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Brief reports

Trace metals in the livers of Finnish Parus species

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Introduction

Human activities have considerably elevated the levels of metals circulating in the forest ecosystem. Acid rain is, in particular, responsible for mobilizing large amounts of inactive metals from the soil. In boreal forest biota, metals mainly accumulate in detritus and detrivores (Nuorteva 1990), but they also occur at high levels in the layer of bast in coniferous trees (Vogel 1986, Reijonen 1988), in bark beetles (Vogel 1986, Reijonen 1988, Nuorteva 1990), in ants (Ylä-Mononen et al. 1989, Nuorteva et al. 1992), and in spiders (Fangmeier & Steubing 1986, Nuorteva et al. 1992).

Tits are of special interest because they eat a considerable amount of spiders (Jansson & von Brömssen 1981, Gunnarson 1983, Hyytiä et al. 1983). The role of spiders as a metal source for tits has become more important through the fact that the crowns of coniferous trees have become thinner through forest decline, and this facilitates the detection of spiders by tits (Gunnarsson 1988).

We analyzed Al and Fe as representatives of common soil metals, Cu and Zn as representatives of essential metals in metabolism, and Cd, Ni and Pb as representatives of toxic metals in tit livers. Variation in metal levels was analysed in relation to the species, age, sex, year of death, and area (urban/rural).

Material and methods

The tits were received from the Zoological Museums of the Universities in Helsinki and Turku. The material consisted of 53 tits of five different species *Parus major* (n = 33), *P. caeruleus* (n = 16), *P. montanus* (n = 2), *P. cinctus* (n = 1), and *P. ater* (n = 1). Even though our material consisted of five different species, only two of them (*P. major* and *P. caeruleus*) were used in the statistical analysis (n = 49). The tits had been found dead in different parts of Finland between the years 1978 and 1992, and had been stored frozen. The material consists of both resident and migrating birds. The exact status could not be determined.

The samples were prepared for analysis as described by Nuorteva (1990). This method gives the results in dry weight. Because our liver samples were small (dry weight around 0.10 g), we used only 2 ml HNO_3 for each sample. Al levels were determined using a flame Atomic Absorption Spectrophotometer, Perkin-Elmer 360. Cu, Fe and Zn levels were determined using a flame AAS, Varian SpectrAA-400 and Cd, Ni and Pb levels by using a graphite-furnace AAS, Varian SpectrAA-400 + GTA 96.

The sex and the age of the birds were determined, if possible, on basis of plumage characteristics (Svensson 1992). We converted ringing age codes (1Y, 2Y, 1Y+, 2Y+) of all individuals that we could age on the basis of plumage into two age groups. Young birds were those whose real age was less than ca 14 months (i.e. birds before their first postnuptial moult). All other birds were classified as adult birds. Ten individuals could not be aged. We also split the material on basis of the year of death: dead before 1986 (n = 14) and dead after 1985 (n = 34). The year of death for the remaining birds was unknown. The birds were also divided into those found dead in urban areas and those found dead in rural areas.

In the statistical analysis of the results, the differences between the groups (species, age, sex, place and year of death) were studied using one-way AOV (Statistix 4.0). For the statistical analysis the results below detection level were given a value of half of the detection level (Ni = 0.001 µg/g, Pb = 0.00045 µg/g). To improve the normality of distributions, all variables, except Cu, were logarithmically transformed. The values of Ni and Al did not reach normality this way.

Results

Soil metals, Al and Fe

Almost all Al results were below the detection limit (< 10 µg/g). The highest concentration was 70 µg/g which was found in *P. major* (Table 1).

The mean levels of Fe in livers of *P. major* and *P. caeruleus* were twice as high as those found in other species (Table 1). Females contained significantly less Fe than males (1500 ± 560 vs. 2100 ± 1100 µg/g, respectively; $P < 0.05$).

