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Lixo marinho no litoral norte do Rio Grande do Sul, Brasil: padrões espaciais e temporais

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ABSTRACT

Marine debris is any solid waste (plastic, polystyrene, rubber, foam, glass, metal, cloth, and other materials) that enters the marine or coastal environments from any source. Sources are frequently defined as land-based and marine-based, and its identification is being recognized as an important step towards the solutions related to marine debris problems. They include damages to the biota, to fishing activities and beach environmental degradation. In Brazil, the occurrence of marine debris is relatively well documented, but quantities, sources and spatial and temporal patterns of marine debris are unknown for the North sector of the Rio Grande do Sul coastline. On Xangri-Lá beaches, marine debris was studied during three months (February, April and August) in ten transects also divided into two horizontal strata (backshore and dunes) which were sampled separately. Plastics (42%) were the main class of material, sampled on all monitored months, transects and strata, followed by cigarette butts (39%). Among plastic debris, fragments (41%) were the majority, showing that beach cleaning services are not an efficient solution to marine debris problem on Xangri-lá beaches. February was the most contaminated month considering the total items sampled on the beach, specific types of plastics and only cigarette butts. No significant differences were detected among backshore and dunes or sampled transects. Land-based sources were where the great majority (68%) of marine debris originated, attributed mostly to beach users. The absence of marine-based sources was related to the nonexistence of big rivers or fishing ports. The necessity of long term educational programs in spite of the short term methods is highlighted.

Keywords: Plastic debris, cigarrete butts, land-based sources, environmental education.

RESUMO

O lixo marinho é definido como qualquer resíduo sólido (plástico, isopor, borracha, espuma, vidro, metal, tecido e outros materiais) que entra nos ambientes marinho e costeiro por qualquer fonte. As fontes são frequentemente definidas como terrestres ou marinhas, sendo a sua identificação uma das etapas mais importantes na determinação de soluções relacionadas ao problema do lixo. Impactos do lixo em ambientes marinhos e costeiros incluem danos à biota, prejuízos às atividades de pesca e a degradação de ambientes costeiros. No Brasil, a ocorrência de lixo marinho é relativamente bem documentada, mas quantidades, fontes e padrões espaciais e temporais do lixo marinho são desconhecidos para o setor norte do litoral do estado do Rio Grande do Sul. Nas praias do município de Xangri-Lá, o lixo marinho foi monitorado durante três meses (fevereiro, abril e agosto), em dez transectos divididos ainda em dois estratos (pós-praia e dunas), que foram amostrados separadamente. Os plásticos (42%) foram a principal classe de material amostrada em todos os meses, transectos e estratos, seguidos pelas pontas de cigarros (39%). Entre os resíduos plásticos, os fragmentos foram significativamente mais presentes que os outros tipos de itens (41%). A presença destes fragmentos

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e de outros resíduos de pequenas dimensões como as pontas de cigarro indica que os serviços municipais de limpeza da praia não são a melhor solução para o problema do lixo em Xangri-Lá. O mês de fevereiro foi o mais contaminado por lixo considerando-se o total de itens amostrados na praia, os resíduos plásticos ou somente as pontas de cigarro, o que foi associado ao uso intenso da praia neste mês. Não foram detectadas diferenças significativas entre os estratos da praia (pós-praia e dunas) ou entre os transectos amostrados. As fontes terrestres representaram a grande maioria (68%), atribuídas principalmente aos usuários da praia. A ausência de fontes marinhas foi associada à inexistência de grandes rios drenando cidades ou portos de pesca artesanal e/ou industrial nas imediações da área de estudo. Destaca-se a necessidade de programas de educação ambiental de longo prazo voltados aos moradores, usuários das praias e proprietários de quiosques, em oposição a métodos de curto prazo, como a distribuição de sacolas plásticas e folhetos educativos, que normalmente se tornam lixo marinho.

