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Temporal trend of litter contamination at Cassino beach, Southern Brazil *

Tendências temporais de contaminação por lixo na Praia de Cassino, Sul do Brasil

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ABSTRACT

This study was undertaken to evaluate temporal trends of litter contamination at Cassino beach, Southern Brazil. Surveys were conducted between 1994 and 1995, and then resumed from 2003 to 2006. Litter composition was related to both land- and marine-based origins. However, seasonal and spatial variations showed that in situ deposition by beach users is still a major source of litter at Cassino beach. The results indicated a significant increase in litter amount at Cassino beach over the survey period. Probably, population growth, tourism activity and fishery activity contributed to this temporal trend. Although few studies have already pointed out the contamination by debris at the study site, no management actions involving education, disposal, clean-ups have being effective enough to cope with this ever-increasing problem. Based on that, new approaches are urgently needed, which may involve the development and use of new products with shorter environmental half-lives.

Keywords: litter, temporal trend, seasonal and spatial variations, Southern Brazil, beach, sources.

RESUMO

O presente estudo foi realizado para avaliar as tendências temporais da contaminação por resíduos sólidos na praia do Cassino (RS, Brasil). Amostragens foram realizadas entre 1994 e 1995, e depois retomadas entre 2003 e 2006. A composição dos resíduos foi relacionada com fontes terrestres e marinhas. Entretanto, as variações sazonais e espaciais mostraram que a deposição in situ pelos usuários da praia ainda é a principal fonte de resíduos sólidos na praia do Cassino. Os resultados indicaram um aumento significativo no montante de lixo na praia do Cassino. Provavelmente, o crescimento populacional, o turismo e a atividade pesqueira contribuíram para essa tendência temporal. Embora o problema da contaminação por resíduos sólidos no local de estudo já tenha sido apontado anteriormente, nenhuma ação de gestão envolvendo educação, destinação, remoção tem sido efetiva o suficiente para solucionar este problema crescente. Baseados nisso, novas ações são urgentemente necessárias, o que poderia envolver o desenvolvimento e uso de novos produtos com uma menor meia-vida ambiental.

Palavras-chave: *resíduos sólidos, tendências temporais, variações sazonais e espaciais, região Sul do Brasil, praia, fontes.*

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1. INTRODUCTION

Over the past five or six decades, contamination and pollution of aquatic environments by debris has been recognized as an ever-increasing phenomenon (Gregory, 2009) and litter on beaches has been well-known as a significant worldwide problem, which is however still not totally elucidated (Moore, 2008). The sources of debris are classified as land-based and marine-based, depending on where the litter is introduced into the environment (Sheavly & Register, 2007). Land-based origins include beach users, river runoff, sewage outputs, while marine-based origins include shipping (recreational boating, merchant ships, and fishing boats), harbour activities and offshore activities (oil and gas exploitation). The occurrence of multiples sources and the non-random transportation of litter cause a great temporal and spatial variability in its quantities, which is a confounding factor in long-term trends studies, requiring large sample replication in time and space (Ryan *et al.*, 2009).

The problems caused by the presence of littering are widely documented. The most emphasized problems are economic impacts (i.e. funds for beach maintenance or health expenses of coastal communities) (Sheavily & Register, 2007), impacts on marine organisms such as ingestion (Colabuono *et al.*, 2009; Tourinho *et al.*, 2010) and entanglement (Moore *et al.*, 2009; Raum-Suryan *et al.*, 2009), smothering, hangers-on, hitch-hiking and alien invasions (Gregory, 2009), and the leasing/sorption of contaminants from/to synthetic materials (Mato *et al.*, 2001; Ogata *et al.*, 2009).

Along the years, the Brazilian government has been gradually acting to sort out the problems related to litter from both sources. In 1995, Brazil ratified the Annex V of the International Convention for the Prevention of Marine Pollution from Ships (MARPOL 73/78), which regulates the dumping of wastes at sea from ships and requires ports and terminals to provide facilities for wastes disposal. More recently in 2010, the government has approved a federal law for dealing with land-based wastes. This law encourages the recycling processes, obliging the manufactures to deal with the wastes directly and indirectly related to their products, prohibits dumping sites and imposes the creation of sanitary landfills in the cities (Law Nº 12.305 of August 2010).

