Marine debris on beaches of Arraial do Cabo, RJ, Brazil: An important coastal tourist destination

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ABSTRACT

Arraial do Cabo, RJ, Brazil, is known as the diving capital due to its clear waters and great biodiversity, a consequence of the upwelling phenomenon. This feature attracts tourists tripling their population during holidays, causing increase in the amount of debris on beaches and waters endangering marine biodiversity. To evaluate the amount of solid waste found on beaches in two different holiday periods, eight people in each beach collected macrodebris (≥ 2 cm) in a transect covering an 20 m wide area, during 20 min, in winter/2015 and summer/2017. The materials were weighed, quantified and characterized. In the summer, when the number of tourists is greater, a larger total amount of waste in units were found. Plastic and cigarette butts were the most abundant. The results show that the city does not have adequate planning to receive a large amount of tourists, being vulnerable to socioeconomic and environmental damages.

1. Introduction

The pollution by marine debris on marine and coastal environments has several negative environmental and socioeconomic effects such as animal death, impact on fishing, transport of exotic species, aesthetic impairment, tourism decrease, besides affecting the health of human population. Recently studies concluded that some residues as micro-plastics can adsorb pollutants present in the water and enter in trophic web ingested by aquatic organisms causing impacts in their metabolism (Lee et al., 2013; Gall and Thompson, 2015).

The origin of the litter found in marine and coastal environments can be classified as terrestrial or marine. Marine sources include oil and gas platform waste, materials used in fishing activity, and garbage dumped into the sea by sailboats, freighters and other vessels (Coe and Rogers, 1997). Terrestrial sources include waste from landfills, domestic and industrial sewage, river drainage and surface runoff (Nollkaemper, 1997); and also the lack of education of the tourists and beaches users, who throw away the garbage produced by them on the sands of the beaches.

The transformation of a region into a tourist destination causes changes in socio-spatial relationships, leading in many situations to the disfigurement of natural landscapes and environmental degradation. Therefore, tourism must be implemented and conducted in a sustainable way, since this activity depends on natural resources. Sustainable tourism considers cultural authenticity, social inclusion, conservation of the environment and quality of services as key to the long-term economic viability of tourism. The systemic and holistic approach is essential in this process, being necessary to consider the set of social and natural elements that compose the landscape, its interactions in the process of planning and territory management (Ruschmann et al., 2008; Soares et al., 2013).

Coastal management should focus on preventing the arrival of litter in coastal environments, which can be done by: educational efforts such as signs at the entrance of the beaches, educational campaigns on a local or national scale, beach-cleaning activities to reduce the debris caused by recreational population; increase the cleaning frequency on beaches; strengthen law enforcement in coast areas; reduce the use of disposable items on this areas; researches and collaboration between different regions and countries (Kuo and WenHuang, 2014; Pasternak et al., 2017).

Tourist coastal cities with an inadequate management of solid residues tend to present greater amount of marine debris, particularly in summer period when has great intensity of use by bathers (Leite et al., 2014; Silva et al., 2016). The coast of Rio de Janeiro is frequented by bathers and tourists throughout the year, especially the area of the coastal lowlands known as “Polo Costa do Sol”, which covers thirteen municipalities, among them, Arraial do Cabo, a city intensely used by tourists, reaching a tripling of its population on summer (Motta and...
Terra, 2011).

2. Study area

Arraial do Cabo has four conservation units: extractive marine reserve of Arraial do Cabo, Cabo Frio dunes, Massambaba environmental preservation area and Massambaba ecological reserve. The most popular is the marine extractive reserve that has 51.601 ha, a territory of great biological importance, highlighting the marine phenomenon of the upwelling, which gives it scenic beauty, great biological diversity and abundance of fish in the region, attracting the fishing industry and divers, being recognized as the “diving capital” in Brazil. This conservation unit was created to protect the culture of artisanal fishing, however, there have been changes in the way of life of traditional communities due to the introduction of industrial fishing, tourism, oil and gas activities (Mendonça et al., 2013; ICMBIO, 2017).

The main economic activities of the city are developed in marine and coastal environment: fishing and tourism; especially during school holidays, in winter and in the summer period. In the summer, the amount of tourists is higher due to the higher temperatures; and fishing is more intense due to the occurrence of upwelling phenomenon increasing the productivity and quantity of fish. Therefore, a fact that deserves attention in the city is the marine debris that can easily be found in the sands of its beaches (Oliveira et al., 2010; Mendonça et al., 2013).

This is the first study that evaluated the marine debris on the beaches of Arraial do Cabo, one of the many tourist coastal cities of Brazil. Identify the sources, types and main generating activities that produce marine litter is the first step in the elaboration of public management policies related to marine litter in coastal cities; so, the objective of this study was to evaluate the amount of marine debris found in the sand of three beaches in the city of Arraial do Cabo, Rio de Janeiro, Brazil: Prainha beach, Pontal beach and Grande beach in two distinct periods of holidays, winter and summer.

