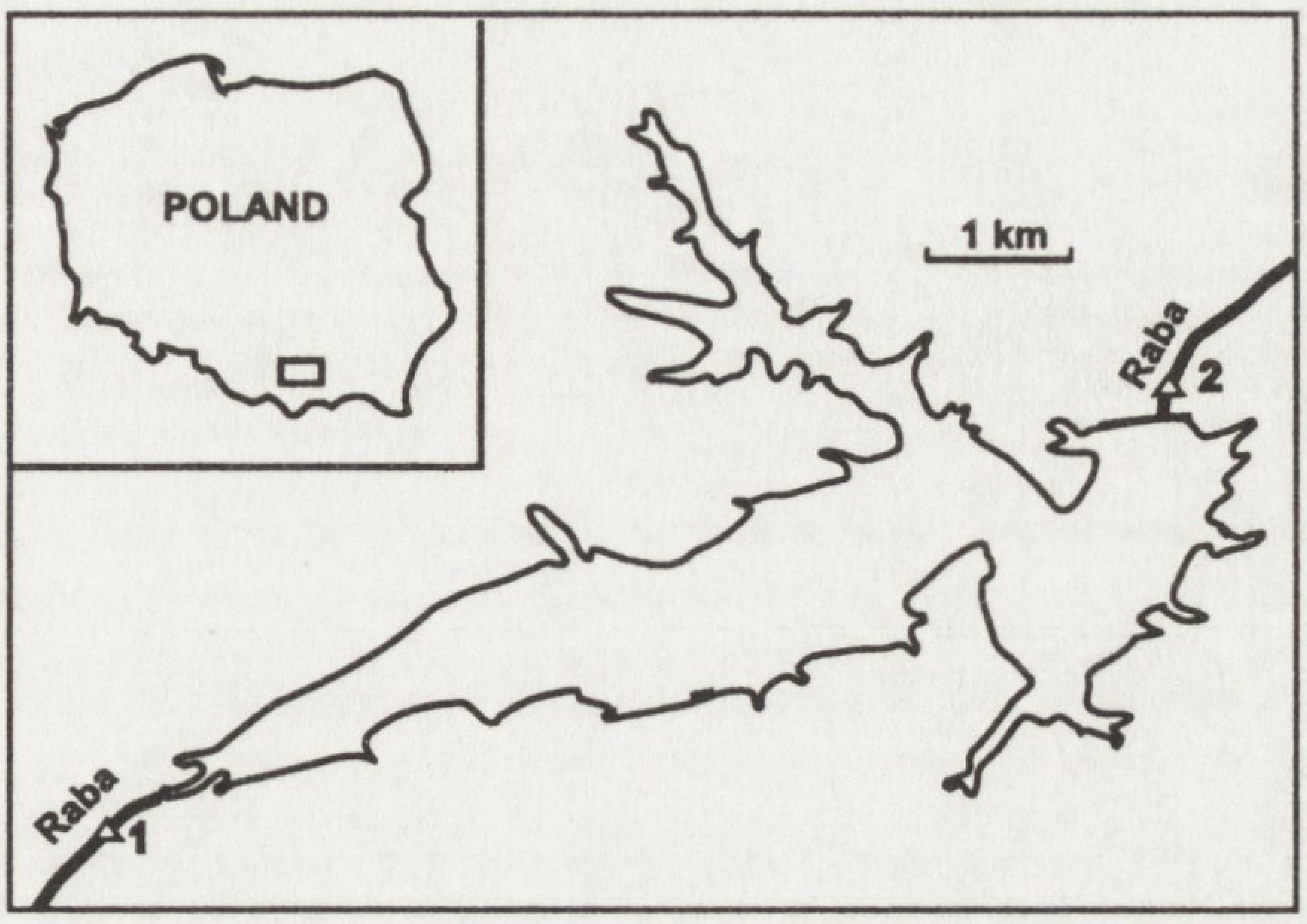

Fig. 1. The locations of the sampling stations on the Raba River above and below the Dobczyce Reservoir.

were determined. All fish were frozen on ice for transport and later stored at –17 °C until analysed. Fish age was determined by otoliths (Amirowicz unpubl.). All of the selected fish were dissected. The tissue samples of muscle, liver and ovaries were dried at the temperature of 60 °C and then digested with a mixture of nitric and perchloric acid (4 : 1) according to the method of Jop and Wojtan (1982). The microelements were determined by the atomic absorption spectrophotometer Perkin-Elmer model 403 with a graphite furnace.

To determine the statistical differences in the heavy metals contents in stone loach between localities Mann-Whitney U-test for two samples (ranked observations, not paired) was used (Sokal and Rohlf 1987).

