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Tissue distribution and association of heavy metal accumulation in a free-living resident passerine bird tree sparrow *Passer montanus* ☆

Jian Ding [a b], Shengnan Wang [b], Wenzhi Yang [b], Huijie Zhang [b], Fei Yu [a], Yingmei Zhang [b]

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Highlights

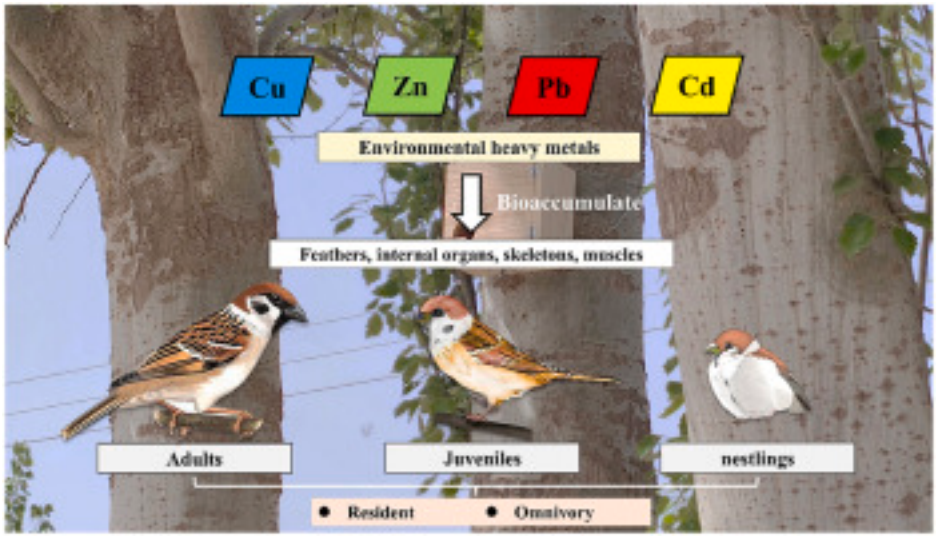
- Higher heavy metal and lower Ca accumulation in sparrows were found in a polluted site.
- Accumulation of heavy metals in organs and tissues of sparrows varied with age and sex.
- The organs and tissues with the greatest accumulation of metals were feathers.
- Correlations of heavy metals between organs and tissues were strong in nestlings and adults.
- Feathers could well predict heavy metals in other organs and tissues.

Abstract

Passerine birds have been increasingly used as effective sentinels of ecosystem contamination. They can provide direct evidence of the bioavailability and accumulation of heavy metal elements in the environment. In this study, the bioaccumulation of four heavy metals (Cu, Zn, Pb, and Cd) and Ca in different organs and tissues (feathers, internal organs, skeletons, and muscles) of an urban bird, tree sparrow (Passer montanus), collected from a polluted site [Baiyin (BY)] and a relatively unpolluted site [Liujiaxia (LJX)], and their associations were investigated. There were significantly higher and lower concentrations of heavy metals and Ca, respectively, in different organs and tissues of sparrows in BY than

those in LJX. However, except for Pb, the heavy metal levels were below the threshold of sublethal effects. Age-dependent variations in metals were quantified, and it was found that adult bird contained higher concentration of different organs and tissue metals, except for feathers, compared with nestlings and juveniles. The tissue distribution of heavy metals in sparrows of different ages and sex was similar in the two study sites, and heavy metal elements were mainly accumulated in the feathers. This study further investigated the correlation between heavy metals in different organs and tissues and found that the correlations between them were strong in nestlings and adults but weak in juveniles. In addition, Pb and Cd in internal organs, skeletons, and muscles of young sparrows can be estimated using feathers, whereas Cu and Zn were found in adult sparrows. Altogether, our results suggest that tree sparrows will serve as valuable biomonitors of environmental heavy metal pollution and will underscore the importance of tissue types in avian ecotoxicology field studies.

Graphical abstract



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Introduction

Owing to growing urbanization, industrialization, and agricultural activities, large quantities of pollutants have continuously been introduced into ecosystems and have caused irreparable effects. Heavy metal contamination is widely present and nonbiodegradable in the environment, so it may adversely affect ecological quality (Fu et al., 2014; Lv and Liu, 2019). Heavy metals can be biomagnified in food chains, but when heavy metal concentrations exceed the threshold value in organisms, it will negatively affect organisms, such as humans and wildlife (Cooper et al., 2017; Mukhtar et al., 2020). Hence, heavy metal accumulated in high trophic level organisms, and the risk of heavy metal pollution and exposure has attracted widespread attention.

