Ornis Fennica 77:57–63. 2000

Metals and trace elements in tissues of Common Eiders (*Somateria mollissima*) from the Finnish archipelago

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Received 17 January 2000, accepted 6 March 2000

We sampled Common Eiders (*Somateria mollissima*) at five locations near coastal Finland in 1997 and 1998 for evidence of exposure to arsenic, cadmium, chromium, copper, iron, mercury, magnesium, manganese, molybdenum, lead, selenium, and zinc. Livers and kidneys were collected from adult males and females found dead and hunter-killed males, and livers were collected from ducklings. Two adult females, one of which had an ingested lead shot in its gizzard, were poisoned by lead. The concentrations of metals and trace elements that we found in tissues of eiders, other than the two lead poisoned birds, were not high enough to have independently caused mortality.

1. Introduction

Trace elements enter the marine environment through a variety of anthropogenic activities including mining, smelting, sewage disposal, and the use of marine paints (Langston 1990). As part of a monitoring program for persistent contaminants in the Baltic Sea, the Baltic Marine Environment Protection Commission conducts a periodic assessment of the concentrations of several metals in water, sediments, and fish tissues (HELCOM, 1996). Birds such as the Common Eider (*Somateria mollissima*) also may be useful for biomonitoring of marine environments because metals and trace elements tend to accumulate in Blue Mussels (*Mytilus edulis*), the primary food item of the eider (Ostapczuk et al. 1997, Öst & Kilpi 1998).

Previous studies in the Gulf of Finland have reported lead poisoning of Common Eiders and potentially toxic levels of exposure of eiders to trace elements such as selenium and arsenic (Hollmén et al. 1998, Franson et al. 2000). In addition to being indicators of environmental contamination, elevated residues of trace elements in bird tissues are of significance because of their asso-

ciation with mortality and sublethal effects in avian populations. Some of the more subtle effects of trace elements in birds include impacts on reproduction, growth, and immunocompetence (Rocke & Samuel 1991, Fairbrother et al. 1994, Stanley et al. 1994).

Our objective in the present study was to measure concentrations of arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), mercury (Hg), molybdenum (Mo), selenium (Se), and zinc (Zn) in tissues of Common Eiders from the Gulf of Finland and Baltic proper. We compared metal and trace element concentrations in tissues of hunter-killed male eiders with those in tissues of adults and ducklings that were found dead.

2. Material and methods

2.1 Sample collection

On 1 June 1997, we collected carcasses of 16 hunter-killed male eiders near Hanko (59°50´N, 22°50´E). All other samples came from birds that were found dead of no obvious cause that could be determined from field observations alone. In 1997, these included one adult female found at Tvärminne (59°50´N, 23°15´E) on 1 June, and 18 ducklings found between 22 May and 29 June at Tvärminne, Rönnskär (59°56´N, 24°22´E), and Söderskär (60°06´N, 25°25´E). In 1998, we collected carcasses of 12 adult males that were found dead on 10–11 May at Utö (59°50´N, 21°25´E), seven adult females found between 9 May and 10 June at Tvärminne, Rönnskär, and Söderskär, and 11 ducklings found between 2 June and 7 July at Tvärminne and Söderskär. Based on the dates that they were found, their body weights, and the presence or absence of a yolk sac, the estimated ages of ducklings ranged from shortly after hatching to about three weeks.

Carcasses were weighed, except for the hunter-killed males (breast muscle had been previously removed) and four ducklings that had been partially scavenged. Livers and kidneys from adults, and livers only from ducklings, were frozen (–20°C) in plastic bags until analysis for trace elements. Sections of kidney tissue were fixed in 10% buffered formalin. When elevated (> 6 ppm dry weight) (Pain 1996) lead concentrations were found in tissues, kidney sections were stained with Ziehl-Neelsen acid-fast stain and examined by light microscopy for acid-fast intranuclear inclusions. Lead inclusions are a characteristic finding in some waterfowl poisoned by lead and have been reported in Common Eiders (Hollmén et al. 1998).

