Arch. Pol. Fish.	Archives of Polish Fisheries	Vol. 13	Fasc. 1	51-61	2005

THE INFLUENCE OF WEIGHT AND LENGTH ON THE MERCURY CONTENT IN THE MUSCLE TISSUE OF FISH FROM FOUR LAKES IN THE OLSZTYN LAKE DISTRICT (POLAND)

Joanna Łuczyńska

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

ABSTRACT. The total mercury content was determined in the muscle of northern pike, perch, and roach caught in four lakes (Łańskie, Pluszne, Dłużek, Maróz) in the Olsztyn Lake District (northeastern Poland) from October 1999 to October 2000. The total mercury was analyzed with flameless cold vapor atomic absorption spectrometry (CV AAS). The total mercury content in the muscle of pike ranged from 0.076 mg kg^{-1} (Łańskie) to 0.902 mg kg^{-1} (Pluszne), in perch from 0.104 mg kg^{-1} (Pluszne) to 1.277 mg kg^{-1} (Dłużek), and in roach from 0.074 mg kg^{-1} (Maróz) to 0.278 mg kg^{-1} (Maróz). In most cases, the strongest positive correlation ($p < 0.001$) was found between the Hg concentration in the muscle tissue of the fish and total body weight ($0.825 < r < 0.967$) or total body length ($0.781 < r < 0.950$). The exception was the roach from Lake Maróz, where the correlation coefficients between mercury content in the muscle of these fish and their body weight and total length were $r = 0.794$ and $r = 0.788$, respectively ($p < 0.01$). Similarly, with pike from Lake Maróz it was found that the correlation coefficient between the mercury concentration in the muscle of these fish and their total length was $r = 0.781$ ($p < 0.01$).

Key words: TOTAL MERCURY, FISH SIZE, NORTHERN PIKE (*ESOX LUCIUS*), EUROPEAN PERCH (*PERCA FLUVIATILIS*), ROACH (*RUTILUS RUTILUS*)

INTRODUCTION

Regardless of its original source (natural or anthropogenic) or the form in which it enters the aquatic environment, mercury (Hg) accumulates mainly in sediments. This element occurs in fish mainly in the form of methylmercury (above 90%) because fish feed on aquatic organisms that belong to the lower trophic levels that contain this compound, which initially originates from bacteria which biomethylate inorganic mercury (Holden 1973, Hudson et al. 1994, WHO-IPCS 2000).

As one of the last links in the aquatic environment chain, fish, which tend to accumulate higher amounts of mercury, are regarded as good indicators of the mercury con-

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) 5234729; e-mail: jlucz@uwm.edu.pl

tamination of aquatic habitats (Protasowicki and Ociepa 1978, Perkowska and Protasowicki 1999). Some authors demonstrated that predatory fish accumulated more mercury than herbivorous fish or those that feed on plankton and benthos. These authors observed that the degree of mercury accumulation is dependent on the length of the food chain (Studnicka 1981, Srebočan et al. 1993, Svobodová et al. 1999). Dissolved forms of mercury enter the body through the respiration epithelium of the gills and the gill cavities as well as through the olfactory epithelium and skin. The bounded forms of mercury and those absorbed by feed surfaces infiltrate through the alimentary canal (Szulkowska-Wojaczek et al. 1998). Eichler (1989) reported that the half-time of clearance is long-term, particularly in organisms with low metabolic rates. A larger, older fish can accumulate greater amounts of metals, especially mercury, if it is ingested continuously but hardly excreted (Jezierska and Witeska 2001). The same authors found that the time of exposure is a primary factor having an effect on the degree of accumulation of mercury in fish and its biomagnification in food chains.

The study conducted by Protasowicki and Ociepa (1978) found a positive correlation between the age and body weight and length of Northern pike, *Esox lucius* L., and the concentration of mercury in all the organs except the gonads. Berninger and Pennanen (1995) observed a positive correlation between age and size and the mercury content in the muscle of European perch, *Perca fluviatilis* L. The effect of the age and size of the fish on the mercury concentration in the muscles and other organs was also described by Verta (1990), Szulkowska-Wojaczek et al. (1998), Svobodová et al. (1999), Falandysz et al. (2000), and Lindeström (2001).

The aim of the present study was to determine the degree to which the content of mercury in the muscles of fish (pike, perch, roach, *Rutilus rutilus* (L.)) depends on fish size (body weight and total length).

