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Revealing accumulation zones of plastic pellets in sandy beaches☆

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ABSTRACT

Microplastics such as pellets are reported worldwide on sandy beaches, and have possible direct and indirect impacts on the biota and physical characteristics of the habitats where they accumulate. Evaluations of their standing stock at different spatial scales generate data on levels of contamination. This information is needed to identify accumulation zones and the specific beach habitats and communities that are likely to be most affected. Standing stocks of plastic pellets were evaluated in 13 sandy beaches in São Paulo state, Brazil. The sampling strategy incorporated across-shore transects from coastal dunes and backshores, and vertical profiles of the accumulated pellets down to 1 m depth below the sediment surface. Accumulation zones were identified at regional (among beaches) and local (between compartments) scales. At the regional scale pellet density tended to increase at beaches on the central and southwestern coast, near ports and factories that produce and transport the largest amounts of pellets in the country. At the local scale coastal dunes showed larger accumulations of pellets than backshores. For both compartments pellets tended to occur deeper in areas where standing stocks were larger. Most of the pellets were concentrated from the surface down to 0.4 m depth, suggesting that organisms inhabiting this part of the sediment column are more exposed to the risks associated with the presence of pellets. Our findings shed light on the local and regional scales of spatial variability of microplastics and their consequences for assessment and monitoring schemes in coastal compartments.

1. Introduction

Contamination of the coastal zone by plastics is a major environmental issue (Eriksen et al., 2014; van Sebille et al., 2015; Zalasiewicz et al., 2016). Plastics in the sea are of different sizes (Ryan et al., 2009), subdivided into macroplastics and microplastics (Cole et al., 2011). Microplastics (MPs) may be spherules, fibers or fragments, and are broadly defined as those less than 5 mm in diameter (Arthur et al., 2009), although definitions vary. Among these MPs are plastic resin pellets, which constitute the raw material for manufacturing plastic goods. Pellets enter the marine environment by losses during production, transport, transshipment at port terminals, and at plastic processing plants (US EPA, 1992; GESAMP, 2015).

In 2014 the world production of plastic materials was 311 million metric tons (Plastics-Europe, 2015). Despite the worldwide management strategies in place to reduce losses along the production chain (e.g. Global Plastics Associations for Solutions on Marine Litter, 2011), pellets are still being lost to the environment. Losses occur directly into marine/estuarine environments or to urban drainage systems and rivers, eventually reaching coastal areas. Less-dense resin pellets tend to disperse more widely (US EPA, 1992). Pellets that enter the marine environment are transported by currents and wind, and aggregate in many habitats, such as on sedimentary shores worldwide (Cole et al., 2011). They have often been reported on sandy beaches (see Hidalgo-Ruz et al., 2012), where they sometimes constitute more than 80% of the beached plastic items (Van Cauwenberghe et al., 2013). Therefore, sandy beaches can be considered as tractable and suitable model systems to evaluate the accumulation patterns of pellets.

Most of the studies that have evaluated the abundance of pellets have focused on the intertidal zone of sandy beaches (see Hidalgo-Ruz et al., 2012; Moreira et al., 2016). Few studies have included the backshore (Turner and Holmes, 2011; Turra et al., 2014) or coastal dunes (Liebezeit and Dubaish, 2012; Dekiff et al., 2014). The majority of the studies sampled at 0–0.1 m below the sediment surface, occasionally down to 0.3 m or 0.5 m (Carson et al., 2011; Claessens et al., 2011; Kusui and Noda, 2003), and more rarely down to 2 m in the sediment column (Turra et al., 2014). Consequently, very little information is available about the standing stock

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and accumulation of pellets across beach zones or compartments.

Pellets accumulated on beaches are carriers of many pollutants (Fisner et al., 2013a,b; Taniguchi et al., 2016). These can leach into the interstitial water in sediment and affect the development of organisms (Nobre et al., 2015). Very large amounts of plastic can also influence the physical characteristics of the environment, such as permeability and heat transfer through the sediment (Carson et al., 2011). These factors may directly or indirectly affect the sandy-beach environment and biodiversity (Carson et al., 2011; Nelms et al., 2016). Thus, evaluation of the distribution of the standing stock of pellets in the sediment and across-shore in sandy beaches could provide information on the specific habitats and communities that are most exposed to their impacts (chronic and/or acute). On the other hand, evaluations at larger spatial scales (i.e. among beaches) could provide information about pellet accumulation hotspots. This sort of information is important in order to understand where to expect higher chances of contact with the biota, and potentially greater risks, as well as for monitoring and management purposes.

Here, we evaluated the areas of accumulation of plastic pellets at different spatial scales, considering differences among beaches, between beach compartments (coastal dunes and backshores), and also at different depths within the sediment.

2. Materials and methods

2.1. Hypotheses tested

We tested the hypothesis that the standing stock of pellets would be unevenly distributed at both regional scale (among beaches; southwestern and central > northeastern beaches; see below) and local scale (between compartments: coastal dune > backshore) (Hypothesis 1). We also evaluated the occurrence of pellets in the sediment column (depth), in order to identify the accumulation zones and beach communities that are most exposed to their impacts. We tested the hypothesis that for both compartments, there would be no significant relationship between the standing stock of pellets and their depth distribution below the sediment surface (Hypothesis 2). We also described the variation in the percentage of the standing stock of pellets accumulated at different depths below the sediment surface. To determine the most appropriate sampling method to identify areas of accumulation, the hypotheses were tested using two parameters of abundance (pellets x m^{-2} and pellets/Strip Transect).

