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ELEVATED LEAD CONCENTRATION IN SKELETONS OF DIURNAL BIRDS OF PREY *Falconiformes* AND OWLS *Strigiformes* FROM EASTERN POLAND - ECOLOGICAL APPROACH AND REVIEW

PODWYŻSZONE STĘŻENIA OŁOWIU W SZKIELETACH PTAKÓW SZPONIASTYCH *Falconiformes* I SÓW *Strigiformes* Z TERENÓW WSCHODNIEJ POLSKI - PRZEGLĄD CZYNNIKÓW EKOLOGICZNYCH

Summary: Lead concentration levels in skeletons of 57 individuals of 15 species of diurnal birds of prey and owls have been determined. The greatest mean concentration of lead in skeletons was exhibited by the Great Spotted Eagle *Aquila clanga*: 44.8 mg/kg (d.m.). In 23 individuals from 11 species the concentration of lead was determined at >10 mg/kg, which indicates elevated and potentially toxic, long-term exposure to lead over the lifetime of the bird. The highest percentage of individuals with lead levels of >10 mg/kg was established for: Great Spotted Eagle, Eurasian Buzzard *Buteo buteo*, Eurasian Marsh Harrier *Circus aeruginosus* and Rough-legged Buzzards *Buteo lagopus*. Raptors, who often use game animals as food resources show the highest determined lead concentration levels.

Keywords: lead concentration, bones of birds, diurnal birds of prey, owls

The impact of heavy metals on the environment can be a serious threat to the stability of the ecosystem. The spread of hunting bullets represents a problem of growing relevance. The wide use of lead shots indeed, increases anthropogenic input of this element into the ecosystems and causes a very specific pollution resulting, in some cases, in avian mortality. For example, in the USA lead poisoning in ducks, swans, geese, barnacles and others was estimated to kill 1.4÷2.6 milions birds per year [1]. Waterbirds ingest lead shot mistakenly as food, or grit, which is next retained in the muscular gizzard as an aid to digestion. Raptors ingest lead shot when they feed upon dead or injured game

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species of birds or mammals, thus lead poisoning has been reported for many species of birds of prey with high conservation priority [2-4].

In some countries and regions lead shot for hunting in wetlands was banned [4, 5]. However in Poland, diurnal birds of prey and owls may be susceptible to lead poisoning, because lead shot is still widely used in the hunting practice across the whole country. The magnitude of the problem of lead poisoning in birds in Poland seems to be largely unidentified and somewhat ignored by hunters as a whole.

At present we posses knowledge which only suggests the possibility of lead contamination of some waterfowls and raptors [6, 7]. The following work is one of two sibling papers devoted to the study of the presence of heavy metals in the skeletons of raptors in Poland. In the first one [8] general aspects of concentration levels of particular nuclides and heavy metals including lead were discussed. The following work, which is based on the magnitude of this problem in Poland, concentrates exclusively on lead concentrations in the bones of diurnal birds of prey and owls, species which in many cases have a high conservation priority.

The aim of this paper was to present the level of contamination in skeletons of diurnal and nocturnal raptors originating from Eastern Poland.

Experimental

Samples of bones derived from the carcasses of individuals were collected between 2000-2007. The collected material in the form of bones was mechanically cleaned from organic remains and soft tissues. Next, it was dried at a temperature of 105ºC and crushed by hand into pieces several millimeters wide.

The evaluation of lead concentrations in samples was performed using the absorption atomic spectroscopy method with flame excitation, taking subsamples of 1÷2 g. The samples were mineralized by boiling either in concentrated nitric acid or aqua regia. After decomposition, the sample solution was filtered out in order to remove insoluble remains and diluted to match the measurement sensitivity range. Measurements were performed with the Spectr AA 880 spectrophotometer (Varian). Lead concentration was determined using the calibration curve method by automatic comparison with the calibration curve. Usually two subsamples from each batch of samples were measured [9]. All denotations of lead concentration results gathered during our study have been presented as median ± SD (standard deviation of median).

The analytical quality of the results was checked through thorough analysis of reference material IAEA-375 [10]. Mean value of lead concentration of 20.35 mg/kg was achieved. The reference mean value however was 21.4 mg/kg at a confidence interval placed in the range of 20.8÷22.0 mg/kg.

