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Abstract We assessed the levels of Pb, Cd, and Mn in contour feathers of the feral pigeon (*Columba livia*) and house crow (*Corvus splendens*) obtained from five urban/suburban locations across Sri Lanka, using the AAS following wet digestion. Our key objectives were to compare accumulation levels in the two avian species with different foraging habits and living in common locations, and to establish baseline information on the presence of these metals in multiple locations in Sri Lanka with varying levels of urbanization. Owing to reservations that have been expressed by previous workers regarding the use of feathers for assessing heavy metal pollution, we first tested the efficacy of contour feathers by using our data for comparing the coefficients of variation in metal levels within and between locations. This showed that in over 95% of the cases, variations within locations were lower than between locations, indicating that freshly shed contour feathers that were used in the present study were reliable indicators of the status of bioaccumulation of the heavy metals in the environment. In interspecific comparisons, other than in the two suburban locations, Pb was present at much higher levels in the house crow than in the feral pigeon, whereas accumulation patterns with respect to Cd and Mn were inconsistent, suggesting that granivores may not, in all situations, accumulate lower levels than scavengers in the same environment. Owing to such interspecific variations in the patterns of accumulation of different heavy metals, the selection of a single species for assessing levels of pollution from heavy metals may not be prudent. Pb and Cd levels in both species were strongly and positively associated with human population density. The levels of Pb and Cd were highest in Colombo (commercial capital). In Colombo and Kalutara, the recorded levels in the house crow exceeded the thresholds that have the potential to inflict adverse impacts on avian species.

Keywords Contour feathers · Granivore · Monitoring · Pollution · Scavenger

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Introduction

Heavy metals are one of the main environmental pollutants known to accumulate and cause adverse effects in faunal species. The degree of heavy metal accumulation varies with the bioavailability of the contaminant in the environment, the duration of exposure, and the taxa concerned (Ali et al. 2019). Birds acquire heavy metals primarily via the ingestion of contaminated food and water, and therefore, their foraging habits would be expected to have a strong influence on the levels of accumulation. It is reported that scavengers, which occupy multiple trophic levels, and raptors, which are top

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carnivores, accumulate high amounts of heavy metals (Castro et al. 2011; Rajamani and Subramanian 2015; Golden et al. 2016), whereas granivores, being primary consumers, accumulate lower amounts (Adout et al. 2007).

Feathers, in which the level of bioaccumulation of heavy metals in proportion to the body load is reported to be fairly constant (Furness et al. 1986; Monteiro et al. 1998; Movalli 2000; Burger and Gochfeld 2009; Costa et al. 2013; Janaydeh et al. 2016), have been used for bioaccumulation studies. The advantage of using feathers is that they offer a readily available and non-invasive tool for gaining information, repeatedly if necessary, on heavy metal levels in the environment (Burger 1993; Mateo et al. 1999; Brait and Filho 2011; Abdullah et al. 2015). But, reservations have been expressed with regard to the use of feathers for assessing the levels of pollutants in the environment owing to the high degree of variability in accumulation levels reported to occur between different types of feathers and between individual feathers (e.g., Nam et al. 2003; Brait and Filho 2011; Debén et al. 2012). Martínez et al. (2012) detected a high degree of inter- and intra-individual variability in Hg levels accumulated in contour feathers of the Common buzzard (*Buteo buteo*) and Goshawk (*Accipiter gentilis*). Burger and Gochfeld (2000) report that in chicks of two albatrosses in the Midway Atoll, metal loads were higher in down feathers than in contour feathers. Feathers of nestlings, those that are recently grown or are still connected to the blood circulatory system, have been recommended over those from adult birds for assessing heavy metals (Burger 1993). A study of the house crow (*Corvus splendens*) has highlighted the usefulness of breast feathers as a suitable indicator for heavy metal accumulation (Janaydeh et al. 2016). Different parts of a single feather may also accumulate heavy metals to varying degrees. For example, in feathers of the Cinereous vulture (*Aegypius monachus*) the calamus and vane had different levels of heavy metals (Yamac et al. 2019). External contamination is also of serious concern when using molted feathers (Borghesi et al. 2017). A study by Dmowski (1999) with nestlings of the Blue tit showed that external contamination causes the vanes to have higher concentrations compared with the shaft, higher in top parts compared with base parts, and higher in older feathers compared with younger ones. This concern can be addressed to some degree by using freshly molted feathers (Borghesi et al. 2017). Some studies have recommended that analyses of heavy metals should be restricted to the shaft or rachis of feathers which would have less external contamination and can be easily and effectively cleaned (Ganz et al. 2018). Probably for these reasons feathers have been suggested as a means of passive monitoring of environmental concentrations of metals, whereby they would provide a snapshot of the pollutant load in the environment, but not necessarily the actual ambient levels (Jaspers et al. 2019).

