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Urbanization effects on different biological organization levels of an estuarine polychaete tolerant to pollution

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ABSTRACT

Estuarine species exposed to diffuse contaminants might trigger either positive or negative feedbacks in many biological scales. Their life history traits performing at different biological organization levels could propose an organism as a useful indicator of environmental pollution, mainly addressed as sensitive or tolerant species. To track the effects of contaminants from the molecular to the population level of the polychaete *Laeonereis acuta* we utilize a framework of biomarkers. For this purpose we assessed the *L. acuta* frequency of micronuclei at the molecular level, the body size and biomass at individual level, and the production-to-biomass ratio at population level in five urbanized and five non-urbanized estuaries in southern Brazil. *L. acuta* had significantly varying positive and negative feedbacks between urbanized and non-urbanized estuaries at multiple biological scales. These generalized effects in all biological organization scales indicate a pollution impact on the polychaete. The main responses accounted for individuals becoming lengthy and weighty, but with molecular damage. The *L. acuta* allocation of energy to body enlargement in polluted environments, and a consequent reduced population turnover, contradicts the expected from an opportunist species. The damages in DNA and the internal strategies of individuals, as antioxidant defense mechanisms, could favor resistance of the population and tolerance to pollutants. All of these characteristics induce bioaccumulation and could cause bottom-up pollution transfer compromising the estuarine food web. These results, ascertain that *L. acuta* could be considered as a tolerant species, instead of an opportunistic, and as a useful indicator of environmental pollution in estuaries.

1. Introduction

Coastal urbanization has increased the discharge of diffuse toxic substances into water bodies responsible for acute and chronic degradation of the estuarine biota. In advanced situations, this process causes elimination of sensitive species and dominance of the most tolerant or opportunistic individuals (Klerks and Weis, 1986; Bickham et al., 2000; D'Alessandro et al., 2015). Along their evolutionary history, tolerant species might have selected life traits with adaptive values (fitness) that are nowadays coupled with or benefited from contaminants (Kawecki and Ebert, 2004). Notwithstanding, species exposed to contaminants usually present negative responses in genetic, physiological, morphological and behavioral levels (Mersch et al., 1996; Fleeger et al., 2003; Schiedek et al., 2006; Catalano et al., 2012). The description of biological mechanisms under such evolutionary and ecological scales has been a current challenge to elucidate how species function as tolerants to environmental pollution.

Evaluation of the effects of contaminants usually involves an outlined bulk of biomarkers (Monserrat et al., 2007). To integrally comprehend those effects, the biomarkers need to be processed in many biological scales, as species may experience stress at different levels of biological organization throughout the medley from molecular to the community level. Among the implications to the environmental management of investigating many biological orga-

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nization levels, the assessment of changes in lower biological levels can be used to avoid further effects on higher levels, when they have not yet happened. However, the uses and responses of biomarkers in molecular or subcellular levels in invertebrates are still poorly known and fragmented (Dixon et al., 2002). Conversely, the expression of both qualitative and quantitative damage to DNA is very similar between invertebrates and higher complexity organisms (Dixon et al., 2002; Hagger et al., 2002; Jha, 2004). These similarities could be used to drive endeavors in researches with marine invertebrates.

Polychaetes numerically dominate the estuarine communities living in the water-sediment interface, have a short lifespan and are less motile than other benthic macroinvertebrates, and thus responsive to changes in their surrounding environment. All of these characteristics confer the generic status of good indicators of environmental health (Durou et al., 2007; Botter-Carvalho et al., 2011). The Nereididae polychaete *Laeonereis acuta* is widely spread in South American Atlantic estuaries and sheltered areas, from 2°S (Brazil) to 42°S (Argentina) (Orensanz and Gianuca, 1974; Pamplin et al., 2007). Early studies have indicated *L. acuta* to have an opportunistic behavior because of their relatively short life cycle and rapid sediment recolonization strategies (Netto and Lana, 1994; Omena and Amaral, 2000). Further studies highlighted the species as pertaining to a tolerant assemblage in urbanized estuaries (Pagliosa and Barbosa, 2006). This was suggested after their density and biomass were found to be related to the general state of the environment, both in water and sediments, than simply to modifications in the sediment. More recently, the potentiality of *L. acuta* as a tolerant bioindicator of pollution has stimulated the mapping of their histological and morphological alterations, as well as biochemical responses, accumulation, and biotransformation after exposure to contaminants (Geracitano et al., 2002; Ferreira-Cravo et al., 2008; Ventura-Lima et al., 2011). However, an integrated biomarkers assessment at different levels of biological organization of *L. acuta* under urbanization effects is still lacking.

The aim of this study was to assess the effects of diffuse pollution caused by urbanization in estuaries at different biological organization levels of the polychaete *L. acuta*. For this purpose we used the biomarkers frequency of micronuclei at subcellular level, body size and biomass at the individual level, and production-to-biomass ratio at the population level. This framework was applied in urbanized and non-urbanized estuaries. Thus, we expected *L. acuta* biomarkers to indicate the environmental health differences between estuaries types which would be detected in all levels of biological organization. It is hypothesized that *L. acuta* from urbanized estuaries will exhibit higher frequencies of micronuclei in cells, lower individual body sizes and biomass, as well as higher production-to-biomass ratio in populations when compared to those from non-urbanized estuaries.

