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Linking environmental heavy metal concentrations and salinity gradients with metal accumulation and their effects: A case study in 3 mussel species of Vitória estuary and Espírito Santo bay, Southeast Brazil

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HIGHLIGHTS

- Metal pollution in estuaries and bays around Vitória island (SE Brazil) was monitored
- (Heavy) Metal load in water, suspended matter and sediment were determined
- Biological parameters and bioaccumulation of metals measured in three mussels species
- Contamination for Cd, Cu, Fe and Mn was higher in mussels at low salinity sites
- Energy store and condition index in mussels correlated with salinity gradient

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ABSTRACT

The present study was conducted to link the heavy metal load in three species of mussels (*Perna perna*, *Mytella falcata* and *Mytella guyanensis*) from the estuaries and bays around Vitória island, south-east of Brazil, with the salinity gradient and the heavy metal levels in the abiotic environment (including water, suspended particulate matter (SPM) and sediment). Primarily based on the salinity gradient, a total of 26 sites around Vitória Island were selected for sampling of water, SPM, sediments and organisms. Besides tissue metal levels, the condition index and energy stores (glycogen, lipid and protein) were quantified as an indicator of fitness in response to metal pollution. Dissolved metals in water indicate that Cd and Mn content was higher along Espírito Santo Bay, while Al, Co, Cu, Cr and Fe were elevated in the sites with low salinity such as river mouths, estuarine and sewage canals. Likewise, suspended matter sampled from low salinity sites showed a higher heavy metal load compared to moderate and high salinity sites. Though mussels were sampled from different sites, the contamination for Cd, Cu, Fe and Mn was higher in mussels inhabiting low salinity sites (*M. guyanensis* and *M. falcata*) compared to *P. perna*, a high saline water inhabitant. However, a higher Zn body burden was observed for *P. perna* compared to *Mytella* species. Tissue Fe accumulation (but not Mn and Zn) correlated with heavy metal levels in suspended material for all three species, and for *M. falcata* this correlation also existed for Cd and Cu. Energy store and condition index in all mussels varied depending on the sampling sites and correlated with salinity gradient rather than tissue metal concentration. Overall, metal concentration in mussels did not exceed the safe levels as per the international standards for metals, and would be of no risk for human consumption.

1. Introduction

Heavy metals (or trace elements) are naturally found in the hydrosphere, with many of them essential in minimal quantities for the well-functioning of living organisms. Nowadays, much more attention is drawn to the wide occurrence of metal pollution in aquatic systems. Heavy metals are deemed serious pollutants because of their toxicity, persistence and non-degradability in the environment. Some heavy metals (Hg, Cr, Cd, Ni, Cu, Pb and Zn) may transform into persistent metallic compounds with high toxicity (Hyun et al., 2006; Maanan, 2007). Even though some metallic compounds can be absorbed onto the suspended particles and sediments, they can be released into the water under favorable conditions depending on salinity, Eh, and pH (Xu and Yang, 1996; Zhou et al., 2008). Furthermore, these metals can bioaccumulate in aquatic organisms and magnify in the food chain,

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and thus can threat human health (Fergusson, 1990; Jin, 1992; Zhou et al., 2008; Li et al., 2010). Elevated concentrations of heavy metals in tissue can cause toxicity, and adversely affect the physiological, metabolic, ion-regulatory and ecological performance (Walker et al., 2012). In the coastal region of Vitória (State of Espírito Santo capital) Southeast Brazil more than 400 industries (typically for steel and iron ore processing) were established by late 2000 and they contribute to the emission of pollution and particulate matter (Ovalle et al., 2013). In general, mussels are consumed all over the area (nearby Vitória, Brazil) without any quality control for public health, underpinning the importance of biomonitoring programs not only for environmental protection but also for health security.

Biomonitoring is a scientific technique assessing environmental exposure, including human exposure to natural and synthetic chemicals, based on sampling and analysis of organism's tissues and fluids. The use of particular organisms as biomonitors of heavy metal bioavailability in coastal water allows comparisons to be made over space and time, as biomonitors provide integrated measures of the ecotoxicologically significant fraction of ambient metal in water, suspended matter and sediment (Phillips and Rainbow, 1993; Rainbow, 1995; Sarkar et al., 2008; Besse et al., 2012). The well known 'mussel watch' monitoring program is used to assess the spatial and temporal trends in chemical contamination in estuarine and coastal areas. Mussels are commonly preferred for biomonitoring of aquatic metal pollution because of their advantages over other organisms such as wide geographical distributing, abundancy, sedentary, tolerance to environmental alterations, tolerance to various environmental contaminants, high bioconcentration factors of pollutants, very low-level metabolizing enzyme activities of organic contaminants, wide and stable populations, reasonably long-lived, reasonable size and sturdy enough to survive in field and laboratory studies (Boening, 1999; Tanabe and Subramanian, 2003; Sarkar et al., 2008; Zhou et al., 2008).

