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Origin of marine debris is related to disposable packs of ultra-processed food

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ABSTRACT

Marine debris is currently distributed worldwide, and the discard and contamination pose hazards to human and wildlife health. One of the gaps in debris science is tracking the source of debris to better evaluate and avoid the pathway of debris from the source to marine environment. For this, we evaluated three beaches of different urbanization levels and environmental influences; a low urbanized beach, a highly urbanized beach and a non-urbanized estuary-associated beach, in order to determine the sources and original use of debris. Plastic was the major material found on beaches, and the urbanized beach recorded the highest debris densities. Marine debris was primarily from land-based sources, and the debris recorded in all beaches was mainly assigned as food-related items. Our results highlight the major presence of disposable and short-lived products comprising the majority of debris that enters the ocean and draw attention to the unsustainable lifestyle of current society.

1. Introduction

Today, marine debris is widely distributed in open oceans and coastal areas, mainly as plastic fragments (Barnes et al., 2009; Cózar et al., 2014; Galgani et al., 2015). Some of plastic's features (*e.g.*, durability and low cost) that have made the material highly useful, popular and profitable to industry and society in the previous and present centuries are the same that today pose a threat to the marine environment (Laist, 1987; Ryan, 2015). The persistence of plastics in nature may lead to serious hazards to human and wildlife health such as disturbances in the biogeochemical processes of ecosystems (Green et al., 2015), exposition to harmful chemicals that are present or absorbed by marine plastic debris (Ashton et al., 2010; Rochman, 2015), and death or sublethal effects through debris ingestion and entanglement by marine fauna (Barreiros and Raykov, 2014; Baulch and Perry, 2014; Santos et al., 2015).

In this context, more than 690 species have already had some interaction with marine debris (Gall and Thompson, 2015). Debris ingestion produces stressful and harmful effects on marine biota and may also pose a pathway of toxic compounds to human health through the consumption of marine target resources (Gall and Thompson, 2015). Although the effects of debris ingestion by marine animals are still poorly known, recent studies shed light on this issue. For instance, ingested microplastic fragments can reach and be retained in different organs, as observed in tropical crabs (Brennecke et al., 2015), and a small amount of debris (0.5 g) may cause blockage of the digestive tract and the death of relatively large animals, such as juvenile marine turtles (Santos et al., 2015).

The consensus in recent scientific approaches is the necessity to understand the consequences of marine debris for the environment, reduce littering and monitor plastic pollution worldwide (Derraik, 2002; Thompson et al., 2009). In addition, reducing the causes of debris requires the participation of multiple sectors of society, including authorities, industries, scientists and citizens (Bergmann et al., 2015). One of the gaps in knowledge of marine debris science is an understanding of an accurate source of debris that enters in the ocean in order to focus on the main threats (Ryan et al., 2009). The source of debris in marine environments has changed across the decades (Ryan et al., 2009). Early works about the distribution and composition of debris in marine environments reported plastic pellets as the most abundant debris material floating in the ocean and ingested by animals (Carpenter and Smith, 1972; Carpenter et al., 1972; Kartar et al., 1973; Morris and Hamilton, 1974). Lately, using seabirds as a proxy to determine the debris content in the marine environment, Vlietstra and Parga, 2002 reported that the type of plastic ingested by seabirds has changed throughout at least two decades (1970s to late 1990s), from typical industrial pellets to user plastics (fragments of larger objects). Indeed, shipping/fisheries were a main pathway to litter entrance in the sea during the middle of the last century (see Ryan et al., 2009 for a review); however, after the International Convention for the Prevention of Pollution from ships (MARPOL) and their Annex V, the litter produced by vessels was more strongly controlled and avoided (Ryan, 2015; Ryan et al., 2009), although some difficulties still arise in this issue (Carpenter and Macgill, 2005).

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Table 1
Location, population density and debris density recorded in three sampled beaches with different levels of urbanization.

Beach	Latitude Longitude	Inhabitants	Inhabitants/km^2	Marine debris (item/m^2)
High urbanized	20°18′ S 40°17′ W	355,875	3338.3	0.58
Low urbanized	20°00′ S 40°08′ W	19,985	58.97	0.18
Non-urbanized estuary-associated	19°39′ S 39°49′ W	1200	–	0.24

The current challenge is identify these new sources of marine debris and their pathways into the marine environment to help mitigate the impacts in human and wildlife spheres. For this, we assessed different types of beaches with respect to human influences and environmental conditions to identify the possible origin of the debris and the influence of adjacent areas in debris deposition on marine environments.