MATERIAL AND METHODS

Concentrations of total mercury were measured in three fish species – pike, perch, and roach, from four lakes (Łańskie, Pluszne, Dłużek, Maróz) in the northeast of Poland (Fig. 1). The fish were killed and then the weight and fork length of each specimen was recorded. The number of fish, body weight, and total length are presented in Table 1.

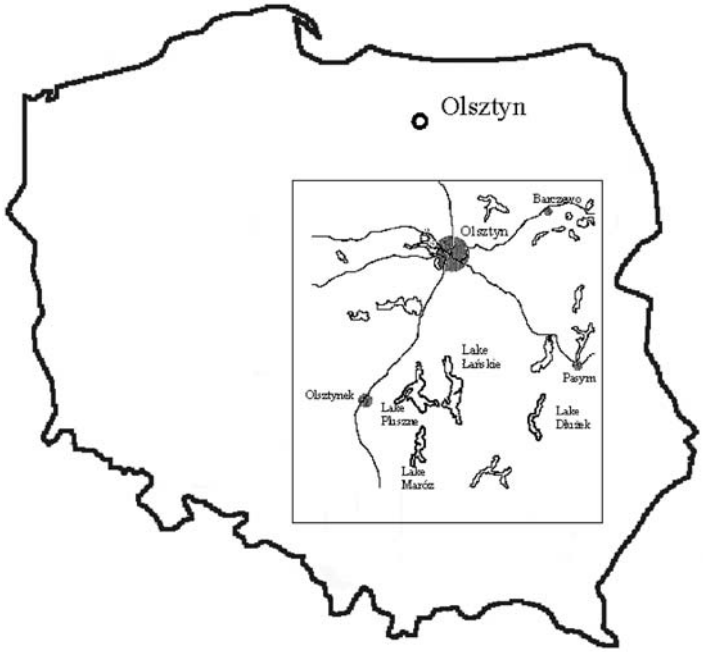

Fig. 1. Sampling area.

TABLE 1

The range of biometric data and total mercury content in muscle tissue of fish

Species/ lake	n	Number of fishes	Body weight (g)	Total length (cm)	Mercury content (mg kg^{-1} ww)
Pike					
Łańskie	14	14	155 - 2682	28.7 - 71.9	0.076 - 0.512
Pluszne	18	18	744 - 2012	48.0 - 63.5	0.146 - 0.367
Dłużek	14	14	791 - 5235	44.4 - 92.0	0.227 - 0.902
Maróz	13	13	191 - 1854	32.1 - 65.1	0.094 - 0.536
Perch					
Łańskie	18	48	36 - 584	14.6 - 33.6	0.126 - 0.370
Pluszne	18	42	40 - 766	15.9 - 36.1	0.104 - 0.530
Dłużek	19	64	22 - 862	12.6 - 368	0.156 - 1.277
Maróz	12	32	46 - 927	12.6 - 38.7	0.158 - 0.828
Roach					
Łańskie	12	48	42 - 342	15.8 - 29.0	0.087 - 0.201
Pluszne	12	38	36 - 532	15.5 - 33.4	0.100 - 0.198
Dłużek	12	49	26 - 540	14.1 - 35.0	0.068 - 0.146
Maróz	12	43	38 - 445	15.4 - 32.0	0.074 - 0.278

n – number of samples

Muscle was removed from the dorsal section of the fish and mixed, then stored frozen in polypropylene bags at –25°C until analysis. In the case of small perch and roach (body weight < 160 g), each sample was prepared from tissues taken from two to nine specimens of approximately the same size in order to enhance the amount of material for parallel analyses. Whereas in the case of large perch and roach, each sample was prepared from the tissue taken from one or two fish. In the case of pike, each sample was prepared from the tissue taken from one fish.

