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Comparison of phytoremediation potential capacity of *Spartina densiflora* and *Sarcocornia perennis* for metal polluted soils

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ABSTRACT

Phytoremediation is considered the most appropriate technique to restore metal polluted soil, given its low cost, high efficiency and low environmental impact. *Spartina densiflora* and *Sarcocornia perennis* are perennial halophytes growing under similar environmental conditions in San Antonio marsh (Patagonia Argentina), therefore it is interesting to compare their phytoremediation potential capacity. To this end, we compared concentrations of Pb, Zn, Cu, and Fe in soils and in below- and above-ground structures of *S. perennis* and *S. densiflora*. It was concluded that both species are able to inhabit Pb, Zn, and Cu polluted soils. Although *Sarcocornia* translocated more metals to the aerial structures than *Spartina*, both species translocated only when they were growing in soils with low metal concentrations. It seems that the plants translocate only a certain proportion of the metal contained in the soil. These results suggest that both species could be considered candidates to phytostabilize these metals in polluted soils.

1. Introduction

During the last decades, anthropogenic activities (e.g., agricultural practices and industrial activities) have been increasingly associated with the accumulation of trace metals in the environment. As intertidal environments, salt marshes can receive trace metals from the ocean or the inland zone, which can be immobilized in the soil as biologically unusable forms (Botté et al., 2010; Hung and Chmura, 2007) or be absorbed by plants (Almeida et al., 2011; Caçador et al., 2009; Duarte et al., 2010; Hempel et al., 2008; Redondo-Gómez et al., 2009). While some plant species are sensitive to the harmful effects of trace metals, others are able to grow on contaminated soils excluding or accumulating these elements. Thereby, when trace metals enter plants, they could either be retained in their underground structures or translocated to their aerial ones (Weis and Weis, 2004).

There are several techniques to remediate soils that contain high levels of trace metals, but currently the phytoremediation techniques are considered the most appropriate, given their low cost, high efficiency and low environmental impact (Ashraf et al., 2010). Some of these techniques are: (1) phytostabilization: use of pollutant tolerant plants to reduce the bioavailability and immobilize pollutants in the rhizosphere; and (2) phytoextraction: direct removal of pollutants by the uptake into plants and their translocation and accumulation in above-ground tissues (Alkorta et al., 2004; Wenzel et al., 2004). Thus, it is essential to perceive that the technique selection has crucial ecological implications, given that the use of each technique leads to differences in the fate of the metals, which may be retained in the soil, accumulated in the plants (roots and aerial tissues) or excreted by the leaves. In this regard, it is important to study the influence of different plant species on soil metals, as well as their capacity to grow in polluted environments and the way that they accumulate or distribute these metals.

In a previous study we investigated the concentration of iron and some trace metals in soils and *Spartina densiflora*'s (Poaceae) tissues in the salt marsh surrounding San Antonio Bay (Río Negro, Argentina, Idaszkin et al., 2015). We found that soil metal concentrations follow a decreasing concentration gradient toward the sea. Potentially, this is due to the fact that the open-air dump is the main source of metals in the salt marsh, and it is located inland near the head of this channel. Also, the results of this research showed moderate pollution and a potentially negative biological effect.

Like *Spartina* spp., *Sarcocornia perennis* (Amaranthaceae) inhabits the salt marsh surrounding the San Antonio Bay. There the pickleweed *S. perennis* and the austral cordgrass *Spartina densiflora* are common perennial species of high marsh levels (Bortolus et al., 2009). *Spartina densiflora* is a C_4 cordgrass species, native of South America coastal marshes, and is invading successfully salt marshes of North America,

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Spain, Portugal and North Africa (Bortolus, 2006). On the other hand, *S. perennis* is a C_3 shrub species found in salt marshes of Europe, Southern Africa and the Atlantic coast of southern South America (Davy et al., 2006). Both are widespread species whose distribution range includes very different climate conditions and environmental scenarios (Bortolus, 2006; Davy et al., 2006; Idaszkin et al., 2011, 2014a), including polluted salt marshes, where they grow in soils with high concentrations of trace metals (Curado et al., 2014; Redondo-Gómez, 2013). Although both species inhabit the same salt marsh level (Bortolus et al., 2009) and are able to grow under similar environmental conditions, they have different life or growth form, therefore, it is interesting to compare their phytoremediation potential capacity. In addition, this comparison could provide valuable information for the studied region that could also be generalizable to other similar environments worldwide. Even though previous studies have shown the phytoremediation capacity of each of these species (or similar ones) (Cambrollé et al., 2008, 2011; Curado et al., 2014; Duarte et al., 2010; Idaszkin et al., 2014a, 2014b, 2015), there is a lack of studies concerning a system in which both species interact and co-exist in the same salt marsh level, thus providing a very complete and complex natural image. So, and for the first time, concentrations of Pb, Zn, Cu, and Fe were determined in soils and in below- and above-ground structures of *S. perennis* to combine with results about *S. densiflora* of a previous study in the San Antonio salt marsh (Idaszkin et al., 2015)), considering the potential interactions they can present in between. Thereby, we compared the capacity of *S. perennis* and *S. densiflora*, the dominant halophytes co-existing in this salt marsh, to absorb and accumulate metals from the soil, as well as their capability to immobilize metals in the rhizosphere soil.

