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Fishes as indicators of untreated sewage contamination in a Mexican coastal lagoon

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ABSTRACT

Lagoons are important nursery habitats for fishes but are often sites of intense human activity including wastewater discharges. The goal of this research was to compare stable nitrogen ($\delta^{15}N$) and carbon ($\delta^{13}C$) isotopes, total mercury (THg) and other metal levels in four selected fish species among sites with different levels of untreated sewage discharge inside Barra de Navidad coastal lagoon in the Mexican Pacific. Three species from sites heavily impacted by sewage showed higher $\delta^{15}N$ and $\delta^{13}C$ compared to those from non-impacted sites. In addition, the highest concentrations of THg were present in fish of two species (*Sciades guatemalensis* and *Diapterus brevirostris*) collected at the two most impacted sites, and exceeded the 0.2 μg/g ww threshold believed to be protective of adult and juvenile fish. No individuals of *Achirus mazatlanus* and *Mugil curema* exceeded this threshold, and liver somatic index and condition did not distinguish high from low impacted sites for all species. In general, the metal levels differed among species but not sites, and were lower than what has been measured in fishes elsewhere. The study also provides the first information on several fish species for coastal areas of Mexico, suggests that THg and isotopes can distinguish sewage-impacted sites, and can serve as a baseline for future studies.

1. Introduction

Human populations, urban development and land use changes are increasingly impacting the world's estuarine ecosystems through nutrient loading and chemical contaminants (Millennium Ecosystem Assessment, 2005). Non-treated sewage discharges are important sources of particulate organic matter and nutrients in estuarine environments and can induce significant changes in water quality and jeopardize the health of aquatic organisms due to habitat loss, contamination, the presence of disease-causing organisms and other factors (Pitt et al., 2009; Rožič et al., 2014). Impacts of sewage on aquatic biota are diverse and have been identified at all levels of ecological organization (Schlacher et al., 2005). Some of the particulate and dissolved nutrients discharged in sewage incorporated by organisms at the base of the food web and their use and transfer through the food web can be traced with carbon and nitrogen stable isotopes ratios (Rogers, 2003; Vizzini and Mazzola, 2006; Barros et al., 2010; Davias et al., 2013). Other impacts of sewage discharge include high concentrations of mercury (Hg) and other metals in species (Alonso et al., 2000; Canli and Atli, 2003; Marcovecchio, 2004; Rocha et al., 2014).

Organisms used as pollution monitors have numerous advantages over the chemical analyses of abiotic compartments because biota only accumulates the bioavailable forms of the contaminants (Azevedo et al., 2009). Fishes have frequently been used to assess aquatic habitat degradation and their numerous advantages, and some disadvantages, as indicator organisms have been summarized by Whitfield and Elliott (2002). In addition, an understanding of contaminants in fishes can be used to determine the risks to fish-eating wildlife and humans. This is a relevant point for coastal areas and particularly in coastal lagoons because many of them support important artisanal fisheries.

Coastal lagoons are considered to be among the most productive ecosystems in the world and provide a host of socioeconomic benefits for humans (Pérez-Ruzafa and Marcos (2012). These habitats have been recognized as important nursery grounds for many fish species (Cowan et al., 2013). Barra de Navidad lagoon is an important coastal wetland in Jalisco State, on the western coast of Mexico. The lagoon provides important ecological services and offers exceptional opportunities for developing tourism, but also can lead to resource conflicts. Previous studies have identified more than 20 species of coastal fishes which use

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the Barra de Navidad lagoon as a nursery area (González-Sansón et al., 2014). Some of these species are caught regularly as adults in the adjacent shelf waters in a successful artisanal fishery. In 2008 the Barra de Navidad lagoon ecosystem was declared a Wetland of International Importance according to the standards of the Ramsar Convention (www.ramsar.org) by the National Commission of Protected Natural Areas (www.ramsar.conanp.gob.mx/lsr.php). The lagoon is also included among the 81 priority mangrove sites in Mexico by the National Commission for the Protection of Biodiversity (CONABIO, 2009). The lagoon's ecological functions are currently impacted by erosion, and changes in land use during last 40 years have been identified in the basins associated with this coastal wetland (Silva-Bátiz et al., 2012) and have altered its hydrological regime in a way which is not well understood.

Considerable anthropogenic stressors are present in the Barra de Navidad lagoon, including residential/wastewater, touristic, agricultural and fisheries impacts. Residential impacts come from a human settlement of ca. 4300 persons on the northwest coast of the lagoon, which discharges untreated sewage, and from a large resort with a hotel, golf course, and marina for large sports boats located along the southwest shore of the lagoon. During the winter, many sailing ships (70–90) use the lagoon as anchorage with low control by harbor authorities, and without waste treatment facilities. Agriculture occurs in the catchment of the lagoon and is a source of residual pesticides and fertilizers, and artisanal fisheries harvest juveniles or preadult species within the lagoon. There has not been any systematic assessment of the impacts of the stressors on the lagoon ecosystem or coastal fish populations. The goal of this research was to conduct a comparative study of selected fish species among sites of Barra de Navidad lagoon with different levels of human impact. We hypothesized that stable isotope levels, mercury and other metals in fish would reflect their proximity to human inputs at sites where high quantities of untreated sewage are discharged into the lagoon.