The samples of muscle tissue were wet digested with a mixture of nitric and sulfuric acid HNO_3:H_2SO_4 (2:1) (v/v) at 100-110°C. Organic compounds were oxidized by the addition of a 6% w/v solution of $KMnO_4$. Excess $KMnO_4$ was reduced with hydroxylammonium chloride (20% w/v) until the sample was discolored. The samples were then treated with 2 cm^3 of a stannous chloride solution. The total mercury content was determined with the flameless cold vapor atomic absorption spectrometry method (UNICAM 939 SOLAR) at 253.7 nm (Hatch and Ott 1968). The reliability of the analytic methods was tested by measuring the elements in reference material: CRM 422 – cod muscle tissue (lyophilized sample) with a certified concentration of Hg (certified 0.559 ± 0.016 mg kg^{-1}; obtained 0.560 ± 0.018 mg kg^{-1}, n = 4) (Quevauviller et al. 1993). In order to find the relationship between mercury concentration in muscles of selected species and the size (body weight and total length), the correlation coefficient and linear regression equation were calculated. The mercury concentration in muscle of fish is expressed in mg kg^{-1} wet weight (ww).

RESULTS

The ranges of total mercury content in the muscle of fish studied at various sites are presented in Table 1. The relationship between the concentration of mercury in the muscles of pike, perch, and roach and fish size (body weight and length) is shown in Fig. 2a–d, Fig. 3a-d, and Fig. 4a-d, respectively. The concentration of mercury in muscles was found to increase with increases in body weight and length, regardless of the species or their habitat.

PIKE

For pike from lakes Łańskie, Pluszne, and Dłużek (Fig. 2c and 2d), the correlation coefficients between mercury concentration and specimen length (r = 0.948, r = 0.883,