After some years studying environmental contamination by litter, it will make it possible to check for temporal trends and see how the so called increasing environmental human consciousness is compensating for the growing anthropogenic activities that contaminate the environment with litter. Extending previous work conducted in 1994-1995 (Wetzel *et al.*, 2004), this study was undertaken to further evaluate temporal trends of litter contamination at Cassino beach. In addition, litter composition and source and, spatial and seasonal variations were also evaluated.

2. MATERIAL AND METHODS

2.1 Study area

Cassino beach (~32º11'S; ~52º10'W) is located at Rio Grande (Southern Brazil), which is a very important city with various anthropogenic activities such as tourism, fisheries, and harbour and industries (Tagliani *et al.*, 2003). Rio Grande holds one of the main harbours of Mercosur, which the handling capacity is expected to increase even more in subsequent years (Porto de Rio Grande, s/d). Moreover, the municipal population has grown from about 180 thousand to over 196 thousand people during 1995 to 2006 (IBGE, 2007). The beach is located in the proximity of Patos Lagoon outlet (Figure 1), which drains an area of about 170,000 km^2 (Calliari *et al.*, 2001) and has an annual mean flow of 2.400 m^3.s^{-1} (Vaz *et al.*, 2006). The coast extends southwards for about 200 km (until the Uruguayan border) of sandy beach, presenting a microtidal regime and different morphodynamic characteristics. In the first 30 km, where the Cassino centre is situated, the beach is classified as dissipative, turning southwards into a beach with intermediate characteristics (Pereira *et al.*, 2010).

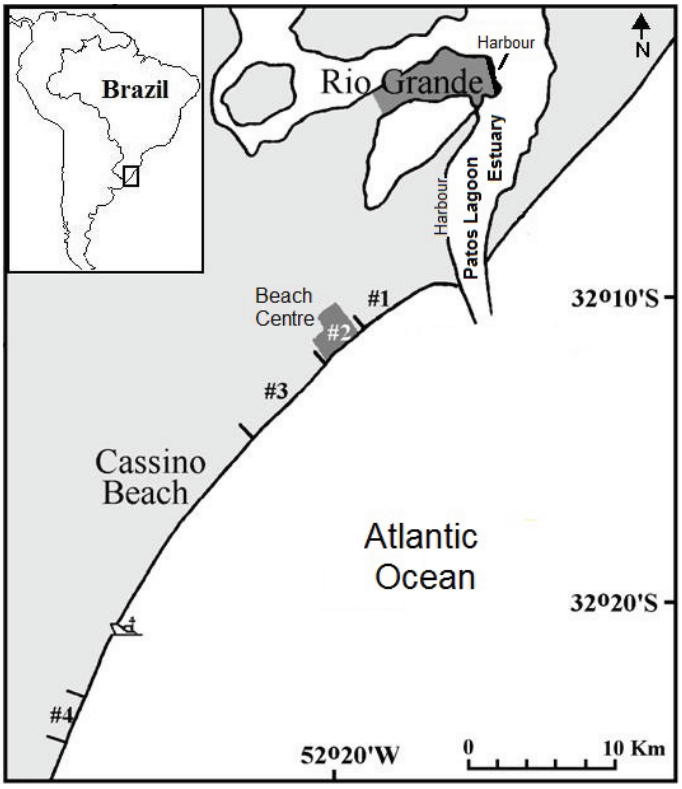

Figure 1. Study area.
Figura 1. Área de estudo.

3. LITTER SURVEYS

Beach litter surveys were conducted monthly from December 1994 to December 1995, according to Wetzel *et al.* (2004). The surveys were resumed in January 2003 and continued until November 2006. Four sites with different occupation characteristics (beach users and recreational fishing activities) were monitored (Figure 1). Sites 1, 2 and 3 were located next to the resort center, covering about 13.6 km southward from the Patos Lagoon output. These three sites were heavily occupied by beach users during summer months (December to March), while site 4 was located at 28 km southward of the resort center and receives very low density of users (mainly fishermen during all year-round).

