

Trace Element Concentrations in Feathers of White-Tailed Sea Eagles *Haliaeetus albicilla* Collected Recently in Poland

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INTRODUCTION

Bird feathers contain relatively high concentrations of trace metals (Berg *et al.* 1966; Doi & Fukuyama 1983; Szefer & Falandysz 1983; Goede & Bruin 1984; Wiemeyer *et al.* 1986). Due to the ease with which feather samples can be taken without injuring birds, as well as the relative stability of feather keratin, feathers have served in many programs as a monitoring medium for environmental pollution and contamination by heavy metals and trace elements (Berg *et al.* 1966; Lindberg & Odsjö 1983; Fiuczynski 1983; Doi *et al.* 1984; Appelquist *et al.* 1985; Wiemeyer *et al.* 1986; Szefer & Falandysz 1987; Thompson *et al.* 1990).

Metals are deposited in feathers during their formation and growth; concentrations appear to reflect both the nutritional status of the bird and the trace metal content of recently consumed food.

Mercury, primarily in the form of methylmercury, seems to be very firmly bound to keratin (Appelquist *et al.* 1984). Feathers are thus an excellent material for studies of temporal trends of this toxic element in both terrestrial and marine environments (Berg *et al.* 1966; Appelquist *et al.* 1985).

When discussing metal content in feathers, however, mechanisms other than internal deposition during formation and growth must be considered. Even after feather growth has stopped, metabolism has ceased, and the feather is dead, external adsorption or leaching can take place. Due to its high total surface to weight ratio, the vane of the feather is suspected to be much more susceptible to alterations in metal content than the shaft.

An external deposition of selenium, lead and arsenic from secretion products of both preen and salt glands has been observed in feather vanes of Dunlin, *Calidris alpina* (Goede & Bruin 1984; 1986). It has also been shown that feathers may take up various metals externally (copper, iron, nickel and zinc) from direct contact with environmental media such as air, water, mud, etc. (Kelsall & Burton 1979; Rose & Parker 1982; Goede & Bruin 1984; 1986).

The purpose of this study is to investigate the degree and possible exposure of White-tailed Sea Eagles breeding in the western part of inland Poland to mercury, lead, cadmium, zinc, copper,

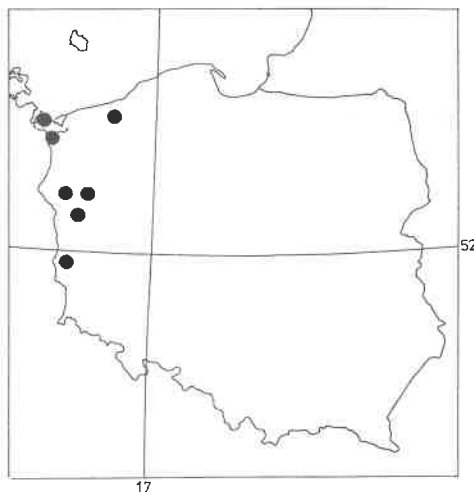
manganese, and iron, using feathers as a monitoring tissue. The present communication is a preliminary result.

MATERIALS AND METHODS

Sample collection and preparation

Most of the different types of feather samples were collected at various nesting grounds of White-tailed Sea Eagles in the western part of Poland between 1986 and 1988 (forest inspectorates Bogdaniec, D bno, Kodawa and Sulechów; Fig. 1). Some of the feathers were also taken from lead-poisoned birds collected in the same areas from 1986 to 1987 (forest inspectorates D bno and Skwierzyna), and from an immature male electrocuted in the northern part of Poland in 1984. The feathers were dried at ambient laboratory temperature, placed individually in clean polyethylene bags, tagged and stored until analysis.

Figure 1: Sites from which feather samples of White-tailed Sea Eagle collected 1986-1988 in western Poland



Chemical analysis

The feathers were measured and then dried at 60°C for 24 hours.