In Sri Lanka, previous studies have reported a steady rise in heavy metal loads in the environment brought about by anthropogenic activities arising from urbanization and other developments including industrialization and intensified agriculture (Kananke et al. 2015; Herath et al. 2018). Taking this into consideration, we assessed accumulation levels of two non-essential and highly toxic heavy metals, lead (Pb) and cadmium (Cd), and one essential heavy metal, manganese (Mn), in contour feathers of two synanthropic avian species, the house crow (*Corvus splendens*) and feral pigeon (*Columba livia*), collected from five locations across Sri Lanka, with varying levels of urbanization and concomitant human population densities.

The present study intended to (i) verify the effectiveness of using freshly molted contour feathers for assessing levels of heavy metal pollutants in the environment, (ii) compare levels of Pb, Cd, and Mn in two avifaunal species living in the same environment but having different foraging habits (house crow a scavenger and the feral pigeon a granivore), and (iii) establish baseline information on the presence and levels of the two potentially toxic heavy metals Pb and Cd in the environment, and predict how this might impact humans and wildlife in the selected locations.

Materials and methods

Feather collection

Fresh contour feathers were used for our study, as previously done by Bortolotti and Barlow (1985), and Ahmadpour et al. (2013). Feathers were obtained from five locations across Sri Lanka: Colombo, Kalutara, Matara, Ampara, and Kithulgala (Fig. 1), with varying levels of urbanization as depicted by differences in the human population density. The population density values were obtained from the most recent information available with the Department of Census and Statistics, Sri Lanka (https://www.citypopulation.

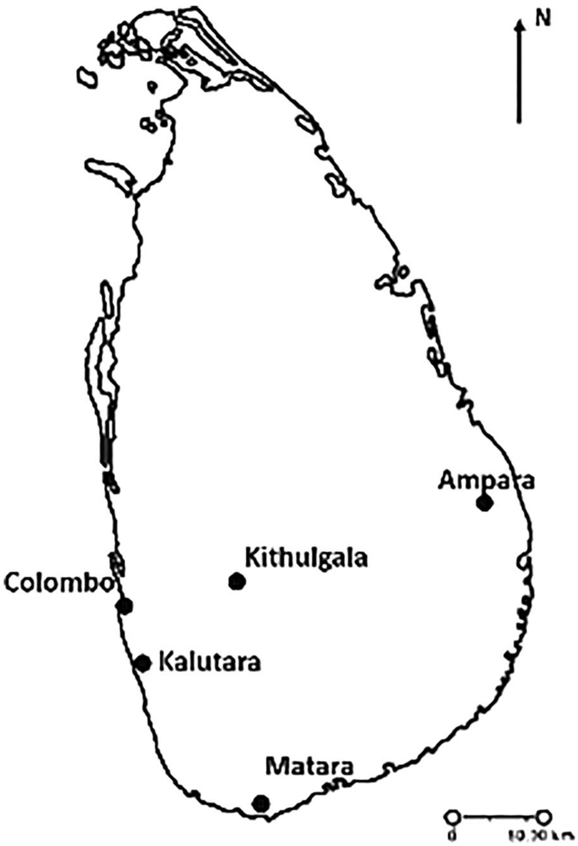

Fig. 1 Sketch map of Sri Lanka showing locations from where feathers of the feral pigeon and house crow were collected