Litter was sampled randomly in four transects for each site. A 5-m wide transect was used in 1995, while a 10-m wide transect was used from 2003 to 2006. Transects covered from the waterline to the presence of primary dunes or vegetation. Litter (visible to the naked eye) was counted and classified in 9 categories: plastic, fishing material (*e.g.* lines, ropes, net, and Styrofoam), cigarette butt, paper, wood, metal, glass,

organic matter (*e.g. food and flowers*) and "others". In 1995, cigarette butt was classified in the category 'others'. In order to standardize the surveys, the results were expressed as items per linear meter of beach (items.m^{-1}). Three-way ANOVA was conducted on litter amount, using season (spring, summer, autumn and winter), year and site of sampling as factors. When significant differences were found ($p<0.05$), a Tukey post hoc test was performed. Data were log transformed and tested for normal distribution (Kolmogorov–Smirnov test) and homogeneity of variances (Levene's test).

4. RESULTS AND DISCUSSION

4.1 Litter composition and source

A total of 29,717 items were collected, with an overall mean concentration of 7.3 items.m^{-1}. Plastic was the most important category (47.9%), followed by cigarette butt (13.6%), fishing material (9.7%), organic matter (8.4%), wood (4.4%), paper (3.6%), metal (1.6%) and glass (1.3%). The category 'others' was also representative (9.5%), which included items that were not classified in the previous categories such as cloth, building rubbish, candles, rubber, charcoal, cigarette butt (only for 1995) and others. The relative abundance of litter composition for each year is shown in Figure 2. Plastic was the most frequent category in all years, varying from 44.7% in 2003 to 53.8% in 2005. It was composed by undefined sources (i.e. soft and rigid fragments), followed by land-based (i.e. food and market plastic bags, straws, cups and drink bottles) and marine-based sources (i.e. international packs, incrusted items). Cigarette butts varied from 7.2% in 2003 to 21.8% in 2006 (this item was not separately measured in 1995), and organic matter varied from 1.8% in 2006 to 16.9% in 2003. These items were mainly related to land-based origins, especially tourism activities. Fishing material varied from 3.8% in 1995 to 16.5% in 2006, being probably more related to marine-based origins (lines, ropes, nets and Styrofoam). The categories wood, paper, metal, and glass were mainly composed by undefined sources, although some items could be related to land- (i.e. building wood rubbish, food and market paper bags, soft drink cans) and marine-sources (i.e. international packs and incrusted items).

Mean litter amounts found by different studies are shown in Table 1. A study conducted in Cassino beach during summer months (January and February) in 2003 indicated that tourism was the main source of debris and that littering is directly related to beach users density (Santos *et al.*, 2005a). However, different origins of debris were found in studies conducted along the Northeastern Brazilian coast. Local rivers input were the main source in Tamandaré beach (Pernambuco), combined with tourism activity (Araújo & Costa, 2006). There was, also, a seasonal variation in this area, which in this case is due to the rainy season that increased river drainage (Araújo & Costa, 2006). Similar result was found in Dendê coast (Bahia), in which the river drainage was the most important source (Santos *et al.*, 2009). The influence of river (Patos Lagoon output) and rain was not evident for the Cassino beach during the present study. It is known that many factors contribute to the marine debris contamination on beaches, such as oceanography variables and socioeconomic variables (Araújo & Costa, 2006). On the other hand, it was evidenced ship-related sources and very low land-based sources in Coqueiros coast (Bahia), which was due to the absence of tourism and large rivers drainage (Santos *et al.*, 2005a). As a result, a extremely low average amount of litter (~0.009 items.m^{-1}) was registered in Costa dos Coqueiros. Low levels (0.05-0.3 items.m^{-1}) were also registered for Fog bay beaches, Australia (Whiting, 1998). Both places were considered under low litter contamination. Conversely, beaches in Transkei coast, South Africa (Madzena & Lasiak, 1997) were considered heavily contaminated by litter (19.6-72.5 items.m^{-1}). However, litter amount at Cassino beach in 1995 and from 2003 to 2006 were in the same magnitude as those reported for Dendê coast and Tamandaré beach (Northeastern Brazilian coast) (Table 1), which represent a level of contamination that must no longer be ignored.

