Comparison of Metal Concentrations in the Fore and Hindguts of the Crayfish *Cambarus bartoni* and *Orconectes virilis* and Implications Regarding Metal Absorption Efficiencies

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Received: 13 December 1993/Accepted: 20 May 1994

The anthropogenic perturbation of trace metal cycle has resulted in increased emission of trace metals into the atmosphere (Nriagu 1988). This in turn has resulted in the elevation of trace metals in recently deposited sediments of lakes far removed from the original source of emissions (Wong et al. 1984). Benthic invertebrates, such as crayfish, live and feed directly on recently deposited sediments and, therefore, are in direct contact with metals both of natural and anthropogenic origin. As a result of this intimate association, recent studies have suggested that crayfish may be good indicators of sediment-metal levels as they appear to retain tissue-metal concentrations that are correlated to environmental levels (e.g., for Cu, Zn and Fe, Bagatto and Alikhan 1987a, 1987b; Zia and Alikhan 1989; for Cd, Mirenda 1986a; Naqvi and Howell 1993). However, several other studies have suggested that as crayfish homeostatically control tissue elemental concentrations they, in fact, cannot be used as indicators of environmental metal levels (e.g., for Cu, Evans 1978; Anderson and Brower 1978; for Zn, Bryan 1968).

One aspect that is often missing in studies relating crayfish elemental tissue concentrations to that of environmental levels is a comparison of how efficiently crayfish can absorb the element from its food under different environmental conditions. Specifically, the amount of element that is absorbed may depend on whether the element is in excess or whether amounts in the environment are meeting metabolic requirements. For example, Bryan (1968) suggested homeostatic control of Zn tissue levels by crayfish is achieved through fecal production while the animal is feeding. As the amount of Zn increases in the food, a smaller percentage is absorbed by the hepatopancreas and more is lost via the feces. It is possible that for essential elements that are not in excess (i.e., uncontaminated sites), the assimilation from the food may be highly efficient, whereas for non-essential trace elements, or for essential trace elements which are in excess in the surrounding environment (i.e., contaminated sites), absorption from food may be extremely low. Differences in the ability of the crayfish to absorb elements from food will in turn influence ultimate tissue concentrations.

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One possible way to assess the importance of food as a source of elemental contamination is through gut content analysis; an estimate of the amount of element absorbed from the food can be made by comparing foregut elemental concentrations to the concentrations of elements in the hindgut, i.e., the difference being the amount absorbed. This approach assumes that excretion of the element via fecal production is the primary route of excess elemental elimination. (Bryan (1968) has shown that this does indeed occur for Zn). For essential elements not in excess (i.e., uncontaminated sites), foregut concentrations should either be equal to or greater than hindgut concentrations. Alternatively, essential elements that are in excess (i.e., from contaminated sites) or non-essential elements such as Cd, foregut elemental concentrations should be less than hindgut (i.e., greater concentrations in hindgut as crayfish are actively excreting excess element). Hence, the objective of this study was to determine the importance of food (foregut contents) as a source of essential (Zn, Cu, Mn, Fe, Mg and Ca) and non-essential elements (Al, Cd) in four populations of crayfish sampled from two metal and acid stressed-sites (herein referred to "stressed-sites") versus two non-contaminated reference sites. A previous study by Bendell-Young and Harvey (1991) determined that concentrations of gill Cd and Mn, muscle Mn and carapace Mn were elevated in crayfish populations sampled from the stressed versus reference sites.

MATERIALS AND METHODS

The four study lakes are located in south-central Ontario, two in the La Cloche Mountain area and two in the Muskoka-Haliburton area of Ontario, Canada. The two lakes in the LaCloche Mountain region have been recently acidified by anthropogenic acids. One of these lakes (George) contains elevated levels of Cu in the recently deposited sediments. Both have elevated concentrations of Zn and Mn in the overlying water column relative to the two reference lakes (Bendell-Young and Harvey 1991). The two reference lakes are circumneutral and are remote from point sources of element emission. Relevant water and sediment chemistry are outlined in Table 1. Crayfish were retrieved from the four lakes by either modified minnow trap or hand-picked by SCUBA divers. Captured crayfish were placed in plastic bags and frozen until analysis. Prior to tissue removal, crayfish length, sex and weight were recorded (see Bendell-Young and Harvey 1991). Species were identified by carapace and cheliped characteristics after Crocker and Barr (1968). A total of 56 crayfish were sampled for gut contents; 16 and 18 Cambarus bartoni from lakes George and Lumsden, respectively, and 16 and 5 Orconectes virilis from lakes Blue Chalk and Red Chalk, respectively. Complete foregut (stomach contents) and hindguts were removed from crayfish using glass knives and plastic forceps. Gut contents were dried to a constant weight and analyzed for Zn, Cu, Cd, Mn, Fe, Al, Ca, and Mg via Inductively Coupled Plasma Atomic Emission Spectrophotometry (ICP-AES) at the University of Toronto Analytical Services. Limits of detection for the tissue analysis were 0.008, 0.004, 0.006, 0.0012, 0.002, 0.033, 0.003 and 0.027 mgL⁻¹ for Zn, Cu, Cd, Mn, Fe, Al, Ca and Mg respectively. Quality control of the