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Trace metal concentration in Great Tit (*Parus major*) and Greenfinch (*Carduelis sinica*) at the Western Mountains of Beijing, China

Haili Deng [a], Zhengwang Zhang [a,*], Chongyan Chang [b], Yong Wang [a,c]

[a] *Ministry of Education Key Laboratory for Biodiversity Sciences and Ecological Engineering, College of Life Sciences, Beijing Normal University, Beijing 100875, China*
[b] *Analytical and Testing Center, Beijing Normal University, Beijing 100875, China*
[c] *Center for Forestry and Ecology, Alabama A&M University, Normal, AL 35762, USA*

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Trace metal concentrations of Great Tits and Greenfinches from Beijing, China, varied by body part, gender, and species, and were below toxic levels.

Abstract

We examined the concentrations of 11 trace metals in tissues from 10 body parts of Great Tits and Greenfinches collected at Badachu Park in the Western Mountains of Beijing, China to assess the metal accumulation level, distribution among body parts, and species and gender related variations. The highest concentrations of Hg, Ni, Zn, and Mn were found in the feather; Pb and Co in the bone; Cd, Cr, and Se in the kidney, and Cu in the liver and heart. Metal concentrations had substantial interspecific variation with Great Tits showing higher levels of Hg, Cr, Ni, and Mn than Greenfinches in tissues of most body parts. Gender related variations were body part and species specific. Meta-analyses using data from this study and other studies suggested that metal concentrations of Great Tits at our study site were relatively low and below the toxic levels.

Keywords: Trace Metal; Great Tit; Greenfinch; Beijing; Pollution

1. Introduction

Trace metals are highly persistent and widespread contaminants. They enter the food webs through pathways such as air, water, soil, and living organisms by agricultural runoff, industrial effluent, mining and mineral processing, storm-water runoff, volcanism, natural bedrock erosion, atmospheric transport, and biogeochemical cycles (Burger and Gochfeld, 1995). As heavy metal pollution poses genuine threats to the quality of environment and biodiversity, both public and government sectors have been increasingly interested in the assessment of ecosystem health by monitoring trace metal pollution.

In recent decades, seabirds and raptors have been shown to be useful bioindicators of heavy metal pollution (Berg et al., 1966; Westermark et al., 1975; Denneman and Douben, 1993; Thompson et al., 1998; Dmowski, 1999; Movalli, 2000; Rainbow and Blackmore, 2001). There is abundant literature referring to the concentration, tissue distribution, biomagnification, and toxic effect of heavy metals in birds of prey and seabird species (Di Giulio and Scanlon, 1984; Honda et al., 1986; Caldwell et al., 1999). The concentration and distribution of a given trace metal in the body depend on the intensity and duration of exposure, the form of the metals, interactions with other toxins, and a variety of factors intrinsic to the host (Gochfeld and Burger, 1987).

Some studies have shown that high levels of metal contaminants affect survival and productivity of wildlife (Scheuhammer, 1987; Janssens et al., 2003). Chronic metal exposure to birds can result in detrimental effects on growth, development,

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* Corresponding author. Tel.: +86 010 58809666; fax: +86 010 58807721.
E-mail address: zzw@bnu.edu.cn (Z. Zhang).

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reproduction, behavior, resistance to diseases, and other physiological mechanisms (Heinz, 1979; Grue et al., 1986; Scheuhammer, 1987; Snoeijs et al., 2004; Dauwe et al., 2005). Reproductive effects could include failure to build nests, decreased testis weight, spermatogenesis failure, decreased egg production, lighter eggs, eggshell thinning, increased embryo mortality, reduced hatching success, teratogenesis and lethargy, and behavioral abnormalities in chicks (Grandjean, 1976; Heinz, 1979; Scheuhammer, 1987; Denneman and Douben, 1993; Eeva et al., 2000; Janssens et al., 2003).

