Bull. Environ. Contam. Toxicol. (1997) 58:518-522

Bulletin of Environmental Contamination and Toxicology

Influence of Life History and Sex on Metal Accumulation in Two Beetle Species (Insecta: Coleoptera)

L. Lindqvist, M. Block

Environmental Toxicology, Uppsala University, Norbyvägen 18 A, S-752 36 Uppsala, Sweden

Received: 1 October 1996/Accepted: 2 January 1997

Insects are important components of most terrestrial environments owing to their great abundance, biomass and diversity. They also make up an important food resource for other animals. Consequently, in many food webs insects constitute important links in metal-transport chains between trophic levels. Therefore trace-metal concentrations in insects have an important influence on the trace-metal distribution in the biosphere.

In various insects, Cd, Cu and Zn are usually accumulated to the extent that they reach levels above those of the food, whereas Fe is not (Heliövaara and Väisänen 1990a). In response to metal pollution, accumulation of non-essential metals was found to increase markedly, whereas essential metals accumulated less owing to regulating mechanisms in the insects (Roth-Holzapfel and Funke 1990).

In polluted environments, metal concentrations were found to be higher in predatory invertebrates than in phytophagous ones in studies where insects were analysed in broad categories such as families (Roberts and Johnson 1978). However, no such trend was observed when species were treated separately (van Straalen and van Wensen 1986).

The pattern of metal accumulation can differ between species (Rabitsch 1994). This is true even for species utilizing the same food resource. For instance, concentrations of Cd, Cu and Fe differed between four species of sawflies feeding on pine needles from the same locality (Heliövaara et al. 1987). It is therefore likely that insects with different food sources accumulate metals differently depending on the concentration and chemical form of the metals in the food.

There have been few studies aimed at determining whether patterns of metal accumulation differ between males and females of the same species. In one such study on the sawfly *Neodiprion sertifer* concentrations of Cd, Cu and Fe tended to be higher in males than in females. However, this pattern was not found in two other sawfly species (Heliövaara and Väisänen 1990b). Target organs for Cd were found to differ between males and females in the grasshopper *Aiolopus thalassinus* (Fabr.). The testis accumulated Cd to a higher degree than the ovaries (Schmidt and Ibrahim 1994).

Correspondence to: L. Lindqvist

The aim of the present study was to determine whether Cd, Cu, Fe or Zn are accumulated to different degrees in two beetle species with different life histories and whether patterns of accumulation differ between males and females. The study was performed at two localities subjected to different degrees of metal pollution.

MATERIALS AND METHODS

Beetles were collected at Smedjebacken and Märsta in central Sweden. The former was subjected to metal pollution caused by nearby factories, whereas no local source of metal pollution was present at the latter.

The two species of beetles chosen for this study were *Pterostichus niger* Schaller and *Melasoma populi* L. *P. niger is* a carnivorous ground-living carabid that feeds on various invertebrates (Lindroth 1986), while *M. populi is* a phytophagous chrysomelid that feeds on leaves of *Populus tremulus* L. (Chinery 1973). These two particular species were chosen because of their different life histories and because their larvae and adults have similar feeding habits.

P. niger was collected in April and May 1994, whereas *M. populi* was collected in May and June of the same year. Beetles were picked by hand or caught by sweeping through vegetation and placed in a killing jar containing ethylacetate. Specimens were then stored in a freezer prior to further treatment and analysis.

Before digestion the beetles were lyophilized. From Smedjebacken 24 males and 22 females of *P. niger* and 16 males and 24 females of *M. populi* were analysed. The number of beetles from Märsta were 30 males and 22 females of *P. niger* and 44 males and 44 females of *M. populi*. Two individuals of *P. niger* or four individuals of *M. populi* were pooled for each metal analysis.

In each case samples consisted of approximately 150 mg dry weight. Digestions were made with concentrated nitric acid *pro analysi*. Each preparation was treated with 2 ml nitric acid at 1-10°C for 8 hr in borosilicate-glass test tubes. Thereafter the test tubes were heated until most of the liquid was evaporated. Residues were treated with 2 ml hydrogen peroxide (30%) *pro analysi* at 110°C for 2 h. Solutions were then diluted with distilled water to approximately 10 ml. For every 15 tests, two reagent blanks were included to determine the baseline level. Metals were analyzed using a Schimadzu model 603, by the flame technique.