2.2 Trace element analysis

Liver and kidney were analyzed by inductively coupled plasma-atomic emission spectroscopy (ICP-AES) on a GBC Integra XM27® (GBC Scientific Equipment, Inc., Arlington Heights, Illinois) spectrophotometer according to Hollmén et al. (1998). Minimum detection limits (ppm wet weight) were: Mg = 0.01; Mn = 0.05; Cd, Cu, Fe, Zn = 0.10; Cr = 0.20; Mo = 0.30; As, Pb = 0.50; Hg, Se = 1.0. Residues were not adjusted for recoveries from standard reference material (National Institute of Standards and Technology 1577b bovine liver), which were greater than 90% for all analytes. We determined the moisture content of tissue samples and report trace element concentrations as parts per million (ppm) on a dry weight basis.

2.3 Statistics

Because of the difficulty in evaluating normality of data with small sample sizes, we used nonparametric statistics. We compared trace element concentrations among the four groups (hunter-killed males, adult males found dead, adult females found dead, and ducklings found dead) with the Kruskal-Wallis test and separated pairs of medians with Dunn's multiple comparison test (Zar 1984). We assigned a concentration of one-half of the lower limit of detection to the samples that contained no residues of a particular element, as long as detectable residues were found in at least 50% of the samples within the group. If detectable residues were found in less than 50% of the samples in a group, no median was calculated and the data were not used in statistical comparisons. When a lack of residues in 50% or more of the samples resulted in only two medians for comparison, we used the Mann-Whitney *U*-test (Zar 1984). Trace element concentrations in tissues

were compared with body mass by calculating Spearman rank correlation coefficients (Zar 1984).

3. Results

3.1 Trace element concentrations

Detectable residues of copper, iron, magnesium, manganese, and zinc occurred in all tissues from adults and ducklings (Table 1). Cadmium was above detectable limits in all livers and kidneys from adults and in about half of the duckling livers, lead was detected in less than one quarter of adults and in none of the ducklings, and selenium was found in livers of about twice as many adults as ducklings (Table 1). A mercury concentration of 7.5 ppm was found in the liver of one adult female, but all other tissues were negative for mercury. Arsenic and chromium were not detected in any of the samples.

Although lead was detected infrequently in eiders, high concentrations of lead were present in tissues of two adult females found dead at Tvärminne. One of these eiders was found in 1997 and had liver and kidney lead concentrations of 98 ppm and 695 ppm, respectively. This bird had no metal in its gizzard contents, but was emaciated and had acid-fast intranuclear inclusion bodies in the proximal tubular epithelial cells of the kidney. The other female, found dead at Tvärminne in 1998, was emaciated and had one piece of lead shot in its gizzard contents and lead concentrations of 34 ppm and 52 ppm in liver and kidney, respectively. Microscopic examination of renal tissue from this eider was equivocal. Although intranuclear inclusions were found in the proximal tubular epithelium, the location where lead inclusions typically occur, the inclusions were lighter in color than the positive controls. Lead was found in kidneys (3.2–5.7 ppm) of four additional adult eiders (three hunter-killed males and one adult female found dead) and in livers (1.7–4.1 ppm) of six adults (three adult males found dead, two adult females found dead, and one hunter-killed male).

In liver tissue, concentrations of cadmium were greater in adults than in ducklings and copper was higher in both groups of adult males than in adult females and ducklings (Table 2). Iron residues were several times greater in adult males and females found dead than in hunter-killed males and ducklings. The concentration of manganese was greater in livers of hunter-killed males than in males found dead, while selenium residues were higher in males found dead than in hunter-killed males. Greater residues of zinc occurred in livers of adult males and females found dead than in hunter-killed males (Table 2).

In kidneys, hunter-killed males had lower concentrations of cadmium and zinc than males and females found dead, while the reverse was true for manganese and molybdenum (Table 3). The median concentration of copper in kidneys of adult males found dead was more than twice as high as the medians in kidneys of hunter-killed males and females found dead (Table 3).