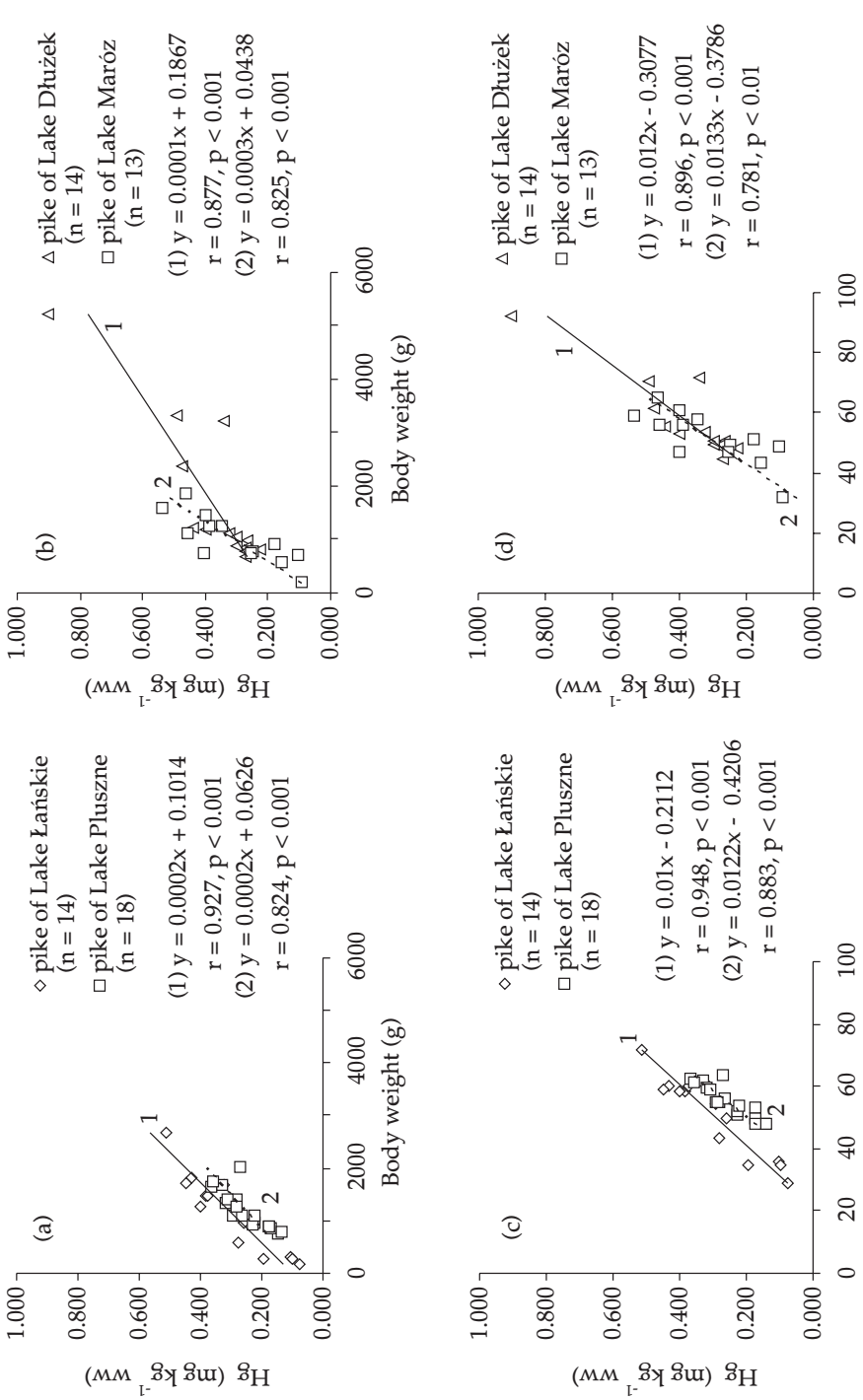

Fig. 2. Total mercury content in the muscle of pike, depending on body weight: a) Łańskie and Pluszne, b) Dłużek and Maróz and total length: c) Łańskie and Pluszne, d) Dłużek and Maróz.

r = 0.896) at $p < 0.001$ were slightly higher than those between mercury concentration and fish weight (r = 0.927, r = 0.824, r = 0.877) at $p < 0.001$ (Fig. 2a and 2b). The correlation factor between the body weight (Fig. 2b) and length (Fig. 2d) of pike from Lake Maróz was r = 0.825 at $p < 0.001$ and r = 0.781 at $p < 0.01$.

PERCH

Figures 3a-d show the correlation between body weight and length and the mercury concentration in perch muscles. Unlike the pike in this study, the correlation between the body weight of perch and the total mercury level (Fig. 3a and 3b) was slightly higher (r = 0.967, r = 0.963, r = 0.876, r = 0.967) at $p < 0.001$ than that between mercury and body length, which was r = 0.933, r = 0.950, r = 0.781, and r = 0.916, respectively, each time at $p < 0.001$ (Fig. 3c and 3d). A positive correlation indicates that, like in the case of pike, the concentration of mercury increases with an increase in perch body weight and length.

ROACH

The strongest positive correlation between total mercury content in muscles with fish weight ($p < 0.001$) and length ($p < 0.001$) was observed in roach, except those from Lake Maróz (Fig. 4a-d). The total mercury accumulation in roach from Lake Maróz (Fig. 4b and 4d) grew linearly with weight and length (r = 0.794, $p < 0.01$; r = 0.788, $p < 0.01$, respectively). The correlation coefficients between total mercury content and fish body weight were r = 0.944, 0.833 (Fig. 4a), and 0.893 (Fig. 4b) or length at r = 0.905, 0.865 (Fig. 4c), and 0.903 (Fig. 4d), respectively.

DISCUSSION

The investigations indicated that the total mercury level increases with weight and length in the muscle of pike, perch, and roach. The very high correlation (r = 0.877) between the concentration of mercury in the muscles of pike from Lake Dłużek and body weight (Fig. 2b) was comparable to the linear correlation coefficient for pike from Kružberk Reservoir, which was reported by Rehulká (2001). A low correlation (r = 0.20) between the mercury content in muscles and the body weight of pike was described by Lindeström (2001) in the study of fish from Lake Vänern (Sweden). However, the author found a correlation of r = 0.66 between the concentration of this

