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Baseline

Accumulation and distribution of trace metals within soils and the austral cordgrass *Spartina densiflora* in a Patagonian salt marsh

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ABSTRACT

Concentrations of Cd, Cu, Fe, Pb, and Zn were determined in soils and in below- and above-ground structures of *Spartina densiflora* in a Patagonian salt marsh (San Antonio, Río Negro, Argentina). Also, the relationship between trace metal concentrations in soils and plants was investigated to improve our knowledge regarding the ability of this plant species to take up and accumulate trace metals from the soil. Our results indicate that, within the studied salt marsh, soil trace metal concentrations follow a decreasing concentration gradient toward the sea. They show moderate pollution and a potentially negative biological effect in one site of the salt marsh. While below-ground structures reflect the soil metal concentration pattern, this is not so evident in above-ground concentrations. Also, *S. densiflora* is able to absorb a limited amount of metals present in the soil, the soil bioaccumulation factor being lower in sites where soil metal concentration is higher.

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Studies concerning the impact of different pollutants such as trace metals, oil, pesticides, and fertilizers on coastal and estuarine environments have increased during the last decades. The presence of trace metals in the soil has mainly lithogenic origin, which is sometimes increased by anthropogenic factors (e.g., agricultural practices and industrial activities). Also, the contamination could be localized and derived from a predominant single source, such as a metal smelter, having a marked effect on soils, plants and even in the health of a local population (Alloway, 2010). Environmental pollution due to chemical toxic substances determines a risk to the health of ecosystems as well as to human life.

The presence of trace metals within the San Antonio Bay (Río Negro Province, Argentina) is well documented (Gil et al., 1996, 1999; Esteves et al., 2004; Vázquez et al., 2007). During the 60s and 80s a mine which extracted zinc, lead, silver and vanadium operated near the San Antonio Oeste City. At the same time, an electrochemical plant was established close to the city for the processing of trace metal ores excavated from the mine. As a consequence, at the upland border of San Antonio Bay there is an open-air dump where the wastes of the processing activities have been piled for over three decades. This residual material from mining activities is subjected to infiltration and leaching when it rains. While at present there are only remnants, previous studies show the presence of trace metals in the sediment and marine invertebrates of the Bay, with a marked concentration gradient in the positive direction west–east (Gil et al., 1999; Esteves et al., 2004; Vázquez et al., 2007).

The San Antonio Bay is surrounded by an extensive salt marsh. These natural features are highly productive environments, and have a very important ecological role due to the fact that they are reproductive and feeding sites for a lot of species, both marine and terrestrial (Mitsch and Gosselink, 2000). These environments can absorb trace metals from the surrounding ecosystems, which may be immobilized and stored in the soil as biologically unusable forms (Hung and Chmura, 2007; Botté et al., 2010) or be absorbed by plants (Hempel et al., 2008; Caçador et al., 2009; Redondo-Gómez et al., 2009; Duarte et al., 2010; Almeida et al., 2011). When trace metals enter salt marshes, they can be absorbed by plants, being either retained in their underground structures or translocated to their aerial structures; depending on the plant species, the physicochemical soil features, and the metal (Weis and Weis, 2004). By absorbing metals plants mobilize them from the soil to the trophic web, either to be consumed directly by herbivores, or through plant debris that are incorporated in the basal level of the food chain, where bioaccumulation (or even biomagnification) may occur through higher trophic levels (Wang, 2002; Barwick and Maher, 2003; Croteau et al., 2005; Rainbow et al., 2006; Beltrame et al., 2010; Simonetti et al., 2012). In this sense, trace metal pollution does not only have a negative effect on soils, which has an impact on plants, but also affects animals, representing a serious risk to the ecosystem.

