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Marine debris in a World Heritage Listed Brazilian estuary

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ABSTRACT

Using monthly otter-trawl deployments, spatial and temporal variability among the relative densities of marine debris were assessed in the Paranaguá estuarine complex; a subtropical World Heritage Listed area in southern Brazil. During 432 deployments over 12 months, 291 marine debris items were identified; of which most (92%) were plastic, and more specifically shopping bags, food packages, candy wrappers and cups typically >21 mm long. The most contaminated sectors were those closest to Paranaguá city and the adjacent port, and had up to 23.37 ± 3.22 pieces ha^{-1}. Less urbanized sectors had between 12.84 ± 1.49 and 9.32 ± 1.10 pieces ha^{-1}. Contamination did not vary between dry or wet seasons, but rather was probably affected by consistent urban disposal and localized hydrological processes. Marine debris might be minimized by using more environment friendly materials, however a concrete solution requires adequately integrating local government and civil society.

1. Introduction

Anthropogenic pollution is a major threat to marine life, with the negative effects related not only to chemical contamination from substances such as heavy metals, nutrients, and hydrocarbons, but also to marine debris (Santos et al., 2009). Of major concern is the direct mortality among charismatic mammals, birds and turtles through the ingestion and entanglement of plastics (Laist, 1997). Where mortality is not an immediate consequence of ingestion, other ancillary concerns focus on the sublethal impacts associated with the absorption of polychlorinated biphenyls (Derraik, 2002). Unfortunately, the versatility of plastics has led to an exponential increase in usage throughout a wide range of products over the past decades, with a concomitant increase in marine debris (Leite et al., 2014).

Following global trends, marine-debris pollution is ubiquitous along the coast of Brazil, and has received some attention in recent years (e.g. Hatje et al., 2013). Most of the relevant studies have focused on oceanic beaches (e.g. Ivar do Sul and Costa, 2007), although it is well recognized that estuaries are an important source of oceanic debris; the contribution of which is potentially exacerbated by various environmental events (e.g. high rainfall and associated hydrology; Ivar do Sul and Costa, 2007). More specifically, several studies have demonstrated a positive correlation between marine debris accumulation on beaches and rainfall, particularly when precipitation is strongly seasonal and river flows are greater (Cunningham and Wilson, 2003; Araújo and Costa, 2007; Ivar do Sul and Costa, 2013).

In addition to season rainfall, it is also important to note that, owing to shorter-term environmental processes (e.g. daily tidal regimes), marine debris (and especially plastics) can remain in large estuarine systems for extended periods, and undergo various degradation processes across different sedimentary habitats (Ivar do Sul and Costa, 2013). The retention of such debris reflects estuary-specific circulation processes (Acha et al., 2003). A plethora of inherent variation among systems means that it is crucial, therefore, to understand how different estuaries affect the rates at which plastics enter oceans across appropriate temporal and spatial scales.

The Paranaguá Estuarine Complex (PEC), located at the northern limit of the Paraná coast is among the largest estuaries in Brazil, and of considerable economic and ecological importance to the entire southern region of the country. Despite being heavily populated, the PEC is considered one of the most preserved Brazilian ecological environments (Sá et al., 2006). Among the anthropogenic activities around the bay, port-related industries dominate, followed by tourism, artisanal fisheries (legally restricted to passive gears—i.e. no trawling), agriculture and aquaculture. Notwithstanding these activities, large areas of the coastal zone have been protected by environmental legislation. This protection encompasses vast mangrove belts bordering the estuary, which serve as

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important habitat for various marine fauna, and are ecologically linked to the extended rainforest zone in the hinterland.

Studies on marine debris remain sparse for the Paraná coast, which makes it difficult to provide conclusive arguments for policy and management actions. This study aimed to provide a first step towards addressing the above shortfall by quantifying tempo-spatial variability in the density of marine debris in this important marine biodiversity hotspot to test the hypothesis that benthic debris dynamics in the PEC are influenced by season precipitation and urbanized-area proximity. The approach employed here is pioneer, representing the first efforts at addressing the issue of marine debris in the PEC.

2. Materials and methods

2.1. Study area

The PEC (48 25′ W, 25 30′ S) has a total surface area of ~61,200 ha and can be considered part of a larger interconnected subtropical estuarine system that includes Iguape-Cananéia Bay to the north (and on the southern coast of São Paulo; Lana et al., 2001; Noernberg et al., 2006) (Fig. 1). The PEC is surrounded by one of the last remnants of Atlantic rainforest (207 1685 ha)—an important characteristic contributing towards its status as a Natural World Heritage site (UNESCO, 2014).

The system extends along two corridors: an east–west axis (56 km long) forming Paranaguá and Antonina bays which are very urbanized, and a north–south axis (30 km) which comprises the less urbanized Laranjeiras and Guaraqueçaba bays (Fig. 1). Smaller segments connect various other water bodies including Guaraqueçaba, Antonina, Pinheiros, Itaqui, Benito bays and the Medeiros River (Lamour et al., 2004). Excluding two conservational areas—the Superagui National Park (SNP) and Environmental Protected Area (EPA) of Guaraqueçaba (Fig. 1)—the rest of the PEC is subjected to either fishing, tourism or other commercial activities (Guebert-Bartholo et al., 2011).

