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Intestinal Fish Parasites as Heavy Metal Bioindicators: A Comparison Between *Acanthocephalus lucii* (Palaeacanthocephala) and the Zebra Mussel, *Dreissena polymorpha*

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A variety of organisms have been investigated to evaluate their potential as biological indicators of different forms of pollution in the aquatic environment (e.g. review by Gunkel 1994). Certain species have been identified as being highly sensitive either in their physiological response to aquatic contaminants or in their ability to accumulate particular toxins in a dose-time dependent manner.

The zebra mussel, *Dreissena polymorpha,* is generally considered to be a reliable bioindicator for passive as well as active biomonitoring and has been frequently used to detect heavy metal contamination in freshwater ecosystems (e.g. Doherty et al. 1993, Reeders et al. 1993, Stab et al. 1995). *D. polymorpha* is well-suited to its role as a bioindicator because of its accumulation potential and sessile nature (Stäb et al. 1995), the latter feature making it very useful in detecting localized pollution.

A major source of aquatic metal contamination is road runoff which contains a complex mixture of potential toxicants. Maltby et al. (1995) described an increase in the sediment and water concentrations of heavy metals and identified zinc, cadmium, chromium and lead as the dominant metal pollutants derived from motorway runoff. These heavy metals are constituents of fuel, brake linings and vehicle tires (Maltby et al. 1995). A study by Meisriemler et al. (1990) showed that zebra mussels collected from sites receiving road runoff contained higher heavy metal burdens than mussels from less polluted sites.

Recently there has also been an increasing interest in the relationship between parasitism and pollution in the aquatic environment as reflected in several reviews (e.g. MacKenzie et al. 1995). Extremely high concentrations of heavy metals have been found to accumulate in fish parasites, principally in adult acanthocephalans but also to a lesser degree in adult cestodes (Riggs et al. 1987, Sures et al. 1994a, b, c, Sures and Taraschewski 1995, Sures 1996, Sures et al. in press a, b).

Parasites may offer advantages over currently-used bioindicators such

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as *D. polymorpha* including a more widespread distribution and a higher accumulation potential.

The present study was conducted in a freshwater subalpine lake in Austria with localized contamination from motorway runoff. It compares the accumulation of lead and cadmium in the mussel *Dreissena polymorpha* with that occurring in a common fish species and its intestinal acanthocephalan parasite *(Acanthocephalus lucii* in close proximity to the motorway and at a distant reference site.

MATERIAL AND METHODS

Ten Perch *(Perca fluviatilis)* infected with adult *Acanthocephalus* lucid and twelve zebra mussels *(Dreissena polymorpha)* were sampled from each of two sites in Lake Mondsee, Austria. The perch were caught using weir-baskets and the mussels were collected by hand from the substratum. One sampling site was close to the Salzburg to Vienna motorway and received road runoff via a small stream entering the lake. The reference site was about 10 km away from the motorway on the opposite shore of the lake.

The fish and mussels were transported alive to the laboratory, weighed and measured for length (see Table 1). Samples of muscle, liver and intestine were taken from perch with the aid of stainless steel scissors and forceps that were cleaned using a 1% ammonium-EDTA solution. The acanthocephalans were removed from the fish intestine and weighed. All *A. lucii* found in the intestine of an individual perch were pooled and treated as one sample. The zebra mussels were thoroughly rinsed with tap water before removing all soft tissues.
After homogenization of the samples, analytical blanks and standard reference material (DORM 1, National Research Council, Canada) were digested with nitric acid following a microwave digestion procedure described by Sures et al. (1995) and analyzed with a Perkin-Elmer 4100ZL spectrometer. Metal concentrations were compared between tissues and sites using the Mann-Whitney U-test and the Wilcoxon-test with a significance level of $p < 0.05$. Spearman's rank correlation coefficient was used to test for associations between fish length or weight and the concentration of lead and cadmium in the parasites and the tissues of the fish. Similar associations were tested for the zebra mussels.