de/en/srilanka/admin/). Colombo with a population density of 17,959 persons per km^2 is Sri Lanka's capital city and the country's commercial hub. Kalutara and Matara, with population densities of 2314 and 2185 persons per km^2, respectively, are bustling coastal towns. Kalutara is in close proximity to Colombo. Ampara and Kithulgala, with population densities of 353.5 and 326.7 persons per km^2, respectively (data for the latter figure from that of the administrative division in which Kithulgala is located), are relatively small, suburban towns. In Ampara, the outskirts and hinterland is considered one of the main paddy growing areas in the country (http://www.statistics.gov.lk/agriculture/Paddy%20Statistics/PaddyStats.htm).

In each of the selected locations, and for each of the species (house crow and feral pigeon), random searches were made to locate five roosting sites. In picking sites for the collection of feathers in each location, we took two factors into consideration. First, the extents of the home ranges of the two species under study and, second, the limits of the urban/suburban locations. A study conducted in an urban habitat in Singapore reports that the home range of the house crow varies from 1.3 to 158.1 ha (i.e., 0.013 to 1.58 km^2) whereas the size of the core area was much smaller, ranging from 0.2 to 22.3 ha (i.e., 0.002 to 0.223 km^2) (Haw et al. 2009). This study further states that individuals return faithfully to specific daytime areas and roost sites. With respect to the feral pigeon, a study in Switzerland states that the birds remained within 0.3 km of the home lofts with only a small proportion (7.5%) flying distances of more than 2 km (Inderwildi et al. 2006). Accordingly, for each of the two species, we decided to look for sites that were separated from each other by a distance of over 500 m—a precaution for minimizing the possibility of pseudo-replication and ensuring that the selected roosting sites remained within the perimeter of the urban/suburban location. A ground sheet was placed under each of the roosting sites for collecting freshly molted feathers, and from each site, three contour feathers were collected. The three feathers, comprising a composite sample, were kept in a sealed plastic bag. The 50 sites provided 50 composite samples, 25 of each species, and each sample comprising 3 feathers.

Sample treatment and analysis

Before taking up each sample for processing, all laboratory materials that were to be used were washed sequentially with soap water, tap water, and distilled water; glassware and metalware were oven dried; plastic items were air dried. Feather barbs, owing to their increased surface area, have been shown to have a high probability of retaining external contaminants (Seoane et al. 2018). In the present study, the entire contour feather was used for analysis, and hence, special care was taken to remove external contaminants.

In the laboratory, the three feathers in each sample were treated in the following manner. They were cut into small pieces, washed vigorously with 100 mL of 0.25 M NaOH solution, and then rinsed with distilled water (3 × 100 mL), after which they were immersed in 100 mL of distilled water for 1 h. Thereafter, the sample material was dried in a drying oven (Heraeus, Burladingen) at 80 °C, to constant weight (20–30 min) (Thompson et al. 1998). The samples were weighed using an analytical balance (PrecisaXB 120A, Switzerland) and transferred to a beaker. A mixture of nitric acid/perchloric acid solution (1:1, *v*/*v*) was added (60 mL), and the beaker was covered with a watch glass. The beaker was heated on a heating mantle (BS-4HC, Qingdao, China) at 150–200 °C for 20–30 min, until digestion was complete (as seen by the solution turning light-yellow and the total volume reducing to around 20–30 mL). The sample was then allowed to cool to room temperature after which distilled water was added to obtain a final volume of 30 mL. The treated samples were stored in polypropylene bottles at 4–8 °C (Refrigerator LG Electrocool GR-262SVQ, Victoria, Australia) until analysis (Pannekoek et al. 1974).