Distributions of metal concentrations were tested for skewness according to Dahlberg (1948). Because the values were not normally distributed, non-parametric tests were used in statistical evaluation. Differences in metal concentrations were determined using the Mann-Whitney U-test.

RESULTS AND DISCUSSION

At both localities concentrations of Cd, Cu and Zn were higher in the phytophagous *M. populi* than in the ground beetle *P. niger*. At Märsta concentrations of Fe were higher in *P. niger*, while there was no difference between the two species at Smedjebacken, Fig. 1. Based on these species then, we conclude that concentrations of these metals are not linked to trophic level.

In general, leaf-eating insects tend to process large quantities of food through their gut (Hodkinson and Hughes 1982). As a result of this large throughput of food, the insect is exposed to considerable quantities of metals, particularly in aerially contaminated localities, where metals are present as deposits on leaf surfaces. Thus, the potential to accumulate metals can be high in phytophagous species.

Carnivorous insects are exposed to metals in various forms, as metals in solution or firmly bound in complexes in different organs of their prey. The relative amounts of these different forms will differ depending on the species and feeding habits of the prey.

Obviously the feeding habits of *M. populi* facilitate the exposure of this species to metals, at least in available forms. However, it is not clear from our results if metal deposits on the body surface of *M. populi* contributed to its overall metal body burden.

The higher concentration of Fe in *P. niger* at Märsta may reflect a tendency for *P. niger* to accumulate more Fe under normal conditions. That no such difference between the species was found at Smedjebacken can be ascribed to the greater ability of *M. populi* to accumulate metals in its diet. As the result, the concentration of Fe in *M. populi* was higher at Smedjebacken than at Märsta. For *P. niger* no such difference in Fe concentration between localities was found.

There was no indication that the pattern of metal accumulation of any the metals differed between males and females. Differences in metal concentrations between males and females only occurred at the less polluted locality, Märsta. In *P. niger*, the Cd concentration was higher in females while the concentration of Cu was higher in males. In *M. populi* the Fe concentration was higher in males. Higher concentrations of Cu in males have also been found in other carabids. For example, in a study of effects of elevated Cu concentrations in food, Cu concentrations were higher in males than in females in the carabid *Pterostichus cupreus* L. (Bayley *et al.* 1995). Similarly, in a mining area males of *Abax parallelepipdus* Piller and Mittbacher contained higher concentrations of Cu compared to females (Rabitsch 1994).

