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Sparrows as Possible Heavy-Metal Biomonitors of Polluted Environments

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As a consequence of increasing urbanization and industrial processes, large quantities of heavy metals have continuously been introduced into the ecosystems. Heavy-metal ions are highly stable chemical substances; though at low concentrations, they can be biomagnified in the trophic network, becoming increasingly dangerous.

Therefore, the assessment of the levels of heavy-metal pollution in vegetables and fauna, used as bioaccumulation indicators of both polluted and unpolluted areas, has become an important task in preventing risks to public health.

It is to be pointed out that for a living species to be used as a bioaccumulator, some essential characteristics are necessary, namely:
1. It must be typical of the ecosystem studied (e.g. non-migratory);
2. It must be ubiquitous and abundant;
3. Its size, biotype and behavior must be such as to make sampling easy;
4. It must bioconcentrate exobiotic substances to a level sufficient to perform a direct analysis without preconcentration;
5 It must be able to stand high concentrations of different toxic substances, so as to survive the pollutant studied (Philips, 1977).

Generally, sedentary birds move no farther than 50 km (Cramp & Simmons, 1977), and *Passer domesticus italiae* (Italian Sparrow) is a sedentary bird primarily associated with human environments. It attends houses, farms and villages, including the surrounding land with cereal cultivation, as well as more extensive areas, where it occurs from the suburbs with their gardens to the more built-up centres and industrial areas with waste ground (Summers-Smith, 1988; Massa *et al.*, 1997). The ecological niche of *P. domesticus italiae* is characterized by the interaction with anthropogenic structures and the incorporation of different rubbish substances; therefore, the Italian sparrow can be considered as a good bio-accumulator of trace elements (Gragnaniello *et al.*, 1997).
In this paper, two populations of *P. domesticus italiae*, living in areas influenced by different levels of human activity, were studied. Liver and kidney were the organs chosen for assaying heavy-metal concentrations, since the highest concentrations of exobiotic substances are usually bioaccumulated in their tissues.

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MATERIALS AND METHODS

A total of 40 *P. domesticus italiae* were collected in 1998 in two different sites of the Campania region (southern Italy), using mist-nets (6x100 m):

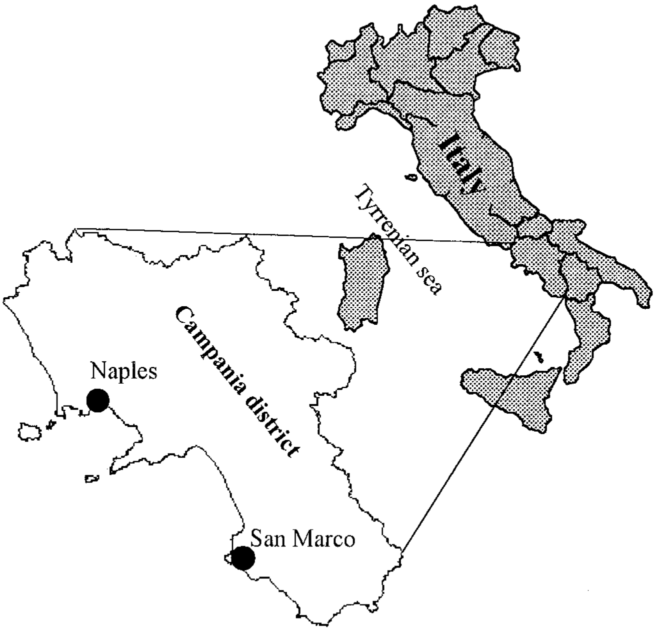

Figure 1. Sampling sites

the hinterland of Naples, a strongly anthropogenic and industrialized urban area with rare and highly fertilized agricultural patches, and San Marco di Castellabate, located in a well preserved natural and rural area of the Cilento-Vallo di Diano National Park (Fig. 1). The birds were labeled and carried to the laboratory; they were then dissected to collect livers and kidneys, which were stored at –20 °C.