Although piscivorous birds have been used in many published studies, the characteristics of wandering and feeding over a large area make it difficult to determine where they acquired the metals. Recently, some researchers explored the potential of monitoring trace metal pollution using passerine species such as Sparrows (e.g., *Passer domesticus*), Starlings (*Sturnus vulgaris*), Great Tits (*Parus major*), and Blue Tits (*Parus caeruleus*) (Getz et al., 1977; Sawicka-Kapusta et al., 1986; Eens et al., 1999; Gragnaniello et al., 2001; Dauwe et al., 2002; Chao et al., 2003). These small passerine species are ideal bioindicators because they are common and widely distributed. In addition, many passerine species have fast metabolic rates and forage in small home ranges near places often close to residential areas, making them ideal for monitoring point-source contamination. China has been experiencing dramatic economic development and population growth during the past 30 years and is becoming increasingly industrialized (Beijing Municipal Bureau of Statistics, 2005). However, little information is available about trace metal concentrations in birds in Beijing, China (except Chao et al. (2003)). Monitoring trace metal pollution with bioindicators is urgently needed.

We measured trace metal concentrations in Great Tits and Greenfinches (*Carduelis sinica*) in Beijing. Our objectives were to (1) assess the status of trace metal accumulation in these two species, (2) quantify the distribution of trace metal among body parts, (3) examine the species and gender related variation in trace metal accumulation, and (4) determine if Great Tits and Greenfinches are threatened by trace metal pollution at the study site.

2. Materials and methods

2.1. Study species

Great tits and Greenfinches are small (approximately 13 g and 19 g, respectively) passerine species that are resident in Beijing and throughout China (Li et al., 1982; Fu et al., 1998). Great Tits are primarily insectivorous, while Greenfinches feed mainly on seeds and fruits (Liang and Liu, 1958). The home range is about 0.6 ha for Great Tit (Masahiko and Noriko, 2001) and is slightly larger for Greenfinch based on our field observation. We chose these two species because of their high metabolic rate, small body size, wide distribution, and small home range, making them suitable as bioindicators of local contamination.

2.2. Specimen collection and metal analyses

We collected bird specimens from Badachu Park (39°58′39″N, 116°10′46″E), a part of the Western Mountains within the Beijing city limit. The park is about 330 ha and 17 km from the city center with the highest elevation of 470 m above the sea level. The study site is relatively undisturbed with forest cover over 97% of the total area.

We captured 25 Great Tits and 20 Greenfinches using mist nets between October and December 2004 with a permit from the Beijing Forest Bureau, China. Each bird was euthanized using ether after capture and then weighed and sexed. All samples were stored in polyethylene bags and frozen at −20 °C until processed. Tissues from 10 body parts, including the brain, lung, heart, kidney, liver, pectoral muscle, sternum, femur, femoral muscle, and feather, were taken from each bird for analysis. The feathers were washed with deionized water and acetone, and tissues were washed with deionized water. Samples were dried in an oven at 70 °C. A sample weighing 100–200 mg of each tissue was dissolved in concentrated HNO_3 (1 ml) and H_2O_2 (1 ml) for 4 h at 160 °C until the tissue was completely dissolved. Each mixture, after cooled, was poured into a numbered container and topped to 10 ml with double-distilled water and stirred. Concentrations of Hg, Se, As, Cr, Zn, Cd, Pb, Ni, Co, Mn, and Cu were determined using an Axial Inductively Coupled Plasma Atomic Emission Spectrophotometer (ICP-AES) (Jobin Yvon-ULTIMA). All samples were analyzed in batches with certified reference material [GBW (E) 0801793] from the National Research Center for Certified Reference Materials (Beijing, China). The results for the certified reference materials were within the accepted confidence intervals.

2.3. Statistical analysis

The distribution of most variables was not normal. Transformations could not improve the distribution and thus, the original data were used for the analysis. We used nonparametric Mann–Whitney *U* tests to compare the metal concentrations between species (Great Tits versus Greenfinches) and between genders (male versus female). To assess difference in trace metal concentration in the feather of Great Tits among the individuals from our study site and those from five other locations, we performed a meta-analysis using one-way ANOVA, followed by Tukey multiple comparisons when ANOVA tests were significant. All tests were two-tailed with the significance level of ≤ 0.05. Concentrations of metals were given relative to dry weight. Unless mentioned otherwise, means were reported ±standard error (SE). Statistical analyses were performed using SPSS for Windows 11.0 (SPSS, 2000).

