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Water striders (Heteroptera, Gerridae) as bioindicators of heavy metal pollution

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Heavy metal contents of water striders collected near a steel factory and from control sites were analyzed by AAS. The average concentrations µg/g of dry weight found near the factory vs. the control areas were: Al 76, 65; Fe 840, 330; Mn 49, 37; Zn 310, 280; Cu 44, 42; Cd 1.6, 6.5, respectively. In most [redacted]

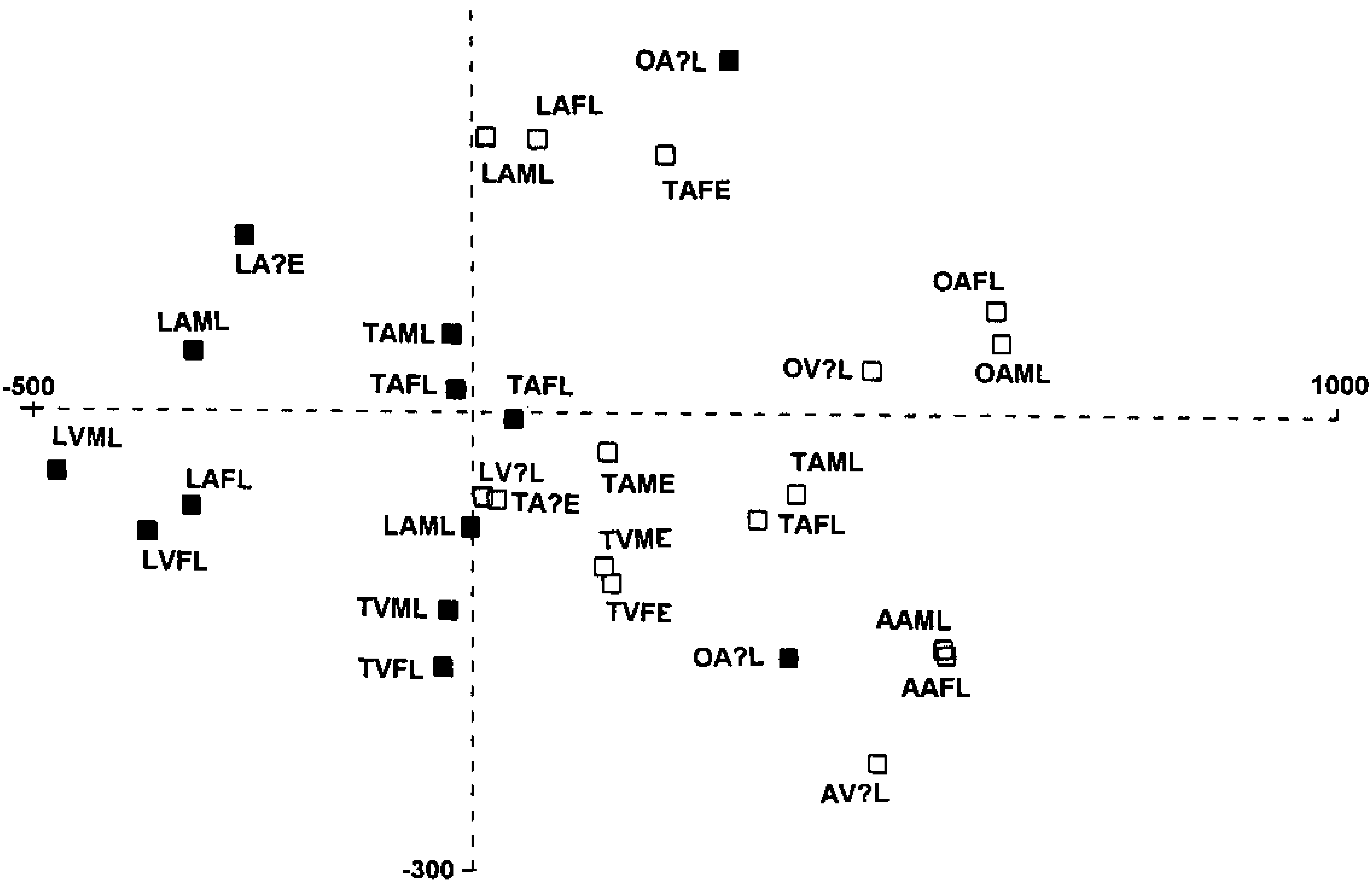

Fig. 1. Ordination diagram based on canonical correspondence analysis (correlation matrix) of the heavy metal concentrations in water strider samples from sites close to the Koverhar iron and steel factory and from a control site. Letters by each point indicate i) species: A = *G. argentatus*, L = *G. lateralis*, O = *G. odontogaster*, T = *G. thoracicus*; ii) developmental stage: A = adult, V = V-instar larva; iii) sex: F = female, M = male, ? = undetermined; iv) sampling time: E = early summer, L = late summer. Samples close to the iron and steel factory are indicated with a black square.

nonical correspondence analysis ordination, *G. odontogaster* values from near the factory differ greatly from the ones collected in the control areas (Fig. 1).