Metabolic metals, Cu and Zn

The content of copper found in livers of *P. major* were significantly greater ($P < 0.05$) than in livers of *P. caeruleus*. The levels of *Parus major* varied between 16 and 45 µg/g and those of *P. caeruleus* between 17 and 30 µg/g (Table 1).

The mean value of Zn in *P. major* was 130 ± 50 µg/g and in *P. caeruleus* was 130 ± 60 µg/g and those of all the other species were 120 µg/g. The highest level was 330 µg/g (*P. caeruleus*) and the lowest level was 78 µg/g (*P. major*) (Table 1). No significant differences between groups were found.

Toxic metals, Cd, Ni and Pb

The cadmium levels increased from 0.4 ± 0.3 µg/g in younger birds to 0.8 ± 0.5 µg/g in older birds. The difference between the age classes was significant ($P < 0.05$).

The highest level of Ni was 1.7 µg/g in *P. major*. Some nickel contents were under the detection limit (< 0.002 µg/g) (Table 1).

Some surprisingly high Pb levels were found in *Parus major*. The highest level was 36 µg/g and the mean value was 3.4 ± 7.4 µg/g. In order to diminish the role of exceptionally high peak contents, results over 12 µg/g, three observations, were excluded from statistical analyses. After that there was a significant difference ($P < 0.05$) between birds found dead before 1986 (mean 2.0 ± 2.5 µg/g, n = 13) and birds found dead after 1985 (mean 0.6 ± 0.9 µg/g, n = 32). The mean Pb level of tit livers in urban areas was 1.4 ± 1.3 µg/g and that of tits in rural areas 0.7±1.9 µg/g. The difference was statistically significant ($P < 0.05$). This difference between locations was not found for any other metal.

Discussion

The liver is known to be a good indicator for the total load of metals in birds (Scheuhammer 1987, Nyholm 1986). Despite this, a study by Kraus (1989) shows that the liver may not always accumulate all of the metals affecting a species. This mostly concerns Ni and Cu (Kraus 1989). Analyses of Al have been problematic because the detection level is higher than the content in animal tissues (Nyholm 1986). We encountered the same problem.

Our results showed that female tits have lower concentrations of Fe in their livers than males. Differences in Fe levels between sexes can be due to differences in metabolism, which for example occur during reproduction. Some female birds show higher levels of Cd in livers (Nyholm 1986) and, according to Hutton (1981), this is due to differences in metabolism. It is, however, difficult to generalize because different species have different food sources and different habits. Females also have the possibility to transfer some metals (e.g. Hg and Pb) to the eggs (Jönsson et al. 1994). This might also be the case with Fe, but as it is a common metal in the blood further studies on this subject should be done.

We compared our results with a similar study made in Poland (Sawicka-Kapusta et al. 1986). The Fe concentrations are approximately the same in all locations, polluted as well as unpolluted, both in Poland and in Finland. This is probably due to the fact that Fe is a common soil metal.

Numerous papers show that metals accumulate in relation to age in both birds and mammals (Honda et al. 1986, Frank 1986, Scheuhammer 1987, Nyholm 1986). Our studies showed age-related accumulation only for Cd in the livers of Finnish tits.

In the polluted areas of Poland the levels of Cd are 27 times higher than they are in Finland. The Cd levels in the unpolluted areas in Poland are, astonishingly, smaller than they are in Finland. On the other hand, Zn levels were mostly higher in Poland than in Finland, whereas the Cu levels were higher in Finland.

Lead is both a local and a long-range atmospheric pollutant. In Finland, high lead values are connected with high traffic and population density in urban areas (Atmospheric Heavy Metal...1990). Birds found dead after 1985 had less Pb in their liver tissues than those found dead before 1986. There has also been a general decline in the lead deposition since 1985, in Finland 30 %. This is due to the leadless petrol that gradually has taken over the market, but still the long-range transport deposition is a problem (Atmospheric Heavy Metal...1990).