Palavras-chave: *Plásticos, pontas de cigarro, fontes baseadas em terra, educação ambiental.*

1. INTRODUCTION

Marine debris is "…any solid waste (plastic, polystyrene, rubber, foam, glass, metal, cloth, and other materials) that enters the marine or coastal environments from any source" (Coe & Rogers, 2000). From a scientific viewpoint, marine debris is one of the most important environmental pollutants in the XXI Century (Goldberg, 1995; Ivar do Sul & Costa, 2007). Consequences of this type of marine pollution were reported on every habitat, on land or oceans around the world. These consequences include damages to the marine biota (Laist, 1997), to fishing activities (Nash, 1992), and beach environmental degradation (Araújo & Costa, 2006), which may result in the reduction of tourism activities (Nollkaemper, 1994) and expensive municipal beach cleaning services.

Sources of marine debris are usually described in the international literature as land-based (beach users, rivers and sewage run-off) and marine-based (ships, fishing boats, oil platforms) sources (Coe & Rogers, 2000). Globally, land-based sources are prevalent and responsible for at least 80% of samples on coastal environments (Nollkaemper, 1994). However, source identification being the most important step towards a definitive solution to marine debris problems is not a simple task, as items have multiple origins and uses (Coe & Rogers, 2000; Santos *et al.,* 2009).

In Brazil, the occurrence of marine debris on beaches and coastal environments is relatively well documented, especially on Pernambuco and Rio Grande do Sul (RGS) coasts (Ivar do Sul & Costa, 2007). On RGS, systematic studies are limited to the southern sector. Therefore, compositions, sources and spatial and temporal patterns of marine debris are unknown to the northern sector of the coast. In addition, previous studies have already reported the ingestion of marine debris by sea turtles and seabirds on the RGS shore (Bugoni *et al.,* 2001; Tourinho *et al.,* 2010), a direct consequence of marine debris contamination on beaches and coastal areas.

The aim of the present study is to quantify, classify and determine the most probable sources of marine debris at Xangri-Lá, a municipality on the northern coast of RGS, determining spatial and temporal patterns of marine debris on the beach, as well as to promote social considerations about the problem.

2. MATERIAL AND METHODS

2.1 Study area

The municipality of Xangri-Lá, on the northern sector of the RGS coast (Figure 1), has 13km of beaches with morphological features (dunes, backshore, water mark and foreshore) disposed in a liner spelling and continuous pattern. The longshore current is, predominantly, from SW to NE (Tomazelli & Villwock, 1992). Alongside the coast are two main connexions with the sea, the Tramandaí channel (25km to the south), and the Mambituba River (90km to the north).

The shore is almost fully urbanized (95%), frequented by tourists mainly in the dry summer season (December-February). During these months, the population grows ten fold and the municipality presents a lack of basic infrastructure (water supply, sewage treatment, solid waste management), health and educational services. Also, during the same period, fixed kiosks are disposed on the backshore, which contribute to the agglomeration of tourists and, consequently, to direct anthropogenic impacts on the beach and adjacent zones.

2.2 Marine debris sampling

Marine debris were sampled in 10 transects (Figure 1) distributed along the beaches. Three months with different intensity on tourism activities were sampled: (1) February – summer season with intense tourism activities, (2) April – autumn season with weak tourism activities, (3) August – winter season with no tourism activity. Each 10 m wide transect was divided into two horizontal strata: (i) backshore, above the hightide strandline through primary dunes or vegetation; and (ii) dunes, from dunes through the Beira Mar Avenue, which were independently sampled. This sampling method allows determination of temporal patterns (among monitored months) and spatial patterns (between horizontal strata, perpendicular to the water mark, and among transects, parallel to the water mark). Sampling procedures were always taken in the afternoon, with items on each transect being quantified, collected and finally correctly discarded. Sampled marine debris was then codified in classes of materials (plastic, cigarette butt, metal, glass, paper, organic matter, anthropogenic wood and other) (IOC/FAO/UNEP, 1989), and, in the case of plastic debris, detailed into specific types of items (fragments, plastic bags, straws, plastic cups, among others). The most probable source of the sampled items was estimated according to its main utilization (Araújo & Costa, 2006, Santos *et al.,* 2009), put as bullets: (1) Beach users, with *in situ* generation of marine debris; (2) Non-local sources, related to items that are normally not discarded on the beach; (3) Fishing activities; (4) Not determined, related to items with multiple usages, being not possible in a conservative approach (Santos *et al.*, 2009) estimate even its most probable source.

