

# Comparative Study of Lead Concentration in Feathers of Urban and Rural Passerines in Merida, Mexico

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**Abstract** Lead is a commonly monitored heavy metal because of potential health effects on exposed organisms. We quantified lead in secondary feathers of two passerine bird species, clay-colored thrushes (*Turdus grayi*) and great-tailed grackles (*Quiscalus mexicanus*), from an urban and a rural site in the municipality of Merida, Yucatan. Urban lead concentration was significantly higher than its rural counterpart for both species ( $p < 0.05$ ). In the urban site, lead concentration was similar in both species ( $p = 0.14$ ). However, data from the rural site showed that lead concentration was significantly higher in thrush feathers ( $p < 0.05$ ). Lead levels herein presented are among the lowest ever reported suggesting that either lead accumulation or absorption is limited. Finally, our data seem to support the hypothesis that species feeding ecology plays a major role in lead accumulation.

**Keywords** Lead · Clay-colored thrush *Turdus grayi* · Great-tailed grackle *Quiscalus mexicanus* · Karst system · Yucatan · Mexico

Pollution is perhaps one of the most pervasive and harmful consequences of the environmental degradation caused by humans worldwide (Lind et al. 2006). A common approach to quantify pollution levels in the environment is based on

the use of bioindicators, organisms whose biological and ecological traits increase their likelihood of exposure to the pollutant (Battaglia et al. 2005). Information on chemical concentrations in bioindicators is valuable because it can provide insight into the biomagnification or biodilution of pollutants through the food web (Campbell et al. 2005). Birds are good bioindicators; their ubiquity (Brown et al. 1997) and their ability to bind metals in feathers (Burger and Gochfeld 1996) make them ideal study subjects. Sampling feathers has practical advantages over other tissues since it is a non-invasive technique, with no birds needing to be killed, and individuals can be resampled through time.

In this study we analyzed lead (Pb) concentration in feathers of two passerine species, the clay-colored thrush (*Turdus grayi*) and the great-tailed grackle (*Quiscalus mexicanus*). Although feather Pb load can be the result of internal and external contamination (Ek et al. 2004), internal concentrations can be attributed to Pb physiologically bound during feather formation. High levels of heavy metals in tissues of wild birds can be the product of environmental pollution transmitted through the food chain (Carpene et al. 2006). External concentrations originate from Pb particle depositions on the feather surface (Pain et al. 2005). The genus *Turdus* has been described as a generalist ground feeder that consumes a wide variety of invertebrates and fruits, dependent on the season of the year. The major food classes observed in stomach content are soft-bodied invertebrates, hard-bodied invertebrates and fruits (Martin et al. 1951). Vidal-Astudillo (2007) recorded an increase of fruit consumption during the rainy season and an increase of invertebrate consumption during dry (reproductive) season in *T. ignobilis*. Grackles have been described as generalists that consume mainly terrestrial invertebrates while breeding, and fruits and grains

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when not breeding (Elphick et al. 2001). The leading diet items of the genus *Quiscalus* in stomach content are bees, grasshoppers, crickets, spiders, myriapods, crustaceans (crayfish and sow bugs), earthworms, snails, and some vertebrates such as toads, salamanders, mice and birds' eggs. Farm crops were the major constituents of the plant diet (Martin et al. 1951).

The main objective of the present study was to assess Pb concentration in feathers in order to substantiate Pb pollution in Merida, a fast-growing city in southeast Mexico. We focused on Pb because it stands as a public health threat mainly due to the long-term effects associated with impaired central nervous system anatomy and function (Cecil et al. 2008). Lead also poses a threat to environmental health since it is highly persistent in soil and water (Agency for Toxic Substances and Disease Registry 2007). It can be transported great distances via the movement of air masses (Bollhöfer and Rosman 2001) and in that way, affect areas with little local contamination. For that reason, we also compared Pb bioavailability between the city and rural sites, assuming the rural site would present lower values, useful for future studies as a reference.

## Materials and Methods

Clay-colored thrushes and great-tailed grackles were captured with mist nets within the municipality of Merida, Yucatan, Mexico. Birds were collected in two contrasting sites: a zoo located in the core built-up area of the city henceforth referred to as urban (20°58'47"N, 89°36'53"W) and in a nature reserve henceforth referred to as rural (20°47'19"N, 89°35'26"W), 21 km from the city (Euclidean distance). The urban land cover is a mixture of cement, dirt, and small vegetated patches interspersed between animal exhibitions, whereas the rural site (1075 km<sup>2</sup> in area), is a former henequen (*Agave fourcroydes*) hacienda characterized by secondary vegetation in different stages of succession, preserved as the water supply area for the city.