For determination of mercury the upper parts (1/3 of the total length) of the feathers were wet-digested with concentrated nitric acid in an all-glass apparatus consisting of a round-bottomed flask, partial condenser and a reflux water cooler. The digest was diluted with redistilled water. Excess oxidizing substances were removed by adding hydroxylamine hydrochloride. Mercury (II) was reduced to metallic mercury by tin chloride solution (20%) in sulfuric acid. Mercury was evaporated by passing a stream of nitrogen through the solution and was determined by cold vapor atomic absorption using a UV Mercury Monitor LDC/Milton Roy, at a setting of 253.7 nm.

For determination of lead, cadmium, manganese, copper, zinc, and iron, the lower parts (2/3 of the total length) of the feathers were placed in silica vessels, and dry-ashed at 420°C. A few drops of concentrated nitric acid were added to whiten the ash. The resulting residue was dissolved in 5-10 ml of 1 M nitric acid and aspirated into the air-acetylene flame of the Pye Unicam SP 9 atomic absorption spectrophotometer.

Most of the analyses were conducted on single feathers, but in the case of small feathers (plumae and some of the tectrices), pooled samples of whole feathers were prepared. Altogether 33 samples were analyzed for mercury and 28 for the other trace elements.

Table 1. Concentrations of trace metals in feathers of White-tailed Sea Eagles ($\mu\text{g/g}$ on a dry weight basis).

Sampling details (location, month, year and feather type)	No.	Lead	Cadmium	Copper	Zinc	Manganese	Iron	Mercury
Forest Inspectorate: Sulechów								
Location: Przetoczna								
May & June 1987; remiges (33 & 37cm)	2	5.6	0.24	6.7	100	7.3	200	4.8
		3.9-8.1	0.14-0.33	6.1-7.3	100-100	5.3-9.2	200-200	1.7-7.9
March 1988; remiges	1	12	1.2	8.9	63	8.2	230	5.7
June 1987; tectrices (16 & 18cm)	2	NA	NA	NA	NA	NA	NA	8.5
June 1987; rectrices (28cm)	1	1.1	0.27	1.4	46	1.2	110	2.6
Location: Nietkowitz								
October 1986; tectrices (23-30cm)	3	6.4 $\pm$ 2.9	0.19 $\pm$ 0.13	8.7 $\pm$ 0.6	120 $\pm$ 16	9.5 $\pm$ 6.5	120 $\pm$ 90	8.3 $\pm$ 2.6*
October 1986; remiges (39cm)	1	10	0.24	11	60	14	450	2.7
May 1987; remiges (48cm)	1	7.6	0.13	7.2	73	5.2	140	3.2
May 1987; rectrices (30cm)	2	5.7	0.29	7.7	100	5.1	240	4.3
		5.3-6.1	0.28-0.29	7.1-8.3	97-110	4.6-5.6	230-250	3.3-5.3
May 1987; tectrices (30cm)	1	6.8	0.17	8.4	120	11	250	18
Location: Białków (Division 7 & 219)								
June 1986; remiges I (46-48cm)	3	7.5 $\pm$ 1.7	0.16 $\pm$ 0.04	7.8 $\pm$ 0.9	88 $\pm$ 13	6.2 $\pm$ 1.8	140 $\pm$ 30	10 $\pm$ 3
		6.5-9.4	0.13-0.20	7.0-8.7	73-96	4.6-8.1	130-170	6.1-17
June 1986; rectrices (32cm)	1	6.0	0.16	7.4	120	4.2	250	10
June 1986; tectrices (31cm)	1	5.2	0.086	7.8	140	6.8	130	12

