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Trace element contamination in nestling black-tailed gulls (*Larus crassirostris*) in Korea

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Abstract At Hongdo Island, Gyeongsangnam-do, Korea, a breeding site of black-tailed gull (*Larus crassirostris*), we collected nestlings from two locations: a “reference” site ($n = 10$) with no known source of lead contamination and “lighthouse” site ($n = 10$) with suspected lead contamination from leaded paint. Iron concentrations in the kidney and bone, manganese in the muscle, copper in the bone, lead in the muscle and bone, and cadmium in the liver, muscle, and bone at the reference site were significantly higher than at the lighthouse. Manganese concentrations in the liver and kidney, and lead in the kidney were significantly greater at the lighthouse than at the reference site. Iron, zinc, manganese, copper, lead and cadmium concentrations had tissue-specific accumulation at both sites. Lead concentrations in 10 % of livers and in 80 % of kidneys at the lighthouse, and in 20 % of livers from the reference were within a range considered toxic (>6.00 μg/g dw in the liver and kidney). Lead concentrations in 50 % of black-tailed gull nestlings at the reference and 80 % nestlings at the lighthouse were greater in livers than in bones, which is suggestive of acute lead exposure. For cadmium, all liver and kidney concentrations from two sites were at a level considered background in birds. Cadmium concentrations of every sample were higher in kidneys than in livers, suggestive of chronic cadmium exposure. Lead concentrations in gull nestlings in the present study were relatively higher than other gull species worldwide, but cadmium concentrations were relatively lower.

Keywords Black-tailed gull nestlings · Lead · Cadmium · Acute and chronic exposure

Introduction

Trace elements are natural components in the environment and many of them serve as essential elements for organisms. They can be found in terrestrial and aquatic systems as well as atmospherically. In general, non-essential elements may also biomagnify through various food webs such that species at the higher trophic levels can accumulate higher concentrations (Hernandez et al. 1999; Niecke et al. 1999). Non-essential elements, including lead and cadmium, can damage various physiological systems such as the endocrine system (Stoica et al. 2000) and can also have a negative effect on the reproduction and general health of birds (Dauwe et al. 2004).

Seabirds, including black-tailed gulls (*Larus crassirostris*), are widely distributed and have a high trophic position in the marine food web. In bird nestlings, accumulations of essential and non-essential elements could be affected by local contamination near their breeding colonies. Black-tailed gulls forage within 3–4 km of their colonies, and their main prey includes various invertebrates, anchovies (*Engraulis japonicus*) and sardines (*Sardinops melanostictus*) (Kwon et al. 2006). These factors, combined with their long life span (Kojadinovic et al. 2007b), make them useful for monitoring trace elements in the environment. Recent studies suggest that seabirds can be used as bioindicators to assess the impact of stressors on the spatial and temporal status of aquatic environments,

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while bird tissues can be used to assess levels and bioaccumulation of heavy metal pollutants (Agusa et al. 2005; Borgå et al. 2006; Braune and Simon 2004; Kojadinovic et al. 2007a, b; Sagerup et al. 2009; Mallory et al. 2010).

In an earlier study at Hongdo Island, Korea, Lee (2003) observed a greater incidence of agonistic behavior (i.e., pecking) among conspecifics for those nestlings in closer proximity to a lighthouse. Lee suggested that highly pecked black-tailed gull nestlings had elevated lead levels due to flaking lead-based paint chips. A possible source of lead on the island was an abandoned lighthouse with visible paint chips. We hypothesized that gull nestlings near the lighthouse would have higher concentrations of lead than those farther away. In this study, black-tailed gull nestlings were evaluated for trace elements, including lead, near the lighthouse and at a reference site more than 50 m away. Heavy metal concentrations in the liver and kidney are recommended as a good bioindicator to evaluate acute exposure for lead contamination, compared to the bone, which indicates more chronic exposure (Scheuhammer 1987; Mateo et al. 2003; Church et al. 2006). Also, the liver and kidney are recommended as good bioindicators to monitor acute and chronic exposure to cadmium contamination, respectively (Scheuhammer 1987). We examined the levels and distributions of two non-essential elements (lead and cadmium) and four essential elements (iron, zinc, manganese and copper) in the liver, muscle (pectoral), kidney, and bone (femur) of black-tailed gull nestlings and evaluated acute and chronic contaminations of lead and cadmium. In addition, we compared trace element concentrations in internal tissues from this study with those from the literature to evaluate the utility of each tissue for trace element monitoring in birds.