In the analysis of the effect of the sampling site (less/over 2 km from the factory) on iron and cadmium, concentrations differed significantly ($P = 0.001$, Sign test, species, sex, developmental stage and water strider generation constant). Iron concentrations were higher and cadmium concentrations lower in samples taken from close to the factory than those from the control sites.

Heavy metal concentrations did not differ significantly between the sexes in any species in pairwise comparisons (Sign test, distance from the factory, species, developmental stage and water strider generation constant).

The iron content of the developmental stages (adults vs. V-instar larvae) differed significantly. Adults had significantly less iron than larvae ($P = 0.008$, Sign test) in pairwise comparisons. There were no differences in other heavy metals between developmental stages (Sign test, distance to factory, species, sex and water strider generation were kept constant).

The efficiency of different species as accumulators of heavy metals was tested from samples taken in August from Långskär island. Since there was a significant difference between adults and V-instars in iron content (see above), iron was omitted from species comparison. *G. thoracicus* accumulated significantly less zinc than *G. argentatus* and *G. odontogaster* ($t = 4.06$, $P = 0.01$, $df = 5$ for *G. argentatus*; $t = -4.33$, $P = 0.008$, $df = 5$ for *G. odontogaster*, two-sample t-test). *G. odontogaster* accumulated significantly less aluminium than *G. argentatus* ($t = 7.78$, $P = 0.002$, $df = 4$) and *G. thoracicus* ($t = 3.02$, $P = 0.029$, $df = 5$). Also *G. argentatus* was more efficient in accumulating aluminium than *G. thoracicus* ($t = 8.37$,

