Journal of Experimental Marine Biology and Ecology 317 (2005) 159–174

Journal of EXPERIMENTAL MARINE BIOLOGY AND ECOLOGY

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Cd transfer in the deposit-feeder Prosobranch *Hydrobia ulvae* (Pennant) from benthic diatoms: the kinetics of rapid Cd assimilation and efflux

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Received 23 February 2004; received in revised form 1 September 2004; accepted 20 November 2004

Abstract

The kinetics of Cd trophic transfer from benthic diatoms to the Prosobranch mud snail *Hydrobia ulvae* was described experimentally in microcosms using Cd contaminated microalgae (0.71, 3.63 and 8.54 μg Cd mg Chl a^{-1}). The depurated mud snails (2 ind. cm^{-2}) were allowed to feed on the stable Cd pre-contaminated benthic diatoms at the concentration of 2 mg Chl *a* dm^{-3} to ensure that the algal food availability was not a limiting factor. Weight-specific ingestion rate (IR) and assimilation efficiency (AE) were calculated by an indirect mass-balance method on the basis of metal residues in the snail tissues, and metal loss (efflux rate, Δe) was estimated for the time intervals when a decrease or no change in the tissue metal concentrations occurred.

A similar pattern of consumption was observed in all experiments: ingestion was rapid over the first 4 h, followed by slower ingestion period (between 4 and 16 h). The feeding behaviour of *H. ulvae* was not affected by the different diatom Cd concentrations. An analogous two-phasic pattern was observed in the tissue Cd concentration changes. Net accumulation of Cd in the snails was observed for the two highest exposures, indicating that the Cd threshold concentration in food above which metal is retained in the body, lies between 0.71 and 3.63 μg Cd mg Chl a^{-1}. The respective 16-h AEs were 0.024% and 0.004% potentially due to rapid gut-passage of microalgae and/or diminished nutritional value of the food. The efflux rates, calculated for the last 12 h of exposure, were positively related to the concentration of Cd in the snail tissues and microalgae. This study demonstrated that trophic transfer should be considered as a source of Cd accumulation in snails and the ability of *H. ulvae* to enhance their rate of Cd elimination in response to elevated metal concentrations in the ambient environment is relevant for models predicting metal bioaccumulation and toxicity in coastal and estuarine systems.

Keywords: Benthic diatoms; Snails; Trophic transfer; Cadmium; Ingestion rate; Assimilation efficiency; Efflux rate

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doi:10.1016/j.jembe.2004.11.020

1. Introduction

Intertidal mudflats, resulting from deposition of fine-grained sediment particles and clays transported by rivers, serve as traps for sediments, nutrients and detritus. Nutrients and detritus are recycled into the nearshore ecosystem and supply primary production. When the turbidity is high it restricts phytoplankton activity in the water column (Monbet, 1992), and the main primary production is generated on the mudflats by epipelic microphytobenthos, which become the dominant food source for many estuarine animals (Schelske and Odum, 1962). Benthic microalgae have a high nutritional value, thus they enter the benthic food web directly and support growth of deposit- and filter-feeding organisms on the mudflats.

Intertidal sediments accumulate large amounts of organic matter and can act as an important reservoir of trace metals, particularly in regions of intense shellfish culture activity where natural sedimentation is enhanced by biodeposition. Due to elevated terrigenic input of trace metals over the last decades, the concentration of metals in coastal sediments often exceeds their natural levels attributed to geochemical weathering (Luoma, 1989; Amiard, 1992). Once deposited, a fraction of the trace metals may be bioavailable and assimilated by benthic primary producers, such as the microphytobenthos. Since benthic producers are a primary food source, metal transfer along the trophic chain can be expected (Thomas and Bendell-Young, 1998). Thus, elevated metal concentrations in the coastal zone may be a potential risk to various compartments of the trophic web, including human beings (UNESCO, 1987; Han et al., 1994). The trophic transfer of metals in marine food webs has been recognised as an important factor in metal cycling and bioaccumulation (Fisher and Reinfelder, 1995; Reinfelder et al., 1997) and a number of studies have investigated dietary intake of metals by marine and estuarine animals, such as: crustaceans (Reinfelder and Fisher, 1991; Wang et al., 1999), bivalves (Wang and Fisher, 1996; Wang et al., 1996; Reinfelder et al., 1997), fish (Reinfelder and Fisher, 1994; Ni et al., 2000) and birds (Braune, 1987).

On intertidal mudflats of the "Pertuis Charentais" (Marennes-Oléron Bay and Aiguillon Bay) on the Atlantic coast of France, a major factor in contamination of fauna is probably through the microphytobenthos due to its role as an initial source in the trophic chain (Cariou-Le Gall and Blanchard, 1995) and capacity to accumulate trace metals (Pigeot, 2001). In the Marennes-Oléron Bay, the occurrence of Cd is attributed to anthropogenic activities (Boutier et al., 2000); the abundance of microphytobenthos, can reach up to 465 mg Chl *a* m^{-2} (Guarini, 1998) on mudflats in the "Pertuis Charentais", suggesting that it is the major food source for benthic invertebrates in the Marennes-Oléron Bay ecosystem. A number of studies have shown that there is a significant fraction of benthic microalgae in the diet of benthic macrofauna for example, *Macoma balthica*, *Scrobicularia plana* and *Mytilus edulis* (Riera et al., 1999), and *Crassostrea gigas* (Riera and Richard, 1996). In addition, Riera et al. (1996) also suggested that the diet of meiofaunal organisms (e.g. nematodes) consists in large part of microphytobenthos.

Two approaches have been employed to model metal transfer to aquatic invertebrates (Landrum et al., 1992; Luoma and Fisher, 1997). The traditional approach with an equilibrium partitioning model assesses trace metal concentration in an organism on the basis of concentrations in the external environment using the ratio of the metal concentration in the animal's body to that of the water or food (Di-Toro et al., 1991). This method provides information about the enrichment of metals in an organism with respect to the bioavailability of the metal in the environment, but does not define environmental and physiological conditions (Reinfelder et al., 1998) that also affect bioaccumulation. The second approach, using a kinetic model, predicts metal concentration by estimating parameters for each of the physiological processes involved in metal accumulation: ingestion, assimilation, elimination and growth (Thomann et al., 1995; Wang et al., 1996; Wang and Fischer, 1997). By quantifying all these processes, the contribution of each to metal bioaccumulation in a trophic chain could be assessed separately thus allowing their respective importance in overall metal transfer to be evaluated. The kinetic model has already proved to be applicable in a variety of experimental conditions (Wang et al., 1999).

The objective of this study is to quantify the trophic transfer of Cd in the deposit feeder *Hydrobia ulvae* (Pennant) from pre-contaminated benthic diatoms using the kinetic model approach. The prosobranch mud snail *H. ulvae* occurs widely on the Atlantic coast