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THE EFFECT OF FISH SIZE ON THE CONTENT OF ZINC, IRON, COPPER, AND MANGANESE IN THE MUSCLES OF PERCH (*PERCA FLUVIATILIS* L.) AND PIKE (*ESOX LUCIUS* L.)

Joanna Łuczyńska, Elżbieta Tońska

Chair of Commodity Science and Food Research, University of Warmia and Mazury in Olsztyn, Poland

ABSTRACT. The correlation coefficients between fish size (body weight and total length) and the content of zinc, iron, copper, and manganese in muscles of perch, *Perca fluviatilis* L., and pike, *Esox lucius* L., were determined. The fish were caught in four lakes (Łańskie, Pluszne, Dłużek, Maróz) located in the Olsztyn Lake District (northeastern Poland) during 1999-2000. With the exception of copper in the perch from Lake Pluszne, in all cases the concentrations of zinc, copper, and manganese in muscle tissue decreased with perch body weight and total length. The content of iron in the muscles of perch from Lake Łańskie was correlated negatively with the size of these fish, but in other cases the levels of iron increased or remained constant. The zinc concentration in muscles of pike was correlated positively with the body weight and total length of these fish. A negative correlation between fish size and iron and manganese content was noted at all sites, except with regard to iron in pike from Lake Pluszne. There was a positive correlation between weight or length and copper concentration in pike from lakes Łańskie and Maróz. However, there was a negative correlation between size and copper content in the muscles of pike from lakes Pluszne and Dłużek. The relationship between the contents of selected metals was calculated.

Key words: ZINC, IRON, COPPER, MANGANESE, BODY WEIGHT, MUSCLES, PERCH (*PERCA FLUVIATILIS*), PIKE (*ESOX LUCIUS*)

INTRODUCTION

The bioaccumulation of heavy metals in different tissues of fish depends on various factors (Badsha and Goldspink 1982, Håkanson 1984, Dobicki 1990, Radwan et al. 1990, Allen-Gil and Martynov 1995, Belinsky et al. 1996, Amundsen et al. 1997). Protasowicki et al. (1983) reported that feeding strategy influenced the content of copper and zinc in fish. Numerous studies have proven that the muscle tissue of fish accumulate lower amounts of zinc, iron, copper, and manganese than do other organs (Falandysz 1992, Szulkowska-Wojaczek et al. 1992, Berninger and Pennanen 1995, Camusso et al. 1995, Pourang 1995, Karadede and Ünlü 2000). Many authors have

CORRESPONDING AUTHOR: Dr Joanna Łuczyńska, Uniwersytet Warmińsko-Mazurski, Wydział Nauki o Żywności, Katedra Towaroznawstwa i Badań Żywności, Plac Cieszyński 1, 10-726 Olsztyn, Tel./Fax: +48 (89) 5234165; e-mail: jlucz@uwm.edu.pl

focused attention on the dependence between the content of Zn, Fe, Cu, and Mn in fish muscles and the size (weight and length) of these fish (Håkanson 1984, Kroupa and Hartvich 1990, Falandysz 1994, Kostecki 2000). Jezierska and Witeska (2001) reported that smaller, younger fish accumulate more metal (except mercury) than larger, older fish, which may stem from the higher metabolic rate.

The aim of the current studies was to examine the dependence between metal concentrations (zinc, iron, copper, manganese) in muscles and the size (body weight and total length) of Eurasian perch, *Perca fluviatilis* L. and pike, *Esox lucius* L.

MATERIAL AND METHODS

All samples of perch and pike were collected in 1999-2000 from four lakes (Łańskie, Pluszne, Dłużek, Maróz) in the Olsztyn Lake District in northeastern Poland (Fig. 1). The fish were sacrificed and then transported to the laboratory where total length (± 0.1 cm) and body weight (± 1 g) were measured. Samples of the dorsal muscles were taken and stored in polypropylene bags at –25°C prior to analysis. In the case of small perch (body weight < 160 g), each sample was prepared from tissues taken from two to nine specimens of approximately the same size in order to supplement the amount of material available for parallel analyses. In the case of large perch, each sample was prepared from tissue taken from one or two fish, while with pike each sample was prepared from tissue taken from one fish.

