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Geogenic metal mobility in a coastal inlet impacted by cannery discharge, Magdalena Bay, Baja California Sur, Mexico

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ABSTRACT

Magdalena Bay is an important habitat for marine organisms, some of which have been the subject of metal bioaccumulation studies. Cannery waste is discharged into the bay providing a plausible source of contamination but this study finds that some metals occur geogenically. Bay sediments and rocks (n = 59) were analyzed for total metals and clustered (HCA) into two distinct groups with PCA indicating concentrations of Cr, Cu, Mn, and Ni influenced samples near ophiolite outcrops, which reported some metal concentrations exceeding averages in the crust by an order of magnitude (up to 4450 ppm Cr and 1269 ppm Ni). Metals at the cannery are rarely elevated above crustal averages except Zn (max. 160 ppm), however, acid-extracted Zn was below recommended sediment quality guidelines in contrast to 80% of ophiolitic samples reporting Ni extractability exceeding such guidelines. This study raises awareness of geogenic metals when considering sources of contamination in marine environments.

1. Introduction

Coastal inlets are important ecosystems for many marine organisms. They provide sheltered conditions for early life cycle processes, such as juvenile nursery grounds for fish (Fodrie and Levin, 2008), secondary dispersal processes of blue crabs (Reyns et al., 2006), shoreline-nesting habitats for sea turtles (Labrada-Martagon et al., 2011), and shallow warm waters for whale calving (Gardner and Chavez-Rosales, 2000). Coastal inlets can also be sites of dense human population and consequently, urban bays often receive metal inputs from anthropogenic disturbances such as dredging (Forstner et al., 2012), storm water runoff, (Acevedo-Figueroa et al., 2006), and industrial discharge waters (Jones et al., 2013). The effect of metal loadings on organisms inhabiting urban coastal inlets is well documented (Bosse et al., 2014; Fonseca et al., 2011; Huang et al., 2012). Biological effects may include cellular and oxidative stress (Morcillo et al., 2016), fish larvae deformities (Sfakianakis et al., 2015) and changes to biochemical enzymes (Hariharan et al., 2014). Such adverse effects demonstrate the sensitivity of marine ecosystems like coastal inlets to anthropogenic disturbance.

Metals in coastal waters do not only originate from anthropogenic sources, however. Most rocks and the minerals therein contain natural concentrations of metals (Rudnick and Gao, 2003) and geogenic metals commonly occur in river and coastal waters as a result of natural rock weathering (Al-Juboury, 2009; Acevedo-Figueroa et al., 2006; Ashley and Napier, 2005). Although capable of producing the same toxicity effects as anthropogenic metals, geogenic metal loadings to coastal inlets are far less studied than their anthropogenic counterparts.

In Baja California Sur, Magdalena Bay is a sparsely populated almost pristine coastal inlet providing protection for many important juvenile and adult marine organisms. Populated mostly by artisanal fishing communities there are very few opportunities for anthropogenic inputs to the bay. Several studies (Gardner et al., 2006; Labrada-Martagon et al., 2011; Riosmena-Rodriguez et al., 2010) have, however, measured metal bioaccumulation in various organisms inhabiting or frequenting the bay, both in sessile (e.g., seagrass) and transient (e.g., turtle) species. One obvious anthropogenic disturbance exists in the small port of San Carlos located in the northeastern corner of Magdalena Bay, which is sustained largely by a fish canning facility. Biological waste in the form of fish bones, blood and other unidentified organic and inorganic components is discharged via a leaking and cracked pipeline directly into Magdalena Bay. This localized point of pollution leaves the beach black and foul smelling and is therefore a plausible source of elevated metal concentrations found in some Magdalena Bay organisms. However, rocks outcropping along the western edge of Magdalena Bay are ophiolitic. Ophiolites are sequences of obducted and altered oceanic rocks, which can be naturally enriched in metals such as Cr and Ni (Morrison et al., 2015). The question then becomes, is the cannery the dominant source or is there a significant component of geogenic metal loading to Magdalena Bay?

This question is addressed by examining rocks and sediments from around Magdalena Bay to determine i) geogenic metal concentrations and enrichment, ii) the impact of cannery waste discharge on metal

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concentrations in sediments near the cannery, and iii) ability of metals to be mobilized from both geogenic and cannery-impacted sediments and rocks. This approach will provide a first step towards understanding the contribution of metals from geogenic versus cannery-impacted sediments at Magdalena Bay.

2. Materials and methods

2.1. Environmental setting

Magdalena Bay is located on the Pacific coast of Baja California Sur, Mexico, and consists of a shallow bay protected by barrier-dune sands which join together to link several high relief islands composed of ophiolitic bedrock (Fig. 1). The town of Puerto San Carlos in the northern region of the bay is home to approximately 3200 people and is supported by a commercial port, a fish canning operation, and a thermoelectric plant.