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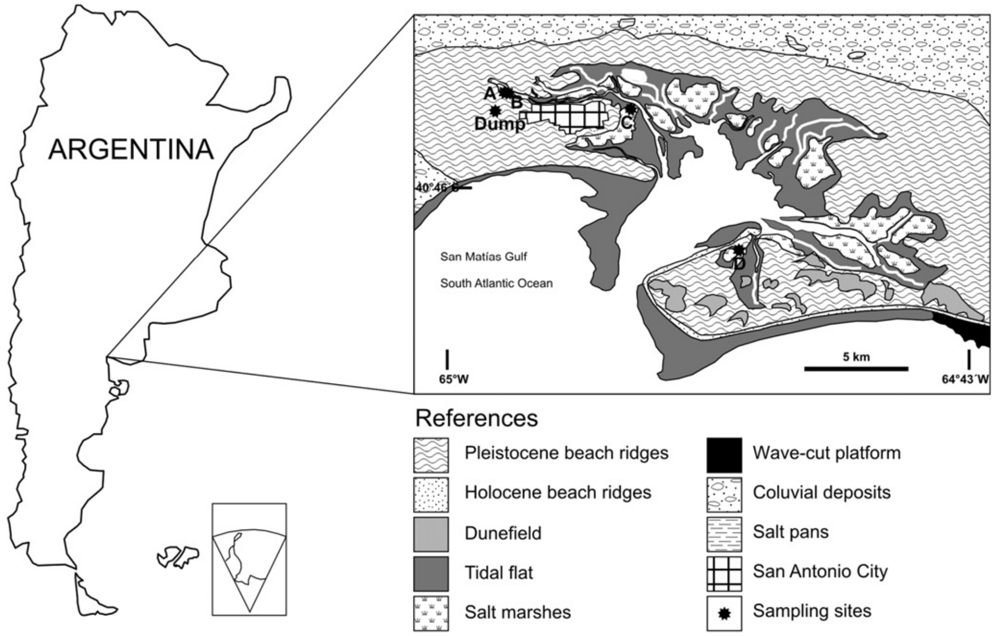

Fig. 1. Main geomorphological units and location of the sampling sites in the San Antonio salt marsh in Argentina.

The surrounding salt marsh is inhabited by perennial halophytics *Spartina alterniflora* and *Spartina densiflora* (Poaceae). The austral cordgrass *S. densiflora* is a common perennial species of middle and high marsh levels in Patagonian salt marshes (Isacch et al., 2006; Bortolus et al., 2009). *S. densiflora* is a C_4 species native of South American coastal marshes, and is invading successfully salt marshes of North America, Spain, Portugal and North Africa (Bortolus, 2006). It is a widespread species, whose distribution range includes very different climate conditions and environmental scenarios (Bortolus, 2006; Idaszkin et al., 2014a), including polluted salt marshes, where they grow in soils with high concentrations of heavy metals (Redondo-Gómez, 2013; Curado et al., 2014). Although there are studies in the San Antonio Bay (Gil et al., 1999; Esteves et al., 2004; Vázquez et al., 2007), to date there is no research evaluating the levels of trace metals in the salt marsh. The main purpose of this study was to determine the concentrations of Cd, Cu, Fe, Pb, and Zn in soils and *S. densiflora* in a Patagonian salt marsh (San Antonio, Río Negro, Argentina). Also, we investigated the relationship between trace metal concentrations in soils and in plants to improve our knowledge regarding the ability of these plant species to take up and accumulate trace metals from the soil.

The present study was conducted within the salt marsh surrounding the San Antonio Bay (hereafter called "San Antonio salt marsh"; 40°44′S, 54°68′W), a Natural Protected Area (Río Negro, Argentina; Fig. 1). This salt marsh is a strictly marine system with a semidiurnal macro-tidal regime (tidal amplitude: ~9 m), and is crossed by several tidal channels. Specifically, three sampling sites were selected within the salt marsh adjacent to the main tidal channel (Fig. 1). The site "A" is nearest to the head of this channel, and is the closest to the largest open-air dump, that due to the topography is a zone largely influenced by the mine superficial run-off erosion. The second site "B" is located nearest the above site and the site "C" is in the outer zone of the channel. A fourth site "D" was placed also out of the Bay. All sampling sites were within the high salt marsh level dominated by *S. densiflora* and *Sarcocornia perennis*, accompanied by *Limonium brasiliense* and *Atriplex* spp. in low proportions (Isacch et al., 2006; Bortolus et al., 2009).

At each site, five core samples were collected in spring 2013 from *S. densiflora* (hereafter called "*Spartina*") 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 surrounded soils of below-ground plant tissues.

Table 1
Soil parameters in the San Antonio salt marsh (mean ± S.E.).

