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Changes in zooplankton communities along a mercury contamination gradient in a coastal lagoon (Ria de Aveiro, Portugal)

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ABSTRACT

The main objective of this paper was to evaluate the impact of mercury on the zooplankton communities' structure and functioning and their bioaccumulation patterns along a contamination gradient in a temperate coastal lagoon. Our results demonstrated that total abundance was not negatively affected by Hg contamination, since the most contaminated areas presented the highest values, being the copepod *Acartia tonsa* the dominant species, which means that it is a very well adapted and tolerant species to mercury. Nevertheless, negative effects were observed in terms of species diversity, since the most contaminated areas presented the lowest values of species richness, evenness and heterogeneity. Moreover, the spatial mercury gradient was reflected on the bioaccumulation patterns of the zooplankton communities. This reinforces the idea that zooplankton can be considered as an important vehicle of mercury transfer through the food pelagic web since it constitutes a primordial food resource for several commercial fish species.

1. Introduction

Mercury (Hg) is one of the most hazardous contaminants in aquatic environments recognized by the European Water Framework Directive (WFD) as a high priority environmental pollutant. Its high mobility, persistence and lipophilicity (Nunes et al., 2008) may lead to severe widespread environmental problems due to its tendency to bioaccumulate, and toxicity for wildlife and humans (e.g. Coelho et al., 2008; Nfon et al., 2009).

The accumulation of mercury from nonpoint sources and direct discharges from industrial factories in aquatic ecosystems, where local populations extensively use resources, is also a serious conservation and human health concern in coastal areas (Selin, 2009; Costa et al., 2012). Estuaries may constantly receive mercury discharges being sediments repositories of this contaminant, and consequently a potential source of mercury for the aquatic environment (De Marco et al., 2006). In turns, mercury biotransfers up to the food chain via both benthic and pelagic pathways (Coelho et al., 2008; Chen et al., 2009), being the contamination a dangerous risk to the estuarine species most of them representing high ecological and economic interest. Moreover, other risks are involved, namely, considering edible species, food safety and lastly public health (Karagas et al., 2012).

Recent studies have emphasized the need to address upper and lower trophic levels separately to understand the accumulation and fate of metal contaminants at different trophic levels (Chen et al., 2000). Many zooplankton species can accumulate and metabolize pollutants and then their abundance and/or the species diversity can be used as an indicator of water quality (Telesh, 2004; Thompson et al., 2007; Stewart et al., 2008). In addition, metal accumulated in these organisms has also the potential to provide information about the bioavailability of toxic metals in aquatic systems (Rainbow, 2002). In this respect, previous research has demonstrated that variations in the zooplankton community structure are associated with variations in the concentrations of mercury in fish tissues and therefore may be effective predictors of mercury biomagnification (Chen and Folt, 2005). On the other hand, phytoplankton accumulates mercury (bioconcentration) and together with mercury enriched particles in the water column serve as a food source supporting zooplankton growth (Mason et al., 1995; Wu and Wang, 2011). This leads to important mercury concentrations in planktivorous fish as well as in top predators in pelagic-based food webs (Stewart et al., 2008; Chetelat et al., 2011).

In estuarine coastal waters copepods are usually the dominant group of mesozooplankton (e.g. Kimmel and Roman, 2004;

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Marques et al., 2007) playing important roles in trophic food webs since they are a link between primary producers and secondary consumers. Their role as major grazers in aquatic food webs (Turner, 2004) attribute them a key role in the estuarine planktonic food web and concomitantly in the pelagic food web mercury dynamics. This increase of mercury concentrations through the trophic web (biomagnification) is well documented in literature (Selin, 2009; Costa et al., 2012), particularly in Ria de Aveiro (Portugal) (Coelho et al., 2008; Pereira et al., 2009, and reference therein). However, to our knowledge, there is a scarce literature on the effects of mercury contamination, on the distribution, structure and functioning of zooplankton in European estuaries. The first works in Ria de Aveiro, from Monterroso et al. (2003) and Pereira et al. (2007), concluded that zooplankton is a key component in the biogeochemical cycle of mercury in estuaries, since it can be a transporting agent to other areas of the system or to the open sea. In the present study the zooplankton was monitored as an indicator of possible ecosystem changes resulting from mercury contamination. The main goals of the present work were: (1) to analyze the distribution of the zooplankton assemblages along a mercury gradient and infer about the impact of this contaminant on their structure (density/biomass and taxonomic groups) and functioning (species diversity), and (2) to analyze the bioaccumulation patterns, highlighting species or groups with higher or lower Hg tolerance. Such knowledge is necessary to fulfill notable data gaps in the literature on mercury in zooplankton in estuarine ecosystems and contribute to the understanding of baseline factors that control mercury uptake and fate in upper trophic levels of estuarine food webs.

