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Field transplantation of the bivalve *Scrobicularia plana* along a mercury gradient in Ria de Aveiro (Portugal): Uptake and depuration kinetics

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HIGHLIGHTS

- Hg kinetics in *Scrobicularia plana* were studied through transplantation experiment.
- Distinct tissues showed a similar saturation model of Hg accumulation.
- Digestive gland was the tissue that reached the highest concentrations.
- Transplanted organisms reached 20–30% of the concentrations observed in resident ones.
- At the end of transplantation period organisms lost about 50% of their Hg body burden.

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ABSTRACT

The bioaccumulation and depuration capabilities of mercury by the edible bivalve *Scrobicularia plana* was studied in a coastal lagoon (Ria de Aveiro, Portugal) through a transplantation experiment. Little information on this topic is available in the literature, especially concerning different tissues' responses to contaminant exposure, but the present study is one of the few works that can surpass this knowledge gap. Organisms from a reference area were transplanted to two different contaminated areas in the Ria de Aveiro. In both areas, the bivalves (i.e., entire organism, digestive gland and the rest of the organism) presented a similar saturation model of mercury accumulation, the digestive gland being the tissue that reached the highest concentrations after 25 days of exposure to the contaminant. During this short uptake period, the transplanted organisms reached 20–30% of the concentrations observed in resident contaminated organisms. After the exposure period, the organisms were transplanted to a clean area for more than 25 days of depuration. At the end of the transplantation period, organisms lost approximately 50% of their mercury body burden (60%: the entire organism and digestive gland; 35%: gills and 40%: the rest of the organism) and the ones from the least contaminated site almost reached the concentrations recorded in the reference area. So, the results suggest that *S. plana* is a promising biomonitoring species, since it accumulates the contaminant in a considerable extent quite rapidly and at the same time it has a low metal retention capacity (low biological half-life) when exposed to clean sediments.

1. Introduction

Mercury is a ubiquitous contaminant in natural waters, sediments, soils and air, making it a global health concern. Although considerable progress has been made in understanding the mercury accumulation in aquatic organisms over the past decades (Metian et al., 2008; Pan and Wang, 2011 and references therein, Raftopoulou and Dimiatris, 2011; Cardoso et al., 2013a, 2013b), there is still a lack of information regarding, specifically, in situ responses to metal contamination.

In aquatic ecosystems, bivalves are widely used to assess contamination levels, particularly of metals. Due to their large filtration capacities and their sedentary life, they are known to provide a space- and time-integrated measure of bioavailable metal fractions, which is of direct ecotoxicological relevance (Marie et al., 2006). On the other hand, bivalves are widely consumed by humans, worldwide, and may constitute an important vector of metal bioaccumulation through the food web. Recent experimental works on mercury kinetics in bivalves (e.g., *Scrobicularia plana* and *Cerastoderma edule*) have demonstrated the strong capability of those organisms to accumulate metals (Cardoso et al., 2009, 2013a). Although former experiments were carried out under controlled conditions, simulating as closely as possible those

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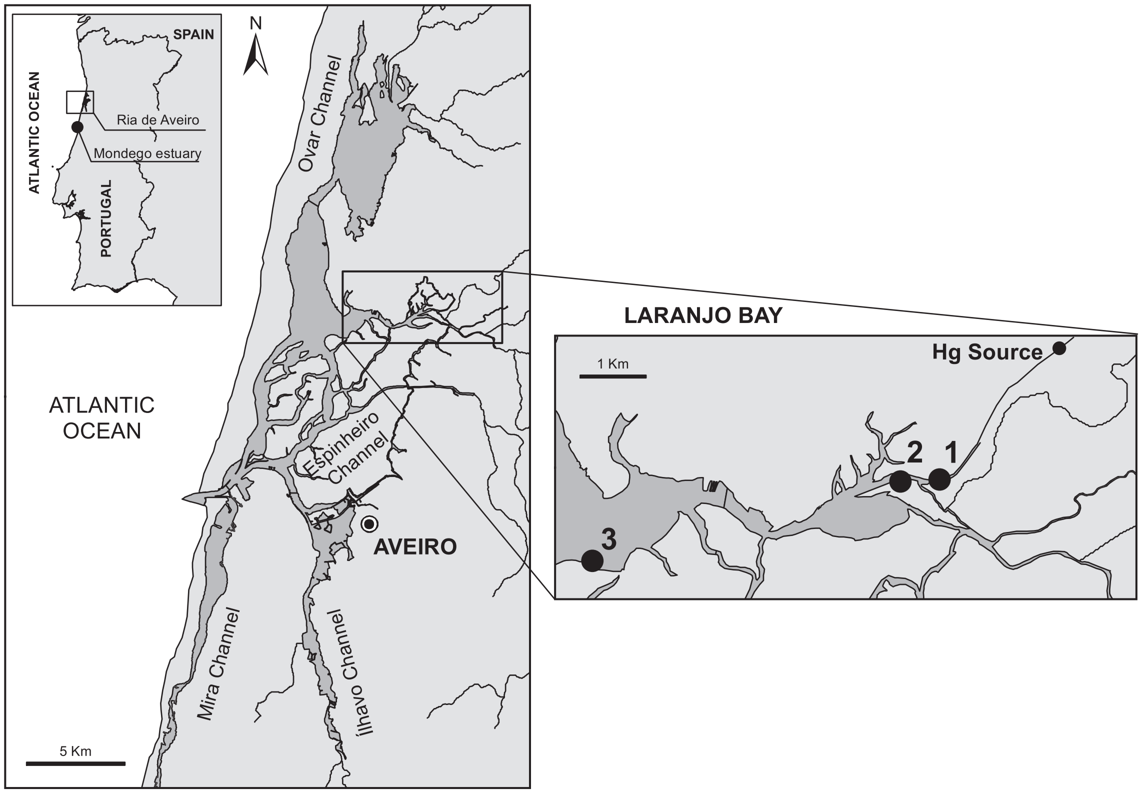