Soil parameters	Site A		Site B		Site C		Site D	
	Non-vegetated soil	*Spartina* soil	Non-vegetated soil	*Spartina* soil	Non-vegetated soil	*Spartina* soil	Non-vegetated soil	Spartina soil
EC (mm hos cm^{-1})	(7.68 ± 0.76)	(9.2 ± 1.15)	(7.27 ± 0.37)	(6.57 ± 0.45)	(3.97 ± 0.1)	(3.75 ± 0.06)	(3.55 ± 0.52)	(3.41 ± 0.31)
Eh (mV)	(142.8 ± 7.36)	(139.6 ± 7)	(143.75 ± 15.1)	(163.2 ± 11.59)	(167 ± 4.01)	(147.2 ± 10.64)	(162.75 ± 5.92)	(189.6 ± 13.87)
pH	(7.66 ± 0.05)	(7.61 ± 0.02)	(7.51 ± 0.01)	(7.68 ± 0.05)	(7.65 ± 0.04)	(7.54 ± 0.05)	(7.74 ± 0.06)	(7.63 ± 0.05)
OM (%)	(5.84 ± 0.41)	(6.46 ± 0.26)	(4.49 ± 0.34)	(5.69 ± 0.64)	(3.08 ± 0.09)	(2.93 ± 0.13)	(2.45 ± 0.26)	(2.55 ± 0.29)
Clay (%)	(18.86 ± 4.09)	(22.63 ± 3.81)	(20.04 ± 2.38)	(14.97 ± 1.03)	(3.85 ± 0.59)	(3.87 ± 0.33)	(4.91 ± 0.89)	(6.1 ± 0.48)
Silt (%)	(52.04 ± 6.49)	(55.57 ± 3.29)	(50.51 ± 4.13)	(52.54 ± 5.48)	(27.41 ± 0.66)	(30.26 ± 1.2)	(26.56 ± 1.73)	(23.75 ± 3.33)
Fine silt (%)	(25.04 ± 4.32)	(27.22 ± 2.64)	(26.4 ± 4.32)	(30.32 ± 3.97)	(13.58 ± 0.99)	(14.33 ± 1.72)	(10.12 ± 0.71)	(9.82 ± 2.41)
Coarse silt (%)	(27 ± 2.35)	(28.34 ± 1.55)	(24.11 ± 0.82)	(22.21 ± 1.76)	(13.83 ± 0.51)	(15.93 ± 0.99)	(16.44 ± 1.45)	(13.93 ± 1.62)
Fine fraction (%)	(70.9 ± 5.42)	(78.2 ± 2.07)	(70.55 ± 6.18)	(67.5 ± 6.28)	(31.26 ± 1)	(34.13 ± 1.02)	(31.48 ± 1.28)	(29.85 ± 3.68)
Sand (%)	(29.09 ± 5.42)	(21.79 ± 2.07)	(29.45 ± 6.18)	(32.5 ± 6.28)	(68.74 ± 1)	(65.87 ± 1.02)	(68.52 ± 1.28)	(70.15 ± 3.68)
Cu (μg g^{-1})	(38.72 ± 3.99)	(38.86 ± 1.76)	(10.8 ± 0.86)	(13.32 ± 2)	(4.98 ± 0.21)	(5.62 ± 0.14)	(5.13 ± 1.23)	(5.92 ± 1.01)
Fe (μg g^{-1})	(14,234 ± 735)	(14,536 ± 180)	(12,055 ± 836)	(12,464 ± 880)	(12,991 ± 569)	(13,994 ± 291)	(13,701 ± 1627)	(14,552 ± 1645)
Pb (μg g^{-1})	(63.9 ± 7.24)	(66.22 ± 3.53)	(13.75 ± 1.85)	(14.52 ± 2.53)	(7.66 ± 0.35)	(8.22 ± 0.22)	(4.3 ± 1.25)	(4.94 ± 0.79)
Zn (μg g^{-1})	(221.6 ± 24.82)	(222.4 ± 4.65)	(47.5 ± 5.85)	(62.2 ± 10.73)	(17.2 ± 0.74)	(19.56 ± 0.48)	(17.85 ± 1.08)	(19.68 ± 1.04)

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