Sampling details (location, month, year and feather type)	No.	Lead	Cadmium	Copper	Zinc	Manganese	Iron	Mercury
(Division 30d)								
May 1987; remiges I (49cm)	1	8.1	0.16	7.9	87	7.3	150	7.6
May 1987; remiges II (33cm)	1	4.4	0.044	6.5	91	3.3	140	2.8
May 1987; rectrices (31cm)	1	4.0	0.14	5.0	76	5.5	220	4.3
Location: Province of Koszalin (electrocuted male) ^e								
1984; remiges I (39-43cm)	6	3.3±0.4 2.7-3.8	0.10±0.07 0.06-0.23	6.2±0.7 5.1-7.4	110±20 95-140	4.7±1.0 3.7-5.9	85±24 54-120	4.3±1.1 2.9-5.6
tectrices (21-25cm)	3(5) ^e	4.5±3.1 2.2-8.0	0.17±0.27 <0.006-0.48	6.2±3.2 2.5-8.3	160±75 120-250	6.9±2.2 4.4-8.2	180±35 160-220	7.8±3.4 3.2-11
Forest Inspectorate: Klodawa (Division 90)								
1986; remiges II (36cm)	1	4.3	0.15	6.7	80	4.5	130	2.8
Location: Lubsko								
remiges I (No.9; left, 43.5cm)	1	3.7	0.10	4.8	110	5.8	140	0.66
remiges I (No.9; right, 50cm)	1	4.0	0.052	5.0	100	5.9	150	2.8
tectrices ^d	1(5)	11	0.38	9.5	360	7.0	590	41
tectrices (vexillum)	1(9)	NA	NA	NA	NA	NA	NA	19
plumae ^d	-	23	0.41	21	300	22	750	37

Sampling details (location, month, year and feather type)	No.	Lead	Cadmium	Copper	Zinc	Manganese	Iron	Mercury
Forest Inspectorate: Skwierzyna								
Location: Lubieniewice, January 1987 ^c								
remiges (vexillum)	2	5.9	0.15	7.1	110	5.8	170	2.7
		5.6-6.1	0.11-0.19	6.7-7.4	100-110	5.1-6.4	170-170	1.6-3.8
rectrices	1	4.3	0.11	6.8	120	5.8	250	2.4
tectrices (9cm)	1	NA	NA	NA	NA	NA	NA	NA
plumae ^d	-	NA	NA	NA	NA	NA	NA	NA
Forest Inspectorate: Debno								
Location: Baranówka								
June 1986; remiges (45cm)	1	3.1	0.063	6.7	90	2.5	65	5.3
Location: Debno, February 1987 ^c								
remiges II	2	5.1	0.29	5.9	120	8.5	180	4.5
		4.2-6.0	0.21-0.36	5.0-6.7	120-120	7.0-10	180-180	4.4-5.2
tectrices	1	NA	NA	NA	NA	NA	NA	6.1
tectrices	1	16	0.92	10	280	36	830	11
plumae ^d	1	9.7	0.61	16	210	14	240	5.8
Forest Inspectorate: Bogdaniec								
Location: Zacisze								
remiges (30 & 33cm)	2	3.1	0.53	6.5	100	3.6	110	8.7
		2.7-3.4	0.044-0.062	6.1-6.8	90-100	3.5-3.6	91-130	5.4-12

^a For mercury No. = 4.

^b Immature bird.

^c Pooled samples (number of feathers in brackets).

^d Determined in the whole feather, otherwise in the upper (1/3 of the total length) or the lower part (2/3 of the total length) for mercury and other trace metals, respectively.

^e Lead-poisoned bird.

RESULTS AND DISCUSSION

Concentrations of trace elements determined in feathers of White-tailed Sea Eagles are presented in Table 1.

Mercury

The mean mercury concentration in the feathers examined was 8.5 ± 8.9 $\mu\text{g/g}$ on a dry-weight basis (range 0.66–41). In three feather samples from Lubsko (Forest Inspectorate Kodawa) and one from Nietkowice (Sulechów) the concentration of mercury ranged from 18 to 41 $\mu\text{g/g}$ (29 ± 12). This is much higher than mercury concentration concentrations determined in the 29 other feather samples, which ranged from 0.66 to 17 $\mu\text{g/g}$ (5.7 ± 3.0).