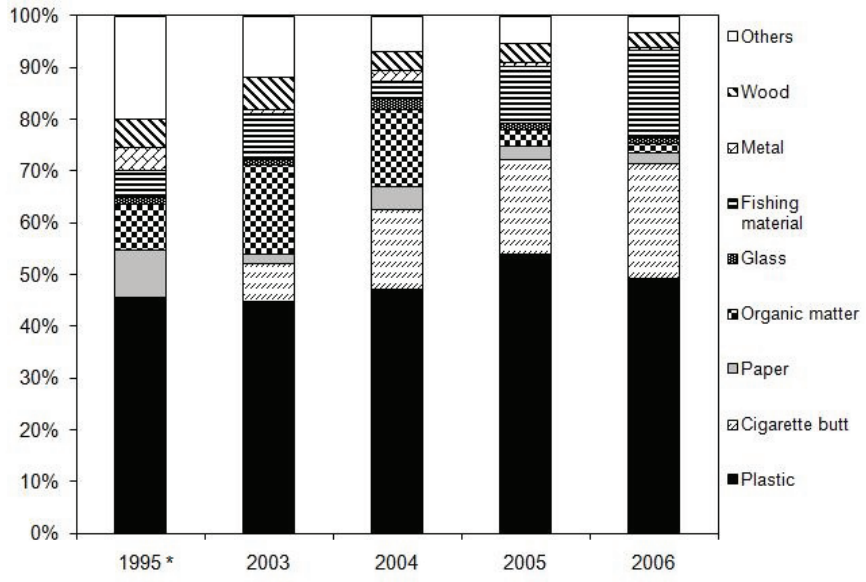

Figure 2. Relative litter composition for each sampling year at Cassino beach. * Cigarette butts were classified in the category 'others' in 1995.
*Figura 2. Composição relativa anual dos resíduos sólidos na praia do Cassino. * as pontas de cigarro foram computadas juntamente a categoria 'others' em 1995.*

Table 1. Mean litter amount (items.m^{-1}) reported for different beach studies.
Tabela 1. Quantidade média de resíduos sólidos (itens.m^{-1}) encontrados em diferentes estudos com praias.

Study area	Survey year	Items.m^{-1}	Reference
Cassino beach, Brazil	1994-1995	7.4	Wetzel *et al.* (2004)
Transkei coast, South Africa	1994-1995	19.6-72.5	Madzena & Lasiak (1997)
Fog bay beaches, Australia	1996-1997	0.05-0.3	Whiting (1998)
Tamandaré beach, Brazil	2001-2002	10.4	Araújo & Costa (2006)
Gulf of Oman, Oman	2002	1.8	Claereboudt (2004)
Cassino beach, Brazil	2003	4.9	Santos *et al.* (2005a)
Coqueiros coast, Brazil	2001-2004	0.009	Santos *et al.* (2005b)
Dendê coast, Brazil	2005	9.1	Santos *et al.* (2009)
Cassino beach, Brazil	2003-2006	5.3-10.7	Present study

4.2 Spatial, seasonal and temporal variations

Seasonal, spatial and temporal variations of litter were analyzed in Cassino beach. It was observed that litter amount presented a seasonal variation (F=12.25, p=0.00; Table 2), with significantly higher values for samples taken during the summer periods. The litter quantity (mean ± SD items.m^{-1}) was 11.1±4.8 in summer, 8.0±4.8 in autumn, 5.1±1.1 in winter, and 5.2±1.0 in spring (data not shown). Beach usage during the summer months is quite intensive at Cassino, resulting in higher levels of littering. From 25,000 permanent inhabitants, Cassino might reach up to 200,000 beach users during a warm and sunny weekend of January and February. The problem in summer time is not worst due to the daily clean-up conducted on the beach by municipality (Santos *et al.*, 2005a). Moreover, the occurrence of storm surge and other high energy events have been documented at Cassino, especially on winter (Parise *et al.*, 2009). Such events can washed away light debris from the beach (Convey *et al.*, 2002; Thornton & Jackson, 1998), reducing the quantities of litter during winter.