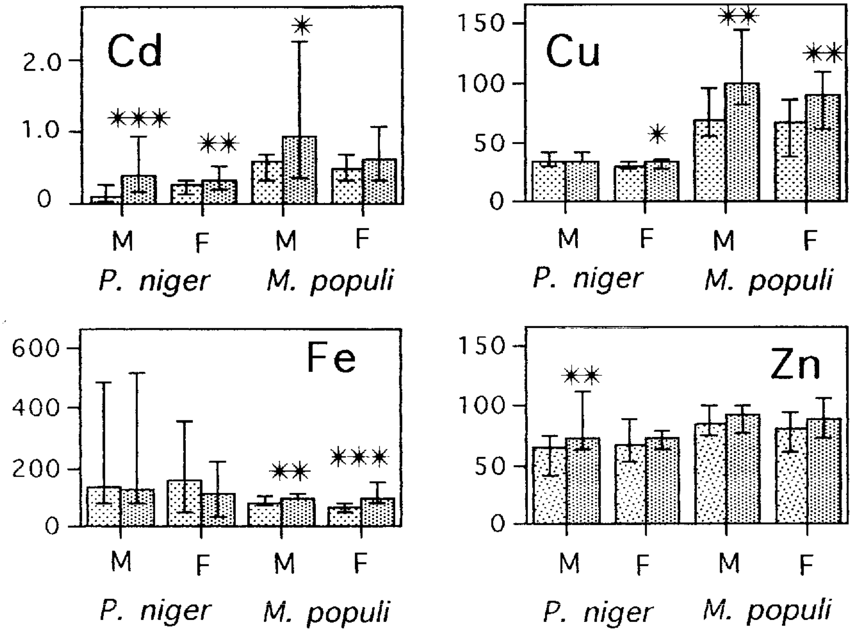

Figure 1. Metal concentrations, µg/g dry weight (median values and range), in males (M) and females (F) of *P. niger* and *M. populi* in Märsta (light bars) and Smedjebacken (dark bars). Difference in metal concentrations between localities significant ✳ $P<0.05$, ✳✳ $P<0.01$ and ✳✳✳ $P<0.001$. Significant difference in concentrations between males and females were found at Märsta in *P. niger* for Cd ($P<0.001$) and Cu ($P<0.05$) and in *M. populi* for Fe ($P<0.001$). Difference in metal concentrations between *P. niger* and *M. populi* significant in all cases except Fe at Smedjebacken; $P<0.01$ except Zn at Märsta where $P<0.05$.

The differences in metal concentrations between the sexes did not show any consistent patterns at the two localities. However, the metal accumulation pattern can differ depending on the degree of metal contamination. In the grasshopper *A. thalassinus*, target organs for Cd accumulation differed between contaminated and control specimens. In those reared in contaminated soil, Cd mainly accumulated in the gut, wings and testes or ovaries. In specimens reared in control soil Cd did not accumulate in testes or ovaries to the same extent (Schimdt and Ibrahim 1994).

Concentrations of Cd, Cu, Fe and Zn in the insect species studied here vary depending on the type of food and chemical form of the metals rather than on trophic level. Although significant differences in metal accumulation occurred between male and female beetles, no consistent sex-specific accumulation pattern was found in this study.

Acknowledgment This study was financed by the Helge Ax:son Johnson Foundation, Stockholm, Sweden.

REFERENCES

Bayley M, Baatrup E, Heimbach U, Bjerregaard P (1995) Elevated copper levels during larval development cause altered locomotor behavior in the adult carabid beetle *Pterostichus cupreus* L. (Coleoptera: Carabidae). Ecotox Environ Safe 32:166-170

Chinery M (1973) A Field guide to the insects of Britain and northern Europe. William Collins Sons and CO, London

Dahlberg G (1948) Statistical methods for medical and biological students. George Allen and Unwin, London

Heliövaara K, Väisänen R (1990a) Concentration of heavy metals in the food, faeces, adults, and empty cocoons of *Neodiprion sertifer* (Hymenoptera, Diprionidae). Bull Environ Contam Toxicol 45:13-18

Heliövaara K, Väisänen R (1990b) Heavy metal concentrations in males and females of three pine diprionids (Hymenoptera). Entomol Fenn 1:175-179

Heliövaara K, Väisänen R, Braunschweiler H, Lodenius M (1987) Heavy metal levels in two biennial pine insects with sap-sucking and gall-forming life-styles. Environ Pollut 48:13-23

Hodkinson ID, Hughes MK (1982) Insect herbivory. Chapman and Hall, London

Lindroth CH (1986) The Carabidae (Coleoptera) of Fennoscandia and Denmark. E.J. Brill/Scandinavian Science Press Ltd, Leiden

Rabitsch WB (1994) Metal accumulation in arthropods near a lead/zinc smelter in Arnoldstein, Austria. I. Environ Pollut 90: 221-237

Roberts RD, Johnson MS (1978) Dispersal of heavy metals from abandoned mine workings and their transference through terrestrial food chains. Environ Pollut 16:293-310

Roth-Holzapfel M, Funke W (1990) Element content of bark-beetles *(Ips typographus* L., *Trypodendron lineatum* Olivier; Scolytidae): a contribution to biological monitoring. Biol Fertil Soils 9: 192-198

Schmidt GH, Ibrahim NMM (1994) Heavy metal content (Hg^{2+}, Cd^{2+}, Pb^{2+}) in various body parts: its impact on cholinesterase activity and binding glycoproteins in the grasshopper *Aiolopus thalassinus* adults. Ecotox Environ Safe 29: 148-164

van Straalen NM, van Wensem J (1986) Heavy metal content of forest litter arthropods as related to body-size and trophic level. Environ Pollut A 42: 209-221