For zinc, copper, iron, and manganese analysis, approximately 10 g of each muscle tissue sample was combusted at 300°C for 6 h, and then digested at a high temperature of 450°C for 12 h. The white ash was dissolved in 1M HNO_3 (Suprapur-Merck), and the samples were processed with flame atomic absorption spectrometry (UNICAM 939 SOLAR). The correlation coefficients between the content of metal and body weight and the total length of the fish were calculated using the EXCEL program by Microsoft. The significance levels of $P \leq 0.001$, $P \leq 0.01$, and $P \leq 0.05$ were used. The contents of Zn, Cu, Fe, and Mn in the muscles of fish are expressed in mg kg^{-1} wet weight (ww).

The reliability and accuracy of the methods were tested by measuring the elements in reference material: BCR CRM 422 (cod *Gadus morhua* (L.) muscles) with a certified value of zinc, iron, copper, and manganese (zinc – certified 19.6 ± 0.5 mg kg^{-1}, measured 20.649 ± 1.384 mg kg^{-1}; n = 4; iron – certified 5.46 ± 0.30 mg kg^{-1}, measured

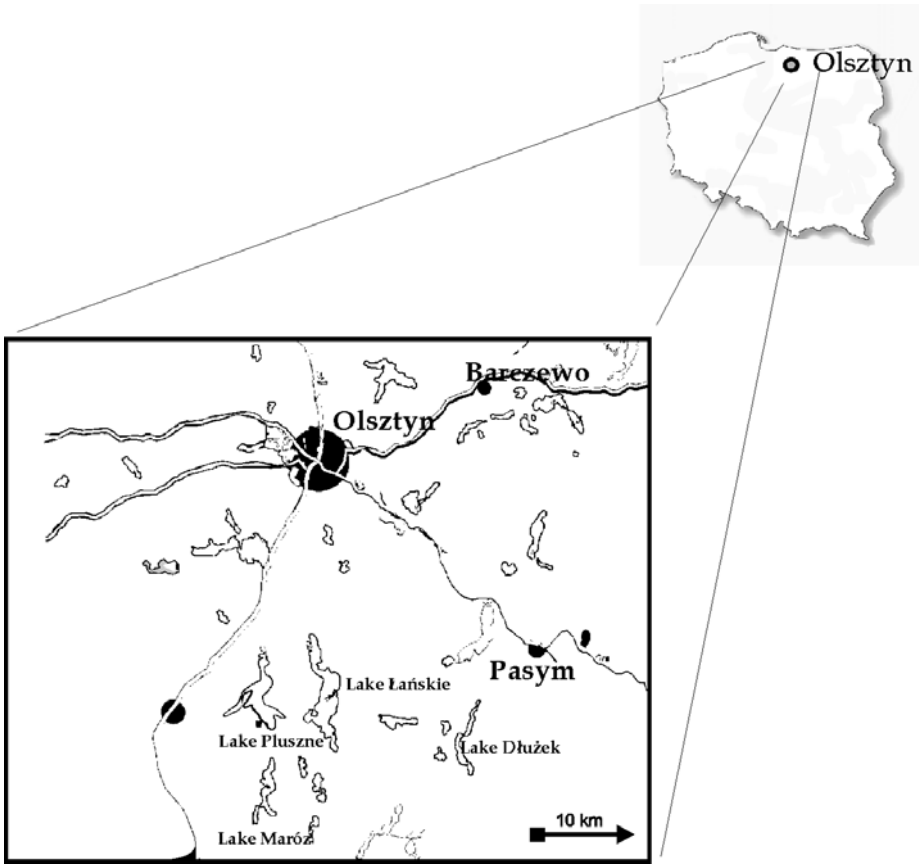

Fig. 1. Sampling area.

5.236 ± 0.249 mg kg^{-1}; n = 4; copper – certified 1.05 ± 0.07 mg kg^{-1}, measured 1.078 ± 0.143 mg kg^{-1}; n = 4; manganese – certified 0.543 ± 0.028 mg kg^{-1}, measured 0.560 ± 0.034 mg kg^{-1}; n = 4) (Certified Reference Material – BCR, cod muscle, Commission of the European Communities – Brussels, March 1992).