3. Results

3.1. Trace metal distributions among body parts

The average body mass of Great Tits and Greenfinches was 10.65 ± 0.94 g and 14.98 ± 1.58 g, respectively. Except As, the levels of trace metal differed among tissues of different body parts in each species (Table 1), indicating tissue-specific accumulation of these elements. In general, the concentrations of the non-essential elements (Hg, As, Pb, and Cd) were lower than that of essential elements (Zn, Se, Cu, Cr, and Mn). In both species, Hg had the highest concentration in the feather and the least in the sternum (Table 1). Pb accumulated differently in the tissues, and its concentration in the hard tissues (feather, sternum and femur) was much higher than in viscera, followed by brain and muscle tissues (Table 1). Concentration of Cd was higher in the kidney and liver than that in other tissues. The brain and muscle tissues (cardiac, pectoral, and femoral muscles) possessed the least Cd. The concentration of As was relatively constant in different body parts.

Among the essential elements, concentrations of Ni and Co were much lower than the others. Feather possessed most Mn, followed by the kidney (Table 1). The concentration of Cu was significantly higher in the liver, kidney and muscles (heart and pectoral) than that in other body parts (Table 1). Cu and Mn

Table 1
Trace metal concentrations (mean ± SE, μg/dry g) in tissues of Great Tit ($n = 25$) and Greenfinches ($n = 20$) at Badachu Park in the Western Mountains, Beijing, China