A standard addition method was followed for the analysis, using $PbNO_3$ (purity, 99%), the Cd metal, and $MnNO_3$ (purity, 98%). The heavy metal levels in the samples were assessed using the Atomic Absorption Spectrophotometer (GBC 932 plus, fuel-Acetylene, Oxidant-Compressed air). Three measurements were taken for each sample, and the average was used for the study. In all instances the standard deviation between the three readings was less than 5%. Recovery studies were done by spiking chicken feathers (reference material) separately with each of the three heavy metals. The generated results for Pb(II) (119%), Cd(II) (110%), and Mn(II) (88%) were within the acceptable range of percentage recovery (80–120%) for matrices containing externally added standards (Tiwari and Tiwari 2010).

Statistical analyses

We tested for significant species-wise and location-wise variations for each of the three metals using the two-way ANOVA. Association between the concentrations of the three metals was examined using a simple multiple Pearson's correlation test, and linear regressions were used to assess the relation between the human population density and the accumulated levels of the three metals in the contour feathers.

Results and discussion

The present study recorded the accumulation of the three test metals Pb, Cd, and Mn in contour feathers of the two avian species *Corvus splendens* (house crow) and *Columba livia* (feral pigeon), co-occurring in five urban/suburban locations in Sri Lanka. The data are presented in Table 1 and Fig. 2. Prior to making interpretations with respect to differences in heavy metal loads between the two species and between the five locations, it was necessary to first test the efficacy of using contour feathers, which was the method used in the present study, as a reliable indicator that would allow comparisons to be made. If the contour feathers are suitable indicators, we would expect the coefficients of variation (CV) within locations to be lower than those between locations. The results presented in Table 2 show that this was so in 96.67% of the cases, confirming

Table 1 The levels of Pb, Cd. and Mn (minimum, maximum, and mean ± standard deviation) recorded in feral pigeon (FP) and house crow (HC) feathers from five selected locations in Sri Lanka

Location	Level (mg/kg d.w.)	Pb		Cd		Mn	
		FP	HC	FP	HC	FP	HC
Colombo	min–max	2.4–5.5	15.7–52.0	0.1–2.8	0.7–14.8	0.1–0.2	4.2–9.5
	$x \pm$ SD	3.8 ± 1.3	40.7 ± 14.6	1.5 ± 1.2	7.0 ± 6.1	0.1 ± 0.0	7.0 ± 2.5
Kalutara	min–max	0.2–2.7	4.8–10.4	0.4–2.8	0.6–1.4	0.1–0.3	1.1–3. 8
	$x \pm$ SD	1.5± 1.2	7.3 ± 2.6	1.4 ± 1.1	1.1 ± 0.3	0.2 ± 0.1	2.0 ± 1.1
Matara	min–max	0.3–1.0	2.2–8.2	ND-0.3	ND-0.3	0.4–2.0	19.8–55.7
	$x \pm$ SD	0.6 ± 0.3	5.5 ± 2.3	0.1 ± 0.1	0.1 ± 0.12	1.0 ± 0.6	34.9 ± 16.3
Ampara	min–max	0.1–0.2	ND	ND	ND	15.1–20.0	ND
	$x \pm$ SD	0.1 ± 0.0				16.5 ± 1.8	
Kithulgala	min–max	ND	ND	ND	ND	ND	ND
	$x \pm$ SD						