2. Materials and methods

2.1. Study area and sampling sites

Barra de Navidad lagoon is located in the southern coast of Jalisco State, Mexico (19°11′25″ N–104°39′53″ W). It has a surface area of 334 ha and is surrounded by a well-developed mangrove forest (571 ha) mainly in its northeastern and southeastern margins. Freshwater inputs are through the Arroyo Seco River and an artificial channel connecting the Marabasco River with the lagoon. The lagoon exchanges water continuously with the sea through a 100 m wide channel.

The research was done in January and February 2014 at four sites of Barra de Navidad lagoon along a gradient of human impact (Fig. 1). Sampling sites were: inside Cabo Blanco Marina's channels (CAN), a site affected by boat anchorages and docking facilities, as well as untreated sewage discharge coming from Barra de Navidad town (ca. 4300 habitants) and many restaurants; Colimilla (COL), a small town (ca. 230 habitants) with untreated sewage from the town and several restaurants, as well as a gas station for boats; a reference site (ATR) which is not impacted directly by sewage discharge but receives runoff from agricultural activities near the lagoon's margins; and, a reference site (TEP) with a low level of impact by sewage discharge and other kinds of human activities (Fig. 1). All sites have mud-sand sediments rich in organic matter (10–20% of dry weight).

2.2. Sampling and methods for chemical and biological analyses

Four species were selected (Latin names after Eschemeyer et al., 2016): Blue sea-catfish, *Sciades guatemalensis* (Ariidae, Siluriformes); Pacific lined sole, *Achirus mazatlanus* (Achiridae, Pleuronectiformes); Short-snout mojarra, *Diapterus brevirostris* (Gerreidae, Perciformes) and White mullet, *Mugil curema* (Mugilidae, Mugiliformes). The main criteria for selection were: abundance, maximum reported size, feeding habits (including species with different feeding habits), and possibilities of capture (Table 1). Fish were captured using a cast net (3 m, 2.5 cm stretched mesh size), gill nets (60 m, 7.0 cm mesh size) and a small trawl net (5 m mouth, 2.5 cm mesh size). Individuals were collected between January and February of 2014 from each site. During each sampling operation salinity and temperature were measured using a YSI-30 probe. Fishes were sacrificed in the field and transported on ice (approximately 20–30 min) to the laboratory at the Department of Coastal Studies from the University of Guadalajara. At the laboratory, fish were individually measured for total length (±1 mm) and total mass (±1 g); sex was determined, viscera were removed and the carcass mass (±1 g) and liver weight (±0.001 g) were determined. Calculations were made from raw data for liver somatic index (LSI; 100 × liver

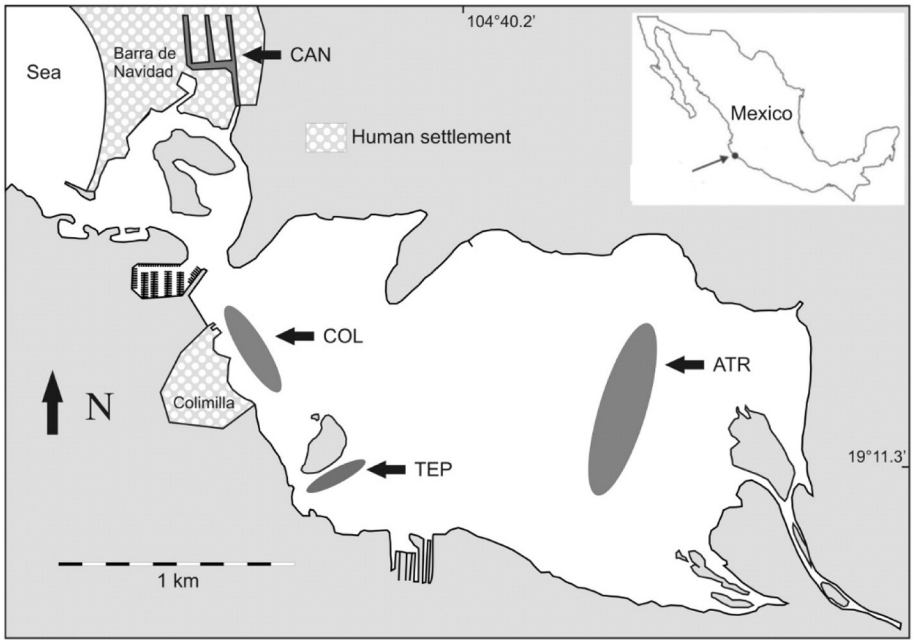

Fig. 1. Sampling sites in Barra de Navidad lagoon.

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