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DIVERSITY OF TOTAL MERCURY CONCENTRATIONS IN KIDNEYS OF BIRDS FROM EASTERN POLAND

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Abstract

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Mercury concentration levels were determined in the kidneys of 131 specimens of 42 species of birds with different food preferences. The highest concentrations were found in piscivorous species such as the goosander, great white egret, white-tailed eagle and black stork. The following sequence was identified for concentration levels in kidneys of birds in different trophic guilds: piscivorous > small mammal eating > bird eating > aquatic invertebrate eating > terrestrial invertebrate eating > herbivorous > omnivorous. The level of renal mercury concentration was found to be significantly lower in young birds than in adults. Increased mercury concentration was also registered in the kidneys of birds from Warsaw, the capital of Poland.

Key words: total mercury concentration, birds, kidneys, Poland

Introduction

Despite significant reduction in mercury release into the environment over the last 20 years resulting mainly from economic development of our country, Poland remains the highest mercury emission country throughout Europe (Rogalski, Warmiński, 2007). Anthropogenic mercury emission in Poland in 2005 was estimated to be approximately 20 tons (Glodek et al., 2010). Together with other European countries, including the European part of Russia, the total annual anthropogenic caused mercury emission was estimated at 240 tons (Pacyna et al., 2006). Hence, monitoring mercury distribution and circulation in Poland's natural environment is regarded as a task of vital importance to compare Polish findings with data gathered both in Europe and in the rest of the world. It is also important to note that mercury present in all types of largely used fluorescent lamps has been excluded from the European Union Directive on the Restriction of the Use of Hazardous Substances (EU RoHS Directive, 2002), since these are a continuous source of mercury discharge into the environment.

As a result of bio-magnification, animals are at the top of food chains, so that animals, including birds, can accumulate large amounts of mercury. Since birds usually head the food web, they can provide valuable monitoring of environmental mercury. In many European areas, and also on other continents, birds have proven to be very useful bio-indicators of mercury (Boening, 2000; Alleva et al., 2006; Houserova et al., 2007; Horai et al., 2007; Komosa et al., 2009). Reasons for this include the integrated spatial and temporal exposure, so that analysis of mercury concentration in key bird organs such as kidneys has been recognized for years as a valuable tool in monitoring environmental contamination levels. After mercury gains entrance to a bird, it can be either stored in internal tissues such as kidneys and liver or it can be excreted in feathers and eggs.

Studies of mercury concentration in kidneys are typically carried out on diurnal raptor species or piscivorous birds which are highly specialised in feeding. It therefore seemed appropriate to supplement studies with birds positioned at different taxonomic levels, and possessing food preferences which are more terrestrial-ecosystem oriented. In this way, results in this paper will, complement available knowledge on this important topic.

The aim of the paper is to determine and discuss bird renal mercury concentrations in over 130 specimens obtained from more than 40 bird species. The investigated birds were classified in relation to their age and trophic requirements.

Material and methods

The kidneys used in this study were taken from wounded birds delivered to veterinary clinics or rehabilitation centres close to bird nesting places between 2008 and 2009. The birds died despite intensive veterinary treatment, or they were untreatable upon delivery and administered lethal injection to spare them suffering. The birds' total occupation of the clinics and rehabilitation centres did not exceed one week. A total of 131 specimens representing 42 species of birds were investigated, with the examined kidneys being taken from adult individuals (n = 122) and young first year birds (n = 9), as presented in Table 1.

The majority of the studied birds originated from rural, aquatic and forest habitats of Eastern Poland (Lublin, Rzeszow and Bialystok regions). There was also the minority of 17 specimens from urban Warsaw. These consisted of; 3 specimens of the hooded crow *Corvus cornix*, jackdaw *Corvus monedula* (2 spec.), common kestrel *Falco tinunnculus* (1 spec.), sparrowhawk *Accipiter nisus* (2 spec.), rook *Corvus frugilegus* (2 spec.), mallard *Anas platyrhynchos* (4 spec.) and the jay *Garrulus glandarius* (3 spec.).