We collected the left third secondary feather from apparently healthy birds for a total of 123 samples (40 thrushes and 83 grackles). All samples were individually identified, kept in plastic bags, and stored until shipped for analysis. Each bird was released on the site of capture after banding.

Lead analysis was conducted in the Atomic Spectroscopy Laboratory of the Autonomous University of Yucatan. In order to assess Pb bioavailability, external contamination was eliminated through feather washing (Adout et al. 2007). Feathers were washed once with ultrapure water in an ultrasonic bath during 5 min to remove external contamination. Washed feathers were then

rinsed with ultrapure water and oven dried at 50°C for 24 h. Dried samples were weighed, and submitted to a digestion with nitric acid (CEM-Corporation Mars-5 microwave digester, Graz, Styria, AT) and subsequently diluted with ultrapure water. The accuracy and precision of the Pb analysis were performed using the method previously described by ICP-MS method 6020 (USEPA 2007) and Wrobel et al. (2004). Lead concentration based on dry weight (d.w.) was determined using an inductively coupled plasma atomic spectrophotometer model X-Series II (Thermo Fisher Corp., Waltham, MA, USA).

Quality control was carried out with method blanks, calibration standards, spiked samples and blind samples. Recoveries of Ge, Tm and Bi internal standards were 97.9 %–99.9 %. Equipment optimization was achieved using a standard sample multi-elemental solution (Thermo Fisher Corp.) using signals of Li, In, U, and oxide percentages of (CeO+/Ce) and Ba double species. Detection limits were 0.05 ppb. All concentrations were expressed as µg/kg (ppb) d.w.

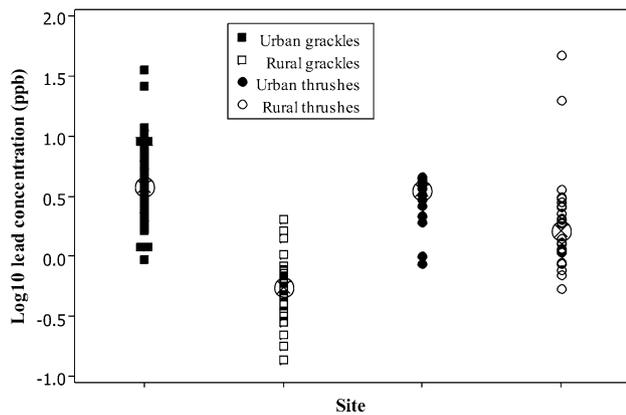
Reported statistics are arithmetic means and ±95 % confidence limit, medians and minimal and maximal values (Table 1). Data were log transformed. Grubbs's (1969) test was used to determine if the extreme values observed in each sample were statistical outliers. For improved visualization, log transformed data were used in Fig. 1. As Pb concentrations did not show a normal distribution, we employed a nonparametric Mann–Whitney-U test. We tested two hypotheses: (1) for both sites, that there were no differences in interspecific Pb concentration and (2) for both species, that Pb concentration was higher in the urban site. Statistical significance was set at  $p < 0.05$ . All statistical analyses were performed using Software 16 (Minitab Inc., State College, PA, USA).

## Results and Discussion

An important fraction of birds had concentrations below 1.0 ppb (30.8 %) while the majority of the birds had concentrations under 10.0 ppb (95.1 %). The range of Pb concentrations differed between species and the pattern changed between sites (Fig. 1).

**Table 1** Descriptive statistics of lead concentrations (ppb) in feathers of two passerine species captured in two habitats in Merida, southeast Mexico

Habitat	Species	N	Mean (95 % CI)	Min.–Max.	Median
Urban	Thrushes	14	3.10 (2.46–3.73)	0.87–4.58	3.49
	Grackles	49	5.40 (3.73–7.06)	0.95–35.82	3.82
Rural	Thrushes	26	4.19 (0.50–7.87)	0.55–47.50	1.64
	Grackles	34	0.63 (0.49–0.76)	0.13–2.02	0.55



**Fig. 1** Distribution of lead concentration (ppb) in feathers of two passerine species collected in an urban and rural site in southeast Mexico. Median represented as *circled times*

The highest mean Pb concentrations were detected in urban great-tailed grackles, while the lowest were observed in grackles from the rural site (Table 1). We found one extreme value in each group except in that of urban thrushes. Although these data were determined to be statistical outliers, we decided not to exclude them from the analyses since we consider the referred individuals to represent populations in response to typical contamination (Pain et al. 2005).