ND, not detectable. Detection limits: Pb and Mn, 2 ppm; Cd, 0.2 ppm

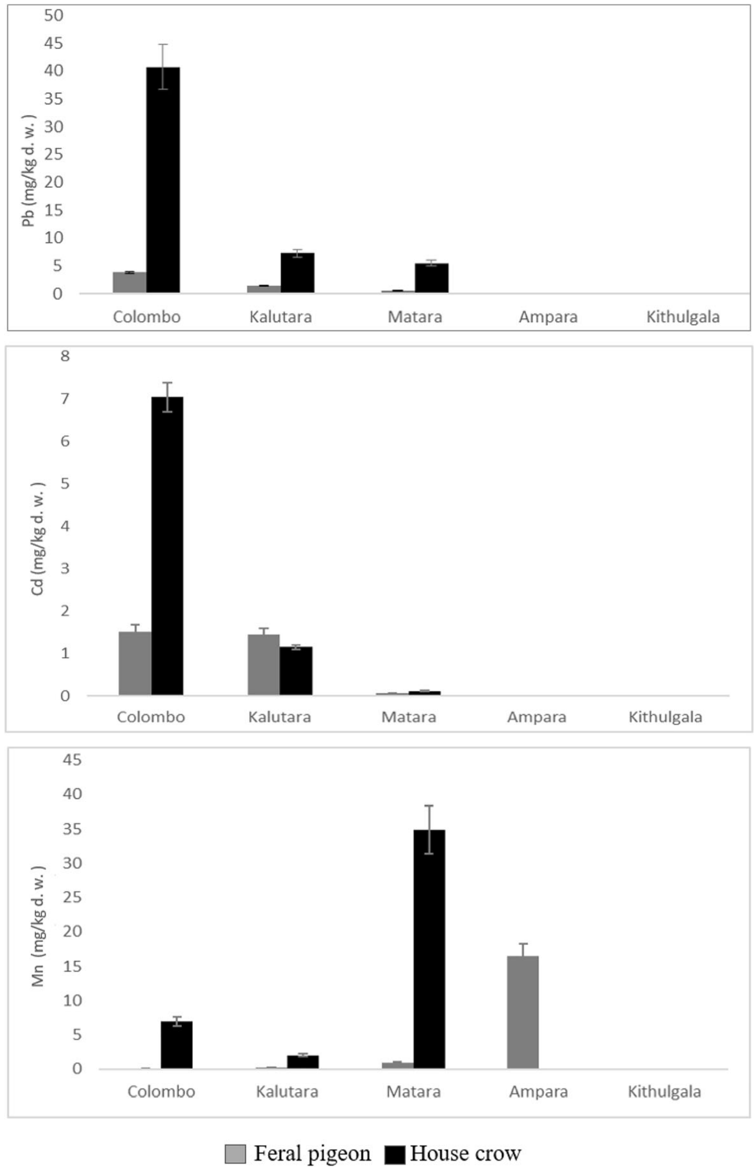

Fig. 2 The levels (mean ± standard deviation) of Pb, Cd, and Mn recorded in feral pigeon and house crow feathers from five selected urban/semiurban locations in Sri Lanka. The absence of bars indicates non-detection or extremely low levels of the metals

the suitability of the method. The use of contour feathers is clearly advantageous since fresh feathers can be easily collected and, if necessary, repeatedly, without affecting the health and condition of the birds (Adout et al. 2007).

This study intended to make comparisons between the heavy metal levels (Pb, Cd, and Mn) in the two avian species *Corvus splendens* and *Columba livia*, co-occurring in anthropogenic environments, both within and between five urban/suburban locations from which the feathers were collected. Statistical analyses showed that, with the exception of the difference in the Cd levels between the two species which was not significant, the other differences in the heavy metal levels across the species, across locations, and across species × location interactions, were highly significant (two-way ANOVA: species-wise; Pb: $F_{(1, 46)} = 49.66$, $P < 0.001$; Cd: $F_{(1, 46)} = 3.46$, $P = 0.07$; Mn: $F_{(1, 46)} = 12.24$, $P < 0.001$; location-wise; Pb: $F_{(4, 46)} = 38.18$, $P < 0.001$; Cd: $F_{(4, 46)} = 8.42$, $P < 0.001$; Mn: $F_{(4, 46)} = 19.30$, $P < 0.0001$; locations × species: Pb: $F_{(4, 46)} = 26.71$, $P < 0.001$, $R^2 = 88.0\%$; Cd: $F_{(4, 46)} = 3.89$, $P < 0.01$, $R^2 = 56.9\%$; Mn: $F(_{4, 46}) = 30.25$, $P < 0.001$, $R^2 = 84.0\%$).