About 500 mg of each biological tissue were dried at 110 °C in a stove to obtain dry weights. The samples were then heat treated in a muffle furnace up to 520 °C, and the ashes obtained were dissolved in superpure HCl and brought to 25 cm^3 with twice distilled water (Van Loon, 1985). Ten samples of kidney and ten of liver tissues chosen randomly among the specimens were spiked with a mix of zinc, copper, cadmium and lead chlorides in such quantities to nearly double the original concentration of different metals. A procedure of mineralization was performed both on the spiked specimens and on the original samples in order to carry out the quality control procedures by recovery measurements.

Heavy-metal concentrations were assayed by anodic stripping polarography, a technique that allows the evaluation of μg kg^{-1} fractions of the analyte investigated. The analyzed elements were Zn, Cu, Pb and Cd, the first two having a physiologic role, while the presence of Pb and Cd is clearly linked to pollution.

The equipment used was a Metrohm device (646 VA processor equipped with a 647 VA stand). The following parameters were used to carry out the measures: deposition potential -1.2 V vs. 3M KCl/AgCl/Ag reference electrode, electrolysis time 90 s.

The standard solutions of metallic ions were prepared by dissolving 1 g of pure metal in a minimum volume of 1:1 nitric acid and bringing them to 1 dm^3 to give a 1000 mg kg^{-1} concentration. From these stocks, solutions of lower concentration were obtained by dilutions. Mixed standard solutions containing the ions Zn^{2+}, Cu^{2+}, Cd^{2+} and Pb^{2+} were prepared for the polarographic measurements to obtain calibration curves.

RESULTS AND DISCUSSION

The quality control procedures show mean recovery percentages ranging from a minimum of 88% for Zn in kidney to a maximum of 102% for copper in liver, suggesting a good quality of procedures and results.
The data were collected considering two main groups of animals, an urban group (U) and a rural one (R), on the basis of the locality where they were captured.

Table 1. Mean concentrations ± SD of Zn^{2+}, Cu^{2+}, Cd^{2+} and Pb^{2+} in the livers of two groups of animals

Metal	Group	Mean	SD	ANOVA	FD	F crit
Zn	Rural	154	76	0.64	19	4.38
	Urban	205	188			
Cd	Rural	0.48	0.31	7.35	19	4.38
	Urban	1.31	0.92			
Pb	Rural	2.71	1.55	1.55	20	4.35
	Urban	3.72	2.21			
Cu	Rural	61.8	16.0	6.91	17	4.45
	Urban	42.0	16.4			

(ANOVA, freedom degrees (FD) and the values of critique F were used to compare the two groups).

Table 2. Mean concentrations ± SD of Zn^{2+}, Cu^{2+}, Cd^{2+} and Pb^{2+} in the kidneys of the two groups of animals

Metal	Group	Mean	SD	ANOVA	FD	F crit
Zn	Rural	133	47	0.56	12	4.75
	Urban	164	98			
Cd	Rural	3.92	3.30	3.55	16	4.49
	Urban	10.8	10.9			
Pb	Rural	6.99	4.61	2.35	16	4.49
	Urban	13.1	11.7			
Cu	Rural	92.7	70.0	0.42	15	4.54
	Urban	74.9	35.5			

(ANOVA, freedom degrees (FD) and the values of critique F were used to compare the two groups).

Table 3. Mean concentrations ± SD of Zn^{2+}, Cu^{2+}, Cd^{2+} and Pb^{2+} determined in urban organisms in kidney and liver

Metal	Organ	Mean	SD	ANOVA	FD	F crit
Zn	Liver	205	187	0.27	16	4.49
	Kidney	164	98			
Cd	Liver	1.31	0.92	8.29	17	4.45
	Kidney	10.8	10.9			
Pb	Liver	3.72	2.20	6.98	17	4.45
	Kidney	13.2	11.7			
Cu	Liver	42.0	16.4	7.42	17	4.45
	Kidney	74.9	35.5			

(ANOVA, freedom degrees (FD) and the values of critique F were used to compare the two groups of values in kidney and liver).

