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Molting as a mechanism of depuration of metals in the fiddler crab, *Uca pugnax*

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Abstract

Metal distributions in the exoskeleton and soft tissues of the fiddler crab, *Uca pugnax*, were examined during intermolt and immediate postmolt to determine if distribution of the metals changed prior to molting and to determine if molting is a feasible mechanism to depurate metals. Fiddler crabs were collected from two locations in New Jersey, a highly contaminated site and a relatively clean environment. The crabs from the contaminated site had higher concentrations of metals in their soft tissues for Cu, significantly higher concentrations of Pb in their soft tissues and carapace, but did not have any significant differences in concentrations of Zn in comparison to their conspecifics from the relatively clean site during intermolt. Crabs from the contaminated site has significantly higher levels of Cu, Pb, and Zn in both their soft tissues and exuvia immediately after molting. Crabs from both sites shifted copper and zinc from the carapace into the soft tissues prior to molting. Lead distribution shifted from the soft tissues to the exoskeleton prior to molting in the population from the contaminated site but shifted from the exoskeleton into the soft tissues for the relatively clean site. Average percent of the total body burden eliminated during the molting process for the highly contaminated site varied with each metal, 12% Cu, 76% Pb, and 22% Zn. Average percent of the total body burden eliminated during molting process for the relatively clean site also varied with each metal and was significantly lower than the conspecifics from the contaminated site, 3% Cu, 56% Pb, and 8% Zn. Molting can reduce overall body burdens significantly and is a feasible mechanism to depurate lead.

Keywords: Metals; Body burden; Molting; *Uca pugnax*; Fiddler crabs; Depuration

1. Introduction

The Atlantic marsh fiddler crab, *Uca pugnax*, is the most abundant of its genus on the eastern coast of the United States. From Cape Cod to Florida, they inhabit intertidal salt marshes in sheltered bays and estuaries and fill a major niche in these ecosystems. *U. pugnax* is a food source for a variety of organisms including birds, fish, and other crabs (Crane, 1975). In addition, their burrowing behavior stimulates the turnover of

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nutrients in the marsh sediment, aerates the soil, and allows deeper root penetration of marsh plants (Bertness, 1985).

Crustaceans have an exoskeleton that must be shed in order to grow. During proecdysis a new cuticle is produced underneath the old one, which is subsequently shed (ecdysis). Calcium is reabsorbed from the exoskeleton just prior to molting, which softens the carapace so that it can be shed (Greenaway, 1985). After ecdysis has occurred, the stored calcium is utilized to harden the new cuticle.

Metals such as copper, lead, and zinc are commonly found in estuaries surrounding urban environments. Metals can be bound to chitin in exoskeletons of crustaceans (Keteles and Fleeger, 2001). These metals become associated with the calcium in the exoskeleton matrix. They may be absorbed to the surface of the exoskeleton or bind to the inner exoskeleton matrix after uptake (Keteles and Fleeger, 2001). Metals also accumulate in the hepatopancreas, and can be stored in granules and/or by binding to metallothioneins (Carvalho and Fowler, 1993; Wallace et al., 2000). Metal-rich granules are a mechanism for long term storage of essential and non-essential metals, where as binding to metallothioneins, regulates internal metal concentrations on shorter time scales (Brown, 1982; Roesijadi, 1992).

Metals can cause disruption of molting, limb regeneration, alteration of blood glucose levels, color changes, and impairment of reproduction in crustaceans (De Fur et al., 1999). Elumalai et al. (2004) found that exposure to cadmium and chromium can alter the reproductive cycle of *Carcinus maenas*, and that the combination of the two metals disrupted the reproductive cycle to a greater extent. Metals have been shown to inhibit regeneration and molting in fiddler crabs (Callahan and Weis, 1983 and Weis et al., 1992). Mercury can also cause sluggishness and lack of responsiveness as well as premature egg dropping in females (Vernberg and Verberg, 1974). As larvae develop, their sensitivity to mercury increases and their swimming behavior is further altered (Vernberg and Verberg, 1974). Vernberg and Verberg (1974) found that sublethal exposure to cadmium affects the development of the larvae and alters their metabolic rate. There has also been some evidence that fiddler crabs may adapt to chronic exposure to toxicants and become more resistant. This could potentially impact the rest of the ecosystem as the toxicants move up the food chain (Callahan and Weis, 1983).

Since some fraction of the body burden of metals is associated with the exoskeleton, molting may be a way for arthropods to depurate metals. Molting in insects has been shown to reduce body burdens of heavy metals (Raessler et al., 2005). However, in the estuarine grass shrimp, *Palaemonetes pugio*, molting did not substantially reduce the amounts of copper, zinc, and cadmium, because they were reabsorbed with the calcium during proecdysis (Keteles and Fleeger, 2001). Bondgaard and Bjerregaard (2005) found that molting of the crab *C. maenas* did not reduce cadmium levels. Molting played a role in metal concentrations and their distributions in soft tissues and the exoskeleton in amphipods (Weeks et al., 1992).

The purpose of the present study was to determine if fiddler crabs can reduce their overall body burdens of metals significantly as a result of molting. We studied two populations, one from a highly contaminated site and one from a relatively clean environment to determine if there were differences in the way copper, lead, and zinc were distributed in intermolt and postmolt individuals.

2. Study sites

2.1. Piles Creek (PC)

Piles Creek (PC) is located in Linden, New Jersey, and is a tributary of the Arthur Kill. The site is surrounded by industrial sites, a sewage treatment plant, and a major highway. Oil spills in the Arthur Kill and possible leachate from landfills have also been a source of organic contaminants (Perez and Wallace, 2004). This site has been the source of ecological research for over 20 years. Studies have been conducted on resident fish, shrimp, crabs, and ecology of the system (Santiago Bass et al., 2001). Elevated levels of organic contaminants and metals have been found in sediments and biota (Weis et al., 2001).

2.2. Great Bay-Mullica River Estuary (TK)

The Tuckerton (TK) site is part of the Great Bay-Mullica River Estuary and part of the Jacques Cousteau National Estuarine Research Reserve in New Jersey. It is part of 3500 acres of protected salt marsh. It is a