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Total Mercury in Feathers of White-Tailed Eagle *(Haliaeetus albicilla* L.) from Northern Germany over 50 Years

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A suitable matrix to determine environmental metal contamination status can be found on the principle feathers of the white-tailed eagle.(Ellenberg and Dietrich 1981; Burger et al. 1994). If it is possible to separate those quantities which were deposited on feathers by airborne particles (exogenous) from those which were eliminated from the bird (endogenous), the results can be interpreted in more detail. The endogenous parts will reflect the food contamination and by accumulation via food chain contamination in the area the bird inhabits (Henning 1992; Lindberg 1984). Hg will be deposited in feathers depending on the dosage and should reflect the body burden during the growing time (Lewis and Furness 1991). Selecting a resident species leads to an indicator of a relatively small area.

The most important source for mercury in feathers is the methyl-mercury (Me-Hg) contamination of the bird (body burden) (Thompson and Furness 1989) and, after cleaning the feathers carefully, probably the only one (see Scharenberg 1998). Using the same feather position and the same feather part will reduce the variability of the concentrations. All these considerations led to the assumption, that small parts of tail feathers from White-tailed Eagles *(Haliaeetus albicilla)* represent a good indicator substrate for the mercury contamination of their habitat.

With our investigation we want to demonstrate spatial differences in mercury contamination of eagles from Schleswig-Holstein (Northern Germany), temporal changes during the last 50 years and to compare our area with other regions. Some individual birds of our area inhabited their nest sites for almost 30 years and all birds are generally resident even during the winter months.

MATERIALS AND METHODS

During the period 1949-1997 tail feathers (n = 214) of White-tailed Eagles (males, females) were collected from 8 different nest sites in Schleswig-Holstein (Fig. 1). We had to compare feathers from different positions in the tail because it was impossible to always collect a feather from only one position over a 50 years period. Each feather can be identified and assigned to individual birds.

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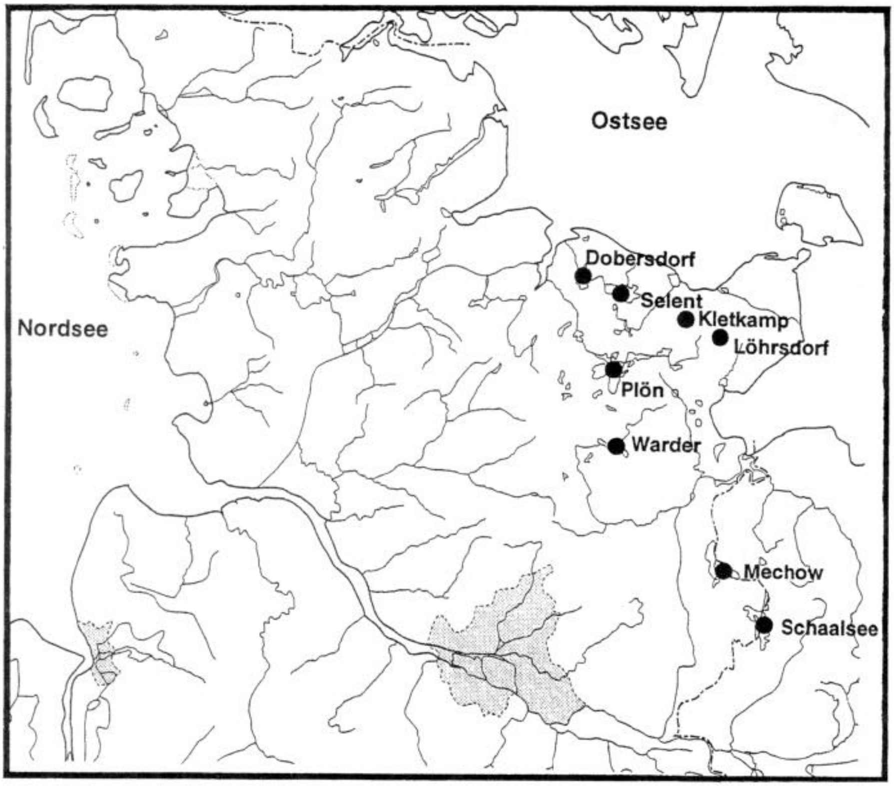

Figure 1. Location of sample sites in Schleswig-Holstein, Germany.

