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First evidence of microplastic ingestion by fishes from the Amazon River estuary

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ABSTRACT

This study investigated occurrence of microplastic particles in digestive tracts of fishes from the Amazon River estuary. A total of 189 fish specimens representing 46 species from 22 families was sampled from bycatch of the shrimp fishery. Microplastic particles removed from fish gastrointestinal tracts were identified using Attenuated Total Reflectance – Fourier Transform Infrared (ATR-FTIR). In total, 228 microplastic particles were removed from gastrointestinal tracts of 26 specimens representing 14 species (30% of those examined). Microplastic particles were categorized as pellets (97.4%), sheets (1.3%), fragments (0.4%) and threads (0.9%), with size ranging from 0.38 to 4.16 mm. There was a positive correlation between fish standard length and number of particles found in gastrointestinal tracts. The main polymers identified by ATR-FTIR were polyamide, rayon and polyethylene. These findings provide the first evidence of microplastic contamination of biota from the Amazon estuary and northern coast of Brazil.

1. Introduction

During recent decades, changes in manufacturing and consumer behavior together with insufficient waste management have resulted in accumulation of plastic debris in oceans throughout the world (e.g., Costa and Barletta, 2015; Jambeck et al., 2015), with plastic now composing between 60% and 80% of all marine debris (Barnes et al., 2009). It has been estimated that nearly half of all plastic products are discarded in < 12 months after production (Hopewell et al., 2009). Once introduced into marine ecosystems, plastic waste becomes fragmented as it disperses via wind and oceanic currents (Barnes et al., 2009; Lebreton et al., 2012) and is distributed throughout the water column (Bellas et al., 2016). Plastic debris accumulates not only in the open ocean, but also on beaches, mangrove forests and other coastal habitats (Ivar do Sul and Costa, 2007). Although some plastic debris is dumped directly into marine waters, rivers accumulate discarded material throughout their watersheds and transport it to the oceans (Lechner et al., 2014; Vendel et al., 2017). Unfortunately, rivers and estuaries have received relatively little attention with regard to the plastic pollution problem (Costa and Barletta, 2015), especially within the southern hemisphere (Cannon et al., 2016).

Reports of interactions between marine fauna and plastic debris have increased by 75% over the last two decades, including 267 species reported in 1997 (Laist, 1997) and 693 species reported in 2015 (Gall and Thompson, 2015). Plastic waste in the environment negatively impacts biota, including entanglement of animals within large items (macroplastics) and ingestion of microplastics (particles < 5 mm) by organisms, with subsequent transfer within the food web (Fossi et al., 2012; Cole et al., 2013; Ivar do Sul and Costa, 2014). Ingestion of plastic can affect organisms both physically and physiologically, including direct mortality from entanglement and choking as well as sublethal effects, such as compromised feeding, digestion, and reproduction activities (Gregory, 2009; Vendel et al., 2017). Exposure to chemical pollutants that bind to plastic particles has become a major concern, especially when chemicals bioaccumulate in fish destined for human consumption (Teuten et al., 2009). The effects of human consumption of organisms that contain microplastics are still poorly understood. Some evidence has been reported that plastic particles may cause immunotoxic responses, resulting either from chemical exposure or particle-induced mechanical stress (Seltenrich, 2015).

In aquatic and marine environments, plastics undergo a continuous process of disintegration from the action of water and wind causing

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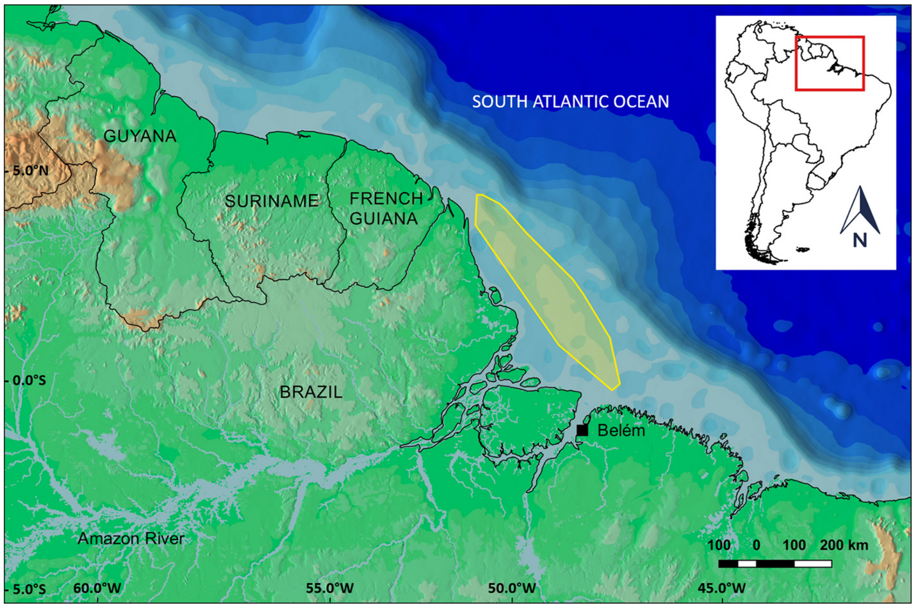