3. Methodology

This research was carried out in three beaches of Arraial do Cabo, Rio de Janeiro, Brazil: Prainha beach, Pontal beach and Grande beach (Fig. 1). Samples were collected in winter (2015/July) and summer (2017/December).

Based on the methodology developed by the United Nations Environment Programme and published in the Guidelines survey and monitoring of marine litter (UNEP, 2009), we delineated a transect on each beach covering an area of 20 m wide, measured parallel to the water line and with the length varying according to the beach, going from the low tide line to the base of the vegetation. On Prainha beach the area was approximately 300 m², on Pontal beach, 600 m² and on Grande beach, 1000 m².

Each transect was divided in two areas, the first area, wet sand, started at the waterline and covered the region known as the beach face (swash zone). The second area, dry sand, started at the ceiling of the top and ended at the vegetation. At Prainha beach, the transect was located in the central part, in front of the main street that gives access to the beach; at Pontal beach was located in the right corner of the beach and at Grande beach was located on the left side of the beach, near the fishermen’s colony.

Eight collectors equipped with gloves collected all the macrodebris (≥ 2 cm) (UNEP, 2009) in each transect during a 20 min time frame. The materials were weighed, quantified and characterized using the Guidelines survey and monitoring of marine litter (UNEP, 2009) with adaptations (Table 1).

The Kruskal-Wallis test was used to assess significant differences between the total amount of marine debris units sampled during winter/2015 and summer/2017. However, due to the reduced number of samples, that could lead to misunderstanding of results and conclusions, and to the large amount of plastic residues found, it was also used the Clean Coast Index (CCI) proposed by Alkalay et al. (2007) and used in the preparation of the Guidelines on survey and monitoring of marine litter (UNEP, 2009). This index that classify beaches according to the amount of plastic on their sand was adequate for the present study due to the large amount of this material found in the studied beaches. The calculation of the CCI is presented in the following equation:

\[
\text{Total plastic parts counted in } Z \text{ lines} = \frac{Z \times 20 \text{[m]} \times \text{beach width [m]}}{\text{Plastic parts/m}^2}
\]

For statistical reasons, coefficient K = 20 was inserted into the equation. Final CCI numbers are as follows: 0–2: very clean (no litter is seen); 2–5: clean (no litter is seen over a large area); 5–10: moderate (a few pieces of litter can be detected) 10–20: dirty (a lot of debris on the shore) 20 or more: extremely dirty (most of the beach is covered with plastic debris) (Alkalay et al., 2007).

4. Results

A total of 2613 units (1080 in the winter and 1533 in the summer) of marine debris were sampled (no significant difference (p > 0.05) was observed between the two periods). Of this total, 989 units (5.7 kg) were collected on Prainha beach, 811 (7.3 kg) on Pontal beach and 812 (5.45 kg) on Grande beach. The amount of marine debris in units and the abundance per m² found on Pontal beach was higher in the summer period (0.92 units/m²) than in the winter period (0.43 units/m²); the same was observed on Grande beach (with 0.5 units/m² in the summer and 0.31 units/m² in the winter). At Prainha beach, the volume and the abundance was near in both periods (1.6 units/m² in the summer and 1.7 units/m² in the winter) (Table 2).

In all studied beaches a greater amount of units of residues was found in dry sand than in wet sand (Table 3). The same was seen in weight, except in the Pontal beach, where the greatest amount was found in wet sand.

The composition of the collected residues varied between winter/2015 and summer/2017 on the three beaches studied (Fig. 2). In all the studied beaches and in the both seasons, the most commonly found material was plastic (61.4% of the total marine debris found in winter and 54.5% of the total marine debris found in summer) followed by the cigarette butts (26.7% of the total marine debris found in winter and 22% of the total marine debris found in summer).

Due to the large occurrence of plastic items, CCI (Alkalay et al., 2007) was applied, resulting in winter/2015: Prainha beach - dirty; Pontal beach - moderate and Grande beach - clean. In the summer/2017 the result was: Prainha beach - moderate; Pontal beach - dirty and Grande beach - moderate. The collected plastic items had several shapes, so they were separated into subcategories as can be seen in Table 4.

5. Discussion

Marine debris can be found in urban and desert beaches around the planet, however, studies point out that in urban beaches the beach user is a major source of pollution, due to the types and the appearance of the residues found in the sand of the beaches (Martinez-Ribes et al., 2007; Santana Neto et al., 2011; Kuo and WenHuang, 2014; Pasternak et al., 2017). Identifying the periods of greatest waste abundance, the main types and the activities that generate them is a critical step in planning to eliminate the problem before it became a serious environmental and economic problem for a region.

5.1. Types and spatial distribution of marine debris

The residue most commonly found in all collections, beaches and
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