Materials and methods

Study site and sampling

Twenty black-tailed gull nestlings were collected from Hongdo Island (34°32′N latitude, 128°44′E longitude), Gyeongsangnam-do, Korea, in June 2007. We collected gull nestlings from nests located close to (<5 m) and distant (50–250 m) from the lighthouse and analyzed iron, zinc, manganese, copper, lead, and cadmium concentrations in tissues from nestlings from both sites. The nests located close to the lighthouse (termed 'lighthouse') were in an area of suspected lead contamination from leaded paint and paint chips. In contrast, paint chips were not observed near the nests distant from the lighthouse (termed 'reference').

Black-tailed gull nestlings were marked with plastic rings 1–3 days after hatching and one chick from each nest was recaptured at 20–22 days after hatching. At capture, weight (0.1 g), culmen length (0.1 mm), and tarsus length (0.1 mm) were measured (Kwon et al. 2006). Specimens were euthanized by thoracic compressions and frozen at −20 °C until they were dissected. The liver, muscle, kidney, and bone were carefully removed from the body of the specimens, weighed (0.1 g), and stored in chemically clean jars (Fig. 1).

Trace element analysis

The liver, muscle, kidney and bone of black-tailed gull nestlings were dried in an oven for 24 h at 105 °C and weighed (±0.1 g). Approximately 3 g of each sample were digested in the presence of a mixture of concentrated nitric, perchloric and/or sulfuric acids in Kjeldahl flasks. Iron, zinc, manganese and copper concentrations were determined by flame atomic absorption (AA) spectrophotometry (Hitachi Z-6100). Low lead and cadmium concentrations in the digested solutions were extracted with DDTC (Sodium *N*,*N*-Diethyldithio-carbamate trihydrate($(C_2H_5)_2NCS_2Na \cdot 3H_2O$)-MIBK [methyl isobutyl ketone ($CH_3COCH_2CH(CH_3)_2$] and determined by flame atomic absorption (AA) spectrophotometry (Kim and Koo 2007). Eight spikes and blanks were included in the analysis (about 20 % of the total number of samples). A spike, a blank, a standard and a sample were run in triplicate in each analytical run. Spikes recoveries ranged from 94 to 106 %.

Fig. 1 Location of study site, Hongdo Island (*filled circle*) in Korea

Recovered concentrations of the samples were within 5 % of the standard error. Detection limits were 1.00 μg/g dry weight for iron and zinc, 0.10 μg/g for manganese, copper, and lead, and 0.01 μg/g for cadmium. All trace element concentrations in livers, muscles, kidneys and bones were estimated on a dry weight basis (μg/g dw).

Lead and cadmium levels

We categorized the toxicity of lead and cadmium tissue concentrations. We selected tissue-specific thresholds for lead toxicity in birds based on the reports by Pain (1996), Franson (1996), Clark and Scheuhammer (2003) and Mateo et al. (2003) where >6.0–24.0 μg/g dw liver concentrations were considered toxic and >24.0 μg/g dw liver concentrations were consistent with death. Lead concentrations in kidney >6.0 μg/g dw were considered toxic and >18.0 μg/g dw were considered consistent with death. Concentrations >10 μg/g dw in bone were considered elevated and >20 μg/g dw were associated with lethal lead poisoning (Mateo et al. 2003). Cadmium toxicity levels were based on the report by Scheuhammer (1987) where >3 μg/g dw in liver and >8 μg/g dw in kidney was considered threshold level of cadmium poisoning.

Statistical analysis

We statistically tested trace elements for differences between the reference site and lighthouse site using *t* tests and among the four tissues using one-way analysis of variance (ANOVA). The Bonferroni mean separation tests was used to separate tissue means following a significant ANOVA. Data were log transformed to obtain a normal distribution that satisfied the homogeneity of variance assumptions of ANOVA (Kim and Koo 2010). We present geometric means, 95 % confidence intervals, arithmetic mean and standard deviation in tables and texts. Pearson's rank correlation coefficient (r) was used to measure the strength of the association between tissues. A *p* value of less than 0.05 was considered to indicate statistical significance in ANOVA and Pearson's rank correlation. Statistical analyses were carried out using SPSS 13.0 version.