Our sampling strategy was specifically designed to test for differences in spatial scales. We also provide additional information on possible influences of physical features of the environment and anthropogenic factors on patterns of accumulation.

2.2. Selection of the study sites

To evaluate the distribution patterns of pellets, 13 beaches were selected along the entire coast of São Paulo state in southeastern Brazil (Fig. 1). The selected beaches had backshore and coastal-dune zones that were free of artificial structures, and were not being mechanically cleaned by municipalities. Many beaches along the São Paulo coast have infrastructure such as hotels, houses, and municipal gardens built on the coastal dunes, and are mechanically cleaned by municipalities. As a result, the beaches were not equally distributed along the coast. Eight beaches were selected toward the northeastern part of the state and in the Santos region (beaches No. 1 to 8: Fazenda, Ubatumirim, Prumirim, Félix, Itamambuca,

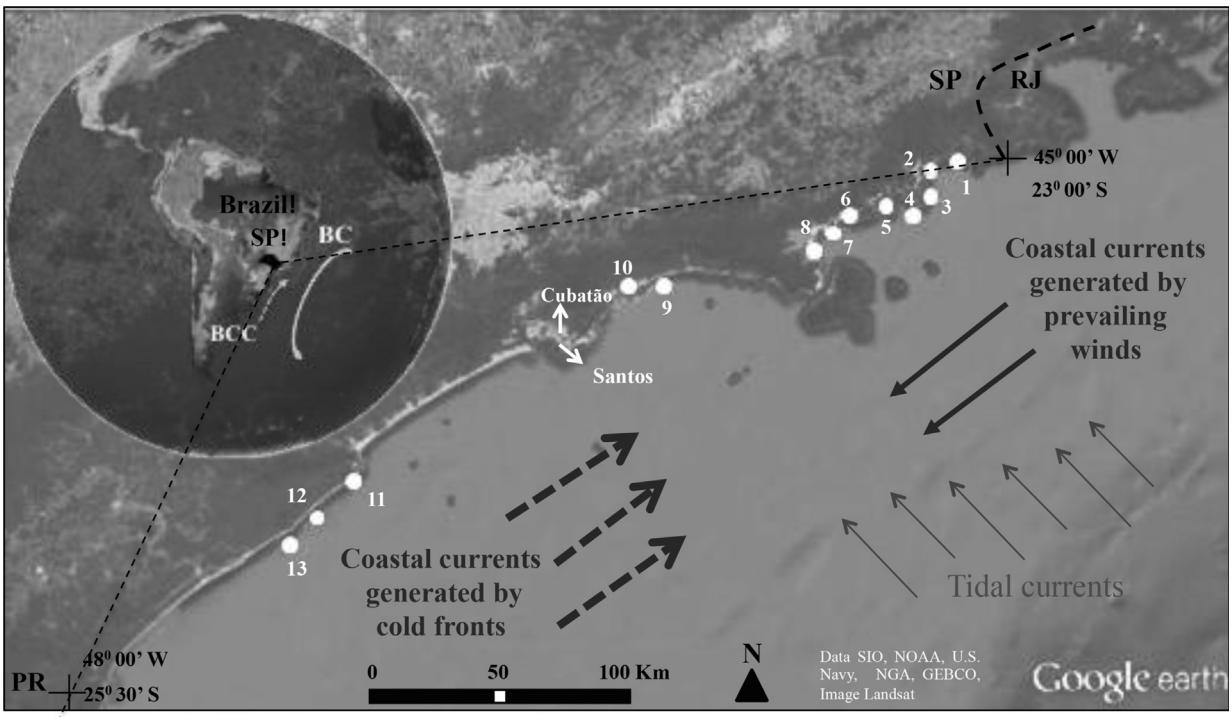

Fig. 1. - Study area. The Brazilian coast and the offshore surface circulation on the continental shelf. White arrows represent the direction of the persistent Brazil Current (BC) and the seasonal Brazilian Coastal Current (BCC) (solid and dashed lines respectively). **Details of the São Paulo coast (SP – sampled area),** showing the locations of the states of Rio de Janeiro (RJ) and Paraná (PR), Santos and Cubatão cities, and the 13 beaches sampled (1- Fazenda, 2 - Ubatumirim, 3 - Prumirim, 4 - Félix, 5 - Itamambuca, 6 - Vermelha do Sul, 7 – Lagoinha, 8 - Capricórnio, 9 – Boracéia, 10 – Itaguaré, 11 - Una, 12 - Juréia and 13 – Ilha Comprida). **Major coastal currents of the São Paulo coast**, arrows represent the direction of the currents generated by the tides (light gray), the prevailing winds (dark gray) and the winds under the influence of systems and wave fronts (dashed dark gray). The thickness of the arrows indicates the relative strength of the currents.

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