	Great Tit Feather	Greenfinch		Great Tit Kidney	Greenfinch		Great Tit Liver	Greenfinch		Great Tit Lung	Greenfinch		Great Tit Brain	Greenfinch	
Hg	5.06 ± 0.40	2.92 ± 0.37	**,[a]	1.58 ± 0.61	**0.009**[b]	**	0.56 ± 0.22	0.05 ± 0.01	ns	0.24 ± 0.09	**0.009**	**	0.41 ± 0.16	**0.009**	**
As	3.34 ± 0.79	1.06 ± 0.19	*	1.91 ± 0.70	0.44 ± 0.13	ns	1.49 ± 0.66	**0.009**	ns	2.49 ± 0.74	0.57 ± 0.11	ns	**0.009**	0.26 ± 0.1	ns
Pb	3.44 ± 0.76	7.43 ± 0.45	***	1.21 ± 0.37	0.68 ± 0.08	ns	0.64 ± 0.15	0.45 ± 0.06	ns	1.66 ± 0.61	0.94 ± 0.19	ns	**0.01**	0.27 ± 0.06	ns
Cd	0.11 ± 0.09	**0.001**	ns	1.32 ± 0.25	2.59 ± 0.41	**	0.68 ± 0.10	0.56 ± 0.09	ns	**0.001**	0.08 ± 0.02	ns	**0.001**	**0.001**	ns
Se	2.17 ± 0.19	1.24 ± 0.14	***	5.47 ± 0.33	5.50 ± 0.30	ns	4.17 ± 0.39	3.46 ± 0.18	ns	2.15 ± 0.18	1.95 ± 0.1	ns	1.39 ± 0.10	1.01 ± 0.15	ns
Cr	2.22 ± 0.13	1.54 ± 0.12	**	6.26 ± 1.08	2.61 ± 0.47	**	1.86 ± 0.33	0.96 ± 0.34	**	8.90 ± 1.99	1.10 ± 0.11	***	1.65 ± 0.26	1.12 ± 0.28	*
Zn	276.60 ± 32.18	128.64 ± 8.28	***	85.50 ± 6.18	88.05 ± 2.43	ns	117.15 ± 7.91	105.89 ± 6.95	ns	44.64 ± 3.29	31.72 ± 0.84	***	55.86 ± 3.38	46.57 ± 3.73	ns
Ni	2.50 ± 0.18	1.36 ± 0.08	***	1.48 ± 0.19	0.91 ± 0.12	*	0.60 ± 0.09	0.28 ± 0.09	**	3.00 ± 0.80	0.57 ± 0.08	***	0.54 ± 0.08	0.32 ± 0.06	ns
Co	**0.002**	**0.002**	ns	0.11 ± 0.04	0.16 ± 0.05	ns	0.06 ± 0.01	0.02 ± 0.01	**	**0.002**	**0.002**	ns	**0.002**	**0.002**	ns
Mn	7.12 ± 0.49	7.14 ± 0.41	ns	6.58 ± 0.40	6.08 ± 0.24	ns	5.14 ± 0.27	4.28 ± 0.22	*	1.38 ± 0.25	0.81 ± 0.03	ns	1.95 ± 0.08	1.68 ± 0.10	ns
Cu	2.78 ± 0.28	8.09 ± 0.38	***	16.11 ± 0.99	20.62 ± 0.83	**	37.47 ± 3.37	27.01 ± 3.52	**	1.67 ± 0.35	1.82 ± 0.05	*	9.71 ± 0.38	11.09 ± 0.93	**
	Femur			Sternum			Pectoral Muscle			Femoral Muscle			Heart		
Hg	0.31 ± 0.23	0.04 ± 0.01	ns	0.21 ± 0.08	**0.009**	*	0.46 ± 0.19	0.05 ± 0.01	ns	0.33 ± 0.17	**0.009**	ns	0.44 ± 0.17	**0.009**	**
As	**0.009**	0.42 ± 0.10	ns	0.55 ± 0.24	0.78 ± 0.22	*	0.10 ± 0.05	0.22 ± 0.07	ns	**0.009**	0.25 ± 0.06	ns	0.67 ± 0.31	**0.009**	ns
Pb	5.81 ± 0.27	7.41 ± 0.80	ns	4.66 ± 0.41	7.48 ± 0.79	*	**0.01**	0.11 ± 0.03	ns	1.08 ± 0.49	**0.01**	**	0.79 ± 0.22	**0.01**	ns
Cd	0.12 ± 0.02	0.18 ± 0.02	*	0.08 ± 0.02	0.16 ± 0.01	***	**0.001**	**0.001**	ns	**0.001**	**0.001**	ns	**0.001**	**0.001**	ns
Se	1.36 ± 0.16	1.19 ± 0.12	ns	1.28 ± 0.08	1.36 ± 0.09	ns	1.45 ± 0.07	3.27 ± 0.26	***	1.49 ± 0.14	2.54 ± 0.16	***	2.51 ± 0.14	2.96 ± 0.19	ns
Cr	2.78 ± 0.92	1.72 ± 0.32	ns	1.83 ± 0.31	0.94 ± 0.07	*	1.14 ± 0.20	1.07 ± 0.54	*	3.82 ± 1.17	1.18 ± 0.31	***	4.66 ± 0.95	0.69 ± 0.06	***
Zn	167.25 ± 6.28	164.36 ± 5.72	ns	124.11 ± 5.18	144.58 ± 4.71	**	32.15 ± 2.77	31.37 ± 1.69	ns	92.09 ± 6.61	108.70 ± 2.71	**	52.00 ± 1.90	47.36 ± 1.38	*
Ni	0.98 ± 0.22	1.05 ± 0.10	ns	0.71 ± 0.10	0.78 ± 0.06	ns	0.41 ± 0.08	1.76 ± 1.51	ns	0.82 ± 0.12	0.30 ± 0.07	***	1.30 ± 0.22	0.40 ± 0.10	**
Co	0.31 ± 0.02	0.42 ± 0.03	**	0.21 ± 0.02	0.37 ± 0.02	***	0.03 ± 0.01	**0.002**	*	**0.002**	**0.002**	ns	0.12 ± 0.02	**0.002**	**
Mn	3.67 ± 0.21	3.84 ± 0.16	ns	3.25 ± 0.14	4.08 ± 0.13	***	1.82 ± 0.19	1.87 ± 0.07	ns	1.48 ± 0.12	1.12 ± 0.04	*	2.98 ± 0.23	1.75 ± 0.05	***
Cu	3.71 ± 0.14	3.09 ± 0.06	***	7.02 ± 0.29	6.83 ± 0.21	ns	13.66 ± 0.85	18.99 ± 0.93	**	7.33 ± 0.52	8.03 ± 0.18	ns	19.29 ± 1.13	20.33 ± 0.62	ns

***$P < 0.001$, **$P < 0.01$, and *$P < 0.05$.

[a] Nonparametric Mann–Whitney U test was used to compare the differences between the two species.

