





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

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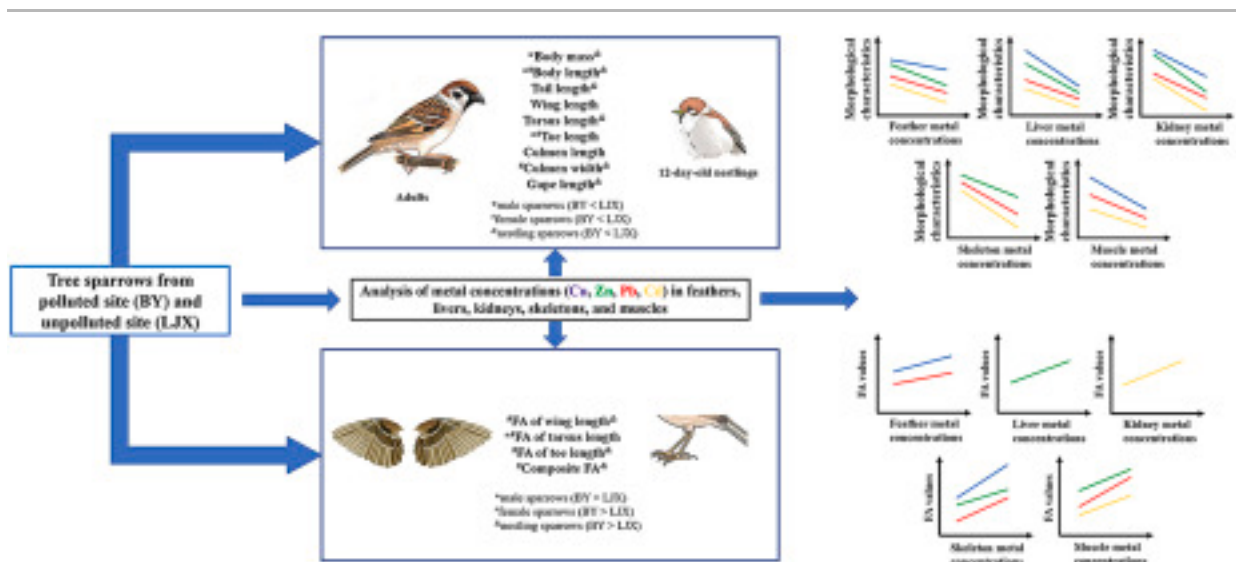
- Tree sparrow morphological characteristics can be used as indicators of metal pollution.
- Smaller body sizes and higher FA values of sparrows were found in the metal-polluted site.
- Negative correlations were found between heavy metals and morphological characteristics.
- Positive correlations were found between heavy metals and FA values.
- The decreased nestling growth rate was associated with higher FA values.

Abstract

Morphological characteristics are the leading indicators of the health status of birds. To explore the effects of heavy metals on bird morphometry in natural populations, tree sparrows (Passer montanus) were studied in a polluted site [Baiyin (BY)] and a relatively unpolluted site [Liujiaxia (LJX)]. This study aimed to examine whether morphological variables, the fluctuating asymmetry (FA) of the wing, tarsus, and toe length, were associated with heavy metals (Cu, Zn, Pb, and Cd) and Ca levels in different tissues and feces of adults and nestlings. Results showed that adults collected from BY contained relatively higher heavy metal concentrations and lower Ca concentrations in different

tissues than those from LJX. Smaller body sizes and higher FA levels of adults and nestlings were found in BY than in LJX. Although higher heavy metal concentrations in some tissues were associated with smaller morphological characteristics of adults, the effects were not obvious in nestlings. The most correlated heavy metal with as many characteristics was heavy metal in primary feather in both sites, and the most affected characteristic was body mass in BY. The FA values of adults and nestlings in BY were positively affected by heavy metal concentrations in different tissues and feces. The growth rate of wing and tarsus length of nestlings in BY were negatively affected by the FA values of wing and tarsus length, respectively. Taken together, environmental metal pollution might affect the morphological characteristics of tree sparrows. These findings suggest that the morphological characteristics of tree sparrows, especially FA, can be used as indicators of metal pollution, underscoring the importance of measuring morphological characteristics in avian ecotoxicology field studies.

Graphical abstract



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Introduction

Heavy metal pollution is a persistent and global problem often produced by human activities. It has spread throughout the environment and resulted in ecosystem changes that affect the growth and survival of wild animals (He et al., 2005; Alleva et al., 2006). Habitat quality is important for the survival and reproduction of wild animals, but heavy metal pollution of habitats can cause health risks to wild animals through bioaccumulation or biomagnification in the food chains/webs (Ali and Khan, 2019).

Birds, especially passerines, are useful biomonitoring species of pollutants due to their wide distribution, contamination sensitivity, and high level in the food chain (Furness, 1993; Dauwe et al., 2002; Eeva et al., 2009; Costa et al., 2017). When measuring

population viability, stress-mediated changes should preferably be measurable before direct components of fitness, such as survival and reproductive success, are affected (Clarke, 1995).

Morphological characteristics, such as body mass, tarsus length, and wing length, are the leading indicators of the health status of birds (Dauwe et al., 2006a). Although the morphological characteristics of wild birds may be affected by heavy metal pollution, understanding the relationship between bird morphometry and heavy metal accumulation is incomplete (Vincent, 2005; Albayrak and Pekgöz, 2021).