Data was tested for normality and log_{10} transformed if necessary. Parametric testes were carried out with a 5% level of significance. Factorial Analysis of Variance was carried out to detect significant differences among the monitored months (February, April and August) and strata (backshore and dunes), considering both the total number of items sampled on the beach and the most common classes of materials. The same analysis was carried out to the different types of plastics. When significant differences were detected, the Tukey HDS test was also applied. Finally, two-way ANOVA was applied to detect significant differences among the sampled transects.
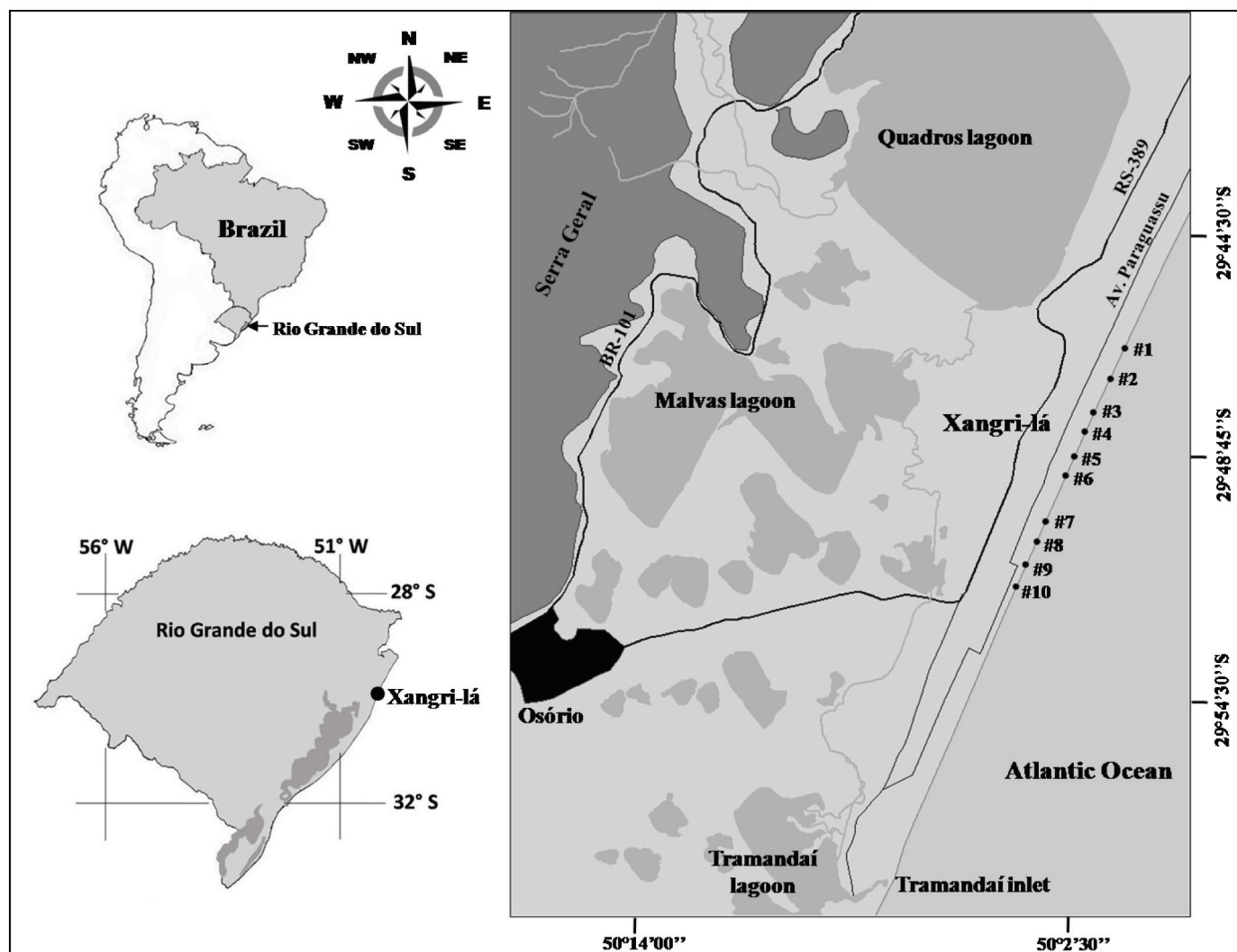
Figure 1. The study area at Xangri-Lá, north coast of Rio Grande do Sul, and the ten sampled transects.
Figura 1. Área de estudo em Xangri-Lá, litoral norte do Rio Grande do Sul, e os dez perfis amostrados.

