Myotis daubentonii can serve as an integrative bioindicator for changes in metal exposure

Many bats species are worldwide endangered due to loss of habitats (e.g., deforestation), new diseases (e.g., White Nose Syndrome) and pollutants in the environment (e.g., pesticides). Beside pesticides like DDT or Lindane metals are one of the most relevant pollutants. They are persistent in the environment, are transferred along food chains and in case of some metals (e.g., lead) can cause toxicity in organs even at low concentrations. Today, metals account for numerous contaminated sites in Europe. Especially in urban and industrialized areas metal depositions on soils and sediments have locally raised metal concentrations markedly above natural background levels. Insect organisms occurring in contaminated areas are exposed to metals and transfer them to higher levels in the food chain like insectivorous bats. For example, larvae of the non-biting midges inhabit freshwater sediments and as adults emerge from the aquatic into the terrestrial environment. These insects are the main food source for the bat species *Myotis daubentonii* that preferably forage over water bodies. To determine exposure of endangered and protected bats to metals via aquatic insects, non-destructive and non-invasive methods are required. As hair samples reflect metal exposure of a bat species in a given time period, they are suitable as monitoring units. Furthermore, hair can be obtained from individual bats in very small amounts (1–5 mg).

Fig. 1. Graphical abstract

The objective of our study was to examine changes in metal exposure of *M. daubentonii* after sediment dredging as a remediation measure in an urban pond by using hair samples from the

bats. We assumed that effects of the remediation measure would be detectable in the hair of the bats that use the pond as their preferred foraging area.

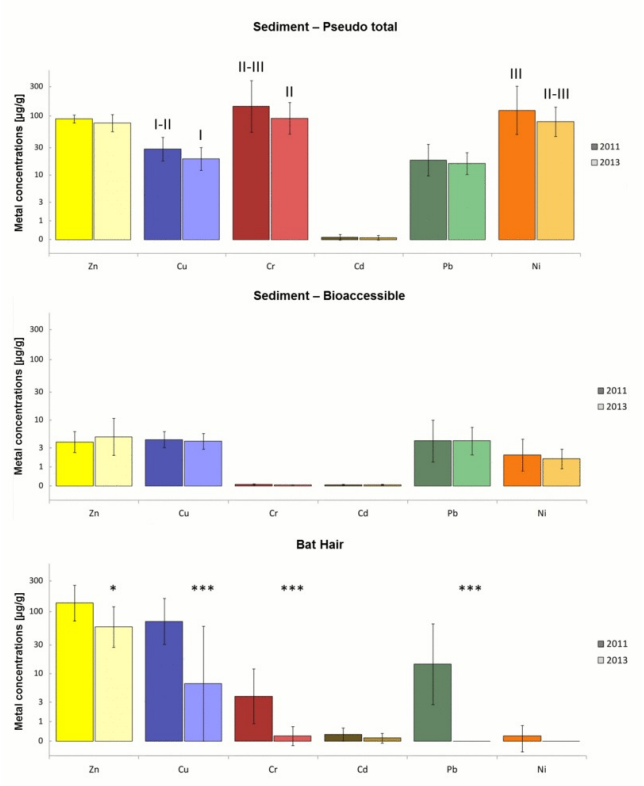

Fig. 2. Metal concentrations (ug/g) of zinc, copper, chromium, cadmium, lead and nickel in sediments (pseudo total and bioaccessible) and bat hair before (in 2011) and after remediation measures (in 2013) at an urban pond. Roman numerals show contamination levels in the sediment according to the German LAWA classification (I = low, I-II = low-to-moderate, II = moderate, II-III = moderate-to-high, III = high). Vertical bars denote 95% confidence intervals and asterisks indicate statistically significant differences between years (*p less than 0.05, ***p less than 0.001).

For this purpose, we took sediment samples from the pond and captured individuals of *M. daubentonii* along their flight path to the pond the year before (in 2011) and after remediation measures (in 2013). Hair of approximately 1–5 mg was sampled from each bat. After preparing of sediment and hair samples metals were extracted using conventional and new microwave-assisted extraction methods. Metal concentrations were quantified by inductively coupled plasma-optical emission spectrometry with the advantage of determining many metals in each sample. With respect to the metal contents in the sediment, we differentiated between pseudo total and bioaccessible concentrations.

Metal concentrations of the sediment (pseudo total and bioaccessible) did not change before and after remediation measures, whereas the contamination of the sediment was reduced from low-to-moderate (I-II) to low (I) for copper, from moderate-to-high (II-III) to moderate (II) for chromium and from high (III) to moderate-to-high (II-III) for nickel according to the German LAWA classification (Länderarbeitsgemeinschaft Wasser, 1998; see Fig. 2). In contrast, concentrations of zinc, copper, chromium and lead in bat hair declined considerably after the remediation (see Fig. 2).

Our results indicate that the effects of the remediation measures to reduce metal contamination of the freshwater sediments were detectable as reduced metal concentrations in hair of *M. daubentonii*. The observed decline in metal levels in bat hair is attributed to a lowered sediment contamination and a resulting lowered transfer of metals from aquatic insects to the bats feeding on them. We concluded that *M. daubentonii* can serve as an integrative bioindicator and that bat hair is a suitable monitoring unit allowing a non-destructive and non-invasive assessment of ambient metal levels.

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