3.2 Body mass and trace elements

In adult females, body mass (mean ± SD = 1,235 ± 205 g, median = 1,230 g, n = 8) was negatively correlated with cadmium concentrations in their livers (Spearman r = – 0.862, P = 0.011) and kidneys (Spearman r = – 0.910, P = 0.005) and copper in their kidneys (Spearman r = – 0.778, P = 0.028). The body mass (mean ± SD = 1,615 ± 198 g, median = 1,538 g, n = 12) of adult male eiders from Utö was negatively correlated with the con-

Table 1. Frequencies (%) of trace elements above detection limits[1)] in tissues of Common Eiders (*Somateria mollissima*).

Element	Adults (n = 36)		Ducklings (n = 29)
	liver	kidney	liver
As	0	0	0
Cd	100	100	55
Cr	0	0	0
Cu	100	100	100
Fe	100	100	100
Hg	3	0	0
Mg	100	100	100
Mn	100	100	100
Mo	67	67	45
Pb	22	17	0
Se	83	42	45
Zn	100	100	100

[1)] Lower limits of detection (ppm wet weight): Mg = 0.01; Mn = 0.05; Cd, Cu, Fe, Zn = 0.10; Cr = 0.20; Mo = 0.30; As, Pb = 0.50; Hg, Se = 1.00.

centration of manganese in their livers (Spearman r = – 0.668, P = 0.018). The zinc concentrations in the livers of ducklings were weakly correlated (Spearman r = 0.415, P = 0.039) with body mass (mean ± SD = 142 ± 99 g, median = 98 g, n = 25).

4. Discussion

4.1 Lead, selenium, and mercury

The lead concentrations (34 – 695 ppm, dry weight) in tissues of two adult females found at Tvärminne, combined with the findings of emaciation, acid-fast intranuclear renal inclusions, and the presence of an ingested lead shot in one of the birds, are consistent with lead poisoning (Pain 1996). These results add to the cases of lead poisoning diagnosed previously in several Common Eiders from coastal Finland (Hollmén et al. 1998), suggesting that lead exposure of eiders that nest in this region is of concern. Our findings in the present study suggest that lead shot ingestion is responsible for at least some of the lead residues found in eider blood samples collected in the Finnish archipelago (Franson et al. 2000).

Selenium occurred in detectable levels in livers of less than half of the adult females and ducklings, but in livers of all adult males. However, none of the birds had selenium concentrations in

Table 2. Concentrations (ppm dry weight) of trace elements in livers of Common Eiders (*Somateria mollissima*).

Element	Hunter-killed males (n = 16)	Males found dead (n = 12)	Females found dead (n = 8)	Ducklings found dead (n = 29)
Cd				
Median	5.49 A[1)]	10.9 A	10.9 A	0.74 B
Min–max	2.42–15.1	5.73–24.1	4.20–35.3	ND[2)]–7.87
Cu				
Median	604 A	1381 A	43.0 B	99.0 B
Min–max	148–1650	18.7–2740	12.3–97.1	3.52–929
Fe				
Median	1210 A	5020 B	7573 B	1220 A
Min–max	618–2380	3270–6060	3410–14600	154–10700
Mg				
Median	756 A	741 A	738 A	846 A
Min–max	442–833	640–820	625–978	427–4120
Mn				
Median	20.8 A	13.9 B	15.8 AB	19.3 AB
Min–max	13.4–24.7	11.3–20.8	10.8–22.0	6.34–108
Mo				
Median	2.06 A	2.04 A	–[3)]	–
Min–max	ND–3.31	ND–8.92	ND–4.40	ND–5.74
Se				
Median	14.1 A	22.5 B	–	–
Min–max	9.63–32.0	8.20–53.7	ND–20.7	ND–28.0
Zn				
Median	137 A	272 B	256 B	180 AB
Min–max	71.0–170	193–344	136–615	57.8–1190

[1)] Within rows, medians not sharing a capital letter in common are significantly different (Kruskal-Wallis test, P = 0.0482 to P < 0.0001; Dunn's multiple comparison test, P < 0.05 to P < 0.001; Mann-Whitney *U*-test, P = 0.0244).