2. Methods

2.1. Study area

Three beaches located in southeastern Brazil were chosen in order to represent different levels of urbanization (developed and undeveloped) and natural dynamics (proximity to a river). Curva da Jurema, the highly urbanized beach, is located in Vitória city (20°18′ S, 40°17′ W). Vitória is the capital of Espírito Santo state and has 355,875 residents, with a population density of 3338.3 inhabitants/km^2 (IBGE, 2015). The beach has infrastructure, such as typical beach kiosks and parking for visitors, and it is a place of easy access for swimmers and receives many tourists during the bathing season, mainly from December to February. The low urbanized beach region comprises a set of small beaches called Porto da Lama and Enseada das Garças, which are located in Fundão city. Fundão (20°00′ S, 40°08′ W) has 19,985 residents and a population density of 58.97 inhabitants/km^2 (IBGE, 2015). In the beaches of Fundão, kiosks or parking are absent, and fishing activities derived from artisanal fisheries are performed in the region. Unlike the former beaches cited, the third beach is Regência (19°39′ S, 39°49′ W), which comprises a non-urbanized small village of fishermen with approximately 1200 residents and 300 houses located adjacent to the large estuarine area of Doce river. Regência beach is included in a protected area (Reserva Biológica de Comboios) that shelters an important nesting ground of threatened leatherback sea turtles (*Dermochelys coriacea*). Beaches and urbanization level are summarized in Table 1.

2.2. Marine debris survey and analysis

Anthropogenic debris was evaluated through visual census on beaches conducted during the four seasons throughout a year, bimonthly in the highly urbanized beach and low urbanized beach, and quarterly in the non-urbanized estuary-associated beach. The censuses were conducted from the sea edge to the highest strandline (the edge of beach vegetation) with a fixed width. Transects length varied depending to beach characteristics, in the highly urbanized ranging from 1.7 to 12.6 m, in the low urbanized 5.3–41.1 m and in the non-urbanized estuary-associated 7.4–48.8 m. In all beaches, the width and length of each transect was measured and calculated in order to obtain the average measures, and then the abundance, of debris per m^2. Number of transects in each beach were 4 in the highly urbanized, 4 in the low urbanized and 20 in the non-urbanized estuary-associated per sampling.

The debris observed was recorded according to material type (hard plastic, soft plastic, glass, cigarette, nylon, paper, rubber, wood and others), size (5 cm size classes up to 25 cm and from 25 cm upwards in 10 cm size classes) and possible origin (source and original use). The source was first classified as land-based or sea-based. Debris generated by beach users and domestic effluents were considered land-based. Debris generated by fishing activities and vessels were classified as sea-based. In addition, we classified debris according to their original use: food-related, cigarette butts, building material, personal care (cosmetic and hygiene products), clothing, toy, medicine (and medical waste) and household cleaning. In order to test difference in debris density among beaches and among seasons within beaches we performed a Kruskal-Wallis test. We used an analysis of similarity (ANOSIM) to evaluate the differences in assigned original uses of debris (identified items) among beaches.

3. Results

Altogether, 4752 items were registered from all beaches, and the most abundant material recorded was plastic (highly urbanized 73.2%, low urbanized 83.2% and non-urbanized estuary-associated 85.9%). Debris densities were significantly different among the beaches (Kruskal-Wallis; $p < 0.05$), with highly urbanized beach showing the highest density (Table 1). Seasonally, the accumulation of debris only differed significantly on the highly urbanized beach, with highest debris amounts recorded during the bathing months, mainly January (Kruskal-Wallis; $p < 0.05$). Most of anthropogenic debris found was in the size class 0–5 and 5–10 cm (Fig. 1). Most of the items in the size class 0–5 cm from the highly urbanized beach were represented by cigarette butts (17.6%) and food related items (51.7%), while, in the non-urbanized estuary-associated beach was non-identified fragments (62.8%). The most prevalent size class in the low urbanized area was 5–10 cm represented mainly by food related items (65.3%).

It was possible to identify the original use of 55.6% of the debris found in the highly urbanized area, 60.2% in the low urbanized area and 48.8% in the non-urbanized estuarine-associated area. Most of the identified debris originated from land-based sources, accounting for 94.8% of the total items in the highly urbanized area, 92.3% in low urbanized area and 93.7% in the non-urbanized estuarine-associated area. All of the debris classified as sea-based sources was related to fishery activities in the three areas. According to analysis of similarity the debris original use were similar among sites (ANOSIM Global R 0.007; $p < 0.05$) with food related items as the most prevalent debris type in all beaches in spite of urbanization level and environmental conditions

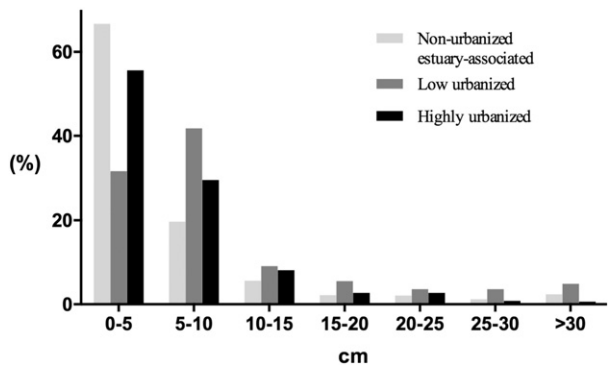

Fig. 1. Relative abundance of debris size recorded in three beaches with different levels of urbanization.