In the interspecific differences, the levels of Pb recorded in the house crow were much higher than those

Table 2 A comparison of the coefficients of variation (CV) obtained for within and between locations with respect to Pb, Cd, and Mn in feral pigeon and house crow feathers

		Feral pigeon		House crow	
		Within-city	Between-city	Within-city	Between-city
Pb	Colombo	33.81	132.43	35.76	156.58
	Kalutara	79.14		35.04	
	Matara	44.29		41.90	
	Ampara	19.70		0.00	
	Kithulgala	0.00		0.00	
Cd	Colombo	81.12	164.39	86.72	225.50
	Kalutara	75.74		27.79	
	Matara	184.64*		107.54	
	Ampara	0.00		0.00	
	Kithulgala	0.00		0.00	
Mn	Colombo	23.87	187.12	35.41	172.87
	Kalutara	30.63		55.58	
	Matara	63,87		46.72	
	Ampara	10.78		0.00	
	Kithulgala	0.00		0.00	

*Within-city CV > between-city CV

in the feral pigeon in Colombo, Kalutara, and Matara. There was no clear-cut pattern for Cd and Mn. For instance, in Colombo, the Cd level in the house crow was much higher than that in the feral pigeon, in Kalutara, the level in the feral pigeon was marginally higher than that in the house crow, and in Matara, both species had near similar amounts. In the case of Mn, although interspecific differences were noted, patterns were not consistent, particularly in Ampara and Matara.

Overall, although in a majority of instances the scavenger (house crow) had higher levels of the studied metals than the granivore (feral pigeon), some exceptions were observed. The house crow scavenges on human scraps, small reptiles, insects and other small invertebrates, eggs, nestlings, grain, and fruit, and would therefore be expected to accumulate higher levels of contaminants (Abbasi et al. 2015). However, the expected differences between levels of accumulation between the house crow and feral pigeon may not occur in some instances owing to altered diets of feral pigeons. Although pigeons are generally granivores, in urban settings, they adjust to also consume other sources of food such as small invertebrates, insects, and protein-rich human food (Lefebvre and Giraldeau 1984; Jokimaki and Suhonen 1998), leading to deviations from the expected trends in the accumulation of heavy metals at the two trophic levels. This might serve as a likely explanation for the higher level of Cd in the feral pigeon in comparison with that in the house crow in Kalutara. It has been suggested that, given differences in heavy metal concentrations across species, inter-area comparisons must be based on a single indicator species (Kim and Koo 2007). However, owing to differences in the patterns of accumulation of the different metals in the two species from a single location as observed in the present study, it would be prudent to use multiple species for assessing pollution levels from heavy metals.

The results also showed that there were considerable differences in the heavy metal loads in the feathers collected from the five locations in Sri Lanka with different levels of urbanization. Regression analyses between heavy metal loads and the human population density at each location (Table 3) showed significant relationships for Pb and Cd in the feral pigeon and house crow, whereas Mn in both species was not affected by human population density. Colombo, Sri Lanka's commercial hub, with a population density far in excess of

Table 3 Association between heavy metal levels in the contour feathers of feral pigeons and house crows and human population density, as revealed by the regression analyses

Metal	Species	Statistic	Human population density
Pb	Feral pigeon	R^2	73.50
		F	63.73
		P	0.001*
	House crow	R^2	86.30
		F	144.99
		P	0.001*
Cd	Feral pigeon	R^2	26.10
		F	8.12
		P	0.01*
	House crow	R^2	54.50
		F	27.58
		P	0.001*
Mn	Feral pigeon	R^2	10.77
		F	2.76
		P	0.11
	House crow	R^2	0.00
		F	0.00
		P	0.98