In our study the Pb levels in urban areas were higher than those in rural areas. Even in urban areas in Finland the level of Pb was, however, one third of the level in the unpolluted area in Poland. The areal differences in Finland are due to lead pollution from automobile traffic, but the difference between the countries must be due to other reasons; possibly coal mining or zinc smelters (Karweta & Proborski 1988, Molski & Dmuchowski 1990, Kabata-Pendias 1991). We found exeptionally high Pb concentrations in three

Table 1. Metal levels (µg/g) in livers of *Parus major* (n = 33), *P. caeruleus* (n = 16), *P. montanus* (n = 2), *P. cinctus* (n = 1) and *P. ater* (n = 1).

	Al	Fe	Cu	Zn	Cd	Ni	Pb
Parus major							
Mean	–	1900	26	130	0.6	0.3	3.4
SD	–	1100	7.7	51	0.4	0.4	7.4
MIN	<10	640	16	–	0.07	<0.002	<0.000978
Median	<10	1600	24	110	0.6	0.2	0.6
MAX	70	5400	45	270	2.0	1.7	36
P. caeruleus							
Mean	–	1700	21	130	0.5	0.3	0.5
SD	–	890	4.6	57	0.6	0.4	0.7
MIN	<10	620	12	–	0.03	<0.002	<0.000986
Median	<10	1500	20	120	0.3	0.2	0.2
MAX	<10	4200	30	330	2.3	1.2	2.4
P. montanus							
Mean	<10	790	24	121	0.3	0.04	0.6
MIN	<10	770	23	96	0.2	0.03	0.09
MAX	<10	810	24	145	0.3	0.04	1.1
P. cinctus							
Mean	<10	580	18	122	0.3	0.4	0.2
P.ater							
Mean	<10	730	29	122	0.5	<0.002	0.4

samples. This can be due to increased exposure to Pb by the side of heavily travelled roads or by shooting fields. The exact place of death could not be confirmed afterwards.

All the levels of Ni were very low. According to Outridge and Scheuhammer (1993), tissue accumulation does not necessarily accompany increased exposure to Ni. Mammals and birds can control their accumulation of Ni, as dietary Ni concentrations, up to at least about 100 μg/g (Outridge & Scheuhammer 1993).

According to Scheuhammer's (1987) definitions, the levels of toxic metals (Cd, Ni and Pb) found in this research are not critical. It is, however, important to remember that the poison tolerance of Finnish birds might be lowered by the hard climate.

Finally, our results indicate the importance of knowing in what kind of environment the bird has been living. Also, it is important to take into consideration the age of the bird.

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Selostus: **Eräiden metallien (Al, Cd, Cu, Fe, Ni, Pb, Zn) pitoisuuksista tiaisten maksoissa Suomessa**

Al, Cd, Cu, Fe, Ni, Pb ja Zn pitoisuuksia tutkittiin Suomesta löytyneiden tiaisten maksoista. Näytteet analysoitiin atomiabsorptiospektrofotometrillä. Cd pitoisuudet maksoissa olivat suurempia vanhemmissa linnuissa. Naaraissa oli matalammat Fe pitoisuudet kuin koiraissa. Suomen teollistuneiden alueiden tiaisten maksoissa oli korkeampia lyijypitoisuuksia kuin maaseutu-Suomen linnuissa. Eroja oli myös lyijypitoisuuksissa ennen vuotta 1986 ja sen jälkeen kuolleiden lintujen välillä. Pitoisuuksia verrattiin Puolassa tehtyyn tutkimukseen (Sawicka-Kapusta 1986). Metallipitoisuudet tiaisten maksoissa olivat samansuuntaisia Puolan saastumattomimpien alueiden lintujen pitoisuuksiin. Suomen teollistuneiden alueiden tiaisten korkeilta tuntuvat lyijypitoisuudet ovat kuitenkin vain kolmannes Puolan puhtailla alueilla havaitusta lyijypitoisuudesta. Yllättäen Suomen tiaisissa havaitut keskimääräiset kadmiumpitoisuudet ovat lähes kaksi kertaa suuremmat kuin Puolan puhtailla alueilla.

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