3. RESULTS

Physical characteristic of the collected fish are presented in Table 1. The maximum length of the fish was 12.3 cm and weight was 21. 3 g. Two and three years old specimens were mainly collected. From Station 1 one 1 year old individual was collected. For comparative study concentrations of heavy metals determined in its tissues were not taken into consideration. In total 12 females from Station 1 and 14 females from Station 2 were collected.

Table 1. Physical characteristic of the stone loach *Noemacheilus barbatulus* (L.) from the Raba River.

	Number of individuals	Length (cm) (range)	Weight (g) (range)
Station 1	20	7.8–12.3	3.4–12.6
Station 2	20	3.4–11.5	3.5–21.3

The concentrations of heavy metals in *Noemacheilus barbatulus* (L.) varied in studied dates and tissues (Figs 2 and 3). Comparing the mean concentrations of Cu and Fe in the tissues of stone loach in October, the following sequence was determined: liver > ovaries > muscle (Figs 2 and 3). For Cd and Zn this sequence was: liver, ovaries > muscle, for Cr: liver > muscle > ovaries, and for Pb: ovaries > liver > muscle. In general, the lowest mean concentrations of metals (with the exception of Cr) were stated in the muscle. In May the lowest mean concentrations of heavy metals were found in the muscle, higher in the ovaries and the highest ones in the liver. The levels of Cd, Zn and Cr in the liver were about 2.5 times and for Pb, Cu and Fe about 5 times higher than in the muscle.