Lead concentration levels in skeletons of 57 individuals of 15 species of diurnal birds of prey and owls have been determined. These birds were the victims of collisions with power lines, aerial masts or high buildings in cities, and brought to licensed veterinary clinics, where attempts of treatment were made. When and where treatment was not possible, or unsuccessful, the injured birds, to shorten their suffering, were humanely sacrificed. However the period of time that these birds spent in veterinary

clinics at no time exceeded one week. In a few cases skeletons used in research were found during field surveys, thus at the place of death of given bird.

With the exception of one specimen of White-tailed Eagle *Halieetus albicilla*, all other birds came from the eastern part of Poland. In brackets are given names of larger towns or villages and number of specimens nearby raptors or their bones were found. Skeletons of the following birds of prey were examined: Great Spotted Eagle *Aquila clanga* (Garwolin - 2), Lesser Spotted Eagle *Aquila pomarina* (Łomża - 1, Olsztyn - 1, Ostrołęka - 1), Eurasian Buzzard *Buteo buteo* (Białystok - 1, Krasnystaw - 1, Lublin - 2, Olsztyn - 1, Wigry - 1), Rough-legged Buzzard *Buteo lagopus* (Biłgoraj - 1, Lublin - 2, Olsztyn - 1), Eurasian Marsh Harrier *Circus aeruginosus* (Łomża - 1, Ryki - 2, Włodawa - 1, Wyszków - 1), Montagu's Harrier *Circus pygargus* (Łomża - 1, Siemiatycze - 1), Sparrowhawk *Accipiter nisus* (Białystok - 1, Białowieża - 1, Ciechanów - 1, Olsztyn - 1, Wigry - 1, Wysokie Mazowieckie - 1), Goshawk *Accipiter gentilis* (Lubartów - 1, Lublin - 3, Rejowiec - 1, Sobibór - 1) and White-tailed Eagle (Drawsko Pomorskie - 1, Garwolin - 1, Gościeradów - 1, Olsztyn - 1). All skeletons of the Common Kestrel, *Falco tinnunculus* only came from towns (Warsaw - 3, Olsztyn - 1). Skeletons of the following owls were analyzed: Common Barn Owl *Tyto alba* (Lubartów - 1, Olsztyn - 1),1 Tawny Owl *Strix aluco* (Garwolin - 1, Łomża - 1, Lublin - 1, Mrągowo - 2, Olsztyn - 1, Wysokie Mazowieckie -1), Ural Owl *Strix uralensis* (Sanok - 1), Long-eared Owl *Asio otus* (Ciechanów - 1, Warsaw - 1, Wysokie Mazowieckie - 1) and Eurasian Eagle Owl *Bubo bubo* (Sobibór - 1).

Among species examined by us the following are sedentary: Goshawk, Common Barn Owl, Tawny Owl, Ural Owl, Eurasian Eagle Owl [11]. With the exception of one specimen of White-tailed Eagle, which came from the vicinity of Drawsko Pomorskie town (NW Poland), all other birds came from the eastern part of Poland. All skeletons of the Common Kestrel came from Warsaw or Olsztyn. Other then the Rough-legged Buzzard, a species which in Poland is a winter visitor, only individual Lesser Spotted Eagles were delivered to the veterinarian during out of time of breeding (autumnal migration). Because of the small amount of bone material derived after bone crushing, subsamples derived from whole skeletal samples, without division into particular parts of the skeleton, were analyzed. Skeletons of raptors examined were of adult individuals with the exception of one, an Eurasian Eagle Owl, which was deducted on the basis of unfused sutures of the skulls.

During the analysis of the feeding preferences of particular raptor species, data derived from literature was used, pertaining particular species such as: Great Spotted Eagle [12-14], Lesser Spotted Eagle [14-18], Common Kestrel [19, 20], Eurasian Buzzard [14, 17], Rough-legged Buzzard [14], Eurasian Marsh Harrier [14, 21, 22], Montagu's Harrier [14, 23, 24], Sparrowhawk [25], Goshawk [14, 17], White-tailed Eagle [16, 26, 27], Common Barn Owl [28], Tawny Owl [17, 29], Long-eared Owl [17], Ural Owl [30, 31], Eurasian Eagle Owl [32, 33].

Results

Results obtained are presented in Tables 1 and 2. As can be seen from Table 1, the highest median lead concentrations in the skeletons of the examined raptors were in the

Great Spotted Eagle 44.8 ± 3.33 mg/kg. Equally high (in excess of 15 mg/kg) and additionally similar to each other, were median concentration levels of lead in the bones of the Eurasian Buzzard and Rough-legged Buzzard.