Fig. 1. Location of the sampling sites.

in the natural environment, laboratory experiments cannot fully reproduce the field conditions. In this respect, in situ experiments offer a more ecologically-realistic approach, since they encompass all the factors that actually occur in the field and may possibly interfere with or influence bioaccumulation processes (Hédouin et al., 2011 and references therein).

Over five decades, Ria de Aveiro (Portugal) received continuous discharges of mercury-rich effluent from a chlor-alkali factory leading to sediments, water and biota contamination. Despite the end of the effluents release, the sediments of the Ria still present high mercury concentrations, creating a well-defined anthropogenic mercury gradient (from 1 μg Hg g^{-1} up to 200 μg Hg g^{-1}) in the inner area of the system (called Laranjo Bay), which was already observed in previous studies (Pereira et al., 2009; Cardoso et al., 2013a, 2013b, 2013c). In this way, Ria de Aveiro functions as a natural laboratory which can be used to reproduce this kind of in situ bioaccumulation experiments.

Active biomonitoring using transplantation of organisms from one site to another is a very efficient way to follow the degree of contamination at various sites (e.g., Hédouin et al., 2011), since these can be chosen independently from the natural populations and internal/external factors (e.g., size, age) capable of inducing bias may be reduced. Therefore, the main objectives of the present study were to assess the in situ kinetics of mercury accumulation and depuration for the edible bivalve *S. plana* and compare the responses of different tissues (i.e., gills, digestive gland) after a medium-term mercury exposure. Central questions such as: 1) how fast will these organisms accumulate when exposed to a realistic scenario of mercury contamination? 2) will different tissues respond in different ways, following distinct pathways of mercury accumulation? and 3) how fast will be the decontamination process? will be addressed in the present manuscript, fulfilling a gap of knowledge in terms of realistic responses of key species to field conditions.

2. Materials and methods

2.1. Study sites

The transplantation experiment 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).

Based on previous field results (Cardoso et al., 2013b), three sampling stations were selected in the Laranjo Bay along a transect defined by the distance from the mercury point source: station 1 was considered to be closest to the mercury point source in the lagoon, and the other stations are progressively further away from this one, respectively 600 m (station 2) and 5000 m (station 3) (Fig. 1). Station 1 is characterized by the highest contamination (sediments: 108.1 ± 53.8 mg kg^{-1} DW (mean ± SD); water pools: 15.3 ± 4.4 ng L^{-1} (mean ± SD)), followed by station 2 (sediments: 18.9 ± 2.3 mg kg^{-1} DW (mean ± SD); water pools: 15.1 ± 2.6 ng L^{-1} (mean ± SD)) and finally station 3, considered as a control area (sediments: 0.5 ± 0.4 mg kg^{-1} DW (mean ± SD); water pools: 11.3 ± 7.7 ng L^{-1} (mean ± SD)) (Cardoso et al., 2013c).

2.2. Collection of the bivalves and caging procedures

Adults of *S. plana* were collected in the Mondego estuary (40°08′ N, 8°50′ W), on the Atlantic coast of Portugal (Fig. 1). This is considered as a reference condition since no local source of mercury contamination is known (Coelho et al., 2006 and references therein). The bivalves were then transported to the laboratory in cool boxes filled with seawater and were constantly aerated. After 48 h of stabilization, homogeneous batches were made up, the selection being based on the maximum length of the shell. According to the nomenclature of Verdelhos et al. (2005) and Coelho et al. (2006), individuals of the size class 2+ (2–3 cm), corresponding to an age of 2.5 years were selected for the experiment. A total of 360 bivalves were then taken to the implantation sites