It was seen that spatial distribution have also influenced the amount of litter deposited on the beach (F=25.02, p=0.00; Table 2). The most contaminated areas were site 1 (9.4±2.0 items.m^{-1}) and 2 (10.8±3.9 items.m^{-1}). This last site is the most visited by beach users, since it is the closest to the beach center (Figure 1). Sites 3 and 4 presented a lower amount of litter (4.7±1.8 and 4.4±2.9 items.m^{-1}, respectively). As expect, site 4 had the lower litter amount, which was mainly from marine-based sources. In addition to the tourism activities, sites 1, 2 and 3 are probably more exposed to the outputs of Patos Lagoon, which receives the drainage of an extensive catchment area. Such input can be a potential source of debris to the coast (Santos *et al.*, 2009), especially for a region with a growing economy. In this way, population and industrial activities growth may contribute to higher rates of litter generation throughout the years. Although this source might be contributing to the spatial variation at Cassino beach, no clear evidence was found to confirm this hypothesis.

The results have showed a significant increase in litter amount at Cassino beach over the survey period (F=7.81, p=0.00; Table 2). The mean litter amount found during 2006 (10.7±1.7 items.m^{-1}) was higher than 2005 (7.6±1.3 items.m^{-1}), 2004 (5.3±0.8 items.m^{-1}), 2003 (5.4±0.7 items.m^{-1}) and 1995 (7.4±1.0 items.m^{-1}) (Figure 3a). Despite beach users have shown some gradual improving in their environmental consciousness, the fast increasing number of users is probably one of the reasons for the rising contamination levels. Ironically Santos *et al.* (2005a) were right when they warned that "The use of southern Brazilian coastal zone has been increasing quickly, but environmental awareness of people has not accompanied it. This indicates that litter input and its impacts to the ocean are likely to increase if no preventive actions were taken." The numbers are proving that taken actions, if so, were not enough to prevent this situation.

The growing amounts of litter main categories found (plastic, cigarette butts and fishing materials) over the years can also help understanding the role of the origins and variations of litter (Figure 3b), since these categories can be related to land- and marine-based activities. Although the increasing of industrial and maritime activities may have

Table 2: Results of three-way ANOVA examining the influence of season, locations and year of sampling on litter amount at Cassino beach.
Tabela 2: Resultados da ANOVA três-vias sobre a influência da estação do ano, local e ano de amostragem na quantidade de resíduos sólidos na praia do Cassino.

Factors	F	p
Season	12.25	0.00
Site	25.02	0.00
Year	7.81	0.00
Season vs Site	0.01	0.98
Season vs Year	1.37	0.21
Site vs Year	1.58	0.14
Season vs Site vs Year	0.46	0.98

also contributed, no direct relationship between the harbour activity and seasonal and temporal variations was easily identified, confirming that other sources rather than ship-generated litter (i.e. tourism and fishery) were responsible for the rising contamination levels in Cassino beach. Despite the Rio Grande harbor handling of cargo have increased from about 9 million tons in 1996 to 22 million tons in 2006, the great increment happened between 1996 and 2003 (ANTAQ, 2010). Moreover, Annex V of the MARPOL 73/78 prohibits the dumping of any plastic waste from ships and, thus, it is expected a reduction of ship-derived plastic debris (Barnes *et al.*, 2009). On the other hand, plastic items together with cigarette butts (which are more related to direct tourism activities on the beach) found stranded on the beach more than double in amount from 2003 to 2006 (Figure 3b).

Tthe interactions among factors (season, site and year) were also tested and showed to be no significant ($p>0.05$; Table 2), suggesting that the effects of each factor were independent of each other. It indicated that seasonal and spatial variations were independent of the year of survey (i.e. high levels were found always on summer in all years).