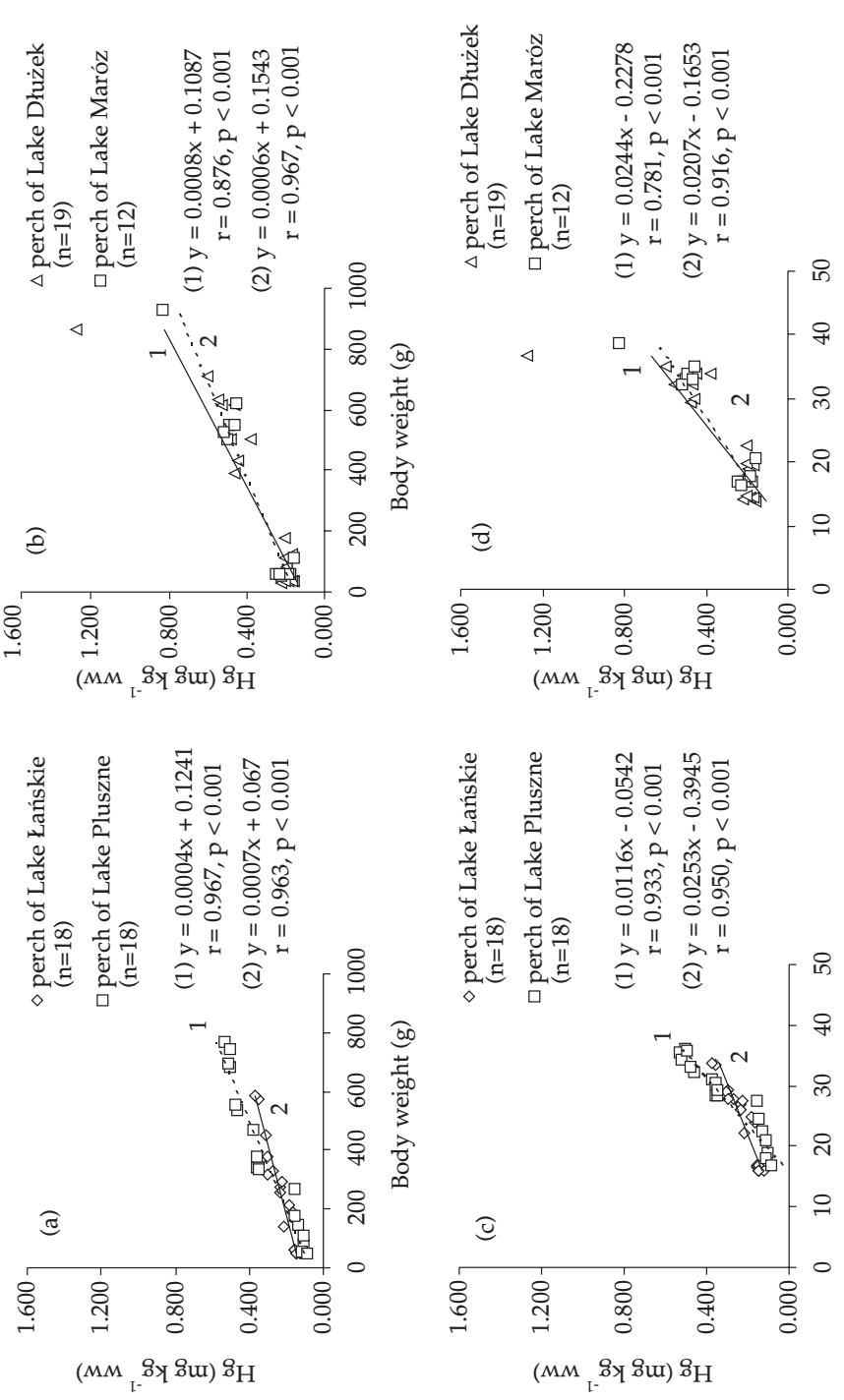

Fig. 3. Total mercury content in the muscle of perch, depending on body weight: a) Łańskie and Pluszne, b) Dłużek and Maróz and total length: c) Łańskie and Pluszne, d) Dłużek and Maróz.