Table 1

Concentration of lead in skeletons [mg/kg] of 57 individuals of studied birds in relation to food habits. N - number of samples. Preferred prey: A - amphibians, C - carrion of game animals, F - fishes, I - insects, R - rodents, M - middle size birds, S - small birds, MDA - minimum detectable amount, SD - calculated standard deviation of the median

Species of birds	N	Median	SD	Max	Min	Preferred prey
		[mg/kg]				
Great Spotted Eagle *Aquila clanga*	2	44.8	3.33	48.1	41.5	M, C
Lesser Spotted Eagle *Aquila pomarina*	3	5.30	2.02	10.0	3.1	R, A
Common Kestrel *Falco tinnunculus*	5	7.7	2.19	16.4	3.2	R, S
Eurasian Buzzard *Buteo buteo*	6	15.7	1.92	17.9	7.6	R, C
Rough-legged Buzzard *Buteo lagopus*	4	15.4	154.2	627.4	2.5	R, M, C
Eurasian Marsh Harrier *Circus aeruginosus*	5	13.0	6.29	38.9	2.5	R, S, C
Montagu's Harrier *Circus pygargus*	2	3.2	0.21	3.4	3.2	R, S, I
Sparrowhawk *Accipiter nisus*	6	10.9	2.30	12.7	<MDA	S
Goshawk *Accipiter gentilis*	6	7.0	3.15	15,0	<MDA	M, S, C
White-tailed Eagle *Haliaeetus albicilla*	4	9.8	2.8	14.5	2.8	M, F, C
Common Barn Owl *Tyto alba*	2	0.4	-	0.4	<MDA	R
Long-eared Owl *Asio otus*	3	7.1	3.0	10.1	<MDA	R
Eurasian Tawny Owl *Strix aluco*	7	6.3	2.08	15.3	2.1	R, A, M, S,
Ural Owl *Strix uralensis*	1	5.1	-	-	-	R, M, S
Eurasian Eagle Owl *Bubo bubo*	1	0.4	-	-	-	R, M, S, C

Table 2

Percentage of individuals (of total number 57) with given concentration of lead in bones, pointing to different exposure to lead. N - number of samples, N_1, N_2, N_3 - number of samples pertaining to concentrations of lead in particular species: >6.75 mg/kg, >10 mg/kg and <MDA, respectively

Species of birds		>6.75 mg/kg		>10 mg/kg		<MDA	
	N	N_1	$\%N_1$	N_2	$\%N_2$	N_3	$\%N_3$
Great Spotted Eagle *Aquila clanga*	2	2	100	2	100	-	-
Lesser spotted Eagle *Aquila pomarina*	3	1	33	1	33	-	-
Common Kestrel *Falco tinnunculus*	5	4	80	2	40		
Eurasian Buzzard *Buteo buteo*	6	5	83	4	67	-	-
Rough-legged Buzzard *Buteo lagopus*	4	2	50	2	50	-	-
Eurasian Marsh Harrier *Circus aeruginosus*	5	4	80	3	60	-	-
Montagu's Harrier *Circus pygargus*	2	-	-	-	-	-	-
Sparrowhawk *Accipiter nisus*	6	3	50	3	50	1	17
Goshawk *Accipiter gentilis*	6	2	33	2	33	2	33
White-tailed Eagle *Halieetus albicilla*	4	2	50	2	50	-	-
Common Barn Owl *Tyto alba*	2	-	-	-	-	1	50
Long-eared Owl *Asio otus*	3	1	33	1	33	1	33
Eurasian Tawny Owl *Strix aluco*	7	3	43	2	29	-	-
Ural Owl *Strix uralensis*	1	-	-	-	-	-	-
Eurasian Eagle Owl *Bubo bubo*	1	-	-	-	-	-	-

Lead concentration value of 10 mg/kg was also exceeded by: Sparrowhawk and Eurasian Marsh Harrier, however median lead concentration in the skeletons of White-tailed Eagle was very close at 10 mg/kg (Table 1).

An examination of the concentration level of lead was carried out on individual specimens. Levels (>10 mg/kg) which indicate a potentially toxic level during long term exposure to lead appeared in the biggest proportion in the following: Great Spotted Eagle, Eurasian Buzzard, Eurasian Marsh Harrier and Rough-legged Buzzards (Table 2). During studies on the last species, an extreme value of lead concentration was shown, at 627.4 mg/kg (Table 1). In only 6 individuals out of 4 species examined by us: Montagu's Harrier, Common Barn Owls, Ural Owl, Eurasian Eagle Owls, the level of accumulated lead did not exceed the background exposure level (< 6.75 mg/kg) (Table 1).