2. Materials and methods

2.1. Study site

The study was conducted in the Ria de Aveiro coastal lagoon, located on the north-west coast of Portugal (40°38′N, 8°45′W) (Fig. 1). Its topography consists of four main channels, which radiate from the mouth with several branches, islands and mudflats (Fig. 1). Tidal influence is the main factor influencing circulation within the lagoon. The system received, from 1950 to mid 1990s, continuous mercury discharges from a chlor-alkali plant located in Estarreja industrial complex (Pereira et al., 2009). This induced an environmental contamination gradient inside the lagoon, mainly in the Laranjo Bay corresponding to a highly contaminated area located close to the mercury discharge source (Coelho et al., 2008). In the last decades, the mercury discharge decreased considerably due to legal restrictions (e.g. 50 μg Hg L^{-1} is the limit value for discharges from chlor-alkali plants, in accordance with the European Union Directive 82/176/EEC). However, the mercury accumulated in the sediments of some areas of the Ria is still high posing several risks to the environment and ultimately to humans (Pereira et al., 2009).

Four sampling stations were selected in the Laranjo Bay along a transect defined by the distance from the mercury point source: station 1 (St 1) is considered to be at the mercury point source in the lagoon, and the others stations are progressively further from this one, respectively 600 m (station 2, St 2), 3000 m (station 3, St 3) and 5000 m (station 4, St 4) (Fig. 1).

2.2. Zooplankton and environmental data

Zooplankton horizontal hauls with a plankton net equipped with 200 μm mesh net were conducted in Ria de Aveiro, on a monthly basis, from September 2010 to September 2011. The samples were collected during the day, at flood tide, across the four sampling stations (Fig. 1). A Hydro-Bios flowmeter was used to estimate volume filtered by each haul. After each haul, the net was rinsed and the samples for Hg determination were immediately frozen while the remaining samples were preserved in 4% formalin-seawater solution. These were later sub-sampled for numerical abundance using a Folsom plankton splitter. At each subsample a minimum of 500 individuals were counted using a

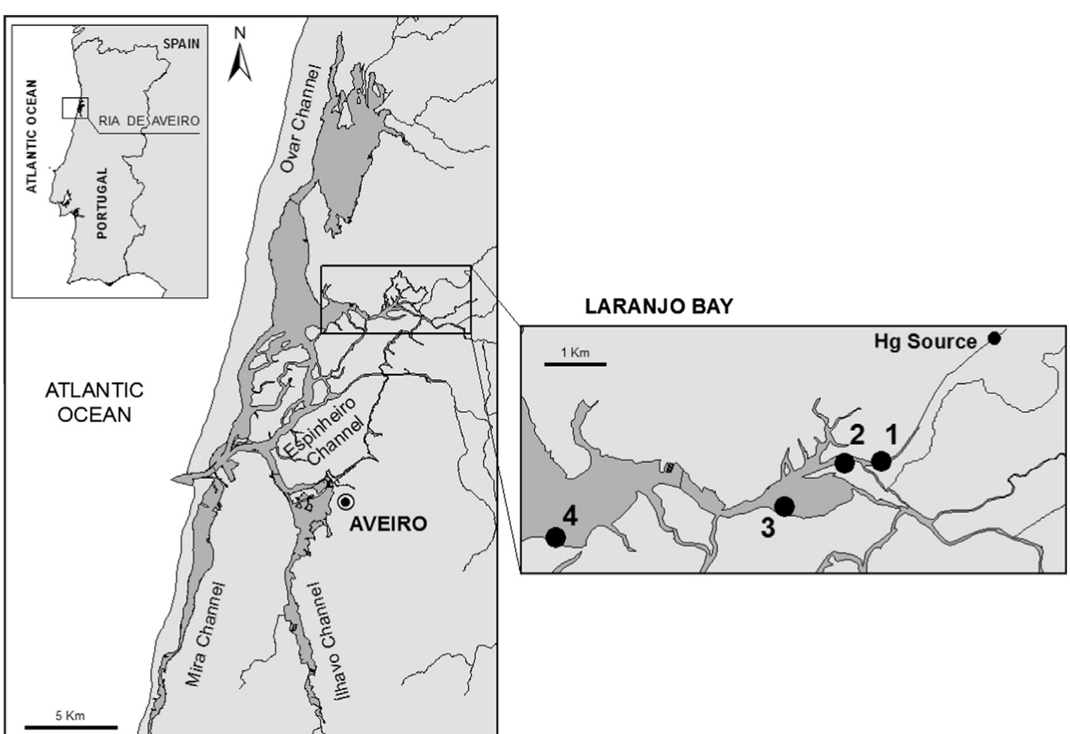

Fig. 1. Overview (left) and detailed map (right) of the study area with location of the sampling stations in Ria de Aveiro.