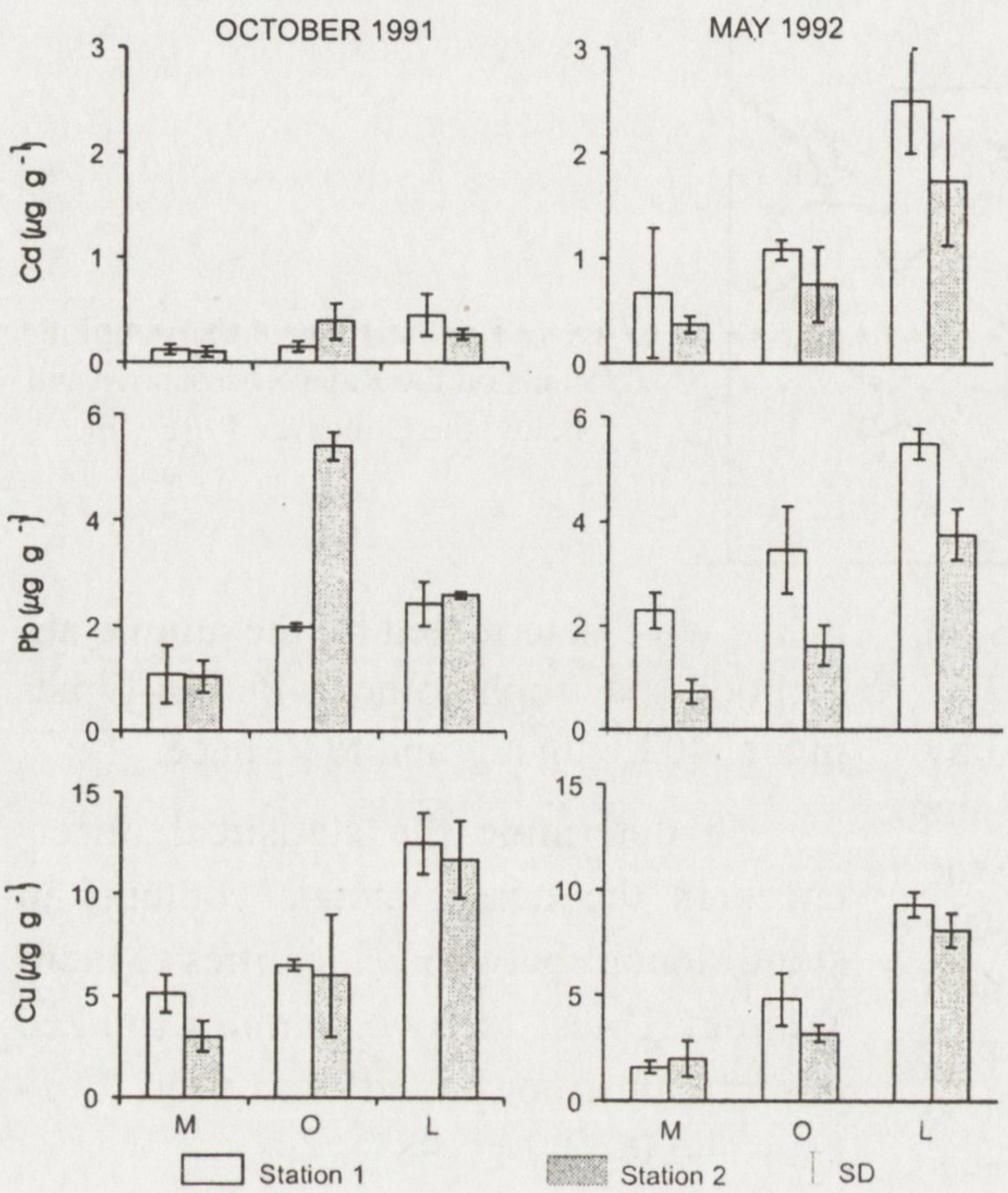

Fig. 2. The mean concentrations and standard deviations (SD) of Cd, Pb and Cu in the muscle (M), ovaries (O) and liver (L) of *Noemacheilus barbatulus* (L.) in the Raba River, in October and May. Station 1 – above reservoir, Station 2 – below reservoir (see Fig. 1).