In general, sediments act as sinks for trace metals in estuaries and other coastal waters as they can readily bind with metal, and are also the source of metals for animals, particularly for burrowing infauna. It is important to distinguish two routes of metal uptake from the sediment — firstly dietary uptake of metals associated with sediment ingested by deposit feeders, and secondly uptake from solution in interstitial pore water released in equilibrium from the sediment particles (Rainbow, 2006; Sarkar et al., 2008). On the other hand, pollutants associated with suspended particulate matter might be more important for filter feeders. When confronted with polluted environments, biota utilizes different physiological and metabolic strategies to maintain homeostasis. Energy translocation which is reflected as the tissue energy stores is the most common compensatory response to cope to adverse situations, and also assist to estimate fitness and/or condition status (Capuzzo, 1988; Smolders et al., 2002, 2004). Persistent organic pollutants (POPs), widely occurring contaminants in coastal areas, can cause potentially harmful effects on ecosystems including human health. POPs are resistant to biological degradation, and are characterized by low water and high lipid solubility, leading to their bioaccumulation in the food chain (Iwata et al., 1993). POPs such as polychlorinated biphenyls (PCBs) and dichloro-diphenyl-trichloroethane (DDT) and its metabolite, polybrominated diphenyl ethers (PBDE), hexachlorocyclohexanes (HCHs), and hexachlorobenzene (HCB) are of global concern due to their intensive use for agricultural and industrial purposes particularly in developing countries (Mao, 1995; Miyamoto and Klein, 1998).

Considering the potential threat of aquatic pollution to mankind, the main aim of the present study was to perform biomonitoring for pollutants in the coastal region of Vitória, Espírito Santo, Southeast Brazil through the assessment of heavy metal contamination in mussels (*Perna perna*, *Mytella falcata* and *Mytella guyanensis*) and other environmental compartments (water, suspended matter and sediment) and to link these with the occurring salinity gradient and the condition of the mussels expressed as the energy status (glycogen, lipid and protein) and the condition index (dry tissue weight/shell weight).

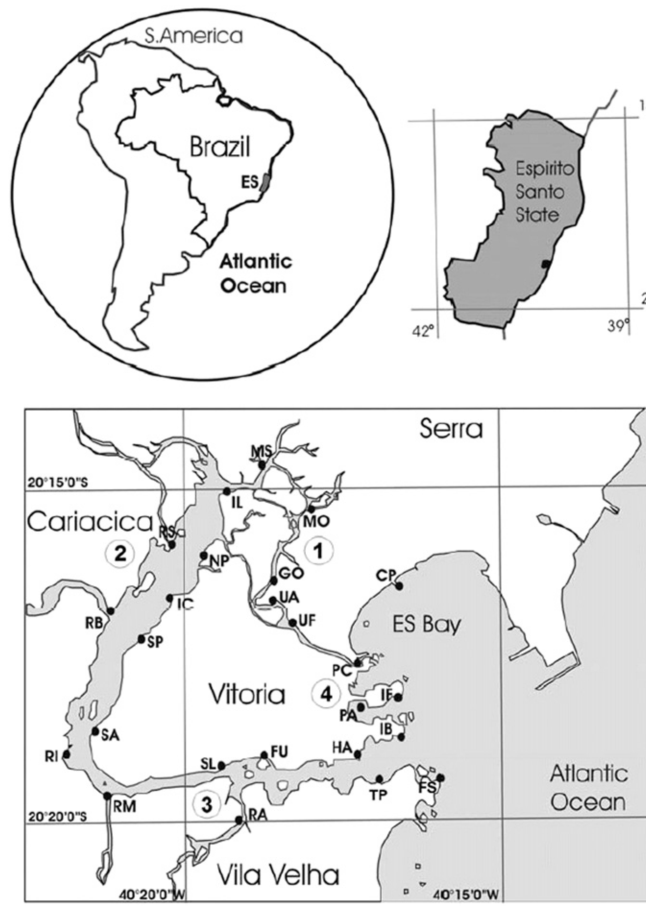

Fig. 1. Study area, marine and estuarine region of Vitória, Espírito Santo, south-east of Brazil. Sampling places indicated on the map are listed in Table 1.

2. Material and methods

2.1. Description of the study sites

The study area is situated in a metropolitan vicinity i.e., Vitória, Espírito Santo State, which is located in the Southeast of Brazil (geographic coordinates of 20° 19′ of South Latitude and 40° 20′ West Longitude). The Grande Vitória (metropolitan area) comprehends the Vitória Capital and its main cities are Vila Velha, Cariacica and Serra. However, this coastal area is composed of river systems, an estuarine region and bays. Most of the human activity and environmental impacts are concentrated on the central zone i.e. Vitória Island (Fig. 1). The estuarine region around the Vitória Island is boarded by continental areas and has a main freshwater influx from the median size Santa Maria River, smaller rivers, Bubu, Itanguá, Marinho and Aribiri. Additionally, there is also the output from natural creeks, transformed in urbanized fluvial drainage channels, and from effluent sewage from the cities. Tides from the Atlantic Ocean influence the Santa Maria River Delta Northwest of the island encompassing 18 km^2 of mangrove ecosystem.

Comparable to the study by Jesus et al. (2004), the total study area was divided in four zones including: 1) Passagem canal (sampling sites: MS, MO, GO, UA, UF); 2) upper Vitória Bay, which comprises the estuarine area northwest face of Vitória Island with a high influence of rivers (sampling sites: SP, IC, RB, NP, RS, IL); 3) Port Canal comprising the south side of the Vitória Island (sampling sites: FU, SL, RA, RM, RI, SA); 4) and Espírito Santo Bay which is oriented toward the Atlantic Ocean (sampling sites: CS, TP, FS, HA, IB, IF, PA, PC, CP). For abbreviations and detailed information of each station see Table 1.