RESULTS

Table 1 shows the contents of zinc, iron, copper, and manganese in the muscles of fish from four lakes in the Olsztyn Lake District.

TABLE 1

Body weight, total length, and metal concentration ranges in the muscles of selected fish species

Species /Lake	Number of samples	Number of fishes	Body weight (g)	Total length (cm)	Zn	Fe	Cu	Mn
					(mg kg^{-1} wet weight)			
Perch								
Łańskie	19	49	36 - 584	14.6 - 33.6	2.502 - 4.796	0.435 - 1.251	0.116 - 0.231	0.040 - 0.104
Pluszne	19	43	40 - 766	15.9 - 36.1	3.224 - 5.728	0.744 - 1.240	0.150 - 0.224	0.045 - 0.112
Dłużek	16	61	22 - 862	12.6 - 36.8	3.809 - 8.252	0.864 - 1.524	0.133 - 0.220	0.027 - 0.116
Maróz	14	39	44 - 927	15.7 - 38.7	3.121 - 6.272	0.867 - 1.792	0.128 - 0.278	0.048 - 0.158
Total	68	192	22 - 927	12.6 - 38.7	2.502 - 8.252	0.435 - 1.792	0.116 - 0.278	0.027 - 0.158
Pike								
Łańskie	15	15	155 - 2682	28.7 - 71.9	4.463 - 10.822	0.742 - 1.401	0.112 - 0.238	0.055 - 0.248
Pluszne	18	18	744 - 2012	48.0 - 63.5	4.799 - 12.142	0.604 - 1.240	0.136 - 0.197	0.060 - 0.086
Dłużek	14	14	684 - 5235	44.4 - 92.0	6.214 - 11.755	0.692 - 1.923	0.163 - 0.350	0.046- 0.149
Maróz	12	12	191 - 1854	32.1 - 65.1	3.306 - 11.462	0.559 - 1.062	0.117 - 0.246	0.054 - 0.218
Total	59	59	155 - 5235	28.7 - 92.0	3.306 - 12.142	0.559 - 1.923	0.112 - 0.350	0.046 - 0.248

ZINC

The values of zinc in the muscle of perch ranged from 2.502 mg kg^{-1} (Lake Łańskie) to 8.252 mg kg^{-1} (Lake Dłużek). In the case of pike, zinc concentration was lowest in the fish from Lake Maróz (3.306 mg kg^{-1}) and highest in those from Lake Pluszne (12.142 mg kg^{-1}). In all cases, there were negative correlations between the zinc content in the muscles of perch and body weight (Table 2) or total length (Table 3). Positive correlations between body weight and total length and the level of zinc were found in the muscles of pike.

IRON

The lowest concentrations of iron (0.435 and 0.559 mg kg^{-1}, respectively) were observed in muscle tissues of perch from Lake Łańskie and pike from Lake Maróz. The highest iron contents in fish were found in the muscles of perch from Lake Maróz and pike from Lake Dłużek (1.792 and 1.923 mg kg^{-1}, respectively). There were no significant positive correlations between the content of iron in the muscles of perch and body weight (Table 2) or total length (Table 3), except in Lake Łańskie where the correlation coefficient was significantly negative. However, a significant positive correlation was found in the pike from Lake Pluszne (Table 2 and 3). The iron levels in the muscles of pike from the remaining lakes decreased as body weight and total length increased. The

correlation was non-significant with the exception of length/iron content in pike from Lake Dłużek (Table 3).

TABLE 2

Linear correlation coefficients (r) between metal contents and body weight of perch and pike

Species/Lake	Zn	Fe	Cu	Mn
Perch				
Łańskie	-0.593**	-0.618**	-0.605**	-0.545*
Pluszne	-0.693**	0.189ns	0.591**	-0.655**
Dłużek	-0.634**	0.143ns	-0.630**	-0.802***
Maróz	-0.607*	0.485ns	-0.541*	-0.236ns
Pike				
Łańskie	0.887***	-0.421ns	0.592*	-0.770***
Pluszne	0.740***	0.659**	-0.277ns	-0.360ns
Dłużek	0.607*	-0.547*	-0.619*	-0.654*
Maróz	0.549ns	-0.359ns	0.280ns	-0.899***

