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Trophic relationships and transference of cadmium, copper, lead and zinc in a subtropical coastal lagoon food web from SE Gulf of California

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ABSTRACT

Trophic relationships and heavy metal transference in a coastal subtropical lagoon marine food web were investigated through the use of stable isotopes in food sources and biota. A selective extraction scheme was applied to the surface sediments as an indirect way to evaluate the potential of toxicity of metals. Results showed that cadmium, copper, lead and zinc concentrations were within sediment quality guidelines criteria. Concentrations of these metals in organisms varied widely among functional groups and within the same and closely related taxa. $\delta^{13}C$ values varied significantly among organisms from different functional groups, while the $\delta^{15}N$ values varied according with their feeding habits. Cd, Cu, Pb, and Zn were not positively transferred (biomagnification factor <1) through entire food web. However, a partial positive transference was observed for Cu and Zn involving three trophic levels (from the phytoplankton to crab as secondary consumer).

1. Introduction

Many studies on the transfer of metals through the food web have been made since 1960s, although the most substantial progress was reached over the past 10 years (Wang, 2002). Nowadays, it is widely recognized that dietary exposure is a major route for the transfer of metals in marine food webs (Rainbow, 2002; Wang, 2002; Croteau et al., 2005). Despite progress made on this matter, the mechanisms that regulate the metal transfer through the food web are still poorly known (Dietz et al., 2000; Rainbow, 2002; Wang, 2002; Barwick and Maher, 2003). It is yet a scientific challenge to understand and predict the concentrations of metals in organisms occupying diverse trophic levels. Moreover, in the most productive marine food webs, such as in tropical and subtropical coastal systems, trophic relationships are even more complex because involve numerous species and linking alternatives (Vega-Cendejas and Arreguín-Sánchez, 2001; Zetina-Rejón et al., 2003). Increasing the food web complexity make more complicate to understand the trophic transfer of metals and to predict the metal concentrations in the aquatic animals (Wang, 2002). Metals passing through food webs in these marine ecosystems have multiple alternatives to transfer, both vertical (between different trophic levels) and horizontal (diet within a same trophic level) positions. In addition, the environmental conditions with contrasting seasonal variations of temperature, salinity and food availability, it makes more complicated such studies. For this reason, it is not a surprise that the studies on trophic transfer of metals are particularly scarce in tropical and subtropical coastal ecosystems (Ruelas-Inzunza and Páez-Osuna, 2008).

In order to address trophic relationships and any potential biomagnification of contaminants in marine food webs, the use of stable isotopes constitutes a valuable tool (Dehn et al., 2006). Nitrogen isotope ratios of prey are reflected in tissues of the consumer, with slight enrichment occurring at each trophic step. This makes $\delta^{15}N$ a reliable indicator of the trophic position of an organism within the food web and usually the basis for this computation is the primary consumers N composition (Minigawa and Wada, 1984). In other hand, stable isotopes of carbon are generally used to provide information on spatial habitat use and carbon sources rather than trophic relationships as they enrich in consumer tissues only to a minor degree (Hobson and Welch, 1992).

The aim of this work was to study the food web interactions and their influence on metal transfer through trophic levels in a subtropical coastal lagoon urbanized, Estero de Urías (EU) located in southeast coast, Gulf of California. Elevated metal concentrations related with long term pollution caused by municipal, industrial and naval activities have been recorded in sediments (Soto-Jiménez and Páez-Osuna, 2001) and some organisms (Szefer et al., 1998) from this lagoon. We investigate the spatial and temporal

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of the isotopic compositions of C and N and the metal concentrations (Cd, Cu, Pb, and Zn) of the primary producers, seston and detritus, and fourteen of the most representative consumer species of the lagoon food web. In addition, the influence of two contrasting climatic seasons (dry and rainy) on metal transference in the food web was evaluated.

2. Materials and methods

2.1. Study area

The Estero de Urías (EU) is located along the southeast coast of the Gulf of California (Fig. 1). Mazatlán harbor is situated in the lower and intermediate parts of the EU lagoon. The EU characteristics were described in previous work (Soto-Jiménez and Páez-Osuna, 2001). The upper lagoon area (ULA) and head lagoon area (HLA) possess the major biodiversity in the lagoon. The Industrial Zone (IZ) is subject to regular discharges of effluents from human activities. Considering that the HLA and the ULA are not directly impacted by anthropogenic effluents, sampling was performed at different sites of both areas assuming homogeneous contaminants (including metals) distribution by the hydrodynamic processes in EU (Montaño-Ley et al., 2008).