RESULTS AND DISCUSSION

The detection limit (± 3 SD) was 2.7 ng ml^{-1} for lead and 0.09 ng ml^{-1} for cadmium. Analysis of the standard reference material yielded a recovery value of 100 % for lead and 102 % for cadmium. A comparison between the amount of lead and cadmium when added either before or after digestion revealed that there was no loss of the metals during the digestion process (for details see Sures et al. 1995; Sures 1996).

Summary data on the perch, acanthocephalans and *D. polymorpha* are presented in Table 1. Although there were no significant differences in the length of perch and the number of *A. lucii* between sample sites, the weight of perch and of parasites was significantly higher at the reference site. In contrast, the mean weight and size of zebra mussels was significantly higher at the motorway site than the reference site. However, despite the smaller size of *D. polymorpha* at the reference site analysis of growth rings on their shells (Neumann et al. 1993) indicated that their ages were similar to those from the motorway site.

Table 1. Size and weight of perch, zebra mussels and weight and number of *A. lucii*

		Reference site		Motorway site	
		$\bar{x} \pm$ S.D.	Range	$\bar{x} \pm$ S.D.	Range
Perch	weight [g]	11.6 ± 5.3	6.7 - 25.5	16.8 ± 7.1	9.7 - 31.8
	size [cm]	10.3 ± 1.3	8.6 - 12.9	11.4 ± 1.4	9.9 - 14.1
A. lucii	weight [g]	10.4 ± 12.4	3.0 - 44.8	25.3 ± 22.4	3.8 - 67.8
	number	8 ± 5	2 - 17	16 ± 18	3 - 62
Zebra mussels	weight [g]	1281 ± 329	844 - 2124	840 ± 152	571 - 1061
	size [cm]	2.2 ± 0.2	1.9 - 2.5	2.1 ± 0.2	1.9 - 2.3

Table 2. Spearman correlation coefficients (r) and levels of significance (p) for the significant relationships between host weight, acanthocephalan weight and metal levels in organs of the fish and the parasites

		r	p
Perch[1]	weight perch - [Pb $_{Intestine}$]	0.6383	< 0.05
	infrapopulation biomass *A. lucii* - [Cd $_{Intestine}$]	-0.7039	< 0.05
	mean individual weight *A. lucii* - [Cd $_{A. lucii}$]	0.5877	< 0.05
	[Cd $_{Liver}$] - [Cd $_{Intestine}$]	0.5984	< 0.05
Perch[2]	weight perch - mean individual weight *A. lucii*	0.7156	< 0.01
	size perch - mean individual weight *A. lucii*	0.7890	< 0.01
	weight perch - [Cd $_{A. lucii}$]	0.8146	< 0.01
	size perch - [Cd $_{A. lucii}$]	0.8024	< 0.01
	mean individual weight *A. lucii* - [Cd $_{A. lucii}$]	0.6994	< 0.05