Among urban birds, Pb concentration did not differ between species (Mann–Whitney  $U = 1657$ ,  $n_1 = 14$ ,  $n_2 = 49$ ,  $p = 0.14$ ) while for rural birds Pb concentration did differ between species (Mann–Whitney  $U = 665$ ,  $n_1 = 26$ ,  $n_2 = 34$ ,  $p < 0.001$ ). With respect to habitat type, data showed that Pb concentration in the urban site were higher than the rural site both for thrushes (Mann–Whitney  $U = 377$ ,  $n_1 = 14$ ,  $n_2 = 26$ ,  $p = 0.01$ ) and grackles (Mann–Whitney  $U = 2874$ ,  $n_1 = 49$ ,  $n_2 = 34$ ,  $p < 0.001$ ).

To our knowledge, this is the first report of Pb levels for clay-colored thrushes and great-tailed grackles, two common species through their distribution range. The species sampled in this study accumulated Pb in their feathers; this confirms Pb bioavailability in the study areas. Lead concentrations found in this study are not comparable to concentrations found in other studies with similar design. Lead levels are usually around three orders of magnitude higher (Roux and Marra 2007; Scheifler et al. 2006; Frantz et al. 2012; Abbasi et al. 2015). The closest values were reported for primary and secondary feathers from Spanish imperial eagle carcasses with a median concentration of 8 and 22 ppm respectively (Rodríguez-Ramos et al. 2011). However, food items consumed by eagles and passerines and their position in the food chain differ, influencing Pb accumulation in feathers (Abbasi et al. 2015). Both species showed a site-dependent contrast with different magnitudes, the urban concentration being twofold higher for

thrushes and seven-fold higher for grackles (Fig. 1). Getz et al. (1977) registered a similar trend in which the smallest coefficient in passerines was close to two and the largest being above thirty-five.

The relatively low levels herein reported suggest that the sampled birds are either only slightly exposed to Pb or that the accumulation of Pb in their feathers is limited. Calcium rich diets reduce Pb absorption (Peraza et al. 1998); Merida rests on a limestone platform (karst) rich in calcium carbonate (Bauer-Gottwein et al. 2011). We propose that the birds are not accumulating Pb at expected concentrations because Pb intestinal absorption is limited by the presence of calcium in the diet. Both species are ground foragers and consume invertebrates, thus calcium sources in the diet are high, not only because of the ingestion of soil particles but also from the invertebrates. Therefore, there is a possibility for decreased Pb absorption. Further studies are needed to estimate environmental loading of Pb in the study sites, and to assess the risk it poses to exposed organisms.

Concentrations showed the traditional distribution found in other studies: a positively skewed distribution linked to the presence of point sources; a basal amount of lead and some individuals of the population with extremely high concentrations (Pain et al. 2005). It is noteworthy that 95 % of birds sampled had Pb concentrations below 10 ppb. Birds with concentrations over 10 ppb were either urban grackles ( $n = 4$ ) or rural thrushes ( $n = 2$ ). Old paint has been known as a source of Pb; in both groups paint flakes from old structures may be acting as a source (Erickson 2003), even for rural thrushes, since some old constructions are still present in the rural area. Though Pb contamination of ground dwelling invertebrates such as earthworms, larval coleopterans and surface dwelling arthropods such as ants and spiders may be lower in the rural site (Scheifler et al. 2006; Berglund et al. 2009) total Pb exposure may be higher for rural thrushes via food web transfer, understanding that their diet may include a larger proportion of these invertebrates. Diet composition may also vary between sites, as urban birds were observed foraging on human food leftovers. There is evidence that diet composition, determined in turn by habitat characteristics or landscape composition, can affect Pb and other pollutants transfer (Fritsch et al. 2012; Schipper et al. 2012) and thus accumulation.

In the present study, both species were suitable bioindicators showing Pb in feathers and site-dependent trends. Additionally, this study has shown that by studying more than one species the magnitude of the contrast between sites may be demonstrated. Several criteria have been set to qualify a species as a suitable bioindicator (Esselink et al. 1995), in some cases particularly in urban areas close to point sources, it is difficult to find a naturally occurring species that can be used. Even with this shortcoming it is important to assess the species ecological traits

in terms of the spatial and temporal heterogeneity of exposure so that collected data suffice to cover the risk spectrum of environmental contamination. In this case both species fulfilled criteria, with grackles excelling because of size, ubiquitous presence and adaptation to anthropic environments. However, future studies should contemplate the inclusion of species with different feeding habits.

The present study demonstrated that Pb is bioavailable in the municipality of Merida, and this evidence should encourage a deeper analysis of the phenomenon. A relevant question that arises is the actual Pb absorption in organisms in the food webs of ecosystems with an underlying karst geological foundation.

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