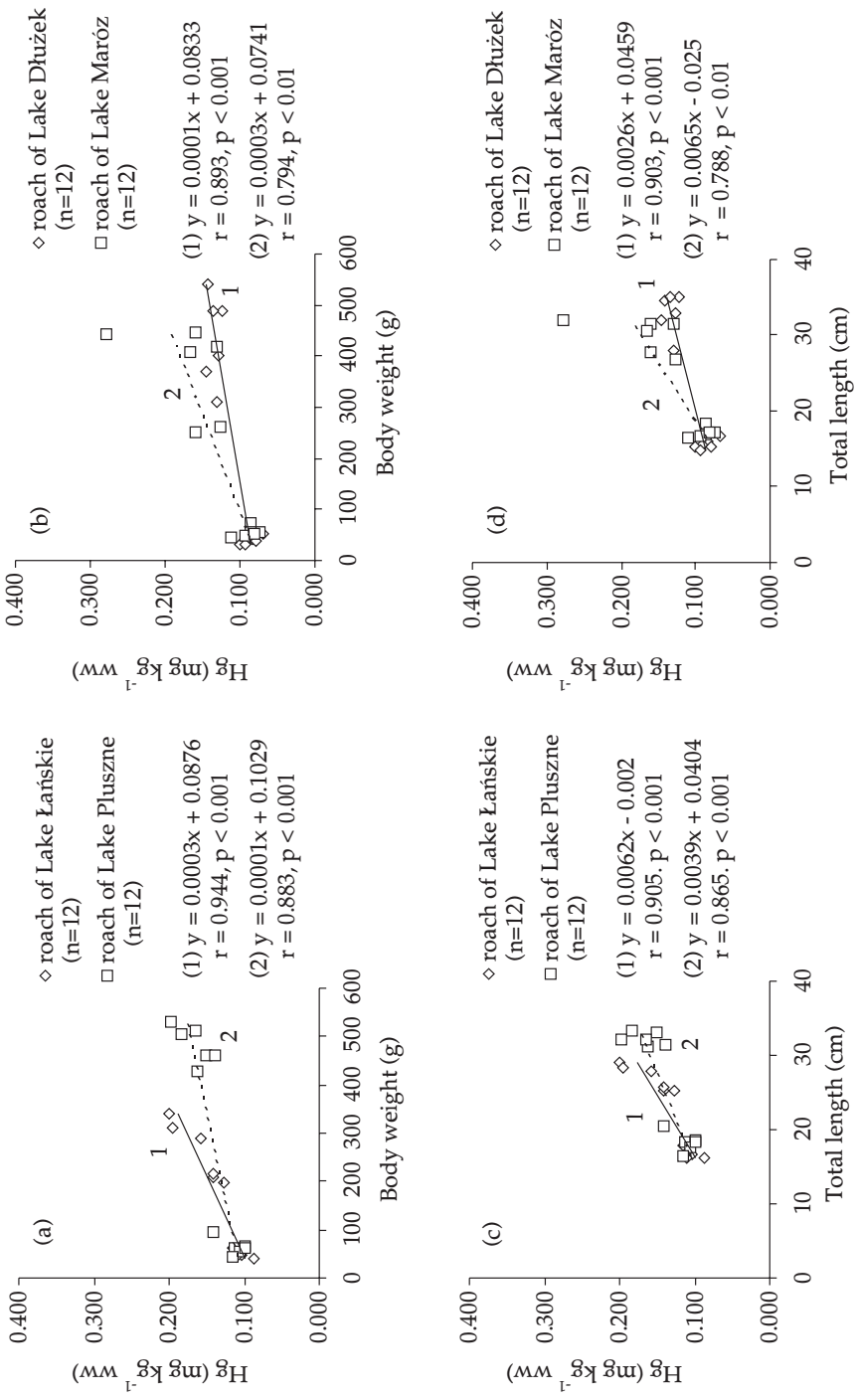

Fig. 4. Total mercury content in the muscle of roach, depending on body weight: a) Łańskie and Pluszne, b) Dłużek and Maróz and total length: c) Łańskie and Pluszne, d) Dłużek and Maróz.

element and fish age. Other authors reported that the mercury content of the muscle of pike from Lake Dąbie increased with fish age, weight, and length ($r = 0.38$, $p < 0.05$) (Protasowicki and Ociepa 1978). Verta (1990) detected much earlier a very high positive correlation between age and size on the one hand and the concentration of mercury in the muscles of pike caught in 1983 and 1984 in the intensely fished Lake Hakojärvi ($r = 0.850$, $p < 0.001$ and $r = 0.890$, $p < 0.001$) on the other. In the case of pike caught in this lake in 1987, such a correlation was found only in relation to age ($r = 0.700$, $p < 0.001$). The author found a positive correlation between the body weight of perch ($r = 0.429$, $p < 0.01$) and the concentration of the element in the muscles of these fish caught in 1987 and 1988.

In the current study, the correlation between body weight and length and the concentration of mercury in the muscle of perch (Fig. 3a-d) was much higher than in the surveys reported by Håkanson (1984), Verta (1990), or Falandysz and Wyrzykowska (1998). Berninger and Pennanen (1995) determined the concentration of mercury in the muscles of perch from two acidified lakes – Iso-Tiilijärvi and Keski-Tiilijärvi (Finland), and found a positive correlation between the concentration of mercury on the one hand and body weight and length ($r = 0.72$, and $r = 0.74$, $p \leq 0.001$) and age of fish ($r = 0.83$, $p \leq 0.001$) on the other. A similar relationship between body length and mercury content in the muscle of perch from Lake Dłużek ($r = 0.781$) was found in perch from Lake Yssel (Luten et al. 1987), while the same authors reported a correlation coefficient of 0.481 and 0.457 ($p < 0.01$) in perch muscle from the Rhine and Lake Fluessen, respectively.