A small part was cut from the vein of the feather basis . The analytical procedure was the same as described by Scharenberg et al. (1994) resp. Hahn et al. (1992): we measured the samples by cold vapour (Perkin Elmer 1100B equipped with FIAS 400) and one half of the samples were analyzed by E. Hahn with Zeeman solid sampling atom absorption spectrometry. Some comparable subsamples were anayzed with both methods without finding any differences in the concentrations.

Statistical analyses were done by U-test to compare sexes of the same nest site and to compare different nest sites. Significance level was $p = 0.05$. Time trends at each nest site were tested by regression analysis.

RESULTS AND DISCUSSION

The concentrations in all feathers differentiated by sex and location are given in Table 1. The differences between concentrations in feathers of males and females are significant only at 2 locations (Table 1). Males are more highly contaminated. At some nest sites females contain slightly higher concentrations, although these differences are not significant. Feathers of all birds combined show no significant differences.

Table 1. Residues of mercury (mg/kg dry mass) in tail feathers of White-tailed Eagle from different nest sites in Schleswig-Holstein (n =214).

Location	Median	Mean	SD	Min.	Max.	Sex	m > f
Warder	6.82	7.21	2.79	2.92	12.07	male	n. s.
	8.67	9.02	3.27	3.90	17.23	female	
Selent	9.29	13.30	9.10	4.46	36.69	male	n. s.
	10.04	12.65	5.90	7.26	33.47	female	
Schaalsee*)	22.88	25.85	7.90	16.63	46.28	male	p=0.05
	17.18	19.30	6.36	13.16	33.08	female	
Ploen *)	17.13	19.39	7.43	10.63	41.39	male	p=0.05
	12.05	14.09	5.79	6.80	29.80	female	
Mechow	10.34	11.78	6.02	6.15	26.90	male	n. s.
	12.14	13.27	5.58	7.89	25.78	female	
Kletkamp	7.82	7.11	1.07	5.60	7.91	male	n. s.
	6.68	7.03	3.08	2.69	13.45	female	
Dobersdorf	11.32	12.92	6.93	4.42	28.76	male	n. s.
	8.95	10.28	2.86	6.16	15.29	female	
Loehrsdorf	10.62	10.46	1.51	8.28	13.37	male	n. s.
	9.34	9.10	2.17	5.68	14.44	female	

SD = standard deviation; Min. = minimum; Max. = maximum; m > f = male signifikant greater than female or n.s. = not signifikant. *) Feathers from this nest sites are more highly contaminated than feathers from all other sites.

Although females can reduce their metal body burden by laying eggs - Braune and Gaskin (1987) demonstrated the same feather residues in males and females before egg laying, lower residues in feathers from females after egg laying and comparable residues before the next breeding period - this does not mean that they are generally less contaminated than males from the same location. It is interesting that sex differences are only significant at the two more contaminated locations in Schleswig-Holstein. Lewis and Furness (1993) contaminated birds experimentally with single doses of Hg and demonstrated a very effective excretion by egg laying during 12 weeks. This lead to significantly higher concentrations in organs of males, while feathers were not significantly more contaminated. But few feathers grew during the experimantal period. The less birds are contaminated, the less feathers are contaminated, too. Possibly significant sex differences in feather residues only occur if moulting is parallel to egg production. If sexes feed on different food sources, this could be a reason for different residues, too, but for Schleswig-Holstein no differences in food items, especially during the breeding and moulting time are obvious (Struwe-Juhl, 1996).