Results

Measurements of nestlings between the reference and the lighthouse sites

Nestlings collected at the two sites were of comparable size. The weight, bill length, wing length and tarsus length of black-tailed gull nestlings were not significantly different between the reference and lighthouse site (Table 1).

Trace elements between the reference and the lighthouse sites

All black-tailed gull nestlings appeared healthy and no marked birds were found dead. Trace element concentrations differed between the reference and the lighthouse (Table 2). Iron concentrations in the kidney (*t* test, $t = 3.629$, $p < 0.01$) and bone (*t* test, $t = 3.786$, $p < 0.01$), manganese in muscle (*t* test, $t = 3.346$, $p < 0.01$), copper in bone (*t* test, $t = 3.494$, $p < 0.01$), lead in muscle (*t* test, $t = 2.285$, $p < 0.05$) and bone (*t* test, $t = 3.350$, $p < 0.01$), and cadmium in liver (*t* test, $t = 4.812$, $p < 0.01$), muscle (*t* test, $t = 7.592$, $p < 0.001$), and bone (*t* test, $t = 5.858$, $p < 0.001$) at the reference were significantly higher than at the lighthouse. Manganese concentrations in the liver (*t* test, $t = 2.279$, $p < 0.05$) and kidney (*t* test, $t = 3.775$, $p < 0.01$), and lead in the kidney (*t* test, $t = 2.232$, $p < 0.05$) were significantly greater at the lighthouse than at the reference.

Trace elements among tissues for each site

Except for lead at the reference, trace element concentrations differed among tissues at the reference and lighthouse (Table 2). Concentrations of iron (one-way ANOVA, $F = 28.03$, $p < 0.001$, reference; $F = 21.41$, $p < 0.001$, lighthouse), manganese (one-way ANOVA, $F = 86.32$, $F = 88.87$, $p < 0.001$, respectively) and copper (one-way ANOVA, $F = 70.72$, $F = 188.2$, $p < 0.001$, respectively) in the livers, and zinc (one-way ANOVA, $F = 332.2$, $F = 92.8$, $p < 0.001$, respectively) concentrations in the bones were highest at both sites among tissues examined. Cadmium concentrations were highest in the muscle at the reference (one-way ANOVA, $F = 22.33$, $p < 0.001$) and in the kidney at the lighthouse (one-way ANOVA, $F = 22.08$, $p < 0.001$). Lead was also significantly higher in the kidney at the reference (one-way ANOVA, $F = 5.034$, $p < 0.001$).

Lead and cadmium toxicity

Lead concentrations in the liver of 20 % of black-tailed gull nestlings (8.60–12.4 μg/g dw) from the reference site and 10 % of nestlings (8.23 μg/g dw) from the lighthouse were within a range considered toxic, but all other samples were at a background level. In the kidney, 80 % of gull nestlings (6.34–10.9 μg/g dw) from the lighthouse but no nestlings from the reference were within concentrations associated with lethal lead poisoning. In the bone, all samples were within the background level.

Every black-tailed gull chick had the background level of cadmium for birds in both the liver (<3 μg/g dw) and the kidney (<8 μg/g dw).

Table 1 Measurements of black-tailed gull nestlings

	Weight (g)	Bill (mm)	Wing (mm)	Tarsus (mm)
Reference (n = 10)				
Mean ± SD	273 ± 46.1	29.7 ± 2.93	102 ± 18.9	47.5 ± 3.36
Min–max	210–352	25.5–33.6	75.0–136	42.1–53.2
Lighthouse (n = 10)				
Mean ± SD	269 ± 41.7	28.9 ± 2.63	108 ± 28.0	46.9 ± 3.32
Min–max	185–354	24.8–33.5	78.9–154	43.2–53.3
p value[a]	NS	NS	NS	NS

NS not significant

[a] Results of *t* test between sites

Ratio of liver to bone for lead and liver to kidney for cadmium

Lead concentrations in 50 % of black-tailed gull nestlings at the reference and 80 % of nestlings at the lighthouse were greater in livers than in bones (acute exposure). In contrast, 50 % of gull nestlings at the reference and 20 % of gull nestlings at the lighthouse, lead concentrations were greater in bones than in livers (chronic exposure). Cadmium concentrations of every sample at the reference and lighthouse were greater in kidneys than in livers (chronic exposure) (Table 3).