Fig. 1. Location of the Amazon River estuary in northeastern Brazil (inset) showing the survey area (yellow shaded area). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

abrasion from contact with solid particles, and through chemical decomposition by exposure to solar radiation (Moore, 2008; Barnes et al., 2009). Plastic debris is classified as macroplastics (particle diameter > 25 mm), microplastics (diameter < 5 mm) (GESAMP, 2015) or mesoplastics (5–25 mm) (Jabeen et al., 2017). Microplastics are further classified according to their origin. Primary microplastics are resin pellets and microbeads used in cleaning products, cosmetics, medicines and other products; secondary microplastics are formed from the fragmentation of larger meso- and macroplastics (Cole et al., 2011). Plastic pellets are used worldwide as a raw material in the production of plastic products (Ogata et al., 2009). With exposure to solar radiation, plastic pellets often lose or change their initial white or translucid coluoration and many anthropogenic and biogenic chemicals can be adsorbed by their surface (Endo et al., 2005; Miranda and Carvalho-Souza, 2015). Hydrophobic characteristics of plastics allow them to function as vectors for organic contaminants and heavy metals (Colabuono et al., 2010; Holmes et al., 2012).

Many fishes ingest tiny plastic particles either intentionally or accidentally while feeding in the water column or the benthos (Browne et al., 2010). Most investigations of microplastic ingestion by wild fish have been conducted in the northern hemisphere (e.g. Boerger et al., 2010; Phillips and Bonner, 2015), especially in Europe (e.g. Neves et al., 2015; Bellas et al., 2016; McGoran et al., 2017) and North America (e. g. Carson, 2013; Petters and Bratton, 2016). Microplastic ingestion by fishes in the Southern Hemisphere has been documented by studies performed in Africa (e.g. Biginagwa et al., 2016; Naidoo et al., 2016), Australia (e.g. Cannon et al., 2016), Easter Island (e.g. Ory et al., 2017), Indonesia (e.g. Rochman et al., 2015), and South America (Mizraji et al., 2017; Ory et al., 2017). Studies in Brazil have been conducted in the northeastern and southeastern regions (e.g. Possatto et al., 2011; Ferreira et al., 2016; Silva-Cavalcanti et al., 2017), with no investigations as yet for the northern region that includes the Amazon River estuary.

Brazil's northern coastline has low human population density and contains the world's second-longest, continuous area of largely undisturbed mangrove forest (ca. 7000 km^2) (Giarrizzo and Krumme, 2008). In 2016, an extensive and biodiverse reef system (~9500 km^2) was discovered offshore from the mouth of the Amazon River (Moura et al., 2016). This discovery, paired with the fact that 20% of Brazil's fisheries landings come from the northern coast (Krumme et al., 2015), lends urgency to the need to improve knowledge about plastic pollution in the region. Based on experiences in estuaries from northeastern Brazil, Costa and Barletta (2015) identified the Amazon River estuary as a priority area for future studies on marine plastic pollution. The goal of our study was to investigate the presence of microplastics ingestion by fishes from the Amazon River estuary on the coast of Brazil. We hypothesized that quantity and size of the ingested particles increases with fish body size, weight and vertical trophic position within the estuarine food web.

2. Material and methods

2.1. Study area

Brazil's North Coast extends over 1400 km along the states of Amapá and Pará, covering an area of approximately 488,000 km^2 and a variety of ecosystems including mesophotic reefs, islands, tidal flats, and estuaries with extensive mangrove forests (Marceniuk et al., 2013) (Fig. 1). The region's equatorial humid climate (Kottek et al., 2006) has annual rainfall up to 3300 mm and average annual temperatures of 27.5 to 29.5 °C (Pereira et al., 2009).

The region includes the estuary of the world's largest river, the Amazon, with its mean annual discharge of 6.3 trillion m^3 of freshwater, 1.2 billion tons of sediments and 290 million tons of solutes that flow onto the continental shelf (Oltman, 1968; Meade, 1985; Nittrouer et al., 1995). The Amazon's freshwater plume can seasonally expand up to 120 km from the river mouth to the open ocean where salinities can close to zero.

The Amazon's massive freshwater discharge affects oceanographic processes, creating dynamic system of currents and tidal fluxes. The large sediment discharge contributes to high primary and secondary productivity, sustaining important artisanal and commercial fisheries (Neiva and Moura, 1977; Wolff et al., 2000). Estuarine fishes and crustaceans have great economic importance and many of them interact with substrates, influencing physical and chemical processes, including nutrient dynamics (Lana et al., 1996).