To monitor environmental heavy metal pollution, monitoring schemes that use indicator species to estimate the levels in the ecosystem have been developed. Therefore, analyzing heavy metal contamination in living organisms, such as wildlife, is more attractive and promising than analyzing metals of the abiotic environment as wildlife can provide precise information regarding the bioavailability and biotransference of heavy metal pollutants (Markowski et al., 2013; Bauerová et al., 2017). Animals at the top of the food chain, especially birds, may bioaccumulate higher amounts of metals in their tissues, depending on age, size, and feeding habits (Alleva et al., 2006). Birds occupy a wide range of trophic levels in different food chains; thus, several studies have shown interest in using birds as bioindicators of heavy metal pollution, thereby monitoring the pollution risk, distribution characteristics, and effects on wildlife of heavy metals in the environment. Some passerines, such as sparrows and tits, are potentially useful bioindicators for monitoring local metal pollution because they are ubiquitous and have a smaller home range (Dauwe et al., 2005; Pan et al., 2008; Eeva et al., 2020). Therefore, numerous studies have recently assessed the effects and exposure risks of environmental heavy metal pollution on passerines (Costa et al., 2013; Markowski et al., 2013; Bauerová et al., 2017; Cooper et al., 2017).

Heavy metals can accumulate in bird's tissues, so assessing their enrichment levels in tissues can provide important information regarding the environmental situation (Dmowski, 1999). Noninvasive samples, such as feathers and excrement (Dauwe et

al., 2000; Adout et al., 2007; Costa et al., 2013; Markowski et al., 2013); common internal organs, such as livers and kidneys (Swaileh and Sansur, 2006; Kitowski et al., 2017; Mukhtar et al., 2020); other tissues, such as skeletons and muscles (Zhang and Ma, 2011; Mukhtar et al., 2020); and eggs (Espín et al., 2016; Ding et al., 2019) have been successfully used in biomonitoring studies on environmental metal pollution. The use of feathers in such analyses has an undisputable advantage as they are easy to collect, nondestructive, and reproducible (Adout et al., 2007), and they are assumed to represent intra-annual heavy metal exposure levels, such as flight and body feathers, which can reflect a long-term accumulation of metal elements (Dauwe et al., 2002a; Dauwe et al., 2002b). Bird excrement is a mixture of feces and urine that can reflect unabsorbed food residues and absorbed and excreted elements (Dauwe et al., 2000; Costa et al., 2013). Other organs and tissues, such as the liver, kidney, and skeleton, are also commonly used to assess enrichment levels and exposure risk, but metal accumulation rates in birds vary depending on the target tissues and type of metal. For instance, Pb tends to bind to skeletons and Cd tends to bind to kidneys and livers (Dauwe et al., 2005; Valladares et al., 2013). In addition, for many birds, it is difficult to define adult age by morphology, making it hard to examine the bioaccumulation of toxic substances with age. Nevertheless, it is possible to distinguish juveniles or first organisms. Owing to feeding differences and contaminants, some studies found that young birds often have lower levels of heavy metals compared with adults (Gochfeld et al., 1996; Malinga et al., 2010). Therefore, it is necessary to understand the enrichment levels of heavy

metals in different organs and tissues of wild birds at different age stages and the correlations between organs and tissues, whether external or internal.

In this study, we identified age and sex-related metal levels in different tissues (e.g., primary feather, tail feather, breast feather, liver, kidney, heart, lung, skeleton, and muscle) of nestlings, juveniles, and adults of one small passerine species tree sparrow (*Passer montanus*) at two study sites known to have either low or high metal contamination. This study aimed 1) to explore the possible difference in the two sites as well as to find an association of heavy metal concentrations among different tissues, if any, dependent on age and sex, 2) to estimate the bioaccumulation trends during the lifetime of tree sparrows from the two study sites differing in metal levels, 3) to evaluate the potential for using feathers to predict heavy metal concentrations in internal organs, skeletons, and muscles, and 4) to evaluate the use and advantage of nondestructive and destructive methods of sampling in assessing metal and metalloid concentrations in birds. This study may be important for understanding both the enrichment and excretion processes of heavy metals in wild birds and the toxicity threshold of heavy metals.