*Significant differences ($P < 0.05$, 0.01, or 0.001) the other locations, recorded the highest levels of the two potentially toxic metals Pb and Cd. In sharp contrast, both avian species in Kithulgala, which is a sub-urban location with a low population density, did not record traces of any of the three metals, signaling a wholesome environment as far as these three heavy metal contaminants are concerned.

Considering Pb, the highest mean levels in both species were recorded in Colombo; the means, and the maximum (given in parenthesis), were as follows: 3.8 mg/kg d.w. (5.5 mg/kg d.w.) in the feral pigeon and 40.7 mg/kg d.w. (52 mg/kg d.w.) in the house crow. Comparable high levels of Pb in the house crow have been recorded in studies elsewhere: a mean Pb level of 32.0 mg/kg d.w. with a maximum of 88.2 mg/kg d.w. in Malaysia (Janaydeh et al. 2016); a mean level of 44.4 mg/kg d.w. and a maximum of 52.6 mg/kg d.w. in the Angur district, India, (Kaur and Khera 2018). In the feral pigeon, the level of Pb reported in Colombo in the present study is below that recorded in Paris (13.82 mg/kg d.w.) by Frantz et al. (2012). Burger and Gochfeld (1995, 2000) report that Pb levels of 4–5 mg/kg in bird feathers are associated with many sub-lethal impacts such as delayed parental and sibling recognition; impaired thermoregulation, locomotion, depth perception; abnormal feeding behavior; and lowered nestling survival. Based on this threshold, the levels of Pb recorded in feathers of the house crow in Colombo, Kalutara, and Matara suggest that some avian species may suffer adverse consequences as a result of Pb pollution.

In the case of Cd, the house crows from Colombo accumulated the highest levels (a mean of 7.0 mg/kg d.w. and a maximum of 14.8 mg/kg d.w.). Feral pigeons in the two locations Colombo and Kalutara, between them, accumulated near similar levels (means 1.5 mg/kg d.w. in Colombo and 1.4 mg/kg d.w. in Kalutara, with a maximum 2.8 mg/kg d.w. in both locations). Comparing these levels with Cd values reported elsewhere, Kaur and Khera (2018) document a mean level of 1.34 mg/kg d.w. and a maximum of 1.55 mg/kg d.w. for house crows in the Sangur district, India, which is much lower than that recorded for Colombo. Frantz et al. (2012) report 0.80 mg/kg d.w. in feral pigeons in Paris. Burger and Gochfeld (2000) report that 3000 μg/kg d.w. (3 mg/kg d.w.) of Cd in feathers has the potential to cause severe physiological, nutritional, and behavioral disorders in birds, and Burger (1993) reports that feather levels of Cd that are associated with adverse effects ranged from 0.01 mg/kg d.w. (shearwaters) to 0.02 mg/kg d.w. (terns). Adverse effects of Cd in birds include reduced growth rates (Spahn and Sherry 1999), disruption in the endocrine system, and impairment of reproduction and molting (Cheney et al. 1981; Stoica et al. 2000). The levels of Cd recorded at some locations in the present study, which exceeded the potential thresholds, may induce adverse impacts in avian species.