Following extraction from the bird's bodies, the kidneys were stored in freezers until analysis, and finally air dried. Kidney mercury contents were determined by non-flame atomic spectrometry absorption by AMA 254, Altec, Czech Republic mercury analyzer. For this analysis, kidney samples were pre-dried at 120 °C in the internal oven of the analyzer and burned in 99.999% pure oxygen at 550 °C. The decomposition products were then carried by oxygen flow to an Au-amalgamator for selective mercury trapping. A brief heating of the amalgamator caused the mercury to be released and measured by cold vapour AAS technique at 253.65 nm in a short and long dual-path cuvette. The same quantity of mercury was thus measured twice with varying sensitivity, enabling mercury determination over the wide range of 0.05 to 600 ng in a single measurement (EPA procedure CAS 7439-97-6. 2010). The detection limit was 10^{-5} mg/kg, and the calibration values provided by the producer were checked at regular intervals with the calibration standard for the mercury solution (AccuTrace single element standard; AccuStandard Inc., New Haven, CT, USA).

The investigated birds were divided into the following7 guilds according to their food preferences (Alleva et al., 2006); piscivorous, aquatic invertebrate-eating, herbivorous, small mammal-eating, bird eating, omnivorous, and terrestrial invertebrate eating. The results were presented as the mean ± SE mg/kg d.w. (dry weight). Differences in mercury concentrations were evaluated by non-parametric tests (Sokal, Rolf, 1981).

Results

Age of individual birds

For species of the cormorant *Phalacrocorax carbo*, night heron *Nycticorax nycticorax*, great white egret *Egretta alba*, grey heron *Ardea cinerea* and black headed gull *Larus ridibundus,* kidneys were studied from both adult birds (n = 10) and juveniles (n = 7). Thus, it was possible to make comparisons within age classes. For adult birds of the selected species a mean accumulated level of 1.963 ± 0.475 mg/kg d.w.mercury was found in their kidneys, while the mean for the juvenile birds equalled 0.659 ± 0.568 mg/kg d.w. The scattering of the results was very close to statistical significance (Mann-Whitney test: $Z = 1.854$, $N_1 = 10$, $N_2 = 7$, $p = 0.058$). All further mercury determination results presented in this paper were only for adult birds.

Taxonomy

Mercury concentration was compared in 10 bird families,in which at least 4 adult individual's kidneys were measured. Birds of *Ardeidae* and *Anatidae* families were found to have accumulated the highest levels of mercury at 2.617 ± 0.529 mg/kg d.w. and 1.284 ± 0.342 d.w. respectively. Lower levels of mercury were found in individuals from *Tytonidae* and *Accipitridae* families, with these reaching 1.226 ± 0.592 mg/kg and 0.979 ± 0.232 mg/kg d.w., respectively. The lowest mercury concentration was found in individuals of *Scolopacidae* (0.859 ± 0.529 mg/kg d.w.), *Laridae* (0.848 ± 0.529 mg/kg d.w.), *Strigidae* (0.578 ± 0.529 mg/kg d.w.), *Rallidae* (0.498 ± 0.529 mg/kg d.w.), *Corvidae* (0.155 ± 0.237 mg/kg d.w.) and *Picidae* (0.107 ± 0.529 mg/kg d.w.). Large statistical differences between the taxonomic families were determined (Kruskall-Wallis ANOVA: $H = 46.37$, $df = 9$, $N = 103$, $p = 0.0001$).

Food preferences

The mercury concentrations were determined in the following seven trophic guilds. (1) Piscivorous birds were found to have accumulated the highest amount of mercury in their kidneys, with 3.267 ± 0.326 mg/kg d.w. (2) Lower mercury amounts accumulated in the kidneys of birds eating small mammals and small birds, and these amounts were 0.931 ± 0.206 mg/kg d.w. and 0.905 ± 0.311mg/kg d.w., respectively. (3) For birds eating aquatic and terrestrial invertebrates, the mercury concentrations in kidneys were determined at the lowest values of 0.760 ± 0.421 mg/kg and 0.544 ± 0.234 mg/kg d.w., respectively. (4) Herbivorous birds accumulated 0.633 ± 0.364 mg/kg d.w. of mercury, and (5) the lowest concentrations of mercury were found in omnivorous birds at 0.286 ± 0.171 mg/kg d.w. The differences here between the studied food guilds showed high statistical significance (Kruskall-Wallis ANOVA: H = 36.84, df = 6, N = 111, p = 0.0001). (6) Birds whose only food source consisted of vertebrates accumulated 1.426 ± 0.212 mg/kg d.w., which was higher than (7) birds who fed only on invertebrates at 0.599 ± 0.297 mg/kg d.w.. These differences here were also found to be statistically significant (Mann-Whitney test: Z = 2.674, N_1 = 47, N_2 = 24, p = 0.007).