2.2. Marine debris samples and statistical analysis

Based on known parameters of the PEC, each of the above described axes were divided into three sectors: outer (sector 1), middle (sector 2) and inner (sector 3) (totaling six sectors; Fig. 1). Sector delineation was based on substrate particle size, water temperature, density, chlorophyll, turbidity, salinity and suspended particulate matter (Lamour et al., 2004; Cattani and Lamour, in press). These variables were incorporated into a database and integrated by ArcGIS software (Esri Pty Ltd).

Using the Hawth's Tools (developed for the ArcGIS software; Beyer, 2004), random monthly sampling points were selected within sectors ($n = 6$ per sector). All sampling points comprised appropriate grid sediments (>3 m depth and coarse grain size).

During each month between November 2012 and October 2013, the six sectors were sampled using one of three penaeid trawls deployed across six replicate 5-min tows in a straight line (with the start and end positions marked using a global position system – GPS map 76S; Garmin). The penaeid trawls were identical in terms of their mesh sizes (42- and 26-mm stretched mesh openings in the bodies and codends, respectively), material (0.6 and 1.0 mm diameter polyamide twine, respectively) and design (two seams, with lead-a-head and no sweeps), and only varied slightly in their total opening width (9.44, 9.46 and 9.92 m). All trawls were fished in a single-rig configuration (Broadhurst et al., 2013)

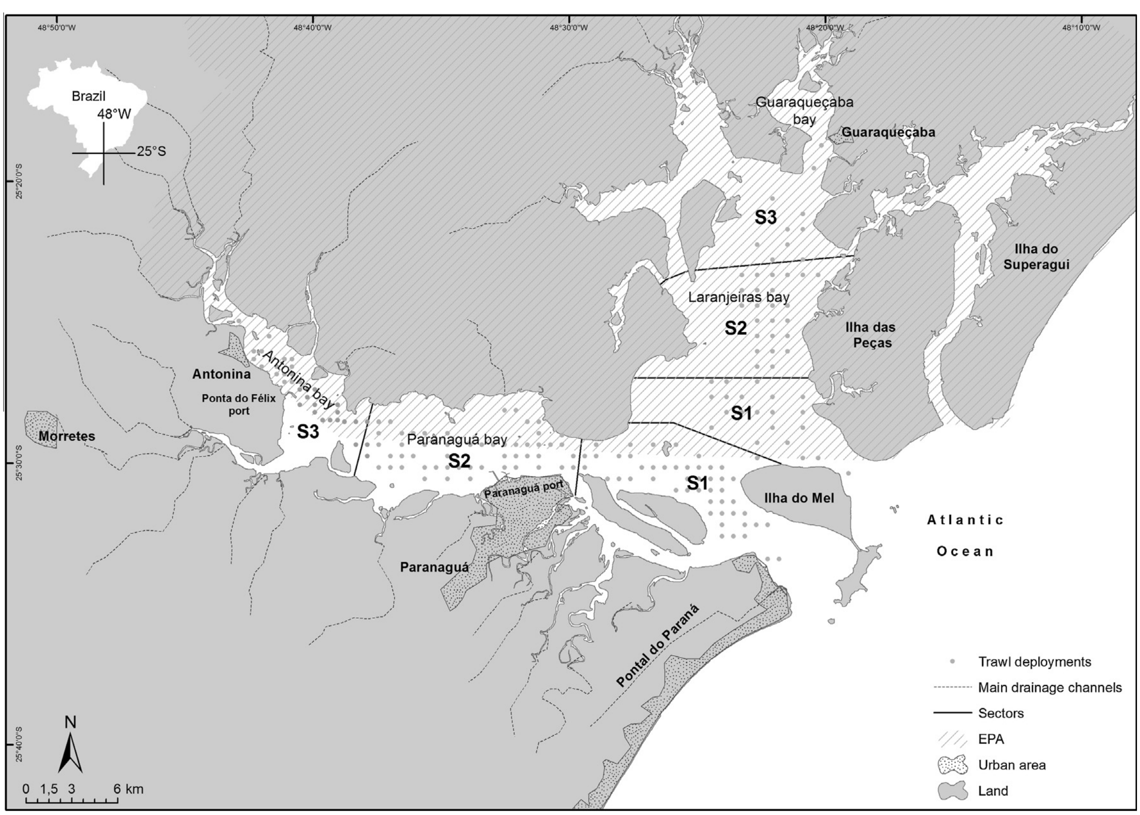

Fig. 1. Location of the Paranaguá Estuarine Complex in southern Brazil, and the key cities and sites. The samples were taken along three sectors in the north–south and east–west axes: outer (S1), middle (S2) and inner (S3), totaling six sectors. EPA, Environmental Protected Area of Guaraqueçaba. The trawl deployments are represented by grey points.