2. Material and methods

2.1. Study area

The sampled salt marsh is located surrounding the San Antonio Bay (40°44′S, 54°68′W), in a Natural Protected Area (Río Negro, Argentina; Fig. 1). Samples were collected at three sites within the salt marsh adjacent to the main tidal channel (sites called "A", "B" and "C") and a fourth site (called "D") outside the channel (Fig. 1). All sampling sites were within the high salt marsh level inhabited by *Spartina densiflora* and *Sarcocornia perennis*, accompanied by other shrubs such as *Limonium brasiliense* and *Atriplex* spp.

2.2. Sampling

At each site in spring 2013, five core samples were collected from *Spartina densiflora* (hereafter called '*Spartina*') stands (Idaszkin et al., 2015) and five from *Sarcocornia perennis* (hereafter called '*Sarcocornia*') stands, all with a distance of 1 m from each other obtained at low tide. Each core sample (15-cm-diameter and 15-cm-depth) consisted of plants (below- and above-ground structures) and surrounding soils of below-ground plant tissues (hereafter called '*Spartina* soil' and '*Sarcocornia* soil' respectively). Five samples of non-vegetated soil in each site were also collected. Samples were kept in polyethylene bags, immediately carried to the laboratory stored, and there were stored in a freezer at −20 °C until they could be analyzed.

2.3. Soil samples

All soil samples, either surrounding below-ground plant structures or from non-vegetated areas, were dried at 80 °C until constant weight and sieved through a 2 mm mesh to remove large stones and dead plant material. In all soil samples the redox potential (Eh), pH, electrical conductivity (EC), organic matter (OM) and percentages of sand, silt, and clay were measured as described in Idaszkin et al. (2015).

2.4. Plant samples

Plants were carefully washed with tri-distilled water and separated into below-ground tissues (roots and rhizomes) and above-ground tissues (stems and leaves). All plant samples were dried at 80 °C until constant weight and pulverized in a mill until the powder was fine enough to pass through a 1-mm sieve.

2.5. Analysis of metals

For the analysis of metals, 1 g of dried and sieved soil or 0.5 g of dried plant material was digested in 2 ml of HNO_3 (Merck) ultrapure using microwave oven MARS-5, CEM Corporation, USA (2011) and was then diluted to a final volume of 15 ml with HNO_3 (EPA, 2000). Lead (Pb),

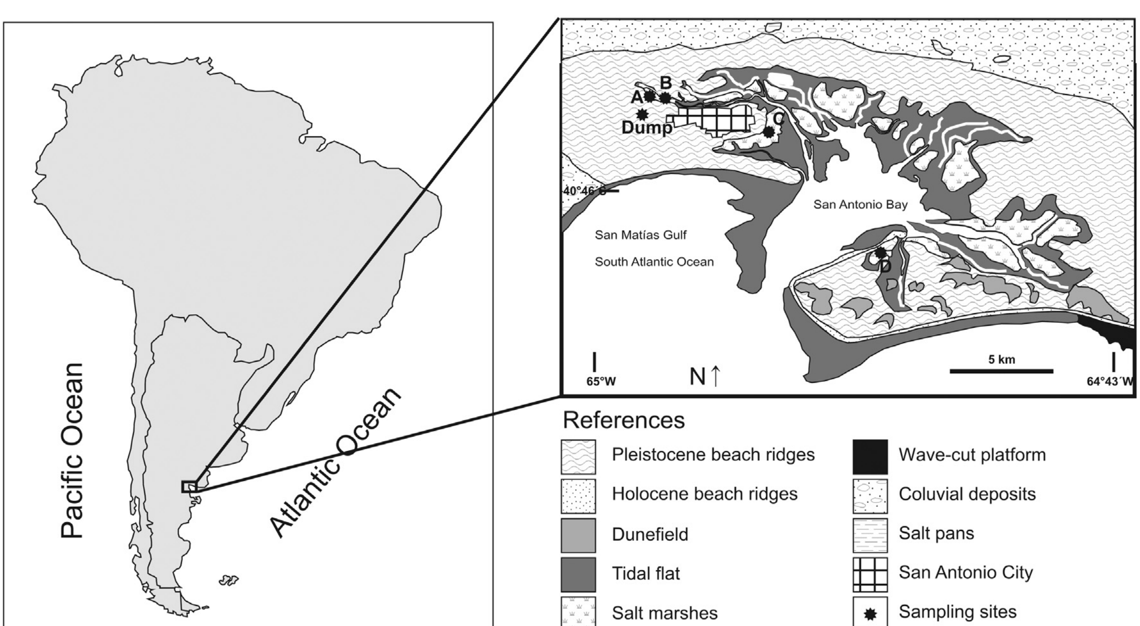

Fig. 1. Location of the sampling sites in the San Antonio salt marsh.

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