Relationships of trace element concentrations between tissues

For all the trace elements examined, significant positive correlations were observed between kidney and bone for iron (r = 0.726, $p < 0.01$), and between liver and kidney (r = 0.803, $p < 0.01$), between liver and bone (r = 0.749, $p < 0.01$), and between kidney and bone (r = 0.711, $p < 0.01$) for cadmium (Table 4).

Discussion

Tissue distribution of trace elements in black-tailed gulls

Concentration of iron in the liver, zinc in the bone, manganese and copper in the liver, and cadmium in the kidney were relatively high compared with those of other tissues in black-tailed gull nestlings (Table 1). Similar pattern with that of the black-tailed gulls was reported for these elements in various seabirds (Kim et al. 1996, 1998), four seabird species (Elliott et al. 1992), black-tailed gull juveniles and adults (Agusa et al. 2005) and juveniles and adults of three seabird species (Kojadinovic et al. 2007a, b). These tissue-specific accumulations of essential elements might be associated with normal homeostatic mechanism (Kim and Koo 2007; Kojadinovic et al. 2007a, b) and the accumulation of non-essential elements (lead and cadmium) in bird nestlings might be related to diet concentrations (Rattner et al. 2008; Kim et al. 2010) and environmental quality such as air and soil pollution (Burger et al. 1992; Boncompagni et al. 2003).

Lead and cadmium levels in gull species

Background lead concentrations in the liver, kidney and bone are considered to be 6, 6 and 10 µg/g dw, respectively (Franson 1996; Pain 1996; Clark and Scheuhammer 2003; Mateo et al. 2003). Only 15 % of specimens had liver lead >6 µg/g dw (8.23–12.4 µg/g dw); 20 % at the reference and 10 % at lighthouse. In worldwide studies, many gull species had the background mean lead levels in the liver (Elliott et al. 1992; Burger et al. 2000; Mallory et al. 2004; Agusa et al. 2005; Borgå et al. 2006), but black-headed gulls (*Larus ridibundus*) (5 fledglings and 9 adults) exceeded the background concentration (Orłowski et al. 2007). Black-tailed gull nestlings, with an average of 3.71 (reference site) and 4.52 (lighthouse site) µg/g dw in the liver, had greater levels of lead than those reported from black-tailed gulls in Japan (juveniles 0.024 and adults 0.048 µg/g dw; Agusa et al. 2005). At the lighthouse, 80 % of gull nestlings had >6 µg/g dw lead in their kidneys (6.34–10.9 µg/g dw), but compared to no gulls at the reference site. In the kidney, mean lead concentrations (reference 4.27, lighthouse 6.25 µg/g dw) from the present study and in black-headed gulls (5.51 µg/g dw, Orłowski et al. 2007) were greater than those in black-tailed gulls (0.082 and 0.249 µg/g dw; Agusa et al. 2005) and glaucous gulls (0.03 µg/g ww; Sagerup et al. 2009). In the bone, mean lead concentrations (reference 3.70, lighthouse 2.14 µg/g dw) in the present study were lower than in black-headed gulls (9.38 µg/g dw, Orłowski et al. 2007) and herring gulls (32.0–64.0 µg/g dw; Elliott et al. 1992) but greater than in black-tailed gulls (1.09 and 1.33 µg/g dw; Agusa et al. 2005).

Black-tailed gull nestlings in this study had lower means levels of cadmium in the liver compared to black-headed gulls (3.73 µg/g dwg dw) from Poland (Orłowski et al. 2007), three gull species (0.19–1.77 µg/g dw) from

Table 2 Comparison of trace element concentrations [Geomean, 95 % confidence intervals (CIs) µg/g dw] in tissues of black-tailed gull nestlings, Korea, 2007