*ns – non-significant correlation, * P < 0.05, ** P < 0.01, *** P < 0.001*

TABLE 3

Linear correlation coefficients (r) between metal contents and total length of perch and pike

Species/Lake	Zn	Fe	Cu	Mn
Perch				
Łańskie	-0.661**	-0.629**	-0739***	-0.442ns
Pluszne	-0.631**	0.013ns	0.623**	-0.641**
Dłużek	-0.743***	0.088ns	-0.710**	-0.733**
Maróz	-0.695**	0.475ns	-0.601*	-0.353ns
Pike				
Łańskie	0.878***	-0.400ns	0.597*	-0.840***
Pluszne	0.781***	0.685**	-0.322ns	-0.268ns
Dłużek	0.632*	-0.491ns	-0.551*	-0.597*
Maróz	0.584*	-0.222ns	0.417ns	-0.883***

*ns – non-significant correlation, * P < 0.05, ** P < 0.01, *** P < 0.001*

COPPER

Copper content in perch muscles ranged from 0.116 mg kg^{-1} (Lake Łańskie) to 0.278 mg kg^{-1} (Lake Maróz); whereas the concentrations of the same metal in the muscles of pike varied from 0.112 mg kg^{-1} (Lake Łańskie) to 0.350 mg kg^{-1} (Lake Dłużek). Negative correlations were noted between copper content and body weight or total length of perch at all sites except Lake Pluszne (Table 2 and 3). The concentration of copper in the muscles of pike from lakes Łańskie and Maróz was positively correlated with body weight and total length, whereas with pike from lakes Pluszne and Dłużek negative correlation was

observed between the copper content and body weight and total length. This correlation was significant in pike from lakes Łańskie and Dłużek (Table 2 and 3).

MANGANESE

The lowest levels of manganese were observed in the muscle of perch and pike from Lake Dłużek (0.027 and 0.046 mg kg^{-1}, respectively), while the highest levels were detected in the muscles of perch from Lake Maróz (0.158 mg kg^{-1}) and pike from Lake Łańskie (0.248 mg kg^{-1}). There were negative correlation coefficients between the content of manganese and body weight or total length of selected fish species at all sites, although they were not always statistically significant.

Significant positive correlation coefficients were noted between metal pairs in the perch (Fe-Zn, Zn-Cu, Zn-Mn) and pike (Fe-Cu) muscles (Table 4). A significant negative correlation between zinc and manganese was found in pike.

TABLE 4

Correlation coefficients (r) of dependence between the contents of metal in fish muscles

	Zn	Cu	Mn
Perch (n = 68)			
Fe	0.305*	0.148ns	0.117ns
Zn	-	0.437**	0.296*
Cu	-	-	0.212ns
Pike (n = 59)			
Fe	-0.004ns	0.660**	0.198ns
Zn	-	0.172ns	-0.473**
Cu	-	-	-0.155ns

*n – number of samples; ns – non-significant correlation; * P<0.05, ** P<0.001*

DISCUSSION

In the present study, the negative correlation between the zinc content and the weight or length of perch at all sites was higher than in the studies by Berninger and Pennanen (1995). These authors observed that the iron content in the muscles of perch was correlated negatively with weight ($r = -0.32$, $P \leq 0.05$) and length ($r = -0.32$, $P \leq 0.05$). These results are similar only in the case of the pike from Lake Maróz. However, a negative relationship was noted for perch and pike from Lake Łańskie and for pike from Lake Dłużek. Pourang (1995) reported that the correlation between the concentration of zinc, copper, and manganese in the muscles of pike and goldfish, *Carrassius*