Feathers from Lake Schaalsee are significantly more contaminated than feathers from all other locations, and feathers from Lake Ploen are also more contaminated than feathers from all other lakes with the exception of females from Lake Mechow and Lake Selent (Table 1). No significant differences occur between all other regions. The Schaalsee region could be influenced by agricultural Hg input. Because of no significant time trend at the lower contaminated lakes, the original background in Schleswig-Holstein seemed to be reflected by approximately 11 mg/kg Hg in eagle feathers. Niecke et al. (1998) mention 7 mg/kg in eagle

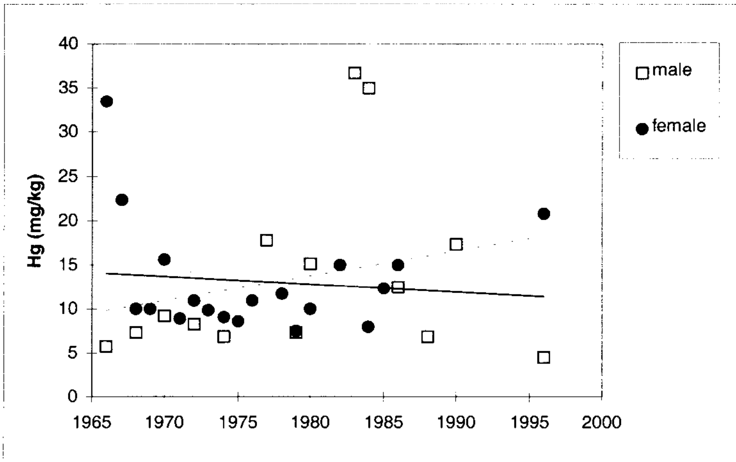

Figure 2. Hg-concentrations in feathers of one female and two male eagles from lake Selent during a period of 30 years. A new male appeared in 1983.

feathers of northeast Germany which is similiar to our value. Slightly higher concentrations were detected in the Great Lakes region influenced by industrial impact (Bowermann et al. 1994) and lower values were presented in Sweden (Berg et al. 1966) before anthropogenic impact, representing original background (Table 2). The higher contaminated sites in Schleswig-Holstein might be influenced by agricultural emissions during the last decades. Especially in the Schaalsee region Hg was used for seed protection until 1990 (Niecke et al. 1998) and the authors found higher residues in feathers of this region, too. (We measured one extremly high value - 215 mg/kg - in 1973 from this region, without consideration for our analysis).

Table 2. Hg-residues (mg/kg dw) in eagle feathers of different regions in Europe and USA.

Period	Sweden[1)]	Germany[2)]	Germany[3)]	USA[4)]
1825-1940	6.6			
1950-1997		13.2	15.8	
1985-1989				21

1) Berg et al. 1966; 2) Schleswig-Holstein: this investigation; 3) Niecke et al. 1998, North-east Germany; 4) Bowermann et al. 1994, Great Lakes.

At some lakes the same individual could be monitored for almost 30 years. For example a juvenile female started breeding at Lake Selent in 1966 and one feather contained 33 mg/kg Hg at that time and 22 mg/kg one year later (Fig.2). Until 1996 the average concenration was 11.4 ± 3.4 mg/kg and relatively constant. The average concentration in feathers of two males during the same period was 14.2 ± 10.3 mg/kg with a little bit higher variability but not statistically different from the female. In particular, the new young male in 1983 contained higher concentrations in the first years than the female did in 1966. At Lake Warder feathers of one female contained 8.2 ± 2.4 mg/kg and the feathers of one male during the same period 7.1 ± 3.1 mg/kg . These differences are also not significant.