[1]: reference site
[2]: motorway site

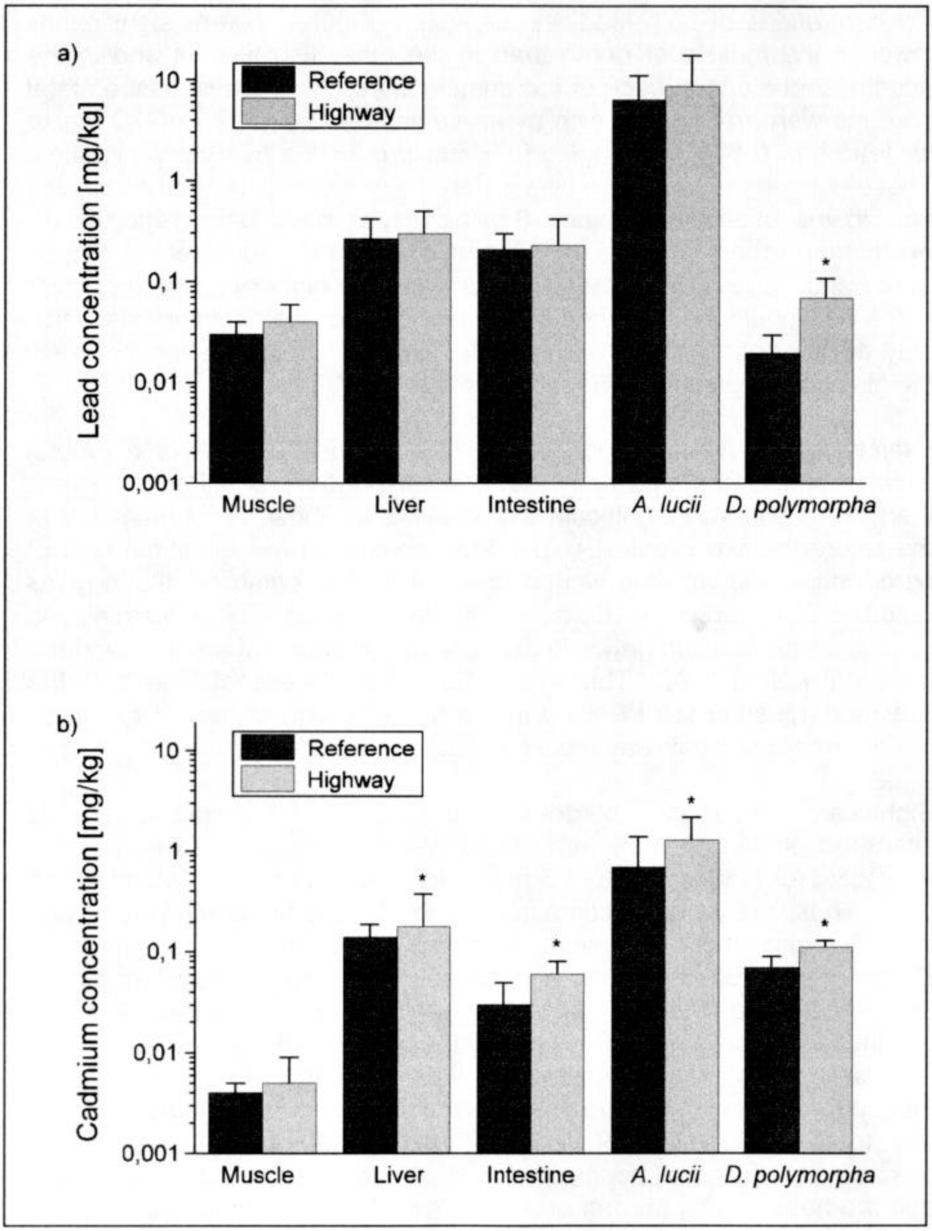

Figure 1. Lead (a) and cadmium (b) concentrations in muscle, liver and intestine of perch, its intestinal parasite *Acanthocephalus* lucii and in the zebra mussel *Dreissena polymorpha* from both sampling sites (*: significant difference).

Concentrations of both lead and cadmium (Figure 1) were significantly lower in the muscle of perch than in the other fish tissues and in the acanthocephalans at each of the sample sites. The highest tissue metal burdens were in the liver with mean values between 0.27 - 0.30 mg/kg for lead and 0.14 - 0.18 mg/kg for cadmium for the two sampling sites. These concentrations in the liver differed significantly from other tissues only in the case of cadmium. Similar results have been reported for perch from other biotopes (Hogstrand et al. 1991, Sures et al. 1994a, Sures and Taraschewski 1995). A considerably higher cadmium content in the liver could be explained by the presence of metallothioneins which play an important role in the accumulation and detoxification of heavy metals such as cadmium (Hogstrand et al. 1991).

Examining correlations between fish weight and tissue metal concentrations and between heavy metal burdens of different organs there were only two significant associations for those perch sampled at the reference site (Table 2). The lead content in the intestinal wall of perch increased with the weight of the fish. The same correlation was reported from turbot by Sures et al. (in press a). There was also a significant association between the cadmium burdens of the liver and the intestinal wall of perch. This association could be expected as both the liver and intestine are involved in the detoxification of heavy metals by the enterohepatic pathway (Lackner 1995).