In addition to studying the conventional morphological characteristics, fluctuating asymmetry (FA; small nondirectional departures of bilateral traits from perfect symmetry due to variation in development; Ludwig, 1932) has received increasing attention and has been suggested as a promising method for environmental assessment (Clarke, 1993). FA is the morphological attribute believed to comprise a more sensitive stress marker and does not require laborious recaptures and destructive sampling (Clarke and McKenzie, 1992; Lens et al., 2002). FA of individuals has been reported to increase as a response to stress, especially environmental pollution (Sillanpää et al., 2010; Herring et al., 2017). Observed asymmetries can reflect the inability of individuals to buffer the development against a small and random disturbance (Auffray et al., 1999). The possible mechanism of a relationship between environmental stress and FA is that the organism compensates for stress through increased energy use (Leung et al., 2000), reducing the energy use available for growth

and reproduction (Sommer, 1996). Thus, FA is a biologically relevant bioindicator for studying stress and developmental stability caused by environmental pollutants in situ. Many studies have shown positive relationships between environmental metal exposure and the FA level of birds (Eeva et al., 2000; Sillanpää et al., 2010; Herring et al., 2017). Although most studies have compared the population level of mean FA, populations differ in features other than specific environmental stress that require a more powerful way to access environmental metal pollution pressure. Thus, studying the relationship between FA and individuals from the same population exposed to different stress levels is also necessary.

Many small passerines, such as tits and sparrows, are particularly useful for monitoring local environmental metal pollution due to their small territories and foraging areas (Dauwe et al., 2006a; Eeva et al., 2009; Albayrak, 2017). The tree sparrow (*Passer montanus*) is native to most of Eurasia and is one of the most intimate birds to humans and the most successful animal in adapting itself to human living environments (Lang and Barlow, 1997). This species is a small, omnivorous, hole-breeding passerine that forages in urban environments and can be an ideal bioindicator of local contamination (Pinowski et al., 1993; Pan et al., 2008). Therefore, this study selected the tree sparrow as its study species, a common resident songbird in the study sites.

Several studies have suggested the effects of metal pollution on sparrows (Pinowski et al., 1993; Swaileh and Sansur, 2006; Baker et al., 2017). There are some studies on the morphological

characteristics of the house sparrow in the same genus under environmental metal-polluted conditions (Albayrak, 2017; Albayrak and Pekgöz, 2021). However, there is a lack of understanding of the morphological variation of tree sparrows exposed to environmental heavy metal pollution. Previous studies have suggested that metal pollution may negatively affect the survival and reproduction of tree sparrows (Ai et al., 2019; Ding et al., 2019, 2020; Yang et al., 2020). This study examined whether metal contamination would affect the morphological characteristics and FA values of tree sparrows. The objectives of this study were (1) to measure the concentrations of heavy metals (Cu, Zn, Pb, and Cd) and Ca in male and female sparrows from two study sites differing in metal levels, (2) to measure the morphological characteristics and FA levels of adult and nestling sparrows from two study sites differing in metal levels, and (3) to investigate the morphological characteristics and FA values in response to different metal levels.

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Ethics statement

The experiments 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 tree sparrow, a resident bird with a habitat range of approximately 2–3 km (Pan and Zheng, 2003), was studied in the two study sites (110 km apart) in Gansu Province from 2016 to 2019. The first study site, Silong Town in Baiyin (BY) City (104°23'E, 36°26'N), is polluted by numerous large industrial enterprises, with Cu, Zn, Pb, ...

Metal levels

There were significant differences in the metal levels of adult sparrows between the two sites (**Table S6**). Heavy metal levels in tissues were significantly higher in BY than in LJX (male: Cu, $F_{1,34} > 5.093$, $p < 0.031$; Zn, $F_{1,34} > 6.751$, $p < 0.014$; Pb, $F_{1,34} > 3.903$, $p < 0.050$; Cd, $F_{1,34} > 5.810$, $p < 0.022$; female: Cu, $F_{1,28} > 8.815$, $p < 0.007$; Zn, $F_{1,28} > 5.153$, $p < 0.033$; Pb, $F_{1,28} > 5.987$, $p < 0.022$; Cd, $F_{1,28} > 5.365$, $p < 0.029$). The Ca levels in primary feather and skeleton were lower in BY ...

Heavy metal contents and enrichment characteristics

Toxic metals and trace metal elements are essential in many biological processes but may be harmful and even toxic in larger

amounts for various organisms. Heavy metals could easily accumulate in different tissues and organs, such as feathers, kidneys, and skeletons, of different birds (Yu et al., 2011; Suljevic et al., 2019). Compared to the less contaminated site LJX, male and female sparrows from BY contained higher heavy metal concentrations in different tissues, except for Zn...

Conclusion

Increasing available information on heavy metal concentrations and bioindicators of resident small passerines is necessary to determine potential effects of environmental pollutants on wild birds in contaminated areas. We herein observed that heavy metal accumulation in some tissues and feces significantly altered the morphology of tree sparrow. In a prolonged heavy metal-polluted environment, tree sparrows had higher heavy metal and lower Ca contents and experience negative impacts on their...

Author contributions statement

Jian Ding: Methodology, Investigation, Writing – original draft, Writing – review & editing. Wenzhi Yang: Investigation, Data curation, Software. Shengnan Wang: Investigation, Resources. Huijie Zhang: Investigation, Resources. Yingmei Zhang: Supervision, Conceptualization, Writing – review & editing, Funding acquisition, Formal analysis....

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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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2023, Environmental Pollution


Citation Excerpt :

...They readily nest in fabricated nest boxes, so some samples can easily be collected. In previous studies, tree sparrows have been proven to


indicate heavy metal contamination in the study sites, such as causing changes in reproductive and morphological characteristics (Ding et al., 2020; Yang et al., 2020; Ding et al., 2022). In addition, since the surrounding environment and food sources contained higher metal concentrations (Liu et al., 2016; Liu et al., 2018; Ai et al., 2019), tree sparrows are at risk of exposure for consuming higher heavy metal concentrations in the contaminated study site (Tables S1–S3)....

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