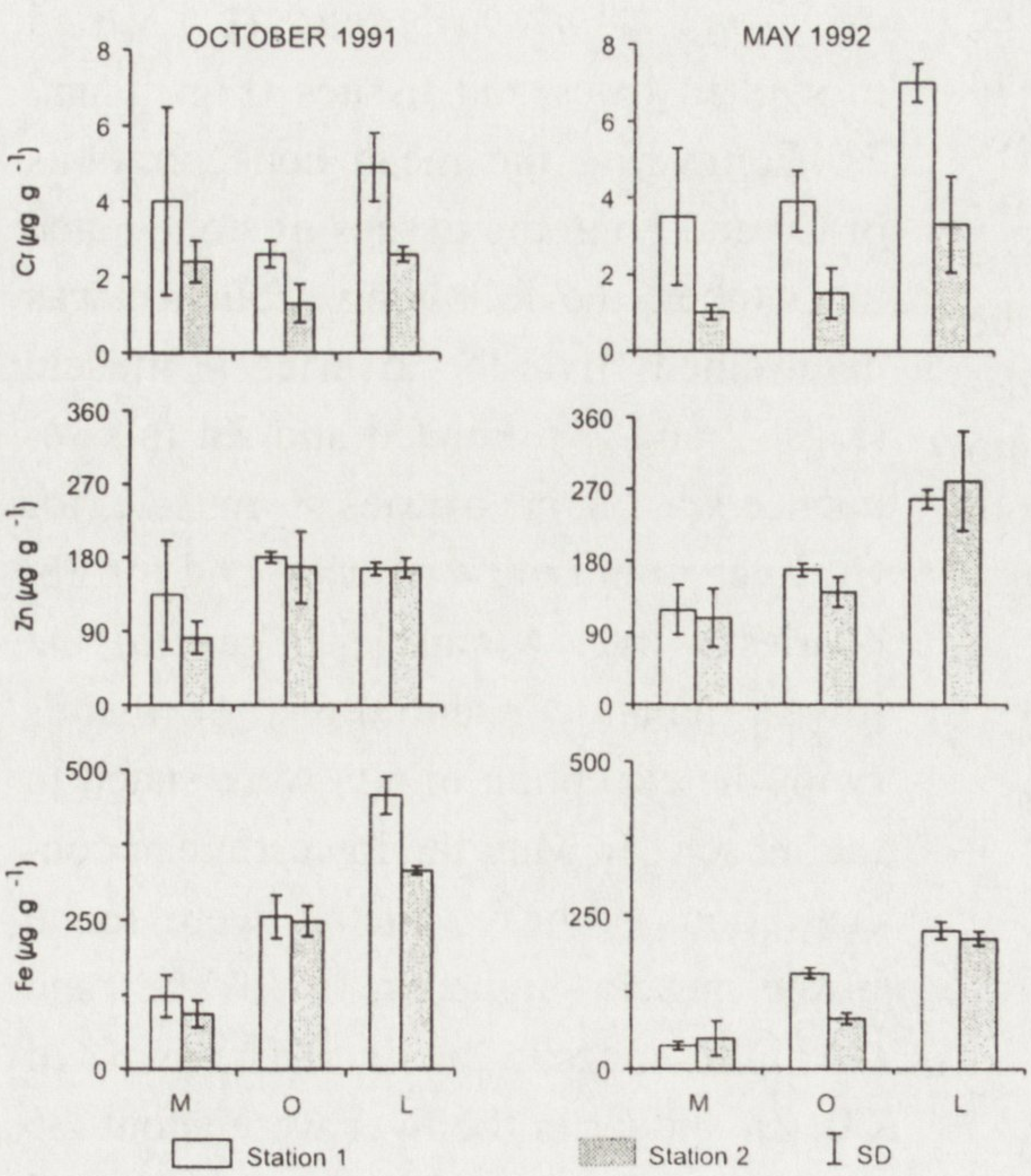

Fig. 3. The mean concentrations and standard deviations (SD) of Cr, Zn and Fe in the muscle (M), ovaries (O) and liver (L) of *Noemacheilus barbatulus* (L.) in the Raba River, in October and May. Station1 – above reservoir, Station 2 – below reservoir (see Fig. 1).

Only in the case of Cr concentrations in the stone loach, there were cleare differences between localities (Fig 3). They were higher about twice in the tissues of fish from the Raba River above the reservoir then those in the Raba River below the reservoir (in the muscle respectively in May and October: $U = 21$, $p = 0{,}05$, $N = 10$ and $U = 35$, $p<0{,}005$, $N = 12$; in the ovaries: $U = 25$, $p = 0{,}005$, $N = 10$ and $U = 25$, $p = 0{,}005$, $N = 10$; in the liver: $U = 25$, $p = 0{,}005$, $N = 10$ and $U = 25$, $p = 0{,}005$, $N = 10$). The concentrations of Cd and Pb in the tissues of fish had the similar level in both localities, in October (Fig. 2). In May, however, they were higher than in October and had higher level in the tissues of stone loach from the Raba River above the reservoir (in the muscle for Cd and Pb respectively: $U = 43$, $p = 0{,}01$, $N = 14$ and $U = 36$, $p < 0{,}005$, $N = 12$; in the ovaries: $U = 22$, $p <0{,}05$, $N = 10$ and $U = 25$, $p = 0{,}005$, $N = 10$; in the liver $U = 22$, $p < 0{,}05$, $N=10$ and $U = 25$, $p = 0{,}005$, $N = 10$). The concentrations of Cu, Zn, and Fe in the tissues of the fish had the similar level in both localities (Figs 2 and 3). In the case of Cu and Fe they were higher in October than those in May.

4. DISCUSSION

The concentrations of heavy metals in the tissues of *Noemacheilus barbatulus* (L.) from Raba River were similar to these from the region polluted by heavy metals to a small extent. Szarek-Gwiazda (1998a, b) found rather low concentration of these metals in the water and sediment of the Dobczyce Reservoir. This shows rather small pollution of this water environment by studied heavy metals.The concentrations of Cd, Pb and Zn in the muscle and liver of *Noemacheilus barbatulus* (L.) from the Raba River had the similar level and Cu content was even lower than those found in the brown trout (*Salmo trutta* morpha *fario* L.) from an unpolluted region of Poland *e.g.* Morskie Oko Lake (the Tatra Mountains) (Mach-Paluszkiewicz 1997). The mean content of Cu in the muscle and liver of *Noemacheilus barbatulus* (L.) from the Raba River was higher than in consumptive carp (0.75 and 2.25, respectively) from the south-west part of Poland (Bieniarz and Epler 1994). Different food preferences of stone loach and carp might have caused higher content of Cu in the tissues of stone loach. However, the concentrations of heavy metals in the tissues of *Noemacheilus barbatulus* (L.) from the Raba River were higher than those determined in an unpolluted region e.i. in an antarctic fish *Pagothenia borchgrevinki* (Honda *et al.* 1983) or other 9 species of arctic fish from Pechora River (Russia) (Allen-Gil and Martynov 1995). On the other hand, the concentrations of Cu and Zn in the tissues of *Noemacheilus barbatulus* (L.) were much lower then those in freshwater fish: whitefish (*Coregonus lavaretus s.l.*), brown trout (*Salmo trutta*) and pike from the River Pasvik, polluted by mining activities and metallurgic smelters, located in the border region between Norvay and Russia (Amundsen *et al.* 1997). The maximum Cu and Zn concentrations observed there in the muscle of fish were 40.5 $\mu g \times g^{-1}$ and 430 $\mu g \times g^{-1}$ (respectively) and in the liver were 354 $\mu g \times g^{-1}$ and 891$\mu g \times g^{-1}$ (respectively).