Birds with fish diet accumulated (3.268 ± 0.329 mg/kg d.w.) more mercury than birds which preferred other food (0.611 ± 0.103 mg/kg d.w.) (Mann-Whitney test: Z = -4.022, N_2 = 10, N_1 = 101, p = 0.001). Although the highest mercury level was found in the piscivorous duck, goosander *Mergus mergus* two other piscivorous species, the black cormorant and herons both accumulated lower amounts of mercury in their kidneys (Table 1).

No statistically significant differences in kidney mercury concentration were discovered between raptors which mainly ate small mammals such as buzzards, harriers, falcons and owls, at 0.925 ± 0.157 mg/kg d.w. and those who mainly hunted for birds like sparrowhawks *Accipiter nisus* and goshawks *A. gentilis*, with 0.905 ± 0.300 mg/kg d.w. (Mann-Whitney test: Z = -0.807, N_1 = 25, N_2 = 11, p = 0.419).

However, significant differences in kidney mercury levels were found between birds eating aquatic invertebrates (0.760 ± 0.273 mg/kg d.w.), those eating soil invertebrates (0.712 ± 0.186 mg/kg d.w.) and birds (woodpeckers) whose major portion of food consisted of invertebrates living in trees (0.107 ± 0.298 mg/kg d.w.). (Kruskall-Wallis ANOVA: H = 6.367, df = 2, N = 24, p = 0.041)

Woodpeckers, whose main diet was tree-bound invertebrates, accumulated significantly lower amounts of mercury in their kidneys compared to all studied bird species which ate invertebrates living in water and soil (0.71 2 ± 0.157 mg/kg d.w.); These differences were also statistically significant (Mann-Whitney test: Z = -2.523, N_1 = 5, N_2 = 19, p = 0.012).

Inter-species comparison

Mercury concentrations were compared in the following five species; the jay *Garrulus glandarius,* the magpie *Pica pica,* the jackdaw *Corvus monedula*, the rook *C. frugilegus* and the hooded crow *C. cornix*. No differences were observed between the corvids species (Kruskall-Wallis ANOVA: H = 3.634, df = 4, N = 24, p = 0.458), whereas Hooded crows tended to accumulate an average of 3.4 times more mercury in their kidneys than all the other studied *Corvus* species put together: 0.093 ± 0.049 mg/kg d.w. (Table 1). These differences were shown to be statistically insignificant (Mann-Whitney U test: Z = -1.429, N_1 =

7, $N_2 = 17$, $p = 0.153$). Similarly, with Mann-Whitney U test results of: $Z = -0.431$, $N_1 = 12$, $N_2 = 11$, $p = 0.666$, no statistically significant differences were found within the *Accipitridae* family, between typical small mammal-eaters such as the buzzard *Buteo* sp. and bird-eaters like hawks and the *Accipiter* sp. represented by sparrowhawks and goshawks: 0.900 ± 0.186 mg/kg d.w. versus 0.905 ± 0. 194 mg/kg d.w.

Discussion

Piscivorous birds such as grebs, herons and cormorants are often identified as organisms which accumulate large amounts of mercury in their kidneys and other organs. This is attributed to the bio-magnification processes which cause even small mercury amounts present in water to be multiplied by 1 to 10 million times in piscivorous animals, This makes these animals particularly susceptible to mercury from polluted environments (Boening, 2000).

High mean mercury concentrations were found in both specimens of white egret *Egretta alba*, with kidney concentrations exceeding 3 mg/kg d.w.,which is higher than the mercury concentration in the geochemical background (Thompson, 1996). Our results appear significantly higher than other reported results. For example, the concentrations found in kidneys of 24 white egrets in the proximity of a Tokyo airport had a mean value of 0.71 ± 0.6 mg/kg d.w. (Horai et al., 2007). While the kidney mercury concentration in some of the Japanese specimens was below the detection limit, the maximum value recorded was 2.8 mg/kg d.w. In our study, herons whose diet consisted mainly of aquatic invertebrates, and also those which had recently feasted on aquatic invertebrates such as night heron and bittern, were discovered to have accumulated less mercury than birds whose basic food consisted of large fish (the grey heron and the great white egret).