Section snippets

Ethics statement

The study complied with the Committee in the Ethics of Animal Experiments of the School of Life Sciences, Lanzhou University (ethical permission no. 20170315)....

Study sites and species

The study is a part of a long-term monitoring study on the effects of environmental pollution on wild birds, which has been ongoing since 2014. The study site, Silong Town (104°23′E, 36°26′N), a moderately polluted area that has been contaminated by industrial wastewater from metal smelting for a long time, with Cu, Zn, Pb, and Cd as the…

Metal level and distribution

There were significant differences in the metal levels of sparrows between the two study sites. A summary of statistical analyses is presented in the supplementary material **(Tables S6–S11)**. The heavy metal levels in feathers of sparrows were significantly higher in BY than in LJX ($F>4.688$, $p<0.037$), and internal organs, skeletons, and muscles showed the same trend ($F>3.700$, $p<0.050$) (Fig. 1). The Ca levels in primary feathers and skeletons in sparrows were lower in BY than in LJX…

Heavy metal accumulation and characteristics

Heavy metals are of special concern to the region of Baiyin because of potential biomagnification and the exposure risks, especially tied to pollution from Pb–Zn mining and smelting (Liu, 2003; Liu et al., 2018; Wang et al., 2012). The concentrations of Cd in soil and Pb and Cd in water all exceeded the environmental quality standards by two-fold, and heavy metal concentrations in food sources and the daily metal intake per unit of body weight for sparrows was also much higher (Ai et al., 2019) …

Conclusion

To increase available information on environmental heavy metal concentrations and determine the potential effects of environmental metal pollution on wild animals, small resident passerines can be selected as bioindicators to determine the potential effects of environmental pollutants. We found that tree sparrows had higher heavy metals and lower Ca contents in a prolonged contaminated environment and that tree sparrows of different ages and sex had different tissue distributions and…

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Credit author statement

Jian Ding: Methodology, Investigation, Writing – original draft, Writing – review & editing. **Shengnan Wang**: Validation, Investigation. **Wenzhi Yang**: Investigation. **Huijie Zhang**: Investigation. **Fei Yu**: Formal analysis. **Yingmei Zhang**: Supervision, Conceptualization, Writing – review & editing, Funding acquisition.…

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.…

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Recommended articles

References (71)

M. Abdullah *et al.*

Avian feathers as a non-destructive bio-monitoring tool of trace metals signatures: a case study from severely contaminated areas

Chemosphere (2015)

A. Adout *et al.*

Determination of trace elements in pigeon and raven feathers by ICPMS

Int. J. Mass Spectrom. (2007)

P. Bauerová *et al.*

Associations of urban environmental pollution with health-related physiological traits in a free-living bird species

Sci. Total Environ. (2017)

J. Burger

A framework and methods for incorporating gender-related issues in wildlife risk assessment: gender-related differences in metal levels and other contaminants as a case study

Environ. Res. (2007)

J. Burger *et al.*

Metal levels in feathers of 12 species of seabirds from Midway Atoll in the northern Pacific Ocean

Sci. Total Environ. (2000)

Z. Cooper *et al.*

Heavy metal bioaccumulation in two passerines with differing migration strategies

Sci. Total Environ. (2017)

T. Dauwe *et al.*

Relationships between metal concentrations in great tit nestlings and their environment and food

Environ. Pollut. (2004)

T. Dauwe *et al.*

Great and blue tit feathers as biomonitors for heavy metal pollution

Ecol. Indicat. (2002)

J. Ding *et al.*

Effects of environmental metal pollution on reproduction of a free-living resident songbird, the tree sparrow (*Passer montanus*)

Sci. Total Environ. (2020)

J. Ding *et al.*

Variations in tree sparrow (*Passer montanus*) egg characteristics under environmental metal pollution

Sci. Total Environ. (2019)

J. Ding *et al.*

Does environmental metal pollution affect bird morphometry? A case study on the tree sparrow *Passer montanus*

Chemosphere (2022)

S. Espín *et al.*

Effects of experimental calcium availability and anthropogenic metal pollution on eggshell characteristics and yolk carotenoid and vitamin levels in two passerine birds

Chemosphere (2016)

J. Fu *et al.*

Heavy metals in surface sediments of the Jialu River, China: their relations to environmental factors