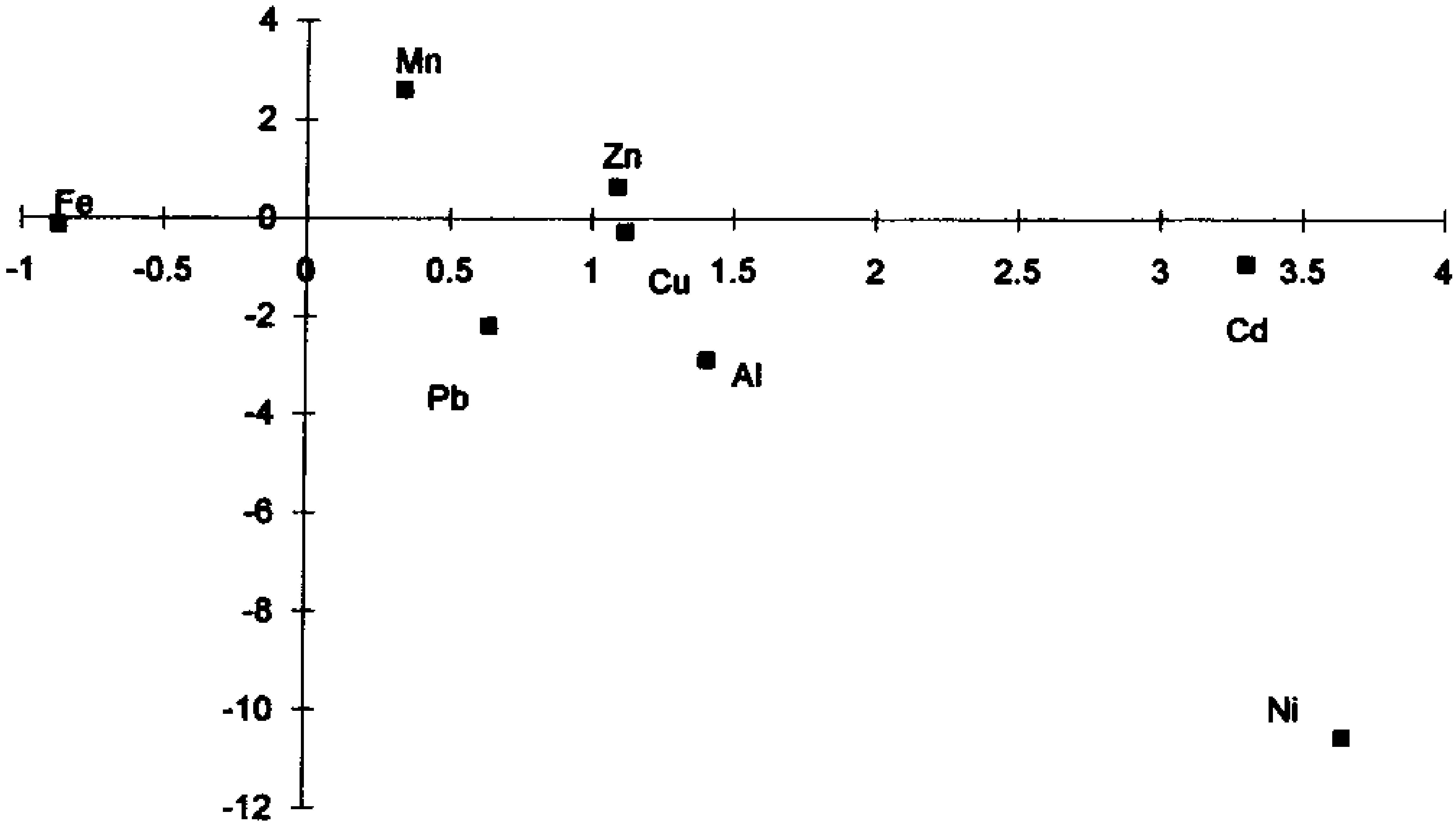

Fig. 2. Ordination diagram based on canonical correspondence analysis (correlation matrix) of the analyzed heavy metal concentrations in water strider samples.

P = 0.0004, df = 5). *G. odontogaster* accumulated significantly more cadmium than *G. thoracicus* (t = – 2.91, P = 0.033, df = 5). All other species-wise comparisons in other heavy metal contents were statistically non-significant (two-sample t-test).

4. Discussion

Water striders seem to be efficient in accumulating cadmium, Cd 6.5 µg/g of dry weight found in in this study, compared with cadmium concentrations considered as high in Formicidae-ants (4–7 µg/g) (Ylä-Mononen *et al.* 1989) and from spiders (2–8 µg/g) (Nuorteva *et al.* 1992). This study confirms the observations by Cheng *et al.* (1984) and Schulz-Baldes (1989) about the suitability of the water strider especially for cadmium indicators. The cadmium concentrations observed in this study are not as high as observed in sea-skaters in tropical oceans (over 100 µg/g) (Cheng *et al.* 1976, Bull *et al.* 1977), but much higher than in Trichoptera larvae in acidificated lakes in Finland (0.5–2 µg/g) (Verta *et al.* 1990). High Cd concentrations in sampled water striders may be partially explained by slightly higher Cd concentrations in stream sediments and stream water in the Hanko area than on average in Finland (Lahermo *et al.* 1995). Also, in the bed rock in the Hanko area, there are small zinc concentrations including cadmium (Raimo Lahtinen, Geological Survey of Finland, pers. comm.). This may also be the case for the bed rock and thus rock pools of Långskär.

This study did not detect any decline in the content of copper and lead with increasing distance from the factory. This type of decline has been detected in mosses in the same area (Rinne & Mäkinen 1988).

In the canonical correspondence analysis, iron, cadmium and nickel seemed to separate each from the cluster of the rest of the heavy metals (Fig. 2). The difference in iron is easy to understand due to the proximity of the factory. Nickel contents were in most cases below the determination level explaining its separation. However, high values of cadmium in "undisturbed" sites require closer studies in the future.

There seems to be a tendency for females to have higher heavy metal contents than males, but the difference is not significant in this study. We hypothesize that the difference could be explained by higher food uptake of larger sized females than males. Additionally, females need more energy and thus food for egg production than males for sperm production. However, possible differences between sexes as heavy metal accumulators need further studies.

V-instar larvae seem to have significantly higher iron contents than adults. The difference between developmental stages were not observed in the contents of the other heavy metals. Syndalsudd spring had a thick rusty sediment on its shallow bottom, and individuals caught in the net were often submerged to the sediment, thus causing external contamination.

G. lateralis populations sampled were almost totally wingless, thus adults originated from the sampling site. Adults in other studied species were winged and thus they may have arrived at the sampling sites from a distance. We believe that *G. thoracicus* adults taken from Lappvik bay in June are most prone to the latter in our samples.

According to the results, it seems that Finnish water striders are suitable as bioindicators for heavy metal studies.

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