Similar differences in our study were identified for black and white stork, where one black stork specimen, which was mainly consuming fish, accumulated a higher level of mercury in its kidneys than that present in the geochemical background (Table 1). Meanwhile, the renal mercury concentrations were much lower in a second specimen whose main diet was insects (Antczak et al., 2002).

Cormorants usually accumulate high renal mercury concentrations. Unfortunately, we were able to study only one adult specimen, and the obtained result was very similar to the 2.3 mg/kg level reported in the renal concentration study of 20 cormorants *Phalacrocorax carbo* in the Czech Republic (Houserova et al., 2005). Additionally, cormorants studied in Japan by Horai et al. (2007) accumulated an average of only 0.34 mg/kg mercury, while a different study by Nam et al. (2005) reported that the accumulation value was 12.0 ± 9.0 mg/kg d.w. in cormorants (n = 30) from the central part of that country. Although this highlights a definite discrepancy in results for this species in Central Europe, and in data from Japan (Saeki et al., 2000), nevertheless it correlated highly with the Mazloomi et al. (2008) results of a mean mercury concentration of 9.25 mg/kg d.w. and a range of 3.30–23.99 mg/kg observed in 14 cormorants on the Iran Caspian coast. Juvenile birds tend to accumulate less mercury in kidneys than adults and this was confirmed in our

T a b l e 1. Concentration of mercury in kidney [mg/kg dry weight (d.w.)] of studied individual birds. N = number of samples, SE = standard error, Min. = minimum value, Max. = maximum value. Trophic Guilds: P = piscivorous, A = aquatic invertebrate eating, H = herbivorous, S = small mammal eating, B = bird eating, O = omnivorous, I = insectivorous, T = terrestrial invertebrate-eating.: * kidneys of Warsaw specimens.

Species	N	Trophic Guild	Mean	SE	Median	Min.	Max.
			[mg/kg (d.w.)]				
Cormorant *Phalacrocorax carbo* ad.	1	P	3.317				
Cormorant *Phalacrocorax carbo* juv.	1	P	1.765				
Bittern *Botaurus stellaris* ad.	1	A	1.004				
Night heron *Nycticorax nycticorax* ad.	1	P	0.686				
Night heron *Nycticorax nycticorax* juv.	1	P	0.052				
Great white egret *Egretta alba* ad.	2	P	4.946	1.32	4.946	3.623	6.269
Great white egret *Egretta alba* juv.	1	P	0.999				
Grey heron *Ardea cinerea* ad.	1	P	1.501				
Grey heron *Ardea cinerea* juv.	4	P	0.668	0.113	0.668	ND	0.821
Black stork *Ciconia nigra* ad.	2	P	1.866	1.433	1.866	0.432	3.299
White stork *Ciconia ciconia* ad.	1	T	0.355				
Mute swan *Cygnus olor* ad.	2	H	0.048			ND	0.048
Mallard *Anas platyrhynchos* ad.	7	O	1.502	0.843	0.718	0.034	2.167*
Scaup *Aythya marila* ad.	1	A	0.858				
Long-tailed duck *Clangula hyemalis* ad.	2	A	0.249	0.171	0.249	0.078	0.421
Goosander *Mergus merganser* ad.	1	P	9.365				
White-tailed eagle *Haliaeetus albicilla* ad.	1	P	3.508				
Eurasian marsh harrier *Circus aeruginosus* ad.	1	S	1.120				
Montagu's harrier *Circus pygargus* ad.	1	S	0.237				
Goshawk *Accipiter gentilis* ad.	4	B	0.402	0.053	0.428	0.253	0.497
Sparrowhawk *Accipiter nisus* ad.	7	B	1.192	0.195	1. 280	0.605	1.837*
Eurasian buzzard *Buteo buteo* ad.	12	S	0.978	0.198	0.974	ND	2.483
Rough-legged buzzard *Buteo lagopus* ad.	1	S	0.035				
Common kestrel *Falco tinunnculus* ad.	3	S	1.675	1. 002	1.675	ND	2.922*
Corncrake *Crex crex* ad.	3	T	0.592	0.308	0.516	0.100	1.159
Coot *Fulica atra* ad.	1	O	0.089				
Water rail *Rallus aquaticus* ad.	1	O	0.670				
Common crane *Grus grus* ad.	1	O	0.182				
Eurasian woodcock *Scolopax rusticola* ad.	10	T	0.753	0.268	0.490	0.327	3.148
Snipe *Gallinago gallinago* ad.	1	A	1.911				
Black-headed gull *Larus ridibundus* ad.	5	O	0.848	0.174	0.929	0.441	1.140
Black-headed gull *Larus ridibundus* juv.	2	O	0.267	0.031	0.267	0.236	0.298
Common gull *Larus canus* juv.	2	P	0.149	0.074	0.149	0.076	0.222
Herring gull *Larus argentatus* juv.	1	P	0.161				
Guillemot *Uria aalge* ad.	1	P	0.688				
Common barn Owl *Tyto alba* ad.	4	S	1.226	0.611	1.075	1.279	2.621
Tawny owl *Strix aluco* ad.	3	S	0.806	0.553	0.267	0.239	1.913
Long-eared owl *Asio otus* ad.	1	S	0.252				
Short-eared owl *Asio flammeus* ad.	1	S	0.378				
Green woodpecker *Picus viridis* ad.	2	T	0.089	0.010	0.089	0.082	0.096
Black woodpecker *Dryocopus martius* ad.	3	T	0.116	0.019	0.115	0.084	0.149
Jay *Garrulus glandarius* ad.	7	O	0.134	0.034	0.162	ND	0.230*
Magpie *Pica pica* ad.	5	O	0. 065	0.031	0. 046	ND	0.143
Jackdaw *Corvus monedula* ad.	4	O	0.076	0.019	0.068	ND	0.128
Rook *Corvus frugilegus* ad.	5	O	0.082	0,032	0.093	ND	0.169
Hooded crow *Corvus cornix* ad.	7	O	0.314	0.374	0.077	ND	1.076*
Raven *Corvus corax* ad.	2	O	0.103			ND	0.103