Berg *et al.* (1966) detected mercury in feathers of White-tailed Sea Eagles collected in different regions of Sweden from 1893 to 1949 in the range of 2.7 to 16 $\mu\text{g/g}$, with a mean for 12 central tail feathers and 5 inner primaries of 6.6 and 9.8 $\mu\text{g/g}$, respectively. These data seem to reflect a "background level" of mercury in White-tailed Sea Eagles from the Swedish environment not contaminated with this metal from anthropogenic sources. Much higher concentrations of mercury, *i.e.* 49 $\mu\text{g/g}$ (38–64) have been reported by the authors cited above in 5 central tail feathers of birds collected between 1952 and 1965 in a region of Sweden close to the Baltic Sea. In a similar study feathers of four birds collected from the Archipelago of Stockholm in 1965 and 1966 contained mercury in the range of 23 to 51 $\mu\text{g/g}$ (40 ± 13 ; Jensen *et al.* 1972).

Lead and cadmium

Lead concentrations determined in the feather samples ranged from 1.1 to 23 $\mu\text{g/g}$, with a mean of 6.8 ± 4.5 $\mu\text{g/g}$. In four samples lead concentrations were above 10 $\mu\text{g/g}$, ranging from 11 to 23 $\mu\text{g/g}$, with a mean of 16 ± 5 . In the remaining samples the mean was 5.4 ± 2.1 $\mu\text{g/g}$. One of two lead-poisoned White-tailed Sea Eagles (from D bno) contained apparently higher concentrations of that metal in two feather samples - 9.7 and 16 $\mu\text{g/g}$ (Table 1).

Raptors breeding in the vicinity of Berlin contained lead in their feathers in concentrations ranging from 11 to 24 $\mu\text{g/g}$ (Fiuczynski 1983), generally higher than the concentrations determined in White-tailed Sea Eagle feathers in our study (Table 1). Lead concentrations similar to those found in this study in feathers of California Condors, *Gymnogyps californianus*, ranged from 1.9 to 14 $\mu\text{g/g}$ (Wiemeyer *et al.* 1986).

The mean concentration of cadmium in the feathers examined was 0.25 ± 0.26 $\mu\text{g/g}$ on a dry weight basis (range <0.006–1.2). Highest concentrations were in the four samples with the highest mercury concentrations (see above), 0.73 ± 0.40 $\mu\text{g/g}$. Mean cadmium concentration in the remaining 24 samples was 0.17 ± 0.12 .

White-tailed Sea Eagle feathers examined previously contained cadmium in concentrations from 0.83 to 1.2 $\mu\text{g/g}$ (Falandysz 1986; Falandysz *et al.* 1988).

Copper, zinc, manganese and iron

The feathers examined contained 7.9 ± 3.6 $\mu\text{g/g}$ (1.4–21) of copper, 130 ± 70 $\mu\text{g/g}$ (46–360) of zinc, 8.1 ± 6.9 $\mu\text{g/g}$ (1.2–36) of manganese, and 240 ± 190 $\mu\text{g/g}$ (91–590) of iron. The concentrations of these essential trace metals are within the ranges found in feathers of potential prey species of White-tailed Sea Eagles, including Long-tailed Ducks, *Clangula hyemalis*, and Scaup Ducks, *Aythya marila* (Szefer & Falandysz 1983; 1987), and appear typical.

Inter-metallic relationships

Linear correlation coefficients (r) between the concentrations of elements determined in feathers of White-tailed Sea Eagles show a lack of significant correlation between pairs Cd-Hg (0.19), Cd-Zn (0.35) and Hg-Mn (0.35). All other pairs of metals showed a significant positive correlation, with highest values of the determination coefficients (r^2) for the pairs Cu-Pb, Mn-Pb, Fe-Pb, Fe-Zn, Fe-Mn and Zn-Hg (0.61–0.74; Table 2).

Table 2. Inter-metallic correlation coefficients, r^a , in feathers of White-tailed Sea Eagles.

	Cd	Cu	Zn	Mn	Fe	Hg
Pb	0.62	0.86	0.67	0.79	0.85	0.65
Cd	-	0.41	0.35	0.60	0.53	0.19
Cu		-	0.62	0.63	0.65	0.68
Zn			-	0.61	0.78	0.82
Mn				-	0.84	0.35
Fe					-	0.65

^a Critical values at 0.05 and 0.01 levels are 0.38 and 0.49, respectively.

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