A positive correlation between the concentration of mercury in the muscles of roach, bream, *Abramis brama* (L.), and perch, and the size (body weight and length) and age of fish was observed by Svobodová et al. (1999) in a study which examined fish from the Kamýk and Orlik reservoirs on the Veltava River (Czech Republic). In roach from four sites on the rivers Brett and Chelmer (eastern England) there was a highly significant correlation ($p < 0.001$) between length and mercury content in the tissues (Barak and Mason 1990a). Whereas Verta (1990) did not find a correlation between mercury concentration and roach body weight, length, or age from an intensively fished lake in 1984, a positive correlation ($p < 0.01$) was noted in 1987-1988. Falandysz et al. (2000) determined the level of mercury in muscles of roach from the Vistula Lagoon. These authors did not detect a correlation between total body weight or length of roach

and mercury content. In the case of bream, perch, and ruffe, *Gymnocephalus cernuus* (L.), the same authors found a positive correlation between body weight and length and the concentration of mercury in the muscles of these fish ($p < 0.01$).

ACKNOWLEDGEMENTS

I would like to thank M. Tymoszczuk (Szwaderki Hatchery, Olsztyn District) for supplying the material used in this study. I am very grateful to Dr. K. Markiewicz and E. Tońska for useful guidance in this research. The study was financed by Project No. 070400.209 and by the University of Warmia and Mazury in Olsztyn, Poland.

REFERENCES

Barak N.A.E., Mason C.F. 1990 – Mercury, cadmium and lead in eels and roach the effects of size, season and locality on metal concentrations in flesh and liver – Sci. Total Envir. 92: 249-256.

Berninger, K., Pennanen J. 1995 – Heavy metals in perch (*Perca fluviatilis* L.) from two acidified lakes in the Salpausselkä Esker area in Finland – Water Air Soil Pollut. 82: 283-294.

Eichler W. 1989 – The poisons in our food – PZWL, Warsaw (in Polish).

Falandysz J., Chwir A., Wyrzykowska B. 2000 – Total mercury contamination of some fish species in the Firth of Vistula and the Lower Vistula River, Poland – Pol. J. Environ. Stud. 9(4): 335-339.

Falandysz J., Wyrzykowska B. 1998 – Total mercury in roach, cyprinid and perch from the Lower Vistula River – Bromat. Chem. Toksykol. 31(3): 291-294 (in Polish).

Håkanson L. 1984 – Metals in fish and sediments from the River Kolbäcksån water system, Sweden – Arch. Hydrobiol. 101(3): 373-400.

Hatch W.R., Ott W.L. 1968 – Determination of submicrogram quantities of mercury by atomic absorption spectrophotometry – Anal. Chem. 40(14): 2085 – 2087.

Holden A.V. 1973 – Mercury in fish and shellfish. A review – J. Fd Technol. 8: 1-25.

Hudson R.J.M., Gherini S.A., Watras C.J., Porcella D.B. 1994 – Modeling the biogeochemical cycle of mercury in lakes: The mercury cycling model (MCM) and its application to the MTL study lakes – In: Mercury pollution. Integration and synthesis (Eds.) C.J. Watras and J.W. Huckabee, Lewis Publishers CRC Press, Boca Raton, Florida: 473-523.

Jezierska B., Witeska M. 2001 – Accumulation of metals in fish. The effect of intrinsic factors. Age and size – In: Metal toxicity to fish. No. 42: 95-98.

Lindeström L. 2001 – Mercury in sediment and fish Communities of lake Vänern, Sweden: Recovery from contamination – Ambio 30(8): 538-544.

Luten J.B., Bouquet W., Riekwel-Booy G., Rauchbaar A.B., Scholte M.W.M. 1987 – Mercury in flounder, *Platichtys flesus*, cod, *Gadus morhua*, and perch, *Perca fluviatilis*, in relation to their length and environment – Bull. Environ. Contam. Toxicol. 38: 318-323.

Perkowska A., Protasowicki M. 1999 – Mercury in fishes and in selected elements of the Świdwie lake ecosystem – Acta Ichth. Piscat. 29(2): 31-41.