Species	Liver	Muscle	Kidney	Bone	*p* value[a]
Iron					
Reference (n = 10)					
Geomean	494a[c]	184c	308b	63.5d	<0.001
CIs	380–608	114–254	197–419	48.7–78.3	
Mean ± SD	526 ± 184	223 ± 113	344 ± 170	66.8 ± 23.9	
Lighthouse (n = 10)					
Geomean	440a	170b	144b	24.6c	<0.001
CIs	341–540	78.9–208	64.7–275	15.2–34.0	
Mean ± SD	461 ± 161	251 ± 169	177 ± 104	29.5 ± 15.1	
p value[b]	NS	NS	<0.01	<0.01	
Zinc					
Reference (n = 10)					
Geomean	94.7b	37.7c	6.56d	176a	<0.001
CIs	83.9–106	29.0–46.5	5.55–7.57	162–189	
Mean ± SD	96.1 ± 17.5	39.9 ± 14.1	6.74 ± 1.55	177 ± 21.9	
Lighthouse (n = 10)					
Geomean	88.6b	37.4c	7.08d	184a	<0.001
CIs	78.3–99.0	20.2–54.6	6.68–7.47	174–194	
Mean ± SD	89.9 ± 16.7	47.2 ± 27.8	7.10 ± 0.63	185 ± 15.7	
p value	NS	NS	NS	NS	
Manganese					
Reference (n = 10)					
Geomean	15.5a	1.56c	2.38b	1.09c	<0.001
CIs	13.4–17.7	0.39–2.74	2.03–2.73	0.73–1.44	
Mean ± SD	16.0 ± 3.49	1.94 ± 1.90	2.43 ± 0.53	1.19 ± 0.57	
Lighthouse (n = 10)					
Geomean	20.4a	0.62d	5.34b	1.13c	<0.001
CIs	16.7–24.1	0.44–0.79	2.55–8.14	1.01–1.25	
Mean ± SD	21.2 ± 6.04	0.68 ± 0.28	6.91 ± 4.51	1.14 ± 0.19	
p value	<0.05	<0.01	<0.01	NS	
Copper					
Reference (n = 10)					
Geomean	15.3a	3.74c	6.56b	1.68d	<0.001
CIs	13.5–17.0	2.74–4.73	5.55–7.57	0.92–2.44	
Mean ± SD	15.5 ± 2.84	4.01 ± 1.61	6.74 ± 1.55	1.90 ± 1.23	
Lighthouse (n = 10)					
Geomean	17.6a	4.29c	7.08b	0.92d	<0.001
CIs	14.4–20.9	3.34–5.25	6.68–7.47	0.75–1.08	
Mean ± SD	18.4 ± 5.27	4.55 ± 1.54	7.10 ± 0.63	0.95 ± 0.26	
p value	NS	NS	NS	<0.05	
Lead					
Reference (n = 10)					
Geomean	3.71	5.29	4.27	3.70	NS
CIs	1.58–5.84	4.01–6.56	3.61–4.93	3.38–4.01	
Mean ± SD	4.58 ± 3.43	5.59 ± 1.95	4.40 ± 1.06	3.73 ± 0.56	
Lighthouse (n = 10)					
Geomean	4.52b	3.59b	6.25a	2.14c	<0.001
CIs	3.40–5.63	2.54–4.64	3.72–8.78	0.90–3.38	

Table 2 continued

Species	Liver	Muscle	Kidney	Bone	p value[a]
Mean ± SD	4.82 ± 1.80	3.95 ± 1.69	7.67 ± 4.08	2.68 ± 1.90	
p value	NS	<0.05	<0.05	<0.01	
Cadmium					
Reference (n = 10)					
Geomean	0.09c	0.29a	0.22a	0.16b	<0.001
CIs	0.07–0.11	0.21–0.38	0.16–0.26	0.14–0.17	
Mean ± SD	0.10 ± 0.03	0.32 ± 0.14	0.23 ± 0.08	0.16 ± 0.03	
Lighthouse (n = 10)					
Geomean	0.03c	0.07b	0.24a	0.05c	<0.001
CIs	0.02–0.05	0.06–0.09	0.15–0.34	0.02–0.07	
Mean ± SD	0.04 ± 0.02	0.08 ± 0.03	0.28 ± 0.14	0.05 ± 0.04	
p value	<0.01	<0.001	NS	<0.001	

NS not significant

[a] Results of one-way ANOVA among tissues

[b] Results of *t* test between sites

[c] Means sharing same letter were not significantly different among tissues

Table 3 Ratio of acute and chronic exposures for lead and cadmium on black-tailed gull nestlings