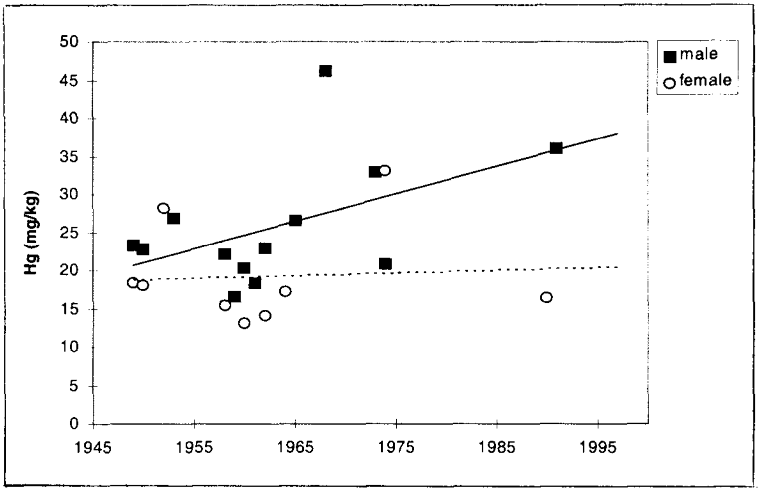

Figure 3. Hg-concentrations in feathers of male and female eagles from lake Schaalsee.

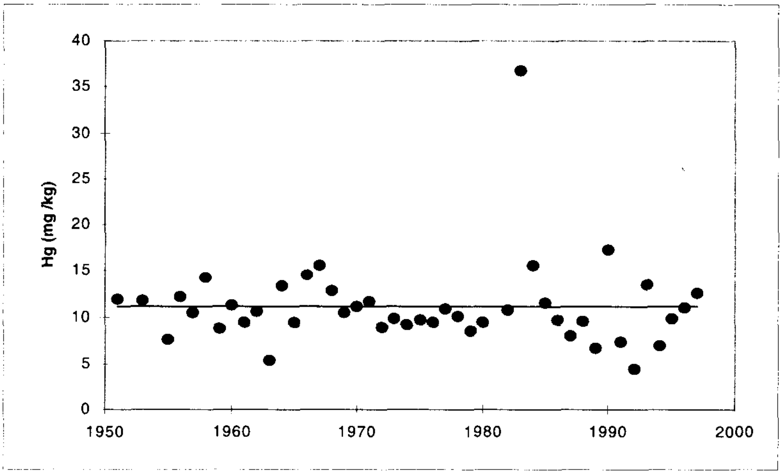

Figure 4. Hg-concentrations in feathers of eagles from different locations in Schleswig-Holstein, without lake Schaalsee and Ploen. (See Table 1).

There is no statistically significant time trend in our dataset for either the highest contaminated region Schaalsee (Fig. 3) or for all lower contaminated lakes (Fig. 4). The geogenic background hasn‘t changed over the last 50 years. The lowest value we measured was 3 mg/kg (Warder) and the average value of all statistically equal contaminated sites was 11.3 mg/kg.

In principle, correlations between Hg organ and feather residues are present (Gochfeld 1980; Heinz 1980). Some authors measured residues in feathers and muscle resp. whole body and demonstrated a relation of around 7:1 (Berg et al. 1966; Jemelov 1974, cited in Niecke 1996; Heinz 1980). For a toxicological assessment, the most sensitive organ seems to be the brain and the most sensitive ecotoxicological parameter is probably the reproduction success. Oehme (1981) measured Hg concentrations in dead White-taile Eagles which obviously caused the death: 45-133 (mg/kg fw) in the liver, 45-306 mg/kg in the kidney and 11-26 mg/kg in the brain. Regarding the relation of 7:1 between feathers and organs the residues in eagles from Schleswig-Holstein should be far below acute toxicity. Bowermann et al. (1994) combined residues in eagle feathers and reproduction success in the Great Lakes region. They concluded that residues of /around 22 mg/kg Hg did not influence reproduction. This seems to be true for our eagle population, too.