3. RESULTS

3.1 Quantities and composition of marine debris

A total of 1,390 items were collected, considering all sampled months, transects and strata. Plastic debris (42%) and cigarette butts (39%) were the majority on the beach (Figure 2). Other classes of materials were paper (7%), anthropogenic wood (4%), glass, organic matter and metal, which comprises 1% each. Other (5%) was represented by polystyrene, clothes and building debris, among others (Figure 2).

A total of 586 plastic debris pieces were sampled. Among them, plastic fragments (41%) and straws (18%) were the most common (Figure 2). Other plastic items were bottle caps (9%), plastic bags (7%), cups (6%), candy wrappers (6%), lolly wrappers (5%), and other (8%).

3.2 Temporal and Spatial patterns of marine debris contamination

February was significantly more contaminated by marine debris than April and August, either when the total number of items sampled on the beach or specific types of plastic debris were considered (Figure 3a).

Considering dunes and backshore contamination, no significant differences were reported when the total number of items sampled on the beach, specific types of plastic debris or only cigarette butts were tested (Figure 3b). Parallel to the waterline, no significant difference on marine debris contamination was detected among sampled transects. On the backshore, P2 was the most contaminated transect, followed by P10 and P9. On dunes, P9 and P10 were the most contaminated ones (Figure 4).

Considering only plastic debris, fragments were significantly more common than the other identified types. This pattern is most evident in February (Figure 5) when beach contamination is highest.