[b] Numbers in bold indicate the equipment detection limits, and the metal concentrations in the tissues were below the limits.

concentrations were the lowest in lung tissues. The concentration of Zn was higher than that of other trace elements for both species (Table 1). However, Zn varied by body parts with relatively higher concentration in the bone, feather, and liver and low concentration in the pectoral muscle. Se exhibited the highest concentration in the kidney and the least in the brain and bone (Table 1). Co burden was much higher in the bone (femur and sternum), and was lower in the feather (Table 1).

3.2. Interspecific variations

The concentration of metals varied between the two species although the birds were captured at the same site (Table 1). Hg, Cr, Ni and Mn were higher in tissues of most body parts of Great Tits than that of Greenfinches; Se was higher in the feather and lower in the muscles of Great Tits than that of Greenfinches. Compared to Greenfinches, Zn in Great Tits was higher in the lung and feather and lower in the sternum and femoral muscles. Co burden was higher in the heart and lower in the bone of Great Tits than those of Greenfinches. Cu was higher in the liver and femoral muscle and was lower in the kidney, pectoral muscle, brain, and feather of Great Tits than that of Greenfinches. We did not detect interspecific differences in As. The distribution of Cr and Ni in Great Tits differed from that in Greenfinches (Table 1). Cr burden was higher in the lung, kidney and heart than that in other tissues of Great Tits, while it had the highest concentration in kidneys of Greenfinches. Ni burden was higher in the lung and feather than in the kidney and heart of Great Tits, while in Greenfinches, the highest concentration of Ni was found in the pectoral muscle, followed by the feather, bone, and kidney.

3.3. Gender variation

In general, trace metal concentration in different body parts were similar between males and females in both species. However, in the liver and feather, there were significant gender related differences, and the pattern was species specific (Tables 2 and 3). In Great Tit, males possessed higher Cr and Ni in the liver and Se in the feather than females, while females had higher levels of Cd in these body parts (Table 2). In Greenfinch, males had higher concentrations of As and Zn than females in the feather, while females had higher concentrations of Zn and Se in the liver (Table 3).

Table 2
Trace metal concentrations (mean ± SE, µg/dry g) in tissues of male ($n = 15$) and female ($n = 10$) Great Tits at Badachu Park in the Western Mountains, Beijing, China

		Cd	Cr	Se	Ni
Feather	Female	0.19 ± 0.15	2.39 ± 0.16	1.82 ± 0.19	2.70 ± 0.27
	Male	**0.001**[b]	1.99 ± 0.18	2.62 ± 0.30*[,a]	2.24 ± 0.22
Liver	Female	0.92 ± 0.12	1.04 ± 0.13	4.63 ± 0.71	0.33 ± 0.06
	Male	0.42 ± 0.11**	2.91 ± 0.55*	3.71 ± 0.34	0.93 ± 0.12**

Trace metals that did not show gender difference were not included in the table.
**$P < 0.01$ and *$P < 0.05$.
[a] Nonparametric Mann–Whitney U test was used to compare the differences between males and females.
[b] Numbers in bold indicate the equipment detection limits, and the metal concentrations in the tissues were below the limits.

