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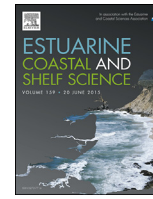

Seasonal distribution and interactions between plankton and microplastics in a tropical estuary

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The seasonal migration of a salt wedge and rainfall were the major factors influencing the spatiotemporal distribution of ichthyoplankton and microplastics along the main channel of the Goiana Estuary, NE Brazil. The most abundant taxa were the clupeids *Rhinosardinia bahiensis* and *Harengula clupeola*, followed by the achirid *Trinectes maculatus* (78.7% of the catch). Estuarine and mangrove larvae (*e.g. Anchovia clupeoides*, *Gobionellus oceanicus*), as well as microplastics were ubiquitous. During drier months, the salt wedge reaches the upper estuary and marine larvae (*e.g. Cynoscion acoupa*) migrated upstream until the zones of coastal waters influence. However, the meeting of waterfronts in the middle estuary forms a barrier that retains the microplastics in the upper and lower estuary most part of the year. During the late dry season, a bloom of zooplankton was followed by a bloom of fish larvae (12.74 ind. 100 m^{-3}) and fish eggs (14.65 ind. 100 m^{-3}) at the lower estuary. During the late rainy season, the high freshwater inflow flushed microplastics, together with the biota, seaward. During this season, a microplastic maximum (14 items 100 m^{-3}) was observed, followed by fish larvae maximum (14.23 ind. 100 m^{-3}) in the lower estuary. In contrast to fish larvae, microplastics presented positive correlation with high rainfall rates, being more strictly associated to flushing out/into the estuary than to seasonal variation in environmental variables. Microplastics represented half of fish larvae density. Comparable densities in the water column increase the chances of interaction between microplastics and fish larvae, including the ingestion of smaller fragments, whose shape and colour are similar to zooplankton prey.

1. Introduction

The connectivity between estuarine and ocean habitats provides a great physic-chemical variability on hydrological circulation patterns, where the denser marine water flows below the river freshwater, creating a stratified water column upstream, commonly referred to as a salt wedge estuary (Kurup et al., 1998; Able, 2005; Barletta and Barletta-Bergan, 2009; Williams et al., 2012; Strydom, 2015). These mechanisms act for the retention of nutrients originated in the river basin and mangrove forest, partially supplying a diverse planktonic community, which function as the basin of the estuarine food web (Kjerfve, 1994; Beck et al., 2003; Nagelkerken et al., 2008).

Estuaries are important marine coastal ecosystems used as settlement, feeding and nursery grounds by many estuarine dependent fish species (Whitfield, 1990; Kjerfve, 1994; Able, 2005; Dantas et al., 2013; Lima et al., 2013; Potter et al., 2013; Gomes et al., 2014). Many fish species spawn in estuaries at times that ensure protection and food availability for their eggs and larvae (Cloern, 1987; North and Houde, 2003; Martino and Houde, 2010). Seasonal variations on salinity, temperature, oxygen, turbidity and availability of food resources, are the main factors influencing the spatiotemporal distribution and abundance of fish larvae and other planktonic organisms in estuaries worldwide (Blaber et al., 1997; Harris et al., 1999; Barletta-Bergan et al., 2002a, b; Hoffmeyer et al., 2009; Ooi and Chong, 2011; Williams et al., 2012).

Although the hydrodynamic complexity of estuaries not only influences the living part of the plankton, but also inanimate material, such as plastics debris, acting in their retention or transportation to other environments (Cole et al., 2011; Costa et al., 2011; Lima et al., 2014). Plastics debris, associated to the increasing urbanization of watersheds, originate mainly on land due to improper disposal, accidental release or natural disasters (Alongi, 1998; Able, 2005; Watters et al., 2010). These fragments enter estuaries by land

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runoff, river discharge or from the ocean (Le Roux, 2005; Nordstorm et al., 2006). However, during their time at land, sea and estuaries, plastics fragment into microplastics (<5 mm) (Barnes et al., 2009; Thompson et al., 2009).

Plastics have been discussed as the principal marine debris to ubiquitously pollute the marine environment. Recent studies recorded high concentration of microplastics in estuarine, coastal waters and sea samples, with densities comparable to the living plankton (Collignon et al., 2012; Frias et al., 2014; Lima et al., 2014). The increasing amount of microplastics in the aquatic environment have raised concerns about their incorporation into food webs. Their small size makes them available to a wide range of marine biota (Barnes et al., 2009; Cole et al., 2011). Microplastic ingestion has been widely reported in marine organisms, including microcrustaceans (Besseling et al., 2014), bivalves (Cauwenberghe and Janssen, 2014), amphipods (Chua et al., 2014), mysid shrimps, copepods, polychaete larvae (Setälä et al., 2014) and fishes (Boerger et al., 2010; Possatto et al., 2011; Dantas et al., 2012; Lusher et al., 2013; Sá et al., 2015). Ingested microplastics might induce gut blockage and limit food intake (Cole et al., 2013). In addition, microplastics have the capacity of adsorb persistent organic pollutants (POPs), biocides and trace metal posing a threat to the environment and organisms, such as the effects of eating contaminated fragments, consequently, reducing the nursery function of estuarine habitats (Moore, 2008; Frias et al., 2010; Tuner, 2010).