[2)] Not detected. Lower limits of detection (ppm wet weight): Cd, Cu, Fe, Zn = 0.10; Mo = 0.30; Se = 1.00; Mg = 0.01, Mn = 0.05.

[3)] No median was calculated because the trace element was detected in < 50% of the samples.

their tissues greater than 60 ppm dry weight, which is the approximate concentration at which survival of birds may be jeopardized (Heinz 1996). This is in contrast to an earlier study in which selenium concentrations of > 60 ppm dry weight were found in livers of five of 18 adult male eiders from Söderskär (Hollmén et al. 1998).

Adult males found dead at Utö had greater residues of selenium, and several other trace elements, in their livers than hunter-killed males from Hanko. These findings could be the result of factors such as differences in dietary exposure between the two locations or the timing of sample collection (males at Utö were collected three weeks earlier than those at Hanko). The males found dead at Utö were in poor body condition, weighing much less than healthy males collected shortly before females began laying at Hanko in 1992 (mean ± SD = 2,270 ± 143 g, n = 12) (M. Kilpi, unpublished data). However, except for manganese concentrations in the liver, body mass was not correlated with trace element levels in tissues of males from Utö. Mercury was detected in the liver of only one eider, an adult male, at a concentration of 7.5 ppm dry weight. Birds that live in fresh water environments tolerate up to 20 to 30 ppm wet weight (about 60 to 90 ppm dry weight) of mercury in liver and kidney, and marine birds can apparently tolerate even higher levels (Thompson 1996).

Table 3. Concentrations (ppm dry weight) of trace elements in kidneys of adult Common Eiders (*Somateria mollissima*).

Element	Hunter-killed males (n = 16)	Males found dead (n = 12)	Females found dead (n = 8)
Cd			
Median	21.4 A[1)]	54.5 B	73.1 B
Min–max	10.8–65.8	18.0–88.0	30.0–135
Cu			
Median	44.1 A	127 B	48.2 A
Min–max	35.4–78.3	34.0–219	23.8–143
Fe			
Median	544 A	555 A	543 A
Min–max	323–684	332–777	412–708
Mg			
Median	858 A	852 A	878 A
Min–max	820–953	772–996	824–1050
Mn			
Median	14.2 A	11.3 B	10.7 B
Min–max	11.0–19.0	8.83–13.3	5.39–15.8
Mo			
Median	2.73 A	1.69 B	–[2)]
Min–max	1.94–4.20	ND[3)]–3.38	ND–1.32
Se			
Median	5.57	–	–
Min–max	ND–12.72	ND–13.2	ND–14.7
Zn			
Median	127 A	274 B	274 B
Min–max	109–155	154–333	199–496

[1)] Within rows, medians not sharing capital letters in common are significantly different (Kruskal-Wallis test, P = 0.0020 to P < 0.0001; Dunn's multiple comparison test, P < 0.05 to P < 0.001; Mann-Whitney *U*-test, P = 0.0017).

[2)] No median calculated because element was detected in < 50% of the samples.

[3)] Not detected. Lower limits of detection (ppm wet weight): Cd, Cu, Fe, Zn = 0.10; Mo = 0.30; Se = 1.00; Mg = 0.01; Mn = 0.05.

4.2 Cadmium, iron, and copper

Our finding of greater concentrations of cadmium in kidneys of Common Eiders than in their livers is typical for birds (Furness 1996). The concentrations of cadmium in tissues of eiders were below toxic levels (Furness 1996), but we found an inverse relationship between tissue residues of cadmium and body mass in adult females. Cadmium levels in the kidneys of adult males and females found dead were significantly greater than in the hunter-killed males, similar to findings of a previous study in which adult female eiders found dead at Söderskär had higher concentrations of cadmium than males that were shot (Hollmén et al. 1998).