auratus L., and fish length was non-significant. Olszewska et al. (1994) reported that Fe, Zn, Cu, and Mn contents in the sand goby, *Pomatoschistus minutus* (Pallas), decrease gradually as fish body length increases. In most of the cases of the perch investigated in the current study, the negative relationship was higher. A positive relationship between the weight and levels of zinc and manganese in the muscles of roach, *Rutilus rutilus* (L.), from Dzierżno Duże dam reservoir (Poland) was reported by Kostecki (2000), while no clear tendency was found in the case of copper. As opposed to roach, the concentrations of these metals in muscles of tench, *Tinca tinca* (L.), decreased as fish weight increased. Unlike Kostecki (2000), Håkanson (1984) reported weak negative correlation between body weight and the contents of copper and zinc in the muscles of roach ($r = -0.37$, $r = -0.26$, respectively). In pike, this same author detected a positive body weight/zinc level correlation ($r = 0.39$, $P = 0.025$) but no significant correlation between body weight/copper ($r = 0.04$). In the present study, the zinc concentration correlated positively with the weight of pike at all sites, too. However, the present study did not confirm the observations of Håkanson (1984) pertaining to the relationship between the content of copper in pike or zinc in perch and fish body weight.

The zinc, iron, and manganese level in the muscles of perch from the Gulf of Gdańsk (Poland) was negatively correlated with body weight (Falandysz 1992). Similarly, zinc and manganese concentration in the tissues of roach and bream, *Abramis brama* (L.), from Luznice River (Czech Republic) decreased as fish age and body weight increased (Kroupa and Hartvich 1990). Protasowicki et al. (1983) reported the negative effect (although not always statistically significant) on copper levels of the weight of all fish species except herring, *Clupea harengus* (L.). The same authors found that copper is an essential microelement and may perform a leading role in the first stages of fish development.

Contrary to the pike examined in the current study, Olszewska et al. (1994) observed that the content of zinc in sand goby increased as manganese increased ($P < 0.001$). Furthermore, the same authors reported positive correlations between the metal pairs Cu-Fe, Zn-Cu, Zn-Fe, Mn-Cu, and Mn-Fe. Significant positive correlation coefficients of the dependence between iron content and concentrations of copper, manganese, and zinc in the muscles of perch ($P < 0.01$) were demonstrated by Falandysz (1992). The relationship between Zn-Mn in perch from the Gulf of Gdańsk,

which was noted by Falandysz (1992), is similar to that in the perch examined in the present study.

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STRESZCZENIE

WPŁYW WIELKOŚCI RYB NA ZAWARTOŚĆ CYNKU, ŻELAZA, MIEDZI I MANGANU W TKANCE MIĘŚNIOWEJ OKONIA (*PERCA FLUVIATILIS* L.) I SZCZUPAKA (*ESOX LUCIUS* L.)

Celem pracy było określenie zależności pomiędzy wielkością ryb (masa i długość ciała) a zawartością cynku, żelaza, miedzi i manganu w tkance mięśniowej okonia i szczupaka. Ryby odławiano z czterech jezior Pojezierza Olsztyńskiego (Łańskie, Pluszne, Dłużek i Maróz) w okresie 1999-2000. We wszystkich przypadkach, z wyjątkiem miedzi u okoni z jeziora Plusznego, zawartość cynku, miedzi i manganu w tkance mięśniowej badanych okoni zmniejszała się wraz ze wzrostem masy i długości ciała ryb (tab. 2 i tab. 3). Stężenie żelaza w mięśniach okonia pochodzącego z Jeziora Łańskiego było ujemnie skorelowane z ich wielkością. W przypadku okonia z pozostałych trzech jezior, w miarę wzrostu masy i długości ciała zawartość żelaza wzrastała lub pozostawała na tym samym poziomie. Niezależnie od miejsca połowu, stężenie cynku w tkance mięśniowej szczupaka wzrastało wraz ze wzrostem masy i długości ciała ryb (tab. 2 i tab. 3). We wszystkich przypadkach, z wyjątkiem żelaza u szczupaka z jeziora Plusznego, stwierdzono ujemny współczynnik korelacji pomiędzy zawartością żelaza i manganu a wielkością ryb. Odnotowano dodatnią korelację pomiędzy stężeniem miedzi w mięśniach szczupaka z Jeziora Łańskiego i Maróz a ich masą i długością ciała. Natomiast w przypadku szczupaka z jeziora Plusznego i Dłużek stwierdzono odwrotną prawidłowość. W pracy określono również zależność pomiędzy zawartością poszczególnych metali (tab. 4).