This study described the spatial movement of the living plankton (ichthyoplankton and zooplankton) and non-living particles (microplastics) according to the seasonal migration of the salt wedge of the Goiana River Estuary, NE Brazil, in order to assess how environmental factors influence their distribution patterns. Whereas researches on the occurrence of microplastic in estuaries are scarce, this study also describes the possible effects of the presence of microplastics within the plankton of the estuary for fish larvae.

2. Material and methods

2.1. Study area

The Goiana Estuary has a main channel 17 km long and its floodplain covers 4700 ha in total area. It is located on the Northeast coast of Brazil (7°32′–7°35′S; 34°50′–34°58′W) and characterised by a tropical semi-arid climate (Fig. 1). The rainfall patterns define four seasons: early dry (September to November), late dry (December to February), early rainy (March to May) and late rainy (June to August) (Barletta and Costa, 2009) (Fig. 2). The Goiana Estuary is also a Marine Conservation Unit (MCU) and the fishery of fish, molluscs and crustaceans all along the year determine the subsistence of traditional populations (Barletta and Costa, 2009). The study area was divided into three portions according to the salinity gradient and the geomorphology of the estuary (Fig. 1). The upper estuary is located next to the river mouth where the width of the main channel varies from 0.05 to 0.09 km, with mean depth of 4.5 m (Fig. 1). The salinity of the upper estuary varies from 0 (late rainy) to 10 (late dry). The middle estuary has between 0.05 and 0.37 km in width, with mean depth of 4.7 m (Fig. 1). It is considered the portion at which occurs the mixing of fresh and salty waters with salinity range from 0 (late rainy) to 21 (late dry). The lower estuary is dominated by marine waters throughout the year with a width range of 0.14–0.61 km and mean depth of 4.1 m (Fig. 1). The salinity of the lower estuary varies from 13 (late rainy) to 35 (late dry) in surface waters; and from 0 (late rainy) to 34 (early rainy) in bottom waters.

2.2. Sampling

Samples were conducted in the main channel of the Goiana Estuary during neap tide cycles from April 2012 to March 2013. Three superficial (0–1 m) and three bottom (3–6 m) water sample replicates were taken monthly in each portion of the estuary (upper, middle and lower) by towing a conical plankton net (300 μm; Ø 0.6 m; 2 m long) for 15 min at an average speed of 2.7 knots, totalling 216 samples. The volume filtered per tow was calculated using a flowmeter (General Oceanics - Model 2030 Digital Series). A GPS (Ensign GPS Trimble Navigation) determined the sampling position and an echo sounder (Eagle Supra Pro D) registered the depth along the track. Water temperature (° C), dissolved oxygen (mg l^{-1}) (Wissenschaftlich Technische Werkstätten, WTW OXI 325; www.wtw.com) and salinity (WTW LF 197) were recorded before the beginning of each sampling, from both surface and bottom waters. Samples were preserved in buffered formalin (4%).

2.3. Laboratory procedures

Samples were divided into smaller aliquots (100 mL) to facilitate the separation of plankton and organic matter with the aid of a

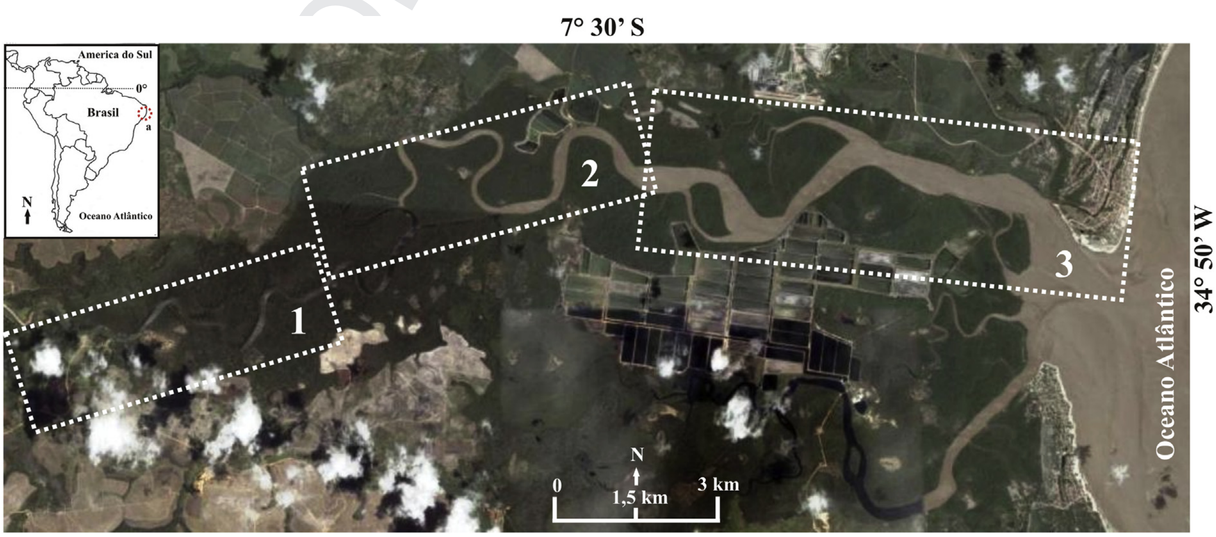

Fig. 1. Goiana Estuary. ⬚ = (1) upper, (2) middle and (3) lower portions of the estuary.
Source: Google Earth (2014).

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