J. Hazard Mater. (2014)

B.L. Liu *et al.*

Metal bioaccessibility in a wastewater irrigated soil-wheat system and associated human health risks: implications for regional thresholds

Ecol. Indicat. (2018)

Z.P. Liu

Lead poisoning combined with cadmium in sheep and horses in the vicinity of non-ferrous metal smelters

Sci. Total Environ. (2003)

J.S. Lv *et al.*

An integrated approach to identify quantitative sources and hazardous areas of heavy metals in soils

Sci. Total Environ. (2019)

P.A. Movalli

Heavy metal and other residues in feathers of laggar falcon *Falco biarmicus jugger* from six districts of Pakistan

Environ. Pollut. (2000)

H. Mukhtar *et al.*

Assessing the association and predictability of heavy metals in avian organs, feathers, and bones using crowdsourced samples

Chemosphere (2020)

R.B. Payne

Mechanisms and control of molt

Avian Biol. (1972)

A.M. Scheuhammer

The chronic toxicity of aluminium, cadmium, mercury, and lead in birds: a review

Environ. Pollut. (1987)

P.N. Smith *et al.*

Contaminant exposure in terrestrial vertebrates

Environ. Pollut. (2007)

P. Szefer

Interphase and trophic relationships of metals in a southern Baltic ecosystem

Sci. Total Environ. (1991)

S.L. Wang *et al.*

Speciation and Risk Assessment of Cd, Zn, Pb, Cu and Ni in Surface Sediments of Dongdagou Stream, Baiyin, China. 2012 International Symposium on Geomatics for Integrated Water Resource Management

(2012)

W.Z. Yang *et al.*

Variation in genetic diversity of tree sparrow (*Passer montanus*) population in long-term environmental heavy metal polluted areas

Environ. Pollut. (2020)

W.W. Zhang *et al.*

Waterbirds as bioindicators of wetland heavy metal pollution

Procedia Environmental Sciences (2011)

S.W. Ai *et al.*

Metal exposure risk assessment for tree sparrows at different life stages via diet from a polluted area in northwestern China

Environ. Toxicol. Chem. (2019)

E. Alleva *et al.*

Organochlorine and heavy-metal contaminants in wild mammals and birds of Urbino-Pesaro province, Italy: an analytic overview for potential bioindicators

Arch. Environ. Contam. Toxicol. (2006)

T.M. Ansara-Ross *et al.*
The use of feathers in monitoring bioaccumulation of metals and metalloids in the South African endangered African grass-owl (*Tyto capensis*)
Ecotoxicology (2013)

Å.M.M. Berglund *et al.*
Temporal trends in metal pollution: using bird excrement as indicator
PLoS One (2015)

J. Blom *et al.*
A comparative study of growth, skeletal development and eggshell composition in some species of birds
J. Zool. (2004)

J. Burger *et al.*
Mercury and other metals in eggs and feathers of glaucous-winged gulls (*Larus glaucescens*) in the Aleutians
Environ. Monit. Assess. (2009)

A.J. Clark *et al.*
Lead poisoning in upland-foraging birds of prey in Canada
Ecotoxicology (2003)

R.A. Costa *et al.*
Assessing heavy metal pollution using great tits (*Parus major*): feathers and excrements from nestlings and adults
Environ. Monit. Assess. (2013)

T. Dauwe *et al.*

Tissue levels of lead in experimentally exposed zebra finches (*Taeniopygia guttata*) with particular attention on the use of feathers as biomonitors

Arch. Environ. Contam. Toxicol. (2002)

T. Dauwe *et al.*

Can excrement and feathers of nestling songbirds be used as biomonitors for heavy metal pollution?

Arch. Environ. Contam. Toxicol. (2000)

There are more references available in the full text version of this article.

Cited by (3)

Bioconcentration of heavy metals in Dinodon Rufozonatum around the Wanshan mercury mining area, Guizhou Province ↗

2024, Huanjing Kexue Xuebao/Acta Scientiae Circumstantiae

The First Field-Laboratory Probing on the Distribution of Metals(Loids) in Fifteen Raptorial Bird Species of Iran at a National Scale ↗

2024, SSRN

Analysis of Heavy Metal Bioaccumulation and Correlation in Nidirana adenopleura from the Wanshan Mercury Mining Area ↗

2024, Chinese Journal of Wildlife

☆ This paper has been recommended for acceptance by Professor Christian Sonne.

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