2. Material and methods

The study was conducted from August to September in 2014 at ten estuaries located between the coordinates 25°5′S–48°3′W and 27°5′S–48°4′W (Fig. 1). The coastal region is typically composed of bights founded by quaternary sediments turning over marine, tidal, and river-lake plains crossed by estuaries. The climate is humid subtropical with rainfall well distributed throughout the year. The annual mean temperature is 20 °C with seasonal differences ranging from 17 to 22 °C. The tidal regime is microtidal with average amplitude of 0.83 m for spring tides and 0.15 m for neap tides (Cruz, 1998). The estuarine basins in south Brazil are generally well preserved areas (highest concentrations recorded: 1 μM of P, 52 μM of N, 27 mg/kg of Cu, 28 mg/kg of Pb, 105 mg/kg of Zn) interspersed with urbanized areas (highest concentrations

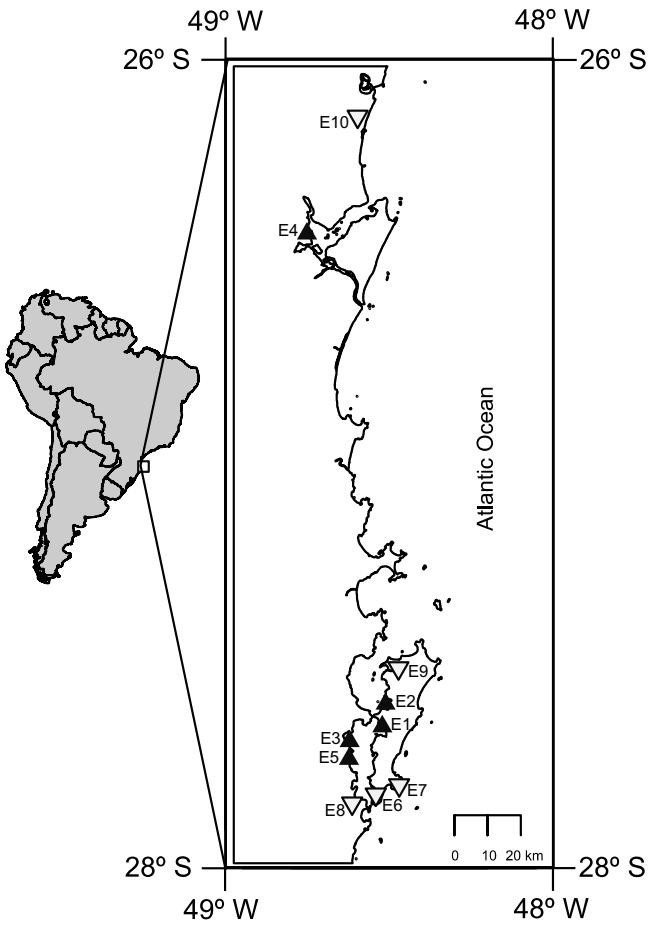

Fig. 1. Map indicating the 10 estuaries in Southern Brazil. E1-Costeira do Pirajubaé, E2–Itacorubi River, E3-Maruim River, E4-Saguaçu Bay, E5-Aririu River, E6-Ribeirão da Ilha, E7-Lagoinha do Leste, E8-Massiambu River, E9-Ratones River, E10-Sai Mirim River.

recorded: 12 μM of P, 217 μM of N, 46 mg/kg of Cu, 56 mg/kg of Pb, 144 mg/kg of Zn) (Pagliosa, 2005; Pagliosa et al., 2006a,b, 2016; Rovai et al., 2013). Then, we performed a visual interpretation of aerial images complemented by field surveys, and used existent data of water and sediment quality to select. In this sense, we have determined two types of estuaries for our study in relation to the degree of anthropogenic environmental disturbance: (i) urbanized estuaries, whenever available, indicated by the water and sediment data, and when a great extent of the estuarine basins was composed of residential, commercial or industrial areas with clear signs of disturbed landscape; and (ii) non-urbanized estuaries, whenever available, indicated by the water and sediment data, and when the estuarine basin presents just a small or absence of signs of anthropic interventions and visually the physiognomy of the landscape is preserved. The study estuaries were spaced from 05 km to 200 km and belonged to a different watershed, avoiding confound effect of urbanization.

In order to assess the responses of *L. acuta* to environmental conditions, three sites were randomly established in shallow waters at the mouth of five urbanized and five non-urbanized estuaries. The mouths of the estuaries were chosen for sampling because they sink the continental material and might therefore represent the general health of these small systems. At each site, individuals of *L. acuta*, sediment and water were sampled. The effects of urbanization on different levels of biological organization of the polychaete were assessed using: (i) the frequency of micronuclei, at the molecular

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