Significantly, the highest burdens of both metals were recorded from the acanthocephalan *A. lucii* with mean values ranging between 6.4 - 8.7 mg/kg for lead and 0.7 - 1.3 mg/kg for cadmium for the two sampling sites. Thus, the parasite contained up to 30 - 38 times more lead and 22 - 23 times more cadmium than the intestinal wall of its host. Compared to studies dealing with the same host-parasite system from a different biotope (Sures et al. 1994, Sures and Taraschewski 1995) the accumulation capacity for lead and cadmium of *A. lucii* from lake Mondsee seems to be somewhat lower but in the same order of magnitude. The slightly depressed accumulation of the metals could be due to the low weight of *A. lucii* from lake Mondsee. Sures (1996) described a significant positive correlation between the individual weight and the heavy metal burden of *A. lucii* from different limnic biotopes and the same relationship was observed for cadmium at each sample site in the present study (Table 2). Taking into consideration correlations between the age and weight of acanthocephalans (see e.g. Kennedy and Moriarty 1987) the above association may reflect a longer exposure time and hence greater metal uptake by the older acanthocephalans.

The mean individual weight of *A. lucii* (motorway site) itself depends on the size and the weight of its host and positive correlations were thus also recorded between the size and weight of perch and the cadmium content of the parasites. An association between the infrapopulation biomass of *A. lucii* and the cadmium burden of the hosts intestine could be found only for those fish caught at the reference site (Table 2) but was described earlier by Sures (1996) for the same host-parasite system from Lake Niemisvesi (Finland). These results indicate that the acanthocephalans seem to reduce the uptake of metals by their hosts and thus may have a sanitary effect on their hosts in this respect. Further studies should be performed to support or refute this hypothesis.

Compared to the zebra mussels from both sampling sites, *A. lucii* contained up to 120 - 320 times more lead and up to 10 - 12 times more cadmium. The lead burden of *D. polymorpha* from the reference site was approximately as low as in the muscle of perch ranging close to the limit of guarantee of purity (Kaiser 1966). In contrast, the lead concentration of the zebra mussels from the motorway site and the cadmium contents of all mussels were higher than the burden of perch muscle. No significant correlations were found between mussel size or weight and metal burden.

The highest lead and cadmium burdens in the organs of perch and in *A. lucii* were at the motorway site. However, the variability at each site was high and differences between sites were significant only for cadmium concentrations in the host liver and intestine and in *A. lucii.* Although the mean heavy metal burdens of the zebra mussels were considerably lower than those of *A. lucii* there was less variability within sites and the concentration of both lead and cadmium was significantly higher in mussels from the motorway site compared to the reference site.

These results demonstrate that zebra mussels are more suitable to detect localized differences in contamination derived from motorway runoff than fish or their endoparasites. The significantly higher accumulation of both lead and cadmium at the motorway site when compared to the reference site may be due to the immobility of the mussel which is attached to the substratum by byssal threads. In contrast to mussels, perch and their acanthocephalans are more mobile and thus less precise indicators of localized differences in pollution. However, the bioconcentration of heavy metals by *A. lucii* was several times greater than that by zebra mussels. Acanthocephalans are therefore more sensitive indicators for detecting low concentrations of dissolved heavy metals in aquatic ecosystems than zebra mussels due to their higher accumulation capacity. Preliminary laboratory studies on the lead accumulation of acanthocephalans (Sures 1996) have demonstrated time-dose dependent lead concentrations in the parasites which suggests they may be valuable in active (not only passive) biomonitoring of heavy metals. By exposing infected fish in weir-baskets the problems associated with their mobility could be eliminated.

It is necessary from a public health viewpoint to determine the heavy metal concentrations in fish captured for human consumption and the analysis of acanthocephalans from their intestines could provide a sensitive indirect measure of this. However, up to now these parasites have been disregarded in trace analytical studies despite their widespread and common occurrence. The results presented in this study provide support for further investigations into these common organisms and their bioindicating properties.

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