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REFERECES

Berg W, Johnels A, Sjoederstrand B, Westermark T (1966) Mercury content in feathers of Swedish birds from the past 100 years. Oikos 17: 71-83

Bowermann WW, Evans ED, Giesy JP, Postupalsky S (1994) Using feathers to assess risk of mercury and selenium to Bald Eagle reproduction in the Great Lakes region. Arch Environ Contam Toxicol 21: 294-298

Braune EM, Gaskin DE (1987)Mercury levels in bonaparte' s gull *(Larus philadelphia)* during autumn moult in the Quoddy region, New Brunswik, Canada. Arch Environ Contam Toxicol 16: 539-549

Burger J, Pokras M, Chafe1 R, Gochfeld M (1994) Heavy metal concentrations in feathers of Common loons *(Gavia immer)* in the northestern United States and age differences in mercury levels. Environ Monit Assess 30: l-7

Ellenberg H, Dietrich J, (1981) The Goshawk as a bioindicator. In: Kennward RE, Lindsay IM (eds) Understanding the Goshawk. The International Association of Falconry and Conservation of Birds of Prey. p. 69-87

Gochfeld M (1980) Tissue distribution of mercury in normal and abnormal young common terns. Mar Pollut Bull 11: 362-366

Hahn E, Hahn K, Kleinstäuber G, (1992) Quecksilbergehalte in Wanderfalkenfedern aus Ostdeutschland. Greifvoegel und Falknerei: 87-93

Henning V, (1992) Elementaranalyse von Kolkraben *(Corvus corax)* und Wanderfalkenfedern *(Falco p. peregrinus).* In: Kohler A, Arndt U (eds) Bioindikatoren fuer Umweltbelastungen. Verlag J Margraf, Weikersheim: 93-110

Heinz GH (1980) Comparison of game-farm and wild-strain mallard ducks in accumulation of methylmercury. J Environ Pathol Toxicol 3: 379-386

Lewis SA, Furness RW (1991) Mercury accumulation and excretion in laboratory reared Black-headed gull *(Larus ridibundus)* chicks. Arch Environ Contam Toxicol 21: 316-320

Lindberg P (1984) Mercury in feathers of swedish gyrfalcons, *Falco rusticolus,* in relation to diet. Bull Environ Contam Toxicol 32: 453-459

Niecke M (1996) Analyse der Quecksilberbelastung in Seeadlerfedern aus Mecklenburg-Vorpommern mit Hilfe der Hamburger Protonenmikrosonde. Institut fuer Experimentalphysik. Universitaet Hamburg

Niecke M, Krueger A, Hauff P, Ellenberg H, Labes R, Niecke S (1998) Analyse von Quecksilber in Seeadlerfedern aus Mecklenburg-Vorpommern mit Hilfe der Hamburger Protonenmikrosonde. UWSF - Z Umweltchem Oekotox 10(1): 3-14

Oehme G (1981)Zur Quecksilberrueckstandsbelastung tot aufgefundener Seeadler, *Haliaeetus albicilla,* in den Jahren 1967-78. Hycernia NF 18: 353-364

Thompson DR, Furness RW (1989) Comparison of the level of total and organic mercury in seabird feathers. Mar Pollut Bull 20: 577-579

Scharenberg W (1998) Schwermetalle in Federn. Probleme der Bestimmung und Moeglichkeiten fuer ein Monitoring. UWSF - Z Umweltchem Oekotox 10(3): 171-177

Scharenberg W, Gramann P, Pfeiffer W (1994): Bioaccumulation of heavy metals and organochlorines in a lake ecosystem with special reference to Bream (Abramis brama L.). Sci Total Environ 155, 187-197

Struwe-Juhl B (1996) Bestand und Nahrungsoekologie des Seeadlers *(Haliaeetus albicilla)* in Schleswig-Holstein mit Angaben zur Bestandsentwicklung in Deutschland. Vogelwelt 117: 341-343