3.3 Sources

The majority (75%) of sampled marine debris had its most probable source estimated. Land-based sources (beach users) represented 68% of the total amount. Marine-based sources were non-local sources (4%) and fishing activities (3%). About 25% of total marine debris did not have even its most probable source identified. These items were mainly unlabelled plastic fragments, plastic bags and PET bottles (Table 1).
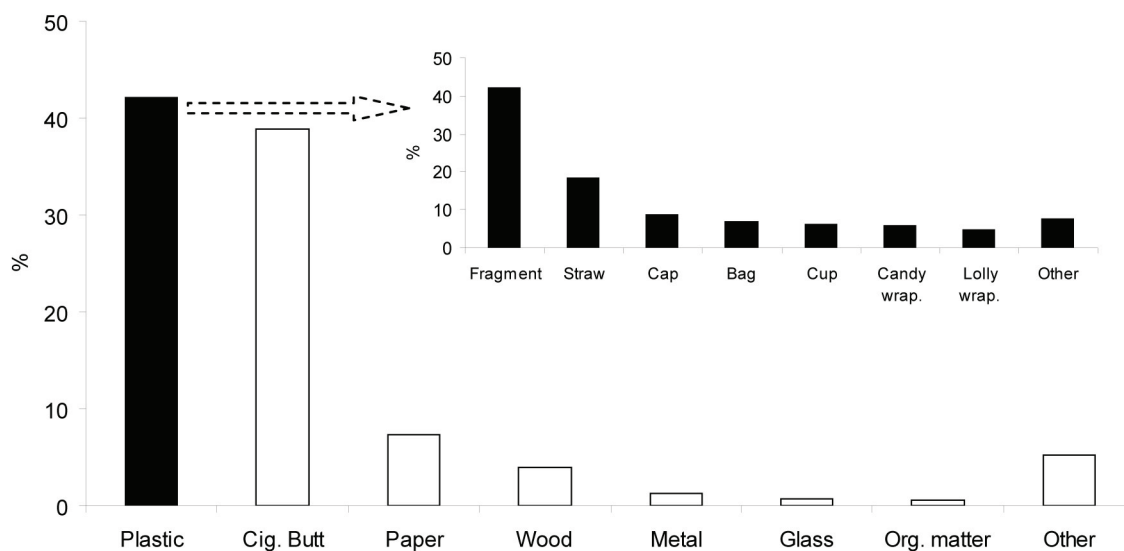
Figure 2. Classes of materials and its respective percentages, identified in all monitored months, transects and strata. See in the detail the types of plastic debris and its respective percentages, also identified in all months, transects and strata.
Figura 2. Classes de materiais e suas respectivas porcentagens, identificadas em todos os meses, perfis e estratos amostrados. Veja no detalhe os tipos de lixo plástico e suas respectivas porcentagens, também identificados em todos os meses, perfis e estratos.
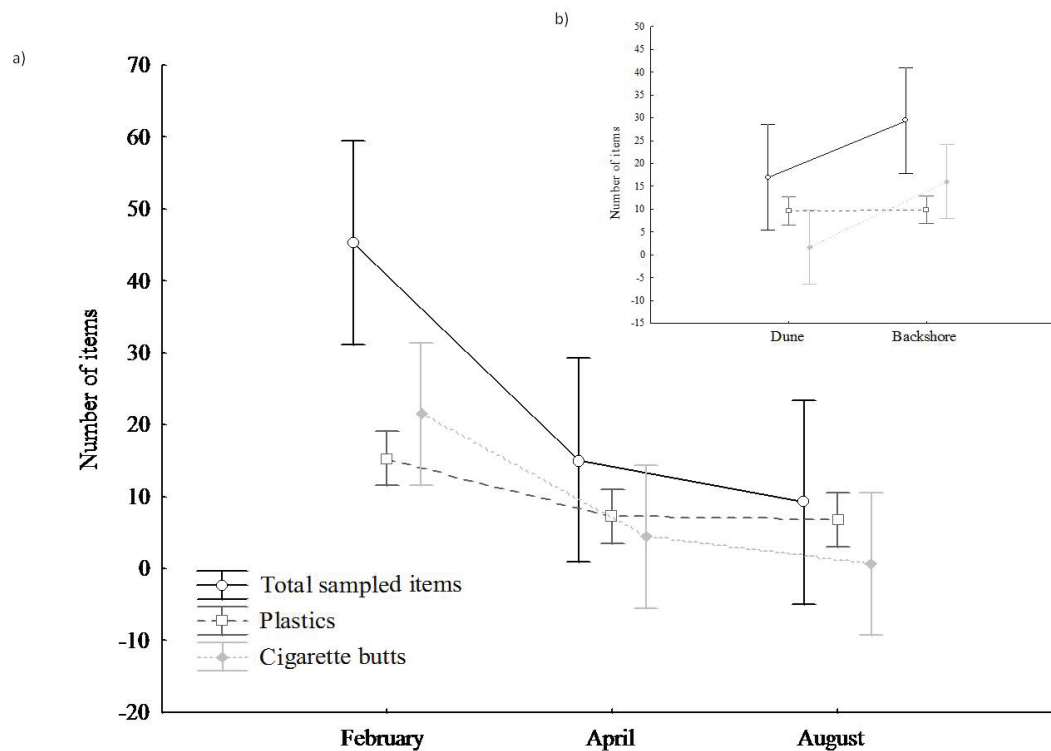