study of both heron species. However, while other researchers reported adult birds' renal mercury concentration levels higher than those for juveniles and chicks (Houserova et al., 2005; Saeki et al., 2000; Komosa et al., 2009), some researchers did not agree with these findings (Mazloomi et al., 2008).

This renal mercury concentration research here was conducted with only one specimen of white tailed eagle, and the value was higher than the geochemical background. The reported mean concentration fell within the lower range of the mean values reported in studies in Poland, Germany and Austria (1.54 mg/kg d.w.) (Komosa et al., 2009), and also in Finland (3.5 mg/kg d.w.) (Kenntner et al., 2001).Results from these countries showed that the mean values for many specimens can reach 13.5 mg/kg wet weight,(w.w.) (Krone et al., 2006) and up to 52 mg/kg d.w. (Falandysz et al., 2001). Moreover, results for individual specimens can be even higher at 52.8 mg/kg d.w. (Krone et al., 2006), and remarkably, 220 mg/kg w.w. (Falandysz et al., 2001).

Noticeably high renal mercury concentrations were also found for woodcock *Scolopax rusticola* specimens in this study. In one specimen the concentration even exceeded the level of 3 mg/kg. Concentrations such as this are most likely related to the capacity for mercury accumulation in the birds' basic prey of earthworms *Lumbricidae* (Hoodless, Hirons, 2007). Carpene et al. (2006) reported this heavy metal contamination in the woodcock's key organs correlated with earthworm pollution levels It is well known and widely accepted that earthworms are capable of accumulating mercury at concentration levels ranging from 0.01 to 4.79 mg/kg (Ernst et al., 2008).

The investigated representatives of the *Anatidae* family accumulated varying mercury levels, dependent on their diet. Highest mercury levels were observed in the goosander's kidney, and these results correspond with those in other studies related to the liver mercury accumulation in this predatory duck (Gestenberger, 2004; Kalisinska et al., 2009). Although lower renal concentrations have been found in mallards, these concentrations were definitely higher than those reported for adult birds from the Szczecin region of North-Western Poland (0.20 ± 0.14 mg/kg d.w., range: 0.01–0.47 mg/kg d.w. (Lisowski, 2009). It is also important to note that some of the studied kidneys originated from mallards specimens nesting in Warsaw, which has 1.7 million inhabitants (GUS, 2010).

Only one specimen of scaup was studied and its kidney mercury concentration did not differ from the values reported for that species in both Poland (0.27 mg/kg d.w., range: 0.06–1.19 mg/kg d.w.) (Lisowski, Kalisińska, 2005) and in other sites (range: 0.32–2.6 mg/kg d.w.) (Cohen et al., 2000). Although renal mercury accumulation normally depends on the ducks' diet, Rasool et al. (2008) reported concentrations of 3.41 ± 0.99 mg/kg, with a range of 1.05–5.20 mg/kg and n = 6, in the kidneys of the omnivorous common teal *Anas crecca,* on the highly polluted Caspian Sea coast.