Table 4. Mean concentrations ± SD of Zn^{2+}, Cu^{2+}, Cd^{2+} and Pb^{2+} determined in rural organisms in kidney and liver

Metal	Organ	Mean	SD	ANOVA	FD	F crit
Zn	Liver	154	76	0.39	15	4.54
	Kidney	133	47			
Cd	Liver	0.48	0.31	10.77	18	4.41
	Kidney	3.92	3.30			
Pb	Liver	2.71	1.55	8.48	19	4.38
	Kidney	6.99	4.61			
Cu	Liver	61.8	16.0	1.48	15	4.54
	Kidney	92.7	70.0			

(ANOVA, freedom degrees (FD) and the values of critique F were used to compare the two groups of values in kidney and liver).

Tables 1 and 2 report the results of the comparison between the two groups of specimens (U and R); tables 3 and 4 show the results of the comparison between liver and kidney.

The results are consistent with the few data reported in literature on the sparrow (Sawicka-Kapusta *et al.*, 1986; Romanowski *et al.*, 1989; Nyhlom, 1995; Nyholm *et al.*, 1995). However, great caution must be used when comparing sedentary species with nesting and wintering ones, insectivores with granivores, and young with adult specimens.

Zinc and copper concentrations were always much higher than those of cadmium and lead. The former have a physiological role and are essential for the organisms, while the latter are not involved in any biological function.

The data concerning liver showed higher concentrations of metallic ions in specimens collected in the urban area than in those found in rural localities (Table 1). This difference sounds quite obvious, since urban areas are associated with pollution and the rural ones are suggestive of uncontaminated environment. The only exception is represented by Cu, which was always found at higher concentrations in the rural specimens than in the urban ones.

By the analysis of variance only two metals, Cd and Cu, exhibited significant differences. In fact, while Cd was more concentrated in the U-liver, Cu was more bioaccumulated in the R-liver. It is not easy to establish the precise origin of Cd in the diet of urban *P. domesticus italiae*, while the