The fish cannery cans tuna and sardines and generates fishmeal and operates intermittently during the year. Although the cannery has recently been fitted with on-site waste treatment facilities, waste is still regularly seen discharging directly into Magdalena Bay (Fig. 2a). The thermoelectric plant, also located in the vicinity of San Carlos, is prohibited to discharge untreated waste into the bay (Comision Federal de Electricidad, 1990) but was not visited as part of this study.

Outside of Puerto San Carlos exist several small fishing villages (e.g., Puerto Magdalena) otherwise the bay is a pristine and relatively isolated area frequented by small numbers of tourists during the whale migration season. The bay is large enough to host three distinct grey whale habitats and thus is the subject of much whale research, in addition to research on fisheries production and management, sea

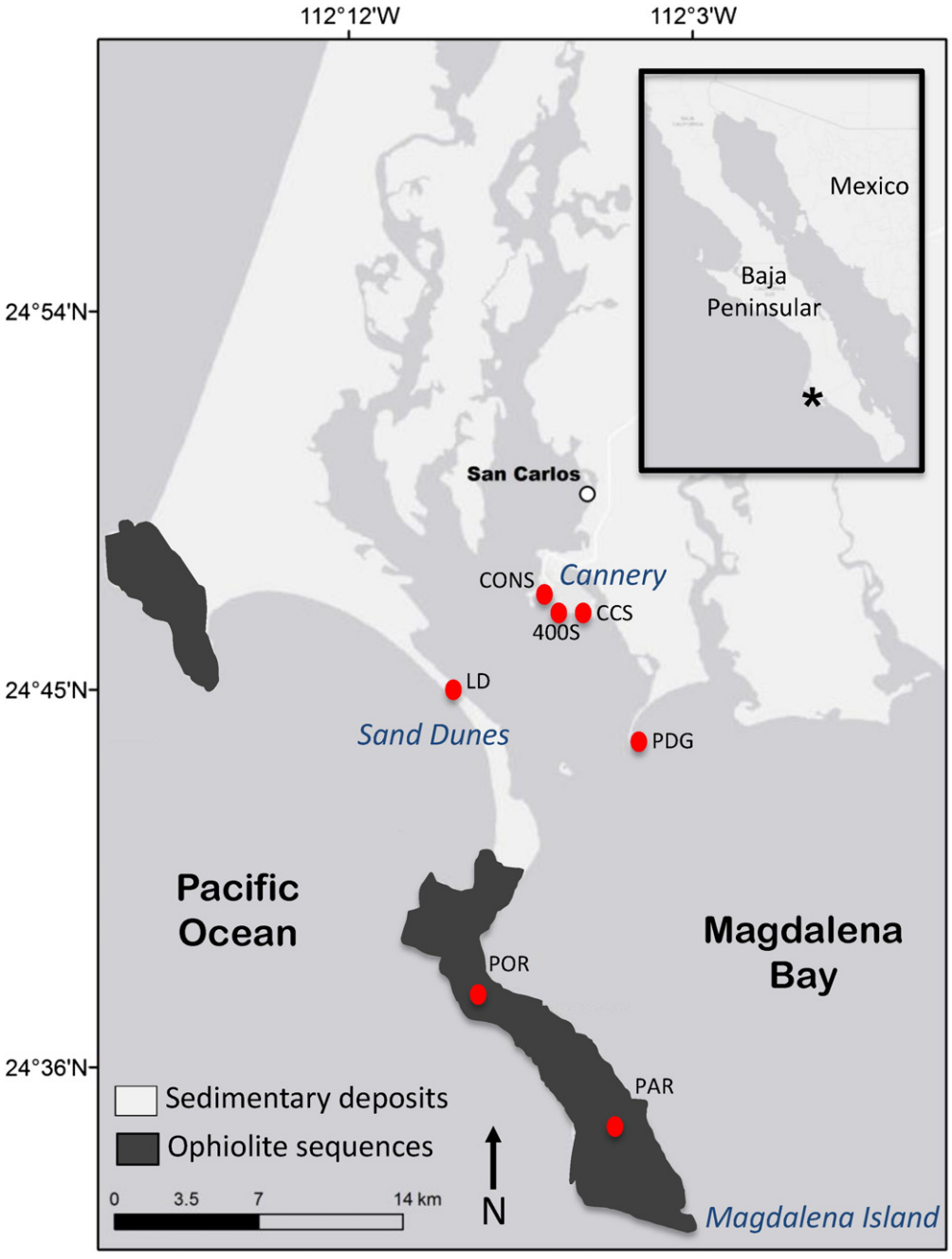

Fig. 1. Magdalena Bay, Baja Sur, Mexico. Location of the fish cannery and three impacted sites CONS, 400S, CCS, with lesser impact occurring at the down current PDG site. The LD samples were collected from pristine sand dunes while the two ophiolite sites, POR and PAR, were collected via random transect from bay coastline to beach coastline.