Median concentrations of iron in the livers of males and females found dead were several times higher than the residues in hunter-killed males and ducklings. Borch-Iohnsen et al. (1991) attributed high iron content in livers of female eiders partly to catabolism of lean body tissue during incubation. Although copper residues in many species of seabirds are generally low (Thompson 1990), much greater concentrations have been found in Common Eiders (Lande 1977, Norheim & Borch-Iohnsen 1990, Hollmén et al. 1998). The copper concentrations that we found in eiders were higher than residues reported in other ducks collected in northern regions (Szefer & Falandysz 1987, Eriksson et al. 1989, Franson et al. 1995). The higher copper concentrations that we found in male versus female eiders may have been the result of gender differences or differences in diet (Haarakangas et al. 1974, Norheim & Borch-Iohnsen 1990), both of which could be related to the fact that females eat little during incubation. Differences among sites also may be involved, because copper residues in females collected exclusively from Söderskär in an earlier study (Hollmén et al. 1998) were considerably higher than residues in females (only one of which was from Söderskär) in the present study.

4.3 Magnesium, manganese, molybdenum, zinc, arsenic, and chromium

Magnesium and manganese concentrations were similar to levels found previously in eiders from Finland and Alaska (Henny et al. 1995, Hollmén et al. 1998). However, the concentrations of molybdenum that we found in eider tissues were lower than residues reported from sea ducks in Alaska (Franson et al. 1995). Zinc concentrations in the livers and kidneys of adult males and females found dead were about twice as high as in hunter-killed males, similar to results from eiders collected at Söderskär in 1994 and 1996 (Hollmén et al. 1998). Still, the zinc concentrations in eider tissues were well below tissue concentrations associated with zinc toxicity in experimental Mallards (*Anas platyrhynchos*) (Levengood et al. 1999). The fact that we found no residues of arsenic and chromium differs from the results of an earlier study in eiders where, of 36 adults sampled, arsenic and chromium were detected in four and 18 birds, respectively (Hollmén et al. 1998).

4.4 Conclusions

Other than the two adult female eiders that were poisoned by lead, it is unlikely that the metals and trace elements that we tested for were directly responsible for the mortalities observed. Potential factors that may have contributed to the differences in trace element concentrations among groups of adults include variability in exposure levels at sampling sites or wintering areas, timing of sample collections, and gender-based differences related to the nesting cycle.

Acknowledgements: Funding support was provided by a research travel grant from The American-Scandinavian Foundation. We thank H. Hedback, J. Högmander, M. Nordström, J. Pokki, V. Ranki, W. Welmala, and M. Öst for assistance with sample collection and T. Pankasalo for laboratory assistance. Helpful comments on the manuscript were provided by C. Brand and two anonymous referees.

Selostus: **Haahkan (*Somateria mollissima*) kudosten metalli- ja hivenainepitoisuuksista Suomen saaristossa**

Tutkimme metallien ja hivenaineiden (arseeni, elohopea, kadmium, kromi, kupari, lyijy, magnesium, mangaani, molybdeeni, rauta, seleeni ja sinkki) esiintymista haahkojen maksoissa ja munuaisissa. Näytteet kerättiin vuosina 1997 ja 1998

yhteensä viideltä haahkan pesimäalueelta Suomen saaristossa. Maksa- ja munuaisnäytteet tutkittiin metsästäjien ampumista koirashaahkoista sekä kuolleena löytyneistä aikuisista koiraista ja naaraista. Kuolleina löytyneistä poikasista tutkittiin maksanäytteet. Kahden aikuisen naaraan, joista toisen lihasmahasta löytyi lyijyhauli, todettiin kuolleen lyijymyrkytykseen. Muiden lintujen kudoksissa ei todettu tappavia metalli- ja hivenainepitoisuuksia.

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