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Metal Pollution and Fat Accumulation in the Carabid Beetle *Pterostichus melanarius* (Coleoptera, Carabidae)

L. Lindqvist, M. Block

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

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Since the beginning of industrial revolution fluxes of metals have increased in the environment (Heliövaara and Väisänen 1993). Elevated concentrations of heavy metals have been found in insects from polluted areas. In heavily polluted areas this has lead to environments lacking insects, while in moderately polluted areas no obvious effects of this pollution are seen in insect populations (Hopkin 1989). Minor effects of heavy metals on insects may only be detectable after measuring physiological parameters.

Insects store fat as an energy reserve in the fat body. This organ can store large amounts of fat, comprising up to 50% of the body weight (Gilbert and Chino 1974). During periods of feeding, these energy reserves are built up and stored to be utilised during non-feeding periods such as diapause (Wigglesworth 1974). Fat content is affected by factors such as the availability of food and the energy needed to maintain the homeostasis of the insect.

Pollutants may alter the metabolism of insects (Heliövaara and Väisänen 1993). Excretion of metal pollutants requires energy and this excretion affects the metabolism of the insect, so that less energy is available for fat accumulation and other physiological activities. For example, elevated levels of cadmium, copper, or zinc were found to decrease levels of fat in larvae of the gypsy moth *Lymantria dispar* L. (Ortel 1995).

The aim of this study was to measure levels of fat in two insect populations, one from a site with a moderate level of metal pollution and one from a site with background pollution only to see if insects that are exposed to pollutants may be less able to accumulate fat.

MATERIALS AND METHODS

The ground beetle *Pterostichus melanarius* Illiger was used in this study. This species usually is incapable of flight (Lindroth 1986), so that individuals can be considered to be stationary and as a consequence, fat accumulation in the population is not influenced by individuals immigrating from other areas.

Correspondence to: L. Lindqvist

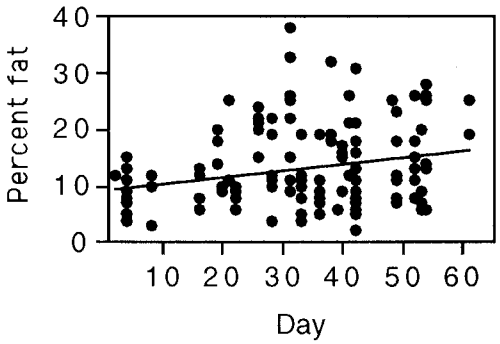

Figure 1. Correlation between day of collection and percent total fat. Regression line y=0.11x+9.36, $r^2<0.05$.

Specimens of *P. melanarius* were collected in the spring, a period during which no oviposition occurs. The beetles were collected 10 kms north of Märsta, a site not close to any large pollution source, and from Smedjebacken, which is a site subjected to pollution by cadmium, zinc, and copper from a nearby metal factory. Elevated levels of cadmium, two to three times those found in Märsta were found in *P. melanarius* and *P. niger* at this site; levels of copper and zinc were only slightly raised. At the background pollution site, variation in fat concentration was also studied during three successive years (Lindqvist and Block 1998a and b).

Specimens of *P. melanarius* were collected by picking specimen by hand under stones. The collection took place during April and May. They were killed with ethyl-acetate vapour and stored in a freezer prior to analysis. The beetles were dried at 60°C for three days, after which they were weighted to the nearest 0.1 mg. The posterior tip of the abdomen was cut open to facilitate fat extraction, which was performed using 3 ml petroleum-ether per beetle. After the extractions the petroleum-ether was sucked off and the beetles were dried at 60°C and weighted again. The extractions were repeated until the beetles lost no more weight. After five extractions no more weight was lost. Fat concentration was calculated as the difference in weight of the beetles before and after the extractions. Differences in fat concentrations were tested using t-test or ANOVA followed by least significance test (Sokal and Rolf 1981).

RESULTS AND DISCUSSION

In females of *P. melanarius*, egg production may interfere with fat accumulation. Reproducing females of the carabid *Pterostichus cupreus* L. were found to allocate their energy reserves into both reproductive organs and the fat body (Bommarco 1998). Differences in fat concentrations between males and females were therefore tested statistically each year *P. melanarius* was collected. The fat accumulation did not differ between males and females in any of these comparisons ($0.25<p<0.99$). Males and females were therefore treated together.