Figure 3. (a) Total number of items sampled on the beach, plastic debris and cigarette butts identified during the three monitored months; (b) Total number of items sampled on the beach, plastic debris and cigarette butts identified on the backshore and dunes.
Figura 3. (a) Número total de itens amostrados na praia, lixo plástico e pontas de cigarro identificados nos 3 meses monitorados; (b) Número total de itens amostrados na praia, lixo plástico e pontas de cigarro identificados na pós-praia e nas dunas.
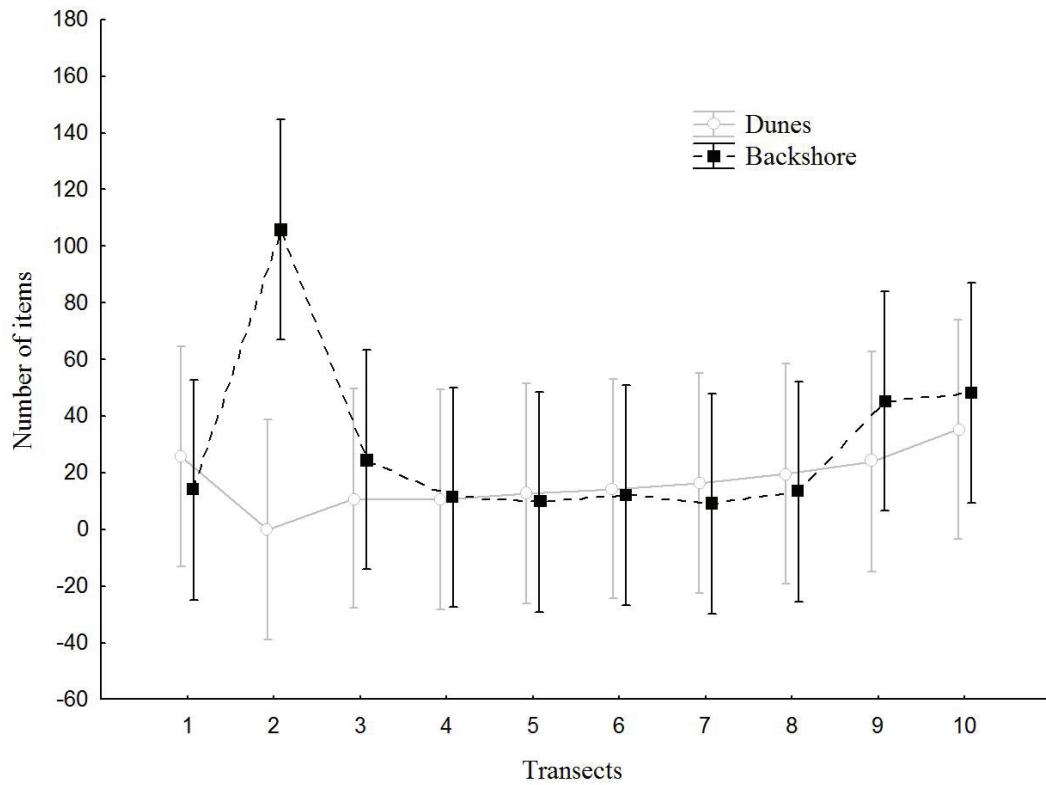
Figure 4. Total number of items (items m⁻¹) sampled on the backshore and dunes during the three monitored months.

Figura 4. Número total de itens (itens m⁻¹) amostrados na pós-praia e nas dunas durante os três meses monitorados.
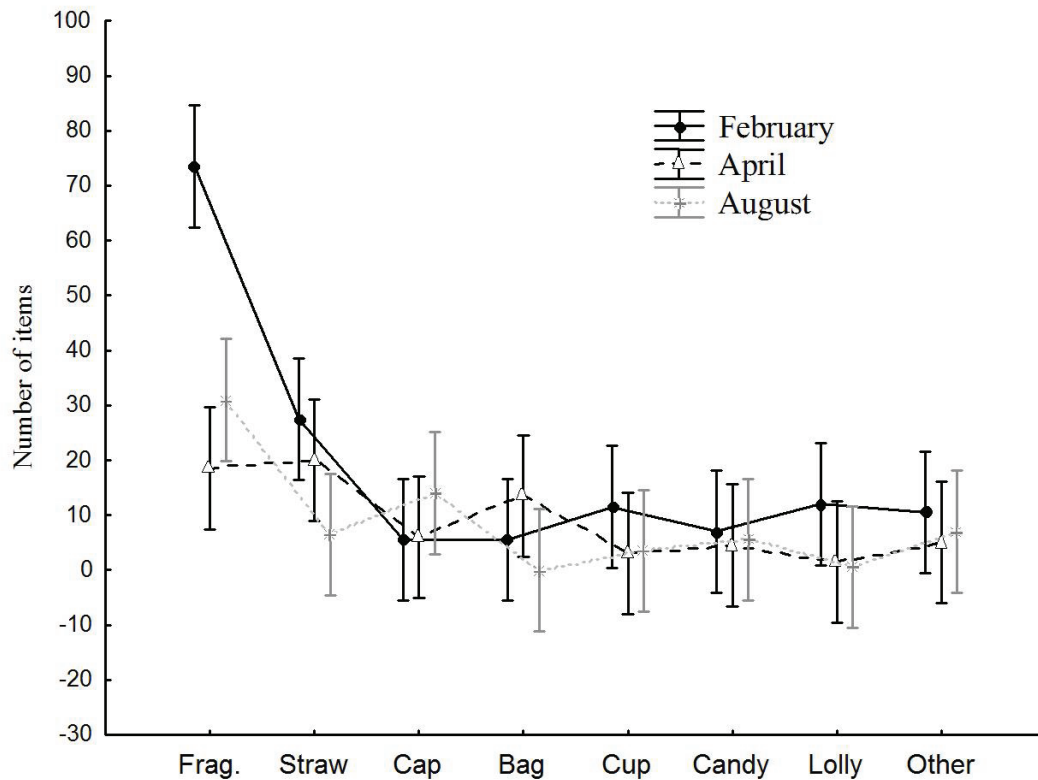