Protasowicki M., Ociepa A. 1978 – Effect of age, weight, and sex on the mercury content in the muscles and selected organs of northern pike (*Esox lucius* L.) – Zesz. Nauk. AR Szczec. Ryb. Mor. 70: 145-155 (in Polish).

Quevauviller P.H., Imbert J.L., Wagstaffe P.J., Kramer G.N., Griepink B. 1993 – Commission of the European Communities BCR Information – Reference materials, ECSC EEC-EAEC Report EUR 14557 EN, Brussels-Luxembourg: 1-64.

Rehulká J. 2001 – Chemical monitoring of three water-supply reservoirs, using fish as bioindicators – Czech J. Anim. Sci. 46 (5): 217-230.

Srebočan E., Pompe-Gotal J., Srebočan V., Prevendar-Crnić A. 1993 – Monitoring of mercury, lead and cadmium concentrations in animals in the Republic of Croatia. I. Sources and magnitude of mercury contamination in freshwater fish – Vet. Arh. 63(5): 217-225.

Studnicka M. 1981 – Studies on mercury content in muscles of fishes from some natural Polish water bodies – Acta Ichth. Piscat. 11(1): 59-71.

Svobodová Z., Dušek L., Hejtmánek M., Vykusová B., Šmid R. 1999 – Bioaccumulation of Mercury in Various Fish Species from Orlik and Kamýk Water Reservoirs in the Czech Republic – Ecotoxicol. Environ. Safety 43: 231-240.

Szulkowska-Wojaczek E., Marek J., Dobicki W., Polechoński R. 1998 – Distribution of mercury in the fishes from the Odra River – Zesz. Nauk. AR Wroc. Zoot. XLIV(350): 143-154 (in Polish).

Verta M. 1990 – Changes in fish. Mercury concentrations in an intensively fished lake – Can. J. Fish. Aquat. Sci. 47: 1888-1897.

WHO-IPCS 2000 – WHO Food Additives Series 44, Safety evaluation of certain food additives and food contaminants, prepared by the 53th meeting of the Joint FAO/WHO Expert Committee on Food Additives, Geneva.

Received – 12 January 2005

Accepted – 24 March 2005

STRESZCZENIE

WPŁYW MASY I DŁUGOŚCI CIAŁA NA ZAWARTOŚĆ RTĘCI W TKANCE MIĘŚNIOWEJ RYB Z CZTERECH JEZIOR POJEZIERZA OLSZTYŃSKIEGO (POLSKA)

Zawartość rtęci całkowitej oznaczono w tkance mięśniowej trzech gatunków ryb: szczupaka, *Esox lucius* (L.), okonia, *Perca fluviatilis* L. i płoci, *Rutilus rutilus* (L.) poławianych od października 1999 roku do października 2000 roku. Przebadano łącznie 423 ryby pochodzące z czterech jezior Pojezierza Olsztyńskiego (Łańskie, Pluszne, Dłużek i Maróz). Stężenie rtęci całkowitej (tab. 1) w tkance mięśniowej szczupaków wahało się w granicach od 0,076 mg kg^{-1} mokrej masy (m.m.) (Łańskie) do 0,902 mg kg^{-1} m.m. (Dłużek), okoni od 0,104 mg kg^{-1} m.m. (Pluszne) do 1,277 mg kg^{-1} m.m. (Dłużek) oraz płoci od 0,074 mg kg^{-1} m.m. (Maróz) do 0,278 mg kg^{-1} m.m. (Maróz). W większości przypadków stwierdzono wysoce dodatni współczynnik korelacji liniowej ($p < 0,001$) między koncentracją rtęci całkowitej a masą ciała ($0,825 < r < 0,967$) i długością całkowitą ryb ($0,781 < r < 0,950$) (rys. 2-4). Wyjątek stanowiły płocie z jeziora Maróz, bowiem w przypadku tych ryb współczynnik korelacji między zawartością rtęci a masą i długością ciała wynosił odpowiednio: $r = 0,794$ przy $p < 0,01$ (rys. 4b), $r = 0,788$ przy $p < 0,01$ (rys. 4d). Podobnie w przypadku szczupaków z jeziora Maróz wykazano, że współczynnik korelacji między długością ciała a poziomem rtęci w tkance mięśniowej ryb wynosił $r = 0,781$ przy $p < 0,01$ (rys. 2d).