Species	Lead		Cadmium	
	Acute liver > bone	Chronic liver < bone	Acute liver > kidney	Chronic liver < kidney
Reference (n = 10)	5 (50.0 %)	5 (50.0 %)	0	10 (100 %)
Lighthouse (n = 10)	8 (80.0 %)	2 (20.0 %)	0	10 (100 %)

Table 4 Pearson's rank correlation coefficient for trace elements between tissues of the black-tailed gull nestlings (n = 20)

	Iron	Zinc	Manganese	Copper	Lead	Cadmium
Liver–muscle	0.039	−0.202	0.171	0.196	0.170	0.054
Liver–kidney	0.425	0.140	−0.071	0.323	0.315	0.803**
Liver–bone	0.236	0.372	0.276	0.108	−0.240	0.749**
Muscle–kidney	0.029	−0.111	−0.350	−0.056	−0.184	−0.041
Muscle–bone	0.102	−0.372	0.036	0.179	0.253	−0.108
Kidney–bone	0.726**	0.355	−0.271	0.106	0.089	0.711**

** $p < 0.01$

northern Baffin Bay (Borgå et al. 2006), black-tailed gulls (3.15 and 4.48 μg/g dw) from Japan (Agusa et al. 2005), glaucous gulls (1.13–10.3 μg/g dw) and herring gulls (0.53–2.16 μg/g dw) from the Barents Sea (Savinov et al. 2003) and three gull species (3.90–26.3 μg/g dw) from Chaun, Russia (Kim et al. 1996). In the present study, mean cadmium concentrations in the kidney were 0.29 (reference) and 0.07 (lighthouse) μg/g dw and these levels were relatively lower than in glaucous gulls (13.7 μg/g ww) from Spitsbergen, Norway (Sagerup et al. 2009), black-headed gulls (5.51 μg/g dw) from Poland (Orłowski et al. 2007), black-tailed gulls (14.0 and 40.7 μg/g dw) from Japan (Agusa et al. 2005), three gull species (18.7–159 μg/g dw) from Chaun, Russia (Kim et al. 1996) and herring gulls (13–40 μg/g dw) from Atlantic Canada (Elliott et al. 1992).

We found support for our hypothesis that the lighthouse site is a source of lead toxicity in black-tailed gull nestlings, as lead levels were higher in nestlings closer to the lighthouse compared to those more distant. Lead concentrations in black-tailed gulls in this study were relatively higher than in other gull species except bone lead levels in herring gulls (Elliott et al. 1992) and fledglings of black-headed gull (Orłowski et al. 2007) and cadmium concentrations were relatively lower than other gull species. Low cadmium levels in black-tailed gull nestlings might reflect their low dietary exposure to cadmium. Elevated lead concentrations in seabird nestlings was reported at a building site in a colony and was associated with the ingestion of paint chips (Work and Smith 1996; Finkelstein et al. 2003). In the present study, elevated lead concentrations might come from paint chips of the lighthouse. Lead and cadmium concentrations might vary widely among different seabird species because of feeding habits, intensity, and timing of exposure in foraging areas and their physiological and biochemical characteristics (Savinov et al. 2003; Mallory et al. 2004; Borgå et al. 2006).

It seems unlikely that the extent of lead exposure constitutes a direct threat to breeding success and the population size of black-tailed gulls, breeding on Hongdo Island, Korea. Some black-tailed gull nestlings had higher lead levels in the liver and kidney than the background levels, but we observed no obvious visible signs of exposure, such as starvation, trauma, and lesions suggestive of poisoning. In addition, the development of nestlings was normal and breeding success was over 60.0 % (Lee et al. 2008). Also, we could not find differences in chick development between the lighthouse and reference site.