Figure 5. Most common types of plastic debris sampled on the beach (backshore and dunes) during the three monitored months.

Figura 5. Tipos mais comuns de lixo plástico amostrado na praia (pós-praia e dunas) durante os três meses monitorados.

Table 1. Most probable sources and its sampled items (and percentages) collected on Xangri-Lá beaches.
Tabela 1. Fontes mais prováveis, itens amostrados (e suas porcentagens) coletados nas praias de Xangri-Lá.

	Most probable source	Sampled items	%
Land-based sources	Beach users	Cigarette butts, straws, paper and cardboard, plastic cups, candy and lolly wrappers, caps, cans, building debris, discarded food.	68
Marine-based sources	Non-local	Plastic containers from cleaning and personal hygiene products, anthropogenic wood, glass containers, rubber, foam, lights.	4
	Fishing activities	Nylon monofilaments, nets, ropes, polystyrene.	3
	Not determined	Plastic fragments, PET caps, plastic bags, PET bottles, metal and glass fragments.	25
	Total		100

4. DISCUSSION

4.1 Marine debris composition and sources

On Xangri-Lá beaches, plastics were the main sampled class of material, identified in all monitored transects, months and strata. The wider dissemination of plastics in relation to the other classes of materials has been previously reported in studies on sand beaches (Araújo & Costa, 2006; Spokas, 2008; Santos *et al.*, 2009), pebble beaches (Williams & Tudor, 2001) and other environments (Coe & Rogers, 2000; Ivar do Sul & Costa, 2007; Ryan *et al.*, 2009), showing the ubiquity of plastics on marine and coastal habitats around the world.

This global pattern can be justified by plastic characteristics such as flexibility, durability (slow natural degradation), low density and cost, since it comprises a wide range of products easily accessible by consumers. Once discarded into the environment, plastics are easily dispersed by winds, surface ocean currents, rivers, rainfall drainage systems and others, which, associated with the absence of solid waste management on coastal municipalities such as Xangri-Lá, also contributes to the current scenario of plastic debris contamination.

Cigarette butts were also sampled at all monitored transects. Its amounts can be directly related to the fixed backshore kiosks and the existence of a football court on the beach, which allow beach users to stay for longer periods on the beach. The occurrence of cigarette butts also reflects beach users' lack of knowledge in relation to the potential damages of this item (i.e. ingestion by marine biota and even by children), and to its highly persistent characteristics, since cigarettes are made by a group of polymers, i.e. by different kinds of plastics. In addition, small items such as cigarettes butts are not effectively removed by cleaning services (Santos *et al.,* 2005; Araújo & Costa, 2006; Ivar do Sul & Costa, 2007; Santos *et al.,* 2009) (observed on Xangri-Lá beaches; transect 2), promoting accumulation and probably its dispersion to adjacent areas.