It has been reported that Pb and Cd concentrations in feathers are good bioindicators of local contamination (Kim and Koo 2007). The correlation matrix showed that there is a strong significant and positive relation between Pb and Cd ($r = 0.85$; $P < 0.001$). The high level of congruence between levels of Pb and Cd suggests common sources of contamination. Pb and Cd have been traced to effluents from industries related to the production of toys, leaded pipes, and containers, and other sources include Ni-Cd batteries, plating, pigments, plastics, and fertilizers (Atafar et al. 2010; Ratnayake and Navaratna 2014). Cd is listed as one of the most dangerous trace elements present in the environment, and both Cd and Pb are particularly harmful owing to their ability to bind to metallothioneins and not being readily evacuated via excretion (Battaglia et al. 2003). Importantly, from the results of the present study, it could be inferred that the recorded levels in Colombo, Kalutara, and Matara would most likely pose risks to wildlife inhabiting forest patches or wetlands located within these urbanized landscapes. The high accumulation levels of Pb and Cd in the avifaunal species in Colombo is particularly important since the city, known for its wetlands and rich avifaunal diversity, has been accredited a "Wetland City," one among 18 cities worldwide in the first list so named under the Ramsar Convention (https://www.ramsar.org/news/18-cities-recognized-for-safeguarding-urban-wetlands). The recorded levels in the present study may signal dangers to people living in Colombo who consume fish and vegetables harvested from this environment.

The accumulation patterns of Mn were different to that of Pb and Cd. For example, the maximum levels of accumulation of Mn in the two species were 20.0 mg/kg d.w. (in the feral pigeon in Ampara) and 55.7 mg/kg d.w. (in the house crow in Matara) whereas the levels of Pb and Cd in the two species from Matara and Ampara were much lower or the metals were not detected. The levels recorded for Mn in the present study, particularly in Ampara and Matara, are much higher than previously recorded levels in feathers of cattle egrets (Ullah et al.

2013) and shore birds (Kim and Koo 2008). Mn is an essential element required for many metabolic and cellular functions—it is a cofactor in a number of enzymatic reactions—but high levels of Mn caused teratogenic effects, behavior impairment, altered growth rates, and reduction of hemoglobin formation in two species of sea birds (*Sterna fuscata* and *Anous stolidus*) in the Pacific basin (Burger and Gochfeld 1995). As with Pb and Cd, although high levels of Mn in the environment are also linked to sources related to urbanization (Abdullah et al. 2015), the lack of congruence between levels of Mn and those of the other two metals in the present study (Pb and Mn: $r = 0.09$, $P = 0.54$; Cd and Mn: $r = 0.05$, $P = 0.73$), and the absence of a significant influence of human population density on the accumulated levels of Mn in both species suggest a departure from the usual sources of the contaminant metal. Two cases stand out in the present study—one, the high level of Mn in the pigeon in Ampara and its absence in the crow, and two, the high level of the metal in the crow in Matara and the much lower level in the pigeon. We assume that the high level of the metal in the feral pigeon in Ampara could be attributed to the use of Mn in agrochemicals such as fertilizers and fungicides (Rollin 2011; Ullah et al. 2013). In Ampara, which is one of the main paddy growing areas in Sri Lanka, the exceedingly high level of Mn in the pigeon in comparison with the crow in which it was not detected could likely be ascribed to the ingestion of contaminated grain and the accidental ingestion of sand from these cultivations (Hui 2002). In the case of Matara, high levels of Mn have been reported in water from dug wells here (Balasooriya et al. 2017), and this is one of the water sources used by people. This might be responsible for the high levels of Mn in the crow (being a scavenger) in this location.

Conclusion

Given its advantages, the results highlight that contour feathers can be used as a reliable tool for regularly monitoring heavy metal pollutants in the environment. The accumulation levels of Pb and Cd in the house crow and feral pigeon are influenced by the degree of urbanization which used human population density as a proxy. The house crow being a scavenger generally accumulated greater amounts of heavy metals than the granivorous feral pigeon. However, deviations do occur owing to altered food habitats and the degree of contamination of the preferred food sources. Hence, the use of a single indicator species for assessing the levels of pollution from heavy metals may not be wise.

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Authors' contributions All authors have contributed to conception and design, acquisition of data or analysis, interpretation of data, drafting the article, and critical reviewing.

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Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflicts of interest.

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