Discussion

Current studies show that raptor bones as well as bones of other birds can be good predictors of lead concentrations in internal organs, which is attested to by important statistical correlations between the concentration levels of this element in bones and the liver [34-36]. However we must acknowledge that the concentration levels in bones are a much better indicator of long-term exposure to lead in birds, in comparison with concentration levels in internal organs, which better reflect short-term exposure to lead [35-37].

Studies also show that a threshold of >10 mg/kg may represent potentially toxic, long-term exposure to lead. It is accepted that the level of lead concentration in bones of 6.75 mg/kg is a threshold amount, allowing to differentiate lead exposure from background concentration [5, 37, 38]. Bone lead concentration levels, shown in this work, reflect the differences in lead exposure among species, which may be explained by foraging habits and potential lead shot ingestion among them. The highest percentage of specimens with concentrations above background levels (6.75 mg/kg) were found in the Great Spotted Eagle, Eurasian Buzzard, Rough-legged Buzzard, Eurasian Marsh harrier and White-tailed Eagle. These species are known to be susceptible to lead poisoning because of their scavenging habits.

In the case of some of the above-mentioned species, we have at our disposal extensive comparative data from different parts of their range. Eurasian Marsh Harrier is widely known as an opportunistic and scavenger species [14, 21]. One of the individuals found dead in France, contained ingested lead shot, and had lead concentrations of 54.9 mg/kg in the liver and 15.6 mg/kg in its bones, and 3 birds of this species had bone levels >10 mg/kg [39]. In Spain 52.5% of the studied Eurasian Marsh Harrier from the Ebro river delta had blood lead levels > 200 ng/cm^3 and four out of seven birds contain bone lead levels > 10 mg/kg [40]. Our results, obtained on the basis of studies carried out on the skeletons of Eurasian Marsh Harrier from Poland, also confirm their high sensitivity to lead bullets, as 60% of the studied birds represented elevated and long-term exposure to lead (Table 2). This elevated and long term exposure to lead from bullets corresponds with records of raised levels of lead in eggshells of Eurasian Marsh Harrier from the Lublin region area (East Poland) in areas where hunting activity was high [41].

Similar to Marsh Harriers, other scavengers such as *Haliaeetus* eagles: White-tailed eagles, Steller's eagles *Haliaeetus pelagicus*, Bald eagles *Haliaeetus lucocephalus* which feed on waterfowl carcasses and deer offals are reported as susceptible to lead poisoning [2, 42, 43]. Levels of concentration obtained by us in White-tailed eagles, point to a similar threat (Tables 1 and 2), resulting from their preference for carrion consumption. Eurasian Buzzards studied in East Poland show accumulated median levels of 15.7 mg/kg Pb in bones, which is significantly higher in comparison with data derived from Western European countries. Garcia-Fernandez et al. [44] found average concentration of lead equal to 2 mg/kg in six Eurasian Buzzards from southeastern Spain. And only one of 107 Eurasian Buzzards studied by Mateo et al. [5] in Spain had >10 mg/kg of lead in its bones, however it was a very atypical sample originated from an individual fed in captivity with shot prey. In France the lead concentrations above 6 mg/kg were found only in 5 (5.6%) of 90 Eurasian Buzzards [39].

Goshawk is another species susceptible to lead poisoning because it consumes live birds (partridges, pigeons), which may have lead shots embedded in their flesh. Additionally our study, based on the example of the Goshawk, suggests that the possibility of contamination can be the result of hunting opportunism, proof of which are the even proportions (33%) in which the level of concentration did not exceed the detection threshold, as well as these, which represented potentially toxic, long-term exposure to lead. This conclusion is supported by works of other researchers. The study report from France showed data on one specimen of Goshawk with a lead concentration in the liver equal to 711 mg/kg [39], simultaneously 18 Goshawks studied in Spain by Mateo et al. [5] had geometric mean lead concentration in bones equal to 1.57 mg/kg.