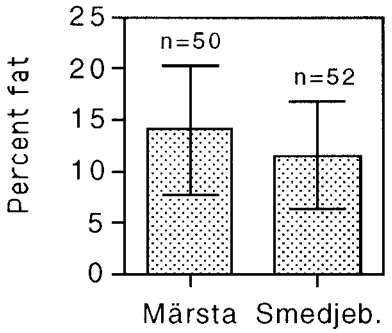

Figure 2. Fat concentrations, mean values and standard deviations, in *P. melanarius* from Märsta and the metal polluted site Smedjebacken in 1998. The difference between the two locations is statistically different $p<0.05$.

To test if the average fat increased during the collection period, a test of the association between collection day and percent fat was performed. The first of April was assigned as day 1 and the last of May as day 61 and the time was plotted against percent lipid. No correlation between time and percent fat was found (Fig. 1).

The mean fat concentration in Märsta was 13.4% of the body dry weight (standard deviation 7.2%). In the carabid *Bembidion lampros* Herbst caught in Denmark in the spring, the fat concentration waried between 6.6 and 23.6% of the body weight depending on type of food they ingested (Petersen 1999). In studies of heavy metal concentrations in various soil invertebrates, carabids tend to have the lowest concentrations in metal polluted sites (Bengtsson and Rundgren 1984, Kramarz and Laskowski 1997). Exposure and absorption of heavy metals by carabids is unlikely to be less than for other invertebrates. Low heavy metal concentrations, therefore, reflect efficient excretion. This requires energy, leaving less energy available for fat accumulation.

P. melanarius, collected in 1998, from the metal polluted locality Smedjebacken had a lower fat concentration compared to specimens from Märsta collected in the same year (Fig. 2). The fat concentration in *P. melanarius* from Märsta varied between successive years (Fig. 3). The reason for these differences might be sought in the conditions the beetles experienced the preceding year. Fat accumulation is influenced by the availability of food, weather conditions etc and the accumulation of fat may therefore vary between years. Weather conditions varied during the years of this study. In 1997 it was warm with a normal amount of rain. In 1998 the weather was unusually cold and rainy, while in 1999 it was warm and with very little rain.

In a laboratory study the heavy metals cadmium, copper, and zinc caused decreased fat concentrations in larvae of the moth *Lymantria dispar* L. (Ortel 1995). The lower fat concentration in *P. melanarius* from Smedjebacken could be a direct effect

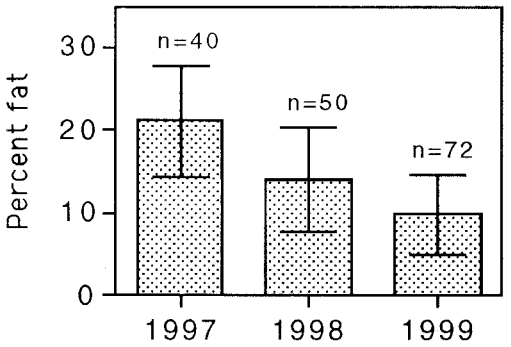

Figure 3. Fat concentrations, mean values and standard deviations, in *P. melanarius* during three successive years in Märsta. All differences are statistically significant, $p<0.001$ in all cases.

by heavy metals in the diet. It may also be an indirect effect because the availability of prey may be lower in the polluted area. However, the different fat concentrations in *P. melanarius* over three years in Märsta show that fat accumulation can vary for other reasons than heavy metal pollution. It cannot be excluded that the difference in fat concentrations between Smedjebacken and Märsta are due to factors other than pollution.

There are also other factors that can affect the fat concentration of carabids. They may be attacked by insect parasitoids and they can also suffer from various parasites, such as nematodes or fungal diseases (Thiele 1977). Individuals which suffer from such lesions are not able to accumulate fat to the same extent as healthy individuals. In a study from a similar habitat in the same geographical area as Märsta, 2.7% of the males and 3.8% of the females of *P. melanarius* were parasitized (Wallin 1989). It is likely that a parasitoid larva accumulates some fat, but how the overall accumulation of fat in the parasite-carabid-complex organised is unclear.

Heavy metal pollutants may influence the fat concentration in insects. According to the results of this study this impact was small however, and variation in fat concentration due to other factors seem to be larger than that of metal pollution.

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