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Effects of ghost shrimp on zinc and cadmium in sediments from Tampa Bay, FL

Paul L. Klerks [a,*], Darryl L. Felder [a], Karen Strasser [b,1], Peter W. Swarzenski [c]

[a] Department of Biology, University of Louisiana at Lafayette, Lafayette, LA 70504, USA
[b] Department of Biology, University of Tampa, Tampa, FL 33606, USA
[c] U.S. Geological Survey, Saint Petersburg, FL 33701, USA

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Abstract

This study investigated the effects that ghost shrimp have on the distribution of metals in sediment. We measured levels of HNO_3-extractable zinc and cadmium in surface sediment, in ghost shrimp burrow walls and in sediment ejected by the ghost shrimp from their burrows, at five sandy intertidal sites in Tampa Bay. Ghost shrimp densities and their rate of sediment ejection were also quantified, as were sediment organic content and silt+clay content. Densities of ghost shrimp (*Sergio trilobata* and *Lepidophthalmus louisianensis*) averaged 33/m^2 at our sites, and they ejected sediment at an average rate of 28 g/burrow/day. Levels of both Zn and Cd were significantly higher in burrow walls than in surface sediments. Sediment ejected by the shrimp from their burrows had elevated levels of Zn (relative to surface sediments) at one of the sites. Sediment organic content and silt+clay content were higher in burrow-wall sediments than in ejected sediment, which in turn tended to have values above those of surface sediments. Differences in levels of HNO_3-extractable Zn and Cd among sediment types may be a consequence of these sediments differing in other physiochemical characteristics, though the differences in metal levels remained statistically significant for some sites after correcting for differences in organic content and silt+clay content. We conclude that the presence of ghost shrimp burrows contributes to spatial heterogeneity of sedimentary metal levels, while the ghost shrimp bioturbation results in a significant flux of metals to the sediment surface and is expected to decrease heterogeneity of metal levels in sedimentary depth profiles.

Keywords: Metals; Sediments; Sediment composition; Bioturbation; Particle size; Ghost shrimp; USA; Florida; Tampa Bay

1. Introduction

Benthic organisms may have substantial influences on their immediate environment. It is well known that some species have large effects on community composition, resulting in their "keystone species" designation (e.g. Birkeland, 1989). But benthic organisms can also influence the abiotic component of their environment, altering sediment physiochemical characteristics. One group of benthic organisms that may play a big role in sediment modification is the thalassinideans (mud- or ghost shrimp), as illustrated by the recent application of the term "ecosystem engineers" to this group of organisms (Berkenbusch and Rowden, 2003). First, ghost shrimp maintain large burrow systems which can extend to a depth of 2–3 m (Felder and Griffis, 1994; Pemberton et al., 1976). These structures greatly increase

* Corresponding author. Department of Biology, Box 42451, University of Louisiana at Lafayette, Lafayette, LA 70504, USA. Tel.: +1 337 482 6356; fax: +1 337 482 5834.
E-mail address: klerks@louisiana.edu (P.L. Klerks).
[1] Present address: Department of Biology, Ferris State University, Big Rapids, MI 49307, USA.

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the surface area of the sediment/water interface (Pemberton et al., 1976), with this additional interface usually differing from the sediment surface in characteristics such as organic content, particle size and microbial abundance (Bird et al., 2000; De Vaugelas and Buscail, 1990; Felder, 2001). Second, ghost shrimp may modify sediments as a consequence of their processing of water and sediment. High individual rates of bioturbation combined with densities that may reach 450/m^2, means that sediment processing rates may exceed 100 kg (dry) sediment/m^2/year (Berkenbusch and Rowden, 1999; Felder and Griffis, 1994). Many ghost shrimp species may actively pump large amounts of water (in part consisting of sediment pore water) out of their burrows (Colin et al., 1986), while suspension-feeding species pull in large amounts of water from the water column (Griffen et al., 2004). These activities thus move around large amounts of sediment and increase fluxes between the water column and the sediment.

This active movement of water and sediment by ghost shrimp means that these bioturbators could have a direct effect on levels and distribution of contaminants in sediment. However, since sediment metal levels are generally influenced by the sediment's other physiochemical characteristics, ghost shrimp activities could also indirectly affect contaminant levels and distribution. Ghost shrimp burrows are often lined with material that is rich in organic components (a combination of material secreted by the ghost shrimp and an enhanced microbial community) and that has a smaller average grain size than does the surrounding sediment (De Vaugelas and Buscail, 1990; Felder and Griffis, 1994). In keeping with the general observation that sediment contamination tends to be positively correlated with sediment organic content and sediment clay content (e.g. Feijtel et al., 1988), there is some evidence for contaminant levels in the walls of ghost shrimp burrows to be enriched relative to the surrounding sediment (Abu-Hilal et al., 1988; Over, 1990; Whitehead et al., 1988). However, it is unclear whether this is a general phenomenon. The situation is likely to differ among species, especially since some ghost shrimp burrows lack a mucous lining (Bird et al., 2000). While differences in sediment particle size and sediment organic content may lead to contaminant levels in ghost shrimp burrows being different from those of surrounding sediment, other factors may play a role. For example, trace metal levels in burrow walls were shown to be relatively depleted when normalized to sediment organic content (Abu-Hilal et al., 1988) but enriched relative to clay abundance (Over, 1990). As indicated above, the influence of ghost shrimp on sediment contamination may not be limited to the construction and maintenance of the burrows, but also to their ventilatory movement of burrow waters and their feeding activities. The high sediment pore water exchange rate between the burrows and the surrounding sediment (Webb and Eyre, 2004) may affect contaminant levels in the burrow walls. Also, materials that ghost shrimp expel from their burrows, consisting of fecal pellets and processed sediment, may differ from surface sediment with respect to contaminant levels. Expelled sediment may be depleted in organic carbon (De Vaugelas and Buscail, 1990) and one would therefore expect lower contaminant levels in this material. Again, factors other than sediment particle size and sediment organic content may play a role. One such factor is the source of this sediment. It was shown that ghost shrimp at Enewetak and Bikini atolls bring some buried radionuclides (present there from past nuclear tests) back to the sediment surface (Suchanek and Colin, 1986). In the typical polluted environment (where contaminant levels decrease with depth in the sediment) one would expect the material brought up by the ghost shrimp to have lower contaminant levels than the surface sediment. It is thus clear that ghost shrimp can have various influences on sediment contamination. Studying the interplay between ghost shrimp and sediment contamination is made especially relevant by the observation that ghost shrimp can be present at very high densities in contaminated areas (Pemberton et al., 1976).

This study was aimed at providing further insight into the effect of ghost shrimp on sediment contaminants, by looking at HNO_3-extractable levels of two metals (Zn and Cd) in both burrow walls and expelled sediment. This study was conducted in Tampa Bay, an estuary well characterized with respect to sediment pollution and sediment toxicity and known to be impacted by pollution (Carr et al., 1996). We choose these specific metals to represent a biologically-essential element (Zn) and a non-essential one (Cd). Tampa Bay sediment is anthropogenically enriched with respect to various metals, and both Zn and Cd are chemicals of concern that appear to play a role in sediment toxicity (Carr et al., 1996; Grabe, 1997; Long and Greening, 1999). We focused on two locally abundant ghost shrimp species (*Sergio trilobata* and *Lepidophthalmus louisianensis*). In addition to quantifying metal levels in ghost shrimp burrow walls, ejected sediment and surface sediment, we quantified sediment organic content and particle size in order to evaluate the extent to which these factors were responsible for changes in trace metal levels. Furthermore, quantifying the amount of sediment ejected by the ghost shrimp allowed us to assess the