The Eurasian Eagle Owl specimen studied by us accumulated very little lead because the bird was young; however significant concentrations of lead in the bones of adult specimens of this species have been noted. This is as a result of the fact that this species feeds on rabbits and birds of similar size to game birds. For example in Spain, Garcia-Fernandez et al. [44] found high bone lead levels (15.4 mg/kg) in 9 specimens of the Eurasian Eagle Owl. However Mateo et al. [5] reported that for 49 studied specimens Eurasian Eagle Owl the geometric mean was only 2.8 mg/kg at range of 0.33÷85.23 mg/kg. This latter high maximal concentration suggests that this individual suffered from plumbism (chronic lead poisoning).

Some studies showed [44] that the lowest lead exposure levels in bones were detected in raptors that fed on small mammalian prey such as rodents *Rodentia* and insectivore *Insectivora* which was confirmed by our results obtained from studies carried out on Common Barn Owls, Long-eared Owl and Montagu's Harrier. These birds are highly specialized in their hunting of small mammals, and thus do not, or only very rarely consume game animal carrion.

Concentration levels of lead shown during the study in Sparrowhawks and Common Kestrels require separate discussion, for the high levels of lead shown there are not a result of a preference for the consumption of game animal carrion. The first species is highly specialized in capturing small passerines [25], while the second is a highly specialized rodent-eater [19]. Therefore the level of lead found in the organism of these species was a result of until recently, widely used leaded petrol in Poland. In accordance to EU recommendations, leaded fuel was withdrawn from circulation by the year 2005 [46]. It is widely known that environmental contamination caused by the use of leaded

fuel is present in the environment for many years after its withdrawal from circulation [47, 48]. Birds of both these species very often feed near roads. The Common Kestrel when found in urban environments, is even able to feed on the strip dividing dual carriageways [3, 20]. Lead may end up in the organisms of these raptors, as well as other birds, through a process of consuming lead contaminated food derived from urban environments or feeding grounds near roads [4, 49].

Research carried out by us can have significant importance for the protection of the species studied. All raptors studied by us are under protection programs of Polish national law and UE Bird Directive [50]. Furthermore among the species of birds studied by us, rare species which often have a high conservatory priority were found to contain high concentration levels of lead. The Great Spotted Eagles is recognized by IUCN (*International Union for Conservation of Nature*) as critically endangered (CR). Lesser Spotted Eagles, White-tailed Eagle, Eurasian Eagle Owl and Ural Owl are in truth considered by IUCN only as Least Concerned (LC) species, but were included in the last edition of the Polish Red Data Book of Animals [18, 26, 30-32]. What is more all species of owls and eagles mentioned above, as well as the Eurasian Marsh Harrier and Montagu's Harrier are listed in Appendix I of Bird Directive of Natura 2000 [50].

Conclusions

Studies carried out by us show high concentration levels of lead in the bones of predatory birds in Poland. These birds are not only rare but of a high conservatory priority. The results of our research show that the only possible source for lead found in these birds are lead bullets used by hunters. This leads to the unanimous conclusion that an urgent need to ban, or at least limit the use of lead bullets by hunters has arisen, particularly in the wetlands area. In any case, this problem was indicated by the hunting community itself [51].

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PODWYŻSZONE STĘŻENIA OŁOWIU W SZKIELETACH PTAKÓW SZPONIASTYCH *Falconiformes* I SÓW *Strigiformes* Z TERENÓW WSCHODNIEJ POLSKI - PRZEGLĄD CZYNNIKÓW EKOLOGICZNYCH

Streszczenie: Zbadano poziomy stężeń ołowiu w szkieletach 57 osobników z 15 gatunków ptaków szponiastych i sów. Największe średnie stężenie ołowiu stwierdzono w kościach orlika grubodziobego *Aquila clanga*: 44,8 mg/kg (s.m.). W 23 osobnikach pochodzących z 11 gatunków stężenia ołowiu określono jako >10 mg/kg, co wskazuje na występowanie podwyższonego, potencjalnie toksycznego długotrwałego narażenia na ołów. Największy procent osobników przekraczających ten poziom skażenia ołowiem (>10 mg/kg) stwierdzono w przypadku orlika grubodziobego *Aquila clanga*, myszołowa *Buteo buteo*, błotniaka stawowego *Circus aeruginosus* i myszołowa włochatego *Buteo lagopus*. Drapieżniki, wykorzystujące zwierzynę łowną jako źródło pokarmu, wykazywały największe poziomy stężeń ołowiu w kościach.

Słowa kluczowe: stężenie ołowiu, kości ptaków, dzienne ptaki drapieżne, sowy