The other sampled classes of materials have been frequently reported on beaches and other marine and coastal environments (IOC/FAO/UNEP, 1989; Coe & Rogers, 2000). Fragments of paper, glass, metal and polystyrene, and mainly plastic fragments, illustrate the lack of efficient cleaning services, and also the fragmentation of bigger items abandoned/deposited on the beach that suffered thermal, photochemical, chemical or physical degradation (Costa *et al.,* 2010). The prevalence of small fragments was also observed on other urbanized and non-urbanized beaches, such as Cassino beach, southern coast of RGS (Wetzel *et al.,* 2004; Santos *et al.,* 2005), Costa do Dendê, Bahia (Santos *et al.,* 2009) and many other sand beaches (Madzena & Lasiak, 1997; Debrot *et al.,* 1999). Plastic fragments were also the main type of item identified on the digestive tracts of *Chelonia mydas* sampled on the RGS coastline, highlighting the eminent risk of marine debris ingestion by the local biota (Tourinho *et al.,* 2010).

Land-based source was quantitatively sampled more than marine-based sources. On Xangri-Lá beaches, it is represented by beach users which are frequently pointed as important sources of marine debris to coastal habitats (Ivar do Sul & Costa, 2007). Items with marine-based sources (non-local sources and fishing activities) were rare, this fact being related to the absence of big rivers and big cities in all the hydrographic basins that flow into the vicinity of the study area. In addition, there is no artisanal or commercial fishing port with constant flux of fishing boats next to Xangri-Lá beaches.

4.2 Spatial and temporal patterns of marine debris contamination

Considering backshore and dunes contamination, no significant differences were detected, in spite of the visual accumulation of marine debris on dunes. Probably, this result is a consequence of several factors. The local motion of low density debris, such as plastics, which are removed from/ to the backshore to/from the dunes by winds, waves and meteorological tides, promotes distribution of these items on the whole beach. Erosion and accretion rates associated to seasonal cycles may also facilitate burial of debris (Ivar do Sul & Costa, 2007), mainly on the backshore. Additionally, bigger items are fragmenting into smaller pieces (Santos *et al.*, 2009; Costa *et al.*, 2010), resulting in accumulation of these items on both strata. This process is evident in the present work since plastic fragments were the most common type of item sampled on the beach. On the backshore those fragments are not effectively collected by municipal cleaning services. Straws and bottle caps were also frequently sampled and with small sizes, these are not as well collected from the beach. On dunes, vegetation might act as a trap of deposited marine debris, which also fragment and increase (in quantities) with time. Plastic bags, for example, were sampled only on dunes, trapped by vegetation.

The most contaminated transects (items m^{-1}), when the whole beach (backshore and dunes) was considered, were P9, P10 and P2, respectively. These transects were next to fixed backshore kiosks (P10 and P2) and the football court (P9), demonstrating the lack of knowledge of beach users in relation to the potential consequences of marine debris (Santos *et al.*, 2005), since rubbish bins are found in all kiosks. In addition, there is no inspection by municipal authorities, and consequently no garbage control associated with the fixed kiosks (or with other facilities on the beach). Solid wastes produced on the beach probably will end up on the adjacent shore.

In relation to the temporal patterns, February was the most contaminated month, an expected pattern on tourist beaches such as Xangri-Lá, since this month registered the highest concentration of tourists. With inefficient cleaning services, marine debris stays on the beach until the following winter (and probably for a long time), when beach erosion can remove it from/to the beach to/from the adjacent surf zone. This process continuous until marine debris is finally removed from the beach.

CONCLUSIONS

Marine debris on coastal and marine ecosystems represents the final product of an endless network, from the unmeasured and ever growing worldwide plastic production together with discarding, to the inadequate manipulation and destination of solid wastes by the municipalities (Ivar do Sul & Costa, 2007).

If cigarette butts are also considered as a type of plastic, almost 81% of the total items sampled on the beach are made from this material. Nowadays there are no doubts concerning the predominance of plastics on marine and coastal environments, and the north coast of RGS is no exception. Plastics were the most sampled items on all monitored transects, months and strata, highlighting the wide range of uses of this material by almost every human activity.

The main source identified on the study area was the land-based source, represented by beach users mainly during the summer season. It was also observed that plastics and other types of solid wastes, such as building debris and grass cuts, are directly abandoned on dunes all year long. The direct throw of garbage on the beach demonstrates the ignorance of beach users and residents in relation to marine debris problems. This scenario highlight the necessity of long term campaigns and environmental education programs, in spite of inefficient short term methods, such as plastic bags and folders distributions on the beach. These actions normally result in even more marine debris on the beach.

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