Table 3
Trace metal concentrations (mean ± SE, µg/dry g) in tissues of male ($n = 10$) and female ($n = 10$) Greenfinches at Badachu Park in the Western Mountains, Beijing, China

		As	Zn	Se
Feather	Female	0.57 ± 0.19	106.56 ± 6.89	1.28 ± 0.19
	Male	3.75 ± 1.39**[,a]	202.40 ± 31.78**	1.20 ± 0.17
Liver	Female	0.18 ± 0.19	120.02 ± 9.81	4.02 ± 0.16
	Male	0.10 ± 0.03	91.76 ± 7.98*	2.90 ± 0.20**

Trace metals that did not show gender difference were not included in the table.
**$P < 0.01$, and *$P < 0.05$.
[a] Nonparametric Mann–Whitney U test was used to compare the differences between males and females.

3.4. Locational variations

The meta-analysis suggested that trace metal concentrations in the feathers of Great Tits varied greatly among the sites. However, the major difference was between the polluted site at Antwerp, Belgium and the other five locations for the concentrations of Cd, Cu, and Pb. The Zn level of Great Tits from Beijing was higher than Wilrijk and Kalmthout Heath of Belgium (Table 4).

4. Discussion

4.1. Distribution patterns of trace metals

Trace metal concentrations differed between the two species, and were unevenly distributed among body parts in both species of this study. Higher concentrations of Hg, Ni, Zn, and Mn were found in feather; Pb and Co in the bone; Cd, Cr, and Se in the kidney; and Cu in the liver and heart. Other studies have shown the similar body part specific distributions such as high concentrations of trace elements in the feather, bone, kidney, liver, and low concentrations in the brain and muscle (Honda et al., 1985, 1986; Kim et al., 1998; Nam et al., 2005). The distribution patterns of trace elements among the body parts in Great Tit and Greenfinch may be related to the metabolism and detoxification. Birds can eliminate metals (such as Hg and Pb) through sequestration in the feather and bone. Moreover, there is a type of metallothionein in the kidney and liver, which can bind some metals such as Hg, Cd, Zn, Se, and Cu.

4.2. Interspecific variations

Although both species in this study are year-round residents and captured at the same study site, significant interspecific differences were observed in metal concentrations among

Table 4
Cadmium, copper, lead, and zinc concentrations (mean ± SE, μg/dry g) in the feather of Great Tit from different studies

	n	Cd	Cu	Pb	Zn
Badachu Park, Beijing, China (This study)	25	0.11 ± 0.09b[e]	2.78 ± 0.28b	3.44 ± 0.76b	276.60 ± 32.18a
Baiyunshan, Guangzhou, China[a]	4	0.20 ± 0.10b	14.80 ± 4.55b	16.80 ± 5.15b	188.00 ± 29.20ab
Wilrijk, Belgium[b]	15	2.56 ± 1.03b	13.82 ± 3.34b	16.28 ± 1.83b	172.66 ± 14.74b
Kalmthout Health, Belgium[b]	16	0.81 ± 0.06b	6.16 ± 0.36b	12.57 ± 2.82b	178.51 ± 11.56b
Polluted site, Antwerp, Belgium[c]	32	11.60 ± 1.50a	88.00 ± 14.00a	250.00 ± 34.00a	240.00 ± 25.00ab
University Antwerp, Belgium[c]	50	0.93 ± 0.07b	7.60 ± 0.90b	7.10 ± 0.6b	176.00 ± 11.00a
F		31.74***[,d]	13.05***	34.17***	3.97**

$^{***}P < 0.001$ and $^{**}P < 0.01$.

[a] Zou et al. (2005).

[b] Eens et al. (1999).

[c] Dauwe et al. (2002).

[d] One-way ANOVA was used to test the difference among the locations.

[e] Means with the same letter in the same column are not different based on Tukey multiple comparisons.

body parts. We have two explanations for this. Firstly, it might be caused by variation in diet between the two species. Most food items of Great Tit are insects, while Greenfinch feed mostly on seeds and fruits (Liang and Liu, 1958). It has been suggested that insectivorous birds accumulated more metals than those species feeding on seeds (Gochfeld and Burger, 1987; Burger and Gochfeld, 1995, 2000; Eens et al., 1999; Goutner et al., 2001). Secondly, it may be caused by differences in physiology between the two species; metabolic rates of small passerines vary inversely with body weight and directly with activities such as flight and rest (Teal, 1969; Welty, 1975); being smaller than Greenfinches, Great Tits were expected to have higher metabolic rate. Higher metabolic rates may cause fast accumulation of trace metals in Great Tits. Our data, in general, support these two hypotheses because the concentrations of most trace metals were higher in Great Tit than in Greenfinch. Additional studies are needed to test the independent effect of these two factors.