Renal mercury concentrations were also investigated in raptors, which forage for avian prey. Kenntner et al. (2003) reported mean renal concentrations of 0.138 mg/kg w.w. in 61 studied specimens of goshawks from Germany. This value was almost 3-times and 8.6-times lower than the values found respectively in the goshawks and sparrowhawks from eastern Poland studied herein. In contrast, however, the concentration ranges for German goshawks were much wider, than observed in our results, at ND = 1.170 mg/kg w.w.

It is worth noting that goshawks investigated in Japan accumulated even more mercury in their kidneys, at a level of 4.29 ± 12.0 mg/kg d.w. with the very wide range of 0.075–42.4 mg/kg d.w. These values were also quite higher than those reported in the Japanese sparrowhawks *Accipiter gularis*, whose kidneys accumulated an average of 0.104 ± 0.126 mg/kg d.w., also with a very wide range of 0.0025–0.261 mg/kg. In this present study the obtained results for sparrowhawks (Table 1) was 10 times higher than the mean value found in the kidneys of the 10 sparrowhawks reported in our previous study. Therein, those 10 sparrowhawks from eastern Poland accumulated only 0.180 ± 0.096 mg/kg d.w., with a range of 0.0005–0.961 mg/kg d.w. (Komosa et al., 2009).

Unlike the renal concentration in raptors, the concentrations in other omnivorous birds, including corvids, were rarely investigated. Some interesting comparative data on the corvids diet in Japan were provided by Horai et al. (2007), who studied mercury renal concentrations in 14 specimens of the jungle crow *Corvus macrorhynchos* and reported a level of 0.39 ± 0.50 mg/kg d.w. with a range of 0.011–1.97 mg/kg d.w. Concentrations for the carrion crow *C. corone* proved to be slightly higher at 0.423 ± 0.50 mg/kg (range: 0.082–1.3 mg/kg, n = 5). Mercury concentrations in kidneys for these species exceeded those for all Polish corvids except the hooded crow. The diet for these species is widely diversified in Japan, and the birds eat all available prey including living and dead plants and animals. They also ingest the waste produced by fish processing factories densely distributed throughout the country (Horai et al., 2007), while omnivorous jackdaws and rooks significantly supplemented their diets with plants (Hogstead, 1980; Czarnecka, Kitowski, 2010).

The results of mercury renal concentrations in the hooded crow were very interesting because one adult specimen from the urban population in Warsaw accumulated 5–10 times more mercury in its kidneys than those wintering in the eastern part of Poland. A further indicator of the high pollution level in the Warsaw environment was the quite high concentration of 2.92 mg/kg of mercury registered in a common kestrel specimen. Increased mercury concentrations, as high as 0.998 mg/kg, in Warsaw urban kestrels had already been observed in our previous study (Komosa et al., 2009).

Woodpeckers eating mainly tree-bound invertebrates accumulated the least amounts of mercury of all the investigated birds. It was also the lowest level for all species eating invertebrates. Nevertheless, the role of invertebrates constituting part of food chains has recently been noted, with some reservations (Brasso, Cristol, 2008; Cristol et al., 2008). It was definitely proven in Cristol et al. (2008) that spiders, and some other terrestrial invertebrates, transfer mercury into the organs of birds, such as woodpeckers, when they are foraging in some polluted areas. This demonstrates that not only aquatic vertebrates play a significant role in mercury's ecological effects, its transport and final location, but invertebrates are also involved in these processes.

In summary, the research carried out on birds kidneys elucidated the following sequence in decreasing order of mercury concentration in the kidneys of birds of various trophic guilds: piscivorous > small mammal eating > bird eating > aquatic invertebrate eating > terrestrial invertebrate eating > herbivorous > omnivorous species. This food preference sequence corresponds to a certain degree with the scheme of mercury concentration in birds' livers reported by Alleva et al. (2006) in birds from central Italy: piscivorous >

aquatic invertebrate eating > bird eating > omnivorous > herbivorous > small mammal eating > insectivorous.

Due, especially, to mercury's high toxicity, and being acutely aware that Poland still remains the source of significant mercury emission, we intend to continue this research into mercury contamination in wild birds' organs.

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