2.2. Sampling collection and processing

Sampling was performed during the dry (April 2006) and rainy (September 2006) seasons at sites A–D (Fig. 1). Duplicate of water samples (depth of 0.1 m below the surface) were collected in HCl-cleaned polyethylene bottles and transported to the laboratory for analysis. Suspended particulate matter (SPM) was collected by filtering 200–1000 mL from one water sample through pre-combusted (500 °C, 4 h) glass fiber filter (GF/F) with vacuum pump. The filters were air-dried at 55 °C. Total SPM was determined by weight differences before and after filtration. SPM is considered the seston. Another water sample was filtered through a nitrocellulose membrane (0.45 μm pore size) and acidified (concentrated HCl, pH < 2). Membranes were digested using microwave (MARS-X, CEM Co.) for suspended metal analysis in one step: 5 mL of concentrated HNO_3 were added to each membrane, then heated to 100 °C for 5 min, to 120 °C for 5 min, and to 140 °C for 10 min. Triplicate of surface sediment samples (2.5 cm depth from the sediment surface) were taken at each station from lagoon sites using a plastic tube (ID = 7 cm). Biological samples representing different trophic levels in network were taken at several stations in EU. These were divided into four functional groups (Table 1): primary producers (mixed phytoplankton, macroalgae, and mangrove), primary consumers (mixed zooplankton, copepod, barnacle, oyster, mussel, polychaete, snail, shrimp, and juvenile and adult mullet), secondary consumers (crab, mojarra, snapper, and grunt) and tertiary consumers (cormorant). Towing of the plankton conical net was carried-out (2 km for ~7 min) to obtain phytoplankton (30 μm mesh) and zooplankton (270 μm mesh) samples. Some particles of detritus were also detected and included because was not possible to remove from the phytoplankton samples. Two samples of copepods were isolated from the zooplankton during the rainy season and were analyzed separately. Macroalgae, mangrove, polychaete and snails were collected by hand, rinsed with water and placed in HCl-washed plastic bags. Oysters, mussels, and barnacles were collected from mangrove roots using a stainless-steel knife at low tide. Shrimps, crabs, and fish (adult and juvenile mullet, mojarra, snapper and grunt) were collected from the area near the sampling stations using local commercial gill nets. Cormorant was obtained from a local hunting association (permit SEMARNAT DOO.02-3324). Sediment and biological samples were transported to the laboratory. The following tissues were obtained by dissection of organisms: soft from bivalves; gills, muscle, exoskeleton and hepatopancreas from crustacean; gills, muscle, liver, stomach (included its content) and remaining tissues from fishes; and muscle, liver, stomach (included its content), feather, gizzard, blood and remaining tissues from cormorant. Sediment and biological samples were freeze-dried. Biological tissues were ground manually (Teflon mortar for 10 min) and digested by microwave system (MARS-X) in one step: 5 mL of concentrated HNO_3 were added to

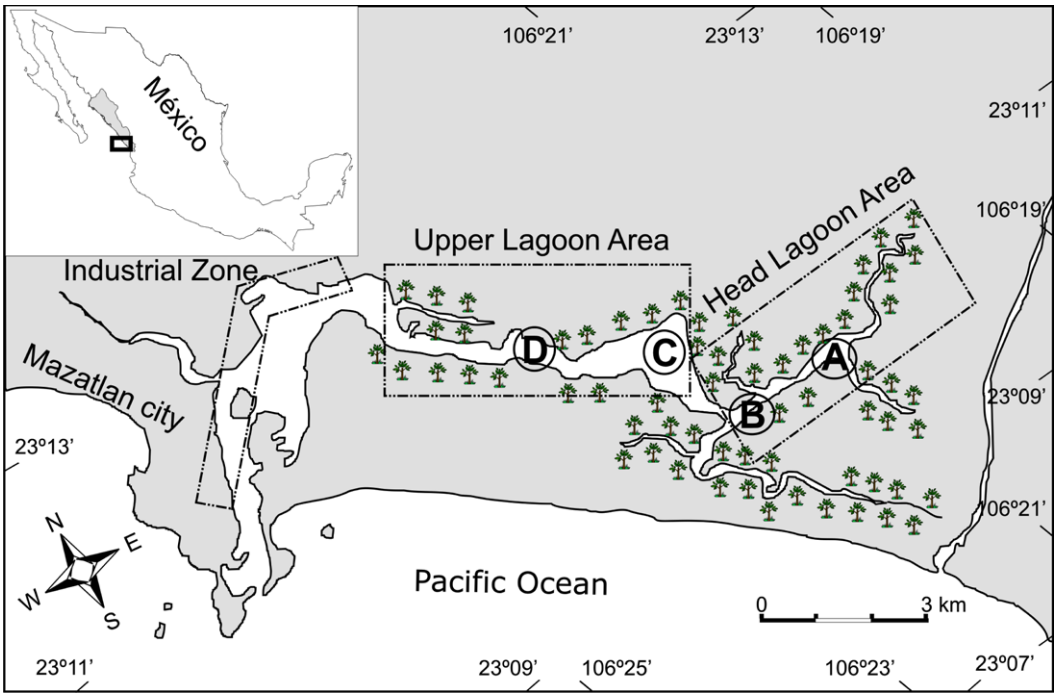

Fig. 1. Map of the study area and the location of sampling sites (A–D) in the Estero de Urías lagoon system. Mangrove areas are indicated by symbol 🌴.