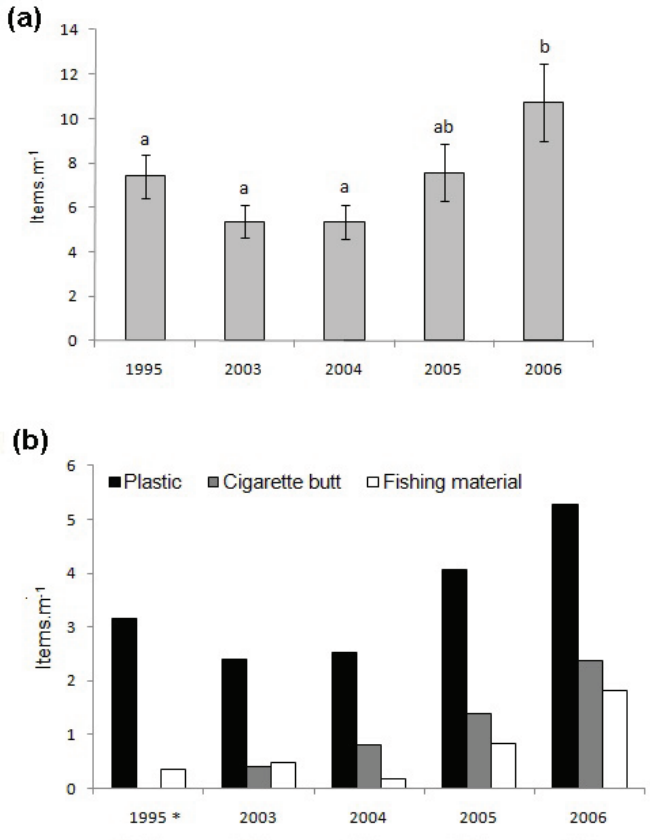

Figure 3. (a) Mean (±S.D.) of total debris (items.m^{-1}) found at Cassino beach for each sampling year. Identical letters means absence of statistical differences ($p>0.05$). (b) Mean abundance (item.m^{-1}) of the main categories of debris for each sampling year. * Cigarette butts were not classified separately in 1995.

*Figura 3. (a) Média (±desvio-padrão) do total de resíduos sólidos (itens.m^{-1}) encontrado na praia do Cassino por ano de coleta. Letras idênticas indicam ausência de diferença estatística ($p>0,05$). (b) Número médio de itens das principais categorias de resíduos sólidos por ano de coleta (itens.m^{-1}). *Pontas de cigarro não foram classificadas separadamente em 1995.*

CONCLUSION

Reports of long-term monitoring of marine debris are extremely necessary in order to better understand the magnitude and the tendency of litter contamination on beaches. In this study, a slow but steady increase in litter amount was observed between 2003 and 2006. Although land-based could be identify as the main source (shown by the seasonal and spatial variations), the items were related to both land- and marine-based origins. Spatial and seasonal variations showed that *in situ* deposition by beach users is still the main source of litter at Cassino beach. In addition, population growth, tourism activity and fishery activity contributed to this temporal trend with increasing litter amount not only during summer, but also during the whole year.

The litter issue can be reduced by locating the responsible parts. In accordance to this study, population must be further aware of the environmental and economic losses caused by litter contamination on beach, such as decreased tourism, public spending on clean-up and damage to biota and natural resources. Specifically, fishermen must be aware of the impacts caused by ghost-fishing gears. Moreover, adequate knowledge of human and environmental hazards should be provided. Litter accumulation can have a "boomerang effect", which can cause remarkable impacts if the whole situation is not utterly assessed and understood.

Despite the efforts to manage them, the environmental and multiple other problems related with litter appear to be always expanding. Although few studies have pointed out the contamination by debris at the study site, there seem to be no easy answers, especially if we consider that action plans involving education, disposal, clean-ups are not being effective enough to cope with this ever-increasing problem. Based on that, new approaches are urgently needed, which may involve the development and use of new products with shorter environmental half-lives.

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