Acute and chronic exposure

In black-tailed gull nestlings, 50 % at reference and 80 % at lighthouse were at an acute level of lead toxicity (the liver > the bone). The percentage was lower than other Korean birds: grey heron (88.9 %) and black-crowned night heron (*Nycticorax nycticorax*) (100 %) nestlings and eurasian eagle owls (*Bubo bubo*) (82.4 %) and white-fronted geese (*Anser albifrons*) (85.7 %), but was greater than five shorebird species (respectively, 0.00 %), black-crowned night heron nestlings (28.0 %) and adults (0.00 %), ancient murrelets (*Synthliboramphus antiquus*) (0.00 %), three shorebird species (0.00–8.33 %), two owl species (10.0–14.3 %) and spot-billed ducks (*Anas poecilorhyncha*) (26.3 %) (Kim and Koo 2007; Kim et al. 2009, 2010; Kim and Oh 2012, 2013). Also, acute level of lead exposure was 70 % in black vultures (*Aegypius monachus*) (Nam and Lee 2009). Japanese black-tailed gull nestlings and adults had greater mean lead concentration in the bone than in the liver (chronic exposure) (Agusa et al. 2005), but in the present study, gull nestlings at the lighthouse site had greater mean lead concentration in the liver than in the bone (acute exposure). In contrast, eurasian eagle owls and white-fronted geese exhibited acute exposure to lead in both juveniles and adults. Elevated lead levels in the liver might reflect recent high dietary and environmental exposure to lead. White-fronted geese might be exposed to short term lead poisoning through ingestion of lead shot and sinkers (Kim and Oh 2013). In this study, five nestlings at the reference and eight nestlings at the lighthouse exhibited acute lead exposure. Also, gull nestlings at the lighthouse site had greater lead concentrations in the liver (slightly) and kidney (significantly) than those of reference site. Therefore, we suggest that leaded paint chips might be one of main factors of the high ratio of acute lead exposure and elevated lead concentrations in livers and kidneys at the lighthouse site.

All (100 %) black-tailed gull nestlings at lighthouse and reference were considered to have chronic exposure to cadmium (the liver < the kidney). Six shorebird species (88.9–100 %, Kim and Koo 2010), black-crowned night heron adults (100 %, Kim et al. 2010), two owl species (88.2–100 %, Kim and Oh 2012), white-fronted geese and spot-billed ducks (100 %, Kim and Oh 2013) also had higher cadmium concentrations in the kidney than in the liver. Also, cadmium concentrations in black-tailed gulls from Japan suggested chronic cadmium exposure (Agusa et al. 2005). In contrast, cadmium concentrations in black vultures from Korea were acute cadmium exposure (Nam and Lee 2009).

Different accumulation trends of lead and cadmium (acute and/or chronic) were found in various birds in earlier studies. Observed different accumulation trends might be attributed to a short and/or long time difference in exposure, degree of accumulation, dilution by weight increase, and environmental quality. Bird nestlings tended to have a higher percentage of acute poisoning than those reported for adults including this study (Kim and Koo 2007). However, tissues of black-crowned night heron nestlings suggested chronic poisoning which might be associated with elevated lead and cadmium levels of prey and the environment such as water and sediment (Kim et al. 2010). Shorebird species (Kim and Koo 2007; Kim et al. 2009) and black-crowned night herons (Kim et al. 2010) had elevated mean lead levels (exceed the background) in the liver, and their bones had higher lead concentrations than those of the liver. We suggest that they might reflect long term exposure of high lead concentrations.

Essential element concentrations

In this study, significant site specific accumulations of essential element including iron, zinc, manganese and copper were observed between lighthouse and reference sites. These have been reported in various birds elsewhere (Eens et al. 1999; Horai et al. 2007; Malik and Zeb 2009; Malinga et al. 2010). Essential element concentrations can be influenced by interaction of other elements, metabolism, body condition and environmental contamination such as air, water and sediment (Deng et al. 2007; Horai et al. 2007; Degernes 2008; Malinga et al. 2010; Jerez et al. 2011). Ecological and physiological toxicities of these essential elements have been reported in various birds (Cork 2000; Takekawa et al. 2002; Sileo et al. 2003; Franson et al. 2012). In this study, tissue concentrations of essential element in black-tailed gull nestlings were within the ranges of concentrations reported elsewhere for various species of birds, including black-tailed gulls (Agusa et al. 2005; Borgå et al. 2006; Deng et al. 2007; Horai et al. 2007; Orłowski et al. 2007, 2012; Malinga et al. 2010). These elements are probably maintained by a normal homeostatic mechanism and are below health risk effect levels (Cork 2000; Takekawa et al. 2002; Sileo et al. 2003; Franson et al. 2012). However, we do not know specifically how toxic levels influence the essential trace elements.

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Conflict of interest The authors declare that they have no conflict of interest.

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