4.3. Gender variations

Several studies have examined the effect of gender on the accumulation of trace metals in the feather or other tissues (Hutton, 1981; Gochfeld and Burger, 1987; Burger and Gochfeld, 1992; Movalli, 2000). Our results suggest that gender related differences were small in most body parts except in the feather and liver. Our data also suggest that the gender related variations were species and metal specific. For example, the concentrations of Cd, Cr, Se, and Ni differed between males and females in Great Tit, while As, Zn, and Se differed between males and females of Greenfinch.

Gender related variation in trace metal accumulation could be related to ecological or physiological factors. Braune and Gaskin (1987) reported that female Bonaparte's Gull (*Larus philadelphia*) could excrete a higher percentage of the body burden of mercury than males in autumn molt. Several studies have also suggested that birds might tolerate some trace metals through metal interactions with calcium and magnesium, and the process was gender specific (Burger and Gochfeld, 1992; Dauwe et al., 2002). Moreover, there is gender related variation in the capability of eliminating trace metals. Females can sequester metals into eggs, which is an effective process for maintaining a lower body burden of trace metals than males (Burger and Gochfeld, 1992; Dauwe et al., 2002).

4.4. Assessment of the trace metal risks at the Western Mountains of Beijing

Among the six locations that we performed meta-analysis, Cd, Cu, and Pb concentrations of Great Tit from our study site were lower. The four sites from Belgium suffered from trace metal pollution in different degrees. Wilrijk is situated at a site close to a waste incinerator of 30 000 ton/year. Although the Kalmthout Heath is the largest state nature reserve of the Flanders, it also suffered from some degree of atmospheric pollution from trace industry situated in the vicinity of the reserve. The polluted site at Antwerp, Belgium had the highest concentration of Cd, Cu, and Pb because the study site is bounded by a metallurgic factory responsible for an extremely high and local pollution with several trace metals including Cd, Cu, Pb, and Zn (Dauwe et al., 2002). Although Baiyunshan at Guangzhou of China is a famous scenic site without major industry in the vicinity, and its environmental quality, to certain degree, is similar to our study site, the concentrations of Cu and Pb in the feather of Great Tits from Guangzhou were about five times higher than the birds of the same species in this study. We suspect this difference was caused by locational variation within the two sites. Compared to the tits from Poland (Sawicka-Kapusta et al., 1986), Norway, and Italy (Hogstad, 1996), tree sparrows from Beijing (Chao et al., 2003), and some seabirds (Burger and Gochfeld, 1995; Kim et al., 1998), the concentrations of most metals (except Cu and Zn) in the tissues of Great Tit and Greenfinch in this study were relatively low, and the absolute concentration was well below the levels reported to have toxic effects. Cu and Zn are essential to the wildlife, and birds often can accumulate a large quantity in their body or feather. Acute Cu poisoning was described in Canada Goose (*Branta canadensis*) with liver Cu concentrations of 187–323 μg/g (Henderson and Winterfield, 1975). Clinical signs of Zn poisoning were observed in Mallards (*Anas platyrhynchos*) with liver Zn concentrations of 473–1990 μg/g (Levengood et al., 1999).

Although the concentration of Zn was the highest in the feather of Great Tits in this study among the six locations, the liver Zn concentration of Great Tits and Greenfinches was still much lower than the level leading to pathological kidney damage (200 µg/dry g, Hutton and Goodman, 1980). Moreover, there was no evidence that the birds from the Western Mountains of Beijing suffered acute toxicities of trace metals. Therefore, we believe that trace metal pollution was limited, and there was no metal toxicity threat to Great Tit and Greenfinch at our study site.

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