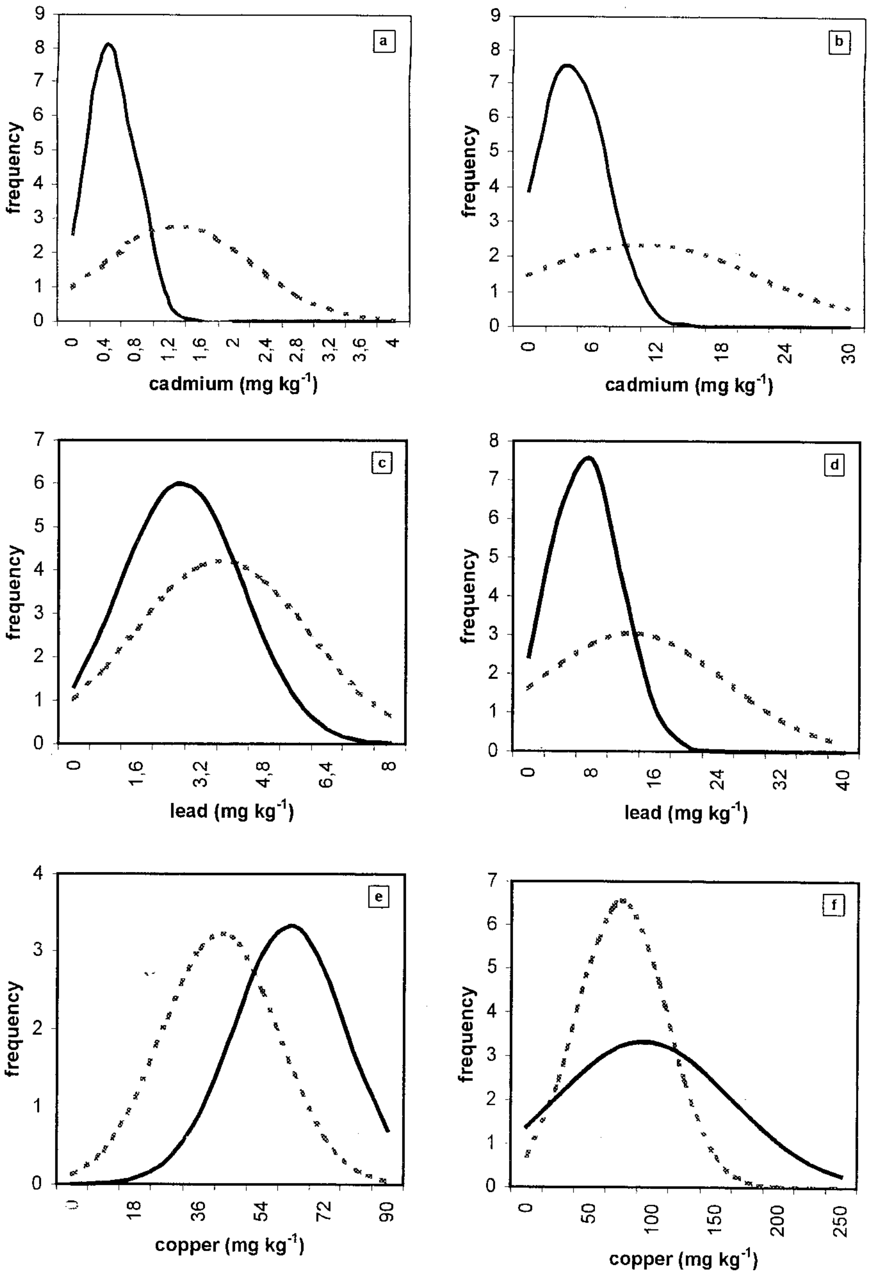

Figure 2. Gaussian curves of frequency distributions relative to concentrations in liver (a, c, e) and kidney (b, d, f). R = continuous line, U = dotted line.

higher Cu content in the liver of rural specimens can be ascribed to fungicides, pesticides and particularly to copper sulfate used in farming.
The concentrations of Pb, which were always higher than those of Cd, were not significantly different between the R and the U group. This can be explained by both a more uniform distribution of this element in the environment and the heterogeneity of trophic sources for sparrows in urban areas; however, a higher number of experimental observations are necessary to explain these differences between the two ecosystems.
No significant difference was observed in Zn concentrations.
Data concerning kidney (Table 2) showed the same trend as those on liver, but the differences in concentration between the U and the R group were never significant.

In urban specimens, Cd, Pb and Cu concentrations were significantly higher in kidney than in liver (Table 3); in rural specimens, these values were significant only as regards Cd and Pb (Table 4). This is in agreement with literature data on healthy adult birds of wild populations, which report liver Cd concentration usually between one half and one tenth of the concentration in the kidneys of the same bird (Lee *et al.*, 1987; Thompson 1990; Lock *et al.*, 1992, Furness, 1996).

Fig. 2 reports the gaussian curves of the frequency distributions of concentration in different cases, calculated on the basis of the experimental values reported in tables 1 and 2. As can be seen, the distribution of Cd and Pb is characterized by a sharper curve for the environment where the metals are less present and by a broader curve where they are more concentrated. A possible explanation of these results is that the pollution of the environment by Cd and Pb might not be uniform, and that, in the same type of environment, sparrows might choose different trophic ecological niches. For example, in Naples (U) there is both an industrial zone on the east side and the Capodimonte Wood on the north side.

On the contrary, the gaussian curve of Cu distribution has the same shape both in U and R environments, which may be indicative of a greater homogeneity of Cu pollution related to the extensive use of products containing this metal.
These observations suggest that this method of biomonitoring must be approached with caution, and above all, that a sufficient amount of specimens is necessary to formulate a diagnosis on an environment.

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