Generally, the lowest concentrations of the metals were found in the muscle, and the highest ones in the liver of *Noemacheilus barbatulus* (L.) from the Raba River. The results of studies, among the others of Honda *et al.* (1983), Stripp *et al.* (1990), Yamazaki *et al.* (1996) and Amundsen *et al.* (1997) showed that the most of the metals are retained in the liver of fish on a high level. The content of metals in liver can be even several times higher than in muscle so liver is known to be an important detoxification centre in fish (Mc Farlane and Franzin 1980). Metals (like Cd and Pb) are bound in liver by metalothionein (a binding protein). The low concentrations of metals observed in muscle tissue reflect the low levels of these binding proteins in muscle (Allen-Gil and Martynov 1995).

The relatively high concentrations of Cd, Pb and Zn were found in the ovaries of *Noemacheilus barbatulus* (L.) in the Raba River. High concentrations of these metals in the ovaries were also found in other species of fish (Honda *et al.* 1983, Seymore *et al.* 1994, Yamazaki *et al.* 1996). High levels of some metals in reproductive organs suggest that metal concentration in organs, tissues and the whole body of fish varies somewhat with reproductive activities, and consequently varies with the life stage and sex (Honda *et al.* 1983).

This study showed that Dobczyce Reservoir was a sink for the Cr, Cd and Pb. The lower concentrations of Cr (for both dates) and Cd and Pb (in May) in the tissues of *Noemacheilus barbatulus* (L.) from the Raba River below the Dobczyce Reservoir pointed that these metals were accumulated in the reservoir. The municipal and communal sewage input to Raba River may be a source of Cr in the water environment. The content of Cr in communal sewage can reach the value 1000 $\mu g \times dm^{-3}$ and in the municipal sewage from 400–800 $\mu g \times dm^{-3}$ (Dojlido 1993). Also atmospheric pollution caused by power plant and metallurgy (Manecki and Tarkowski 1993) may be a considerable source of Cr in the environment (Kabata--Pendias 1993). Dam reservoirs may accumulate heavy metals (mainly in their sediment) in a high degree (Pasternak and Gliński 1972, Harding *et al.* 1981, Reczyńska--Dutka 1985) and in this way change the pollution level of its main supplier. According to Harding *et al.* (1981) up to about 70% of Zn, 98% of Cd and 89% of Pb were accumulated in Dervent Reservoir (Northern England). Almost 70 % of Cd and Zn were deposited in Kozłowa Góra Reservoir (southern Poland) (Reczyńska-Dutka 1985). The increase in the Cd and Pb concentrations in the tissues of *Noemacheilus barbatulus* (L.) in May (comparing with October) point at increasing pollution of the Raba River by these metals. Similar concentrations of Cu, Zn and Fe in stone loach in both localities pointed that Dobczyce Reservoir did not influence their contents in the Raba River.

Some authors claim that concentrations of heavy metals in fish tissues do not correlate with the contents of these metals in water and sediment. The contents of metals in fish reflect their availability to the biota and pointed at the biological impact of heavy metals pollution (McFarlane and Franzin 1980, Amundsen *et al.* 1997). So it may be said that Dobczyce dam Reservoir influenced the availability of Cr, Cd and Pb for *Noemacheilus barbatulus* (L.) living in the Raba River below of them.

5. SUMMARY

The concentrations of Cd, Pb, Cu, Cr, Zn and Fe in tissues (liver, ovaries and muscle) of stone loach *Noemacheilus barbatulus* (L.) living in the Raba River above and below Dobczyce dam reservoir, typical for mountain foot part of the Polish Carpathians were determined. The stone loach *Noemacheilus barbatulus* (L.) was chosen for this study, because of its wide distribution and small environmental requirement (can live even in very polluted water). The stone loach *Noemacheilus barbatulus* (L.) were collected from two sites in the Raba River: Station 1 was located above and station 2 below the reservoir (Fig. 1).

Physical characteristic of collected fish are presented in Table 1. The maximum length of *Noemacheilus barbatulus* (L.) was 12.3 cm and weight was 21. 3 g. II and III year old specimens were mainly collected.

The concentrations of heavy metals in the tissues of *Noemacheilus barbatulus* (L.) from the Raba River were similar to these from the region polluted by heavy metals to a smaller extent. They varied in the studied dates and tissues (Figs 2 and 3). Generally, the lowest concentrations of heavy metals were determined in muscle and the highest one in liver or ovaries.

The concentrations of Cr (in both dates), Cd and Pb (in May) in the tissues of *Noemacheilus barbatulus* (L.) were lower in the Raba River below the reservoir then those above (Figs 2 and 3). It suggest that the Dobczyce Reservoir was a sink for these metals or on the other hand, influence their availability for fish. The concentrations of Cu, Zn and Fe in the tissues of *Noemacheilus barbatulus* (L.) had the similar level in both localities (Figs 2 and 3).

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